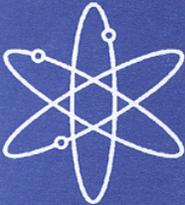# Experience With the SCALE Criticality Safety Cross-Section Libraries

Oak Ridge National Laboratory

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Experience With the SCALE Criticality Safety Cross-Section Libraries

Prepared by
S. M. Bowman,
W. C. Jordan,* J. F. Mincey,*
C. V. Parks, L. M. Petrie, ORNL

Oak Ridge National Laboratory
Managed by UT-Battelle, LLC
Oak Ridge, TN 37831-6370

C. J. Withee, NRC Project Manager

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*Formerly with Oak Ridge National Laboratory

ABSTRACT

This report provides detailed information on the SCALE criticality safety cross-section libraries. Areas covered include the origins of the libraries, the data on which they are based, how they were generated, past experience and validations, and performance comparisons with measured critical experiments and numerical benchmarks.

The performance of the SCALE criticality safety cross-section libraries on various types of fissile systems are examined in detail. Most of the performance areas are demonstrated by examining the performance of the libraries vs critical experiments to show general trends and weaknesses. In areas where directly applicable critical experiments do not exist, performance is examined based on the general knowledge of the strengths and weaknesses of the cross sections. In this case, the experience in the use of the cross sections and comparisons with the results of other libraries on the same systems are relied on for establishing acceptability of application of a particular SCALE library to a particular fissile system.

This report should aid in establishing when a SCALE cross-section library would be expected to perform acceptably and where there are known or suspected deficiencies that would cause the calculations to be less reliable. To determine the acceptability of a library for a particular application, the calculational bias of the library should be established by directly applicable critical experiments.

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1 INTRODUCTION

Multi-energy group neutron cross-section libraries included in the SCALE code system[1] have seen widespread use over the years since the first release of SCALE in 1980. Numerous validation studies have been performed to satisfy ANSI/ANS-8.1-1998[2] and ANSI/ANS-8.17-1984,[3] but this information is scattered and not succinctly compiled into an easy-to-use format.

This report is intended to begin where the SCALE user manual leaves off in identifying the performance of the SCALE libraries in the analysis of various fissile systems. Some of the performance areas can be demonstrated by examining the performance of the libraries when calculating critical experiments. In areas where directly applicable critical experiments do not exist, other factors must be examined based on the general knowledge of the strengths and weaknesses of the cross sections. In this case, the experience in the use of the cross sections and comparisons to the results of other libraries on the same systems must be relied on for establishing the acceptability of the application of a particular SCALE library to a particular fissile system.

This report will aid in establishing when a SCALE cross-section library should perform acceptably and what areas of application should be more carefully scrutinized. To determine the acceptability of a library for a particular application, the calculational bias of the library should be established by directly applicable critical experiments. Preferably, the bias for a particular application should be small; however, if the bias and any trends in the bias are well defined, then the library can be used, provided the bias and trends have been properly taken into account.

Table 1.1 shows the six neutron cross-section libraries currently available in SCALE. The SCALE Hansen-Roach library is a version of the Los Alamos 16-group Hansen-Roach library[4] that has been modified at Oak Ridge National Laboratory (ORNL) and implemented into SCALE. The remaining five libraries were generated at ORNL for use as quasi system-independent criticality safety libraries. The two 27-group libraries are treated as one library in the performance comparisons presented in this report. The group-wise energy boundaries for these libraries are presented in Appendix A.

Table 1.1 SCALE cross-section libraries[5]

Library	SCALE designator
SCALE 16-group Hansen-Roach	HANSEN-ROACH
218-group ENDF/B-IV[6]	218GROUPNDF4
27-group ENDF/B-IV	27GROUPNDF4
27-group ENDF/B-IV Burnup Library	27BURNUPLIB
238-group ENDF/B-V[7]	238GROUPNDF5
44-group ENDF/B-V[8]	44GROUPNDF5

Some of the generic strengths and weaknesses of the SCALE libraries will be discussed in Section 2. Included in that section are some common characteristics of the libraries and a discussion of the SCALE codes that perform resonance processing. Also included in Section 2 is a brief description of the calculational models and methodology used to demonstrate the performance of the libraries.

In the subsequent sections a more detailed description of each cross-section library will be presented. The performance of each library will be presented against a standard set of critical experiments to show general trends and weaknesses. The discussions in these sections will aid in identifying when a library would be expected to perform acceptably and where there are known or suspected deficiencies that would cause the calculations to be less reliable.

2 GENERAL DISCUSSION

Some of the strengths and weaknesses of the SCALE libraries may be discussed in general terms. As an example, the strengths and weaknesses (assumptions and approximations) used in the codes that generate/process the SCALE cross sections become generic strengths and weaknesses of the SCALE cross-section libraries. BONAMI[9] and NITAWL,[10] the two codes used for resonance processing in SCALE, are discussed below. The manner in which a cross-section set is generated, including the processing code and assumed generating flux, also affects the performance of a library. When using any SCALE library, one of the Criticality Safety Analysis Sequences (CSAS) should be used to ensure that the resonance self-shielding is handled appropriately. An overview of common characteristics of the SCALE libraries is presented here.

In general, all of the SCALE libraries perform acceptably for unmoderated fast systems and hydrogen-moderated thermal systems. These systems represent the largest class of application of the libraries and have the largest collection of critical experiments against which to validate. The SCALE libraries should be expected to perform less reliably for systems that have intermediate spectra and/or intermediate mass moderators that dominate the system transport, because of the lack of experimental data in these areas and the lack of emphasis in these areas during the preparation of the libraries. Note that many of the weaknesses of the SCALE libraries stem from weaknesses in the adequacy of the base data used to generate the libraries. Any library can perform only as well as the data upon which it is based. In the United States, the current source for base cross-section data is the Evaluated Nuclear Data Files (ENDF) maintained at Brookhaven National Laboratory.

2.1 CROSS-SECTION GENERATION

Several factors affect the performance of multigroup cross-section libraries, regardless of the reliability of the base data. These factors include the number of energy groups, the location of the energy-group boundaries, the flux used to generate the cross-section library, and the methods used to self-shield resonance nuclides.

Two fine-group libraries have been generated and used extensively with SCALE: the 218-group ENDF/B-IV Criticality Safety Reference Library (CSRL) and the 238-group ENDF/B-V Library to Analyze Radioactive Waste (LAW). Both libraries were generated into an AMPX[11] master library format that contains all the needed information to further process the cross sections for problem-specific temperature and resonance effects (i.e., a problem-specific or working library). Thus, the AMPX master libraries are intended to be quasi-system-independent criticality safety libraries. The problem-specific resolved resonance processing for both libraries (with the exception of a few nuclides) is via the Nordheim Integral Treatment within the NITAWL code. Single-level Breit-Wigner resolved resonance data are carried on the AMPX master library for resonance nuclides.

The unresolved resonance region is processed at a fixed potential scattering cross section (σ_p) of 50,000 barns for the 218-group library. As σ_p approaches infinity, the flux spectrum approaches an infinitely dilute flux spectrum.[a] Therefore, as σ_p increases, the self-shielding decreases. Using such a large value for σ_p results in insufficient self-shielding of the cross sections in the unresolved resonance region. For typical fast and thermal systems, this lack of self-shielding is not a problem. The unresolved resonance region in the 238-group library is handled by

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[a]Infinite dilution assumes that the amount of the nuclide is infinitesimally small (or infinitely dilute) so that there is no effect on the flux and thus no self-shielding of the cross-section resonances. Self-shielding reduces the magnitude of the resonance because of reduction in the flux caused by other atoms of the same nuclide. See Figure 2.1.

Bondarenko data, which are processed by BONAMI on a problem-specific basis. This method of handling the unresolved resonance region is more accurate.

The group structure for the fine-group libraries was developed for use on fast systems and thermal systems. Groups were intentionally added in the 238-group library structure to subdivide resolved resonances of important nuclides (for example ^{238}U) to minimize the effects of limitations of the Nordheim treatment within NITAWL on resonance processing. The additional energy-group structure allows the resonance structure to be described in multigroup data similar to point data. Other groups were added in going from the 218- to the 238-group library to specifically address the 0.3 eV thermal resonance in ^{239}Pu that cannot be properly modeled in NITAWL due to its low energy and lack of resonance data and the thermal Maxwellian peak. The additional energy-group structure also enables more accurate handling of thermal upscatter.

The two fine-group libraries were generated with a different flux function. Resonance nuclides were generated with a fission Maxwellian (10 MeV to 70 keV) - 1/E (70 keV to 0.125 eV) - thermal Maxwellian (0.125 to 10^{-5} eV) flux function in both libraries. Nonresonance nuclides were generated with a fission Maxwellian - $1/(E\sigma_t)$ - thermal Maxwellian flux function in the 218-group library and with a fission Maxwellian - 1/E - thermal Maxwellian flux function in the 238-group library. This difference in generating function can cause the two libraries to calculate differently for certain classes of systems.

The use of a $1/(E\sigma_t)$ weighting function results in a flux spectrum approximating the spectrum in a material composed entirely of that nuclide. Conversely, the use of a 1/E weighting function results in an infinitely dilute flux spectrum, thus providing no self-shielding effect and resulting in the loss of resonance data. In the former case, the cross-section structure is highly shielded and in the latter it is totally unshielded. The significance of this difference lies in the fact that there are many nuclides in ENDF which have significant resonance structure but which, according to ENDF, are considered to be nonresonance nuclides. These nuclides are usually intermediate-mass nuclides (e.g., Al, Si, S, Cl, K) and, if they play a significant role in the absorption and/or transport in a calculation, the two fine-group libraries can perform quite differently. The impact of the weighting on cross-section performance will be discussed more fully in the respective sections for the 218- and 238-group libraries.

The manner in which the ENDF/B-IV 27-group library and the ENDF/B-V 44-group library were collapsed from the parent fine-group libraries is also characteristically different. The 27-group library was collapsed using the generating flux of the 218-group library described above. This characteristic causes all nonresonance nuclides to have any cross-section structure fully self-shielded; both capture and scatter cross sections are minimized. This characteristic is desirable for systems where a nuclide other than hydrogen dominates the transport (intermediate spectrum), but has little impact on fast or well-thermalized systems.

The 44-group library was collapsed using a typical light-water-reactor lattice spectrum at room temperature conditions. This spectrum is very similar to an infinite dilute 1/E spectrum, except that structure due to oxygen and ^{238}U cross-section structure appears in the collapsing flux. The group structure of the library is the same as the 27-group library except that additional groups have been added below 0.4 eV to address the ^{239}Pu resonance region (0.2 – 0.4 eV) and the thermal Maxwellian (0.003 – 0.1 eV). The library performs well on fast or well-thermalized systems and for lattices of fuel pins. The use of an infinite dilute collapsing flux causes all nonresonance nuclides to have cross-section structure shielded at minimum values. Both capture and scatter cross sections are maximized, which adversely impacts some classes of homogeneous systems and systems where nuclides other than hydrogen dominate the transport.
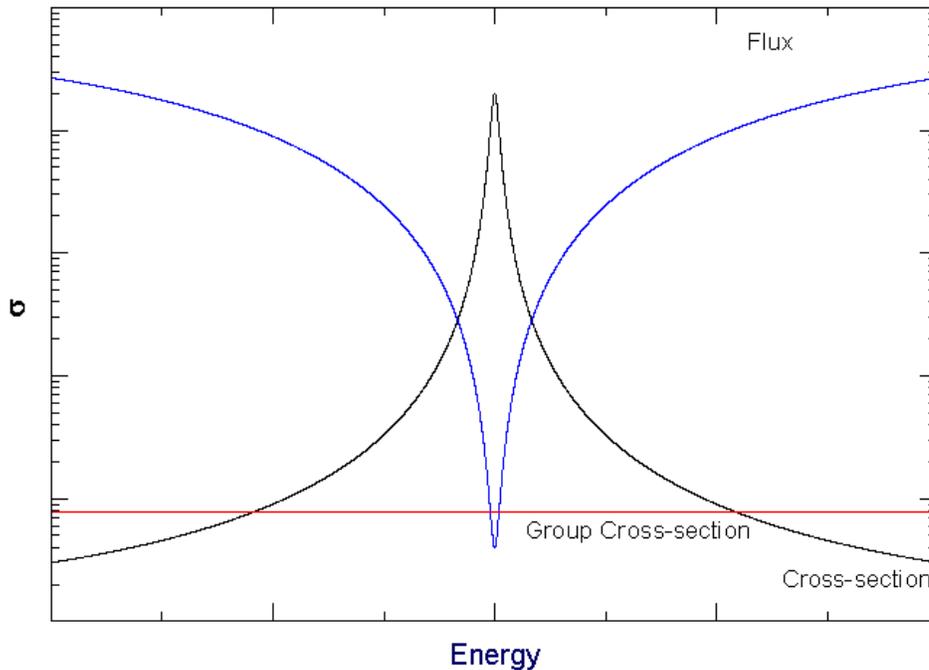
Figure 2.1 Self-shielding of cross-section resonance

2.2 RESONANCE PROCESSING

Resonance processing in the SCALE sequences is performed by BONAMI and NITAWL. Both of these codes are able to process resolved and unresolved resonance data using different methods discussed in the following sections. A common trait between both modules is that neither BONAMI nor NITAWL treat resonance overlap or resonance interference. Resonance overlap may occur because of several characteristics of a system. Typically, resonance overlap occurs when two nuclides in a mixture have resonances at the same or nearly the same energies, as discussed in Section M7.A of the SCALE manual.[1] When resonance overlap is ignored, the flux used to shield the cross section is incorrect and thus the group cross section can be in error. Another form of resonance overlap can occur when the same resonance nuclide appears in different regions (mixtures) of a geometry specification, because SCALE currently only processes one region at a time. Again, because an incorrect flux is used to shield the cross sections, the group cross sections can be in error. An example of this is in a dissolver where a fuel lump is surrounded by fissile solution containing the same resonance absorbers.

Resonance interference is similar to resonance overlap. When two resonances are close together, the higher-energy resonance affects the flux shape in the lower-energy resonance, because the flux does not reach the asymptotic flux form before the next resonance. Resonance interference can occur between resonances of different nuclides or two closely spaced resonances of the same nuclide. The limitations and approximations used in BONAMI and NITAWL will be discussed below.

5

NITAWL performs temperature broadening during resonance processing. If temperature data are included in the library, BONAMI performs temperature broadening at the user-specified problem temperature during resonance processing. Starting with SCALE 4.3, NITAWL also performs a temperature interpolation of thermal-scattering data on the master library.

2.2.1 BONAMI

The BONAMI module self-shields cross sections with Bondarenko data using the shielding-factor methodology. Nuclides with Bondarenko data carry an infinite dilute cross section on the master library and tables of shielding factors that are dilution-dependent. BONAMI performs an iteration for each nuclide and each energy group that has shielding factors. Convergence is achieved when the sum of the individually shielded cross sections agrees with the shielded total cross section. In this manner, the problem-dependent self-shielded cross sections for each nuclide and each group are determined and interacting effects are taken into account. When CSAS calls BONAMI, heterogenous geometry effects are accounted for in the escape cross section that is passed to BONAMI. The escape cross section is determined based on the system geometry specified in the cross-section processing portion of the SCALE input. The geometry type, materials, characteristic dimensions, and the Dancoff factor are all used to determine the escape cross section. By using the escape cross section to account for geometry effects, all nuclides can be processed by BONAMI as infinite homogeneous media in the CSAS sequences.

The performance of libraries shielded by the Bondarenko method depends on the adequacy of the approximations used to generate the Bonderenko data. The typical approach is to use the narrow resonance approximation to generate these data, which is adequate for a broad range of applications. When a resonance is not narrow relative to the slowing down in the system, the narrow resonance approximation breaks down and the resonance corrections for the cross sections can be in error. This breakdown has been observed for libraries that use the Bondarenko method to shield the low-energy resolved resonances for ^{238}U for systems with low hydrogen moderation[12] and for many nuclides when the principal moderator is an intermediate-mass nuclide. The solution to this type of breakdown is to either carry sufficient cross-section energy groups to march across the resonance and/or to use more appropriate flux-generating methods to compute the Bondarenko factors. This problem does not occur in the SCALE libraries because Bondarenko data are only used in the unresolved resonance range.

2.2.2 NITAWL

The NITAWL-II module shields cross sections with resonance data utilizing the Nordheim integral transport method. In the SCALE implementation, the infinite-dilute multi-group cross sections are adjusted by a correction value determined by NITAWL. The correction is calculated by first determining the infinite dilute contribution of each resonance to the group cross section and then by calculating what the contribution would be if the resonance was shielded for the specific problem. The geometry type, materials, characteristic dimensions, and Dancoff factor are all passed to NITAWL for determining the details of the approximations used to self-shield the cross sections. NITAWL uses two moderators when reconstructing the shielded flux. The slowing-down mass and scatter cross section for the principal material (first moderator) mixed with the fuel are used explicitly. The remaining materials (second moderator) are treated using an averaged slowing-down mass and scatter cross section.

A fundamental assumption of the Nordheim method is that resonances are widely spaced, both within a particular nuclide and between nuclides. If this assumption is not correct, the flux used to construct the resonance contribution to the group cross section is incorrect. Breakdowns have been observed when NITAWL was used to

self-shield cross sections of fissile nuclides with overlapping resonances in dissolver-type systems[13] and in systems with intermediate-mass moderators and intermediate-mass resonance materials.

2.2.3 Thermal-Scattering Data Limitation

A discrepancy was discovered prior to the release of SCALE 4.3, when KENO V.a calculations using the 27-group library were compared with calculations using a commercial 2-D lattice physics code for LWR fuel assemblies in a storage configuration as a function of temperature. The two codes were in relative agreement at low temperatures (20°C) and small water gaps between assemblies. However, as the temperature of the system was increased to 120°C, the 2-D lattice code calculations gave increasingly larger values of k_{eff} relative to KENO. Larger water gaps (between assemblies) enhanced the temperature effects on calculated k_{eff}. The KENO results were as much as 3% lower at 120°C.

The cause of this discrepancy was identified as a limitation in processing the thermal-scattering data when NITAWL makes a working library in versions of SCALE prior to 4.3. The SCALE ENDF/B-IV hydrogen has scattering matrices at 293 K and 550 K (20°C and 277°C). When NITAWL processes hydrogen, the scattering matrix with a temperature closest to that specified is used. It was determined that the temperature dependence of the scattering can increase the multiplication factor by as much as 2.5%. Users of earlier versions of SCALE should be aware of this problem and ensure that the hydrogen-scattering matrices used in their analyses are either appropriate or conservative with respect to k_{eff}. The SCALE ENDF/B-V libraries contain hydrogen scattering matrices at eight temperatures and were not released until SCALE 4.3, so this problem does not exist for the ENDF/B-V libraries.

Information on the thermal-scattering data available in the SCALE criticality-safety libraries may be found in Appendices C–E.

2.3 GENERAL DESCRIPTION OF THE VALIDATION EXPERIMENTS

In addition to discussing general experience and performance for each SCALE cross-section library, the performance of each library will be demonstrated for a set of benchmark models. These models are primarily composed of critical experiment models that have been used in the past to validate one or more of the SCALE libraries.

The performance of each library for these calculations provides a measure of the adequacy of the library. It is not surprising that, in general, the libraries perform rather predictably for these benchmarks; after all, most of the systems fall into the realm of typical applications for which the libraries were intended. The calculations show the general range of application of the libraries. **It cannot be emphasized too strongly that application of cross sections outside the range of validation must be done with great care, regardless of the criticality safety code and/or cross sections used.** This caution is due to potential unidentified deficiencies in both the base cross-section data and in the manner the cross sections are processed from ENDF/B formats for use by the various codes.

The descriptions and results for several calculational benchmarks are presented in Appendix B. These calculational benchmarks are models that are hypothetical and do not model actual critical experiments, but were

set up to study characteristics of the library over a range of parameters and to allow for easy comparison of two or more cross-section libraries. Because they do not model an actual experiment, the calculational benchmarks do not demonstrate the adequacy of a particular code or cross-section set, but show over the range of possible application where different cross-section libraries agree or disagree. Agreement between the libraries for the various parametric studies does not, in itself, demonstrate the adequacy of the library for the application. Disagreement between libraries, however, does indicate where one or another of the libraries may be deficient. An obvious extension of this statement is that when different cross-section libraries give different results for the same system, similar differences should show up in the equivalent validations for the libraries; otherwise, neither library has been validated for the application.

2.3.1 High-Enriched Homogeneous ^{235}U Experiments

More than 130 critical experiments from Table 5 of ORNL/TM-238 (Ref. 14) and the *International Handbook of Evaluated Criticality Safety Benchmark Experiments*[15] (IHECSBE) were selected to evaluate the performance of the cross-section libraries for high-enriched homogeneous uranium systems. In addition, eight experiments using high-enriched uranium disks and polyethylene disks,[16] commonly referred to as the Jemima plates, were selected. A list of the experiments is provided in Table 2.1. The experiments can be subdivided into three groups: (1) uranium metal systems with fast or intermediate-energy spectra; (2) Jemima high-enriched experiments with intermediate-energy spectra; and (3) uranyl nitrate and uranyl fluoride solutions with thermal-energy spectra. These experiments are similar to those that have been used for criticality safety validation of weapons facilities. Six of the experiments in Table 5 of ORNL/TM-238 were also included in the evaluated experiments of Ref. 15. The evaluated models were used when available.

Table 2.1 High-enriched homogeneous ^{235}U experiments

Case	Experimental description
CAS01[a]	Y-12 validation case A-1. 93.8% U metal sphere, unreflected (GODIVA)
CAS04	Y-12 validation case A-2. 93.2% U-Mo alloy cylinder annulus, unreflected
CAS05	Y-12 validation case A-3. 93.2% UO_2F_2 solution, 19.992 g U/L, in Al sphere, unreflected
CAS06[a]	Y-12 validation case A-4. 93.18% $UO_2(NO_3)_2$ solution, 20.12 g U/L, in Al sphere, unreflected
CAS07	Y-12 validation case A-5. 93.5% U metal hemispherical shell, H_2O-reflected
CAS08	Y-12 validation case A-6. 93.2% U metal cylinder annulus, graphite-reflected
CAS09	Y-12 validation case A-7. 94% U metal cuboid, natural U-reflected
CAS10	Y-12 validation case A-8. 93.1% U metal hemispherical shell, oil-reflected
CAS11	Y-12 validation case A-9. 93.1 % U metal hemispherical shell, steel center and oil-reflected
CAS02[a]	Y-12 validation case A-10. 97.67% U metal sphere, H_2O-reflected
CAS03[a]	Y-12 validation case A-11. 93.172% $UO_2(NO_3)_2$ solution, 346.7 g U/L, in SS cylinder, unreflected
CAS12	Y-12 validation case B-1. 93.2% U metal cylinder annulus, unreflected, smaller U cylinder in hole touching one wall
CAS22	Y-12 validation case B-2. 93.2% U metal cylinder annulus, unreflected, smaller U block in hole touching one wall
CAS23	Y-12 validation case B-3. 93.2% U metal, unreflected cylinders and cuboids in approximate circular arrangement, cylinder, cuboid, and hemisphere stack in center

Table 2.1 (continued)

Case	Experimental description
CAS24	Y-12 validation case B-4. 93.2% U metal cylinders, $4 \times 4 \times 4$ array, unreflected
CAS25	Y-12 validation case B-5. 93.2% U metal cylinders, $2 \times 2 \times 2$ array, each unit in the array is a smaller cylinder capped on each end by a larger cylinder, unreflected
CAS26	Y-12 validation case B-6. 93.2% U metal cylinders, $2 \times 2 \times 2$ array, paraffin-reflected
CAS27	Y-12 validation case B-7. 93.2% U metal cylinders, $2 \times 2 \times 2$ array, each unit in the array is a smaller cylinder capped on each end by a larger cylinder, paraffin-reflected
CAS28	Y-12 validation case B-8. 93.2% U metal cylinders each in a Plexiglas box, $2 \times 2 \times 2$ array of these units unreflected
CAS14	Y-12 validation case B-11. 93.2% $UO_2(NO_3)_2$ solution, 505 g U/L, in SS cylinders, 4×4 array, standing in a solution slab, Plexiglas-reflected
CAS15	Y-12 validation case B-12. 93.2% U metal cylinders, $2 \times 2 \times 2$ array, graphite-moderated and polyethylene-reflected
CAS19	Y-12 validation case B-16. 93.1% $UO_2(NO_3)_2$ solution, 450.8 g U/L, in SS containers, square central column with 8 perpendicular cylindrical arms unreflected
CAS20[a]	Y-12 validation case B-17. 93.17% $UO_2(NO_3)_2$ solution, 355.9 g U/L, in A1 cylinders, 4×4 array, Plexiglas-reflected
CAS21[a]	Y-12 validation case B-18. 93.17% $UO_2(NO_3)_2$ solution, 364.1 g U/L, in A1 cylinders, 4×4 array, concrete-reflected
CAS30	Problem S333SP0. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs, three 7.62-cm slabs in 3×1 array, 0 cm separation, unreflected, cylindrical tank, floor and walls in experiment room included
CAS32	Problem S333SP1. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs, three 7.62-cm slabs in 3×1 array, 2.54-cm separation, unreflected, cylindrical tank, floor, and walls in experiment room included

Table 2.1 (continued)

Case	Experimental description
CAS34	Problem S333SP3. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs, three 7.62-cm slabs in 3×1 array, 7.62 cm separation, unreflected, cylindrical tank, floor, and walls in experiment room included
CAS 36	Problem S333SP4. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al stabs, three 7.62-cm slabs in 3×1 array, 11.43-cm separation, unreflected,cylindrical tank, floor, and walls in experiment room included
CAS38	Problem S333SP5. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs, three 7.62-cm slabs in 3×1 array, 13.97 cm separation, unreflected, cylindrical tank, floor, and walls in experiment room included
CAS40	Problem S333SP6. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs, three 7.62-cm slabs in 3×1 array, 15.24 cm separation, unreflected, cylindrical tank, floor, and walls in experiment room included
CAS31	Problem S333SP0R. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs, three 7.62-cm slabs in 3×1 array, 0 cm separation, H_2O-reflected
CAS33	Problem S333SP1R. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs, three 7.62-cm slabs in 3×1 array, 2.54-cm separation, H_2O-reflected
CAS35	Problem S333SP3R. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs, three 7.62-cm slabs in 3×1 array, 7.62-cm separation, H_2O-reflected
CAS37	Problem S333SP4R. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs, three 7.62-cm slabs in 3×1 array, 11.43-cm separation, H_2O-reflected
CAS39	Problem S333SP5R. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs, three 7.62-cm slabs in 3×1 array, 13.97-cm separation, H_2O-reflected
CAS42	Problem S36SP2. 93.2% UO_2F_2 solution, 81.8 g U/L in A1 slabs, 7.62- and 14.834-cm slabs in 2×1 array, 5.08-cm separation, unreflected

Table 2.1 (continued)

Case	Experimental description
CAS41	Problem S36SP15. 93.2% UO_2F_2 solution, 81.8 g U/L in Al slabs, 7.62- and 14.834-cm slabs in 2×1 array, 38.1-cm separation, unreflected
CAS43	Problem S36SP30. 93.2% UO_2F_2 solution, 81.8 g U/L in A1 slabs, 7.62- and 14.834-cm slabs in 2×1 array, 76.2-cm separation, unreflected
CAS44	Problem S36SP48. 93.2% UO_2F_2 solution, 81.8 g U/L in A1 slabs, 7.62- and 14.834-cm slabs in 2×1 array, 121.92-cm separation, unreflected
CAS45	Problem S363SP0. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs, 7.62-, 14.834-, and 7.62-cm slabs in 3×1 array, 0-cm separation, unreflected
CAS46	Problem S363SP10. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs, 7.62-, 14.834-, and 7.62-cm slabs in 3×1 array, 25.4-cm separation, unreflected
CAS47	Problem S363SP20. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs, 7.62-, 14.834-, and 7.62-cm slabs in 3×1 array, 50.8-cm separation, unreflected
CAS48	Problem S363SP32. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs, 7.62-, 14.834-, and 7.62-cm slabs in 3×1 array, 81.28-cm separation, unreflected
CAS52	Problem S63SP6. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs. One slab is made up from two 7.62-cm slabs snugly fit together, the other is 7.62 cm, 2×1 array, 15.24-cm separation, unreflected
CAS49	Problem S63SP12. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs. One slab is made up from two 7.62-cm slabs snugly fit together, the other is 7.62-cm, 2×1 array, 30.48-cm separation, unreflected
CAS50	Problem S63SP18. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs. One slab is made up from two 7.62-cm slabs snugly fit together, the other is 7.62 cm, 2×1 array, 45.72-cm separation, unreflected

Table 2.1 (continued)

Case	Experimental description
CAS51	Problem S63SP30. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs. One slab is made up from two 7.62-cm slabs snugly fit together, the other is 7.62 cm, 2×1 array, 76.2-cm separation, unreflected
CAS54	Problem S66SP2. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs. One slab is 14.834 cm, and the other is made up from two 7.62-cm slabs snugly fit together, 2×1 array, 5.08-cm separation, unreflected
CAS58	Problem S66SP6. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs. One slab is 14.834 cm, and the other is made up from two 7.62-cm slabs snugly fit together, 2×1 array, 15.24-cm separation, unreflected
CAS53	Problem S66SP15. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs. One slab is 14.834 cm, and the other is made up from two 7.62-cm slabs snugly fit together, 2×1 array, 38.1-cm separation, unreflected
CAS55	Problem S66SP20. 93.2% UO_2F_2 solution, 81.8 g U/L, in A1 slabs. One slab is 14.834 cm, and the other is made up from two 7.62-cm slabs snugly fit together, 2×1 array, 50.8-cm separation, unreflected
CAS56	Problem S66SP30. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs. One slab is 14.834 cm, and the other is made up from two 7.62-cm slabs snugly fit together, 2×1 array, 76.2-cm separation, unreflected
CAS57	Problem S66SP48. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs. One slab is 14.834 cm, and the other is made up from two 7.62-cm slabs fit snugly together, 2×1 array, 121.92-cm separation, unreflected
CAS59	Problem S66SP66. 93.2% UO_2F_2 solution, 81.8 g U/L, in Al slabs. One slab is 14.834 cm, and the other is made up from two 7.62-cm slabs fit snugly together, 2×1 array, 167.64-cm separation, unreflected
CAS91	Problem U6B271F. 92.6% $UO_2(NO_3)_2$ solution, 63.3 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, unreflected, walls, floor, and tank in experiment room included

Table 2.1 (continued)

Case	Experimental description
CAS60	Problem U2B271F. 92.6% $UO_2(NO_3)_2$ solution, 279 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, unreflected, walls, floor, and tank in experiment room included
CAS61	Problem U2B81F. 92.6% $UO_2(NO_3)_2$ solution, 279 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, unreflected, walls, floor, and tank in experiment room included
CAS62	Problem U4B1251F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $5 \times 5 \times 5$ array, unreflected, walls, floor, and tank in experiment room included
CAS64	Problem U4B641F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $4 \times 4 \times 4$ array, unreflected, walls, floor, and tank in experiment room included
CAS63	Problem U4B271F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, unreflected, walls, floor, and tank in experiment room included
CAS65	Problem U4B81F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, unreflected, walls, floor, and tank in experiment room included
CAS90	Problem U4U2B27. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, unreflected, 279 g U/L in 5 central units, walls, floor, and tank in experiment room included
CAS66	Problem U4R27AlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 15.24 cm paraffin on bottom, 1.27-cm Plexiglas on other faces
CAS67	Problem U4R27BlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 15.24-cm paraffin on bottom, 2.54-cm Plexiglas on other faces
CAS68	Problem U4R27C1F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 15.24-cm paraffin on bottom, 1.27-cm paraffin on other faces
CAS69	Problem U4R27D1F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 15.24-cm paraffin on 5 faces, 15.24-cm Plexiglas on 1 face

Table 2.1 (continued)

Case	Experimental description
CAS70	Problem U4R27ElF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 15.24-cm paraffin on bottom, 3.81-cm paraffin on other faces
CAS71	Problem U4R27FlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 15.24-cm paraffin on bottom, 7.62-cm paraffin on other faces
CAS72	Problem U4R27GlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 1.27-cm Plexiglas all faces
CAS73	Problem U4R27Hl F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 1.27-cm paraffin all faces
CAS74	Problem U4R27IlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 15.24-cm paraffin all faces
CAS75	Problem U4R27JlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $3 \times 3 \times 3$ array, reflected, 3.81-cm paraffin all faces
CAS76	Problem U4R8AlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin on bottom, 1.27-cm Plexiglas on other faces
CAS77	Problem U4R8BlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin on bottom, 11.43-cm Plexiglas on other faces
CAS78	Problem U4R8C1F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin on bottom, 15.24-cm Plexiglas on other faces
CAS79	Problem U4R8D1F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin on bottom, 2.54-cm Plexiglas on other faces
CAS80	Problem U4R8ElF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin on bottom, 4.45-cm Plexiglas on other faces

Table 2.1 (continued)

Case	Experimental description
CAS81	Problem U4R8FlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin on bottom, 6.35-cm Plexiglas on other faces
CAS82	Problem U4R8GlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin on bottom, 1.27-cm Plexiglas on other faces
CAS83	Problem U4R8HlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin on bottom, 3.81-cm Plexiglas on other faces
CAS84	Problem U4R8IlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin on bottom, 7.62-cm Plexiglas on other faces
CAS85	Problem U4R8J1F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 1.27-cm Plexiglas all faces
CAS86	Problem U4R8KlF. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 1.27-cm paraffin all faces
CAS87	Problem U4R8L1F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 15.24-cm paraffin all faces
CAS88	Problem U4R8M1F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 3.81-cm paraffin all faces
CAS89	Problem U4R8N1F. 92.6% $UO_2(NO_3)_2$ solution, 415 g U/L, in Plexiglas cylinders, $2 \times 2 \times 2$ array, reflected, 7.62-cm paraffin all faces
HEU-MET-FAST-001	Bare, highly enriched uranium sphere (Godiva) Same as CAS01
HEU-MET-FAST-004	Water-reflected, highly enriched uranium sphere Same as CAS02
HEU-SOL-THERM-001	Minimally reflected cylinders of highly enriched solutions of uranyl nitrate (10 experiments - Exp. 2 same as CAS03)

Table 2.1 (continued)

Case	Experimental description
HEU-SOL-THERM-007	Concrete reflected arrays highly enriched solutions of uranyl nitrate (17 experiments - Exp. 4 same as CAS21)
HEU-SOL-THERM-008	Plexiglas reflected arrays highly enriched solutions of uranyl nitrate (14 experiments - Exp. 4 same as CAS20)
HEU-SOL-THERM-013	Unreflected 174-L spheres of enriched uranium nitrate solutions (4 experiments - Exp. 1 same as CAS06)
Jemima	1/8 in.-thick × 15 in.-diam U(93) plates Experiment 1 – with no polyethylene disks Experiment 2 – with 1/16 in.-thick polyethylene disks Experiment 3 – with 1/8 in.-thick polyethylene disks Experiment 4 – with 1/4 in.-thick polyethylene disks Experiment 5 – with ½ in.-thick polyethylene disks Experiment 6 – with 1 in.-thick polyethylene disks Experiment 7 – with 1-1/2 in.-thick polyethylene disks Experiment 8 – with 2 in.-thick polyethylene disks

[a] Case from IHECSBE used instead

2.3.2 Low-Enriched Homogeneous ^{235}U Experiments

Forty-nine critical experiments from Table 3 of ORNL/TM-238 (Ref. 14) were selected to evaluate the performance of the cross-section libraries for low-enriched homogeneous uranium systems. A list of the experiments is provided in Table 2.2. The experiments consist of three types: (1) UF_4/paraffin blocks; (2) damp oxide powders (U_3O_8); and (3) uranyl fluoride solutions. These experiments are typical of those used to perform criticality-safety validation for the low-enriched portion of a diffusion plant.

Table 2.2 Low-enriched homogeneous ^{235}U experiments

Case	Experimental description
CAS04	An unreflected rectangular parallelepiped of homogeneous U(1.4)F$_4$ and paraffin with an H/U-235 atomic ratio of 421.8; 93.1 cm $\times$ 93.0 cm $\times$ 123.8 cm
CAS05	An unreflected rectangular parallelepiped of homogeneous U(1.4)F$_4$ and paraffin with an H/U-235 atomic ratio of 421.8; 100.0 cm $\times$ 99.9 cm $\times$ 103.1 cm
CAS06	An unreflected rectangular parallelepiped of homogeneous U(1.4)F$_4$ and paraffin with an H/U-235 atomic ratio of 421.8; 130.7 cm $\times$ 130.6 cm $\times$ 74.2 cm
CASl1	A reflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 195.2; 56.22 cm $\times$ 56.22 cm $\times$ 112.88 cm, reflected with 15.2 cm of paraffin on top and sides and 15.2 cm of Plexiglas on the bottom
CAS12	An unreflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 195.2; 71.47 cm $\times$ 71.47 cm $\times$ 94.14 cm
CAS13	A reflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 293.9; 51.11 cm $\times$ 51.11 cm $\times$ 73.87 cm, reflected with 15.2 cm of paraffin on top
CAS14	An unreflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 293.9; 56.22 cm $\times$ 56.22 cm $\times$ 122.47 cm
CAS15	A reflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 406.3; 53.67 cm $\times$ 53.67 cm $\times$ 54.29 cm, reflected with 15.2 cm of paraffin on top and sides and 15.2 cm of Plexiglas on the bottom

Table 2.2 (continued)

Case	Experimental description
CAS16	A reflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 495.9; 46.00 cm × 46.00 cm × 96.57 cm, reflected with 15.2 cm of paraffin on top and sides and 15.2 cm of Plexiglas on the bottom
CAS17	A reflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 613.6; 56.32 cm × 61.29 cm × 54.08 cm, reflected with 15.2 cm of polyethylene on top and sides and 15.2 cm of Plexiglas on the bottom
CAS18	An unreflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 613.6; 61.3 cm × 66.54 cm × 66.52 cm
CAS19	A reflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 971.7; 76.51 cm × 76.44 cm × 82.42 cm, reflected with 5.2 cm of polyethylene on top and sides and 15.2 cm of Plexiglas on the bottom
CAS20	An unreflected rectangular parallelepiped of homogeneous U(2)F$_4$ and paraffin with an H/U-235 atomic ratio of 971.7; 81.45 cm × 86.70 cm × 88.22 cm
CAS21	A reflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 133.4; 51.14 cm × 51.14 cm × 51.27 cm, reflected with 15.2 cm of paraffin on top and sides and 15.2 cm of Plexiglas on the bottom
CAS22	A reflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 133.4; 43.47 cm × 43.47 cm × 86.39 cm, reflected with 15.2 cm of paraffin on top and sides and 15.2 cm of Plexiglas on the bottom
CAS23	A reflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 133.4; 46.02 cm × 46.02 cm × 67.57 cm, reflected with 15.2 cm of paraffin on top and sides and 15.2 cm of Plexiglas on the bottom
CAS24	A reflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 133.4; 56.25 cm × 56.25 cm × 43.41 cm, reflected with 15.2 cm of paraffin on top and sides and 15.2 cm

Table 2.2 (continued)

Case	Experimental description
	of Plexiglas on the bottom
CAS25	A reflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 133.4; 61.36 cm $\times$ 61.36 cm $\times$ 38.67 cm, reflected with 15.2 cm of paraffin on top and sides and 15.2 cm of Plexiglas on the bottom
CAS26	An unreflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 133.4; 56.47 cm $\times$ 56.47 cm $\times$ 86.64 cm
CAS27	An unreflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 133.4; 56.25 cm $\times$ 61.36 cm $\times$ 74.38 cm
CAS28	An unreflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 133.4; 61.4 cm $\times$ 61.4 cm $\times$ 66.0 cm
CAS29	A reflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 276.9; 40.81 cm $\times$ 40.80 cm $\times$ 39.49 cm, reflected with 15.2 cm of polyethylene on top and sides and 15.2 cm of Plexiglas on the bottom
CAS30	An unreflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 276.9; 40.90 cm $\times$ 40.93 cm $\times$ 116.80 cm
CAS31	An unreflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 276.9; 48.59 cm $\times$ 51.14 cm $\times$ 48.53 cm
CAS32	An unreflected rectangular parallelepiped of homogeneous U(3)F$_4$ and paraffin with an H/U-235 atomic ratio of 276.9; 81.71 cm $\times$ 81.66 cm $\times$ 31.34 cm
CAS33	A composite cadmium/steel/water side reflected stainless steel cylinder of 0.079 cm wall thickness and 19.545 cm IR filled to a height of 54.45 cm with U(4.98)O$_2$F$_2$ solution at an H/U-235 atomic ratio of 488
CAS34	A composite 1-in. steel/water side reflected steel cylinder of 0.079 cm wall thickness and 16.51 cm IR filled to a height of 143 cm with U(4.98)O$_2$F$_2$ solution at an H/U-235 atomic ratio of 488

Table 2.2 (continued)

Case	Experimental description
CAS35	An unreflected sphere of U(4.98)O_2F_2 with an H/U-235 atomic ratio of 490. Solution radius of 25.3873 cm and stainless steel container wall thickness of 0.0508 cm
CAS36	An unreflected stainless steel cylinder of 0.07874 cm wall thickness and a 19.55 cm IR filled to a height of 101.7 cm, with U(4.98)O_2F_2 solution at H/U-235 atomic ratio of 496
CAR01	Experiment 1. 4.46%-enriched U_3O_8, H/U = 0.77, 42 fuel cans with 2.44-cm interstitial moderation, plastic-reflected
CAR02	Experiment 2. 4.46%-enriched U_3O_8, H/U = 0.77, 43 fuel cans with 2.44-cm interstitial moderation, plastic-reflected
CAR03	Experiment 3. 4.46%-enriched U_3O_8, H/U = 0.77, 100 fuel cans with 0.929-cm interstitial moderation, plastic-reflected
CAR04	Experiment 13. 4.46%-enriched U_3O_8, H/U = 0.77, 40 fuel cans with 2.44-cm interstitial moderation, concrete-reflected
CAR05	Experiment 15. 4.46%-enriched U_3O_8, H/U = 0.77, 98 fuel cans with 0.929-cm interstitial moderation, concrete-reflected
CAR06	4.46%-enriched U_3O_8, H/U = 0.77, driven by 93.12%-enriched uranium metal sphere (29.870 kg), 120 + 4S fuel cans, plastic-reflected
CAR07	4.46%-enriched U_3O_8, H/U = 0.77, driven by high-concentration (14.844 kg 351.18 gU/L) 93.17%-enriched $UO_2(NO_3)_2$, 119 + 2S fuel cans, plastic-reflected
CAR08	4.46% enriched U_3O_8, H/U = 0.77, driven by low-concentration (12.871 kg 86.42 gU/L) 93.17%-enriched $UO_2(NO_3)_2$, 119 + 2S fuel cans, plastic-reflected
CAR09	4.46% enriched U_3O_8, H/U = 0.77, driven by low-concentration (13.001 kg 86.42 gU/L) 93.17%-enriched $UO_2(NO_3)_2$, 119 + 2S fuel cans, plastic-reflected

Table 2.2 (continued)

Case	Experimental description
CAR10	4.46%-enriched U_3O_8, H/U = 0.77, driven by low concentration (12.446 kg 86.42 gU/L) 93.17%-enriched $UO_2(NO_3)_2$, 119 + 2S fuel cans, concrete-reflected
CAR11	Experiment A. 4.46%-enriched U_3O_8 H/U = 1.25, 38 fuel cans with 2.44-cm interstitial moderation, plastic-reflected
CAR12	Experiment B. 4.46%-enriched U_3O_8 H/U = 1.25, 78 fuel cans with 0.929-cm interstitial moderation, plastic-reflected
CAR13	Experiment C. 4.46%-enriched U_3O_8 H/U = 1.25, 80 fuel cans with 0.929-cm interstitial moderation, plastic-reflected
CAR14	4.46%-enriched U_3O_8 H/U = 1.25, driven by high concentration (12.268 kg 351.64 gU/L), 93.17%-enriched $UO_2(NO_3)_2$, 119 + 2S fuel cans, plastic-reflected
CAR15	4.46%-enriched U_3O_8 H/U = 1.25, driven by high concentration (12.400 kg 351.65 gU/L), 93.17%-enriched $UO_2(NO_3)_2$, 119 + 2S fuel cans, plastic-reflected
CAR16	4.46%-enriched U_3O_8 H/U = 1.25, driven by low concentration (10.836 kg 86.60 gU/L), 93.17% enriched $UO_2(NO_3)_2$, 119 + 2S fuel cans, plastic-reflected
CAR17	Experiment F. 4.46%-enriched U_3O_8 H/U = 2.03, 48 fuel cans with 0.92-cm interstitial moderation, plastic-reflected
CAR18	Experiment G. 4.46%-enriched U_3O_8 H/U = 2.03, 30 fuel cans with 2.44-cm interstitial moderation, plastic-reflected
CARl9	Experiment D. 4.46%-enriched U_3O_8 H/U = 2.03, driven by 93.12% enriched-uranium metal sphere (13.73 kg), 120 + 4S fuel cans, plastic-reflected
CAR20	Experiment E. 4.46%-enriched U_3O_8 H/U = 2.03, driven by 93.12%-enriched hollow uranium metal sphere (12.786 kg), 120 + 4S fuel cans, plastic-reflected

2.3.3 LWR Lattice Experiments

Critical experiment cases 1 through 59 were selected from Table 4.1 of NUREG/CR-6102 (Ref. 8) to evaluate the performance of the SCALE codes and cross-section libraries for heterogeneous systems.   A list of the experiments is given in Table 2.3. These experiments are low-enriched light-water-reactor (LWR) lattices. The series of experiments demonstrates the performance of both the cross sections and the SCALE resonance cross-section processing methodology. These experiments span a range of moderation and fuel pin arrangements that might be of interest in evaluating LWR fuel storage and transport.

Table 2.3 LWR lattice experiments

Case No.	Case designation	Enrich. (wt %)	Description	Lattice water/fuel volume ratio
1	p2438x05	2.35	No absorber plates	2.92
2	p2438x17	2.35	Boral absorber plates	2.92
3	p2438x28	2.35	Stainless steel absorber plates	2.92
4	p2615x14	4.31	Stainless steel absorber plates	3.88
5	p2615x23	4.31	Cadmium absorber plates	3.88
6	p2615x31	4.31	Boral absorber plates	3.88
7	p2827u2a	2.35	Uranium reflector	2.92
8	p2827l2a	2.35	Lead reflector	2.92
9	p2827non	2.35	No reflector	2.92
10	p2827u2b	4.31	Uranium reflector	3.88
11	p2827l2b	4.31	Lead reflector	3.88
12	p3314a	4.31	0.226-cm Boroflex absorber plates	1.6
13	p3314b	4.31	0.452-cm Boroflex absorber plates	1.6
14	p3602n2	2.35	Steel reflector, no absorber	2.92
15	p3602non	4.31	Steel reflector, no absorber	1.6
16	p3602s4	4.31	Steel reflector, borated steel absorber plates	1.6
17	p3602b4	4.31	Steel reflector, Boral absorber plates	1.6

Table 2.3 (continued)

Case No.	Case designation	Enrich. (wt %)	Description	Lattice water/fuel volume ratio
18	p3602c4	4.31	Steel reflector, cadmium absorber plates	1.6
19	p3926u2a	2.35	Uranium reflector	1.6
20	p3926l2a	2.35	Lead reflector	1.6
21	p3926n2	2.35	No reflector	1.6
22	p3926u4a	4.31	Uranium reflector	1.6
23	p3926l4a	4.31	Lead reflector	1.6
24	p3926nob	4.31	No reflector	1.6
25	p4267a	4.31	No soluble boron	1.59
26	p4267b	4.31	2550 ppm soluble boron	1.59
27	p4267c	4.31	No soluble boron	1.09
28	p4267d	4.31	2550 ppm soluble boron	1.09
29	pnl194	4.31	Hexagonal lattice, narrow pitch	0.509
30	ft214r	4.31	Flux traps, no voids	1.6
31	ft214v3	4.31	Flux traps with voids	1.6
32	baw1231a		Core I — 1152 ppm soluble borom	0.994
33	baw1231b		Core I — 3389 ppm soluble borom	0.994
34	baw1273m	2.46	Core XX — 1675 ppm soluble boron	0.999
35	baw1484a	2.46	2.46 Core IV — 84 B4C pins — 1 pitch between assemblies	1.84
36	baw1484b	2.46	Core IX - No B4C pins — 4 pitches between assemblies	1.84
37	baw1484c	2.46	Core XIII - 1.6 wt % Boral — 1 pitch between assemblies	34.55
38	baw1484d	2.46	Core XXI - 0.1 wt % Boral — 3 pitches between assemblies	35.17
39	baw1645t	2.46	Triangular pitch, pitch = pin O.D.	0.149

Table 2.3 (continued)

Case No.	Case designation	Enrich. (wt %)	Description	Lattice water/fuel volume ratio
40	baw1645s	2.46	Square pitch, pitch = pin O.D.	0.383
41	bw1645so	2.46	Square pitch, pitch = 1.17*pin O.D.	1.014
42	bnw1810a	2.46 and 4.02	Core 12 - No Gd fuel rods	1.84 and 1.53
43	bnw1810b	2.46 and 4.02	Core 14 - 12 Gd fuel rods	1.84 and 1.53
44	bnw1810c	2.46 and 4.02	Core 16 - 16 Gd fuel rods	1.84 and 1.53
45	e196u6n	2.35	0.615-in. pitch, 0 ppm soluble boron	1.196
46	epru615b	2.35	0.615-in. pitch, 464 ppm soluble boron	1.196
47	epru75	2.35	0.750-in. pitch, 0 ppm soluble boron	2.408
48	epru75b	2.35	0.750-in. pitch, 568 ppm soluble boron	2.408
49	e196u87c	2.35	0.870-in. pitch, 0 ppm soluble boron	3.687
50	epru87b	2.35	0.870-in. pitch, 286 ppm soluble boron	3.687
51	saxu56	5.74	2 lattice pitches, SS clad, 0.56-in. pitch	1.933
52	saxu792	5.74	2 lattice pitches, SS clad, 0.792-in. pitch	5.067
53	w3269a	3.7	Ag-In-Cd (0.330-in. O.D) absorber rods, 0.405-in. pitch	2.2
54	w3269b	3.7	Ag-In-Cd (0.330-in. O.D) absorber rods, 0.435-in. pitch	2.9
55	w3269c	2.72	Ag-In-Cd (0.403-in. O.D) absorber rods, 0.600-in. pitch	3.1
56	ans33bp2	4.75	Cruciform box, polyethylene powder absorbers	1.81
57	ans33bb2	4.75	Cruciform box, polyethylene balls absorbers	1.81
58	ans33bh2	4.75	Cruciform box only	1.81
59	ans33h2	4.75	No absorbers	1.81

2.3.4 ^{239}Pu Experiments

Thirty-four critical experiments from Table E.2 of ORNL/TM-12374 (Ref. 17) were utilized to evaluate the plutonium cross sections in SCALE (see Table 2.4). These experiments span a range of geometry, moderation level, and ^{240}Pu content. In addition, four models were taken from the IHECSBE Handbook. These experiments are listed in Table 2.5.

Table 2.4 ^{239}Pu experiments from ORNL/TM-12374

Koponen citation ID No.[a]	H/Pu atom ratio	% ^{240}Pu ratio	Pu density (g/cm**3)	Geometry	Reflector
2110-2	125	5	0.172	Sphere	None
2110-4	758	5	0.034	Sphere	6.6 mm steel
2110-5	15	2	1.12	Parallelpiped	None
2110-6	15	2	1.12	Parallelpiped	Plexiglas
2110-7	422	5	0.058	Slab	None
2110-8	50	18	0.37	Parallelpiped	None
2110-9, 13	50	18	0.37	Parallelpiped	Plexiglas
2210-14	210	8	0.116	Cylinder	20 cm water
2110-15, 16	0	18	5.8	Parallelpiped	None
2110-17, 21	0	18	5.8	Parallelpiped	Plexiglas
2110-23	5	11	2.3	Parallelpiped	None
2110-24, 27	5	11	2.3	Parallelpiped	Plexiglas
2110-29	623	43	0.041	Cylinder	20 cm water
2110-30	1067	4.6	0.024	Sphere	20 cm water
2110-32	1031	4.6	0.025	Sphere	2 mm steel + 20 cm water
2109-20	684	4.6	0.036	Sphere	25.4 cm concrete
2109-21	684	4.6	0.0355	Sphere	10.16 cm concrete
2109-22	496	4.6	0.0452	Sphere	10.16 cm concrete
2109-23	454	4.6	0.0509	Sphere	0.762 mm Cd + 10.16 cm concrete
2109-24	540	4.6	0.0469	Sphere	0.762 mm Cd + 32 cm concrete
2109-25	0	4.8	15.375	Sphere	19.6 cm natural U
1727-09	0	5.5	19.74	Cylinder	Water

^{a} Comma denotes inclusive (i.e., 17, 22 means experiments 17 through 22).

Table 2.5 ^{239}Pu experiments from IHECSBE Handbook

Case	Experiment description
PU-MET-FAST-001	^{239} Pu Jezebel: Bare Sphere of Plutonium-239 Metal
PU-MET-FAST-002	^{240} Pu Jezebel: Bare Sphere of Plutonium-239 Metal (20.1 at. % 240 Pu, 1.01 wt % Ga)
PU-SOL-THERM-004	Water-Reflected 14-in.-diam Spheres of Plutonium Nitrate Solutions, 0.54% to 3.43%
PU-SOL-THERM-009	Unreflected 48-in.-diam Sphere of Plutonium Nitrate Solution

2.3.5 ^{233}U Experiments

Thirty-three critical experiments involving ^{233}U were taken from the IHECSBE Handbook (see Table 2.6). These experiments span a range of geometry and moderation level. Only evaluated experiments were chosen for inclusion here because of known deficiencies in some of the experimental models and descriptions previously utilized for validation.

Table 2.6 ^{233}U critical experiments

IHECSBE Case No.	Experimental description
U233-MET-FAST-001	^{233}U Jezebel: A Bare Sphere of ^{233}U Metal
U233-MET-FAST-002	Benchmark Critical Experiments of ^{233}U Spheres Surrounded by ^{235}U Experiment No. 1, 10 kg ^{233}U core Experiment No. 2, 7.6 kg ^{233}U core
U233-MET-FAST-003	Benchmark Critical Experiments of Highly Enriched ^{233}U Spheres Reflected by Normal Uranium Experiment No. 1, 10 kg ^{233}U core Experiment No. 2, 7.6 kg ^{233}U core
U233-MET-FAST-004	Benchmark Critical Experiments of Highly Enriched ^{233}U Spheres
U233-MET-FAST-005	Benchmark Critical Experiment of Highly Enriched ^{233}U Spheres
U233-MET-FAST-006	Benchmark Critical Experiment of a ^{233}U Sphere Reflected by Natural Uranium with Flattop

Table 2.6 (continued)

IHECSBE Case No.	Experimental description
U233-SOL-THERM-002	Paraffin-reflected 8-, 8.5-, 9-, 10-, and 12-in.-diam cylinders of ^{233}U Uranyl Nitrate Solutions

Experiment No.	Cylinder diameter (in.)	Solution height (cm)
4	8	16.5195
5	8	16.8195
8	8	18.9195
22	8	14.8195
24	8	14.5195
34	8	16.8195
35	8	19.4195
10	8.5	19.5253
11	8.5	21.6253
12	9	21.4331
36	9	23.0331
14	10	19.4482
15	10	
38	10	
17	12	
18	12	
19	12	

IHECSBE Case No.	Experimental description
U233-SOL-THERM-004	Paraffin-reflected 5-, 6-, and 7.5-in.-diam Cylinders of ^{233}U Uranyl

Experiment No.	Cylinder diameter (in.)	Solution height (cm)
3	6	38.5880
6	6	46.8880
20	6	30.7880
25	6	27.9880
30	6	29.0880
27	7.5	16.4109
28	7.5	16.3109
33	7.5	18.7109

2.3.6 Mixed-Oxide (MOX) Experiments

Critical experiment cases 60 through 77 from Table 4.1 of NUREG/CR-6102 (Ref. 8) were used to evaluate the performance of the SCALE codes and cross sections for mixed-oxide systems. These experiments include both LWR and fast-reactor-type mixed-oxide fuel pin lattices.   The experiments are listed in Table 2.7.

Table 2.7 Mixed-oxide (MOX) lattice experiments

Case No.	Case designation	Enrich. (wt %)	Description	Lattice water/fuel volume ratio
LWR-type mixed-oxide (UO$_2$-PuO$_2$) fuel pin lattices				
60	epri70un	^{235}U: 0.72 ^{239}Pu: 90	0.700-in. pitch, 0 ppm soluble boron, 2 wt % PuO$_2$	1.195
61	epri70b	^{235}U: 0.72 ^{239}Pu: 90	0.700-in. pitch, 681 ppm soluble boron, 2 wt % PuO$_2$	1.195
62	epri87un	^{235}U: 0.72 ^{239}Pu: 90	0.870-in. pitch, 0 ppm soluble boron, 2 wt % PuO$_2$	1.527
63	epri87b	^{235}U: 0.72 ^{239}Pu: 90	0.870-in. pitch, 1090 ppm soluble boron, 2 wt % PuO$_2$	1.527
64	epri99un	^{235}U: 0.72 ^{239}Pu: 90	0.990-in. pitch, 0 ppm soluble boron, 2 wt % PuO$_2$	3.641
65	epri99b	^{235}U: 0.72 ^{239}Pu: 90	0.990-in. pitch, 767 ppm soluble boron, 2 wt % PuO$_2$	3.641
66	saxton52	^{235}U: 0.72 ^{239}Pu: 90	UO$_2$/PuO$_2$ square lattice, 0.52-in. pitch, 6.6 wt % PuO$_2$	1.681
67	saxton56	^{235}U: 0.72 ^{239}Pu: 90	UO$_2$/PuO$_2$ square lattice, 0.56-in. pitch, 6.6 wt % PuO$_2$	2.165
68	saxtn56b	^{235}U: 0.72 ^{239}Pu: 90	UO$_2$/PuO$_2$ square lattice, 0.56-in. pitch, 337 ppm boron, 6.6 wt % PuO$_2$	2.165
69	saxtn735	^{235}U: 0.72 ^{239}Pu: 90	UO$_2$/PuO$_2$ square lattice, 0.735-in. pitch, 6.6 wt % PuO$_2$	4.699
70	saxtn792	^{235}U: 0.72 ^{239}Pu: 90	UO$_2$/PuO$_2$ square lattice, 0.792-in. pitch, 6.6 wt % PuO$_2$	5.673
71	saxtn104	^{235}U: 0.72 ^{239}Pu: 90	UO$_2$/PuO$_2$ square lattice, 1.04-in. pitch, 6.6 wt % PuO$_2$	10.754

Table 2.7 (continued)

Case No.	Case designation	Enrich. (wt %)	Description	Lattice water/fuel volume ratio
72	pnl4976	^{235}U: 0.72 ^{239}Pu: 90 and ^{235}U: 4.31	MOX & UO$_2$ rods in uniform pattern, 2 wt % PuO$_2$ in MOX	0.460 and 0.509
Fast Reactor (FFTF) mixed oxide (UO$_2$-PuO$_2$) fuel pin lattices				
73	p5803x21	^{235}U: 0.72 ^{239}Pu: 86	FFTF rods, H$_2$O-moderated, 0.968-cm pitch, 20 wt % PuO$_2$	3.49
74	p5803x32	^{235}U: 0.72 ^{239}Pu: 86	FFTF rods, H$_2$O-moderated, 1.935-cm pitch, 20 wt % PuO$_2$	18.13
75	p5803x43	^{235}U: 0.72 ^{239}Pu: 86	FFTF rods, H$_2$O-moderated, 1.242-cm pitch, 20 wt % PuO$_2$	6.65
76	p5803x67	^{235}U: 0.72 ^{239}Pu: 86	FFTF rods, H$_2$O-moderated, 0.761-cm pitch, 20 wt % PuO$_2$	1.62
77	p5803x68r	^{235}U: 0.72 ^{239}Pu: 86	FFTF rods, H$_2$O-moderated, 1.537-cm pitch, 20 wt % PuO$_2$	10.93

2.4 INTERPRETATION AND PRESENTATION OF CALCULATED RESULTS

Substantial emphasis is placed on the demonstration of performance of the cross-section libraries for a set of critical experiments. This method is an ideal means of evaluating a cross-section library for a particular application. It establishes the bias and trends of the codes and cross-section data used for specific types of applications. All of the critical systems have an experimental $k_{eff} = 1$. However, not all of the experiments and models utilized here have been evaluated for uncertainties in the experimental descriptions or approximations used to develop the models. Because of this, one cannot absolutely show that differences between the calculated k_{eff} value and a $k_{eff} = 1$ are due to the codes and cross sections used in the calculation. Several calculated k_{eff} values from the cross-section libraries may show similar trends. These trends could be due to common characteristics of the cross sections or may stem from uncertainties in the experiments or calculational models. In either case, when there are unexplained trends or large scatter in the calculational results, a larger margin of subcriticality should be applied when establishing the subcriticality of similar systems. A statistical method for establishing the upper subcritical limit is presented in Ref. 18.

When calculations are performed with multiple cross-section libraries for the same set of experiments, several items become of interest: overall shift in the average bias for a set of experiments, any changes in trends, and

whether the scatter in the calculated k_{eff} values becomes larger or smaller. Comparison of the performance of multiple libraries against the same set of models can effectively show when there are significant deficiencies in one or more of the libraries.

The figures in the subsequent sections are presented as calculated k_{eff} values vs the calculated spectral parameter defined as the energy corresponding to the average lethargy of the neutron causing fission (EALF). This parameter is useful because it contains significant information about the neutronics of the system. It is an indicator of the average neutron flux spectrum for a system and the relative importance of the various energy regions of the flux on the fission multiplication. The EALF is sensitive to characteristics of the system moderator, the degree of moderation, the effect of absorbers in the system, fissile materials in the system, and the effects of leakage and reflecting materials on the system. The EALF, however, does not indicate directly what material is governing the slowing down and transport in the system.

For most of the systems utilized in this performance assessment, hydrogen is the principal moderator. Extension of the results to interpret performance for systems in which materials other than hydrogen are the principal moderator is not recommended. Benchmark calculations using critical experiments with the same moderator material are strongly recommended.

3 THE SCALE 16-GROUP HANSEN-ROACH LIBRARY

3.1 ORIGINS OF THE LIBRARY

The SCALE 16-group Hansen-Roach library is based on the original Los Alamos report[4] by Hansen and Roach. It was originally intended for fast calculations (6 fast groups), and later extended to 16 groups, covering the full energy range. It is the only library discussed in this report that was not generated at ORNL. The original Hansen-Roach library was modified for easy use in the SCALE system. Several important nuclides not available in the original library were added by collapsing the 27-group ENDF/B-IV library to the 16-group structure of the Hansen-Roach library. The 16-group Hansen-Roach energy-group structure is shown in Appendix A. A list of available nuclides in the library together with the source of the data for each nuclide are provided in Appendix C.

The original Hansen-Roach library was primarily developed for fast ^{235}U systems. There are 12 fast groups and 4 thermal groups (below 3 eV). However, thermal upscatter was not included in the original Hansen-Roach data. It has been included in the nuclides added for SCALE, although most of those are heavy nuclides where thermal upscatter is not important. The original cross sections are generally P_0 cross sections that are transport corrected to account for leakage. Two exceptions are hydrogen and deuterium, which are P_1 with P_2 transport corrections. All of the nuclides later added to the original library were generated to the P_3 scattering order. One other significant improvement to the original library was made by Knight's modifications, where multipliers for the ^{238}U capture cross section were generated as a function of background cross section based on three sets of low-enriched critical experiments (PCTR). This last modification was key to extending the use of the SCALE Hansen-Roach library to thermal low-enriched-uranium systems.

Resonance nuclides in the original Hansen-Roach library had cross sections tabulated at several σ_p values. Prior to the development of the CSAS sequences in SCALE, the selection of one of these preprocessed shielded cross-section sets at Oak Ridge[19] was made by hand calculation of σ_p for the problem of interest and the user then selecting the closest shielded cross-section set. When the Hansen-Roach library was incorporated into SCALE, the calculation of σ_p was automated. The method used to calculate σ_p and to select the shielded cross-sections will impact the performance of the Hansen-Roach library. The SCALE methodology has been used for the calculations discussed here.

In SCALE, σ_p is calculated on a group-wise basis using the total cross section. Cross-section shielding is then done on a group-wise basis with standard SCALE cross-section processing modules, in particular, the BONAMI module.

To make the original Hansen-Roach cross sections compatible with the SCALE system, an infinite dilution set was defined for each resonance nuclide and Bondarenko data were generated for the remaining values of σ_p. This procedure required the generation of a 16-group total cross section for each nuclide to allow BONAMI to perform automatic problem-dependent cross-section processing. The original Hansen-Roach library did not carry total cross sections, per se, but contained a total cross section that included a transport correction. In order to implement the Hansen-Roach cross sections in SCALE, an infinitely dilute 16-group total cross section was generated from the SCALE 27-group library and added to the SCALE Hansen-Roach library as MT-201. The Bondarenko iteration scheme in BONAMI automatically uses MT-201 when it is present in a cross-section library; this feature permitted the original SCALE control modules to use BONAMI with the SCALE Hansen-Roach library.

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Another characteristic of the SCALE Hansen-Roach library is that two sets of hydrogen cross sections are available: the dE/E set and the χ(E) set. These cross sections use different weighting schemes in the fast region. Historically, the χ(E) hydrogen was intended for fast systems and the dE/E hydrogen was intended for thermal systems. In SCALE, dE/E hydrogen is used by default in the standard compositions that contain hydrogen. Differences as large as 2% in k_{eff} can occur, depending on which hydrogen is used. All of the calculations presented here utilize the default dE/E hydrogen.

It is important to note that the original Hansen-Roach library is still used and that several techniques exist for calculating σ$_p$ values (for example, see Ref. 20). Use of the original library and/or use of an approach to determine σ$_p$ values other than that employed in SCALE can provide different performance than reported here for the SCALE Hansen-Roach library.

3.2 PERFORMANCE WITH HIGH-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

Figure 3.1 shows calculated k_{eff} values for highly enriched ^{235}U systems using the SCALE 16-group Hansen-Roach library. The overall trend shows an average k_{eff} of approximately 0.990 for thermal systems and 0.995 for fast systems.

3.2.1 High-Enriched Fast Systems

Fast systems in Figure 3.1 are represented by the group of calculations at an EALF of 8×10^5 eV. The original 16-group Hansen-Roach library was designed for calculation of systems similar to these. The fast systems have an average k_{eff} of about 0.995, with a variation of about ±1%.

3.2.2 High-Enriched Thermal Systems

Thermal systems in Figure 3.1 are about 0.990, with a variation of about ±2%. There is a wide spread of results in the thermal range (k_{eff} <0.96 to k_{eff} > 1.02). Similar spreads can be seen in the results for the other libraries, too. The possibility of large uncertainties in the specifications for the critical systems used to validate the thermal range cannot be ruled out as the source of the large variations in calculated k_{eff} values.

The trends and large variability of the SCALE Hansen-Roach library have been encountered in the past. Similar trends have been observed previously with uranyl nitrate solution benchmark calculations.

3.2.3 High-Enriched Intermediate-Spectrum Systems

Intermediate spectrum systems in Fig. 3.1 are those with an EALF between 3 eV and 8×10^5 eV. Few critical experiments are in the intermediate range. These systems are characterized by an ill-defined average around a k_{eff} of 1.005, with a spread of about ±1.5%. The Hansen-Roach library has few groups across the intermediate energy range. The library is a transport-corrected P$_0$ (isotropic-scatter) library, except for hydrogen and deuterium, which are P$_2$ transport-corrected P$_1$ cross sections. Generally, only the fissile and fissionable isotopes have resonance data. **The cross sections are not well suited for calculation of systems in the intermediate-spectrum range.**
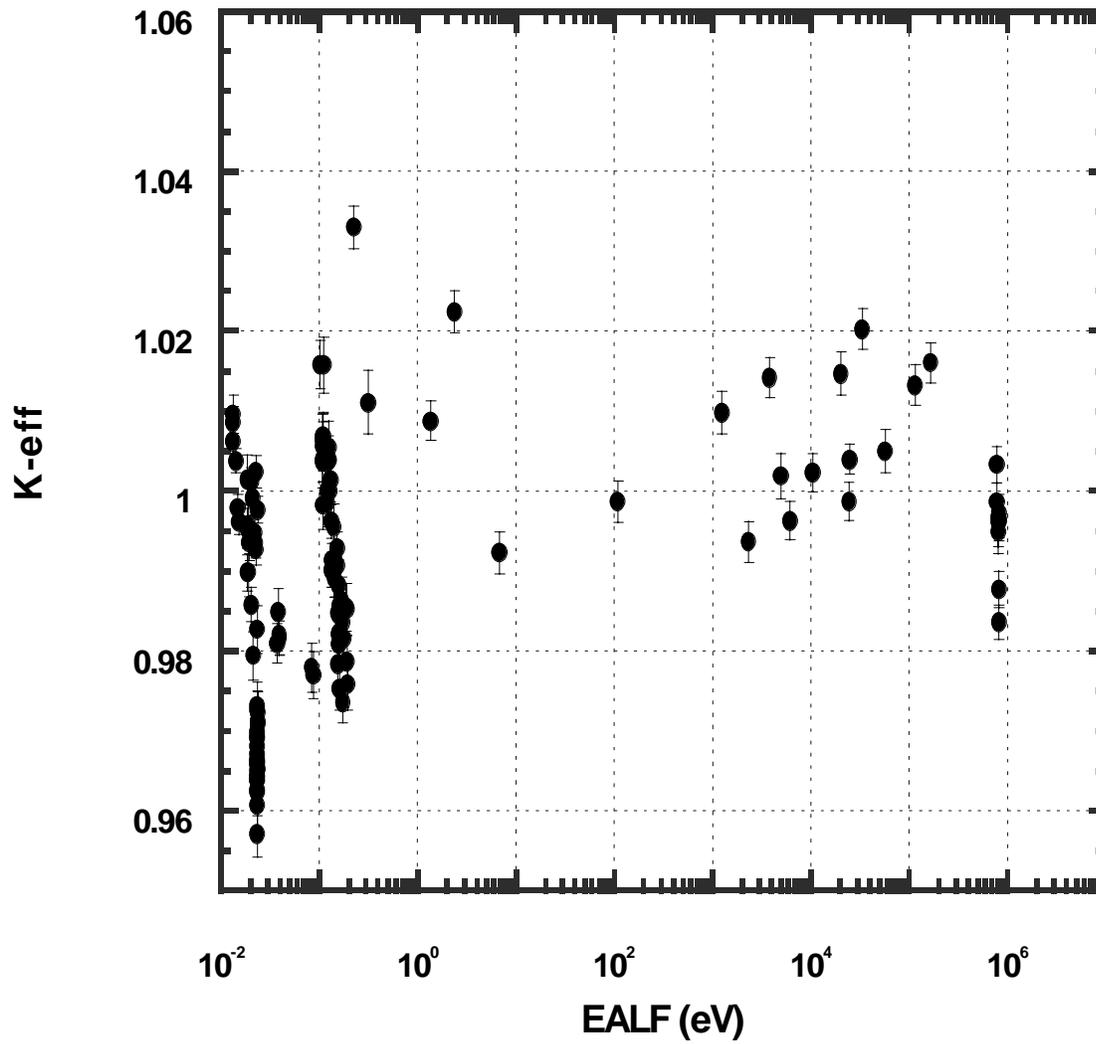
Figure 3.1 SCALE 16-group Hansen-Roach library high-enriched ^{235}U system results

3.3 PERFORMANCE WITH LOW-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

The performance of the SCALE 16-group Hansen-Roach library for homogeneous low-enriched systems is shown in Figure 3.2. The homogeneous experiments have ^{235}U enrichments below 5%. The calculations show a strong trend as a function of EALF, which is directly related to the moderation level. This trend is probably related to limitations in the narrow resonance approximation and to the ^{238}U resonance cross sections in the Hansen-Roach library.
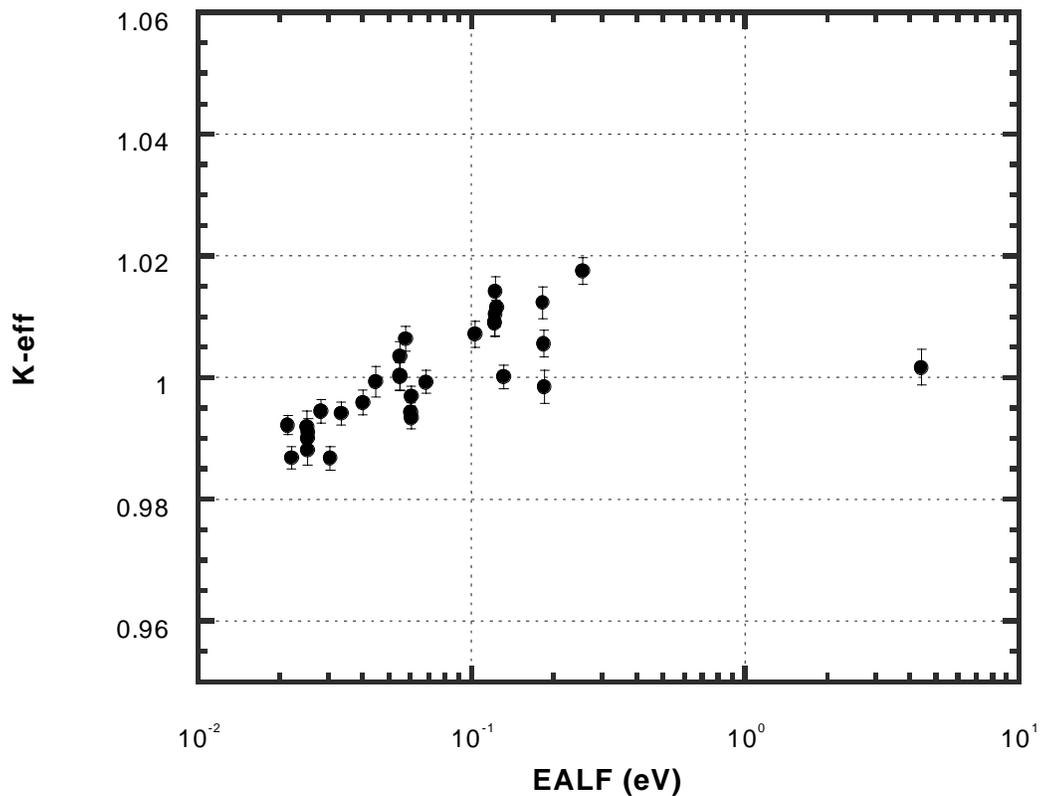
Figure 3.2 SCALE 16-group Hansen-Roach library low-enriched homogeneous ^{235}U system results

3.4 PERFORMANCE WITH LWR LATTICES

The performance of the SCALE 16-group Hansen-Roach library for heterogeneous low-enriched LWR lattice systems is shown in Figure 3.3. The maximum enrichment in the LWR lattice experiments is 5.74 wt % [235]U. No significant trends are apparent in the SCALE Hansen-Roach library results for heterogeneous low-enriched uranium calculations. Almost all of the cases containing boron had a calculated k_{eff} value of 1.0 or greater. The experiments have an average k_{eff} of about 1.0 with a ±1.5% variation.
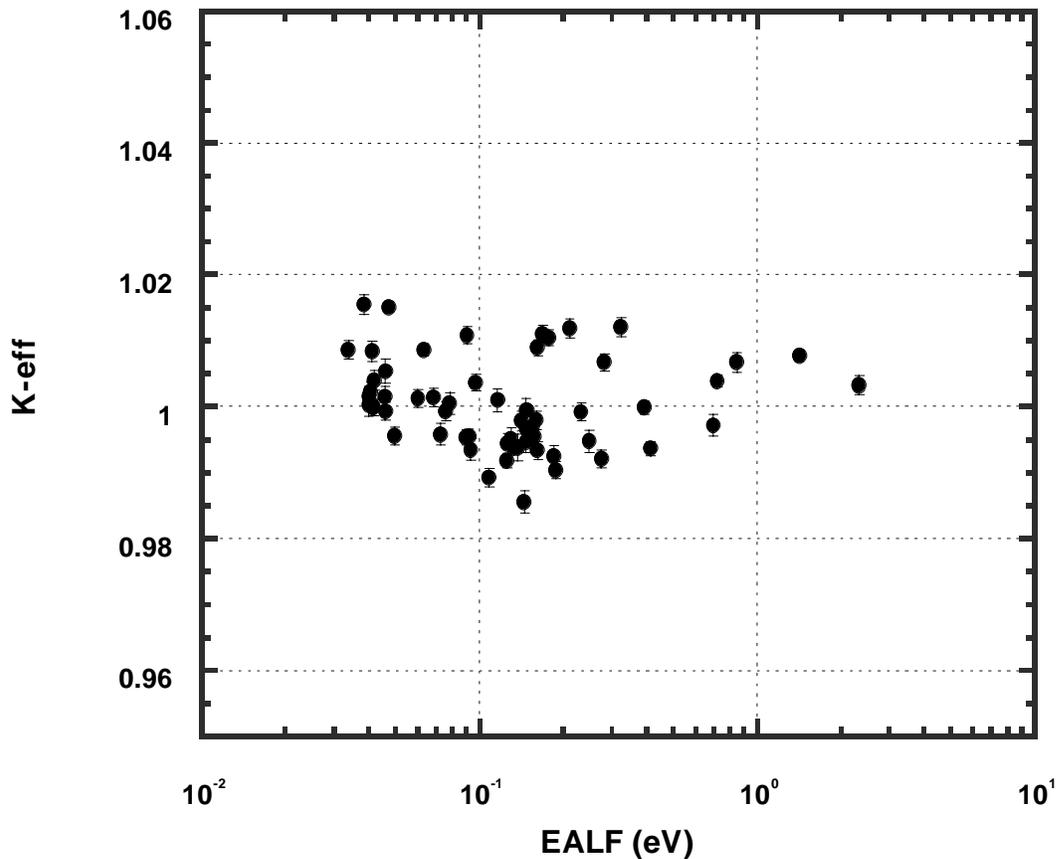
Figure 3.3 SCALE 16-group Hansen-Roach library low-enriched LWR lattice results

3.5 PERFORMANCE WITH ^{239}Pu SYSTEMS

The performance of the SCALE 16-group Hansen-Roach library for ^{239}Pu systems is shown in Figure 3.4. The performance of the library is generally poor. The library shows an overall 2% positive bias with a +1% to ‒3% variation. This bias is probably due to poor thermal cross sections and inadequate group structure and resonance data. There are strong localized trends in the thermal region and the intermediate-spectrum region which would be difficult to take into account for systems that are not closely related to the validation experiments.
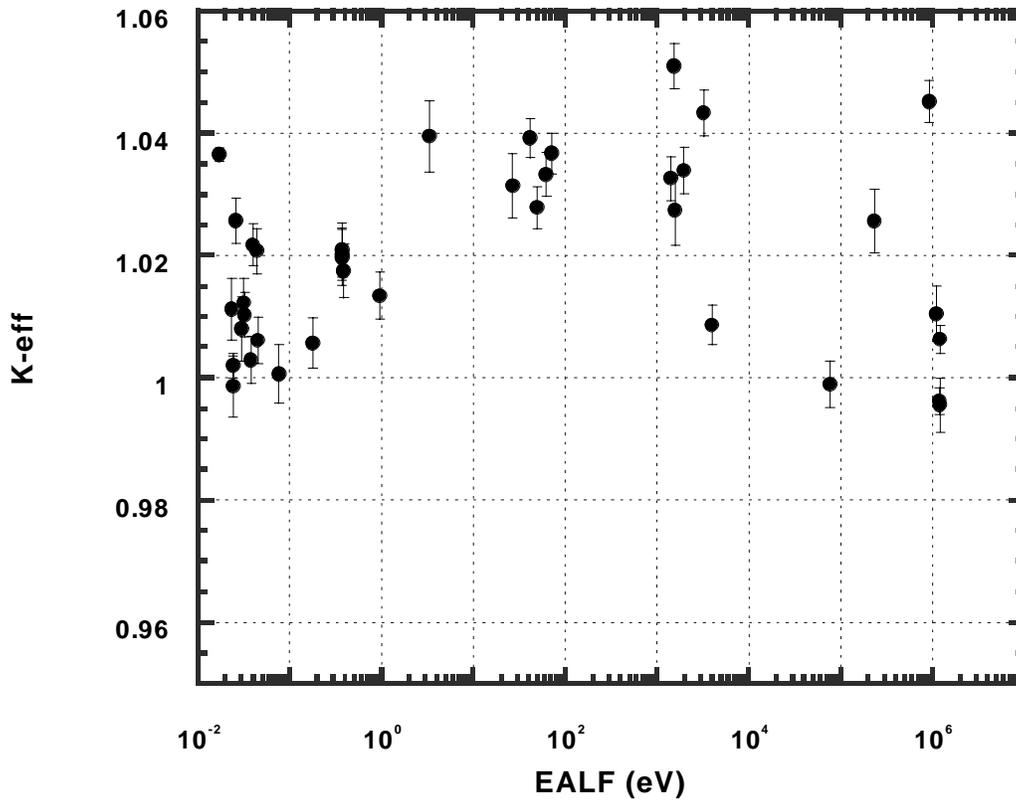
Figure 3.4 SCALE 16-group Hansen-Roach library plutonium system results

3.6 PERFORMANCE WITH ^{233}U SYSTEMS

The performance of the SCALE 16-group Hansen-Roach library for ^{233}U systems is shown in Figure 3.5. The performance of the library is generally poor, with the exception of the fast ^{233}U metal systems with an EALF around 1×10^6 eV. This performance is probably due to poor thermal cross sections and inadequate group structure and resonance data. The thermal systems have an average k_{eff} of about 0.99 with a ±2% variation. There is a strong local trend in the thermal data, similar to that seen for the highly enriched uranium systems. This trend would be difficult to take into account for systems that are not closely related to the validation experiments.
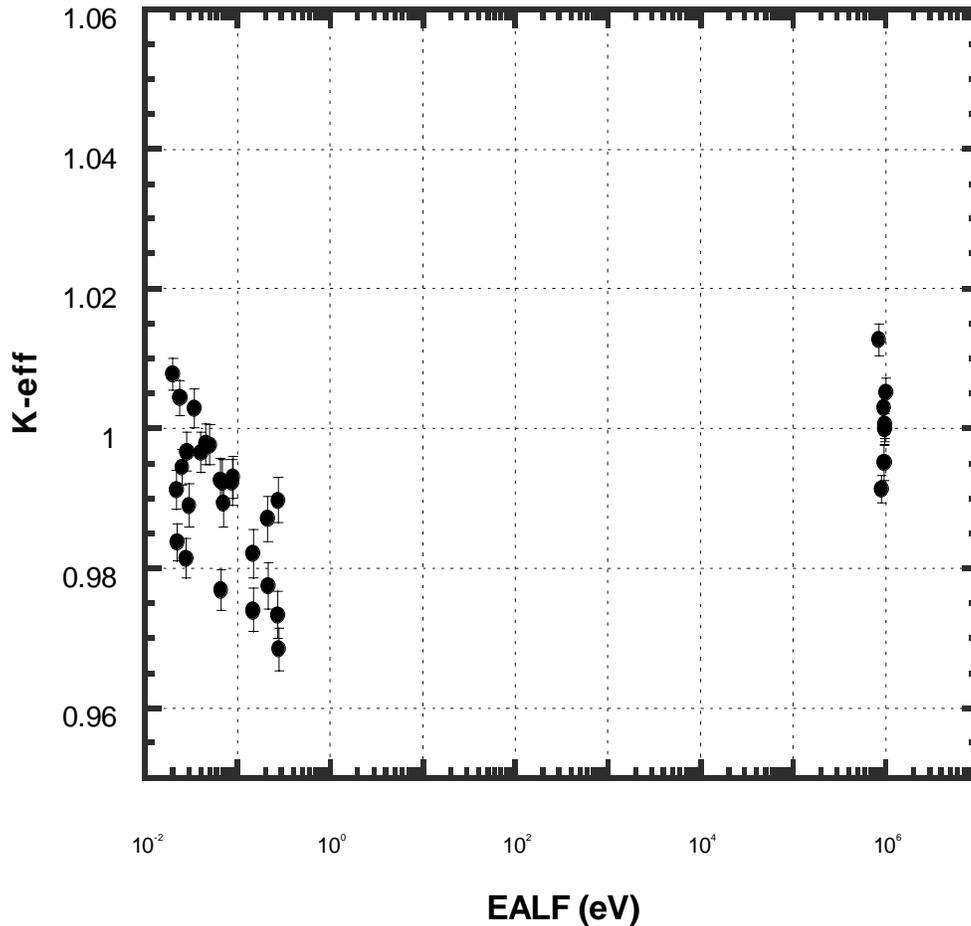
Figure 3.5 SCALE 16-group Hansen-Roach library ^{233}U system results

3.7 PERFORMANCE WITH MIXED-OXIDE LATTICES

The performance of the SCALE 16-group Hansen-Roach library for mixed-oxide (MOX) lattices is shown in Figure 3.6. All of the MOX lattice systems considered here are water-moderated thermal systems. The performance of the library is poor, probably due to inadequate group structure and resonance data. Calculated results show a sharply negatiave trend as a function of EALF, with k_{eff} values ranging from about 1.03 to 0.985. This trend would be difficult to take into account for systems that are not closely related to the validation experiments.

Figure 3.6 SCALE 16-group Hansen-Roach library mixed-oxide lattice results

4 THE 218-GROUP ENDF/B-IV LIBRARY

4.1 ORIGINS OF THE LIBRARY

The 218-group ENDF/B-IV library[6] was the most complete library available in SCALE prior to the release of the SCALE ENDF/B-V libraries in SCALE 4.3. The source of the data was ENDF/B-IV, and the processing of the cross sections by XLACS in the AMPX system is well documented.[6] The weighting function used in the P_3 cross-section generation was a fission-1/($E\sigma_t$)-Maxwellian weighting [except for resonance nuclides, which were weighted 1/E instead of 1/($E\sigma_t$)]. The 1/($E\sigma_t$) weighting preserved the resonance structure in nonresonance nuclides and allowed the library to be successfully collapsed to a broad-group structure that generally could reproduce the behavior of the fine-group library. One of the features of the library is that explicit resonance data carried with it can be used to generate problem-dependent, resolved resonance region multigroup cross sections using NITAWL-II. This capability allows great flexibility in the use of the library as a general-purpose criticality safety analysis library. Only the *s*-wave resonances are contained explicitly. Any *p*- and *d*-wave resonances were integrated into the background cross section. The library has 140 fast groups and 78 thermal groups (below 3.05 eV). The group structure was designed to fit the cross-section variation and reaction thresholds of the light and intermediate nuclides and to fit the major resonances of the intermediate and heavy nuclides. No unresolved resonance data are carried in the library. The unresolved resonance region was processed at σ_p = 50,000 barns.

The 218-group library has not been routinely validated because of its size and the related costs. However, the 27-group ENDF/B-IV library was derived directly from the 218-group library and has been validated against a large number of critical experiments (see Section 5). The 218-fine-group structure of the library generally will give either the same or more precise results than its companion 27-broad-group library.

An obvious advantage of a fine-group library over a broad-group library is that the library is less sensitive to the weighting spectrum used to generate the library. The cross sections more closely represent the base data, and the group structure allows a more detailed determination of the energy dependence of the flux. In past validations, it has been found useful to compare a fine-group calculation against a broad-group calculation when bias is observed. Appendix D contains a complete listing of the 218-group library nuclides, as well as those nuclides that have resonance data or thermal scattering data.

4.2 CHARACTERISTICS OF THE ENDF/B-IV LIBRARIES

The ENDF/B-IV libraries have generally displayed a negative bias of approximately 1%, and in some cases as much as 2%, for low-enriched, water-moderated UO_2 rods. The bias appears to be greatest for epithermal systems (e.g., borated water and/or closely spaced rods) and less significant for more thermalized systems. The bias has been traced in part to the lack of data in the unresolved resonance region for [238]U in ENDF/B-IV. The unresolved resonance region in the SCALE ENDF/B-IV libraries was processed at σ_p = 50,000 barns, which is extremely high compared to σ_p values of 3500 barns for [235]U and 65 barns for [238]U in a typical LWR lattice. For well-thermalized systems, the unresolved resonance region is not important, and the high σ_p value is inconsequential. However, as the spectrum hardens the resolved resonance region (where ENDF/B-IV had some inadequacies) and the unresolved region become more important. Thus, the SCALE ENDF/B-IV libraries trend toward a lower k_{eff} value as the spectrum hardens. Improved resonance data in ENDF/B-V eliminated this bias in the 44-group library.

A positive bias has been routinely observed in the ENDF/B-IV libraries for thermal ^{239}Pu systems and mixed-oxide (MOX) fuel rods. The MOX fuel rod bias increases with increasing thermalization. One problem identified in the 27-group library was inadequate group structure to account for flux changes across the 0.3-eV resonance of ^{239}Pu. This problem has been rectified in the 44-group ENDF/B-V library by the addition of more energy groups in this energy range.

Carbon system numerical benchmarks have shown a negative bias of as much as 2.5% with the ENDF/B-IV libraries when compared with the Hansen-Roach and ENDF/B-V libraries. Analysis of the 218-group cross-section data has revealed an incorrect scatter matrix for carbon in energy group 10 (3000 to 550 eV). In addition, the graphite thermal kernel is deficient. The impact of this deficiency is unknown.

The hafnium cross-section data available in the 218- and 27-group ENDF/B-IV libraries are not ENDF/B-IV data. The hafnium data were submitted for ENDF/B-II, but never included. Hafnium cross sections were not included in ENDF until version V. Known irregularities are present in the cross sections, and no resonance data are available with the nuclide. The cross sections are infinite dilution (1/E weighting) across the resonance range. **Use of the hafnium data in the ENDF/B-IV libraries is not recommended and should be done with caution.** Note that none of the benchmark cases in this report contain hafnium.

Systems containing gadolinium have not calculated well with the 27-group library. The problem stems from the characteristic of the gadolinium data in the thermal range. Gadolinium has low-energy resonance data down to 10^{-5} eV. The resonances are so broad that the implementation of the Nordheim treatment in NITAWL-II fails to have a mesh point in group 27 (0.01 to 0.00001 eV) of the 27-group structure. This difficulty has been addressed by setting the bottom energy of the resonance data to that of group 26 (0.03 to 0.01 eV) and carrying infinite dilution cross sections in group 27 of the master library. In addition, the ENDF resonance data for gadolinium prior to version VI are not well defined. **Use of the gadolinium data in the ENDF/B-IV libraries is not recommended and should be done with caution**. Two of the LWR lattice experiments contain gadolinium.

4.3 PERFORMANCE WITH HIGH-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

Figure 4.1 shows calculated k_{eff} values for highly enriched ^{235}U systems using the SCALE 218-group ENDF/B-IV library. The overall trend shows an average k_{eff} of approximately 1.00 for thermal and fast systems, with a large variation in results for thermal systems.

4.3.1 High-Enriched Fast Systems

Fast systems in Figure 4.1 are represented by the group of calculations at an EALF of 8×10^5 eV or greater. The fast systems have an average k_{eff} of about 1.00, with a variation of about ±1%.

4.3.2 High-Enriched Thermal Systems

Thermal systems in Figure 4.1 are represented by the calculations with an EALF below about 3 eV. The average k_{eff} in the thermal region is about 1.00, with a variation of roughly ±2%. There is a wide spread of results in the thermal range (k_{eff} <0.98 to k_{eff} > 1.03). Similar spreads can be seen in the results for the other libraries, too.

Most of the cases between 0.01 and 0.1 eV are uranyl fluoride solutions that tend to have a more negative bias. Most of the cases between 0.1 and 1 eV are uranyl nitrate solutions that show a more positive bias. The possibility of large uncertainties in the specifications for the critical systems used to validate the thermal range cannot be ruled out as the source of the large variations in calculated k_{eff} values.

4.3.3 High-Enriched Intermediate-Spectrum Systems

Intermediate-spectrum systems in Figure 4.1 are those with an EALF between 3 eV and 8×10^5 eV. Few critical experiments are in the intermediate range. These systems are characterized by an ill-defined average k_{eff} of 1.00, with a spread of about ±1.5%.
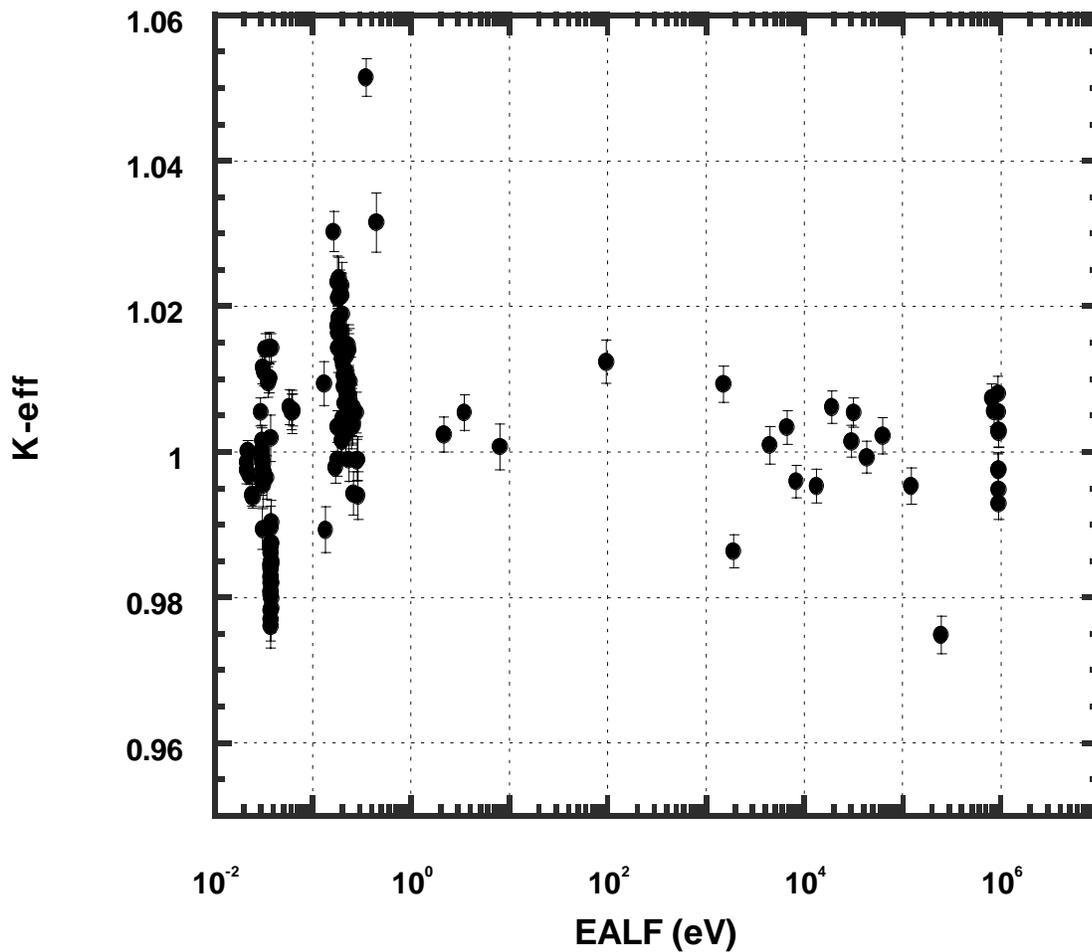
Figure 4.1 SCALE 218-group ENDF/B-IV library high-enriched ^{235}U system results

4.4 PERFORMANCE WITH LOW-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

The performance of the SCALE 218-group ENDF/B-IV library for homogeneous low-enriched systems is shown in Figure 4.2. The homogeneous experiments have ^{235}U enrichments below 5%. The calculations do not show a trend as a function of EALF, which is directly related to the moderation level. The average calculated k_{eff} value is approximately 0.995 ± 1.5%.
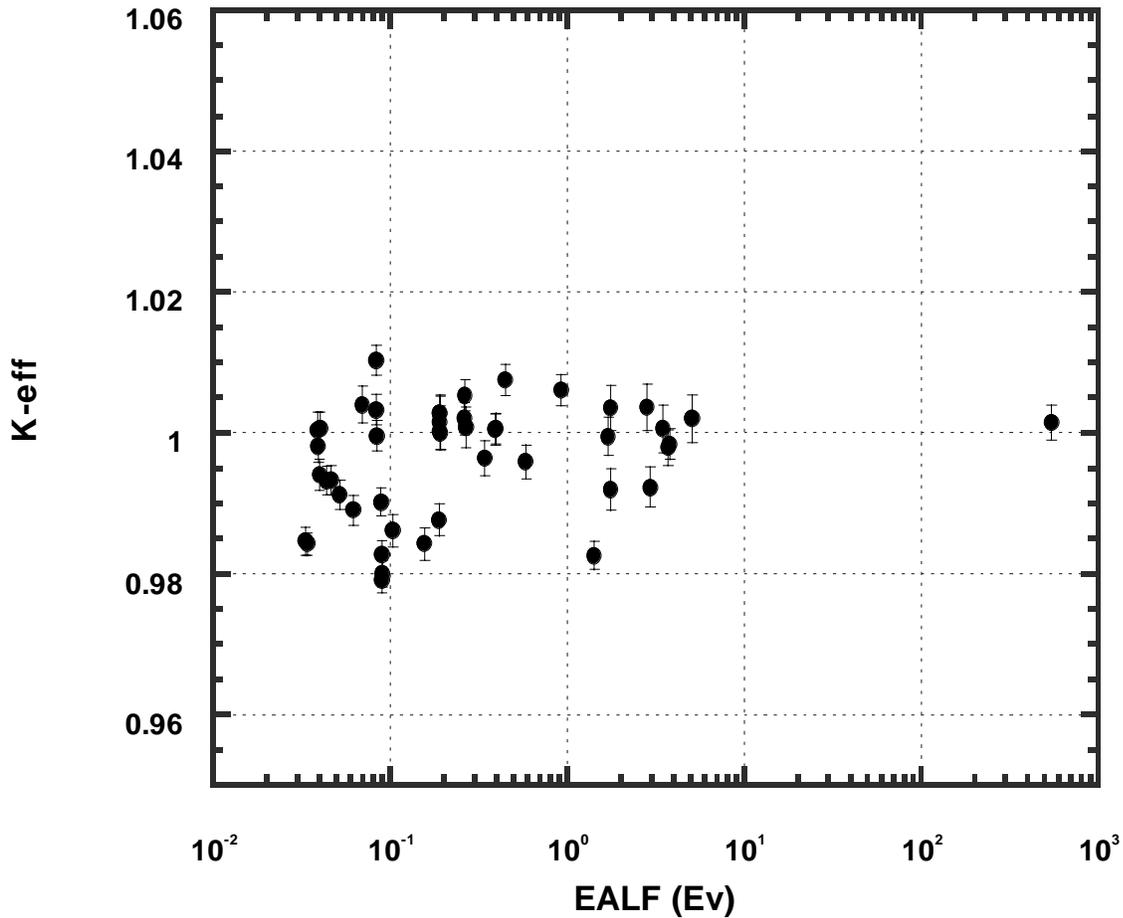
Figure 4.2 SCALE 218-group ENDF/B-IV library low-enriched homogeneous ^{235}U system results

4.5 PERFORMANCE WITH LWR LATTICES

The performance of the SCALE 218-group ENDF/B-IV library for heterogeneous low-enriched LWR lattice systems is shown in Figure 4.3. The maximum enrichment in the LWR lattice experiments is 5.74 wt % ^{235}U. The experiments have an average k_{eff} of about 0.990, with a $\pm1\%$ variation. The trend of lower calculated k_{eff} values for harder thermal spectra is consistent with previous LWR fuel lattice validation experience with the 27-group ENDF/B-IV library. Because boron hardens the spectrum in LWR lattices, cases containing boron may have lower calculated k_{eff} values, although this trend was not observed for these cases.
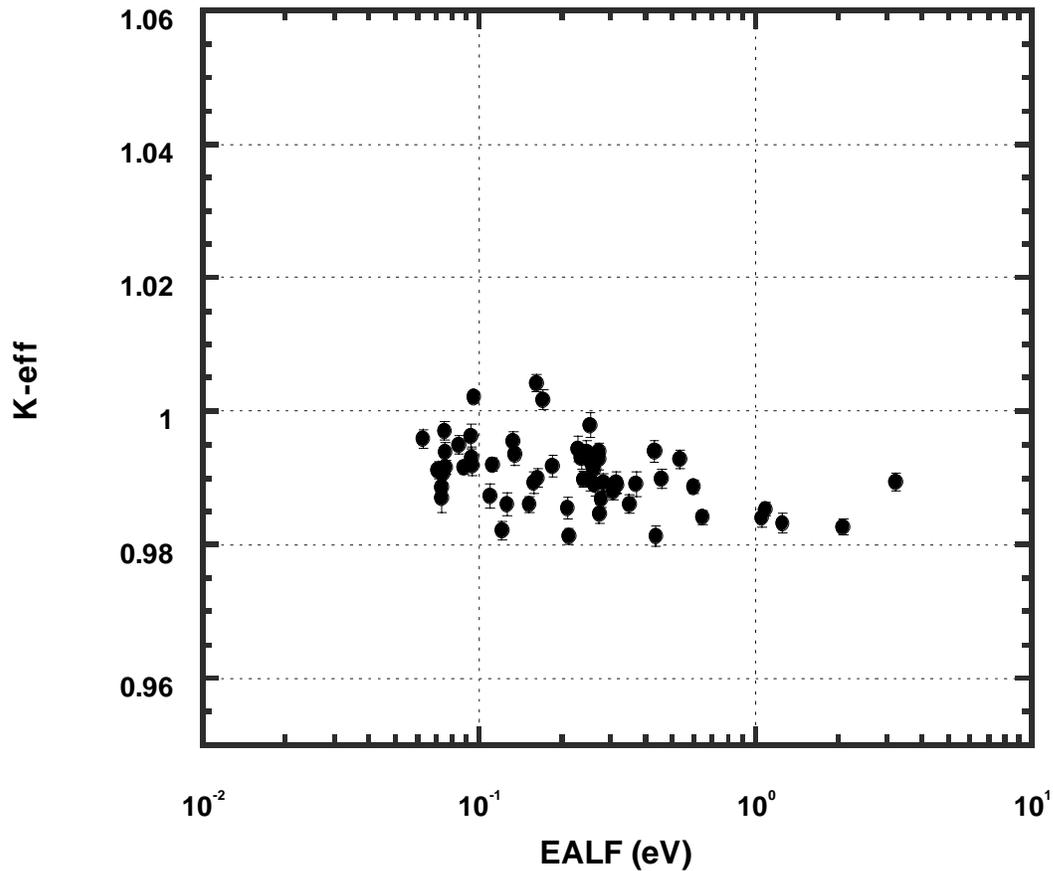
Figure 4.3 SCALE 218-group ENDF/B-IV library low-enriched LWR lattice results

4.6 PERFORMANCE WITH ^{239}Pu SYSTEMS

The performance of the SCALE 218-group ENDF/B-IV library for ^{239}Pu systems is shown in Figure 4.4.
The performance of the library is generally poor. The library shows an overall 2 to 3% positive bias with a range
of 1.00 to 1.05 in calculated k_{eff} values. The poor results are probably due to the base ENDF/B-IV ^{239}Pu data.
The intermediate-spectrum results are worse than the thermal results. **The SCALE ENDF/B-IV libraries are not
recommended for ^{239}Pu systems.**
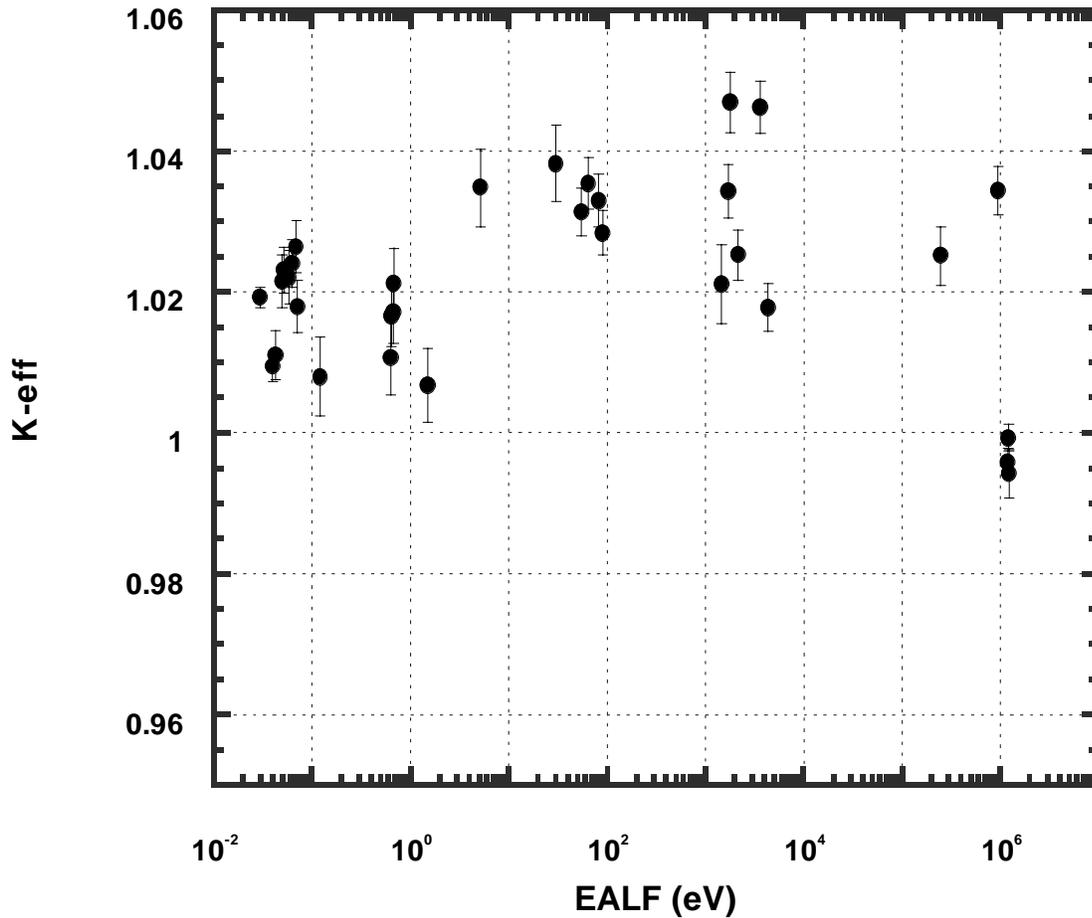
Figure 4.4 SCALE 218-group ENDF/B-IV library plutonium system results

4.7 PERFORMANCE WITH [233]U SYSTEMS

The performance of the SCALE 218-group ENDF/B-IV library for [233]U systems is shown in Figure 4.5. The performance of the library varies significantly between the thermal systems and the fast systems. The thermal systems show a strong positive bias. The thermal system results have an average calculated k_{eff} value of about $1.015 \pm 1.5\%$. Conversely, the fast systems show a strong negative bias, with results ranging from 0.96 to 0.98. These results emphasize the importance of validation, not only for the materials in the system, but also for the appropriate energy range. Note also the lack of data in the intermediate-energy range.
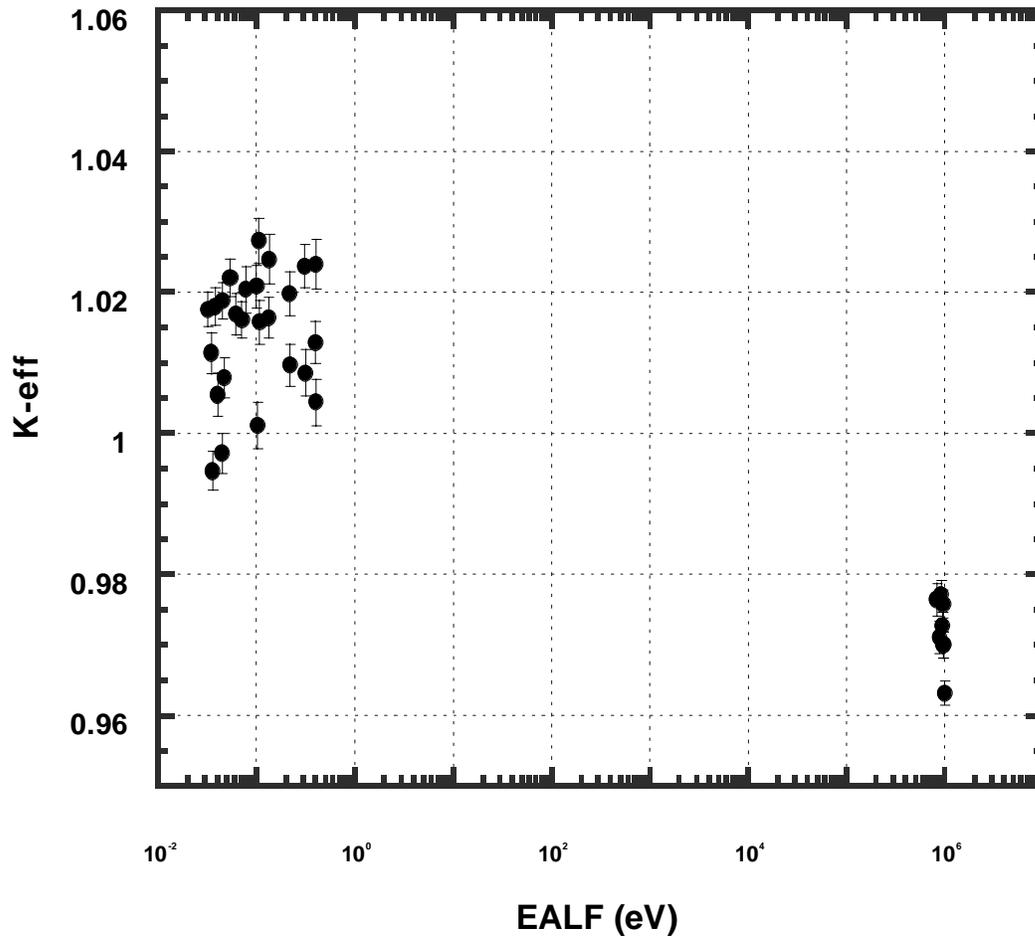
Figure 4.5 SCALE 218-group ENDF/B-IV library [233]U system results

4.8 PERFORMANCE WITH MIXED-OXIDE LATTICES

The performance of the SCALE 218-group ENDF/B-IV library for mixed-oxide (MOX) lattices is shown in Figure 4.6. All of the MOX lattice systems considered here are water-moderated thermal systems. The performance of the library is fair, probably due to the positive bias in the ENDF/B-IV ^{239}Pu resonance data offsetting the negative bias in the ^{238}U resonance data. The most thermalized systems (about 0.1 eV) show a small positive bias, with results ranging from 0.995 to 1.01. As the spectrum becomes harder, the calculated k_{eff} values show an increasingly negative bias, similar to that seen for the LWR lattices.
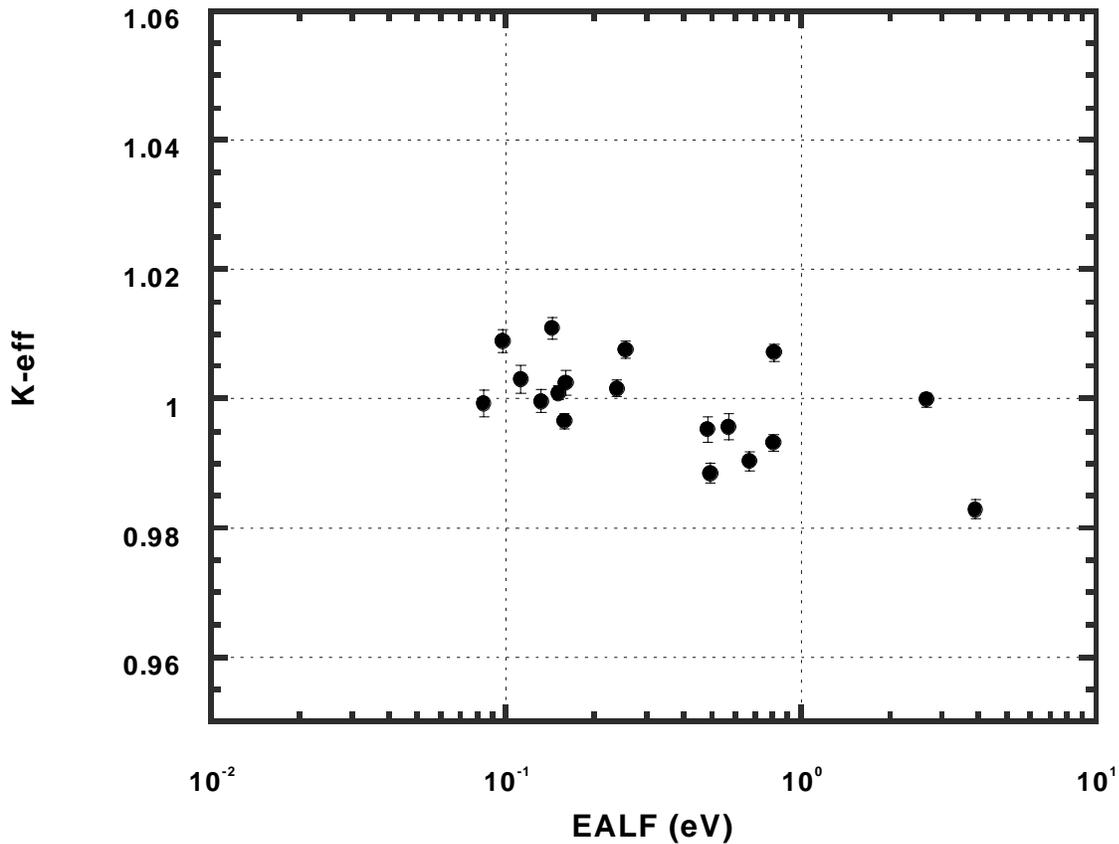
Figure 4.6 SCALE 218-group ENDF/B-IV library mixed-oxide lattice results

5 THE 27-GROUP ENDF/B-IV LIBRARIES

5.1 ORIGINS OF THE 27-GROUP ENDF/B-IV LIBRARY

The 27-group ENDF/B-IV library is the broad-group companion library to the 218-group ENDF/B-IV library. The 218-group library was flux collapsed using MALOCS and the MT 1099 flux file carried with the fine-group cross sections. (This flux file is the group representation of the original weighting spectrum used to generate the 218-group cross sections from ENDF/B-IV data.) Because of the $1/(E\sigma_t)$ weighting in the resolved resonance range, the broad-group library calculates many systems nearly as well as the fine-group library does. Trends and biases in the 218-group library are preserved in the 27-group library. The library has 14 fast groups and 13 thermal groups (below 3 eV). The group structure was chosen to match the 16-group Hansen-Roach structure with two additional fast groups and nine additional thermal groups. The additional groups were chosen such that, for the systems considered, the broad-group calculations meet an acceptance criterion of $\Delta k/k < 0.3\%$ when compared with the reference 218-group calculation using the XSDRN code. This criterion was relaxed to 1% for [238]U in systems where the median fission energy was greater than 1 eV and less than 100 eV. The resonance data and the thermal scattering data carried with the 27-group library and the 218-group library are the same and are processed by NITAWL-II. The library was conceived as a general-purpose criticality-analysis library, with a special interest in applicability toward shipping cask analysis and thermal neutron systems.

The 27-group library has been extensively validated against critical experiments.[14, 21-30] Areas of validation include highly enriched uranium-metal, compound and solution systems, moderated low-enriched uranium, heterogeneous and homogeneous systems, and plutonium metal and solution systems.

5.2 ORIGINS OF THE 27-GROUP BURNUP (DEPLETION) LIBRARY

The 27-group burnup library is a criticality-safety library for spent fuel, originally developed for use in the SAS2H depletion-control module (Section S2 of the SCALE manual). The library consists of the 27-group ENDF/B-IV library discussed above supplemented with data from a pre-release version of ENDF/B-V for a large number of fission products. Prior to the release of the 44-group ENDF/B-V library the large number of nuclides in this version of the 27-group library made it the preferred library for use in burnup studies when spent fuel characterization (isotopics, radiation sources, and decay heat) was the objective. **This library is no longer recommended for such studies**, because the 44-group ENDF/B-V library contains more nuclides and better base data. Because the base library was the 27-group ENDF/B-IV library, all the comments regarding the 218-group and 27-group libraries are also directly applicable to the 27-group burnup library.

5.3 CHARACTERISTICS OF THE ENDF/B-IV LIBRARIES

The ENDF/B-IV libraries have generally displayed a negative bias of approximately 1%, and in some cases as much as 2%, for low-enriched, water-moderated UO_2 rods. The bias appears to be greatest for epithermal systems (e.g., borated water and/or closely spaced rods) and less significant for more thermalized systems. The bias has been traced in part to the lack of data in the unresolved resonance region for [238]U in ENDF/B-IV. The unresolved resonance region in the SCALE ENDF/B-IV libraries was processed at $\sigma_p = 50,000$ barns, which is extremely high compared with σ_p values of 3500 barns for [235]U and 65 barns for [238]U in a typical LWR lattice. For well-thermalized systems, the unresolved resonance region is not important, and the high σ_p value is inconsequential. However, as the spectrum hardens the resolved resonance region (where ENDF/B-IV had some

inadequacies) and the unresolved region become more important. Thus, the SCALE ENDF/B-IV libraries trend toward a lower k_{eff} value as the spectrum hardens. Improved resonance data in ENDF/B-V eliminated this bias in the 44-group library.

A positive bias has been routinely observed in the ENDF/B-IV libraries for thermal ^{239}Pu systems and mixed oxide (MOX) fuel rods. The MOX fuel rod bias increases with increasing thermalization. One problem identified in the 27-group library was inadequate group structure to account for flux changes across the 0.3-eV resonance of ^{239}Pu. This problem has been rectified in the 44-group library by the addition of more energy groups in this energy range.

Carbon system numerical benchmarks have shown a negative bias of as much as 2.5% with the ENDF/B-IV libraries when compared with the Hansen-Roach and ENDF/B-V libraries. Analysis of the 218-group cross-section data has revealed an incorrect scatter matrix for carbon in energy group 10. In addition, the graphite thermal kernel is deficient. The impact of this deficiency is unknown.

The hafnium cross-section data available in the 218- and 27-group ENDF/B-IV libraries are not ENDF/B-IV data (ENDF/B-IV did not include hafnium). Known irregularities are present in the cross section, and no resonance data are available with the nuclide. The cross sections are infinite dilution (1/E weighting) across the resonance range. **Use of the hafnium data in the ENDF/B-IV libraries is not recommended and should be done with caution.**

Systems containing gadolinium have not calculated well with the 27-group library. The problem stems from the characteristic of the gadolinium data in the thermal range. Gadolinium has low-energy resonance data down to 10^{-5} eV. The resonances are so broad that the implementation of the Nordheim treatment in NITAWL-II fails to have a mesh point in group 27 of the 27-group structure. This difficulty has been addressed by setting the bottom energy of the resonance data to that of group 26 and carrying infinite dilution cross sections in group 27 of the master library. In addition, the ENDF resonance data for gadolinium prior to version VI are not well defined. **Use of the gadolinium data in the ENDF/B-IV libraries is not recommended and should be done with caution**.

5.4 PERFORMANCE WITH HIGH-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

Figure 5.1 shows calculated k_{eff} values for highly enriched ^{235}U systems using the SCALE 27-group ENDF/B-IV library. The overall trend shows an average k_{eff} of approximately 1.00 for thermal and fast systems, with a large variation in results for thermal systems. As expected, the results are very similar to the 218-group library results.

5.4.1 High-Enriched Fast Systems

Fast systems in Figure 5.1 are represented by the group of calculations at an EALF of 8×10^5 eV or greater. The fast systems have an average k_{eff} of about 1.00, with a variation of about $\pm 1\%$.

5.4.2 High-Enriched Thermal Systems

Thermal systems in Figure 5.1 are represented by the calculations with an EALF below about 3 eV. The average k_{eff} in the thermal region is about 1.00, with a variation of roughly ±2%. There is a wide spread of results in the thermal range (k_{eff} <0.98 to k_{eff} > 1.03). Similar spreads can be seen in the results for the other libraries, too. Most of the cases between 0.01 and 0.1 eV are uranyl fluoride solutions that tend to have a more negative bias. Most of the cases between 0.1 and 1 eV are uranyl nitrate solutions that show a more positive bias. The possibility of large uncertainties in the specifications for the critical systems used to validate the thermal range cannot be ruled out as the source of the large variations in calculated k_{eff} values.

5.4.3 High-Enriched Intermediate-Spectrum Systems

Intermediate-spectrum systems in Figure 5.1 are those with an EALF between 3 eV and 8×10^5 eV. Few critical experiments are in the intermediate range. These systems are characterized by an ill-defined average k_{eff} of 1.01, with a spread of about ±1%.
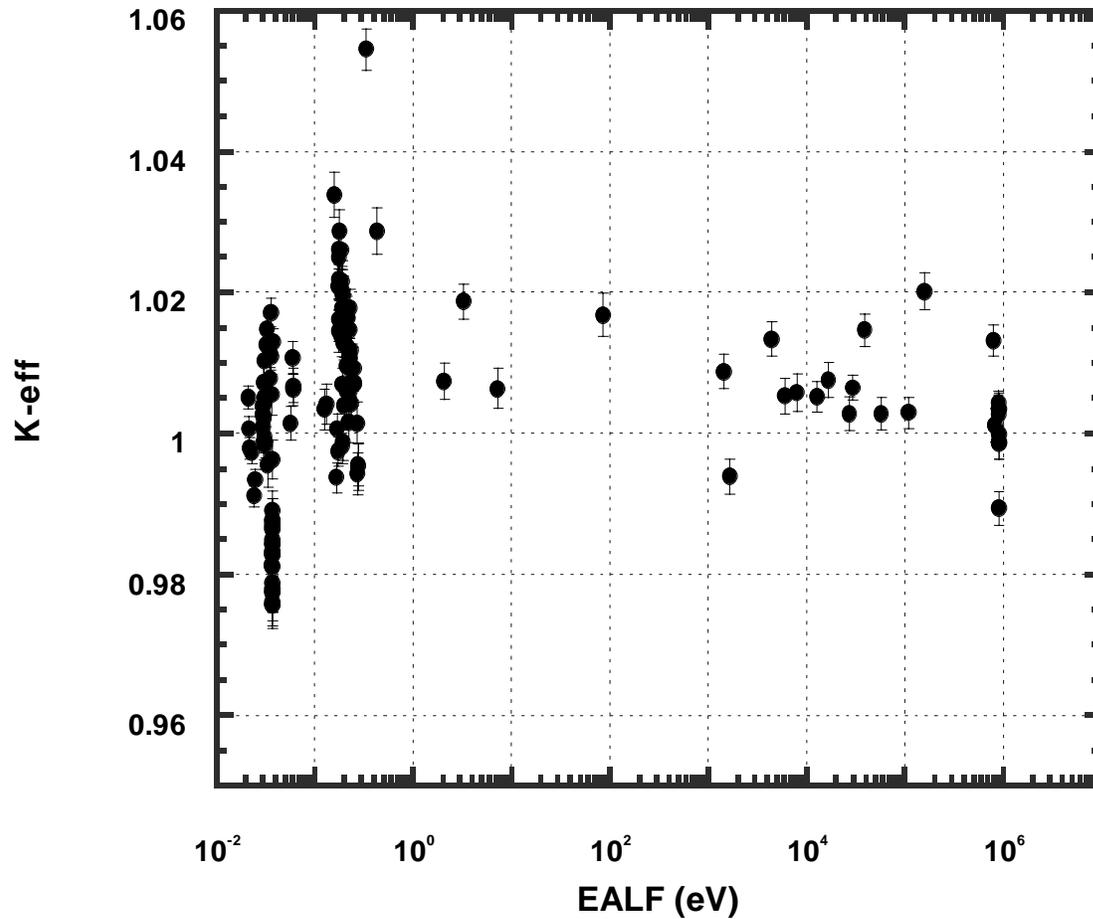
Figure 5.1 SCALE 27-group ENDF/B-IV library high-enriched ^{235}U system results

5.5 PERFORMANCE WITH LOW-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

The performance of the SCALE 27-group ENDF/B-IV library for homogeneous low enriched systems is shown in Figure 5.2. The homogeneous experiments have ^{235}U enrichments below 5%. The calculations do not show a trend as a function of energy. The average calculated k_{eff} value is approximately 1.00 ± 1.5%, about 0.5% more positive than the 218-group library results.
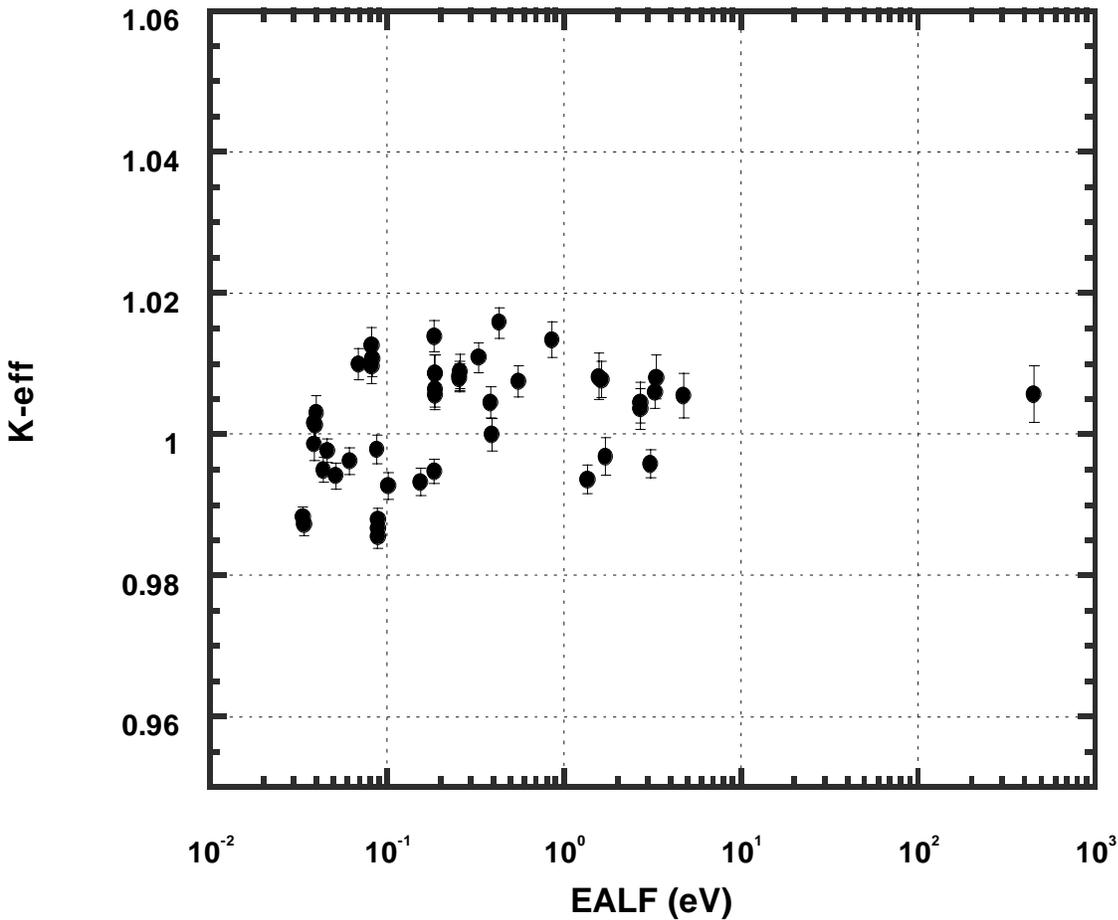
Figure 5.2 SCALE 27-group ENDF/B-IV library low-enriched homogeneous ^{235}U system results

5.6 PERFORMANCE WITH LWR LATTICES

The performance of the SCALE 27-group ENDF/B-IV library for heterogeneous low-enriched LWR lattice systems is shown in Figure 5.3. The maximum enrichment in the LWR lattice experiments is 5.74 wt % [235]U. The experiments have an average k_{eff} of about 0.995, with a ±1% variation, about 0.5% more positive than the 218-group library results. The trend of lower calculated k_{eff} values for harder thermal spectra is consistent with previous LWR fuel lattice validation experience with the 27-group ENDF/B-IV library. Because boron hardens the spectrum in LWR lattices, cases containing boron may have lower calculated k_{eff} values, although this trend was not observed for these cases.
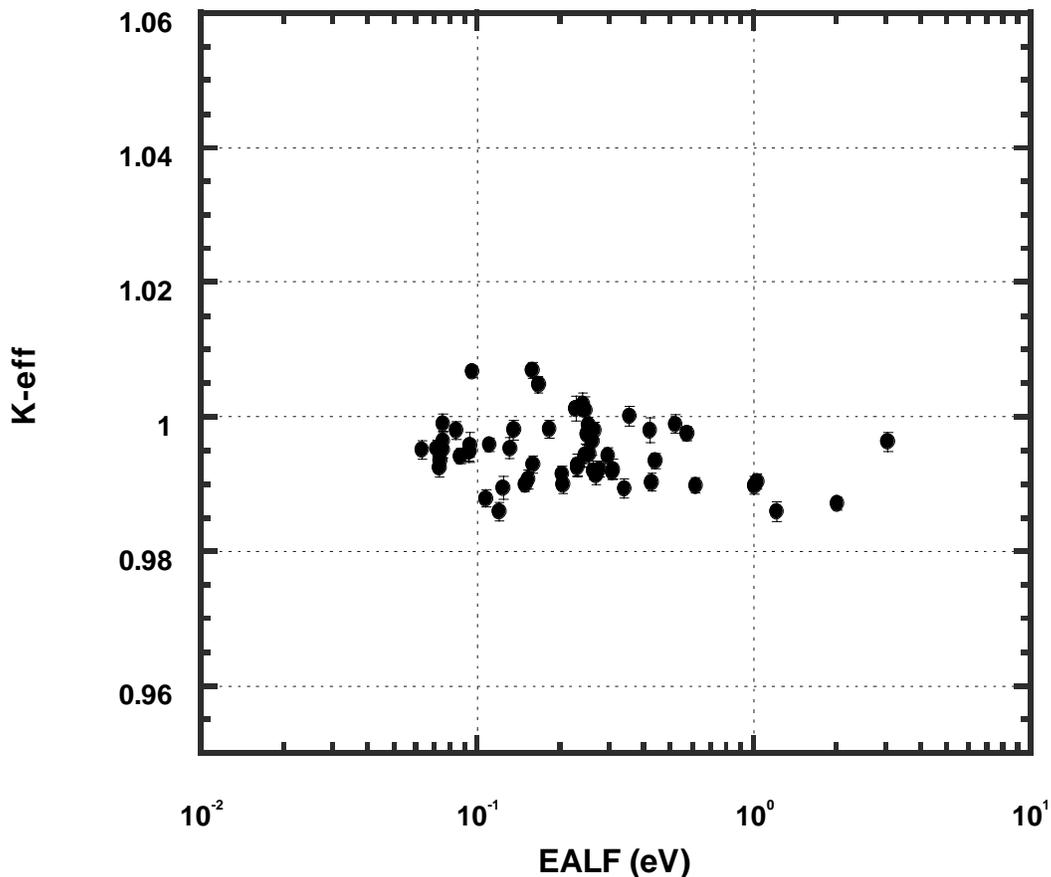
Figure 5.3 SCALE-27 group ENDF/B-IV library low-enriched LWR lattice results

5.7 PERFORMANCE WITH ^{239}Pu SYSTEMS

The performance of the SCALE 27-group ENDF/B-IV library for ^{239}Pu systems is shown in Figure 5.4. The performance of the library is generally poor. The library shows an overall 2 to 3% positive bias, with a range of 1.00 to 1.05 in calculated k_{eff} values. The results are very similar to the 218-group library results. The poor results are probably due to the base ENDF/B-IV ^{239}Pu data. The intermediate-spectrum results are worse than the thermal results. **The SCALE ENDF/B-IV libraries are not recommended for ^{239}Pu systems.**
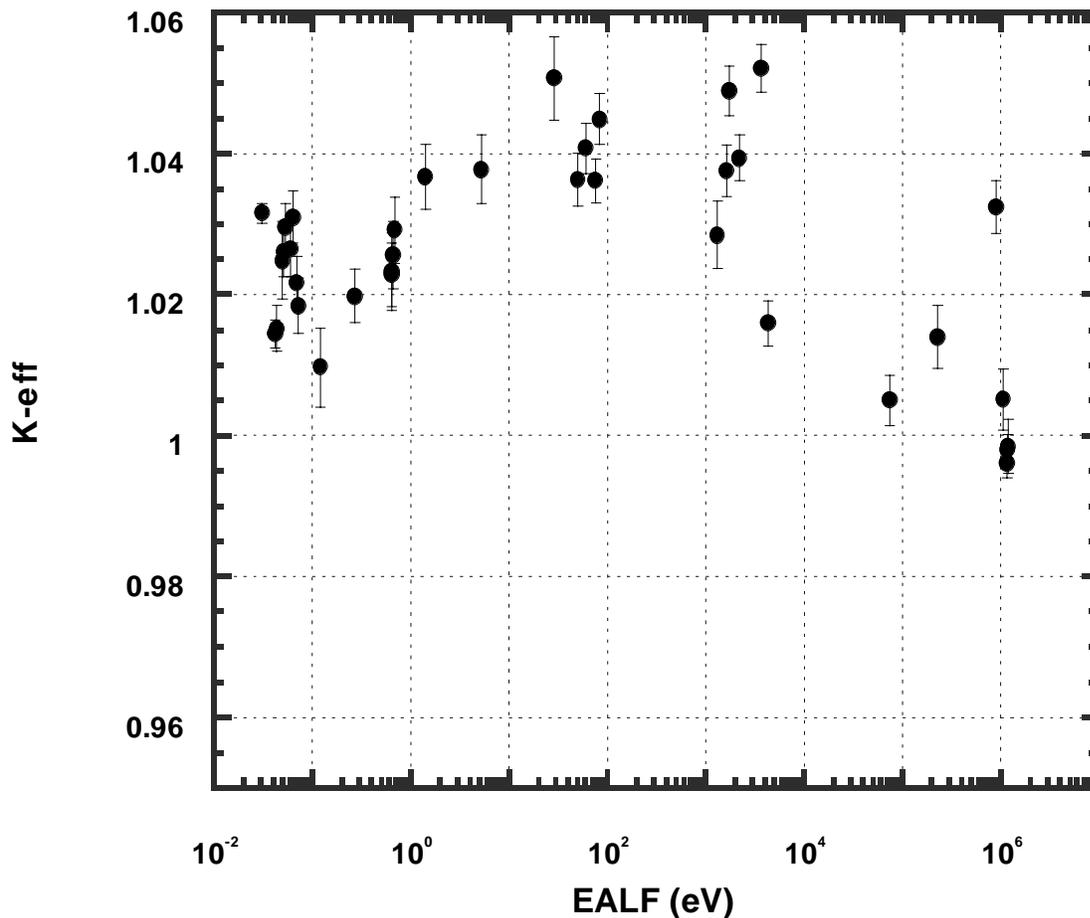
Figure 5.4 SCALE-27 group ENDF/B-IV library plutonium system results

5.8 PERFORMANCE WITH ^{233}U SYSTEMS

The performance of the SCALE 27-group ENDF/B-IV library for ^{233}U systems is shown in Figure 5.5. The performance of the library varies significantly between the thermal systems and the fast systems. The thermal systems show a strong positive bias. The thermal system results are clustered about an average k_{eff} of about $1.02 \pm 1.5\%$, about 0.5% more positive than the 218-group library results. Conversely, the fast systems show a strong negative bias, with results ranging from 0.96 to 0.98, very similar to the 218-group library results. These results emphasize the importance of validation, not only for the materials in the system, but also for the appropriate energy range.
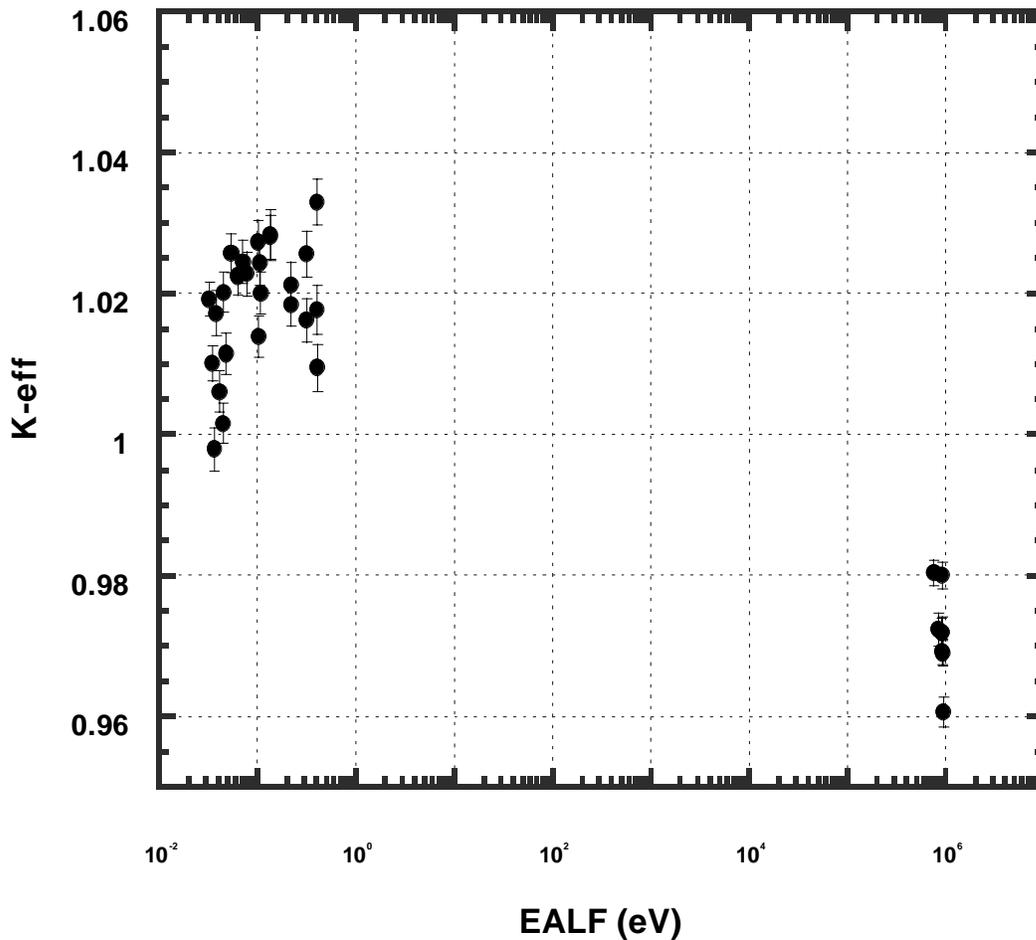
Figure 5.5 SCALE-27 group ENDF/B-IV library ^{233}U system results

5.9 PERFORMANCE WITH MIXED-OXIDE LATTICES

The performance of the SCALE 27-group ENDF/B-IV library for mixed-oxide (MOX) lattices is shown in Figure 5.6. All of the MOX lattice systems considered here are water-moderated thermal systems. The performance of the library is fair, probably due to the positive bias in the ENDF/B-IV [239]Pu resonance data offsetting the negative bias in the [238]U resonance data. The most thermalized systems (about 0.1 eV) show a small positive bias, with results ranging from 0.995 to 1.01. As the spectrum becomes harder, the calculated k_{eff} values show an increasingly negative bias, similar to that seen for the LWR lattices. As in the case of the LWR lattices, the cause may be the [238]U resonance data. Once again, the results are very similar to the 218-group library results.
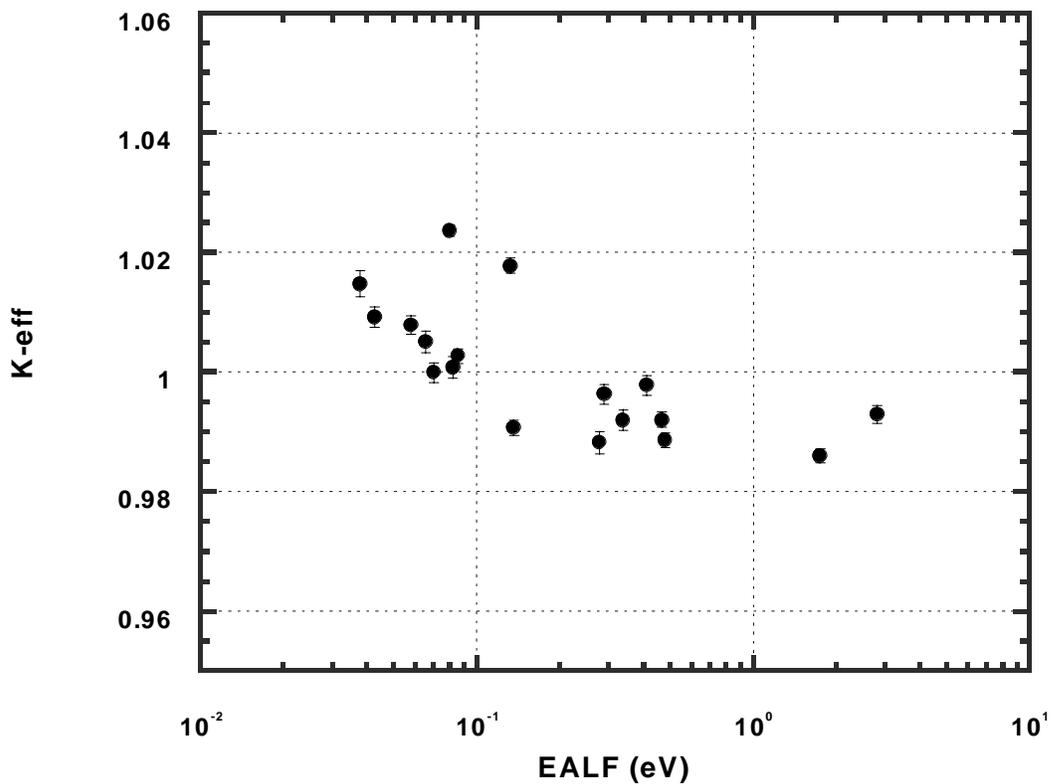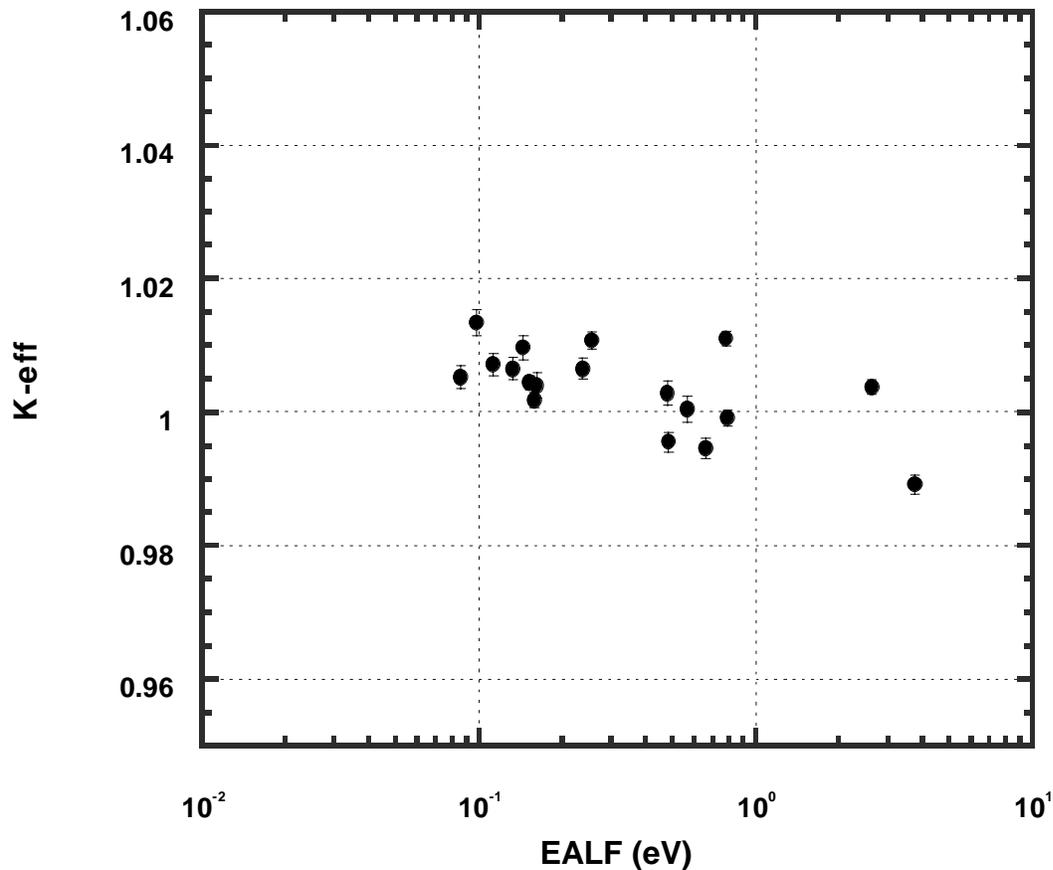

Figure 5.6 SCALE 27-group ENDF/B-IV library mixed-oxide lattice results

6 THE 238-GROUP ENDF/B-V LIBRARY

6.1 ORIGINS OF THE LIBRARY

The 238-group ENDF/B-V library[7] is a general-purpose criticality analysis library, and the most complete library available in SCALE. This library is also known as the LAW (Library to Analyze Radioactive Waste) Library. It was initially released in version 4.3 of SCALE. The library contains data for all nuclides (more than 300) available in ENDF/B-V processed by the AMPX-77 system.[11] It also contains data for ENDF/B-VI evaluations of ^{14}N, ^{15}N, ^{16}O, ^{154}Eu, and ^{155}Eu that are discussed in Section 6.2.   The library has 148 fast groups and 90 thermal groups (below 3 eV). The group structure is listed in Appendix A.

Most resonance nuclides in the 238-group and 44-group ENDF/B-V libraries have resonance data (to be processed by NITAWL-II) in the resolved resonance range and Bondarenko factors (to be processed by BONAMI) for the unresolved range. Both libraries contain resolved resonance data for *s*-wave, *p*-wave, and *d*-wave resonances ($\ell = 0$, $\ell = 1$, and $\ell = 2$, respectively) as shown in Table E.1. These data can have a significant effect on results for undermoderated, intermediate-energy problems. Resonance structures in several light-to-intermediate mass nonresonance ENDF nuclides (i.e., ^{7}Li, ^{19}F, ^{27}Al, ^{28}Si) are accounted for using Bondarenko shielding factors. These structures can also be important in intermediate-energy problems. Nuclides with thermal scattering data are listed in Table E.2. The ^{235}U ENDF/B-V data have slightly too much fission, while the ^{238}U data have slightly too much capture. Although better than the ENDF/B-IV data, the thermal plutonium data still appear to have problems.

All nuclides in the 238-group LAW Library use the same weighting spectrum, consisting of

1. Maxwellian spectrum (peak at 300 K) from 10^{-5} to 0.125 eV,
2. a 1/E spectrum from 0.125 eV to 67.4 keV,
3. a fission spectrum (effective temperature at 1.273 MeV) from 67.4 keV to 10 MeV, and
4. a 1/E spectrum from 10 to 20 MeV.

A plot of this spectrum is shown in Figure 6.1. The use of this spectrum (as opposed to the $1/(E\sigma_t)$ spectrum used to generate the 218-group library) makes it difficult to collapse a general- purpose broad-group library that is valid over a wide range of problems.

All nuclides use a P_5 Legendre expansion to fit the elastic and discrete-level inelastic scattering processes in the fast range, thereby making the library suitable for both reactor and shielding applications. A P_3 fit was used for thermal-scattering. All other scattering processes use P_0 fits.

Data testing has been performed for 33 benchmarks,[8] including 28 Cross-Section Evaluation Working Group (CSEWG) benchmarks. Results obtained for these benchmarks are very close to those obtained by other data testers using different ENDF/B-V-based cross-section libraries. There is considerable improvement in the trend of k_{eff} vs leakage obtained with the use of the ENDF/B-VI oxygen evaluation.
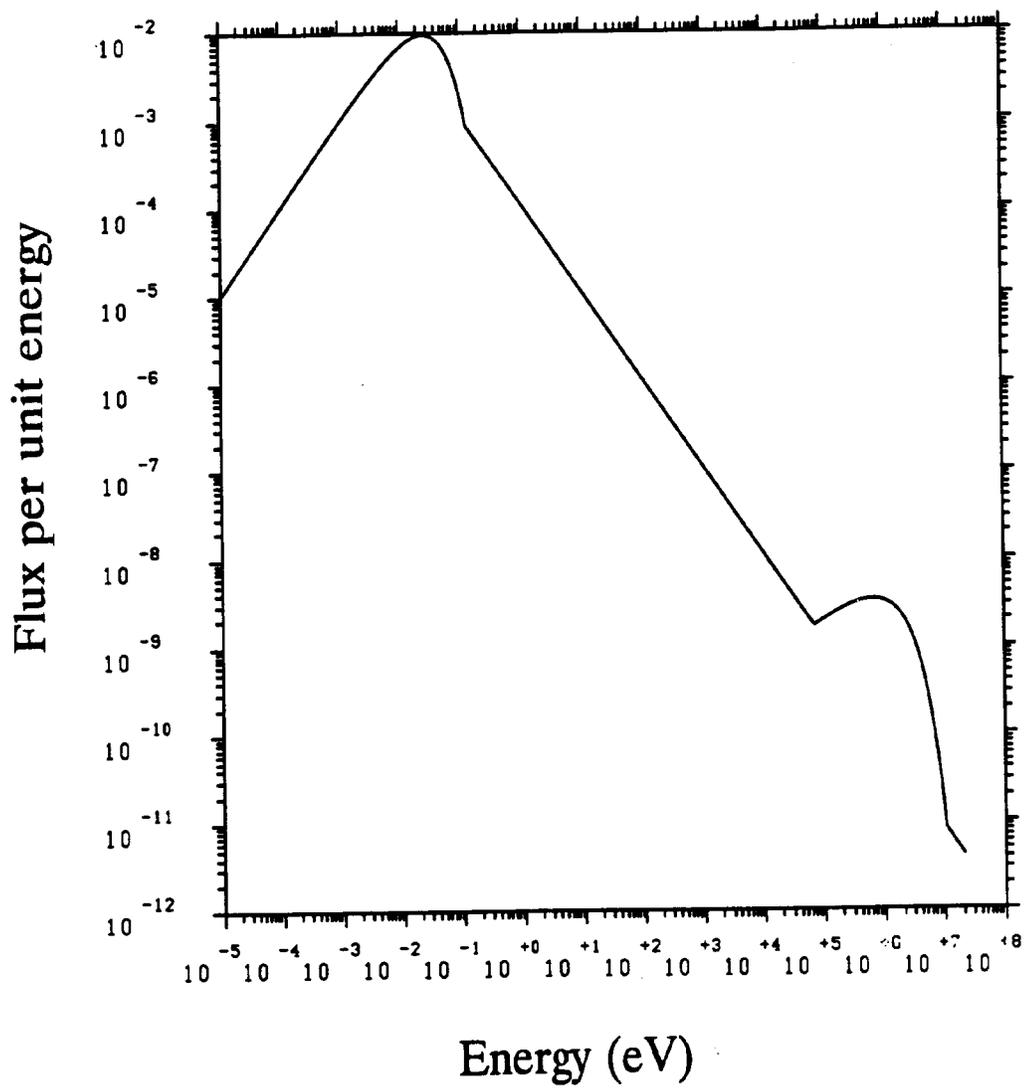
Figure 6.1 Weighting function for 238-group ENDF/B-V library

6.2 ENDF/B-VI DATA IN THE LIBRARY

Because of the significantly improved and conservative behavior of the ENDF/B-VI ^{16}O evaluation under conditions where higher-order scattering terms are important (e.g., high-leakage geometries), this cross section has been included in the 238-group and 44-group libraries as the default for ^{16}O. The ENDF/B-V evaluation is available within the library as cross-section number 801601, and may be copied into an AMPX master library using AJAX for subsequent use in calculations. Similarly, ENDF/B-VI evaluations of ^{14}N and ^{15}N are included in the library; however, ENDF/B-V versions remain the default for these isotopes. The ENDF/B-VI nitrogen data were processed using the same methods used for ^{16}O and, like oxygen, were tested to see if significant differences between ENDF/B-V and ENDF/B-VI could be identified. No significant differences have been identified; however, because they had already been processed into AMPX master library format and were readily available, ENDF/B-VI ^{14}N and ^{15}N cross sections are included in the library as cross sections 701401 and 701501, respectively. Finally, ENDF/B-VI evaluations of ^{154}Eu and ^{155}Eu are also included in the library as default cross sections 63154 and 63155, respectively. The more recent ENDF/B-VI evaluations include resonance parameters not included in previous evaluations and yield energy-dependent cross sections significantly different from those obtained using ENDF/B-V cross sections. Comparisons of depletion/decay calculations with experimental isotopic measurements have indicated that the ENDF/B-VI europium evaluations are more accurate than those available in ENDF/B-V. However, as with ^{16}O, ENDF/B-V cross sections are available within the library, as isotopes 631541 and 631551.

6.3 PERFORMANCE WITH HIGH-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

Figure 6.2 shows calculated k_{eff} values for highly enriched ^{235}U systems using the SCALE 238-group ENDF/B-V library. The overall trend shows an average k_{eff} of approximately 0.995 for thermal and fast systems, with a large variation in results for thermal systems.

6.3.1 High-Enriched Fast Systems

Fast systems in Figure 6.2 are represented by the group of calculations at an EALF of 8×10^5 eV or greater. The fast systems have an average k_{eff} of about 0.995, with a variation of about ±1%.

6.3.2 High-Enriched Thermal Systems

Thermal systems in Figure 6.2 are represented by the calculations with an EALF below about 3 eV. The average k_{eff} in the thermal region is about 1.00, with a variation of roughly ±2%. There is a wide spread of results in the thermal range (k_{eff}<0.98 to k_{eff}> 1.02). Similar spreads can be seen in the results for the other libraries, too. The possibility of large uncertainties in the specifications for the critical systems used to validate the thermal range cannot be ruled out as the source of the large variations in calculated k_{eff} values.

6.3.3 High-Enriched Intermediate-Spectrum Systems

Intermediate-spectrum systems in Figure 6.2 are those with an EALF between 3 eV and 8×10^5 eV. Few critical experiments are in the intermediate range. These systems are characterized by an ill-defined average k_{eff} of $0.99 \pm 1.5\%$.
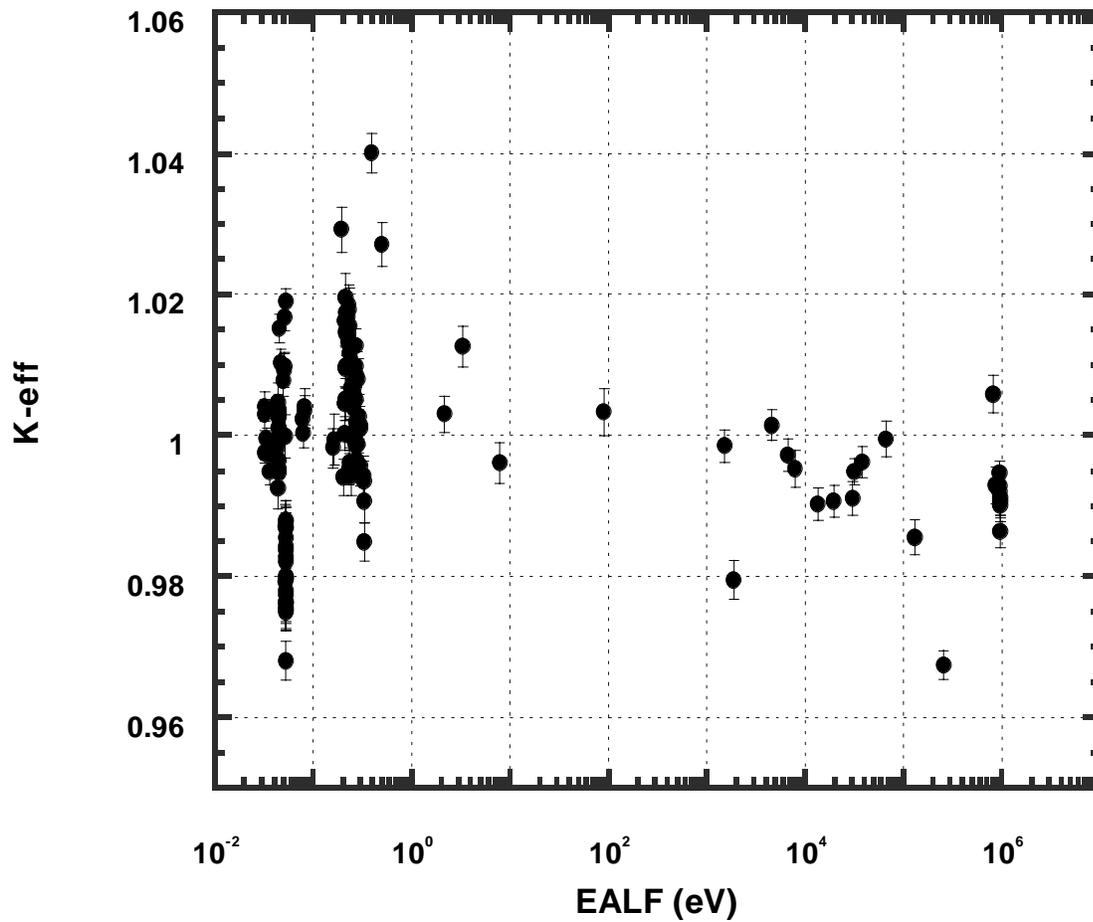
Figure 6.2 SCALE 238-group ENDF/B-V library high-enriched ^{235}U system results

6.4 PERFORMANCE WITH LOW-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

The performance of the SCALE 238-group ENDF/B-V library for homogeneous low-enriched systems is shown in Figure 6.3. The homogeneous experiments have ^{235}U enrichments below 5%. The calculations do not show a trend as a function of EALF, which is directly related to the moderation level. The average calculated k_{eff} value is approximately $1.005 \pm 1.5\%$.
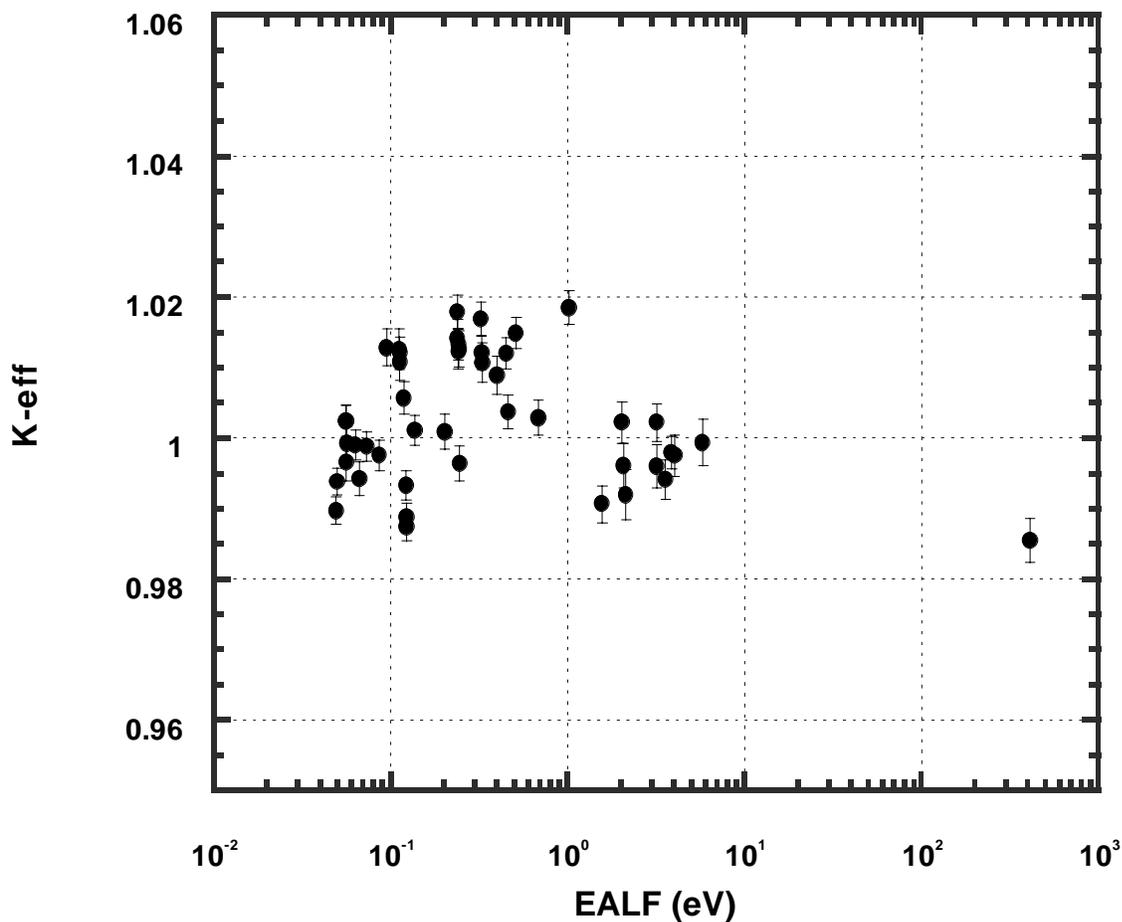
Figure 6.3 SCALE 238-group ENDF/B-V library low-enriched homogeneous ^{235}U system results

6.5 PERFORMANCE WITH LWR LATTICES

The performance of the SCALE 238-group ENDF/B-V library for heterogeneous low-enriched LWR lattice systems is shown in Figure 6.4. The maximum enrichment in the LWR lattice experiments is 5.74 wt % ^{235}U. The experiments have an average k_{eff} of about 0.995 ± 1%. The results show no bias vs energy. The cases containing boron showed no apparent bias.
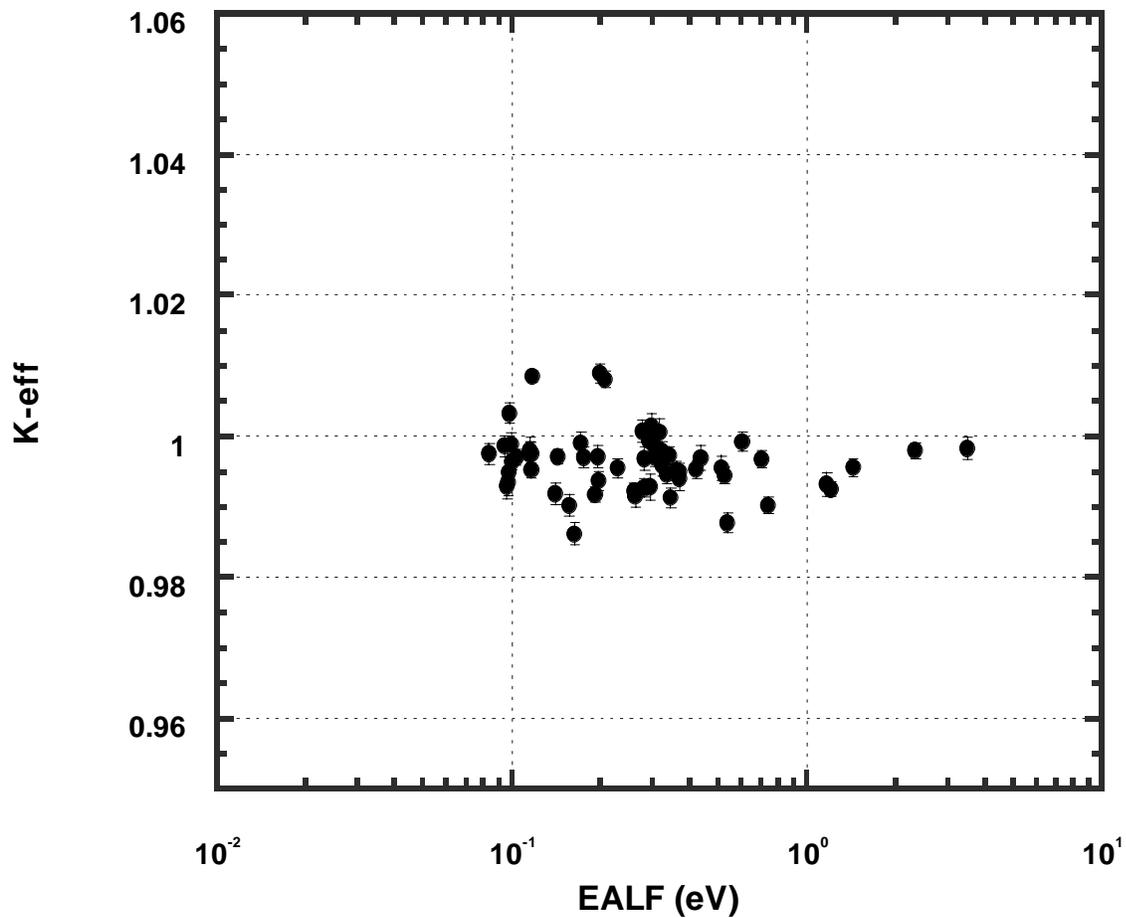
Figure 6.4 SCALE 238-group ENDF/B-V library low-enriched LWR lattice results

6.6 PERFORMANCE WITH ^{239}Pu SYSTEMS

The performance of the SCALE 238-group ENDF/B-V library for ^{239}Pu systems is shown in Figure 6.5. The performance of the library is fair, with an average k_{eff} of about 1.015 ± 2%. The results indicate possible problems in the base ENDF/B-V ^{239}Pu data. These results are better than the ENDF/B-IV libraries, particularly in the intermediate-energy range, with less variation and no apparent trends vs. energy.
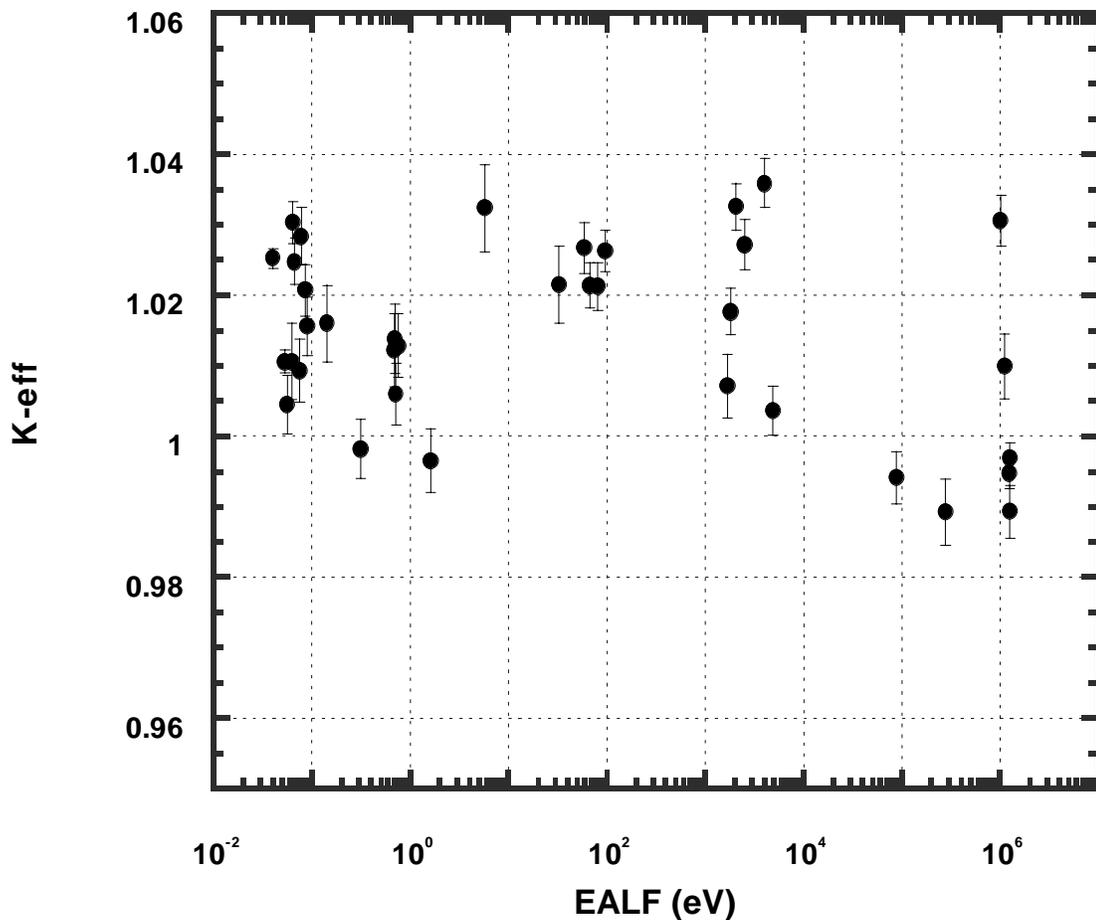
Figure 6.5 SCALE 238-group ENDF/B-V library plutonium system results

6.7 PERFORMANCE WITH [233]U SYSTEMS

The performance of the SCALE 238-group ENDF/B-V library for [233]U systems is shown in Figure 6.6.
The performance of the library is good, and it is consistent between the thermal systems and the fast systems.
The thermal system results have an average calculated k_{eff} value of about $0.995 \pm 1.5\%$. The fast system results
are excellent, with an average calculated k_{eff} value of about $0.999 \pm 0.4\%$. These results are substantially better
than the ENDF/B-IV libraries.
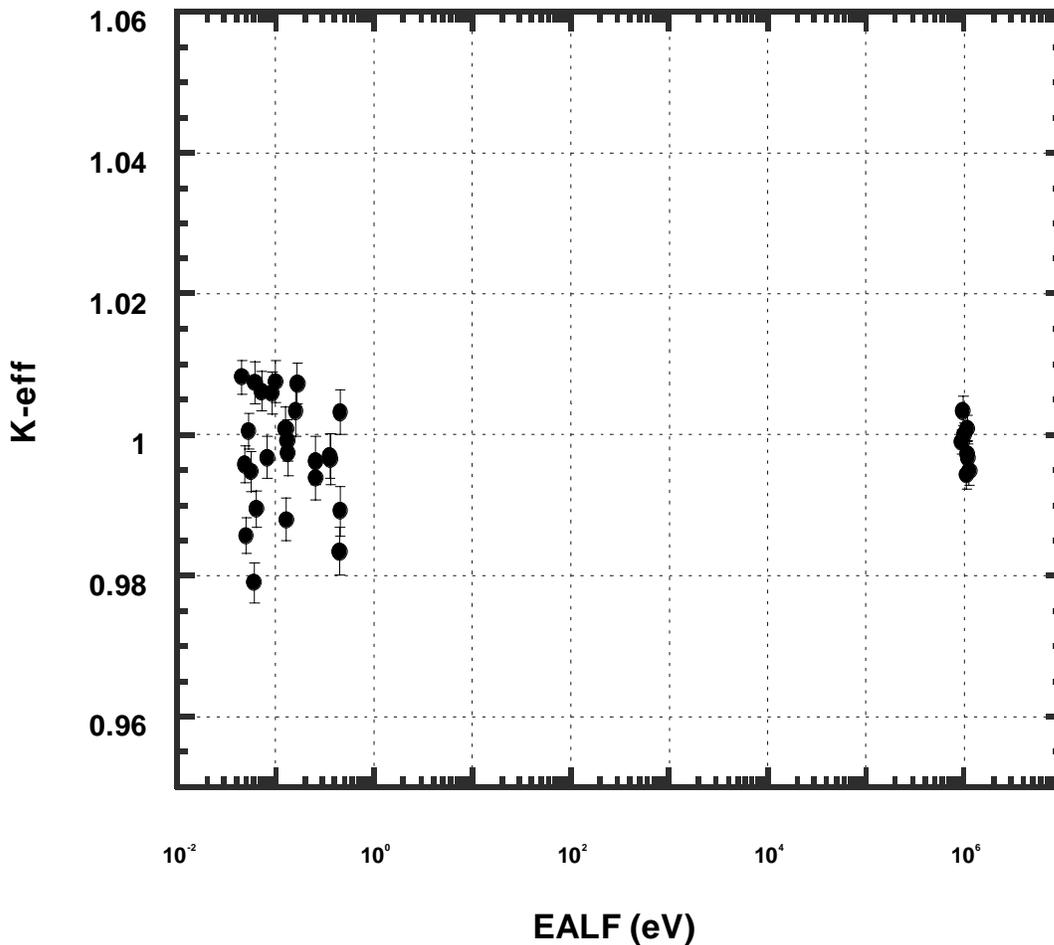
Figure 6.6 SCALE 238-group ENDF/B-V library [233]U system results

6.8 PERFORMANCE WITH MIXED-OXIDE LATTICES

The performance of the SCALE 238-group ENDF/B-V library for mixed-oxide (MOX) lattices is shown in Figure 6.7. All of the MOX lattice systems considered here are water-moderated thermal systems. The performance of the library is very good. The average calculated k_{eff} value is approximately $1.0 \pm 1\%$. The results show a trend vs energy (i.e., moderation). The most thermal cases have a slightly positive bias, while those with a harder spectrum have a slightly negative bias.
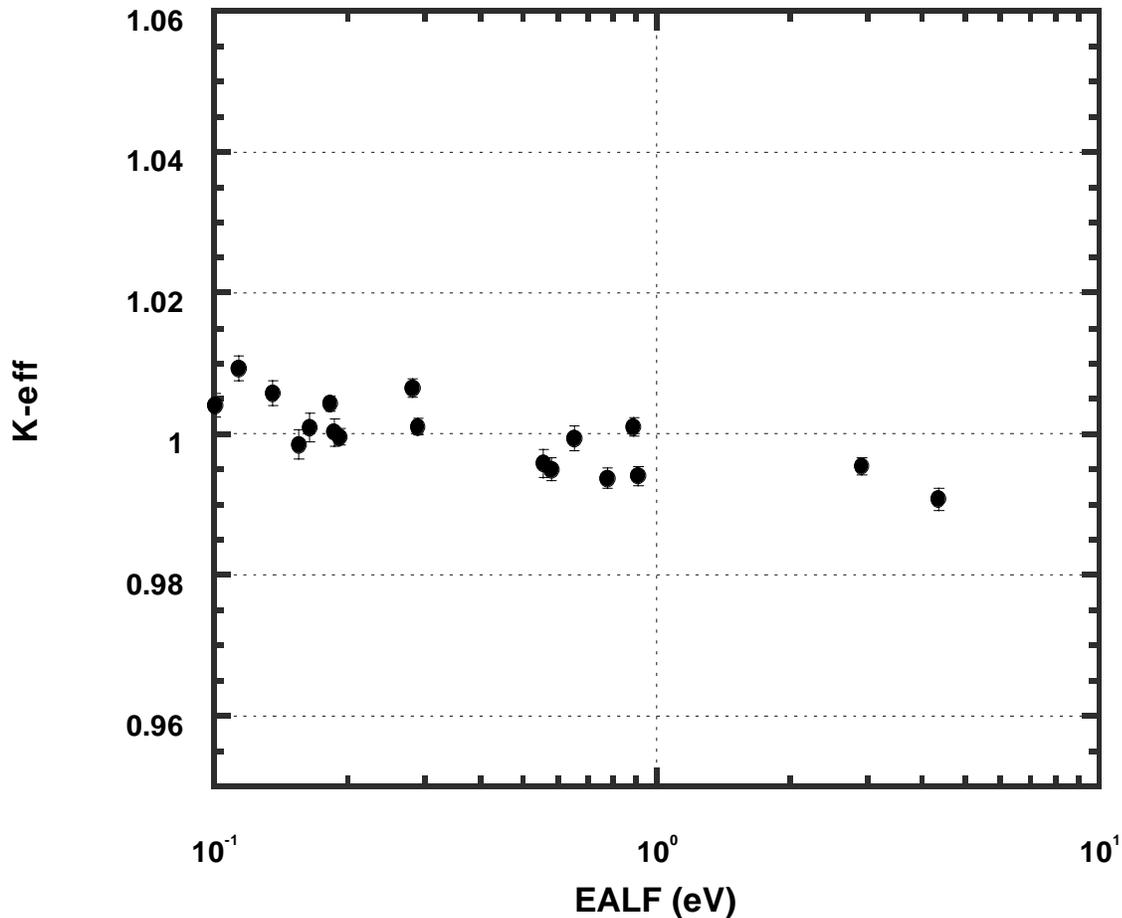
Figure 6.7 SCALE 238-group ENDF/B-V library mixed-oxide lattice results

7 THE 44-GROUP ENDF/B-V LIBRARY

7.1 ORIGINS OF THE LIBRARY

The 44-group ENDF/B-V library[8] has been developed for use in the analysis of fresh and spent fuel and radioactive waste systems. The library was initially released in version 4.3 of SCALE. Collapsed from the fine-group 238-group ENDF/B-V cross-section library, this broad-group library contains all nuclides (more than 300) from the ENDF/B-V data files. Broad-group boundaries were chosen as a subset of the parent 238-group ENDF/B-V boundaries, emphasizing the key spectral aspects of a typical LWR fuel package. Specifically, the broad-group structure was designed to accommodate the following features: two windows (where the cross section drops significantly at a particular energy, allowing neutrons at that energy to pass through the material) in the oxygen cross-section spectrum; a window in the cross section of iron; the Maxwellian peak in the thermal range; and the 0.3-eV resonance in ^{239}Pu (which, due to its low energy, cannot be properly modeled via the SCALE Nordheim Integral Treatment module NITAWL-II). The resulting boundaries represent 22 fast and 22 thermal energy groups; the full-group structure is compared with that of the 238-group library in Table A.1. The fine-group 238-group ENDF/B-V cross sections were collapsed into this broad-group structure using a fuel-cell spectrum calculated based on a 17×17 Westinghouse pressurized-water reactor (PWR) assembly. Thus, the 44-group library performs well for LWR lattices, but not as well for other types of systems.

The 44-group ENDF/B-V library has been tested against its parent library, using a set of 33 benchmark problems[8] in order to demonstrate that the collapsed set was an acceptable representation of 238-group ENDF/B-V, except for intermediate-energy systems. Validation of the library within the SCALE system was based on a comparison of calculated values of k_{eff} with that of 93 experiments: 92 critical and 1 subcritical experiments.[8] The experiments consisted primarily of various configurations of light-water-reactor-type fuel representative of transportation and storage conditions. Additional experiments were included to allow a comparison with results obtained in an earlier validation of the 27-group ENDF/B-IV library.

Results show that the broad 44-group structure is an acceptable representation of its parent 238-group library for thermal LWR lattice systems, as well as hard fast spectrum systems.   The 44-group library is the recommended SCALE library for criticality safety analysis of arrays of light-water-reactor-type fuel assemblies, as would be encountered in fresh or spent fuel transportation or storage environments. Validation results for LWR-type UO_2 fuel show virtually no bias. A positive bias of 0.5 to 1% has been observed for very thermal mixed-oxide systems. The bias is caused by inadequate representation of plutonium cross sections, possibly in the ENDF/B-V data. The validation results for the 44-group library are consistently better relative to the same cases using the 27-group ENDF/B-IV library. Because of the weighting spectrum used to generate the 238-group library, it is difficult to collapse a general-purpose broad-group library that is valid over a wide range of problems. **For all other systems, the parent 238-group ENDF/B-V library is recommended.** A user could generate their own broad group library for a particular application by collapsing with a problem-specific flux spectrum.

7.2 ENDF/B-VI DATA IN THE LIBRARY

Because of the significantly improved and conservative behavior of the ENDF/B-VI ^{16}O evaluation under conditions where higher-order scattering terms are important (e.g., high-leakage geometries), this cross section has been included in the 238-group and 44-group libraries as the default for ^{16}O. The ENDF/B-V evaluation is available within the library as cross-section number 801601, and may be copied into an AMPX working library using AJAX for subsequent use in calculations. Similarly, ENDF/B-VI evaluations of ^{14}N and ^{15}N are included in

the library; however, ENDF/B-V versions remain the default for these isotopes. The ENDF/B-VI nitrogen data were processed using the same methods used for ^{16}O, and, like oxygen, were tested to see if significant differences between ENDF/B-V and ENDF/B-VI could be identified. No significant differences have been identified; however, because they had already been processed into AMPX master library format and were readily available, ENDF/B-VI ^{14}N and ^{15}N cross sections are included in the library as cross sections 701401 and 701501, respectively. Finally, ENDF/B-VI evaluations of ^{154}Eu and ^{155}Eu are also included in the library as default cross sections 63154 and 63155, respectively. The more recent ENDF/B-VI evaluations include resonance parameters not included in previous evaluations and yield energy-dependent cross sections that are significantly different from those obtained using ENDF/B-V cross sections. Comparisons of depletion/decay calculations with experimental isotopic measurements have indicated that the ENDF/B-VI europium evaluations are more accurate than those available in ENDF/B-V. However, as with ^{16}O, ENDF/B-V cross sections are available within the library, as isotopes 631541 and 631551.

7.3 PERFORMANCE WITH HIGH-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

Figure 7.1 shows calculated k_{eff} values for highly enriched ^{235}U systems using the SCALE 44-group ENDF/B-V library. The overall trend shows an average k_{eff} of approximately 1.00 for thermal and fast systems, with a large variation in results for thermal systems.

7.3.1 High-Enriched Fast Systems

Fast systems in Figure 7.1 are represented by the group of calculations at an EALF of 8×10^5 eV or greater. The fast systems have an average k_{eff} of about 1.00, with a variation of about $\pm 1\%$, very similar to the 238-group library results.

7.3.2 High-Enriched Thermal Systems

Thermal systems in Figure 7.1 are represented by the calculations with an EALF below about 3 eV. The average k_{eff} in the thermal region is about 1.00, with a variation of roughly $\pm 2\%$. There is a wide spread of results in the thermal range (k_{eff} <0.98 to k_{eff} > 1.03).   Similar spreads can be seen in the results for the other libraries, too. As observed with the other libraries, the uranyl fluoride results tend to be less than the uranyl nitrate results. The possibility of large uncertainties in the specifications for the critical systems used to validate the thermal range cannot be ruled out as the source of the large variations in calculated k_{eff} values.

7.3.3 High-Enriched Intermediate-Spectrum Systems

Intermediate spectrum systems in Figure 7.1 are those with an EALF between 3 eV and 8×10^5 eV. Few critical experiments are in the intermediate range. These systems are characterized by an ill-defined average k_{eff} of $1.00 \pm 1.5\%$. Some cases are roughly 1% higher while others are nearly the same as the 238-group results.
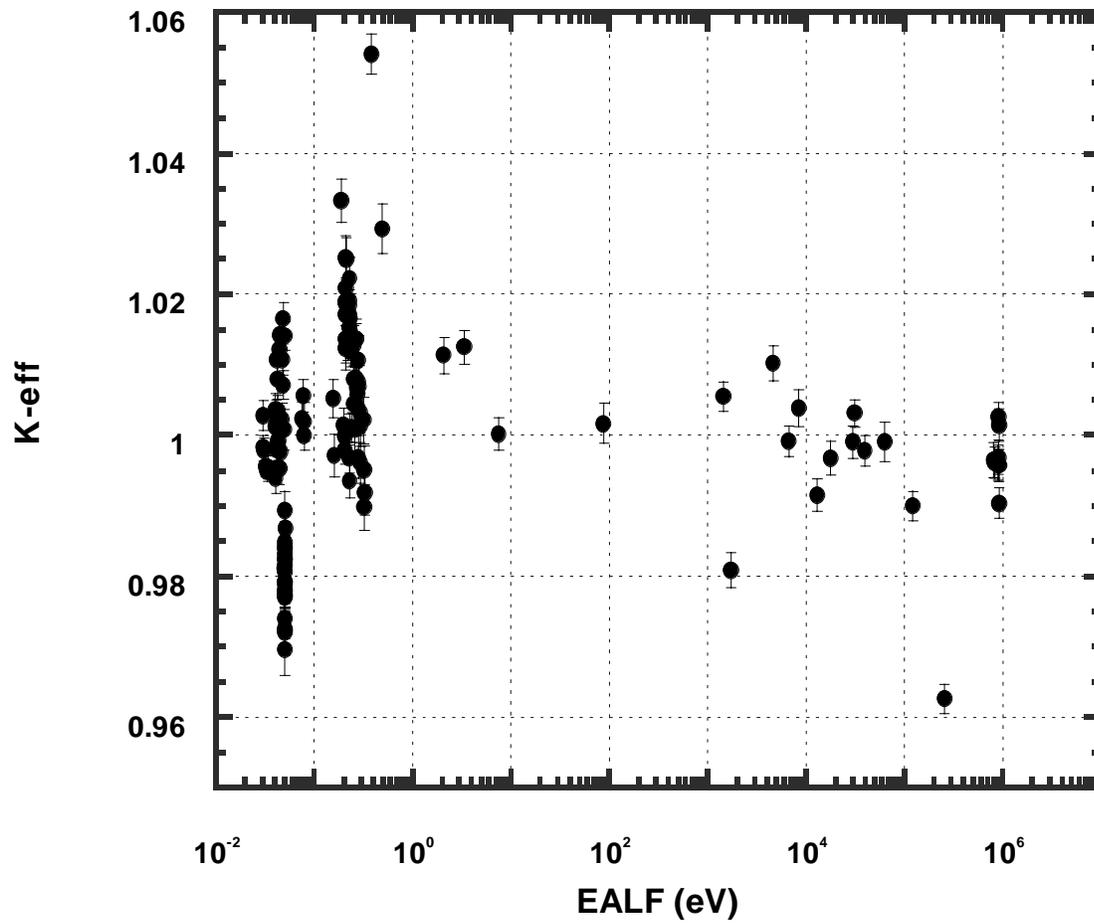
Figure 7.1 SCALE 44-group ENDF/B-V library high-enriched homogeneous ^{235}U system results

7.4 PERFORMANCE WITH LOW-ENRICHED HOMOGENEOUS ^{235}U SYSTEMS

The performance of the SCALE 44-group ENDF/B-V library for homogeneous low-enriched systems is shown in Figure 7.2. The homogeneous experiments have ^{235}U enrichments below 5%. Some of the more thermal cases show a negative bias, but all remaining cases have a positive bias. There is less scatter in these results than the 238-group library results. The harder spectra cases (> 1 eV) are about 2% higher than the 238-group results. The average calculated k_{eff} value is approximately $1.01 \pm 1.5\%$.
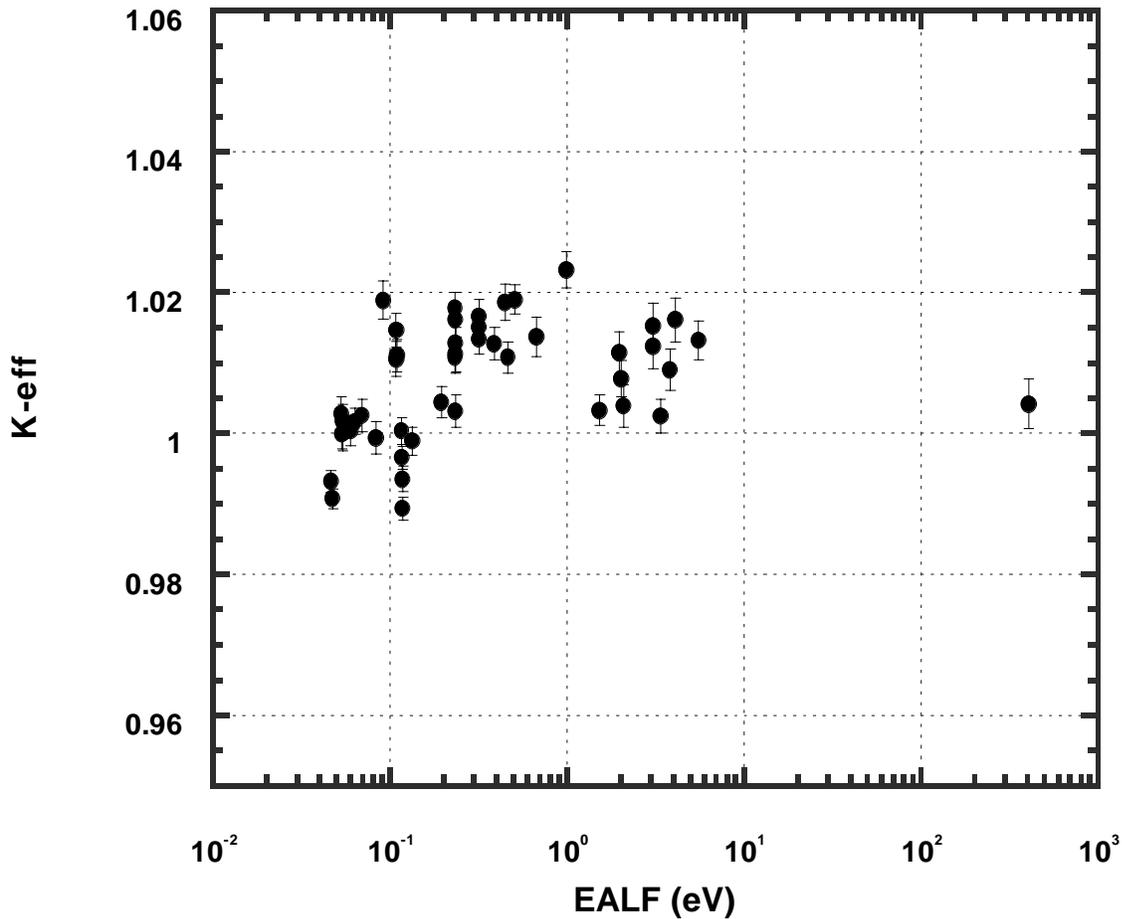
Figure 7.2 SCALE 44-group ENDF/B-V library low-enriched homogeneous ^{235}U system results

7.5 PERFORMANCE WITH LWR LATTICES

The performance of the SCALE 44-group ENDF/B-V library for heterogeneous low-enriched LWR lattice systems is shown in Figure 7.3. The maximum enrichment in the LWR lattice experiments is 5.74 wt % ^{235}U. The results for these cases are excellent, as should be expected, because the library was collapsed with an LWR lattice spectrum specifically for these types of applications. The experiments have an average k_{eff} of about 1.00 ± 1%. The results show no bias vs energy. The cases containing boron showed no apparent bias.
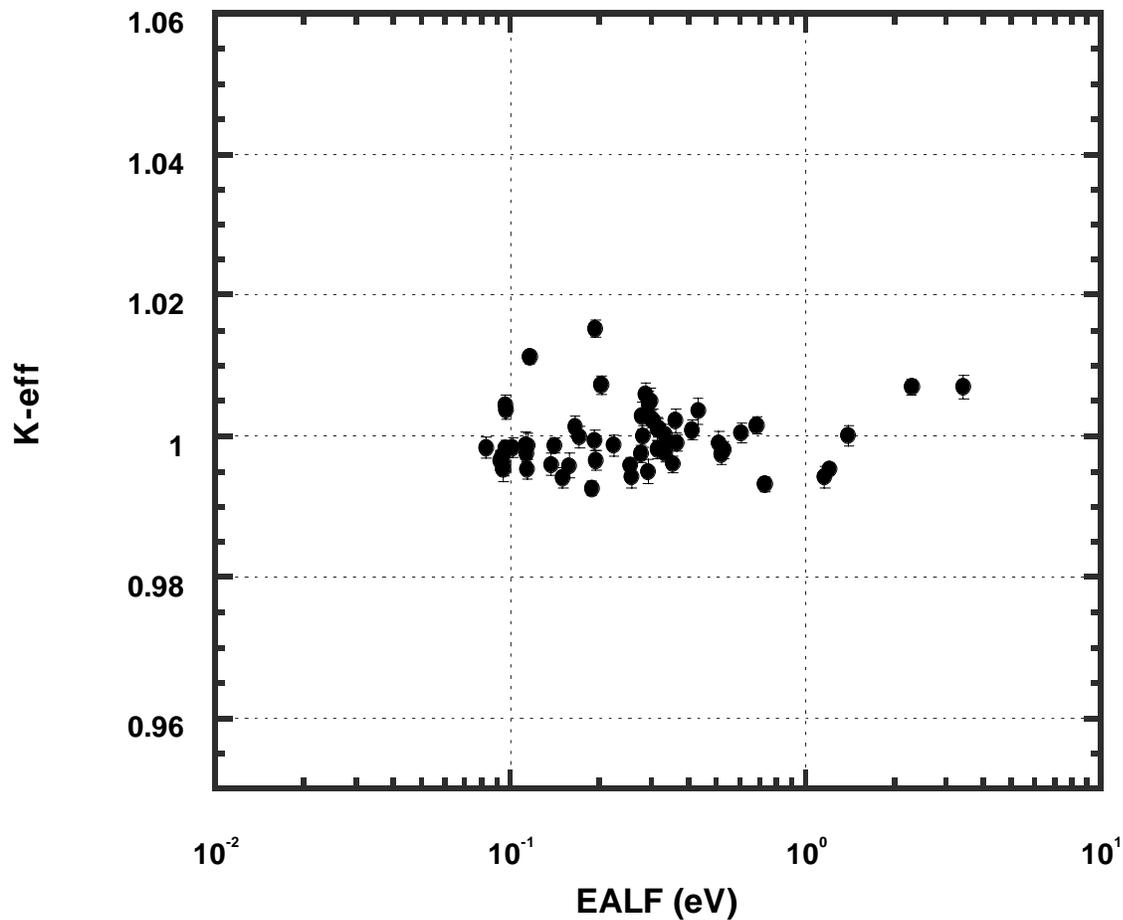
Figure 7.3 SCALE 44-group ENDF/B-V library low-enriched LWR lattice results

7.6 PERFORMANCE WITH ^{239}Pu SYSTEMS

The performance of the SCALE 44-group ENDF/B-V library for ^{239}Pu systems is shown in Figure 7.4.
The performance of the library is fair, with an average k_{eff} of about $1.02 \pm 2\%$. The results indicate possible
problems in the base ENDF/B-V ^{239}Pu data. These results are 0.5 to 1.0% higher than the 238-group library for
several cases.

Figure 7.4 SCALE 44-group ENDF/B-V library plutonium system results

7.7 PERFORMANCE WITH ^{233}U SYSTEMS

The performance of the SCALE 44-group ENDF/B-V library for ^{233}U systems is shown in Figure 7.5.
The performance of the library is good, and it is consistent between the thermal systems and the fast systems.
The thermal system results have an average calculated k_{eff} value of about $1.0 \pm 1.5\%$. The fast system results are
excellent, with an average calculated k_{eff} value of about $0.997 \pm 0.5\%$. These results are very similar to the
238-group library results.
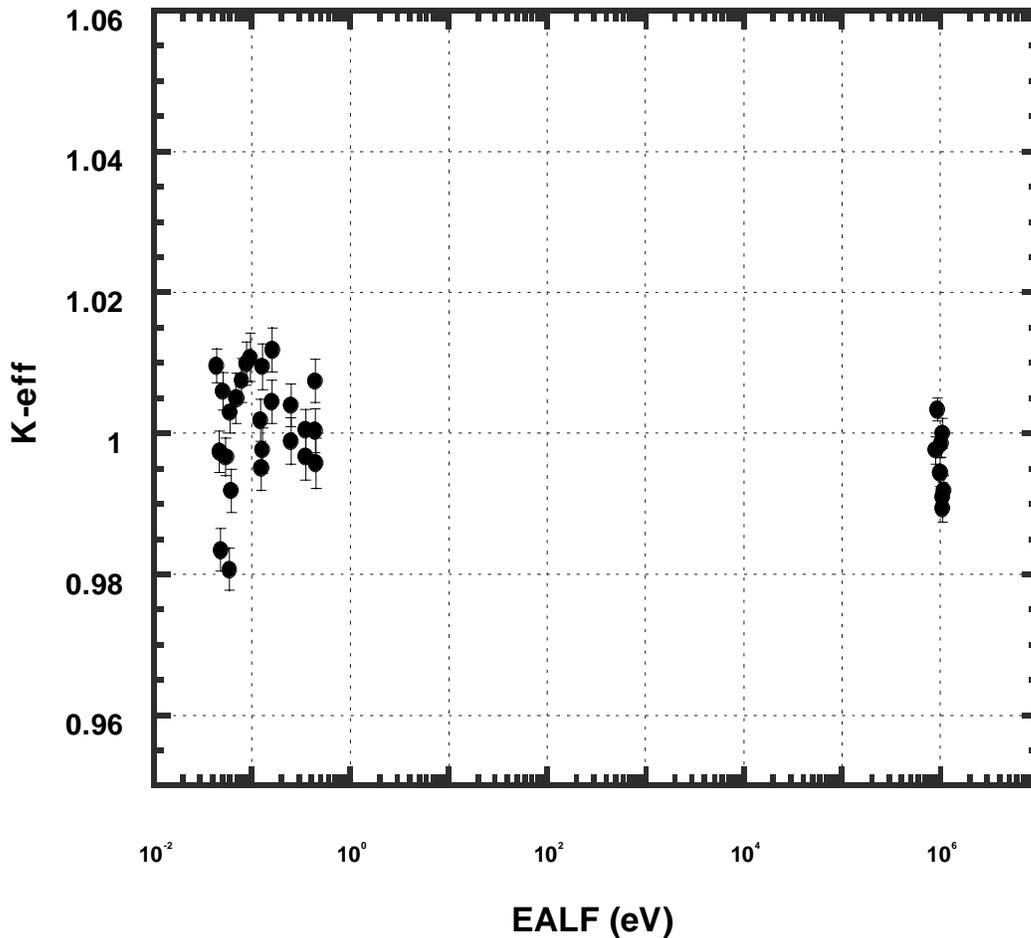
Figure 7.5 SCALE 44-group ENDF/B-V library ^{233}U system results

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7.8 PERFORMANCE WITH MIXED-OXIDE LATTICES

The performance of the SCALE 44-group ENDF/B-V library for mixed-oxide (MOX) lattices is shown in Figure 7.6. All of the MOX lattice systems considered here are water-moderated thermal systems. The performance of the library is excellent. The average calculated k_{eff} value is approximately $1.003 \pm 0.6\%$. The results may show a slight negative trend vs energy (i.e., moderation), but it is not definite.
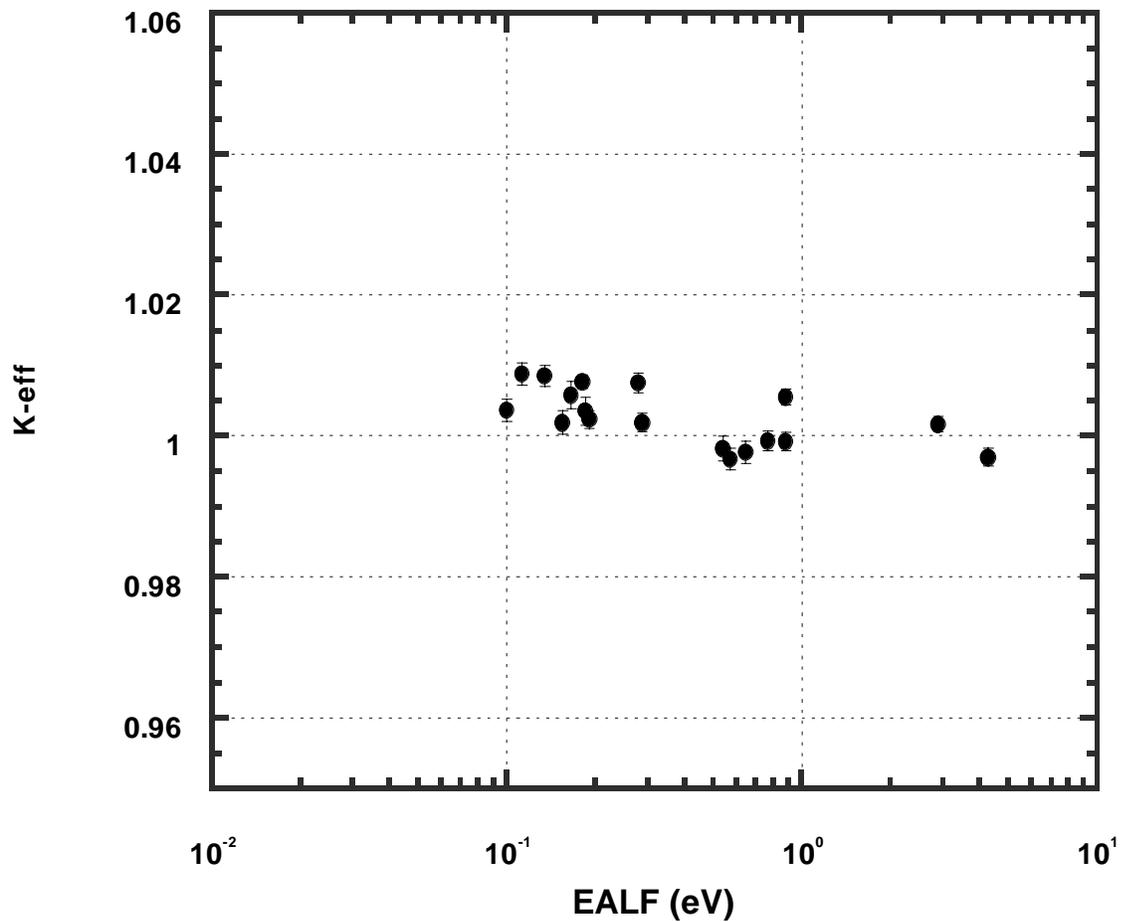
Figure 7.6 SCALE 44-group ENDF/B-V library mixed-oxide lattice results

8 SUMMARY AND CONCLUSIONS

This report provides detailed information on the SCALE criticality-safety cross-section libraries. Areas covered include the origins of the libraries, the data on which they are based, how they were generated, past experience and validations, and performance comparisons with measured critical experiments and numerical benchmarks. Performance results of each library for seven different application areas are summarized in Table 8.1.

The remainder of this section contains a brief verbal summary of each library.

Table 8.1 Summary of SCALE library performance for various applications

	Cross-section library				
Problem Type	SCALE 16-group Hansen-Roach	27-group[a] ENDF/B-IV	218-group[a] ENDF/B-IV	44-group ENDF/B-V	238-group ENDF/B-V
Fast HEU	Very good 0.995 ± 1%	Very good 1.00 ± 1%	Very good 1.00 ± 1%	Very good 1.00 ± 1%	Very good 0.995 ± 1%
Thermal HEU	Very poor 2% high to 4% low	Poor 3% high to 2% low	Poor 1.00 ± 2%	Poor 1.00 ± 3%	Poor 1.00 ± 2%
LWR Lattices	Fair ±1.5%	Good 0.995 ± 1% small bias vs energy	Good 0.99 ± 1% small bias vs energy	Very good 1.00 ± 1%	Very good 0.995 ± 1%
Homogeneous LEU	Poor ±2% bias vs energy	Fair 1.00 ± 1.5%	Fair 0.995 ± 1.5%	Fair 1.01 ± 1.5%	Fair 1.005 ± 1.5%
^{239}Pu	Very poor up to 5% high bias vs energy	Poor up to 5% high bias vs energy	Poor up to 5% high bias vs energy	Fair 1.02 ± 2%	Fair 1.015 ± 2%
MOX lattices	Very poor 3% high to 1% low	Fair 1.00 ± 1.5% bias vs energy	Fair 1% high to 2% low bias vs energy	Excellent 1.003 ± 0.6%	Very good 1.00 ± 1% small bias vs energy
^{233}U	Poor thermal - 0.99 ± 2% fast - 1.0 ± 1%	Poor thermal - 1.02 ± 1.5% fast - 0.97 ± 1%	Poor thermal - 1.015 ± 1.5% fast - 0.97 ± 1%	Good thermal - 1.00 ± 1.5% fast - 0.997 ± 0.5%	Good thermal - 0.995 ± 1.5% fast - 0.999 ± 0.4%

[a]Use of hafnium and gadolinium data not recommended.

8.1 SCALE 16-GROUP HANSEN-ROACH LIBRARY

1. **How the library was generated or collapsed:**

    The library was generated from available data of 1960 vintage. It was originally intended for fast calculations (6 fast groups), and later extended to 16 groups, covering the full energy range. Most of the data is P_0 transport-corrected data, but hydrogen and deuterium are P_1 data with a P_2 transport correction. The ^{238}U data in the resonance range were adjusted to give good results for the PCTR experiments.

2. **Known biases/weaknesses in original data for this library:**

    The age and sparseness of the base data (pre-ENDF) are the major weakness. Temperature effects and thermal upscatter are not treated.

3. **Application areas where the library performs well:**

    The library performs well for small high-enriched ^{235}U metal systems and fairly well for many LEU thermal systems.

4. **Application areas where the library performs poorly:**

    Optimally moderated uranyl nitrate solutions underpredict by as much as 2.5 to 3% in k_{eff}. Other thermal HEU systems may vary from 2% high to 4% low. Plutonium systems may be high by 2 to 4%. Thermal ^{233}U systems can underpredict k_{eff} by 2 to 3%.

8.2 SCALE 218-GROUP LIBRARY

1. **How the library was generated or collapsed:**

    This library was generated from ENDF/B-IV data using $\chi(E)$-1/$(E\sigma_t)$-Maxwellian weighting. The base weighting allowed the library to be successfully collapsed using the weighting spectrum to a broad-group structure that could reproduce the behavior of the fine-group library. The unresolved resonance region was processed with an extremely high-background cross section of 50,000 barns, resulting in infinite-dilution cross sections in this region. Only the *s*-wave resonances were carried on the library, and any *p*-wave and *d*-wave resonances were integrated into the background cross section. The processing of the unresolved resonances with the extremely high-background cross section and the integration of the higher angular momentum *p*- and *d*-wave resolved resonances into the background cross section resulted in too much absorption in the intermediate-energy range.

2. **Known biases/weaknesses in original data for this library:**

    The ^{238}U base data had too much capture in the epithermal range, leading to the underprediction of k_{eff} for low-enriched systems, particularly for harder thermal systems. The graphite thermal kernel is deficient, with unknown results. There may be a problem with the thermal plutonium cross sections.

3. **Application areas where the library performs well:**

This library performs well for most realistic criticality safety problems. Fast, small metal units, highly enriched thermal systems, and very thermal low-enriched systems are generally well predicted.

4. **Application areas where the library performs poorly:**

Low-enriched systems with a hard thermal spectrum underpredict by approximately 1% and sometimes more. Plutonium thermal systems overpredict k_{eff} by 1.5 to 3%. The 218-group library overpredicts thermal ^{233}U systems by about 2%, while it underpredicts fast ^{233}U systems by 2 to 4%. Intermediate-energy systems, such as the Palmer problems (see Appendix B), can be wrong by large amounts.

8.3 SCALE 27-GROUP LIBRARY

1. **How the library was generated or collapsed:**

The 27-group library was collapsed from the 218-group library, using the weighting spectra with which the nuclides were originally generated. Because of the $1/(E\sigma_t)$ weighting in the resonance range, the broad-group library calculates many systems nearly as well as the fine-group library does. Trends and biases in the fine-group library were preserved in the broad-group library.

2. **Known biases/weaknesses in original data for this library:**

Same as the 218-group library.

3. **Application areas where the library performs well:**

Generally the same as the 218-group library. Some trends and biases may be slightly more pronounced in the broad-group library, but most results are fairly equivalent.

4. **Application areas where the library performs poorly:**

Same as the 218-group library.

8.4 SCALE 238-GROUP LIBRARY

1. **How the library was generated or collapsed:**

The library was generated from ENDF/B-V data, using a $\chi(E)$-1/E-Maxwellian spectrum. The integrating function makes it more difficult to collapse a general-purpose broad-group library that is valid over a large range of problems. It contains all nuclides (over 300) in ENDF/B-V plus data for ENDF/B-VI evaluations of ^{14}N, ^{15}N, ^{16}O, ^{154}Eu, and ^{155}Eu.

2. **Known biases/weaknesses in original data for this library:**

The ^{235}U fission data and the ^{238}U capture data are slightly too high. There may be a problem with the thermal plutonium cross sections.

3. **Application areas where the library performs well:**

Generally, this library has done very well for high-enriched fast systems and low-enriched thermal homogeneous and lattice systems. Results for mixed-oxide lattices and ^{233}U systems are good, too. This library is recommended as the best library in SCALE for general-purpose criticality-safety analyses.

4. **Application areas where the library performs poorly:**

This library has problems with intermediate-energy problems that involve nuclides with cross-section structure without resonance parameters. Although any intermediate-energy problems are suspect because of the scarcity of critical experiments, this library performs better than any other library in SCALE.

8.5 SCALE 44-GROUP LIBRARY

1. **How the library was generated or collapsed:**

This library was collapsed from the 238-group library, using a LWR flux spectrum. Consequently, the library does well predicting LWR lattices, but not as well for other types of systems.

2. **Known biases/weaknesses in original data for this library:**

Same as the 238-group library. Because of the 1/E weighting in the 238-group library, this library is not a good general-purpose library.

3. **Application areas where the library performs well:**

LWR and mixed-oxide lattices are the library's strong point, and it is the recommended SCALE library for these applications. It calculates highly enriched metal systems well. It also predicts ^{233}U systems reasonably well. For other types of thermal systems, the more the spectrum differs from a LWR spectrum, the more likely it is that the calculated k_{eff} will show a bias.

4. **Application areas where the library performs poorly:**

The 44-group library has all the shortcomings of the 238-group library, as well as not being able to calculate homogeneous thermal, epithermal, and intermediate-energy systems as accurately as the 238-group library.

9 LESSONS LEARNED AND FUTURE DEVELOPMENTS

As this report indicates, there has been considerable experience gleaned from the processing and use of multigroup libraries for the SCALE code system. This section briefly reviews the history and lessons learned in the context of ongoing and future developments relative to SCALE cross-section libraries and problem-dependent cross-section processing.

Initially, the SCALE system criticality analysis modules utilized two well-established, existing multigroup libraries (modified Hansen-Roach and 123-group GAM-THERMOS library[31]) and the relatively new SCALE ENDF/B-IV library. A problem-dependent (fixed σ_p values) version of the Hansen-Roach library was originally distributed with early versions of SCALE to be used for running the KENO V.a sample problems only. Some users were employing it for safety analyses, running KENO V.a in stand-alone mode. This technique resulted in the misapplication of problem-dependent cross sections to other types of problems and was removed from versions after the release of SCALE 4.0. More recently, the 123-group library was removed because of problems found when using the library for high-enriched systems with low H/X ratios.[31] Because this library was removed with the release of SCALE 4.3 and is no longer considered a part of the SCALE system, this report does not discuss its characteristics or performance.

Several new development efforts are now under way to improve and update the cross-section data and resonance processing in SCALE. One of the most significant efforts is the development of an ENDF/B-VI cross-section library. The format of the ENDF data was expanded to include new parameters in version VI. These format changes resulted in incompatibilities with the cross-section processing methods used in the AMPX-77[11] and SCALE systems. A new version of AMPX is near production status, and work to produce a SCALE ENDF/B-VI library should commence in FY 2001. Experience from previous processing efforts and validation studies will be incorporated in this production effort. Like the SCALE ENDF/B-V libraries, the preparation of multigroup data for all of the nuclides present on the ENDF/B-VI files is planned. Also, application experience with the SCALE ENDF/B-IV and ENDF/B-V libraries demonstrates that the versatility of the library will be improved if a fission-$(1/E\sigma_t)$-Maxwellian energy weighting is used in generating the group cross-section data from ENDF/B. Use of a $1/E\sigma_t$ weighting, rather than a $1/E$ weighting, provides some pseudo-self-shielding for the non-resonance nuclides and is a better approximation of the physics than the infinite dilute processing that results otherwise. Relative to the group structure, it is anticipated that the established 238-group structure will be used initially to more easily test and validate the production capabilities of the new AMPX system and the NITAWL-III resonance processing code (a new version of NITAWL that is compatible with ENDF/B-VI data formats). A refined library with additional groups (partially to facilitate analysis of problems with a dominant intermediate-energy spectrum) will likely be produced subsequent to the production of a 238-group ENDF/B-VI library for SCALE.

Another important development is CENTRM, a pointwise energy discrete-ordinates computer code that generates problem-dependent cross-sections from either ENDF/B-V or ENDF/B-VI data. CENTRM uses a fine multigroup calculation in the high- and low-energy ranges combined with a continuous-energy (i.e., pointwise) solution for energies in the resolved resonance region. A new CSAS sequence that uses CENTRM instead of NITAWL to perform resonance processing of the nuclides in the unit cell has been developed and tested. Continuous-energy cross-section libraries from ENDF/B-V and ENDF/B-VI have been developed and tested for use with CENTRM. The next version of SCALE will include a continuous-energy cross-section library, CENTRM, and the new CSAS sequence.

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APPENDIX A

SCALE CROSS-SECTION LIBRARY
ENERGY-GROUP BOUNDARIES

APPENDIX A

SCALE CROSS-SECTION LIBRARY ENERGY-GROUP BOUNDARIES

Table A.1 SCALE cross-section library energy-group boundaries

ENDF/B-V 238-group	ENDF/B-IV 218-group	ENDF/B-V 44-group	ENDF/B-IV 27-group	Hansen-Roach 16-group	Upper energy (eV)
1	1	1	1		2.0000E+07
2					1.7333E+07
3					1.5683E+07
					1.5000E+07
4					1.4550E+07
5					1.3840E+07
6					1.2840E+07
7				1	1.0000E+07
8		2			8.1873E+06
9	2	3	2		6.4340E+06
10	3	4			4.8000E+06
11	4				4.3040E+06
12	5	5	3	2	3.0000E+06
13	6	6			2.4790E+06
14	7	7			2.3540E+06
15	8	8	4		1.8500E+06
16	9				1.5000E+06
17	10	9	5	3	1.4000E+06
18	11				1.3560E+06
19	12				1.3170E+06
20	13				1.2500E+06
21	14				1.2000E+06
22	15				1.1000E+06
23	16				1.0100E+06
24	17				9.2000E+05
25	18	10	6	4	9.0000E+05
26	19				8.7500E+05
27	20				8.6110E+05
28	21				8.2000E+05
29	22				7.5000E+05
30	23				6.7900E+05
31	24				6.7000E+05

Table A.1 (continued)

ENDF/B-V 238-group	ENDF/B-IV 218-group	ENDF/B-V 44-group	ENDF/B-IV 27-group	Hansen-Roach 16-group	Upper energy (eV)
32	25				6.0000E+05
33	26				5.7300E+05
34	27				5.5000E+05
35	28				4.9952E+05
36	29				4.7000E+05
37	30				4.4000E+05
38	31				4.2000E+05
39	32	11	7	5	4.0000E+05
40	33				3.3000E+05
41	34				2.7000E+05
42	35				2.0000E+05
43	36				1.5000E+05
44	37				1.2830E+05
45	38	12	8	6	1.0000E+05
46	39				8.5000E+04
47	40				8.2000E+04
48	41				7.5000E+04
49	42				7.3000E+04
50	43				6.0000E+04
51	44				5.2000E+04
52	45				5.0000E+04
53	46				4.5000E+04
54	47				3.0000E+04
55	48	13			2.5000E+04
56	49	14	9	7	1.7000E+04
57	50				1.3000E+04
58	51				9.5000E+03
59	52				8.0300E+03
60	53				6.0000E+03
61	54				3.9000E+03
62	55				3.7400E+03
63	56	15	10	8	3.0000E+03
64	57				2.5800E+03
65	58				2.2900E+03
66	59				2.2000E+03
67	60				1.8000E+03
68	61				1.5500E+03

Table A.1 (continued)

ENDF/B-V 238-group	ENDF/B-IV 218-group	ENDF/B-V 44-group	ENDF/B-IV 27-group	Hansen-Roach 16-group	Upper energy (eV)
69	62				1.5000E+03
70	63				1.1500E+03
71	64				9.5000E+02
72	65				6.8300E+02
73	66				6.7000E+02
74	67	16	11	9	5.5000E+02
75	68				3.0500E+02
76	69				2.8500E+02
77	70				2.4000E+02
78	71				2.1000E+02
79	72				2.0750E+02
80	73				1.9250E+02
81	74				1.8600E+02
82	75				1.2200E+02
83	76				1.1900E+02
84	77				1.1500E+02
85	78				1.0800E+02
86	79	17	12	10	1.0000E+02
87	80				9.0000E+01
88	81				8.2000E+01
89	82				8.0000E+01
90	83				7.6000E+01
91	84				7.2000E+01
92	85				6.7500E+01
93	86				6.5000E+01
94	87				6.1000E+01
95	88				5.9000E+01
96	89				5.3400E+01
97	90				5.2000E+01
98	91				5.0600E+01
99	92				4.9200E+01
100	93				4.8300E+01
101	94				4.7000E+01
102	95				4.5200E+01
103	96				4.4000E+01
104	97				4.2400E+01
105	98				4.1000E+01

Table A.1 (continued)

ENDF/B-V 238-group	ENDF/B-IV 218-group	ENDF/B-V 44-group	ENDF/B-IV 27-group	Hansen-Roach 16-group	Upper energy (eV)
106	99				3.9600E+01
107	100				3.9100E+01
108	101				3.8000E+01
109	102				3.7000E+01
110	103				3.5500E+01
111	104				3.4600E+01
112	105				3.3750E+01
113	106				3.3250E+01
114	107				3.1750E+01
115	108				3.1250E+01
116	109	18	13	11	3.0000E+01
117	110				2.7500E+01
118	111				2.5000E+01
119	112				2.2500E+01
120	113				2.1000E+01
121	114				2.0000E+01
122	115				1.9000E+01
123	116				1.8500E+01
124	117				1.7000E+01
125	118				1.6000E+01
126	119				1.5100E+01
127	120				1.4400E+01
128	121				1.3750E+01
129	122				1.2900E+01
130	123				1.1900E+01
131	124				1.1500E+01
132	125	19	14	12	1.0000E+01
133	126				9.1000E+00
134	127	20			8.1000E+00
135	128				7.1500E+00
136	129				7.0000E+00
137	130				6.7500E+00
138	131				6.5000E+00
139	132				6.2500E+00
140	133	21			6.0000E+00
141	134				5.4000E+00
142	135				5.0000E+00

Table A.1 (continued)

ENDF/B-V 238-group	ENDF/B-IV 218-group	ENDF/B-V 44-group	ENDF/B-IV 27-group	Hansen-Roach 16-group	Upper energy (eV)
143	136	22			4.7500E+00
144	137				4.0000E+00
145	138				3.7300E+00
146	139				3.5000E+00
147	140				3.1500E+00
148	141		15		3.0500E+00[a]
149	142	23		13	3.0000E+00[b]
150	143				2.9700E+00
151	144				2.8700E+00
152	145				2.7700E+00
153	146				2.6700E+00
154	147				2.5700E+00
155	148				2.4700E+00
156	149				2.3800E+00
157	150				2.3000E+00
158	151				2.2100E+00
159	152				2.1200E+00
160	153				2.0000E+00
161	154				1.9400E+00
162	155				1.8600E+00
163	156	24	16		1.7700E+00
164	157				1.6800E+00
165	158				1.5900E+00
166	159				1.5000E+00
167	160				1.4500E+00
168	161				1.4000E+00
169	162				1.3500E+00
170	163		17		1.3000E+00
171	164				1.2500E+00
172	165				1.2250E+00
173	166				1.2000E+00
174	167				1.1750E+00
175	168				1.1500E+00
176	169				1.1400E+00
177	170		18		1.1300E+00
178	171				1.1200E+00
179	172				1.1100E+00

Table A.1 (continued)

ENDF/B-V 238-group	ENDF/B-IV 218-group	ENDF/B-V 44-group	ENDF/B-IV 27-group	Hansen-Roach 16-group	Upper energy (eV)
180	173				1.1000E+00
181	174				1.0900E+00
182	175				1.0800E+00
183	176				1.0700E+00
184	177				1.0600E+00
185	178				1.0500E+00
186	179				1.0400E+00
187	180				1.0300E+00
188	181				1.0200E+00
189	182				1.0100E+00
190	183	25	19	14	1.0000E+00
191	184				9.7500E-01
192	185				9.5000E-01
193	186				9.2500E-01
194	187				9.0000E-01
195	188				8.5000E-01
196	189		20		8.0000E-01
197	190				7.5000E-01
198	191				7.0000E-01
199	192				6.5000E-01
200		26			6.2500E-01
201	193				6.0000E-01
202	194				5.5000E-01
203	195				5.0000E-01
204	196				4.5000E-01
205	197	27	21	15	4.0000E-01
206	198	28			3.7500E-01
207	199	29			3.5000E-01
208	200	30	22		3.2500E-01
209	201				3.0000E-01
210	202	31			2.7500E-01
211	203	32			2.5000E-01
212	204	33	23		2.2500E-01
213	205	34			2.0000E-01
214	206				1.7500E-01
215	207	35			1.5000E-01
216	208				1.2500E-01

Table A.1 (continued)

ENDF/B-V 238-group	ENDF/B-IV 218-group	ENDF/B-V 44-group	ENDF/B-IV 27-group	Hansen-Roach 16-group	Upper energy (eV)
217	209	36	24	16	1.0000E‑01
218	210				9.0000E‑02
219	211				8.0000E‑02
220	212	37			7.0000E‑02
221	213				6.0000E‑02
222	214	38	25		5.0000E‑02
223	215	39			4.0000E‑02
224	216	40	26		3.0000E‑02
225	217	41			2.5300E‑02
226	218	42	27		1.0000E‑02
227		43			7.5000E‑03
228					5.0000E‑03
229					4.0000E‑03
230		44			3.0000E‑03
231					2.5000E‑03
232					2.0000E‑03
233					1.5000E‑03
234					1.2000E‑03
235				*c	1.0000E‑03
236					7.5000E‑04
237					5.0000E‑04
238					1.0000E‑04
*c	*c	*c	*c		1.0000E‑05

[a]Thermal boundary for ENDF/B-IV libraries.
[b]Thermal boundary for ENDF/B-V libraries.
[c]Lower boundary for library.

APPENDIX B

CALCULATIONAL BENCHMARKS

APPENDIX B

CALCULATIONAL BENCHMARKS

B.1 DESCRIPTION OF THE BENCHMARKS

B.1.1 Palmer Benchmarks

The Palmer benchmarks consist of three calculational benchmarks that were devised to study the performance of various cross-section sets for calculating *k-infinite* for ^{235}U/metal mixtures.[32] The following systems are considered: ^{235}U/Al at an Al/^{235}U atom ratio of 2470, ^{235}U/Fe at an Fe/^{235}U atom ratio of 320, and ^{235}U/Zr at a Zr/^{235}U atom ratio of 103. These simple systems are all dominated by scattering and fission in the intermediate energy range of 10 eV to 1 MeV and, as such, provide a severe test of the cross-section data and processing methodologies in this energy range. Studies of these systems using various codes and data libraries[32] have demonstrated a wide variation in results due to deficiencies in ENDF/B data as well as discrepancies and deficiencies in the processing of data for use by the codes. Although these systems were originally developed to have a *k-infinite* = 1.0 utilizing the ENDF/B-V cross sections in MCNP, the best estimates of *k-infinite* for the Al, Fe, and Zr systems are 1.12 ± 0.04, 1.09 ± 0.04, and 1.11 ± 0.04, respectively. There are no experiments which validate the reliability of the cross sections for these applications. The large uncertainties indicate the uncertainties expected from the known deficiencies in the cross sections.

B.1.2 Fe Benchmark

Like the Palmer benchmarks, this finite-sphere Fe benchmark is another calculational benchmark that provides a rigorous test of not only the scattering and fission but also the transport in systems with no light element thermalization (i.e., neutrons will not reach thermal energies prior to absorption). The benchmark is a simplification of the critical experiment HEU-MET-FAST-035 (Ref. 15), also known as ZPR-9/34, into a simple unreflected ^{235}U/Fe sphere, 107-cm radius, at an Fe/^{235}U atom ratio = 63.2 (N_{Fe} = 8.13913-2, N_{U-235} = 1.28882-3). The best estimate of the "correct k_{eff}" for this sphere is 1.00 ± 0.02. The benchmark complements the Palmer benchmarks and shows how calculational performance for an infinite system is not necessarily indicative of performance for a finite system.

B.1.3 UO_2F_2 *K-Infinite* Calculations

The UO_2F_2 *k-infinite* calculations are a series of calculational benchmarks that span a moderation range from H/X = 0 to 700. The benchmarks were developed to study fully enriched UO_2F_2/H_2O systems. This series of benchmarks was used to identify significant deficiencies in the SCALE 123 group cross-section library[31] and ultimately led to the removal of the library from SCALE. The "expected value" was determined using MCNP and ENDF/B-V cross sections for uranium, fluorine, and hydrogen, and ENDF/B-VI oxygen. An uncertainty of 0.5% in the expected values was assigned to the series of calculations.

B.1.4 PCTR Experiments

The PCTR benchmarks are a series of *k-infinite* measurements for low-enriched UO_3 which were performed in the Physical Constant Test Reactor at Hanford.[33-35] The experiments were designed to help predict the minimum enrichment that could be made critical in a homogeneous light-water-moderated system. These experiments provide a good test of the ^{238}U cross sections and have been used to identify deficiencies in the Hansen-Roach cross-section library for LEU systems.

B.2 BENCHMARK RESULTS

A comparison of the performance of the SCALE cross-section libraries for these calculational benchmarks is presented in this section. This comparison shows how the various SCALE cross-section libraries perform for ^{235}U systems across a range of interest. This series of benchmarks includes the Palmer problems, the Fe sphere, $U(100)O_2F_2$ *k-infinite* calculations, and the PCTR LEU *k-infinite* experiments. All of these calculations, with the exception of the PCTR experiments, are numerical (i.e., calculational) benchmarks for library comparison. The results presented here may be used to supplement the information presented in Sections 3–7 of this report.

Table B.1 shows the results for all of the SCALE libraries. The "expected" k_{eff} value and an estimate of the uncertainty of the expected value are given. Excluding the PCTR experiments, the expected value is a best estimate of the correct *k* for the specified system. The uncertainty has been assigned based on previous evaluation of these systems and general uncertainties encountered in the ENDF cross sections. The PCTR values are experimentally determined *k-infinite* values and uncertainties.

Figure B.1 presents a comparison of results for the Palmer benchmarks. Note that the shift in the EALF between libraries is due to the combined effects of differences in cross sections and in averages performed over different group structures. Figure B.2 shows the results of the UO_2F_2 *k-infinite* calculations as a function of EALF. The SCALE 16-group Hansen-Roach library, which has only four thermal groups, exhibits the largest shifts in EALF. Figures B.3 – B.5 display the results for the three different enrichments of the PCTR experiments. Because no EALF data corresponding to the expected k_{eff} values are available, the expected k_{eff} values are plotted vs the 44-group library EALF values as a convenience in Figures B.1 – B.5.

B.2.1 Performance of the SCALE 16-group Hansen-Roach Library

The results in Table B.1 and Figure B.1 show that the SCALE 16-group Hansen-Roach library that calculated *k-infinite* values for the Palmer Al/U and Fe/U benchmarks are about 10% low. The Palmer Zr/U benchmark calculates about 25% high. These results are due to a combination of factors, including lack of resonance data for Al, Fe, and Zr cross sections and a broad-group structure. **The library should not be used for applications where intermediate-mass nuclides are the principal scattering materials or in intermediate-spectrum systems where absorption is dominated by intermediate-mass absorbers.**

The high-enriched U/Fe sphere calculates 20% high, but the Palmer Fe/U system calculates 10% low. This discrepancy demonstrates that flux-weighted multigroup cross sections as generated in AMPX cannot correctly model transport through thick materials with cross-section energy windows (i.e., energies where there are large "dips" in the cross-section data), such as pure iron. **Errors on the order of up to 30% in *k* can exist for similar systems.** The discrepancy does not occur unless the energy windows are seen on the macroscopic level; e.g., thick material mixtures such as iron oxide would not exhibit the characteristic.

Figure B.2 shows that there may be a large variation in performance, depending on the moderation level of the system. The calculated *k-infinite* value is 2% high when oxygen and fluorine are the principal moderators (i.e., no hydrogen present). Calculated *k-infinite* values are approximately 1% low over the intermediate-spectrum range and trend to nominally unbiased for more thermal systems. This behavior indicates that the SCALE 16-group cross-section set should be used with caution in the intermediate-spectrum, hydrogen-moderated systems.

Figures B.3 – B.5 show that there is a fairly consistent 2% positive bias for the PCTR LEU experiments. This bias is probably due to the broad-group structure and inadequate resonance processing for this system.

B.2.2 Performance of the SCALE 218-group ENDF/B-IV Library

Table B.1 and Figure B.1 show that the SCALE 218-group library calculates from 10 to 25% low for the Palmer benchmarks. Poor performance for the Al/U benchmark can be primarily attributed to poor ENDF/B-IV cross sections for Al. Poor performance for the Fe systems is probably due to a combination of effects, which include inadequate group structure, cross-section generation methods, and resonance-processing methodology (e.g., no *p*- and *d*-wave resonances and fixed σ_p value for unresolved resonance region). The Zr/U benchmark calculates low due to poor ENDF/B-IV cross sections for Zr and due to inadequate resonance processing in the SCALE 218-group library.

Similar to the Hansen-Roach library, the U/Fe sphere calculates nearly 20% high, but the Palmer Fe/U system calculates 25% low. Once again, this difference in results indicates the use of flux weighting to generate multigroup cross sections will not conserve the neutron transport for this type system unless the group structure is extremely fine across the resonance region of Fe. It is difficult to conserve both the reaction rate and the transport for systems similar to the U/Fe sphere when no low-mass moderator is present.

Figure B.2 shows that the SCALE 218-group library performs adequately across the range of the UO_2F_2 *k-infinite* benchmarks. The library shows a 0.5% positive bias across the intermediate spectrum, and a ⁻0.5% bias for the most thermal systems.

Figures B.3 – B.5 show that the SCALE 218-group library calculates these LEU systems approximately 1% low. This is primarily due to poor ENDF/B-IV [238]U cross sections and inadequate unresolved- resonance-region processing in the 218-group library.

B.2.3 Performance of the SCALE 27-group ENDF/B-IV Library

Table B.1 and Figure B.1 show that the SCALE 27-group library calculates from 10 to 20% low for the Palmer benchmarks. Poor performance for the Al/U benchmark can be primarily attributed to poor ENDF/B-IV cross

sections for Al. Poor performance for the Fe systems is probably due to a combination of effects which include inadequate group structure, cross-section generation methods, and resonance-processing methodology. The Zr/U benchmark calculates low due to poor ENDF/B-IV cross sections for Zr and inadequate resonance processing in the SCALE 27-group library.

Like the 218-group library, the U/Fe sphere calculates 20% high, but the Palmer Fe/U system calculates 20% low. Once again, this difference in results indicates the use of flux weighting to generate multigroup cross sections will not conserve the neutron transport for this type system unless the group structure is extremely fine across the resonance region of Fe.

Figure B.2 shows that the SCALE 27-group library performs adequately across the range of the UO_2F_2 *k-infinite* benchmarks. The results are virtually identical to the 218-group results. The library shows a 0.5% positive bias across the intermediate spectrum, and a -0.5% bias for the most thermal systems.

Figures B.3 – B.5 show that the SCALE 27-group library calculates these LEU systems nominally 0.5 to 1% low. The results are slightly higher than the 218-group results. This is primarily due to poor ENDF/B-IV [238]U cross sections and inadequate unresolved-resonance-region processing in the 27-group library.

B.2.4 Performance of the SCALE 238-group ENDF/B-V Library

Table B.1 and Figure B.1 show that the SCALE 238-group library calculates from 2 to 13% low for the Palmer benchmarks. Even though the Al/U results are very similar to the ENDF/B-IV libraries, the Fe/U and Zr/U are significantly better. The poor performance for the Al/U benchmark can be primarily attributed to a lack of resonance data for Al in ENDF/B-V. Aluminum has significant resonance structure but is not considered a resonance nuclide in ENDF. The Fe/U benchmark is approximately 3% low, and the Zr/U benchmark is only 2% low.

The disparity in the 238-group library results for the U/Fe sphere (10% high) and the Palmer Fe/U system (3% low) is much smaller than the other libraries. As stated previously, it is difficult to conserve both the reaction rate and the transport for systems similar to the U/Fe sphere in a multigroup structure.

Figure B.2 shows that the SCALE 238-group library performs well across the range of the UO_2F_2 *k-infinite* benchmarks. The library shows almost no bias across the entire spectrum.

Figures B.3 – B.5 show that the SCALE 238-group library calculates these LEU systems very well, within ±0.5%.

B.2.5 Performance of the SCALE 44-group ENDF/B-V Library

Table B.1 and Figure B.1 show that the SCALE 44-group library calculates from 0 to 20% low for the Palmer benchmarks. The Al/U results are 10% lower than any other library. This difference is apparently due to the broad-group collapse of the 44-group library. The resonance structure for aluminum evidently occurs over several fine groups in the 238-group library that are collapsed to a single broad group in the 44-group library, causing the loss of that resonance structure. This problem does not occur in the 27-group library collapse because of the different weighting $[1/(E\sigma_t)]$ used in the 218-group library. As stated earlier in this report, the 1/E weighting of the resonance region in the 238-group library makes it difficult to collapse a general-purpose broad-group library.

Table B.1 Calculational benchmark results

Benchmarks	Expected k	Uncertainty	Calc. k (16 group)	Calc. k (27 group)	Calc. k (218 group)	Calc. k (44 group)	Calc. k (238 group)
Palmer Al/U	1.120E+00	4.000E−02	1.005E+00	1.021E+00	1.001E+00	8.808E−01	9.818E−01
Palmer Fe/U	1.090E+00	4.000E−02	1.003E+00	8.576E−01	8.193E−01	1.049E+00	1.055E+00
Palmer Zr/U	1.110E+00	4.000E−02	1.383E+00	1.027E+00	9.602E−01	1.117E+00	1.089E+00
High-enriched U/Fe sphere	1.000E+00	2.000E−02	1.203E+00	1.198E+00	1.169E+00	1.142E+00	1.105E+00
U(100)O$_2$F$_2$, h/x=0	2.087E+00	5.000E−03	2.133E+00	2.081E+00	2.076E+00	2.077E+00	2.085E+00
U(100)O$_2$F$_2$, h/x=5	1.795E+00	5.000E−03	1.797E+00	1.807E+00	1.802E+00	1.808E+00	1.804E+00
U(100)O$_2$F$_2$, h/x=10	1.796E+00	5.000E−03	1.785E+00	1.807E+00	1.800E+00	1.809E+00	1.803E+00
U(100)O$_2$F$_2$, h/x=20	1.836E+00	5.000E−03	1.819E+00	1.839E+00	1.834E+00	1.844E+00	1.840E+00
U(100)O$_2$F$_2$, h/x=50	1.892E+00	5.000E−03	1.876E+00	1.888E+00	1.885E+00	1.895E+00	1.894E+00
U(100)O$_2$F$_2$, h/x=100	1.898E+00	5.000E−03	1.884E+00	1.890E+00	1.889E+00	1.899E+00	1.898E+00
U(100)O$_2$F$_2$, h/x=200	1.843E+00	5.000E−03	1.835E+00	1.835E+00	1.834E+00	1.844E+00	1.844E+00
U(100)O$_2$F$_2$, h/x=300	1.775E+00	5.000E−03	1.771E+00	1.767E+00	1.767E+00	1.776E+00	1.776E+00
U(100)O$_2$F$_2$, h/x=500	1.643E+00	5.000E−03	1.645E+00	1.635E+00	1.635E+00	1.643E+00	1.643E+00
U(100)O$_2$F$_2$, h/x=700	1.526E+00	5.000E−03	1.532E+00	1.519E+00	1.519E+00	1.526E+000	1.526E+00
PCTR 1.006%, h/u=3.83	9.860E−01	5.000E−03	1.014E+00	9.807E−01	9.756E−01	9.894E−01	9.863E−01
PCTR 1.006%, h/u=6.23	9.860E−01	7.000E−03	9.978E−01	9.758E−01	9.727E−01	9.828E−01	9.815E−01
PCTR 1.006%, h/u=6.95	9.740E−01	5.000E−03	9.893E−01	9.683E−01	9.655E−01	9.749E−01	9.739E−01
PCTR 1.006%, h/u=7.52	9.600E−01	5.000E−03	9.812E−01	9.614E−01	9.588E−01	9.677E−01	9.669E−01
PCTR 1.071%, h/u=3.78	1.005E+00	6.000E−03	1.035E+00	1.001E+00	9.953E−01	1.010E+00	1.006E+00
PCTR 1.071%, h/u=5.84	1.005E+00	6.000E−03	1.025E+00	1.002E+00	9.987E−01	1.010E+00	1.008E+00
PCTR 1.071%, h/u=7.14	9.920E−01	7.000E−03	1.011E+00	9.902E−01	9.874E−01	9.970E−01	9.960E−01
PCTR 1.157%, h/u=3.73	1.031E+00	6.000E−03	1.059E+00	1.025E+00	1.019E+00	1.034E+00	1.030E+00
PCTR 1.157%, h/u=5.99	1.031E+00	5.000E−03	1.052E+00	1.029E+00	1.026E+00	1.037E+00	1.035E+00
PCTR 1.157%, h/u=6.90	1.030E+00	7.000E−03	1.043E+00	1.022E+00	1.019E+00	1.029E+00	1.028E+00
PCTR 1.157%, h/u=7.52	1.019E+00	5.000E−03	1.036E+00	1.016E+00	1.013E+00	1.022E+00	1.022E+00

Palmer Benchmarks

^{235}U / Metal Mixtures
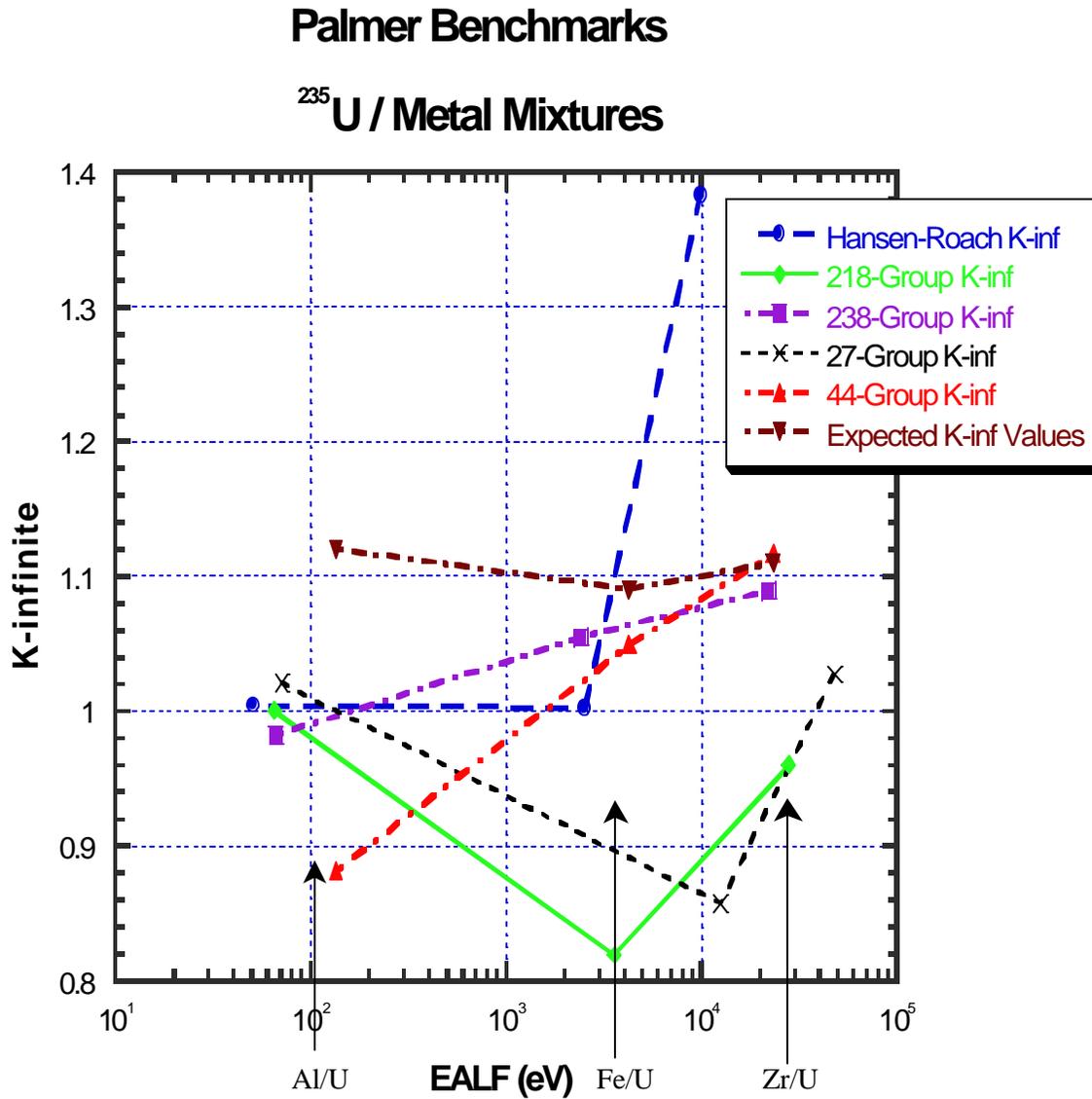
Figure B.1 Palmer ^{235}U/metal mixture benchmark results

Fully Enriched UO2F2 / H2O
k-infinite Benchmarks
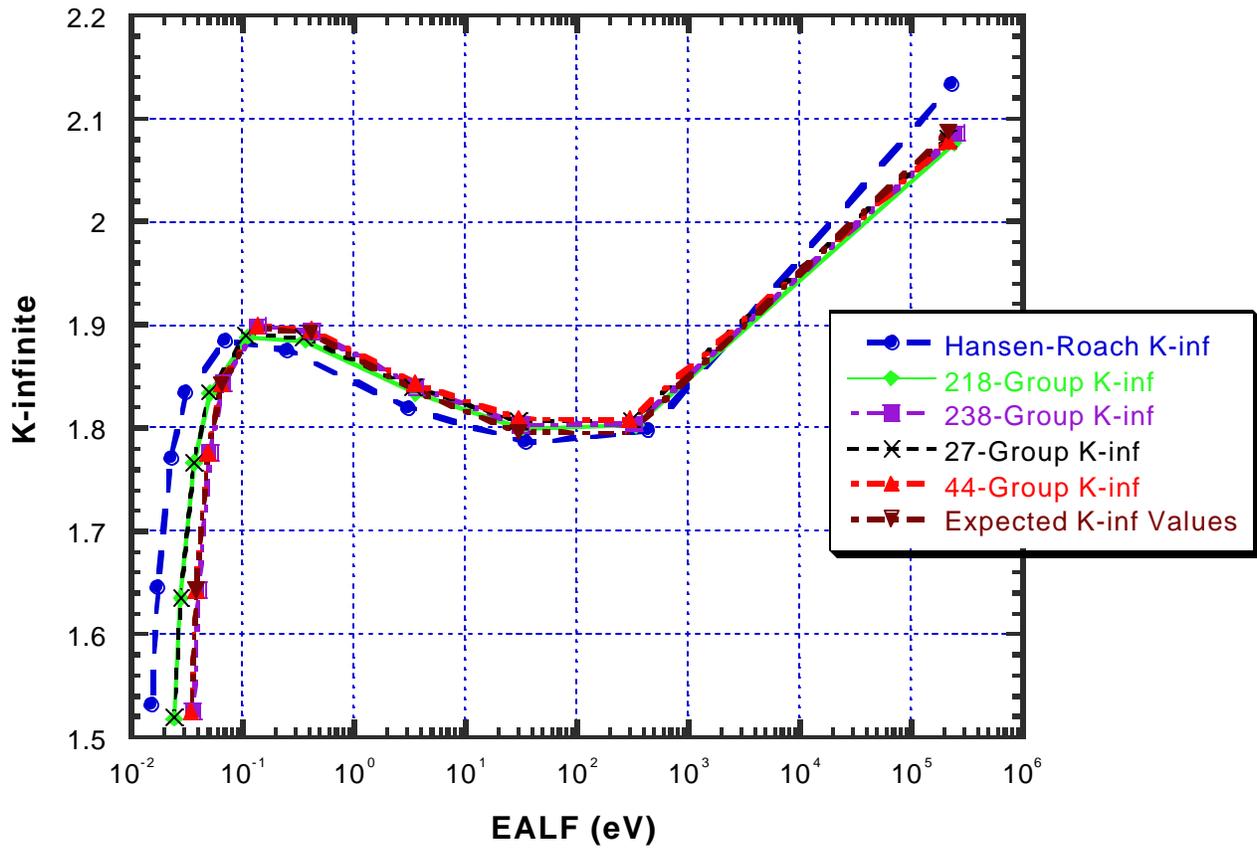
Figure B.2 Fully enriched UO_2F_2/H_2O *k-infinite* benchmark results
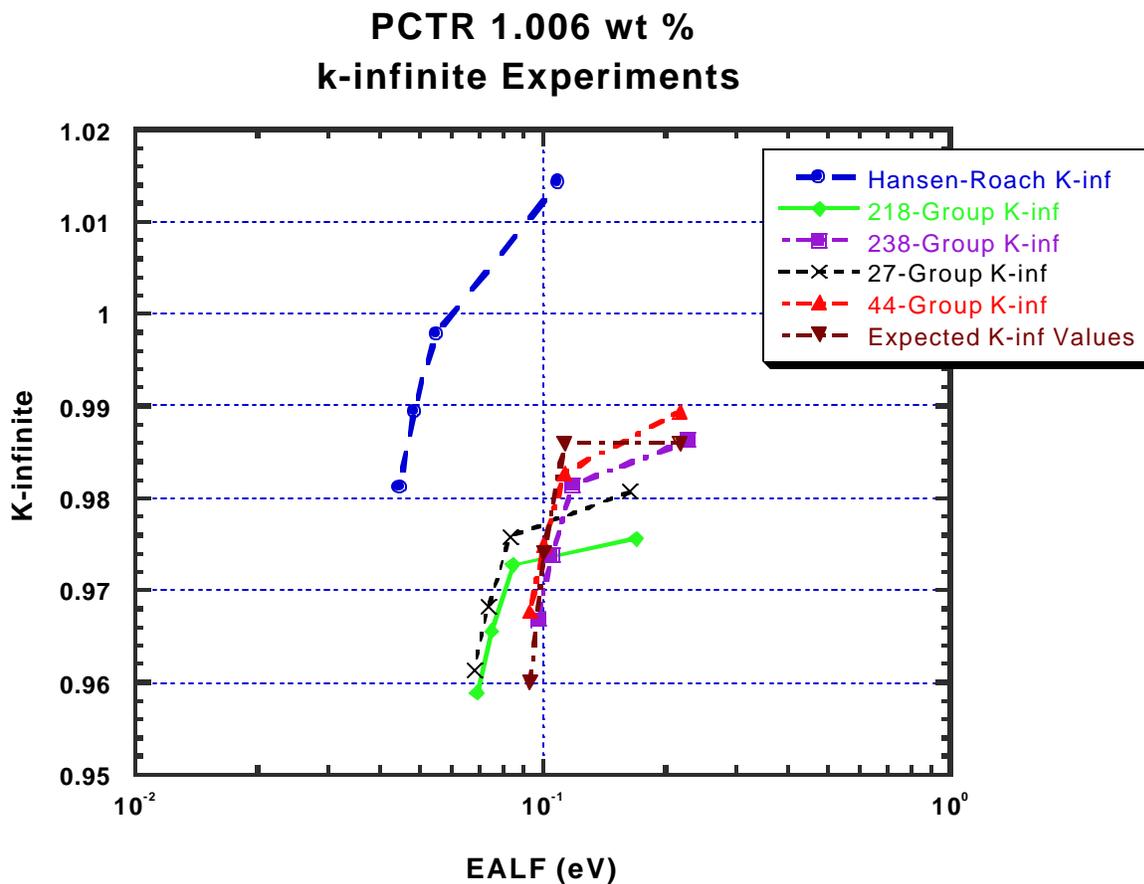
Figure B.3 PCTR 1.006 wt % *k-infinite* experiment results

**PCTR 1.071 wt %
k-infinite Experiments**
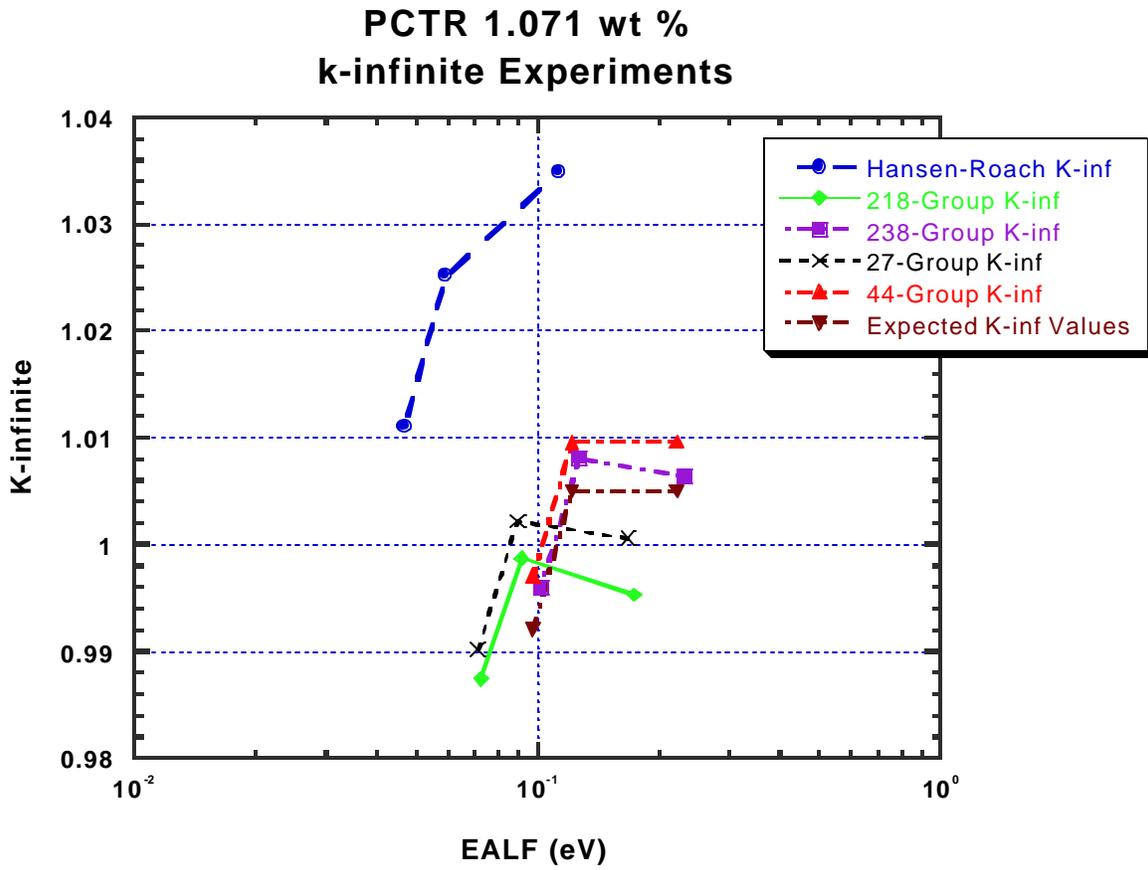
Figure B.4 PCTR 1.071 wt % *k-infinite* experiment results

PCTR 1.157 wt %
k-infinite Experiments
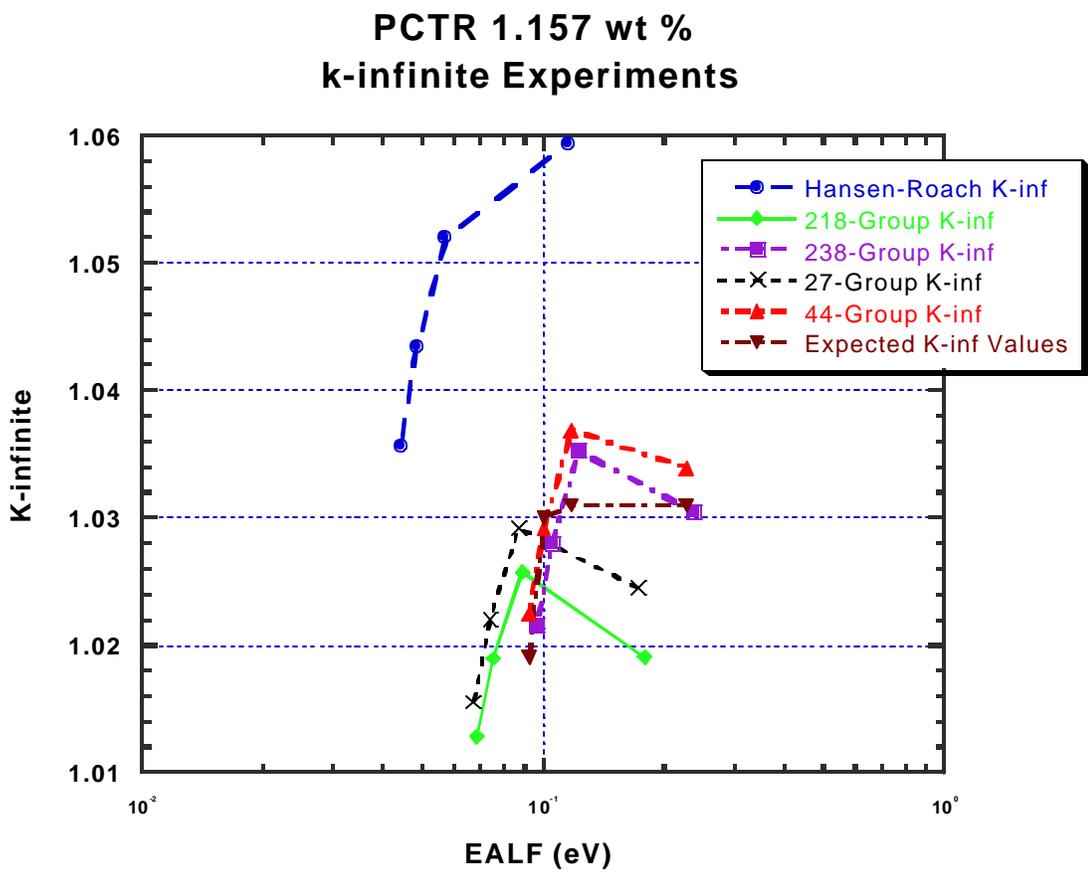
Figure B.5 PCTR 1.157 wt % *k-infinite* experiment results

The Fe/U benchmark is approximately 4% low, and the Zr/U benchmark shows agreement with the expected value. The consistent Fe/U results between the 44- and 238-group libraries is due to the careful preservation of energy windows in the Fe cross sections in the 44-group structure.

The disparity in the 44-group library results for the U/Fe sphere (14% high) and the Palmer Fe/U system (4% low) is similar to the 238-group library. As stated previously, it is difficult to conserve both the reaction rate and the transport for systems similar to the U/Fe sphere in a multigroup structure.

Figure B.2 shows that the SCALE 44-group library performs well across the range of the UO_2F_2 *k-infinite* benchmarks. The library has about a 0.5% bias for fast and intermediate-spectrum cases and no bias for thermal cases.

Figures B.3 – B.5 show that the SCALE 44-group library calculates these LEU systems very well, within ±0.5%.

APPENDIX C

DETAILS OF THE SCALE 16-GROUP
HANSEN-ROACH LIBRARY

APPENDIX C

DETAILS OF THE SCALE 16-GROUP HANSEN-ROACH LIBRARY

Table C.1 Resonance nuclides found
on the SCALE 16-group Hansen-Roach library

Standard composition alphanumeric name	Nuclide ID No.
Mn	25055
Ag-107	47107
Ag-109	47109
In-113	49113
In-115	49115
Dy-164	66164
Lu-175	71175
Lu-176	71176
W-182	74182
W-183	74183
W-184	74184
W-186	74186
Re-185	75185
Re-187	75187
Au	79197
Th-232	90232[a]
Pa-233	91233
U-233	92233[a]
U-234	92234
U-235	92235[a]
U-236	92236
U-238	92238[a]
Np-237	93237
Pu-238	94338[a]
Pu-239	94239[a]
Pu-240	94240[a]
Pu-241	94241
Pu-242	94242
Am-241	95241
Am-243	95243
Cm-244	96244

[a]Denotes nuclides having Bondarenko data in lieu of resonance parameters.

Table C.2 Nuclides in SCALE 16-group Hansen-Roach
library with multiple sets of thermal-scattering data

Standard composition alphanumeric name	Nuclide ID No.	Temperature (K) for which different sets of thermal scattering cross-section data are available
B-10	5010	293,550
B-11	5011	293,550

Table C.3 Contents of the SCALE 16-group Hansen-Roach library

```
table of contents for /scale4.4/data/scale.rev03.xn16          on logical unit  1
tape id                    4016000
number of nuclides              84
number of neutron groups        16
first thermal group             13
number of gamma groups           0
       scale 4 - 16 neutron group criticality safety library
         hansen-roach data with knight modifications and some endf/b 4 data
           compiled for nrc        1/27/89
             last updated                                             08/12/94
               l.m.petrie       ornl
     999          1/v cross sections normalized to 1.0 at 0.0253 ev
    1001          hydrogen de/e                  hansen-roach          updated 08/12/94
    1301          hydrogen x(e)                  hansen roach          updated 08/12/94
    1002          deuterium x(e)                 hansen roach          updated 08/12/94
    2004           helium-4 endf/b-iv mat 1270                         updated 08/12/94
    3006          lithium-6                      hansen roach          updated 08/12/94
    3007          lithium-7                      hansen roach          updated 08/12/94
    4009          beryllium                      hansen roach          updated 08/12/94
    5000          boron                          hansen roach          updated 08/12/94
    5010           boron-10 endf/b-iv mat 1273                         updated 08/12/94
    5011           boron-11       endf/b-iv mat 1160                   updated 08/12/94
    6012          carbon                         hansen roach          updated 08/12/94
    7014          nitrogen                       hansen roach          updated 08/12/94
    8016          oxygen                         hansen roach          updated 08/12/94
    9019          fluorine                       hansen roach          updated 08/12/94
   11023          sodium                         hansen roach          updated 08/12/94
   12000           magnesium endf/b-iv mat 1280                        updated 08/12/94
   13027          aluminum                       hansen roach          updated 08/12/94
   14000           silicon         endf/b-iv mat 1194                  updated 08/12/94
   15031           phosphorus-31 lendl mat 7019                        updated 08/12/94
   16000          sulfur  lendl mat 7020                               updated 08/12/94
   17000          chlorine                       hansen roach          updated 08/12/94
   19000          potassium                      hansen-roach          updated 08/12/94
   20000          calcium endf/b-iv mat 1195                           updated 08/12/94
   22000           titanium        endf/b-iv mat 1286                  updated 08/12/94
   23051          vanadium endf/b-iv mat 1196                          updated 08/12/94
   24000          chromium                       aerojet               updated 08/12/94
   24304           chromium endf/b-iv mat 1191 ss-304 wt               updated 08/12/94
   24404           chromium endf/b-iv mat 1191 inconel wt              updated 08/12/94
   25055           manganese-55 endf/b-iv mat 1197                     updated 08/12/94
   26000          iron                           hansen roach          updated 08/12/94
   26304           iron endf/b-iv mat 1192 ss-304 wt                   updated 08/12/94
   26404           iron endf/b-iv mat 1192 inconel wt                  updated 08/12/94
```

```
27059           cobalt                          hansen roach        updated 08/12/94
28000           nickel                          hansen roach        updated 08/12/94
28304            nickel endf/b-iv mat 1190 ss-304 wt                updated 08/12/94
28404            nickel endf/b-iv mat 1190 inconel wt               updated 08/12/94
29000            copper endf/b-iv mat 1295                          updated 08/12/94
30000           zinc                    gam-2                       updated 08/12/94
40000           zirconium                       hansen roach        updated 08/12/94
40302            zircalloy-2 endf/b-iv mat 1284                     updated 08/12/94
41093           niobium                         hansen roach        updated 08/12/94
42000           molybdenum                      hansen roach        updated 08/12/94
47107            silver-107     endf/b-iv mat 1138                  updated 08/12/94
47109            silver-109 endf/b-iv mat 1139                      updated 08/12/94
48000            cadmium        endf/b-iv mat 1281                  updated 08/12/94
49113            indium-113     endf/b-iv mat 445                   updated 08/12/94
49115            indium-115 endf/b-iv mat 449                       updated 08/12/94
50000            tin lendl mat 7039                                 updated 08/12/94
56138            barium-138 lendl mat 7040                          updated 08/12/94
58000           cerium                          hansen roach
62000           samarium                        gam-2
63000           europium                        gam-2               updated 08/12/94
64000            gadolinium endf/b-iv mat 1030                      updated 08/12/94
66164            dyprosium-164   endf/b-iv mat 1031                 updated 08/12/94
71175            lutetium-175   endf/b-iv mat 1032                  updated 08/12/94
71176            lutetium-176 endf/b-iv mat 1033                    updated 08/12/94
72000            hafnium endf/b-iv mat 1034                         updated 08/12/94
73181           tantalum                        hansen roach        updated 08/12/94
74182            tungsten-182   endf/b-iv mat 1128                  updated 08/12/94
74183            tungsten-183   endf/b-iv mat 1129                  updated 08/12/94
74184            tungsten-184   endf/b-iv mat 1130                  updated 08/12/94
74186            tungsten-186   endf/b-iv mat 1131                  updated 08/12/94
75185            rhenium-185 endf/b-iv mat 1083                     updated 08/12/94
75187            rhenium-187    endf/b-iv mat 1084                  updated 08/12/94
79197            gold-197       endf/b-iv mat 1283                  updated 08/12/94
82000            lead endf/b-iv mat 1288                            updated 08/12/94
90232           th-232  infinite dilution       hansen roach        updated 08/12/94
91233            protactinium-233 endf/b-iv mat 1297                updated 08/12/94
92233           u-233                           hansen roach        updated 08/12/94
92234            u-234 endf/b-iv mat 1043                           updated 08/12/94
92235           u-235 yr                        hansen roach        updated 08/12/94
92236            u-236 endf/b-iv mat 1163                           updated 08/12/94
92238           u-238 y                         hansen roach        updated 08/12/94
93237            neptunium-237   endf/b-iv mat 1263                 updated 08/12/94
94238           pu-238                          hansen roach        updated 08/12/94
94338           pu-238 y                        persimmon
94239           pu-239                          hansen roach        updated 08/12/94
94240           pu-240                          hansen roach        updated 08/12/94
94241            pu-241 endf/b-iv mat 1266                          updated 08/12/94
94242            plutonium-242   endf/b-iv mat 1161                 updated 08/12/94
95241            am-241 endf/b-iv mat 1056                          updated 08/12/94
95243            am-243 endf/b-iv mat 1057                          updated 08/12/94
96244            cm-244 endf/b-iv mat 1162                          updated 08/12/94
```

APPENDIX D

DETAILS OF THE ENDF/B-IV LIBRARIES

APPENDIX D

DETAILS OF THE ENDF/B-IV LIBRARIES

Table D.1 Resonance nuclides in the ENDF/B-IV libraries

Standard composition alphanumeric name	Nuclide ID No.
Na	11023
Mn	25055
Fe	26000
Co	27059
Co-59	27059
Cu	29000
Br-79	35079
Br-81	35081
ZIRCALLOY	40302
Nb-93	41093
Mo	42000
Ag-107	47107
Ag-109	47109
In-113	49113
In-115	49115
Cs-133	55133
Gd	64000
Dy-164	66164
Lu-175	71175
Lu-176	71176
Ta-181	73181
W-182	74182
W-183	74183
W-184	74184
W-186	74186
Re-185	75185
Re-187	75187
Au	79197
Th-232	90232
Pa-233	91233
U-233	92233
U-234	92234
U-235	92235

Table D.1 (continued)

Standard composition alphanumeric name	Nuclide ID No.
U-236	92236
U-238	92238
Np-237	93237
Pu-238	94238
Pu-239	94239
Pu-240	94240
Pu-241	94241
Pu-242	94242
Am-241	95241
Am-243	95423
Cm-244	96244

Table D.2 Nuclides in ENDF/B-IV libraries with multiple sets of thermal-scattering data

Standard composition alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
H	1001	293, 550
D	1002	293, 550
Be	4009	296, 900, 1000, 1200
B-10	5010	293, 550
B-11	5011	293, 550
C	6012	

Table D.3 Contents of the 218-group ENDF/B-IV library

```
table of contents for /scale4.4/data/scale.rev04.xn218            on logical unit  1
 tape id                         4321
 number of nuclides                79
 number of neutron groups         218
 first thermal group              141
 number of gamma groups             0
          scale 4.2 - 218 group neutron library
            based on endf-b version 4 data
              compiled for nrc    1/27/89
                last updated                                           08/12/94
                  l.m.petrie   -   ornl
      999          1/v cross sections normalized to 1.0 at 0.0253 ev  updated 08/12/94
     1001            hydrogen       endf/b-iv mat 1269/thrm1002        updated 08/12/94
     1002            deuterium      endf/b-iv mat 1120                 updated 08/12/94
     2004            helium-4       endf/b-iv mat 1270                 updated 08/12/94
     3006            lithium-6      endf/b-iv mat 1271                 updated 08/12/94
     3007            lithium-7      endf/b-iv mat 1272                 updated 08/12/94
     4009            beryllium-9    endf/b-iv mat 1289/thrm1064        updated 08/12/94
     5010          b-10 1273 218ngp 042375 p-3 293k                   updated 08/12/94
     5011            boron-11       endf/b-iv mat 1160                 updated 08/12/94
     6012          c-12 1274f,1065t 218 gp 030476(7)                  updated 08/12/94
     7014          n-14 1275 218 gp 030476(7)                         updated 08/12/94
     8016            oxygen-16      endf/b-iv mat 1276                 updated 08/12/94
     9019          f 1277 218gp 030476(7)                             updated 08/12/94
    11023            sodium-23      endf/b-iv mat 1156                 updated 08/12/94
    12000          mg 1280 218 gp 1/e*sigt 040375(5)                  updated 08/12/94
    13027          al-27 1193 218 gp 040375(5)                        updated 08/12/94
    14000            silicon        endf/b-iv mat 1194                 updated 08/12/94
    15031            phosphorus-31  endf/b-iv mat 7019                 updated 08/12/94
    16000          sulfur  lendl mat 7020                             updated 08/12/94
    19000          potassium endf/b-iv mat 1150                       updated 08/12/94
    20000          calcium endf/b-iv mat 1195                         updated 08/12/94
    22000          ti 1286 218 gp wt 1/est 042375 p3 293k             updated 08/12/94
    23051          v 1196 218 gp 1/e*sigt 040375(5)                   updated 08/12/94
    24000          cr 1191 218ngp wt 1/e p-3 293k sigp=5+4 re(042375) updated 08/12/94
    24304          cr 1191 wt ss-304(1/est) p-3 293k sp=5+4(42375)'   updated 08/12/94
    24404            cr (inconel)   endf/b-iv mat 1191                 updated 08/12/94
    25055            manganese-55   endf/b-iv mat 1197                 updated 08/12/94
    26000            iron           endf/b-iv mat 1192                 updated 08/12/94
    26304          fe 1192 wt ss-304(1/est) p-3 293k sp=5+4(42375)'   updated 08/12/94
    26404          fe 1192 wt inconl(1/est) p-3 293k sp=5+4(42375)'   updated 08/12/94
    27059            cobalt-59      endf/b-iv mat 1199                 updated 08/12/94
    28000          ni 1190 218ngp wt 1/e p-3 293k sigp=5+4 re(042375) updated 08/12/94
    28304            nickel (ss304) endf/b-iv mat 1190                 updated 08/12/94
    28404          ni 1190 wt inconl(1/est) p-3 293k sp=5+4(42375)'   updated 08/12/94
    29000            copper         endf/b-iv mat 1295                 updated 08/12/94
    35079            bromine-79     endf/b-iv mat 108                  updated 08/12/94
    35081            bromine-81     endf/b-iv mat 112                  updated 08/12/94
    40000            zirconium      endf/b-iv mat 7141                 updated 08/12/94
    40302            zircalloy      endf/b-iv mat 1284                 updated 08/12/94
    41093            niobium-93     endf/b-iv mat 1189                 updated 08/12/94
    42000            molybdenum     endf/b-iv mat 1287                 updated 08/12/94
    47107            silver-107     endf/b-iv mat 1138                 updated 08/12/94
    47109            silver-109     endf/b-iv mat 1139                 updated 08/12/94
    48000            cadmium        endf/b-iv mat 1281                 updated 08/12/94
    49113            indium-113     endf/b-iv mat 445                  updated 08/12/94
    49115            indium-115     endf/b-iv mat 449                  updated 08/12/94
    50000          sn 7039 wt 1/est 218ngp p-3 293k re(042375)        updated 08/12/94
    56138            barium-138     endf/b-iv mat 7040                 updated 08/12/94
    64000          gd (1030) sig0=1.+5p3 293k f-1/e-m vb 61479        updated 08/12/94
    66164            dyprosium-164  endf/b-iv mat 1031                 updated 08/12/94
    71175            lutetium-175   endf/b-iv mat 1032                 updated 08/12/94
    71176            lutetium-176   endf/b-iv mat 1033                 updated 08/12/94
    72000          hf(nat) 1034 218ngp wt 1/e p-3 sigp=5+4 293k re(042375) updated 08/12/94
    73181            tantalum-181   endf/b-iv mat 1285                 updated 08/12/94
    74182            w-182  1128 sigp=5+4 newxlacs 218ngp p-3 293k    updated 08/12/94
```

```
74183            tungsten-183   endf/b-iv mat 1129                updated 08/12/94
74184            tungsten-184   endf/b-iv mat 1130                updated 08/12/94
74186            tungsten-186   endf/b-iv mat 1131                updated 08/12/94
75185            rhenium-185    endf/b-iv mat 1083                updated 08/12/94
75187            rhenium-187    endf/b-iv mat 1084                updated 08/12/94
79197            gold-197       endf/b-iv mat 1283                updated 08/12/94
82000         pb   1288 218ngp 042375 p-3 293k                   updated 08/12/94
90232            thorium-232    endf/b-iv mat 1296                updated 08/12/94
91233            paladium-231   endf/b-iv mat 1297                updated 08/12/94
92233         u-233  1260 sigp=5+4 newxlacs 218ngp p-3 293k      updated 08/12/94
92234         u-234 1043 sigo=5+4 newxlacs p-3 293k f-1/e-m(1.+5)  updated 08/12/94
92235            uranium-235    endf/b-iv mat 1261                updated 08/12/94
92236            uranium-236    endf/b-iv mat 1163                updated 08/12/94
92238            uranium-238    endf/b-iv mat 1262                updated 08/12/94
93237            neptunium-237  endf/b-iv mat 1263                updated 08/12/94
94238            plutonium-238  endf/b-iv mat 1050                updated 08/12/94
94239            plutonium-239  endf/b-iv mat 1264                updated 08/12/94
94240            plutonium-240  endf/b-iv mat 1265                updated 08/12/94
94241            plutonium-241  endf/b-iv mat 1266                updated 08/12/94
94242            plutonium-242  endf/b-iv mat 1161                updated 08/12/94
95241         am-241 1056 sigp=5+4 newxlacs 218ngp p-3 293k      updated 08/12/94
95243         am-243 1057 218 gp wt f-1/e-m 090376 p3 293k       updated 08/12/94
96244            curium-244     endf/b-iv mat 1162                updated 08/12/94
17000         chlorine (mat 1149 from version iv) using 1/sigt weightiupdated 08/12/94
```

Table D.4 Contents of the 27-group ENDF/B-IV library

```
table of contents for /scale4.4/data/scale.rev04.xn27          on logical unit  1
tape id                         4321
number of nuclides                83
number of neutron groups          27
first thermal group               15
number of gamma groups             0
        scale 4.2 - 27 group neutron group library
          based on endf-b version 4 data
            compiled for nrc     1/27/89
              last updated                                            08/12/94
                l.m.petrie   -    ornl
     900         dose factors from ansi/ans-6.1.1-1977        updated 9/07/89
     999         1/v cross sections normalized to 1.0 at 0.0253 ev  updated 08/12/94
    1001           hydrogen      endf/b-iv mat 1269/thrm1002   updated 08/12/94
    1002           deuterium     endf/b-iv mat 1120            updated 08/12/94
    2004           helium-4      endf/b-iv mat 1270            updated 08/12/94
    3006         li-6 1271 218 gp 1/e*sigt 040375(5)           updated 08/12/94
    3007         li-7 1272 218 gp 1/e*sigt 040375(5)           updated 08/12/94
    4009           beryllium-9   endf/b-iv mat 1289/thrm1064   updated 08/12/94
    5010         b-10 1273 218ngp 042375 p-3 293k              updated 08/12/94
    5011           boron-11      endf/b-iv mat 1160            updated 08/12/94
    6012           carbon-12     endf/b-iv mat 1274/thrm1065   updated 08/12/94
    7014           nitrogen-14   endf/b-iv mat 1275            updated 08/12/94
    8016           oxygen-16     endf/b-iv mat 1276            updated 08/12/94
    9019           fluorine      endf/b-iv mat 1277            updated 08/12/94
   11023           sodium-23     endf/b-iv mat 1156            updated 08/12/94
   12000         mg 1280 218 gp 1/e*sigt 040375(5)             updated 08/12/94
   13027         al-27 1193 218 gp 040375(5)                   updated 08/12/94
   14000           silicon       endf/b-iv mat 1194            updated 08/12/94
   15031         p-31 7019 218ngp wt 1/est 042375 p3 293k      updated 08/12/94
   16000         sulfur  lendl mat 7020                        updated 08/12/94
   19000           potassium     endf/b-iv mat 1150            updated 08/12/94
   20000         calcium endf/b-iv mat 1195                    updated 08/12/94
   22000           titanium      endf/b-iv mat 1286            updated 08/12/94
   23051         v 1196 218 gp 1/e*sigt 040375(5)              updated 08/12/94
   24000         cr 1191 218ngp wt 1/e p-3 293k sigp=5+4 re(042375)  updated 08/12/94
```

```
24304          cr 1191 wt ss-304(1/est) p-3 293k sp=5+4(42375)'          updated 08/12/94
24404          cr 1191 wt inconl(1/est) p-3 293k sp=5+4(42375)'          updated 08/12/94
25055           manganese-55   endf/b-iv mat 1197                        updated 08/12/94
26000           iron           endf/b-iv mat 1192                        updated 08/12/94
26304          fe 1192 wt ss-304(1/est) p-3 293k sp=5+4(42375)'          updated 08/12/94
26404          fe 1192 wt inconl(1/est) p-3 293k sp=5+4(42375)'          updated 08/12/94
27059           cobalt-59      endf/b-iv mat 1199                        updated 08/12/94
28000          ni 1190 218ngp wt 1/e p-3 293k sigp=5+4 re(042375)        updated 08/12/94
28304          ni 1190 wt ss-304(1/est) p-3 293k sp=5+4(42375)'          updated 08/12/94
28404          ni 1190 wt inconl(1/est) p-3 293k sp=5+4(42375)'          updated 08/12/94
29000           copper         endf/b-iv mat 1295                        updated 08/12/94
35079           bromine-79     endf/b-iv mat 108                         updated 08/12/94
35081           bromine-81     endf/b-iv mat 112                         updated 08/12/94
40000           zirconium      endf/b-iv mat 7141                        updated 08/12/94
40302           zircalloy      endf/b-iv mat 1284                        updated 08/12/94
41093           niobium-93     endf/b-iv mat 1189                        updated 08/12/94
42000          mo (1287) sigp=5+4 newxlacs 218ngp f-1/e-m p-3 293k       updated 08/12/94
47107           silver-107     endf/b-iv mat 1138                        updated 08/12/94
47109           silver-109     endf/b-iv mat 1139                        updated 08/12/94
48000          cd 1281 wt 1/est 218ngp p-3 293k re(042375)              updated 08/12/94
49113           indium-113     endf/b-iv mat 445                         updated 08/12/94
49115           indium-115     endf/b-iv mat 449                         updated 08/12/94
50000          sn 7039 wt 1/est 218ngp p-3 293k re(042375)              updated 08/12/94
54135           xenon-135      endf/b-iv mat 1294                        updated 08/12/94
55133           cesium-133     endf/b-iv mat 1141                        updated 08/12/94
56138          ba-138 7040 218ngp wt 1/est 042375 p3 293k               updated 08/12/94
64000          gd (1030) sig0=1.+5p3 293k f-1/e-m vb 61479              updated 08/12/94
66164           dyprosium-164  endf/b-iv mat 1031                        updated 08/12/94
71175           lutetium-175   endf/b-iv mat 1032                        updated 08/12/94
71176           lutetium-176   endf/b-iv mat 1033                        updated 08/12/94
72000          hf(nat) 1034 218ngp wt 1/e p-3 sigp=5+4 293k re(042375)  updated 08/12/94
73181           tantalum-181   endf/b-iv mat 1285                        updated 08/12/94
74182           tungsten-182   endf/b-iv mat 1128                        updated 08/12/94
74183           tungsten-183   endf/b-iv mat 1129                        updated 08/12/94
74184           tungsten-184   endf/b-iv mat 1130                        updated 08/12/94
74186           tungsten-186   endf/b-iv mat 1131                        updated 08/12/94
75185           rhenium-185    endf/b-iv mat 1083                        updated 08/12/94
75187           rhenium-187    endf/b-iv mat 1084                        updated 08/12/94
79197           gold-197       endf/b-iv mat 1283                        updated 08/12/94
82000          pb   1288 218ngp 042375 p-3 293k                         updated 08/12/94
90232           thorium-232    endf/b-iv mat 1296                        updated 08/12/94
91233          pa-233 1297 218 gp wt f-1/e-m 090376 p3 293k             updated 08/12/94
92233          u-233  1260 sigp=5+4 newxlacs 218ngp p-3 293k            updated 08/12/94
92234           uranium-234    endf/b-iv mat 1043                        updated 08/12/94
92235           uranium-235    endf/b-iv mat 1261                        updated 08/12/94
92236          u-236 1163 sigo=5+4 newxlacs p-3 293k f-1/e-m(1.+5)      updated 08/12/94
92238           uranium-238    endf/b-iv mat 1262                        updated 08/12/94
93237           neptunium-237  endf/b-iv mat 1263                        updated 08/12/94
94238          pu-238 1050 sigo=5+4 newxlacs p-3 293k f-1/e-m(1.+5)     updated 08/12/94
94239           plutonium-239  endf/b-iv mat 1264                        updated 08/12/94
94240           plutonium-240  endf/b-iv mat 1265                        updated 08/12/94
94241           plutonium-241  endf/b-iv mat 1266                        updated 08/12/94
94242           plutonium-242  endf/b-iv mat 1161                        updated 08/12/94
95241          am-241 1056 sigp=5+4 newxlacs 218ngp p-3 293k            updated 08/12/94
95243          am-243 1057 218 gp wt f-1/e-m 090376 p3 293k             updated 08/12/94
96244           curium-244     endf/b-iv mat 1162                        updated 08/12/94
500000         jrk's neutron(9029) dose factors from ansi/ans-6.1.1-1977.
17000          chlorine (mat 1149 from version iv) using 1/sigt weightiupdated 08/12/94
```

Table D.5 Contents of the 27-group burnup library

```
table of contents for /scale4.4/data/scale.rev05.xn27burn          on logical unit  1
tape id                      27
number of nuclides          252
number of neutron groups     27
first thermal group          15
number of gamma groups        0
        scale - 27 group neutron burnup library
          based on endf-b version 4 data with endf-b version 5 fission products
            compiled for nrc    1/27/89
              last updated      1/14/98
                 l.m.petrie   -   ornl
    900        dose factors from ansi/ans-6.1.1-1977         updated 9/15/89
    999        1/v cross sections normalized to 1.0 at 0.0253 ev     updated 08/12/94
   1001          hydrogen      endf/b-iv mat 1269/thrm1002           updated 08/12/94
   1002          deuterium     endf/b-iv mat 1120                    updated 08/12/94
   2004        he-4 1270 218 gp wt f-1/est-m 042375 p3 293k          updated 08/12/94
   3006        li-6 1271 218 gp 1/e*sigt 040375(5)                   updated 08/12/94
   3007        li-7 1272 218 gp 1/e*sigt 040375(5)                   updated 08/12/94
   4009          beryllium-9    endf/b-iv mat 1289/thrm1064          updated 08/12/94
   5010        b-10 1273 218ngp 042375 p-3 293k                      updated 08/12/94
   5011          boron-11       endf/b-iv mat 1160                   updated 08/12/94
   6012          carbon-12      endf/b-iv mat 1274/thrm1065          updated 08/12/94
   7014          nitrogen-14    endf/b-iv mat 1275                   updated 08/12/94
   8016          oxygen-16      endf/b-iv mat 1276                   updated 08/12/94
   9019          fluorine       endf/b-iv mat 1277                   updated 08/12/94
  11023          sodium-23      endf/b-iv mat 1156                   updated 08/12/94
  12000        mg 1280 218 gp 1/e*sigt 040375(5)                     updated 08/12/94
  13027        al-27 1193 218 gp 040375(5)                           updated 08/12/94
  14000          silicon        endf/b-iv mat 1194                   updated 08/12/94
  15031        p-31 7019 218ngp wt 1/est 042375 p3 293k              updated 08/12/94
  16000        sulfur    lendl    mat 7020                           updated 08/12/94
  19000          potassium      endf/b-iv mat 1150                   updated 08/12/94
  20000        calcium   endf/b-iv mat 1195                          updated 08/12/94
  22000          titanium       endf/b-iv mat 1286                   updated 08/12/94
  23051        v 1196 218 gp 1/e*sigt 040375(5)                      updated 08/12/94
  24000        cr 1191 218ngp wt 1/e p-3 293k sigp=5+4 re(042375)    updated 08/12/94
  24304        cr 1191 wt ss-304(1/est) p-3 293k sp=5+4(42375)'      updated 08/12/94
  24404        cr 1191 wt inconl(1/est) p-3 293k sp=5+4(42375)'      updated 08/12/94
  25055          manganese-55   endf/b-iv mat 1197                   updated 08/12/94
  26000          iron           endf/b-iv mat 1192                   updated 08/12/94
  26304        fe 1192 wt ss-304(1/est) p-3 293k sp=5+4(42375)'      updated 08/12/94
  26404        fe 1192 wt inconl(1/est) p-3 293k sp=5+4(42375)'      updated 08/12/94
  27059          cobalt-59      endf/b-iv mat 1199                   updated 08/12/94
  28000        ni 1190 218ngp wt 1/e p-3 293k sigp=5+4 re(042375)    updated 08/12/94
  28304        ni 1190 wt ss-304(1/est) p-3 293k sp=5+4(42375)'      updated 08/12/94
  28404        ni 1190 wt inconl(1/est) p-3 293k sp=5+4(42375)'      updated 08/12/94
  29000          copper         endf/b-iv mat 1295                   updated 08/12/94
  32072          ge-72          mt=102                               updated 08/12/94
  32073          ge-73          mt=102                               updated 08/12/94
  32074          ge-74          mt=102                               updated 08/12/94
  32076          ge-76          mt=102                               updated 08/12/94
  33075          as-75          mt=102                               updated 08/12/94
  34076          se-76          mt=102                               updated 08/12/94
  34077          se-77          mt=102                               updated 08/12/94
  34078          se-78          mt=102                               updated 08/12/94
  34080          se-80             mt=  102                          updated 08/12/94
  34082          se-82          mt=102                               updated 08/12/94
  35079          bromine-79     endf/b-iv mat 108                    updated 08/12/94
  35081          bromine-81     endf/b-iv mat 112                    updated 08/12/94
  36080          kr-80             mt=  102, 103, 104, 105, 106, 107 updated 08/12/94
  36082          kr-82             mt=  102, 103, 104, 105, 106, 107 updated 08/12/94
  36083          kr-83          mt=102,103,103,105,106,107           updated 08/12/94
  36084          kr-84             mt=  102, 103, 104, 105, 106, 107 updated 08/12/94
  36085          kr-85             mt=  102                          updated 08/12/94
  36086          kr-86             mt=  102, 103, 104, 105, 107      updated 08/12/94
  37085          rb-85          mt=102                               updated 08/12/94
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37086       rb-86           mt=102                                  updated 08/12/94
37087       rb-87           mt=102                                  updated 08/12/94
38086       sr-86            mt=  102                               updated 08/12/94
38087       sr-87           mt=102                                  updated 08/12/94
38088       sr-88            mt=  102                               updated 08/12/94
38089       sr-89           mt=102                                  updated 08/12/94
38090       sr-90           mt=102                                  updated 08/12/94
39089        y-89           mt=102                                  updated 08/12/94
39090        y-90            mt=  102                               updated 08/12/94
39091        y-91           mt=102                                  updated 08/12/94
40000       zirconium       endf/b-iv mat 7141                      updated 08/12/94
40090       zr-90            mt=  102                               updated 08/12/94
40091       zr-91            mt=  102                               updated 08/12/94
40092       zr-92           mt=102                                  updated 08/12/94
40093       zr-93            mt=  102                               updated 08/12/94
40094       zr-94           mt=102                                  updated 08/12/94
40095       zr-95           mt=102                                  updated 08/12/94
40096       zr-96            mt=  102                               updated 08/12/94
40302       zircalloy       endf/b-iv mat 1284                      updated 08/12/94
41093       niobium-93      endf/b-iv mat 1189                      updated 08/12/94
41094       nb-94           mt=102                                  updated 08/12/94
41095       nb-95           mt=102                                  updated 08/12/94
42000       mo (1287) sigp=5+4 newxlacs 218ngp f-1/e-m p-3 293k     updated 08/12/94
42094       mo-94            mt=  102                               updated 08/12/94
42095       mo-95           mt=102                                  updated 08/12/94
42096       mo-96           mt=102                                  updated 08/12/94
42097       mo-97           mt=102                                  updated 08/12/94
42098       mo-98           mt=102                                  updated 08/12/94
42099       mo-99           mt=102                                  updated 08/12/94
42100       mo-100          mt=102                                  updated 08/12/94
43099       tc-99           mt=102                                  updated 08/12/94
44099       ru-99           mt=102                                  updated 08/12/94
44100       ru-100          mt=102                                  updated 08/12/94
44101       ru-101          mt=102                                  updated 08/12/94
44102       ru-102          mt=102                                  updated 08/12/94
44103       ru-103          mt=102                                  updated 08/12/94
44104       ru-104          mt=102                                  updated 08/12/94
44105       ru-105          mt=102                                  updated 08/12/94
44106       ru-106          mt=102                                  updated 08/12/94
45105       rh-105           mt=  102                               updated 08/12/94
46104       pd-104          mt=102                                  updated 08/12/94
46105       pd-105          mt=102                                  updated 08/12/94
46106       pd-106          mt=102                                  updated 08/12/94
46107       pd-107          mt=102                                  updated 08/12/94
46108       pd-108          mt=102                                  updated 08/12/94
46110       pd-110          mt=102                                  updated 08/12/94
47107       silver-107      endf/b-iv mat 1138                      updated 08/12/94
47109       silver-109      endf/b-iv mat 1139                      updated 08/12/94
47111       ag-111          mt=102                                  updated 08/12/94
48000       cadmium         endf/b-iv mat 1281                      updated 08/12/94
48108       cd-108          mt=102                                  updated 08/12/94
48110       cd-110          mt=102                                  updated 08/12/94
48111       cd-111          mt=102                                  updated 08/12/94
48112       cd-112          mt=102                                  updated 08/12/94
48113       cd-113           mt=  102, 103, 107                     updated 08/12/94
48114       cd-114          mt=102                                  updated 08/12/94
48601       cd-115m          mt=  102                               updated 08/12/94
48116       cd-116           mt=  102                               updated 08/12/94
49113       indium-113      endf/b-iv mat 445                       updated 08/12/94
49115       indium-115      endf/b-iv mat 449                       updated 08/12/94
50000       sn 7039 wt 1/est 218ngp p-3 293k re(042375)             updated 08/12/94
50115       sn-115          mt=102                                  updated 08/12/94
50116       sn-116           mt=  102                               updated 08/12/94
50117       sn-117           mt=  102                               updated 08/12/94
50118       sn-118          mt=102                                  updated 08/12/94
50119       sn-119          mt=102                                  updated 08/12/94
50120       sn-120          mt=102                                  updated 08/12/94
50122       sn-122          mt=102                                  updated 08/12/94
50123       sn-123          mt=102                                  updated 08/12/94
50124       sn-124          mt=102                                  updated 08/12/94
50125       sn-125          mt=102                                  updated 08/12/94
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50126          sn-126          mt=102                                        updated 08/12/94
51121          sb-121          mt=102                                        updated 08/12/94
51123          sb-123          mt=102                                        updated 08/12/94
51124          sb-124          mt=102                                        updated 08/12/94
51125          sb-125          mt=102                                        updated 08/12/94
51126          sb-126          mt=102                                        updated 08/12/94
52122          te-122          mt=102                                        updated 08/12/94
52123          te-123          mt=102                                        updated 08/12/94
52124          te-124          mt=102                                        updated 08/12/94
52125          te-125          mt=102                                        updated 08/12/94
52126          te-126          mt=102                                        updated 08/12/94
52601          te-127m            mt=  102                                   updated 08/12/94
52128          te-128          mt=102                                        updated 08/12/94
52611          te-129m            mt=  102                                   updated 08/12/94
52130          te-130          mt=102                                        updated 08/12/94
52132          te-132          mt=102                                        updated 08/12/94
53127           i-127          mt=102                                        updated 08/12/94
53129           i-129          mt=102                                        updated 08/12/94
53130           i-130             mt=  102                                   updated 08/12/94
53131           i-131             mt=  102                                   updated 08/12/94
53135           i-135             mt=  102                                   updated 08/12/94
54128          xe-128          mt=102,103,104,105,106,107                    updated 08/12/94
54129          xe-129          mt=102,103,104,105,106                        updated 08/12/94
54130          xe-130          mt=102,103,104,105,106                        updated 08/12/94
54131          xe-131          mt=102,103,104,105,106                        updated 08/12/94
54132          xe-132          mt=102,103,104,105,106                        updated 08/12/94
54133          xe-133             mt=  102                                   updated 08/12/94
54134          xe-134          mt=102,103,104,105,106                        updated 08/12/94
54135          xenon-135       endf/b-iv mat 1294                            updated 08/12/94
54136          xe-136             mt=  102, 103, 104, 105, 107               updated 08/12/94
55133          cesium-133      endf/b-iv mat 1141                            updated 08/12/94
55134          cs-134          mt=102                                        updated 08/12/94
55135          cs-135             mt=  102                                   updated 08/12/94
55136          cs-136             mt=  102                                   updated 08/12/94
55137          cs-137          mt=102                                        updated 08/12/94
56134          ba-134          mt=102                                        updated 08/12/94
56135          ba-135             mt=  102                                   updated 08/12/94
56136          ba-136          mt=102                                        updated 08/12/94
56137          ba-137             mt=  102                                   updated 08/12/94
56138          ba-138 7040 218ngp wt 1/est 042375 p3 293k                    updated 08/12/94
56140          ba-140             mt=  102                                   updated 08/12/94
57139          la-139          mt=102                                        updated 08/12/94
57140          la-140          mt=102                                        updated 08/12/94
58140          ce-140          mt=102                                        updated 08/12/94
58141          ce-141          mt=102                                        updated 08/12/94
58142          ce-142          mt=102                                        updated 08/12/94
58143          ce-143             mt=  102                                   updated 08/12/94
58144          ce-144             mt=  102                                   updated 08/12/94
59141          pr-141          mt=102,103,104,105,106,107                    updated 08/12/94
59142          pr-142             mt=  102                                   updated 08/12/94
59143          pr-143          mt=102                                        updated 08/12/94
60142          nd-142          mt=102                                        updated 08/12/94
60143          nd-143          mt=102                                        updated 08/12/94
60144          nd-144          mt=102                                        updated 08/12/94
60145          nd-145          mt=102                                        updated 08/12/94
60146          nd-146             mt=  102, 103, 104, 105, 106, 107          updated 08/12/94
60147          nd-147          mt=102                                        updated 08/12/94
60148          nd-148          mt=102                                        updated 08/12/94
60150          nd-150          mt=102                                        updated 08/12/94
61147          pm-147          mt=102                                        updated 08/12/94
61148          pm-148             mt=  102                                   updated 08/12/94
61149          pm-149          mt=102                                        updated 08/12/94
61151          pm-151          mt=102                                        updated 08/12/94
62147          sm-147          endf/b-v fission product                      updated 08/12/94
62148          sm-148             mt=  102                                   updated 08/12/94
62149          sm-149          mt=102,103,107                                updated 08/12/94
62150          sm-150          mt=102                                        updated 08/12/94
62151          sm-151          mt=102,103,104,105,106,107                    updated 08/12/94
62152          sm-152          mt=102,103,104,105,106,107                    updated 08/12/94
62153          sm-153          mt=102                                        updated 08/12/94
62154          sm-154          mt=102                                        updated 08/12/94
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63151          eu-151        mt=102,103,104,105,106,107            updated 08/12/94
63152          eu-152        mt=102,103,104,105,106,107            updated 08/12/94
63153          eu-153        mt=102,103,104,105,106,107            updated 08/12/94
63154          eu-154        mt=102,103,104,105,106,107            updated 08/12/94
63155          eu-155        mt=102,103,104,105,106,107            updated 08/12/94
63156          eu-156        mt=102                                updated 08/12/94
63157          eu-157           mt=  102                           updated 08/12/94
64000          gd (1030) sig0=1.+5p3 293k f-1/e-m vb 61479         updated 08/12/94
64154          gd-154        mt=102                                updated 08/12/94
64155          gd-155        mt=102                                updated 08/12/94
64156          gd-156        mt=102                                updated 08/12/94
64157          gd-157        mt=102                                updated 08/12/94
64158          gd-158        mt=102                                updated 08/12/94
64160          gd-160        mt=102                                updated 08/12/94
65159          tb-159        mt=102                                updated 08/12/94
65160          tb-160           mt=  102                           updated 08/12/94
66160          dy-160        mt=102                                updated 08/12/94
66161          dy-161        mt=102                                updated 08/12/94
66162          dy-162        mt=102                                updated 08/12/94
66163          dy-163        mt=102                                updated 08/12/94
66164          dyprosium-164  endf/b-iv mat 1031                   updated 08/12/94
67165          ho-165        mt=102                                updated 08/12/94
68166          er-166        mt=102                                updated 08/12/94
68167          er-167        mt=102                                updated 08/12/94
71175          lutetium-175   endf/b-iv mat 1032                   updated 08/12/94
71176          lutetium-176   endf/b-iv mat 1033                   updated 08/12/94
72000          hf(nat) 1034 218ngp wt 1/e p-3 sigp=5+4 293k re(042375) updated 08/12/94
73181          tantalum-181   endf/b-iv mat 1285                   updated 08/12/94
74182          tungsten-182   endf/b-iv mat 1128                   updated 08/12/94
74183          tungsten-183   endf/b-iv mat 1129                   updated 08/12/94
74184          tungsten-184   endf/b-iv mat 1130                   updated 08/12/94
74186          tungsten-186   endf/b-iv mat 1131                   updated 08/12/94
75185          re-185 1083 sigp=5+4 newxlacs 218ngp p-3 293k       updated 08/12/94
75187          rhenium-187    endf/b-iv mat 1084                   updated 08/12/94
79197          gold-197       endf/b-iv mat 1283                   updated 08/12/94
82000          pb   1288 218ngp 042375 p-3 293k                    updated 08/12/94
90232          th-232 1296 sigp=5+4 newxlacs 218ngp p-3 293k       updated 08/12/94
91233          pa-233 1297 218 gp wt f-1/e-m 090376 p3 293k        updated 08/12/94
92233          u-233  1260 sigp=5+4 newxlacs 218ngp p-3 293k       updated 08/12/94
92234          u-234 1043 sigo=5+4 newxlacs p-3 293k f-1/e-m(1.+5) updated 08/12/94
92235          uranium-235    endf/b-iv mat 1261                   updated 08/12/94
92236          u-236 1163 sigo=5+4 newxlacs p-3 293k f-1/e-m(1.+5) updated 08/12/94
92238          uranium-238    endf/b-iv mat 1262                   updated 08/12/94
93237          neptunium-237  endf/b-iv mat 1263                   updated 08/12/94
94238          pu-238 1050 sigo=5+4 newxlacs p-3 293k f-1/e-m(1.+5) updated 08/12/94
94239          plutonium-239  endf/b-iv mat 1264                   updated 08/12/94
94240          plutonium-240  endf/b-iv mat 1265                   updated 08/12/94
94241          plutonium-241  endf/b-iv mat 1266                   updated 08/12/94
94242          plutonium-242  endf/b-iv mat 1161                   updated 08/12/94
95241          am-241 1056 sigp=5+4 newxlacs 218ngp p-3 293k       updated 08/12/94
95243          am-243 1057 218 gp wt f-1/e-m 090376 p3 293k        updated 08/12/94
96244          curium-244     endf/b-iv mat 1162                   updated 08/12/94
500000         jrk's neutron(9029) dose factors from ansi/ans-6.1.1-1977.
17000          chlorine (mat 1149 from version iv) using 1/sigt weightiupdated 08/12/94
45103           45rh103 hedl baw evalnov78 schenter livols        mod1 01/09/98
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APPENDIX E

DETAILS OF THE ENDF/B-V LIBRARIES

APPENDIX E

DETAILS OF THE ENDF/B-V LIBRARIES

Table E.1 Resonance nuclides in the ENDF/B-V libraries

Standard composition alphanumeric name	Nuclide ID No.	Highest order resonance (ℓ value)
NA	11023	2
S	16000	2
CR	24000	1
MN	25055	1
FE	26000	2
CO-59	27059	1
NI	28000	1
CU	29000	0
GE-72	32072	0
GE-73	32073	0
GE-74	32074	1
GE-76	32076	0
AS-75	33075	0
SE-74	34074	0
SE-76	34076	1
SE-77	34077	0
SE-78	34078	1
SE-80	34080	0
SE-82	34082	0
BR-79	35079	0
BR-81	35081	0
KR-78	36078	0
KR-80	36080	0
KR-82	36082	0

Table E.1 (continued)

Standard composition alphanumeric name	Nuclide ID No.	Highest order resonance (ℓ value)
KR-83	36083	0
KR-84	36084	0
KR-86	36086	0
RB-85	37085	1
RB-87	37087	1
SR-84	38084	0
SR-86	38086	0
SR-87	38087	0
SR-88	38088	0
Y-89	39089	0
ZR	40000	2
ZR-90	40090	2
ZR-91	40091	1
ZR-92	40092	1
ZR-94	40094	1
ZR-96	40096	1
NB-93	41093	1
NB-94	41094	0
MO	42000	1
MO-92	42092	0
MO-94	42094	0
MO-95	42095	0
MO-96	42096	1
MO-97	42097	0
MO-98	42098	0
MO-100	42100	0

Table E.1 (continued)

Standard composition alphanumeric name	Nuclide ID No.	Highest order resonance (ℓ value)
TC-99	43099	1
RU-99	44099	0
RU-100	44100	0
RU-101	44101	0
RU-102	44102	0
RU-104	44104	0
RH-103	45103	1
PD-104	46104	0
PD-105	46105	0
PD-106	46106	0
PD-108	46108	0
AG-107	47107	0
AG-109	47109	0
CD-110	48110	1
CD-111	48111	0
CD-112	48112	0
CD-113	48113	0
CD-114	48114	1
CD-116	48116	0
IN-113	49113	0
IN-115	49115	0
SN-112	50112	0
SN-114	50114	0
SN-115	50115	0
SN-116	50116	0
SN-117	50117	0

Table E.1 (continued)

Standard composition alphanumeric name	Nuclide ID No.	Highest order resonance (ℓ value)
SN-118	50118	0
SN-119	50119	0
SN-120	50120	0
SN-122	50122	0
SN-124	50124	0
SB-121	51121	0
SB-123	51123	0
TE-122	52122	0
TE-123	52123	0
TE-124	52124	0
TE-125	52125	0
TE-126	52126	0
TE-128	52128	0
TE-130	52130	0
I-127	53127	0
I-129	53129	0
XE-124	54124	0
XE-126	54126	0
XE-128	54128	0
XE-129	54129	0
XE-130	54130	0
XE-131	54131	0
XE-132	54132	0
XE-134	54134	0
CS-133	55133	0
CS-136	55136	0

Table E.1 (continued)

Standard composition alphanumeric name	Nuclide ID No.	Highest order resonance (ℓ value)
BA-134	56134	0
BA-135	56135	0
BA-136	56136	0
BA-137	56137	0
LA-139	57139	0
PR-141	59141	0
ND-142	60142	0
ND-143	60143	0
ND-144	60144	0
ND-145	60145	0
ND-146	60146	0
ND-148M	60148	0
ND-150	60150	0
PM-147	61147	0
PM-148M	61601	0
SM-147	62147	0
SM-149	62149	0
SM-150	62150	0
SM-151	62151	0
SM-152	62152	0
SM-154	62154	0
EU	63000	0
EU-151	63151	0
EU-152	63152	0
EU-153	63153	0
EU-154 a	63154	0

Table E.1 (continued)

Standard composition alphanumeric name	Nuclide ID No.	Highest order resonance (ℓ value)
EU-155 a	63155	0
GD-152	64152	0
GD-154	64154	0
GD-155	64155	0
GD-156	64156	0
GD-157	64157	0
GD-158	64158	0
GD-160	64160	0
TB-159	65159	0
DY-160	66160	0
DY-161	66161	0
DY-162	66162	0
DY-163	66163	0
DY-164	66164	0
HO-165	67165	0
ER-166	68166	1
ER-167	68167	0
LU-175	71175	0
LU-176	71176	0
HF	72000	0
HF-174	72174	0
HF-176	72176	0
HF-177	72177	0
HF-178	72178	0
HF-179	72179	0
HF-180	72180	0

Table E.1 (continued)

Standard composition alphanumeric name	Nuclide ID No.	Highest order resonance (ℓ value)
TA-181	73181	0
TA-182	73182	0
W	74000	0
W-182	74182	0
W-183	74183	0
W-184	74184	0
W-186	74186	0
RE-185	75185	0
RE-187	75187	0
AU	79197	0
TH-230	90230	0
TH-232	90232	1
PA-231	91231	0
PA-233	91233	0
U-232	92232	0
U-234	92234	0
U-235	92235	0
U-236	92236	0
U-237	92237	0
U-238	92238	1
NP-237	93237	0
PU-236	94236	0
PU-238	94238	0
PU-239	94239	0
PU-240	94240	0
PU-242	94242	0

Table E.1 (continued)

Standard composition alphanumeric name	Nuclide ID No.	Highest order resonance (ℓ value)
PU-243	94243	0
PU-244	94244	0
AM-241	95241	0
AM-243	95243	0
AM-242M	95601	0
CM-242	96242	0
CM-243	96243	0
CM-244	96244	0
CM-245	96245	0
CM-246	96246	0
CM-247	96247	0
CM-248	96248	0
BK-249	97249	0
CF-249	98249	0
CF-250	98250	0
CF-251	98251	0
CF-252	98252	0
ES-253	99253	0
EU-154 (ENDF/B-V)	631541	0

Table E.2 Nuclides in ENDF/B-V libraries with multiple sets of thermal-scattering data

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
H	1001	296, 350, 400, 450, 500, 600, 800, 1000
D	1002	296, 350, 400, 450, 500, 600, 800, 1000
H-3	1003	296, 500, 900
H-ZRH2	1701	296, 400, 500, 600, 700, 800, 1000, 1200
HFREEGAS	1801	296, 500, 900
DFREEGAS	1802	296, 500, 900
H-POLY	1901	296, 350
HE-3	2003	296, 500, 900
HE	2004	296, 500, 900
LI-6	3006	296, 500, 900
LI-7	3007	296, 500, 900
BE	4009	296, 400, 500, 600, 700, 800, 1000, 1200
BEBOUND	4309	296, 400, 500, 600, 700, 800, 1000, 1200
B-10	5010	296, 500, 900
B-11	5011	296, 500, 900
C-12	6012	296, 500, 900
C-GRAPHITE	6312	296, 400, 500, 600, 700, 800, 1000, 1200, 1600, 2000
N-14	7014	296, 500, 900
N-15	7015	296, 500, 900
O-16a	8016	296, 500, 900
O-17	8017	296, 500, 900
F	9019	296, 500, 900
NA	11023	296, 500, 900
MG	12000	296, 500, 900
AL	13027	296, 500, 900
SI	14000	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
P	15031	296, 500, 900
S	16000	296, 500, 900
S-32	16032	296, 500, 900
CL	17000	296, 500, 900
K	19000	296, 500, 900
CA	20000	296, 500, 900
TI	22000	296, 500, 900
V	23000	296, 500, 900
CR	24000	296, 500, 900
CR (1/EsigT)	24301	296, 500, 900
CRSS	24304	296, 500, 900
MN	25055	296, 500, 900
FE	26000	296, 500, 900
FE (1/EsigT)	26301	296, 500, 900
FESS	26304	296, 500, 900
CO-59	27059	296, 500, 900
NI	28000	296, 500, 900
NI (1/EsigT)	28301	296, 500, 900
NISS	28304	296, 500, 900
CU	29000	296, 500, 900
GA	31000	296, 500, 900
GE-72	32072	296, 500, 900
GE-73	32073	296, 500, 900
GE-74	32074	296, 500, 900
GE-76	32076	296, 500, 900
AS-75	33075	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
SE-74	34074	296, 500, 900
SE-76	34076	296, 500, 900
SE-77	34077	296, 500, 900
SE-78	34078	296, 500, 900
SE-80	34080	296, 500, 900
SE-82	34082	296, 500, 900
BR-79	35079	296, 500, 900
BR-81	35081	296, 500, 900
KR-78	36078	296, 500, 900
KR-80	36080	296, 500, 900
KR-82	36082	296, 500, 900
KR-83	36083	296, 500, 900
KR-84	36084	296, 500, 900
KR-85	36085	296, 500, 900
KR-86	36086	296, 500, 900
RB-85	37085	296, 500, 900
RB-86	37086	296, 500, 900
RB-87	37087	296, 500, 900
SR-84	38084	296, 500, 900
SR-86	38086	296, 500, 900
SR-87	38087	296, 500, 900
SR-88	38088	296, 500, 900
SR-89	38089	296, 500, 900
SR-90	38090	296, 500, 900
Y-89	39089	296, 500, 900
Y-90	39090	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
Y-91	39091	296, 500, 900
ZR	40000	296, 500, 900
ZR-90	40090	296, 500, 900
ZR-91	40091	296, 500, 900
ZR-92	40092	296, 500, 900
ZR-93	40093	296, 500, 900
ZR-94	40094	296, 500, 900
ZR-95	40095	296, 500, 900
ZR-96	40096	296, 500, 900
ZR-ZRH2	40701	296, 400, 500, 600, 700, 800, 1000, 1200
NB-93	41093	296, 500, 900
NB-94	41094	296, 500, 900
NB-95	41095	296, 500, 900
MO	42000	296, 500, 900
MO-92	42092	296, 500, 900
MO-94	42094	296, 500, 900
MO-95	42095	296, 500, 900
MO-96	42096	296, 500, 900
MO-97	42097	296, 500, 900
MO-98	42098	296, 500, 900
MO-99	42099	296, 500, 900
MO-100	42100	296, 500, 900
TC-99	43099	296, 500, 900
RU-96	44096	296, 500, 900
RU-98	44098	296, 500, 900
RU-99	44099	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
RU-100	44100	296, 500, 900
RU-101	44101	296, 500, 900
RU-102	44102	296, 500, 900
RU-103	44103	296, 500, 900
RU-104	44104	296, 500, 900
RU-105	44105	296, 500, 900
RU-106	44106	296, 500, 900
RH-103	45103	296, 500, 900
RH-105	45105	296, 500, 900
PD-102	46102	296, 500, 900
PD-104	46104	296, 500, 900
PD-105	46105	296, 500, 900
PD-106	46106	296, 500, 900
PD-107	46107	296, 500, 900
PD-108	46108	296, 500, 900
PD-110	46110	296, 500, 900
AG-107	47107	296, 500, 900
AG-109	47109	296, 500, 900
AG-111	47111	296, 500, 900
CD	48000	296, 500, 900
CD-106	48106	296, 500, 900
CD-108	48108	296, 500, 900
CD-110	48110	296, 500, 900
CD-111	48111	296, 500, 900
CD-112	48112	296, 500, 900
CD-113	48113	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
CD-114	48114	296, 500, 900
CD-116	48116	296, 500, 900
CD-115M	48601	296, 500, 900
IN-113	49113	296, 500, 900
IN-115	49115	296, 500, 900
SN-112	50112	296, 500, 900
SN-114	50114	296, 500, 900
SN-115	50115	296, 500, 900
SN-116	50116	296, 500, 900
SN-117	50117	296, 500, 900
SN-118	50118	296, 500, 900
SN-119	50119	296, 500, 900
SN-120	50120	296, 500, 900
SN-122	50122	296, 500, 900
SN-123	50123	296, 500, 900
SN-124	50124	296, 500, 900
SN-125	50125	296, 500, 900
SN-126	50126	296, 500, 900
SB-121	51121	296, 500, 900
SB-123	51123	296, 500, 900
SB-124	51124	296, 500, 900
SB-125	51125	296, 500, 900
SB-126	51126	296, 500, 900
TE-120	52120	296, 500, 900
TE-122	52122	296, 500, 900
TE-123	52123	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
TE-124	52124	296, 500, 900
TE-125	52125	296, 500, 900
SB-126	52126	296, 500, 900
TE-126	52128	296, 500, 900
TE-130	52130	296, 500, 900
TE-132	52132	296, 500, 900
TE-127M	52601	296, 500, 900
TE-129M	52611	296, 500, 900
I-127	53127	296, 500, 900
I-129	53129	296, 500, 900
I-130	53130	296, 500, 900
I-131	53131	296, 500, 900
I-135	53135	296, 500, 900
XE-124	54124	296, 500, 900
XE-126	54126	296, 500, 900
XE-128	54128	296, 500, 900
XE-129	54129	296, 500, 900
XE-130	54130	296, 500, 900
XE-131	54131	296, 500, 900
XE-132	54132	296, 500, 900
XE-133	54133	296, 500, 900
XE-134	54134	296, 500, 900
XE-135	54135	296, 500, 900
XE-136	54136	296, 500, 900
CS-133	55133	296, 500, 900
CS-134	55134	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
CS-135	55135	296, 500, 900
CS-136	55136	296, 500, 900
CS-137	55137	296, 500, 900
BA-134	56134	296, 500, 900
BA-135	56135	296, 500, 900
BA-136	56136	296, 500, 900
BA-137	56137	296, 500, 900
BA-138	56138	296, 500, 900
BA-140	56140	296, 500, 900
LA-139	57139	296, 500, 900
LA-140	57140	296, 500, 900
CE-140	58140	296, 500, 900
CE-141	58141	296, 500, 900
CE-142	58142	296, 500, 900
CE-143	58143	296, 500, 900
CE-144	58144	296, 500, 900
PR-141	59141	296, 500, 900
PR-142	59142	296, 500, 900
PR-143	59143	296, 500, 900
ND-142	60142	296, 500, 900
ND-143	60143	296, 500, 900
ND-144	60144	296, 500, 900
ND-145	60145	296, 500, 900
ND-146	60146	296, 500, 900
ND-147	60147	296, 500, 900
ND-148	60148	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
ND-150	60150	296, 500, 900
PM-147	61147	296, 500, 900
PM-148	61148	296, 500, 900
PM-149	61149	296, 500, 900
PM-151	61151	296, 500, 900
PM-148M	61601	296, 500, 900
SM-144	62144	296, 500, 900
SM-147	62147	296, 500, 900
SM-148	62148	296, 500, 900
SM-149	62149	296, 500, 900
SM-150	62150	296, 500, 900
SM-151	62151	296, 500, 900
SM-152	62152	296, 500, 900
SM-153	62153	296, 500, 900
SM-154	62154	296, 500, 900
EU	63000	296, 500, 900
EU-151	63151	296, 500, 900
EU-152	63152	296, 500, 900
EU-153	63153	296, 500, 900
EU-154a	63154	296, 500, 900
EU-155a	63155	296, 500, 900
EU-156	63156	296, 500, 900
EU-157	63157	296, 500, 900
GD-152	64152	296, 500, 900
GD-154	64154	296, 500, 900
GD-155	64155	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
GD-156	64156	296, 500, 900
GD-157	64157	296, 500, 900
GD-158	64158	296, 500, 900
GD-160	64160	296, 500, 900
TB-159	65159	296, 500, 900
TB-160	65160	296, 500, 900
DY-160	66160	296, 500, 900
DY-161	66161	296, 500, 900
DY-162	66162	296, 500, 900
DY-163	66163	296, 500, 900
DY-164	66164	296, 500, 900
HO-165	67165	296, 500, 900
ER-166	68166	296, 500, 900
ER-167	68167	296, 500, 900
LU-175	71175	296, 500, 900
LU-176	71176	296, 500, 900
HF	72000	296, 500, 900
HF-174	72174	296, 500, 900
HF-176	72176	296, 500, 900
HF-177	72177	296, 500, 900
HF-178	72178	296, 500, 900
HF-179	72179	296, 500, 900
HF-180	72180	296, 500, 900
TA-181	73181	296, 500, 900
TA-182	73182	296, 500, 900
W	74000	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
W-182	74182	296, 500, 900
W-183	74183	296, 500, 900
W-184	74184	296, 500, 900
W-186	74186	296, 500, 900
RE-185	75185	296, 500, 900
RE-187	75187	296, 500, 900
AU	79197	296, 500, 900
PB	82000	296, 500, 900
BI-209	83209	296, 500, 900
TH-230	90230	296, 500, 900
TH-232	90232	296, 500, 900
PA-231	91231	296, 500, 900
PA-233	91233	296, 500, 900
U-232	92232	296, 500, 900
U-233	92233	300, 500, 900, 2100
U-234	92234	296, 500, 900
U-235	92235	296, 500, 900
U-236	92236	296, 500, 900
U-237	92237	296, 500, 900
U-238	92238	300, 500, 900
NP-237	93237	296, 500, 900
PU-236	94236	296, 500, 900
PU-237	94237	296, 500, 900
PU-238	94238	296, 500, 900
PU-239	94239	296, 500, 900
PU-240	94240	296, 500, 900

Table E.2 (continued)

Std. comp. alphanumeric name	Nuclide ID No.	Temperatures (K) for which thermal-scattering cross-section data are available
PU-241	94241	300, 500, 900, 2100
PU-242	94242	296, 500, 900
PU-243	94243	296, 500, 900
PU-244	94244	296, 500, 900
AM-241	95241	296, 500, 900
AM-242M	95243	296, 500, 900
AM-243	95601	296, 500, 900
CM-241	96241	296, 500, 900
CM-242	96242	296, 500, 900
CM-243	96243	296, 500, 900
CM-244	96244	296, 500, 900
CM-245	96245	296, 500, 900
CM-246	96246	296, 500, 900
CM-247	96247	296, 500, 900
CM-248	96248	296, 500, 900
BK-249	97249	296, 500, 900
CF-249	98249	296, 500, 900
CF-250	98250	296, 500, 900
CF-251	98251	296, 500, 900
CF-252	98252	296, 500, 900
ES-253	99253	296, 500, 900
EU-154 (ENDF/B-V)	631541	296, 500, 900
EU-155 (ENDF/B-V)	631551	296, 500, 900
N-14 (ENDF/B-VI)	701401	296, 500, 900
N-15 (ENDF/B-VI)	701501	296, 500, 900
O-16 (ENDF/B-V)	801601	296, 500, 900

Table E.3 Contents of the 238-group ENDF/B-V library

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table of contents for  scale.rev08.xn238                       on logical unit  1
tape id                    238
number of nuclides         315
number of neutron groups   238
first thermal group        149
number of gamma groups       0
        scale - 238 neutron group library        based on endf-b version 5 data
          generated with a chi-1/e-maxwellian weight spectrum
            compiled for doe        8/18/94
              last updated           7/29/99
                n.m.greene & l.m.petrie    nuclear eng. appl. - cped - ornl
    24301          24CR BNL EVALDEC77 A.PRINCE AND T.    (1/esigt) MOD2 11/18/91
    24304          24CR BNL EVALDEC77 A.PRINCE AND T.    (1/esigtSS304) MOD2 11/18/91
    26301          26FE 0 ORNL EVALOCT77 C.Y.FU F.G.PE  (1/esigt)   MOD3 11/18/91
    26304          26FE 0 ORNL EVALOCT77 C.Y.FU F.G.PE  (1/esigtSS304)  MOD3 11/18/91
    28301          28NI 0 BNL NNDC EVALMAR77 M.DIVADEENAM (1/esigt) MOD2 11/18/91
    28304          28NI 0 BNL NNDC EVALMAR77 M.DIVADEENAM (1/esigtSS304) MOD2 11/18/91
     1701            smiler for h-1 (hzrh)  tape 132, mat 7   5-14-98
    40701            smiler for zr (in zrh)  tape 133, mat 58   5-15-98
    19000          19k gga evalfeb67 m.k.drake              mod1 1updated 01/18/95
    92232          92u232 hedl evalnov77 mann               mod1 11/14/97
    33075          33as 75 hedl evalapr74 r.e.schenter an   mod1 04/02/97
    56135          56ba135 hedl evalapr74 r.e.schenter an   mod1 04/02/97
    48110          48cd110 hedl evalapr74 r.e.schenter an   mod1 04/02/97
    48114          48cd114 hedl evalapr74 r.e.schenter an   mod1 04/02/97
    96244          96cm244 hedlsrlllll evalapr78 mann benjamin h   mod2 11/14/97
    96248          96cm248 hedlsrlllll evalapr78 mann benjamin h   mod1 11/14/97
    66160          66dy160 hedl evalapr74 r.e.schenter an   mod1 04/08/97
    66163          66dy163 hedl evalapr74 r.e.schenter an   mod1 04/09/97
    68166          68er166 hedl evalapr74 r.e.schenter an   mod1 04/23/97
    32074          32ge 74 hedl evalapr74 r.e.schenter an   mod1 04/23/97
    42096          42mo 96 hedl rcn evalfeb80 r.e.schenter an   mod1 04/23/97
    60145          60nd145 hedl bnl+ evalfeb80 schenter schmit   mod1 04/23/97
    60146          60nd146 hedl bnl+ evalfeb80 schenter schmit   mod1 04/24/97
    60150          60nd150 hedl bnl+ evalfeb80 schenter schmit   mod1 04/24/97
    46108          46pd108 hedl rcn evalfeb80 r.e.schenter an   mod1 04/24/97
    34076          34se 76 hedl evalapr74 r.e.schenter an   mod1 04/24/97
    34078          34se 78 hedl evalapr74 r.e.schenter an   mod1 04/24/97
    62152          62sm152 hedl bnl+ evalfeb80 schenter schmit   mod1 04/29/97
    62154          62sm154 hedl evalapr74 r.e.schenter an   mod1 04/29/97
    52122          52te122 hedl evalapr74 r.e.schenter an   mod1 04/29/97
     4309          be metal 13041064                        mod2 04/29/97
    60143          60nd143 hedl bnl+ evalfeb80 schenter schmit   mod1 04/23/97
    62147          62sm147 hedl bnl+ evalfeb80 schenter + man   mod2 04/24/97
       99          collected weight functions for use in collapsing   updated 5/12/95
      900          neutron dose factors from ansl/ans 6.1.1-1977   updated 5/12/95
     1802          1d 20lasl eval nov67 l.stewart lasl mod2 12/11/92 free gas
     2003          2he 30lasl evaljun68 leona stewart mod1 12/23/92 free gas
     2004          2he 40lasl evaloct73 nisley hale young mod0 12/23/92 free gas
     3006          3li0060lasl eval sep77 g.hale l.stewart mod1 12/11/92 free gas
     3007          3li 7 lanl evaldec81 p.g.young mod1 12/11/92 free gas
     4009          4be 9 free gas. lll evaloct76 howerton/perkins   mod 08/17/94
     5010          5b 100lasl evaldec76 g.hale l.stewart mod1 12/11/92 free gas
     5011          5b11 gebnl evalsep71 c.cowan mod1 12/11/92 free gas
     6012          6c ornl evaldec73 c.y.fu and f.g. perey mod2 12/11/92 free gas
     7015           7n 15 lasl evalmar77 e.arthur p.youn   mod1 12/16/88
    40096           40zr 96 sai evalapr76 m.drake d.sa   mod2 01/04/89
    74183           74w183 las anl brcevaldec80 arthur young sm   mod2 01/04/89
    74184           74w184 las anl brcevaldec80 arthur young sm   mod2 01/05/89
    92238           92U 238 ANL+ EVALJUN77 E.PENNINGTON A.   MOD3 02/13/92
   701501           7n 15 from version 6 evaluation
    14000           14si 0 ornl evalfeb74 larson perey dr   mod3 12/20/88
    63154          EU-154 FROM VERSION 6 OF ENDFB (2/9/93)
    63155          EU-155 FROM VERSION 6 OF ENDFB (6/30/93)
   631541           63eu154 bnl evaldec73 h.takahashi   mod1 12/28/88
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631551          63eu155 bnl hedl + evaldec79 princeschenter      mod1 01/16/89
94241           AMPX MASTER FILE FOR ENDF MAT 1381   ***  PU-241 ***
92233           AMPX MASTER FILE FOR ENDF MAT 1393   ***  U-233  ***
43099           43TC 99 HEDL BAW EVALNOV78 SCHENTER LIVOLS       MOD2 01/18/91
40091           40ZR 91 SAI EVALAPR76 M.DRAKE D.SA               MOD2 01/18/91
13027           13al 270lasl evaldec73 p.g. young d.g            mod1 11/29/88
27059           27co 59 bnl evaljun77 s.mughabghab               mod3 12/20/88
24000           24cr bnl evaldec77 a.prince and t.               mod2 11/29/88
 9019           9f 19 ornl evaljul74 c.y.fu d.c.lars             mod3 12/16/88
26000           26fe 0 ornl evaloct77 c.y.fu f.g.pe             mod3 11/29/88
25055           25mn 55 bnl evalmar77 s.f. mughabghab            mod2 12/20/88
42000           42mo lll hedl evalfeb79 howerton schmit          mod1 02/17/89
11023           11na 23 ornl evaldec77 d. c. larson              mod3 11/29/88
41093           41nb 93 anl lll evalmay74 r.howerton lll         mod1 12/28/88
28000           28ni 0 bnl nndc evalmar77 m.divadeenam          mod2 11/29/88
37085           37rb 85 bnlbrc evaloct79 a. prince               mod1 01/03/89
37087           37rb 87 bnlbrc evaloct79 a. prince               mod1 12/29/88
45103           45rh103 hedl baw evalnov78 schenter livols       mod1 12/28/88
16000           16 s 0 bnl evalapr79 divadeenam                 mod1 12/20/88
90232           90th232 bnl evaldec77 bhat smith leon            mod2 01/05/89
40000           40zr sai evalapr76 m.drake d.sa                  mod2 01/03/89
40090           40zr 90 sai evalapr76 m.drake d.sa               mod2 01/04/89
40092           40zr 92 sai evalapr76 m.drake d.sa               mod2 01/04/89
40094           40zr 94 sai evalapr76 m.drake d.sa               mod2 01/04/89
 6312           graphite 1306/1065 96 angles 10/21/92 jpr eval.
61601           61PM148MHEDL INEL EVALDEC79 SCHENTER SCHMIT      MOD1 01/22/91
 8016           8O 16 from version 6 evaluation
 1901           hydrogen in ch2   1301/1114          11/25/92
 1002           deuterium in d2o  1302/1004   96 angles    11/13/92
 1001           hydrogen in water 1301/1002    mod1   11/23/92
  999           1/v function (normalized to 1.0 at 2200m/s<==>0.0253ev)
96242           96CM242 HEDLSRLLLL EVALAPR78 MANN BENJAMIN H     MOD1 01/18/91
66164           66DY164 BNW EVALJUN67 B.R.LEONARD JR.            MOD1 01/18/91
63151           63EU151 BNL EVALDEC77 S.F. MUGHABGHAB            MOD1 01/21/91
64155           64GD155 BNL EVALJAN77 B.A.MAGURNO                MOD1 01/21/91
64157           64GD157 BNL EVALJAN77 B.A.MAGURNO                MOD1 01/18/91
72176           72HF176 SAI EVALAPR76 M.DRAKE D.SA               MOD1 01/18/91
72179           72HF179 SAI EVALAPR76 M.DRAKE D.SA               MOD1 01/18/91
60144           60ND144 HEDL EVALFEB80 SCHENTER SCHMIT           MOD1 01/22/91
93237           93NP237 HEDL SRL + EVALAPR78 MANN BENJAMIN S     MOD2 01/23/91
91231           91PA231 HEDL EVALNOV77 MANN                      MOD1 01/18/91
94236           94PU236 HEDL SRL EVALAPR78 MANN SCHENTER B       MOD1 01/18/91
94237           94PU237 HEDL EVALAPR78 MANN AND SCHENT           MOD1 01/18/91
94238           94PU238 HEDL AI + EVALAPR78 MANN SCHENTER A      MOD3 01/18/91
94242           94PU242 HEDL SRL + EVALOCT78 MANN BENJAMIN M     MOD2 01/21/91
94243           94PU243 BNL SRL LLLEVALJUL76 KINSEYASSEMBLE      MOD1 01/18/91
94244           94PU244 HEDL SRL EVALAPR78 MANN SCHENTER B       MOD1 01/18/91
73181           73TA181 LLL EVALJAN72 HOWERTON PERKI             MOD2 01/22/91
90230           90TH230 HEDL EVALNOV77 MANN                      MOD1 01/18/91
92234           92U 234 BNL HEDL + EVALJUL78 DIVADEENAM MANN     MOD3 01/10/91
92236           92U 236 BNL HEDL + EVALJUL78 DIVADEENAM MANN     MOD3 01/23/91
47107           47ag107 bnl hedl evaljun83 a.prince r.e.sc       mod2 01/04/89
47109           47ag109 bnl hedl evaljun83 a.prince r.e.sc       mod2 01/04/89
47111           47ag111 hedl inel evaldec79 schenter schmit      mod1 01/12/89
95241           95am241 hedl ornl evalapr78 mann schenter        mod2 01/10/90
95601           95am242mhedlsrllll evalapr78 mann benjamin h     mod1 01/16/90
95243           95am243 hedlsrllll evalapr78 mann benjamin h     mod2 01/10/90
79197           79au197 bnl evalfeb77 s.f.mughabghab             mod3 01/04/89
56134           56ba134 hedl evalapr74 r.e.schenter an           mod1 01/13/89
56136           56ba136 hedl evalapr74 r.e.schenter an           mod1 01/13/89
56137           56ba137 hedl evalapr74 r.e.schenter an           mod1 01/13/89
56138           56ba138 lll evalaug78 howerton                   mod1 01/03/89
56140           56ba140 hedl inel evaldec79 schenter schmit      mod1 01/13/89
83209           83bi209 anl lll evalapr80 d.smith a.smith        mod1 01/04/89
35079           35br 79 hedl evalapr74 r.e.schenter an           mod1 01/11/89
35081           35br 81 hedl evalapr74 r.e.schenter an           mod1 01/11/89
20000           20ca ornl evalaug71 c.y.fu and d.m.              mod3 12/20/88
48000           48cd bnl evalmay74 s.pearlstein tr               mod1 01/03/89
48106           48cd106 hedl evalfeb80 f.m.mann                  mod2 01/12/89
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48108           48cd108 hedl evalapr74 r.e.schenter an        mod1 01/12/89
48111           48cd111 hedl evalapr74 r.e.schenter an        mod1 01/12/89
48112           48cd112 hedl evalapr74 r.e.schenter an        mod1 01/12/89
48113           48cd113 bnl hedl evalnov78 pearlstein mann     mod1 01/03/89
48601           48cd115mhedl inel evaldec79 schenter schmit    mod1 01/12/89
48116           48cd116 hedl evalapr74 r.e.schenter an        mod1 01/12/89
58140           58ce140 hedl evalapr74 r.e.schenter an        mod1 01/13/89
58141           58ce141 hedl inel evaldec79 schenter schmit    mod1 01/13/89
58142           58ce142 hedl evalapr74 r.e.schenter an        mod1 01/13/89
58143           58ce143 hedl inel evaldec79 schenter schmit    mod1 01/13/89
58144           58ce144 hedl inel evaldec79 schenter schmit    mod1 01/16/89
98249           cf249 bnl srl lllevaljul76 kinseyassemble       mod1 01/12/89
98251           98cf251 bnl srl lllevaljul76 kinseyassemble     mod1 01/10/89
98252           98cf252 bnl srl lllevaljul76 kinseyassemble     mod1 01/10/89
17000           17cl gga evalfeb67 m.s.allen and m             mod1 03/14/89
96241           96cm241 hedl evalapr78 mann and schent          mod1 01/10/90
96243           96cm243 hedlsrlllll evalapr78 mann benjamin h   mod1 01/10/90
96245           96cm245 srl lll evaljan79 benjamin and ho       mod2 01/05/89
96246           96cm246 bnl srl lllevaljul76 kinseyassemble     mod1 01/10/90
96247           96cm247 bnl srl lllevaljul76 kinseyassemble     mod1 01/10/89
55133           55cs133 hedl bnl evalnov78 schenter bhat p      mod1 01/03/89
55134           55cs134 hedl inel evaldec79 schenter schmit     mod1 01/13/89
55135           55cs135 hedl inel evaldec79 schenter schmit     mod1 01/13/89
55136           55cs136 hedl inel evaldec79 schenter schmit     mod1 01/13/89
55137           55cs137 hedl inel evaldec79 schenter schmit     mod1 01/13/89
29000           29cu ornl sai evaldec73 fu drake fricke         mod1 12/20/88
66161           66dy161 hedl evalapr74 r.e.schenter an          mod1 01/16/89
66162           66dy162 hedl evalapr74 r.e.schenter an          mod1 04/03/89
68167           68er167 hedl evalapr74 r.e.schenter an          mod1 04/03/89
99253           99es253 bnl srl evaljul76 kinsey benjamin       mod1 01/10/89
63000           63eu nndc evalaug81 autocombined               mod1 01/04/89
63152           63eu152 bnl evaldec73 h.takahashi               mod2 02/28/89
63153           63eu153 bnl evalfeb78 s.mughabghab              mod1 01/03/89
63156           63eu156 hedl inel evaldec79 schenter schmit     mod1 01/16/89
63157           63eu157 hedl evalfeb80 r.e.schenter an          mod1 01/17/89
31000           31ga lll lasl evalmay80 howerton young          mod1 12/21/88
64152           64gd152 bnl evaljan77 b.a.magurno               mod2 01/03/89
64154           64gd154 bnl evaljan77 b.a.magurno               mod1 01/03/89
64156           64gd156 bnl evaljan77 b.a.magurno               mod2 01/04/89
64158           64gd158 bnl evaljan77 b.a.magurno               mod1 01/04/89
64160           64gd160 bnl evaljan77 b.a.magurno               mod1 01/04/89
32072           32ge 72 hedl evalapr74 r.e.schenter an          mod1 01/11/89
32073           32ge 73 hedl evalapr74 r.e.schenter an          mod1 01/11/89
32076           32ge 76 hedl evalapr74 r.e.schenter an          mod1 01/11/89
 1801           1h 10lasl evalaug70 l.stewart r.j.              mod1 12/16/88
72000           72hf sai evalapr76 m.drake d.sa                 mod1 01/04/89
72174           72hf174 sai evalapr76 m.drake d.sa              mod1 03/21/89
72177           72hf177 sai evalapr76 m.drake d.sa              mod1 03/21/89
72178           72hf178 sai evalapr76 m.drake d.sa              mod1 03/21/89
72180           72hf180 sai evalapr76 m.drake d.sa              mod1 01/04/89
67165           67ho165 hedl evalapr74 r.e.schenter an          mod1 01/16/89
53127           53i 127 hedl rcn evalfeb80 r.e.schenter an      mod1 01/13/89
53129           53i 129 hedl inel+ evalfeb80 schenter schmit    mod1 01/13/89
53130           53i 130 hedl inel evaldec79 schenter schmit     mod1 01/13/89
53131           53i 131 hedl inel evaldec79 schenter schmit     mod1 01/13/89
53135           53i 135 hedl inel evaldec79 schenter schmit     mod1 01/13/89
49113           49in113 hedl evalapr74 r.e.schenter an          mod1 01/12/89
49115           49in115 hedl inel evaldec79 schenter schmit     mod1 01/12/89
36078           36kr 78 bnl evalapr78 a.prince                  mod1 12/29/88
36080           36kr 80 bnl evalapr78 a.prince                  mod1 12/29/88
36082           36kr 82 bnl evalapr78 a.prince                  mod1 12/29/88
36083           36kr 83 bnl evalapr78 a.prince                  mod1 12/29/88
36084           36kr 84 bnl evalapr78 a.prince                  mod1 12/29/88
36085           36kr 85 hedl inel evaldec79 schenter schmit     mod1 01/11/89
36086           36kr 86 bnl evaljul72 a.prince                  mod1 12/30/88
57139           57la139 hedl rcn evalfeb80 r.e.schenter an      mod1 01/13/89
57140           57la140 hedl inel evaldec79 schenter schmit     mod1 01/13/89
71175           71lu175 bnw evaljun67 b.r.leonard jr.           mod1 12/22/88
71176           71lu176 bnw evaljun67 b.r.leonard jr.           mod1 12/22/88
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12000          12mg ornl evalfeb78 d.c.larson                  mod1 12/16/88
42092          42mo 92 hedl evalfeb80 f.m.mann                 mod1 01/12/89
42094          42mo 94 hedl rcn evalfeb80 r.e.schenter an      mod1 01/11/89
42095          42mo 95 hedl rcn evalfeb80 r.e.schenter an      mod1 01/11/89
42097          42mo 97 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
42098          42mo 98 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
42099          42mo 99 hedl inel evaldec79 schenter schmit     mod1 01/12/89
42100          42mo100 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
 7014          7n 14 lasl evaljul73 p.young d.fost             mod2 11/28/88
41094          41nb 94 hedl inel evaldec79 schenter schmit     mod1 01/11/89
41095          41nb 95 hedl inel evaldec79 schenter schmit     mod1 01/11/89
60142          60nd142 hedl evalapr74 r.e.schenter an          mod1 01/16/89
60147          60nd147 hedl inel evaldec79 schenter schmit     mod1 01/16/89
60148          60nd148 hedl bnl+ evalfeb80 schenter schmit     mod1 03/21/89
 8017          8o 17 bnl evaljan78 b.a.magurno                 mod1 12/20/88
15031          15p 31 lll evaloct77 howerton                   mod1 12/20/88
82000          82pb ornl evaljul71 c.y.fu and f.g.             mod2 01/04/89
46102          46pd102 hedl evalfeb80 f.m.mann                 mod2 01/12/89
46104          46pd104 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
46105          46pd105 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
46106          46pd106 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
46107          46pd107 hedl inel+ evalfeb80 schenter schmit    mod1 01/12/89
46110          46pd110 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
61147          61pm147 hedl inel +evalfeb80 schenter + rei     mod1 01/16/89
61148          61pm148 hedl inel evaldec79 schenter schmit     mod1 01/16/89
61149          61pm149 hedl inel evaldec79 schenter schmit     mod1 01/16/89
61151          61pm151 hedl inel evaldec79 schenter schmit     mod1 01/16/89
59141          59pr141 hedl bnl+ evalfeb80 schenter schmit     mod1 03/21/89
59142          59pr142 hedl inel evaldec79 schenter schmit     mod1 01/16/89
59143          59pr143 hedl inel evaldec79 schenter schmit     mod1 01/16/89
94239          94pu239 lanl jun83 e.arthur p.you               mod2 02/28/89
94240          94pu240 ornl evalapr77 l.w. weston              mod3 12/12/88
37086          37rb 86 hedl inel evaldec79 schenter schmit     mod1 01/11/89
75185          75re185 ge nmpo evaljan68 w.b.henderson a       mod1 12/22/88
75187          75re187 ge nmpo evaljan68 w.b.henderson a       mod1 12/22/88
45105          45rh105 hedl inel evaldec79 schenter schmit     mod2 01/12/89
44096          44ru 96 hedl evalfeb80 f.m.mann                 mod2 01/12/89
44098          44ru 98 hedl evalfeb80 f.m.mann                 mod2 01/12/89
44099          44ru 99 hedl evalapr74 r.e.schenter an          mod1 01/12/89
44100          44ru100 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
44101          44ru101 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
44102          44ru102 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
44103          44ru103 hedl inel evaldec79 schenter schmit     mod1 01/12/89
44104          44ru104 hedl rcn evalfeb80 r.e.schenter an      mod1 01/12/89
44105          44ru105 hedl inel evaldec79 schenter schmit     mod1 01/12/89
44106          44ru106 hedl inel evaldec79 schenter schmit     mod1 01/12/89
16032          16s 32 lll evaloct77 howerton                   mod1 12/20/88
51121          51sb121 hedl rcn evalfeb80 r.e.schenter an      mod1 01/13/89
51123          51sb123 hedl rcn evalfeb80 r.e.schenter an      mod1 01/13/89
51124          51sb124 hedl inel evaldec79 schenter schmit     mod1 01/13/89
51125          51sb125 hedl inel evaldec79 schenter schmit     mod1 01/13/89
51126          51sb126 hedl inel evaldec79 schenter schmit     mod1 01/13/89
34074          34se 74 hedl evalfeb80 f.m.mann                 mod2 03/21/89
34077          34se 77 hedl evalapr74 r.e.schenter an          mod1 01/11/89
34080          34se 80 hedl evalapr74 r.e.schenter an          mod1 03/21/89
34082          34se 82 hedl evalapr74 r.e.schenter an          mod1 01/11/89
62144          62sm144 hedl evalfeb80 f.m.mann                 mod2 01/16/89
62148          62sm148 hedl evalfeb80 schenter schmit          mod1 01/16/89
62149          62sm149 hedl bnw evalnov78 schenter leonar      mod1 01/03/89
62150          62sm150 hedl evalapr74 r.e.schenter an          mod1 03/21/89
62151          62sm151 hedl inel +evalfeb80 schenter + rei     mod1 01/16/89
62153          62sm153 hedl inel evaldec79 schenter schmit     mod1 01/16/89
50112          50sn112 hedl evalfeb80 f.m.mann                 mod2 01/12/89
50114          50sn114 hedl evalfeb80 f.m.mann                 mod2 01/12/89
50115          50sn115 hedl evalapr74 r.e.schenter an          mod1 01/12/89
50116          50sn116 hedl evalapr74 r.e.schenter an          mod1 01/12/89
50117          50sn117 hedl evalapr74 r.e.schenter an          mod1 01/12/89
50118          50sn118 hedl evalapr74 r.e.schenter an          mod1 01/12/89
50119          50sn119 hedl evalapr74 r.e.schenter an          mod1 01/12/89
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 50120           50sn120 hedl evalapr74 r.e.schenter an            mod1 01/12/89
 50122           50sn122 hedl evalapr74 r.e.schenter an            mod1 01/12/89
 50123           50sn123 hedl inel evaldec79 schenter schmit       mod1 01/12/89
 50124           50sn124 hedl evalapr74 r.e.schenter an            mod1 01/12/89
 50125           50sn125 hedl inel evaldec79 schenter schmit       mod1 01/13/89
 50126           50sn126 hedl inel evaldec79 schenter schmit       mod1 01/12/89
 38084           38sr 84 hedl evalfeb80 f.m.mann                   mod2 01/11/89
 38086           38sr 86 hedl evalapr74 r.e.schenter an            mod1 01/11/89
 38087           38sr 87 hedl evalapr74 r.e.schenter an            mod1 01/11/89
 38088           38sr 88 hedl evalapr74 r.e.schenter an            mod1 01/11/89
 38089           38sr 89 hedl inel evaldec79 schenter schmit       mod1 01/11/89
 38090           38sr 90 hedl inel evaldec79 schenter schmit       mod1 01/11/89
  1003           1t 30lasl evalfeb65 leona stewart                 mod2 12/16/88
 73182           73ta182 ai evalapr71 j.otter c.dunfo              mod1 12/22/88
 65159           65tb159 hedl rcn evalfeb80 r.e.schenter an        mod1 01/16/89
 65160           65tb160 hedl inel evaldec79 schenter schmit       mod1 01/16/89
 52120           52te120 hedl evalfeb80 f.m.mann                   mod2 01/13/89
 52123           52te123 hedl evalapr74 r.e.schenter an            mod1 03/21/89
 52124           52te124 hedl evalapr74 r.e.schenter an            mod1 01/13/89
 52125           52te125 hedl evalapr74 r.e.schenter an            mod1 01/13/89
 52126           52te126 hedl evalapr74 r.e.schenter an            mod1 01/13/89
 52601           52te127mhedl inel evaldec79 schenter schmit       mod1 01/13/89
 52128           52te128 hedl evalapr74 r.e.schenter an            mod1 01/13/89
 52611           52te129mhedl inel evaldec79 schenter schmit       mod1 01/13/89
 52130           52te130 hedl evalapr74 r.e.schenter an            mod1 01/13/89
 52132           52te132 hedl inel evaldec79 schenter schmit       mod1 01/13/89
 22000           22ti buranllll evalaug77 c.philis a.smit          mod1 12/20/88
 92235           92u 235 bnl evalapr77 m.r.bhat                    mod3 02/28/89
 92237           92u237 bnl srl lllevaljul76 kinseyassemble        mod1 01/10/89
 23000           23v anlllllhedl evaljan77 a.smith+ h.howe         mod1 12/20/88
 74000           74w lanl evalmar82 e.d.arthur                     mod1 01/04/89
 74182           74w182 las anl brcevaldec80 arthur young sm       mod2 01/04/89
 74186           74w186 las anl brcevaldec80 arthur young sm       mod2 01/05/89
 54124           54xe124 bnl evalmar78 m.r.bhat and s.             mod1 12/29/88
 54126           54xe126 bnl evalmar78 m.r.bhat and s.             mod1 12/29/88
 54128           54xe128 bnl evalmar78 m.r.bhat and s.             mod1 12/30/88
 54129           54xe129 bnl evalmar78 m.r.bhat and s.             mod1 01/03/89
 54130           54xe130 bnl evalmar78 m.r.bhat and s.             mod1 12/30/88
 54131           54xe131 bnl evalmar78 m.r.bhat and s.             mod1 01/03/89
 54132           54xe132 bnl evalmar78 m.r.bhat and s.             mod2 01/03/89
 54133           54xe133 hedl inel evaldec79 schenter schmit       mod1 01/13/89
 54134           54xe134 bnl evalmar78 m.r.bhat and s.             mod1 01/03/89
 54135           54xe135 bnw evaljun67 b.r.leonard jr.             mod1 12/28/88
 54136           54xe136 bnl evalmar78 m.r.bhat and s.             mod1 01/03/89
 39089           39y 89 hedl evalapr74 r.e.schenter an             mod1 01/11/89
 39090           39y 90 hedl inel evaldec79 schenter schmit        mod1 01/11/89
 39091           39y 91 hedl inel evaldec79 schenter schmit        mod1 01/11/89
 40093           40zr 93 hedl inel evaldec79 schenter schmit       mod1 01/11/89
 40095           40zr 95 hedl inel evaldec79 schenter schmit       mod1 01/11/89
801601           8o 16 lasl evalaug73 p.young d.fost               mod2 12/16/88
701401           7n 14 from version 6 evaluation
 98250           98cf250 bnl srl lllevaljul76 kinseyassemble       mod1 11/14/97
 91233           91PA233 HEDL INEL EVALMAY78 MANN SCHENTER R       MOD2 01/18/91
 97249           97bk249 bnl srl lllevaljul76 kinseyassemble       mod1 01/11/89
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Table E.4   Contents of the 44-group ENDF/B-V library

```
table of contents for  scale.rev10.xn44                          on logical unit  1
tape id                          44
number of nuclides              315
number of neutron groups         44
first thermal group              23
number of gamma groups            0
         scale - 44 neutron group library        based on endf-b version 5 data
           collapsed with a light water reactor cell flux spectrum from 238 groups
             compiled for nrc       9/01/94
               last updated        7/29/99
                 m.d.dehart & l.m.petrie    nuclear eng. appl. - cped - ornl
    24301           24CR BNL EVALDEC77 A.PRINCE AND T.    (1/esigt) MOD2 11/18/91
    24304           24CR BNL EVALDEC77 A.PRINCE AND T.    (1/esigtSS304)  MOD2 11/18/91
    26301           26FE 0 ORNL EVALOCT77 C.Y.FU F.G.PE  (1/esigt)   MOD3 11/18/91
    26304           26FE 0 ORNL EVALOCT77 C.Y.FU F.G.PE  (1/esigtSS304)   MOD3 11/18/91
    28301           28NI 0 BNL NNDC EVALMAR77 M.DIVADEENAM (1/esigt) MOD2 11/18/91
    28304           28NI 0 BNL NNDC EVALMAR77 M.DIVADEENAM (1/esigtSS304) MOD2 11/18/91
     1701             smiler for h-1 (hzrh)  tape 132, mat 7   5-14-98
    40701             smiler for zr (in zrh)  tape 133, mat 58   5-15-98
    19000           19k gga evalfeb67 m.k.drake              mod1 1updated 01/18/95
    92232           92u232 hedl evalnov77 mann               mod1 11/14/97
    33075           33as 75 hedl evalapr74 r.e.schenter an       mod1 04/02/97
    56135           56ba135 hedl evalapr74 r.e.schenter an       mod1 04/02/97
    48110           48cd110 hedl evalapr74 r.e.schenter an       mod1 04/02/97
    48114           48cd114 hedl evalapr74 r.e.schenter an       mod1 04/02/97
    96244           96cm244 hedlsrllll evalapr78 mann benjamin h  mod2 11/14/97
    96248           96cm248 hedlsrllll evalapr78 mann benjamin h  mod1 11/14/97
    66160           66dy160 hedl evalapr74 r.e.schenter an       mod1 04/08/97
    66163           66dy163 hedl evalapr74 r.e.schenter an       mod1 04/09/97
    68166           68er166 hedl evalapr74 r.e.schenter an       mod1 04/23/97
    32074           32ge 74 hedl evalapr74 r.e.schenter an       mod1 04/23/97
    42096           42mo 96 hedl rcn evalfeb80 r.e.schenter an    mod1 04/23/97
    60145           60nd145 hedl bnl+ evalfeb80 schenter schmit   mod1 04/23/97
    60146           60nd146 hedl bnl+ evalfeb80 schenter schmit   mod1 04/24/97
    60150           60nd150 hedl bnl+ evalfeb80 schenter schmit   mod1 04/24/97
    46108           46pd108 hedl rcn evalfeb80 r.e.schenter an    mod1 04/24/97
    34076           34se 76 hedl evalapr74 r.e.schenter an       mod1 04/24/97
    34078           34se 78 hedl evalapr74 r.e.schenter an       mod1 04/24/97
    62152           62sm152 hedl bnl+ evalfeb80 schenter schmit   mod1 04/29/97
    62154           62sm154 hedl evalapr74 r.e.schenter an       mod1 04/29/97
    52122           52te122 hedl evalapr74 r.e.schenter an       mod1 04/29/97
     4309           be metal 13041064                        mod2 04/29/97
    60143           60nd143 hedl bnl+ evalfeb80 schenter schmit   mod1 04/23/97
    62147           62sm147 hedl bnl+ evalfeb80 schenter + man    mod2 04/24/97
       99           collected weight functions for use in collapsing   updated 5/12/95
      900           neutron dose factors from ansl/ans 6.1.1-1977     updated 5/12/95
     1802           1d 20lasl eval nov67 l.stewart lasl mod2 12/11/92 free gas
     2003           2he 30lasl evaljun68 leona stewart mod1 12/23/92 free gas
     2004           2he 40lasl evaloct73 nisley hale young mod0 12/23/92 free gas
     3006           3li0060lasl eval sep77 g.hale l.stewart mod1 12/11/92 free gas
     3007           3li 7 lanl evaldec81 p.g.young mod1 12/11/92 free gas
     4009           4be 9 free gas. lll evaloct76 howerton/perkins   mod 08/17/94
     5010           5b 100lasl evaldec76 g.hale l.stewart mod1 12/11/92 free gas
     5011           5b11 gebnl evalsep71 c.cowan mod1 12/11/92 free gas
     6012           6c ornl evaldec73 c.y.fu and f.g. perey mod2 12/11/92 free gas
     7015            7n 15 lasl evalmar77 e.arthur p.youn       mod1 12/16/88
    40096           40zr 96 sai evalapr76 m.drake d.sa          mod2 01/04/89
    74183           74w183 las anl brcevaldec80 arthur young sm   mod2 01/04/89
    74184           74w184 las anl brcevaldec80 arthur young sm   mod2 01/05/89
    92238           92U 238 ANL+ EVALJUN77 E.PENNINGTON A.       MOD3 02/13/92
   701501           7n 15 from version 6 evaluation
    14000           14si 0 ornl evalfeb74 larson perey dr       mod3 12/20/88
    63154           EU-154 FROM VERSION 6 OF ENDFB (2/9/93)
    63155           EU-155 FROM VERSION 6 OF ENDFB (6/30/93)
   631541            63eu154 bnl evaldec73 h.takahashi         mod1 12/28/88
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631551          63eu155 bnl hedl + evaldec79 princeschenter    mod1 01/16/89
 94241          AMPX MASTER FILE FOR ENDF MAT 1381   ***  PU-241 ***
 92233          AMPX MASTER FILE FOR ENDF MAT 1393   ***   U-233  ***
 43099          43TC 99 HEDL BAW EVALNOV78 SCHENTER LIVOLS      MOD2 01/18/91
 40091          40ZR 91 SAI EVALAPR76 M.DRAKE D.SA              MOD2 01/18/91
 13027          13al 270lasl evaldec73 p.g. young d.g           mod1 11/29/88
 27059          27co 59 bnl evaljun77 s.mughabghab              mod3 12/20/88
 24000          24cr bnl evaldec77 a.prince and t.              mod2 11/29/88
  9019          9f 19 ornl evaljul74 c.y.fu d.c.lars            mod3 12/16/88
 26000          26fe 0 ornl evaloct77 c.y.fu f.g.pe             mod3 11/29/88
 25055          25mn 55 bnl evalmar77 s.f. mughabghab           mod2 12/20/88
 42000          42mo lll hedl evalfeb79 howerton schmit         mod1 02/17/89
 11023          11na 23 ornl evaldec77 d. c. larson             mod3 11/29/88
 41093          41nb 93 anl lll evalmay74 r.howerton lll        mod1 12/28/88
 28000          28ni 0 bnl nndc evalmar77 m.divadeenam          mod2 11/29/88
 37085          37rb 85 bnlbrc evaloct79 a. prince              mod1 01/03/89
 37087          37rb 87 bnlbrc evaloct79 a. prince              mod1 12/29/88
 45103          45rh103 hedl baw evalnov78 schenter livols      mod1 12/28/88
 16000          16 s 0 bnl evalapr79 divadeenam                 mod1 12/20/88
 90232          90th232 bnl evaldec77 bhat smith leon           mod2 01/05/89
 40000          40zr sai evalapr76 m.drake d.sa                 mod2 01/03/89
 40090          40zr 90 sai evalapr76 m.drake d.sa              mod2 01/04/89
 40092          40zr 92 sai evalapr76 m.drake d.sa              mod2 01/04/89
 40094          40zr 94 sai evalapr76 m.drake d.sa              mod2 01/04/89
  6312          graphite 1306/1065 96 angles 10/21/92 jpr eval.
 61601          61PM148MHEDL INEL EVALDEC79 SCHENTER SCHMIT     MOD1 01/22/91
  8016          8O 16 from version 6 evaluation
  1901          hydrogen in ch2    1301/1114         11/25/92
  1002          deuterium in d2o   1302/1004    96 angles    11/13/92
  1001          hydrogen in water 1301/1002     mod1   11/23/92
   999          1/v function (normalized to 1.0 at 2200m/s<==>0.0253ev)
 96242          96CM242 HEDLSRLLLL EVALAPR78 MANN BENJAMIN H    MOD1 01/18/91
 66164          66DY164 BNW EVALJUN67 B.R.LEONARD JR.           MOD1 01/18/91
 63151          63EU151 BNL EVALDEC77 S.F. MUGHABGHAB           MOD1 01/21/91
 64155          64GD155 BNL EVALJAN77 B.A.MAGURNO               MOD1 01/21/91
 64157          64GD157 BNL EVALJAN77 B.A.MAGURNO               MOD1 01/18/91
 72176          72HF176 SAI EVALAPR76 M.DRAKE D.SA              MOD1 01/18/91
 72179          72HF179 SAI EVALAPR76 M.DRAKE D.SA              MOD1 01/18/91
 60144          60ND144 HEDL EVALFEB80 SCHENTER SCHMIT          MOD1 01/22/91
 93237          93NP237 HEDL SRL + EVALAPR78 MANN BENJAMIN S    MOD2 01/23/91
 91231          91PA231 HEDL EVALNOV77 MANN                     MOD1 01/18/91
 94236          94PU236 HEDL SRL EVALAPR78 MANN SCHENTER B      MOD1 01/18/91
 94237          94PU237 HEDL EVALAPR78 MANN AND SCHENT          MOD1 01/18/91
 94238          94PU238 HEDL AI + EVALAPR78 MANN SCHENTER A     MOD3 01/18/91
 94242          94PU242 HEDL SRL + EVALOCT78 MANN BENJAMIN M    MOD2 01/21/91
 94243          94PU243 BNL SRL LLLEVALJUL76 KINSEYASSEMBLE     MOD1 01/18/91
 94244          94PU244 HEDL SRL EVALAPR78 MANN SCHENTER B      MOD1 01/18/91
 73181          73TA181 LLL EVALJAN72 HOWERTON PERKI            MOD2 01/22/91
 90230          90TH230 HEDL EVALNOV77 MANN                     MOD1 01/18/91
 92234          92U 234 BNL HEDL + EVALJUL78 DIVADEENAM MANN    MOD3 01/10/91
 92236          92U 236 BNL HEDL + EVALJUL78 DIVADEENAM MANN    MOD3 01/23/91
 47107          47ag107 bnl hedl evaljun83 a.prince r.e.sc      mod2 01/04/89
 47109          47ag109 bnl hedl evaljun83 a.prince r.e.sc      mod2 01/04/89
 47111          47ag111 hedl inel evaldec79 schenter schmit     mod1 01/12/89
 95241          95am241 hedl ornl evalapr78 mann schenter       mod2 01/10/90
 95601          95am242mhedlsrlllll evalapr78 mann benjamin h   mod1 01/16/90
 95243          95am243 hedlsrllll evalapr78 mann benjamin h    mod2 01/10/90
 79197          79au197 bnl evalfeb77 s.f.mughabghab            mod3 01/04/89
 56134          56ba134 hedl evalapr74 r.e.schenter an          mod1 01/13/89
 56136          56ba136 hedl evalapr74 r.e.schenter an          mod1 01/13/89
 56137          56ba137 hedl evalapr74 r.e.schenter an          mod1 01/13/89
 56138          56ba138 lll evalaug78 howerton                  mod1 01/03/89
 56140          56ba140 hedl inel evaldec79 schenter schmit     mod1 01/13/89
 83209          83bi209 anl lll evalapr80 d.smith a.smith       mod1 01/04/89
 35079          35br 79 hedl evalapr74 r.e.schenter an          mod1 01/11/89
 35081          35br 81 hedl evalapr74 r.e.schenter an          mod1 01/11/89
 20000          20ca ornl evalaug71 c.y.fu and d.m.             mod3 12/20/88
 48000          48cd bnl evalmay74 s.pearlstein tr              mod1 01/03/89
 48106          48cd106 hedl evalfeb80 f.m.mann                 mod2 01/12/89
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48108              48cd108 hedl evalapr74 r.e.schenter an        mod1 01/12/89
48111              48cd111 hedl evalapr74 r.e.schenter an        mod1 01/12/89
48112              48cd112 hedl evalapr74 r.e.schenter an        mod1 01/12/89
48113              48cd113 bnl hedl evalnov78 pearlstein mann     mod1 01/03/89
48601              48cd115mhedl inel evaldec79 schenter schmit    mod1 01/12/89
48116              48cd116 hedl evalapr74 r.e.schenter an        mod1 01/12/89
58140              58ce140 hedl evalapr74 r.e.schenter an        mod1 01/13/89
58141              58ce141 hedl inel evaldec79 schenter schmit    mod1 01/13/89
58142              58ce142 hedl evalapr74 r.e.schenter an        mod1 01/13/89
58143              58ce143 hedl inel evaldec79 schenter schmit    mod1 01/13/89
58144              58ce144 hedl inel evaldec79 schenter schmit    mod1 01/16/89
98249              cf249 bnl srl lllevaljul76 kinseyassemble      mod1 01/12/89
98251              98cf251 bnl srl lllevaljul76 kinseyassemble    mod1 01/10/89
98252              98cf252 bnl srl lllevaljul76 kinseyassemble    mod1 01/10/89
17000              17cl gga evalfeb67 m.s.allen and m            mod1 03/14/89
96241              96cm241 hedl evalapr78 mann and schent        mod1 01/10/90
96243              96cm243 hedlsrllll evalapr78 mann benjamin h   mod1 01/10/90
96245              96cm245 srl lll evaljan79 benjamin and ho     mod2 01/05/89
96246              96cm246 bnl srl lllevaljul76 kinseyassemble    mod1 01/10/90
96247              96cm247 bnl srl lllevaljul76 kinseyassemble    mod1 01/10/89
55133              55cs133 hedl bnl evalnov78 schenter bhat p     mod1 01/03/89
55134              55cs134 hedl inel evaldec79 schenter schmit    mod1 01/13/89
55135              55cs135 hedl inel evaldec79 schenter schmit    mod1 01/13/89
55136              55cs136 hedl inel evaldec79 schenter schmit    mod1 01/13/89
55137              55cs137 hedl inel evaldec79 schenter schmit    mod1 01/13/89
29000              29cu ornl sai evaldec73 fu drake fricke        mod1 12/20/88
66161              66dy161 hedl evalapr74 r.e.schenter an        mod1 01/16/89
66162              66dy162 hedl evalapr74 r.e.schenter an        mod1 04/03/89
68167              68er167 hedl evalapr74 r.e.schenter an        mod1 04/03/89
99253              99es253 bnl srl evaljul76 kinsey benjamin      mod1 01/10/89
63000              63eu nndc evalaug81 autocombined              mod1 01/04/89
63152              63eu152 bnl evaldec73 h.takahashi             mod2 02/28/89
63153              63eu153 bnl evalfeb78 s.mughabghab            mod1 01/03/89
63156              63eu156 hedl inel evaldec79 schenter schmit    mod1 01/16/89
63157              63eu157 hedl evalfeb80 r.e.schenter an        mod1 01/17/89
31000              31ga lll lasl evalmay80 howerton young        mod1 12/21/88
64152              64gd152 bnl evaljan77 b.a.magurno             mod2 01/03/89
64154              64gd154 bnl evaljan77 b.a.magurno             mod1 01/03/89
64156              64gd156 bnl evaljan77 b.a.magurno             mod2 01/04/89
64158              64gd158 bnl evaljan77 b.a.magurno             mod1 01/04/89
64160              64gd160 bnl evaljan77 b.a.magurno             mod1 01/04/89
32072              32ge 72 hedl evalapr74 r.e.schenter an        mod1 01/11/89
32073              32ge 73 hedl evalapr74 r.e.schenter an        mod1 01/11/89
32076              32ge 76 hedl evalapr74 r.e.schenter an        mod1 01/11/89
 1801              1h 10lasl evalaug70 l.stewart r.j.            mod1 12/16/88
72000              72hf sai evalapr76 m.drake d.sa               mod1 01/04/89
72174              72hf174 sai evalapr76 m.drake d.sa            mod1 03/21/89
72177              72hf177 sai evalapr76 m.drake d.sa            mod1 03/21/89
72178              72hf178 sai evalapr76 m.drake d.sa            mod1 03/21/89
72180              72hf180 sai evalapr76 m.drake d.sa            mod1 01/04/89
67165              67ho165 hedl evalapr74 r.e.schenter an        mod1 01/16/89
53127              53i 127 hedl rcn evalfeb80 r.e.schenter an     mod1 01/13/89
53129              53i 129 hedl inel+ evalfeb80 schenter schmit   mod1 01/13/89
53130              53i 130 hedl inel evaldec79 schenter schmit    mod1 01/13/89
53131              53i 131 hedl inel evaldec79 schenter schmit    mod1 01/13/89
53135              53i 135 hedl inel evaldec79 schenter schmit    mod1 01/13/89
49113              49in113 hedl evalapr74 r.e.schenter an        mod1 01/12/89
49115              49in115 hedl inel evaldec79 schenter schmit    mod1 01/12/89
36078              36kr 78 bnl evalapr78 a.prince                mod1 12/29/88
36080              36kr 80 bnl evalapr78 a.prince                mod1 12/29/88
36082              36kr 82 bnl evalapr78 a.prince                mod1 12/29/88
36083              36kr 83 bnl evalapr78 a.prince                mod1 12/29/88
36084              36kr 84 bnl evalapr78 a.prince                mod1 12/29/88
36085              36kr 85 hedl inel evaldec79 schenter schmit    mod1 01/11/89
36086              36kr 86 bnl evaljul72 a.prince                mod1 12/30/88
57139              57la139 hedl rcn evalfeb80 r.e.schenter an     mod1 01/13/89
57140              57la140 hedl inel evaldec79 schenter schmit    mod1 01/13/89
71175              71lu175 bnw evaljun67 b.r.leonard jr.          mod1 12/22/88
71176              71lu176 bnw evaljun67 b.r.leonard jr.          mod1 12/22/88
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12000            12mg ornl evalfeb78 d.c.larson              mod1 12/16/88
42092            42mo 92 hedl evalfeb80 f.m.mann             mod1 01/12/89
42094            42mo 94 hedl rcn evalfeb80 r.e.schenter an  mod1 01/11/89
42095            42mo 95 hedl rcn evalfeb80 r.e.schenter an  mod1 01/11/89
42097            42mo 97 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
42098            42mo 98 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
42099            42mo 99 hedl inel evaldec79 schenter schmit mod1 01/12/89
42100            42mo100 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
 7014            7n 14 lasl evaljul73 p.young d.fost         mod2 11/28/88
41094            41nb 94 hedl inel evaldec79 schenter schmit mod1 01/11/89
41095            41nb 95 hedl inel evaldec79 schenter schmit mod1 01/11/89
60142            60nd142 hedl evalapr74 r.e.schenter an      mod1 01/16/89
60147            60nd147 hedl inel evaldec79 schenter schmit mod1 01/16/89
60148            60nd148 hedl bnl+ evalfeb80 schenter schmit mod1 03/21/89
 8017            8o 17 bnl evaljan78 b.a.magurno             mod1 12/20/88
15031            15p 31 lll evaloct77 howerton               mod1 12/20/88
82000            82pb ornl evaljul71 c.y.fu and f.g.         mod2 01/04/89
46102            46pd102 hedl evalfeb80 f.m.mann             mod2 01/12/89
46104            46pd104 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
46105            46pd105 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
46106            46pd106 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
46107            46pd107 hedl inel+ evalfeb80 schenter schmit mod1 01/12/89
46110            46pd110 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
61147            61pm147 hedl inel +evalfeb80 schenter + rei mod1 01/16/89
61148            61pm148 hedl inel evaldec79 schenter schmit mod1 01/16/89
61149            61pm149 hedl inel evaldec79 schenter schmit mod1 01/16/89
61151            61pm151 hedl inel evaldec79 schenter schmit mod1 01/16/89
59141            59pr141 hedl bnl+ evalfeb80 schenter schmit mod1 03/21/89
59142            59pr142 hedl inel evaldec79 schenter schmit mod1 01/16/89
59143            59pr143 hedl inel evaldec79 schenter schmit mod1 01/16/89
94239            94pu239 lanl jun83 e.arthur p.you           mod2 02/28/89
94240            94pu240 ornl evalapr77 l.w. weston          mod3 12/12/88
37086            37rb 86 hedl inel evaldec79 schenter schmit mod1 01/11/89
75185            75re185 ge nmpo evaljan68 w.b.henderson a   mod1 12/22/88
75187            75re187 ge nmpo evaljan68 w.b.henderson a   mod1 12/22/88
45105            45rh105 hedl inel evaldec79 schenter schmit mod2 01/12/89
44096            44ru 96 hedl evalfeb80 f.m.mann             mod2 01/12/89
44098            44ru 98 hedl evalfeb80 f.m.mann             mod2 01/12/89
44099            44ru 99 hedl evalapr74 r.e.schenter an      mod1 01/12/89
44100            44ru100 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
44101            44ru101 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
44102            44ru102 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
44103            44ru103 hedl inel evaldec79 schenter schmit mod1 01/12/89
44104            44ru104 hedl rcn evalfeb80 r.e.schenter an  mod1 01/12/89
44105            44ru105 hedl inel evaldec79 schenter schmit mod1 01/12/89
44106            44ru106 hedl inel evaldec79 schenter schmit mod1 01/12/89
16032            16s 32 lll evaloct77 howerton               mod1 12/20/88
51121            51sb121 hedl rcn evalfeb80 r.e.schenter an  mod1 01/13/89
51123            51sb123 hedl rcn evalfeb80 r.e.schenter an  mod1 01/13/89
51124            51sb124 hedl inel evaldec79 schenter schmit mod1 01/13/89
51125            51sb125 hedl inel evaldec79 schenter schmit mod1 01/13/89
51126            51sb126 hedl inel evaldec79 schenter schmit mod1 01/13/89
34074            34se 74 hedl evalfeb80 f.m.mann             mod2 03/21/89
34077            34se 77 hedl evalapr74 r.e.schenter an      mod1 01/11/89
34080            34se 80 hedl evalapr74 r.e.schenter an      mod1 03/21/89
34082            34se 82 hedl evalapr74 r.e.schenter an      mod1 01/11/89
62144            62sm144 hedl evalfeb80 f.m.mann             mod2 02/16/89
62148            62sm148 hedl evalfeb80 schenter schmit      mod1 01/16/89
62149            62sm149 hedl bnw evalnov78 schenter leonar  mod1 01/03/89
62150            62sm150 hedl evalapr74 r.e.schenter an      mod1 03/21/89
62151            62sm151 hedl inel +evalfeb80 schenter + rei mod1 01/16/89
62153            62sm153 hedl inel evaldec79 schenter schmit mod1 01/16/89
50112            50sn112 hedl evalfeb80 f.m.mann             mod2 01/12/89
50114            50sn114 hedl evalfeb80 f.m.mann             mod2 01/12/89
50115            50sn115 hedl evalapr74 r.e.schenter an      mod1 01/12/89
50116            50sn116 hedl evalapr74 r.e.schenter an      mod1 01/12/89
50117            50sn117 hedl evalapr74 r.e.schenter an      mod1 01/12/89
50118            50sn118 hedl evalapr74 r.e.schenter an      mod1 01/12/89
50119            50sn119 hedl evalapr74 r.e.schenter an      mod1 01/12/89
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50120            50sn120 hedl evalapr74 r.e.schenter an          mod1 01/12/89
50122            50sn122 hedl evalapr74 r.e.schenter an          mod1 01/12/89
50123            50sn123 hedl inel evaldec79 schenter schmit     mod1 01/12/89
50124            50sn124 hedl evalapr74 r.e.schenter an          mod1 01/12/89
50125            50sn125 hedl inel evaldec79 schenter schmit     mod1 01/13/89
50126            50sn126 hedl inel evaldec79 schenter schmit     mod1 01/12/89
38084            38sr 84 hedl evalfeb80 f.m.mann                 mod2 01/11/89
38086            38sr 86 hedl evalapr74 r.e.schenter an          mod1 01/11/89
38087            38sr 87 hedl evalapr74 r.e.schenter an          mod1 01/11/89
38088            38sr 88 hedl evalapr74 r.e.schenter an          mod1 01/11/89
38089            38sr 89 hedl inel evaldec79 schenter schmit     mod1 01/11/89
38090            38sr 90 hedl inel evaldec79 schenter schmit     mod1 01/11/89
 1003            1t 30lasl evalfeb65 leona stewart               mod2 12/16/88
73182            73ta182 ai evalapr71 j.otter c.dunfo            mod1 12/22/88
65159            65tb159 hedl rcn evalfeb80 r.e.schenter an      mod1 01/16/89
65160            65tb160 hedl inel evaldec79 schenter schmit     mod1 01/16/89
52120            52te120 hedl evalfeb80 f.m.mann                 mod2 01/13/89
52123            52te123 hedl evalapr74 r.e.schenter an          mod1 03/21/89
52124            52te124 hedl evalapr74 r.e.schenter an          mod1 01/13/89
52125            52te125 hedl evalapr74 r.e.schenter an          mod1 01/13/89
52126            52te126 hedl evalapr74 r.e.schenter an          mod1 01/13/89
52601            52te127mhedl inel evaldec79 schenter schmit     mod1 01/13/89
52128            52te128 hedl evalapr74 r.e.schenter an          mod1 01/13/89
52611            52te129mhedl inel evaldec79 schenter schmit     mod1 01/13/89
52130            52te130 hedl evalapr74 r.e.schenter an          mod1 01/13/89
52132            52te132 hedl inel evaldec79 schenter schmit     mod1 01/13/89
22000            22ti buranllll evalaug77 c.philis a.smit        mod1 12/20/88
92235            92u 235 bnl evalapr77 m.r.bhat                  mod3 02/28/89
92237            92u237 bnl srl lllevaljul76 kinseyassemble      mod1 01/10/89
23000            23v anllllhedl evaljan77 a.smith+ h.howe        mod1 12/20/88
74000            74w lanl evalmar82 e.d.arthur                   mod1 01/04/89
74182            74w182 las anl brcevaldec80 arthur young sm     mod2 01/04/89
74186            74w186 las anl brcevaldec80 arthur young sm     mod2 01/05/89
54124            54xe124 bnl evalmar78 m.r.bhat and s.           mod1 12/29/88
54126            54xe126 bnl evalmar78 m.r.bhat and s.           mod1 12/29/88
54128            54xe128 bnl evalmar78 m.r.bhat and s.           mod1 12/30/88
54129            54xe129 bnl evalmar78 m.r.bhat and s.           mod1 01/03/89
54130            54xe130 bnl evalmar78 m.r.bhat and s.           mod1 12/30/88
54131            54xe131 bnl evalmar78 m.r.bhat and s.           mod1 01/03/89
54132            54xe132 bnl evalmar78 m.r.bhat and s.           mod2 01/03/89
54133            54xe133 hedl inel evaldec79 schenter schmit     mod1 01/13/89
54134            54xe134 bnl evalmar78 m.r.bhat and s.           mod1 01/03/89
54135            54xe135 bnw evaljun67 b.r.leonard jr.           mod1 12/28/88
54136            54xe136 bnl evalmar78 m.r.bhat and s.           mod1 01/03/89
39089            39y 89 hedl evalapr74 r.e.schenter an           mod1 01/11/89
39090            39y 90 hedl inel evaldec79 schenter schmit      mod1 01/11/89
39091            39y 91 hedl inel evaldec79 schenter schmit      mod1 01/11/89
40093            40zr 93 hedl inel evaldec79 schenter schmit     mod1 01/11/89
40095            40zr 95 hedl inel evaldec79 schenter schmit     mod1 01/11/89
801601           8o 16 lasl evalaug73 p.young d.fost             mod2 12/16/88
701401           7n 14 from version 6 evaluation
98250            98cf250 bnl srl lllevaljul76 kinseyassemble      mod1 11/14/97
91233            91PA233 HEDL INEL EVALMAY78 MANN SCHENTER R     MOD2 01/18/91
97249            97bk249 bnl srl lllevaljul76 kinseyassemble      mod1 01/11/89
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APPENDIX F

CALCULATIONAL RESULTS

APPENDIX F

CALCULATIONAL RESULTS

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                              Hansen-Roach_High-Enriched_Uranium
Case              Title                                                k-eff    sigma       EALF
----------     ------------------------------------------------------  ------   ------   ------------
cas04          keno-5 validation case a-2                              1.0033   0.0023   7.77607E+05
cas05          keno-5 validation case a-3                              1.0087   0.0019   1.33937E-02
cas07          keno-5 validation case a-5                              1.0098   0.0027   1.24027E+03
cas08          keno-5 validation case a-6                              1.0160   0.0025   1.66572E+05
cas09          keno-5 validation case a-7                              0.9986   0.0024   7.73553E+05
cas10          keno-5 validation case a-8                              1.0142   0.0025   3.80165E+03
cas11          keno-5 validation case a-9                              1.0023   0.0024   1.04495E+04
cas12          keno-5 validation case b-1                              0.9961   0.0030   8.14558E+05
cas14          keno-5 validation case b-11                             1.0330   0.0027   2.24871E-01
cas15          keno-5 validation case b-12                             1.0203   0.0025   3.35858E+04
cas19          keno-5 validation case b-16                             1.0111   0.0040   3.11702E-01
cas22          keno-5 validation case b-2                              0.9973   0.0023   8.21774E+05
cas23          keno-5 validation case b-3                              0.9877   0.0023   8.17676E+05
cas24          keno-5 validation case b-4                              0.9836   0.0022   8.23963E+05
cas25          keno-5 validation case b-5                              0.9965   0.0023   8.20854E+05
cas26          keno-5 validation case b-6                              0.9963   0.0024   6.16140E+03
cas27          keno-5 validation case b-7                              1.0019   0.0028   4.98093E+03
cas28          keno-5 validation case b-8                              1.0050   0.0027   5.69274E+04
cas30          93.2% uo2f2 3 in al slab 3x1x1 array 0 in sep room      0.9827   0.0030   2.32358E-02
cas31          93.2% uo2f2 3 in al slab 3x1x1 array 0 in sep h2o refl  0.9794   0.0030   2.10961E-02
cas32          93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep room      0.9726   0.0024   2.34384E-02
cas33          93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep h2o refl  0.9898   0.0030   1.91490E-02
cas34          93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep room      0.9652   0.0029   2.37152E-02
cas35          93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep h2o refl  0.9953   0.0025   1.85122E-02
cas36          93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep room    0.9708   0.0027   2.36975E-02
cas37          93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep h2o refl 1.0015  0.0030   1.87347E-02
cas38          93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep room    0.9712   0.0027   2.37213E-02
cas39          93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep h2o refl 0.9957  0.0026   1.88407E-02
cas40          93.2% uo2f2 3 in al slab 3x1x1 array 6 in sep room      0.9722   0.0027   2.36949E-02
cas41          93.2% uo2f2 3, 6 in al slabs 2x1x1 array 15 in sep      0.9623   0.0029   2.34795E-02
cas42          93.2% uo2f2 3, 6 in al slabs 2x1x1 array 2 in sep       0.9698   0.0032   2.34051E-02
cas43          93.2% uo2f2 3, 6 in al slabs 2x1x1 array 30 in sep      0.9626   0.0027   2.34482E-02
cas44          93.2% uo2f2 3, 6 in al slabs 2x1x1 array 48 in sep      0.9571   0.0029   2.33963E-02
cas45          93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 0 in sep    0.9658   0.0029   2.32727E-02
cas46          93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 10 in sep   0.9650   0.0027   2.35586E-02
cas47          93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 20 in sep   0.9637   0.0031   2.35362E-02
cas48          93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 32 in sep   0.9643   0.0029   2.35072E-02
cas49          93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 12 in sep     0.9691   0.0030   2.34210E-02
cas50          93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 18 in sep     0.9660   0.0034   2.35640E-02
cas51          93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 30 in sep     0.9607   0.0030   2.34900E-02
cas52          93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 6 in sep      0.9671   0.0027   2.35545E-02
cas53          93.2% uo2f2 6 in al slab 2x1x1 array 15 in sep          0.9694   0.0028   2.34794E-02
cas54          93.2% uo2f2 6 in al slab 2x1x1 array 2 in sep           0.9638   0.0030   2.34929E-02
cas55          93.2% uo2f2 6 in al slab 2x1x1 array 20 in sep          0.9681   0.0034   2.34771E-02
cas56          93.2% uo2f2 6 in al slab 2x1x1 array 30 in sep          0.9661   0.0026   2.34327E-02
cas57          93.2% uo2f2 6 in al slab 2x1x1 array 48 in sep          0.9731   0.0030   2.33448E-02
cas58          93.2% uo2f2 6 in al slab 2x1x1 array 6 in sep           0.9664   0.0029   2.34476E-02
cas59          93.2% uo2f2 6 in al slab 2x1x1 array 66 in sep          0.9644   0.0032   2.34246E-02
cas60          uo2(no3)2 279 g U/L 3x3x3 array unrefl. walls, tank, & floor  0.9770  0.0029  8.69611E-02
cas61          uo2(no3)2 279 g U/L 2x2x2 array unrefl. walls, tank, & floor  0.9779  0.0031  8.47812E-02
cas62          uo2(no3)2 415 g U/L 5x5x5 array unrefl. walls, tank, & floor  0.9852  0.0032  1.89848E-01
cas63          uo2(no3)2 415 g U/L 3x3x3 array unrefl. walls, tank, & floor  0.9758  0.0032  1.94881E-01
cas64          uo2(no3)2 415 g U/L 4x4x4 array unrefl. walls, floor, & tank  0.9787  0.0032  1.92820E-01
cas65          uo2(no3)2 415 g U/L 2x2x2 array unrefl.  walls, floor, & tank 0.9855  0.0030  1.86427E-01
cas66          uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p 0.9823  0.0032  1.62225E-01
cas67          uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 2.54 cm p 0.9955  0.0029  1.42671E-01
cas68          uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p 0.9882  0.0032  1.56155E-01
cas69          uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par 5 fc, plex 1 fc  1.0040  0.0029  1.08541E-01
cas70          uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 3.81 cm p 0.9985  0.0030  1.21692E-01
cas71          uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 7.62 cm p 1.0158  0.0035  1.11321E-01
cas72          uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm plexiglass refl.      0.9836  0.0027  1.72521E-01
cas73          uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm paraffin refl.        0.9847  0.0032  1.65077E-01
cas74          uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm paraffin refl.       1.0056  0.0031  1.09818E-01
cas75          uo2(no3)2 415 g U/L 3x3x3 array 3.81 cm paraffin refl.        1.0054  0.0034  1.24189E-01
cas76          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p 0.9846  0.0031  1.57781E-01
cas77          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 11.43 cm  1.0068  0.0031  1.08926E-01
cas78          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 15.24 cm  1.0064  0.0032  1.07953E-01
cas79          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 2.54 cm p 0.9900  0.0033  1.42225E-01
cas80          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 4.45 cm p 1.0040  0.0029  1.23314E-01
cas81          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 6.35 cm p 1.0040  0.0032  1.14418E-01
cas82          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p 0.9908  0.0029  1.52040E-01
cas83          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 3.81 cm p 1.0000  0.0032  1.20155E-01
cas84          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 7.62 cm p 0.9982  0.0030  1.09533E-01
cas85          uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm plexiglass refl.      0.9863  0.0029  1.69409E-01
cas86          uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm paraffin refl.        0.9857  0.0029  1.61786E-01
cas87          uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm paraffin refl.       1.0037  0.0033  1.07370E-01
cas88          uo2(no3)2 415 g U/L 2x2x2 array 3.81 cm paraffin refl.        1.0038  0.0027  1.22459E-01
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cas89      uo2(no3)2 415 g U/L 2x2x2 array 7.62 cm paraffin refl.      1.0065   0.0032   1.09826E-01
cas90      uo2(no3)2 415 g U/L 3x3x3 array unrefl. 279 g U/L 5 cent. uni 0.9784  0.0032   1.53642E-01
cas91      uo2(no3)2 63.3 g U/L 3x3x3 array unrefl. walls, floor, & tank 0.9952  0.0030   1.90523E-02
jemima     disks - 15" diam plates 93.15 w% enriched stacked to 3.0258" 0.9962  0.0024   8.21013E+05
jemima     jemima - ~1/8" x 15" diam u(93.29) plates with 1/16" thk poly 1.0133  0.0025   1.15950E+05
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1/8" thk pol 1.0147  0.0027   2.03747E+04
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1/4" thk pol 0.9936  0.0026   2.35579E+03
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1/2" thk pol 0.9987  0.0026   1.09210E+02
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1" thk poly 0.9923   0.0026   6.83616E+00
jemima     jemima - ~1/8" x 15" dia u(93) with symetric 1-1/2" thk poly, 1.0224  0.0026   2.39521E+00
jemima     jemima - ~1/8" x 15" dia u(93) with symetric 2" thk poly, pg- 1.0088  0.0024   1.35447E+00
heumf001   godiva                                                        0.9968   0.0022   8.11167E+05
heumf004   water-reflected heu sphere on hollow plexiglas cylinder       1.0040   0.0019   2.49125E+04
heust001   case 1 heust001                                               0.9820   0.0026   3.91734E-02
heust001   case 2 heust001                                               0.9753   0.0027   1.60525E-01
heust001   case 3 heust001                                               0.9849   0.0029   3.84310E-02
heust001   case 4 heust001                                               0.9816   0.0027   1.74350E-01
heust001   case 5 heust001                                               0.9898   0.0023   1.86292E-02
heust001   case 6 heust001                                               0.9935   0.0022   1.93724E-02
heust001   case 7 heust001                                               0.9810   0.0025   3.68972E-02
heust001   case 8 heust001                                               0.9816   0.0021   3.92983E-02
heust001   case 9 heust001                                               0.9736   0.0026   1.73976E-01
heust001   case 10 heust001                                              0.9858   0.0022   2.01686E-02
heust007   case 1 , heust007                                             0.9992   0.0022   2.08291E-02
heust007   case 2 , heust007                                             0.9928   0.0021   1.52516E-01
heust007   case 3 , heust007                                             1.0012   0.0017   2.02094E-02
heust007   case 4 , heust007                                             0.9962   0.0021   1.31990E-01
heust007   case 5 , heust007                                             0.9935   0.0019   2.23399E-02
heust007   case 6 , heust007                                             0.9821   0.0022   1.57065E-01
heust007   case 7 , heust007                                             0.9948   0.0022   2.19533E-02
heust007   case 8 , heust007                                             0.9848   0.0027   1.53818E-01
heust007   case 9 , heust007                                             0.9927   0.0019   2.28056E-02
heust007   case 10 , heust007                                            0.9977   0.0017   2.36936E-02
heust007   case 11 , heust007                                            0.9916   0.0019   1.44416E-01
heust007   case 12 , heust007                                            1.0024   0.0020   2.26783E-02
heust007   case 13 , heust007                                            1.0000   0.0021   1.27157E-01
heust007   case 14 , heust007                                            0.9902   0.0022   1.33280E-01
heust007   case 15 , heust007                                            0.9913   0.0021   1.33863E-01
heust007   case 16 , heust007                                            0.9890   0.0022   1.44398E-01
heust007   case 17 , heust007                                            0.9900   0.0020   1.33672E-01
heust013   uranium aqueous 23 cm sphere #1                               1.0063   0.0017   1.34537E-02
heust013   uranium aqueous 32 cm sphere #2                               1.0038   0.0015   1.41402E-02
heust013   uranium aqueous 32 cm sphere #3                               0.9979   0.0017   1.48319E-02
heust013   uranium aqueous 32 cm sphere #4                               0.9961   0.0015   1.51659E-02
```

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                        Hansen-Roach_Low-Enriched_Uranium
Case              Title                                            k-eff    sigma      EALF
----------   ----------------------------------------------------  ------   ------   ------------
car04      rocky flats criticals nureg/cr-1071 experiment number 13 (27 1.0176  0.0022   2.54486E-01
car10      rocky flats criticals nureg/cr-0674 concrete reflected (27 gr 1.0017  0.0029   4.41936E+00
cas04      british handbook of criticality safety u(1.42)f4 & paraffin ( 0.9943  0.0016   5.98346E-02
cas05      british handbook of criticality safety u(1.42)f4 & paraffin ( 0.9934  0.0018   6.02642E-02
cas06      british handbook of criticality safety u(1.42)f4 & paraffin ( 0.9970  0.0016   6.01956E-02
cas11      raffety and malhalczo u(2)f4-1 reflected (case 11)            1.0071   0.0022   1.02945E-01
cas12      raffety and malhalczo u(2)f4-1 unreflected (case12)           1.0001   0.0019   1.31206E-01
cas13      raffety and malhalczo u(2)f4-2 reflected (case 13) no biasing 1.0064  0.0021   5.75211E-02
cas14      raffety and malhalczo u(2)f4-2 unreflected (case 14)          0.9993   0.0019   6.83002E-02
cas15      raffety and malhalczo u(2)f4-3 reflected (case 15)            0.9959   0.0020   4.01377E-02
cas16      raffety and malhalczo u(2)f4-4 reflected (case 16)            0.9941   0.0019   3.34136E-02
cas17      raffety and malhalczo u(2)f4-5 reflected (case 17)            0.9945   0.0019   2.81481E-02
cas18      raffety and malhalczo u(2)f4-5 unreflected (case18)           0.9867   0.0019   3.04016E-02
cas19      raffety and malhalczo u(2)f4-6 reflected (case 19)            0.9922   0.0016   2.13396E-02
cas20      raffety and malhalczo u(2)f4-6 unreflected (case20)           0.9868   0.0018   2.19281E-02
cas21      raffety and milhalczo u(3)f4-1 reflected (case 21) no bias    1.0089   0.0022   1.21645E-01
cas22      raffety and malhalczo u(3)f4-1 reflected (case 22)            1.0142   0.0024   1.22539E-01
cas23      raffety and malhalczo u(3)f4-1 reflected (case 23)            1.0115   0.0025   1.23546E-01
cas24      raffety and malhalczo u(3)f4-1 reflected (case 24) no biasing 1.0105  0.0022   1.22432E-01
cas25      raffety and malhalczo u(3)f4-1 reflected (case 25)            1.0092   0.0024   1.21949E-01
cas26      raffety and malhalczo u(3)f4-1 unreflected (case 26)          1.0123   0.0026   1.82095E-01
cas27      raffety and malhalczo u(3)f4-1 unreflected (case 27)          0.9985   0.0027   1.84934E-01
cas28      raffety and malhalczo u(3)f4-1 unreflected (case 28)          1.0056   0.0022   1.84011E-01
cas29      raffety and malhalczo u(3)f4-2 reflected (cas29)              0.9994   0.0025   4.46403E-02
cas30      raffety and malhalczo u(3)f4-2 unreflected (case 30)          1.0003   0.0024   5.47192E-02
cas31      raffety and malhalczo u(3)f4-2 unreflected (case 31)          1.0035   0.0024   5.46609E-02
cas32      raffety and malhalczo u(3)f4-2 unreflected (case 32)          1.0001   0.0023   5.47027E-02
cas33      critical reflected cylinder of aqueous u(4.98)o2f2 (case 33)  0.9910   0.0022   2.52174E-02
cas34      critical reflected cylinder of aqueous u(4.98)o2f2 (case 34)  0.9901   0.0023   2.50841E-02
cas35      critical sphere of aqueous u(4.98)o2f2 (case 35)             0.9919   0.0027   2.49452E-02
cas36      critical cylinder of aqueous u(4.98)o2f2 (case 36)           0.9881   0.0025   2.51360E-02
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                          Hansen-Roach_LWR_Lattices
Case                Title                                          k-eff   sigma     EALF
----------  --------------------------------------------------    ------  ------  ------------
cas01       exp#5, 8.39 cm h2o separating 3 20x16 arrays          1.0016  0.0015  4.01212E-02
cas02       exp#017, 5.05 cm h2o/boral separating 2 22x16 arrays and 1 20  0.9999  0.0012  4.16543E-02
cas03       exp#28, 6.88 cm h2o/ss separating 3 20x16 arrays      1.0022  0.0016  4.06589E-02
cas04       exp no. 14 8.58 cm h2o/ss separating 3 15x8 arrays    0.9993  0.0014  4.59885E-02
cas05       exp no. 23 7.28 cm h2o/cadmium separating 3 15x8 arrays  1.0015  0.0016  4.58746E-02
cas06       exp no. 31 6.72 cm h2o/boral separating 3 15x8 arrays  1.0054  0.0018  4.60670E-02
cas07       u refl. 1.956 cm from array,   14.11 cm h2o separating 3 19x1  0.9993  0.0015  7.58374E-02
cas08       pb refl. .660 cm from array, 13.72 cm h2o separating 3 19x16  1.0084  0.0015  4.11320E-02
cas09       no refl. 8.31cm h2o separating 19x16 arrays           1.0003  0.0017  4.00471E-02
cas10       uranium refl. 15.32cm h2o separating 12x8  arrays     1.0010  0.0017  1.15835E-01
cas11       lead refl. 20.78cm h2o separating 13x8  arrays        1.0151  0.0008  4.73598E-02
cas12       2.83cm and 3.60cm separating 4 11x14 arrays           0.9969  0.0017  1.55706E-01
cas13       2.83cm and 4.94cm separating 2 11x14 + 2 11x16 arrays  0.9955  0.0012  1.57698E-01
cas14       ss refl. 0.66 cm from array, 11.20 cm h2o separating 3 19x16  1.0040  0.0015  4.19563E-02
cas15       steel refl. 15.84cm h2o separating 3 12x16 arrays     0.9938  0.0020  1.37992E-01
cas16       steel refl.  9.83cm h2o separating 3 12x16 arrays  w/borated   0.9947  0.0017  1.47802E-01
cas17       steel refl.  8.30cm h2o separating 3 12x16 arrays  w/boral pl  0.9995  0.0018  1.47371E-01
cas18       steel refl.  8.94cm h2o separating 3 12x16 arrays  w/cd plate  0.9966  0.0011  1.48039E-01
cas19       u refl 1.321 cm from array, 9.50 cm h2o sep. 23x18/2-20x18 ar  0.9934  0.0014  1.62719E-01
cas20       pb refl 0.660 cm from array, 10.11 cm h2o sep. 23x18/2-20x18  1.0005  0.0016  7.83753E-02
cas21       no refl infinite from array, 6.59 cm h2o sep. 23x18/2-20x18 a  0.9958  0.0016  7.26904E-02
cas22       uranium refl. 19.24cm h2o separating 12x16 arrays     0.9948  0.0017  2.48751E-01
cas23       lead refl. 18.18cm h2o separating 12x16 arrays        0.9979  0.0015  1.42233E-01
cas24       no refl. 12.91cm h2o separating 3 12x16 arrays        0.9951  0.0018  1.29982E-01
cas25       pnl-4267 exp. 173 40 x 8.92 array (357 total rods) boron = 0   0.9938  0.0011  1.33170E-01
cas26       pnl-4267 exp.177 40 x 30.92 array 1237 total rods) boron = 2.  1.0121  0.0014  3.24686E-01
cas27       pnl-4267 exp. 178 44 x 11.57array (509 total rods) boron = 0   0.9921  0.0013  2.75387E-01
cas28       pnl-4267 exp. 181 44 x 27.09 array (1192 total rods) boron =   0.9972  0.0017  6.94395E-01
cas29       pnl-4976 4.3-000-194 4.3%uo2 1.598cm-pitch            1.0033  0.0014  2.33139E+00
cas30       flux trap assembly no. 214r                           0.9925  0.0016  1.86083E-01
cas31       flux trap assembly no. 214v3                          0.9904  0.0013  1.88319E-01
cas32       baw-1231 core i 936 rods  boron=1.152 g/l             0.9937  0.0011  4.13858E-01
cas33       baw-1231 core i 4904 rods  boron=3.389 g/l            1.0039  0.0009  7.19295E-01
cas34       baw-1273 core xx           2.46 wt%u235   5137 rods   1.0067  0.0013  2.81765E-01
cas35       baw-1484-7 core iv exp 2282  2.46 wt%u235   9 assys 14x14 w/ 8  0.9954  0.0012  8.97058E-02
cas36       baw-1484-7 core ix exp 2321  2.46 wt%u235   9 assys 14x14       1.0012  0.0014  6.01269E-02
cas37       baw-1484-7 core xiii exp 2378  2.46 wt%u235   9 assys 14x14     0.9935  0.0016  9.30151E-02
cas38       baw-1484-7 core xxi exp 2420   2.46 wt%u235   9 assys 14x14     1.0014  0.0014  6.85769E-02
cas39       baw-1645-4 exp,mt=2452  triangular pitch=o.d.     boron=435ppm  1.0078  0.0009  1.42185E+00
cas40       baw-1645-4 exp,mt=2485   pitch=o.d.     boron=886ppm  1.0067  0.0015  8.44659E-01
cas41       baw-1645-4 exp,mt=2500   pitch=1.17*o.d.     boron=1156ppm      1.0119  0.0015  2.11017E-01
cas42       baw-1810 core 12 - 4.02 & 2.46 w/o uo2 1899.3 ppm; no uo2-gd2   1.0105  0.0012  1.78132E-01
cas43       baw-1810 core 14 - 4.02 & 2.46 w/o uo2 1654 ppm; 28 uo2-gd2o3   1.0110  0.0013  1.69295E-01
cas44       baw-1810 core 16 - 4.02 & 2.46 w/o uo2 1579 ppm; 36 uo2-gd2o3   1.0089  0.0012  1.62736E-01
cas45       epri np-196 .615 inch pitch unborated uo2             0.9944  0.0015  1.26813E-01
cas46       epri np-196 .615 inch pitch borated uo2               0.9980  0.0014  1.61003E-01
cas47       epri np-196 .75 inch pitch unborated uo2              0.9956  0.0014  4.96818E-02
cas48       epri np-196 .75 inch pitch borated uo2                1.0086  0.0009  6.33596E-02
cas49       epri np-196 .87 inch pitch unborated uo2              1.0086  0.0014  3.38758E-02
cas50       epri np-196 .87 inch pitch borated uo2                1.0155  0.0015  3.84836E-02
cas51       saxton uo2 5.742 wt% u-235 critical exp. 0.56 inch pitch (wca   0.9856  0.0017  1.45548E-01
cas52       saxton uo2 5.742 wt% u-235 critical exp. 0.792inch pitch (wca   1.0000  0.0013  4.16089E-02
cas53       wcap-3269-39, 2692 fuel rods, 16 ag-in-cd rods,h2o ht=115.55    0.9999  0.0010  3.92248E-01
cas54       wcap-3269-39, 2209 fuel rods, 24 ag-in-cd rods,h2o ht=64.56 c   0.9992  0.0014  2.32561E-01
cas55       wcap-3269-39,  945 fuel rods, 16 ag-in-cd rods,h2o ht=89.75     0.9918  0.0010  1.25826E-01
cas56       4-18x18 array 5.0cm int.,polyethylene powder in box,30.16cm h   0.9892  0.0014  1.08875E-01
cas57       4-18x18 array 5.0cm int.,polyethylene balls in box,30.73cm h2   1.0036  0.0013  9.73983E-02
cas58       4-18x18 array 5.0cm int.,water in box,32.78cm h2o height        1.0108  0.0013  9.06123E-02
cas59       4-18x18 array 5.0cm int.,water without box,31.47cm h2o height   0.9955  0.0012  9.17513E-02


                          Hansen-Roach_Mixed_Oxide
Case                Title                                          k-eff   sigma     EALF
----------  --------------------------------------------------    ------  ------  ------------
cas60       epri .70inch pitch unborated plutonium                0.9963  0.0016  2.88863E-01
cas61       epri .70inch pitch borated plutonium                  0.9978  0.0017  4.11172E-01
cas62       epri .87inch pitch unborated plutonium                1.0027  0.0012  8.54599E-02
cas63       epri .87inch pitch borated plutonium                  1.0178  0.0013  1.32185E-01
cas64       epri .99inch pitch unborated plutonium                1.0079  0.0015  5.77115E-02
cas65       epri .99inch pitch borated plutonium                  1.0237  0.0010  7.98822E-02
cas66       saxton puo2-uo2 critical exp. 0.52 inch pitch (wcap-3385-54)    0.9920  0.0013  4.66612E-01
cas67       saxton puo2-uo2 critical exp. 0.56 inch pitch (wcap-3385-54)    0.9882  0.0019  2.77775E-01
cas68       saxton puo2-uo2 critical exp. 0.56 inch pitch with boron (wca   0.9920  0.0017  3.37919E-01
cas69       saxton puo2-uo2 critical exp. 0.735 inch pitch (wcap-3385-54)   1.0008  0.0018  8.16982E-01
cas70       saxton puo2-uo2 critical exp. 0.792 inch pitch (wcap-3385-54)   1.0050  0.0018  6.52434E-02
cas71       saxton puo2-uo2 critical exp. 01.04 inch pitch (wcap-3385-54)   1.0148  0.0022  3.77593E-02
cas72       pnl4976 exp196 1174 uo2 & 583 mo2 rods to approx. 20,000 mwd/   0.9929  0.0015  2.80791E+00
cas73       exp.no 021(063) pitch=968 (fuel region = pin array + mix 500    0.9886  0.0012  4.79901E-01
cas74       exp.no 032(060) pitch=1.935(fuel region=pin array+mix 500 wit   1.0092  0.0017  4.26464E-02
cas75       exp.no 043(062) pitch=1.242(fuel region=pin array+mix 500 wit   0.9907  0.0013  1.35829E-01
cas76       exp.no 067 pitch=0.761 (fuel region = pin array + mix 500 wit   0.9860  0.0012  1.74172E+00
cas77       exp. no 68r pitch=1.537 (fuel region = pin array + mix 500 wi   0.9999  0.0017  6.98325E-02
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                              Hansen-Roach_Plutonium
Case                 Title                                              k-eff   sigma     EALF
----------  ---------------------------------------------------------- ------  ------  -----------
1727_09     la-3067-msr table iiia1, entry 13, water ref., metal, pu sphe  0.9989  0.0038  7.58773E+04
2109_20     benchmark 20, pu sphere with 25.4 cm concrete ref. h/pu=684.3  1.0103  0.0037  3.27775E-02
2109_21     benchmark 21, pu sphere with 10.16 cm concrete ref. h/pu=684.  1.0122  0.0040  3.15817E-02
2109_22     benchmark 22, pu sphere with 10.16 cm concrete ref. h/pu=496   1.0217  0.0034  3.96408E-02
2109_23     benchmark 23, pu sphere with cd shell & 10.16 cm concrete ref  1.0207  0.0037  4.42417E-02
2109_24     benchmark 24, pu sphere with cd shell & 32.00 cm water, h/pu=  1.0029  0.0038  3.82479E-02
2109_25     pu benchmark 25 from 2109, pu metal sphere reflected with nat  1.0105  0.0045  1.10321E+06
2110_02     benchmark#2 critical pu(no3)4solution, unreflected in a ss(ty  1.0057  0.0041  1.76977E-01
2110_04     sphere described by keno geometry                             1.0080  0.0053  2.97914E-02
2110_05     rectangular parallelpipeds of homogeneous pu(2.2)o2           1.0314  0.0052  2.66686E+01
2110_06     rectangular parallelipiped of pu(2.2)o2 reflected with 15cm p  1.0395  0.0059  3.28196E+00
2110_07     benchmark#7 semi-inf homogeneous critical solution of pu-239  1.0061  0.0038  4.57238E-02
2110_08     rectangular parallelipiped of puo2                            1.0134  0.0039  9.58870E-01
2110_09     rectangular parallelipipeds of pu02                           1.0175  0.0044  3.87028E-01
2110_10     rectangular parallelipipeds of pu02                           1.0197  0.0046  3.71340E-01
2110_11     rectangular parallelipipeds of pu02                           1.0209  0.0044  3.73535E-01
2110_12     rectangular parallelipipeds of pu02                           1.0202  0.0043  3.70099E-01
2110_13     sphere described by keno geometry                             0.9955  0.0044  1.21372E+06
2110_14     cylinder described by keno geometry                           1.0006  0.0048  7.59820E-02
2110_15     rectangular parallelipipeds of puo2-h20                       1.0256  0.0052  2.34687E+05
2110_16     rectangular parallelipipeds of puo2-h20                       1.0452  0.0034  9.22063E+05
2110_17     rectangular parallelipipeds of puo2-h20                       1.0326  0.0036  1.42087E+03
2110_18     rectangular parallelipipeds of puo2-h20                       1.0433  0.0038  3.24817E+03
2110_19     rectangular parallelipipeds of puo2-h20                       1.0086  0.0032  3.99149E+03
2110_20     rectangular parallelipipeds of puo2-h20                       1.0339  0.0038  1.95737E+03
2110_21     rectangular parallelipipeds of puo2-h20                       1.0510  0.0037  1.53926E+03
2110_23     rectangular parallelipipeds of puo2-polystyrene               1.0274  0.0057  1.59507E+03
2110_24     rectangular parallelipipeds of puo2-polystyrene               1.0367  0.0033  7.07344E+01
2110_25     rectangular parallelipipeds of puo2-polystyrene               1.0333  0.0036  6.23229E+01
2110_26     rectangular parallelipipeds of puo2-polystyrene               1.0278  0.0034  4.93146E+01
2110_27     rectangular parallelipipeds of puo2-polystyrene               1.0392  0.0032  4.15995E+01
2110_29     cylinder described by keno geometry                           1.0257  0.0037  2.59491E-02
2110_30     sphere described by keno geometry                             1.0112  0.0050  2.32226E-02
2110_32     sphere described by keno geometry                             0.9986  0.0050  2.42950E-02
pumf001     read parameters                                               0.9962  0.0022  1.20071E+06
pumf002     pu-met-fast-002                                               1.0063  0.0023  1.20410E+06
pust004     case 1,kvpusolnsphexp,27gp,26.27gpU/L, 0.54w/o240,h2orefl,14i  1.0020  0.0020  2.43301E-02
pust009     case 3a,kvpusolnsphexp,27,9.457gpU/L, 2.5w/o240,bare,48in dia  1.0365  0.0011  1.71242E-02


                              Hansen-Roach_U-233
Case                 Title                                              k-eff   sigma     EALF
----------  ---------------------------------------------------------- ------  ------  -----------
u233mf001   unreflected u233 sphere                                       1.0051  0.0021  9.96734E+05
u233mf002   case 1, 10 kg u233/heu sphere, ref u233-met-fast-002          1.0030  0.0021  9.42421E+05
u233mf002   case 2, 7.6 kg u233/heu sphere, ref u233-met-fast-002         1.0006  0.0020  9.73504E+05
u233mf003   case 1, 10 kg u233 sphere natural uranium reflector, ref u233  1.0000  0.0024  9.71277E+05
u233mf003   case 2, 7.6 kg u233 sphere natural uranium reflector, ref u23  1.0001  0.0020  9.70456E+05
u233mf004   case 1, 10 kg u233 sphere reflected by tungsten               0.9913  0.0019  8.87722E+05
u233mf005   case 1, 10 kg u233 sphere be reflector, ref u233-met-fast-xxx  1.0127  0.0023  8.42475E+05
u233mf006   u-233/nu sphere                                               0.9951  0.0025  9.62912E+05
u233st002   exp 4 simplified model                                        0.9930  0.0030  8.88939E-02
u233st002   exp 5 simplified model                                        0.9769  0.0029  6.63200E-02
u233st002   exp 8 simplified model                                        0.9977  0.0028  5.06006E-02
u233st002   exp 10 simplified model                                       0.9966  0.0029  3.99158E-02
u233st002   exp 11 simplified model                                       1.0029  0.0028  3.39182E-02
u233st002   exp 12 simplified model                                       0.9890  0.0031  2.98367E-02
u233st002   exp 14 simplified model                                       0.9814  0.0028  2.80096E-02
u233st002   exp 15 simplified model                                       0.9945  0.0026  2.53109E-02
u233st002   exp 17 simplified model                                       0.9837  0.0026  2.25552E-02
u233st002   exp 18 simplified model                                       0.9912  0.0028  2.17131E-02
u233st002   exp 19 simplified model                                       1.0078  0.0023  1.99151E-02
u233st002   exp 22 simplified model                                       0.9740  0.0031  1.47011E-01
u233st002   exp 24 simplified model                                       0.9733  0.0034  2.72694E-01
u233st002   exp 34 simplified model                                       0.9893  0.0034  6.96272E-02
u233st002   exp 35 simplified model                                       0.9978  0.0029  4.52550E-02
u233st002   exp 36 simplified model                                       0.9967  0.0028  2.84089E-02
u233st002   exp 38 simplified model                                       1.0044  0.0025  2.37650E-02
u233st004   exp 3 simplified model                                        0.9923  0.0033  8.79058E-02
u233st004   exp 6 simplified model                                        0.9927  0.0030  6.54092E-02
u233st004   exp 20 simplified model                                       0.9821  0.0035  1.46772E-01
u233st004   exp 25 simplified model                                       0.9684  0.0030  2.76581E-01
u233st004   exp 30 simplified model                                       0.9775  0.0033  2.13731E-01
u233st004   exp 27 simplified model                                       0.9897  0.0032  2.74376E-01
u233st004   exp 28 simplified model                                       0.9871  0.0032  2.11394E-01
u233st004   exp 33 simplified model                                       0.9923  0.0032  6.90990E-02
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                              218-Group_High-Enriched_Uranium
Case                  Title                                               k-eff   sigma      EALF
----------   -------------------------------------------------------     ------  ------   -----------
cas04        keno-5 validation case a-2                                  1.0056  0.0021   8.57235E+05
cas05        keno-5 validation case a-3                                  0.9975  0.0019   2.11803E-02
cas07        keno-5 validation case a-5                                  1.0093  0.0025   1.49343E+03
cas08        keno-5 validation case a-6                                  0.9748  0.0026   2.46935E+05
cas09        keno-5 validation case a-7                                  1.0074  0.0019   8.04930E+05
cas10        keno-5 validation case a-8                                  1.0009  0.0026   4.48635E+03
cas11        keno-5 validation case a-9                                  0.9954  0.0023   1.34541E+04
cas12        keno-5 validation case b-1                                  0.9948  0.0025   9.43110E+05
cas14        keno-5 validation case b-11                                 1.0515  0.0026   3.51906E-01
cas15        keno-5 validation case b-12                                 0.9993  0.0022   4.27514E+04
cas19        keno-5 validation case b-16                                 1.0315  0.0041   4.43410E-01
cas22        keno-5 validation case b-2                                  1.0080  0.0024   9.35405E+05
cas23        keno-5 validation case b-3                                  0.9977  0.0022   9.39647E+05
cas24        keno-5 validation case b-4                                  0.9929  0.0021   9.49648E+05
cas25        keno-5 validation case b-5                                  1.0029  0.0023   9.39287E+05
cas26        keno-5 validation case b-6                                  0.9959  0.0022   8.36677E+03
cas27        keno-5 validation case b-7                                  1.0034  0.0023   6.66272E+03
cas28        keno-5 validation case b-8                                  1.0022  0.0025   6.19139E+04
cas30        93.2% uo2f2 3 in al slab 3x1x1 array 0 in sep room          1.0019  0.0032   3.68823E-02
cas31        93.2% uo2f2 3 in al slab 3x1x1 array 0 in sep h2o refl      0.9965  0.0030   3.39431E-02
cas32        93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep room          0.9829  0.0028   3.71593E-02
cas33        93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep h2o refl      0.9955  0.0030   3.13895E-02
cas34        93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep room          0.9786  0.0034   3.75107E-02
cas35        93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep h2o refl      0.9894  0.0028   3.07313E-02
cas36        93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep room        0.9847  0.0029   3.76951E-02
cas37        93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep h2o refl    0.9978  0.0028   3.07684E-02
cas38        93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep room        0.9904  0.0029   3.75307E-02
cas39        93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep h2o refl    0.9983  0.0027   3.10940E-02
cas40        93.2% uo2f2 3 in al slab 3x1x1 array 6 in sep room          0.9875  0.0030   3.77210E-02
cas41        93.2% uo2f2 3, 6 in al slabs 2x1x1 array 15 in sep          0.9862  0.0029   3.72357E-02
cas42        93.2% uo2f2 3, 6 in al slabs 2x1x1 array 2 in sep           0.9761  0.0031   3.70742E-02
cas43        93.2% uo2f2 3, 6 in al slabs 2x1x1 array 30 in sep          0.9808  0.0032   3.72255E-02
cas44        93.2% uo2f2 3, 6 in al slabs 2x1x1 array 48 in sep          0.9769  0.0028   3.70845E-02
cas45        93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 0 in sep        0.9782  0.0031   3.70304E-02
cas46        93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 10 in sep       0.9799  0.0034   3.75152E-02
cas47        93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 20 in sep       0.9839  0.0032   3.73240E-02
cas48        93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 32 in sep       0.9809  0.0034   3.73044E-02
cas49        93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 12 in sep         0.9897  0.0029   3.73073E-02
cas50        93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 18 in sep         0.9850  0.0029   3.74113E-02
cas51        93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 30 in sep         0.9826  0.0030   3.73340E-02
cas52        93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 6 in sep          0.9874  0.0027   3.73524E-02
cas53        93.2% uo2f2 6 in al slab 2x1x1 array 15 in sep              0.9847  0.0030   3.72580E-02
cas54        93.2% uo2f2 6 in al slab 2x1x1 array 2 in sep               0.9803  0.0036   3.71434E-02
cas55        93.2% uo2f2 6 in al slab 2x1x1 array 20 in sep              0.9870  0.0028   3.71939E-02
cas56        93.2% uo2f2 6 in al slab 2x1x1 array 30 in sep              0.9842  0.0029   3.70609E-02
cas57        93.2% uo2f2 6 in al slab 2x1x1 array 48 in sep              0.9820  0.0031   3.71613E-02
cas58        93.2% uo2f2 6 in al slab 2x1x1 array 6 in sep               0.9820  0.0025   3.74674E-02
cas59        93.2% uo2f2 6 in al slab 2x1x1 array 66 in sep              0.9845  0.0034   3.70261E-02
cas60        uo2(no3)2 279 g U/L 3x3x3 array unrefl. walls, tank, & floor 0.9893 0.0032   1.35560E-01
cas61        uo2(no3)2 279 g U/L 2x2x2 array unrefl. walls, tank, & floor 1.0094 0.0030   1.30203E-01
cas62        uo2(no3)2 415 g U/L 5x5x5 array unrefl. walls, tank, & floor 0.9989 0.0029   2.84541E-01
cas63        uo2(no3)2 415 g U/L 3x3x3 array unrefl. walls, tank, & floor 0.9990 0.0030   2.87533E-01
cas64        uo2(no3)2 415 g U/L 4x4x4 array unrefl. walls, floor, & tank 0.9940 0.0033   2.89598E-01
cas65        uo2(no3)2 415 g U/L 2x2x2 array unrefl.  walls, floor, & tank 1.0054 0.0028  2.76754E-01
cas66        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p 1.0036 0.0032  2.47625E-01
cas67        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 2.54 cm p 1.0111 0.0030  2.21864E-01
cas68        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p 1.0076 0.0031  2.37434E-01
cas69        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par 5 fc, plex 1 fc  1.0163 0.0035  1.80759E-01
cas70        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 3.81 cm p 1.0218 0.0029  1.94018E-01
cas71        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 7.62 cm p 1.0239 0.0029  1.83646E-01
cas72        uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm plexiglass refl.      0.9943 0.0030  2.59663E-01
cas73        uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm paraffin refl.        1.0048 0.0027  2.49685E-01
cas74        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm paraffin refl.       1.0184 0.0035  1.83359E-01
cas75        uo2(no3)2 415 g U/L 3x3x3 array 3.81 cm paraffin refl.        1.0215 0.0030  1.98010E-01
cas76        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p 1.0097 0.0034  2.41320E-01
cas77        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 11.43 cm  1.0211 0.0031  1.81104E-01
cas78        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 15.24 cm  1.0233 0.0036  1.78291E-01
cas79        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 2.54 cm p 1.0134 0.0033  2.19405E-01
cas80        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 4.45 cm p 1.0167 0.0030  1.98364E-01
cas81        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 6.35 cm p 1.0219 0.0031  1.87721E-01
cas82        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p 1.0147 0.0028  2.31556E-01
cas83        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 3.81 cm p 1.0145 0.0029  1.95659E-01
cas84        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 7.62 cm p 1.0143 0.0033  1.82143E-01
cas85        uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm plexiglass refl.      1.0041 0.0031  2.56820E-01
cas86        uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm paraffin refl.        1.0055 0.0033  2.46967E-01
cas87        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm paraffin refl.       1.0173 0.0029  1.78054E-01
cas88        uo2(no3)2 415 g U/L 2x2x2 array 3.81 cm paraffin refl.        1.0128 0.0029  1.97267E-01
cas89        uo2(no3)2 415 g U/L 2x2x2 array 7.62 cm paraffin refl.        1.0179 0.0029  1.83059E-01
cas90        uo2(no3)2 415 g U/L 3x3x3 array unrefl. 279 g U/L 5 cent. uni 0.9990 0.0031  2.34043E-01
cas91        uo2(no3)2 63.3 g U/L 3x3x3 array unrefl. walls, floor, & tank 1.0003 0.0030  3.02549E-02
jemima       disks - 15" diam plates 93.15 w% enriched stacked to 3.0258" 1.0028 0.0021  9.48314E+05
jemima       jemima - ~1/8" x 15" diam u(93.29) plates with 1/16" thk poly 0.9953 0.0025  1.23178E+05
jemima       jemima - ~1/8" thk 15" diam u(93.24) plates with 1/8" thk pol 1.0062 0.0022  1.91947E+04
jemima       jemima - ~1/8" thk 15" diam u(93.24) plates with 1/4" thk pol 0.9863 0.0023  1.90790E+03
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jemima      jemima - ~1/8" thk 15" diam u(93.24) plates with 1/2" thk pol    1.0124   0.0030   9.54148E+01
jemima      jemima - ~1/8" thk 15" diam u(93.24) plates with 1" thk poly,    1.0007   0.0032   7.97240E+00
jemima      jemima - ~1/8" x 15" dia u(93) with symetric 1-1/2" thk poly,    1.0054   0.0025   3.47882E+00
jemima      jemima - ~1/8" x 15" dia u(93) with symetric 2" thk poly, pg-    1.0024   0.0024   2.16156E+00
heumf001    read parameters                                                  1.0055   0.0021   9.24612E+05
heumf004    water-reflected heu sphere on hollow plexiglas cylinder          1.0054   0.0020   3.14659E+04
heust001    case 1 heust001                                                  1.0058   0.0022   6.18678E-02
heust001    case 2 heust001                                                  1.0053   0.0029   2.38542E-01
heust001    case 3 heust001                                                  1.0055   0.0025   6.07781E-02
heust001    case 4 heust001                                                  1.0062   0.0029   2.55761E-01
heust001    case 5 heust001                                                  1.0055   0.0019   2.94557E-02
heust001    case 6 heust001                                                  1.0116   0.0023   3.07806E-02
heust001    case 7 heust001                                                  1.0062   0.0024   5.83064E-02
heust001    case 8 heust001                                                  1.0055   0.0030   6.17842E-02
heust001    case 9 heust001                                                  1.0037   0.0025   2.55768E-01
heust001    case 10 heust001                                                 0.9973   0.0023   3.20292E-02
heust007    case 1 , heust007                                                1.0141   0.0021   3.30667E-02
heust007    case 2 , heust007                                                1.0139   0.0023   2.31938E-01
heust007    case 3 , heust007                                                1.0111   0.0021   3.22024E-02
heust007    case 4 , heust007                                                1.0189   0.0022   2.02858E-01
heust007    case 5 , heust007                                                1.0102   0.0021   3.54239E-02
heust007    case 6 , heust007                                                1.0062   0.0025   2.36377E-01
heust007    case 7 , heust007                                                1.0096   0.0021   3.49131E-02
heust007    case 8 , heust007                                                1.0080   0.0019   2.32824E-01
heust007    case 9 , heust007                                                1.0101   0.0020   3.64053E-02
heust007    case 10 , heust007                                               1.0143   0.0019   3.77483E-02
heust007    case 11 , heust007                                               1.0077   0.0021   2.21192E-01
heust007    case 12 , heust007                                               1.0143   0.0021   3.62600E-02
heust007    case 13 , heust007                                               1.0138   0.0021   1.98880E-01
heust007    case 14 , heust007                                               1.0120   0.0026   2.04744E-01
heust007    case 15 , heust007                                               1.0105   0.0023   2.05797E-01
heust007    case 16 , heust007                                               1.0078   0.0021   2.21208E-01
heust007    case 17 , heust007                                               1.0089   0.0023   2.05418E-01
heust008    case 1 , heust008                                                0.9989   0.0019   3.06830E-02
heust008    case 2 , heust008                                                1.0046   0.0022   2.01218E-01
heust008    case 3 , heust008                                                0.9962   0.0021   2.98479E-02
heust008    case 4 , heust008                                                0.9990   0.0023   1.78648E-01
heust008    case 5 , heust008                                                0.9995   0.0019   3.06064E-02
heust008    case 6 , heust008                                                1.0024   0.0025   2.19197E-01
heust008    case 7 , heust008                                                1.0000   0.0020   3.00992E-02
heust008    case 8 , heust008                                                1.0066   0.0027   2.08335E-01
heust008    case 9 , heust008                                                1.0016   0.0021   3.05784E-02
heust008    case 10 , heust008                                               1.0016   0.0024   1.99162E-01
heust008    case 11 , heust008                                               0.9995   0.0019   2.92645E-02
heust008    case 12 , heust008                                               0.9979   0.0022   1.71894E-01
heust008    case 13 , heust008                                               1.0017   0.0024   1.96629E-01
heust008    case 14 , heust008                                               1.0035   0.0022   1.77598E-01
heust013    uranium aqueous 23 cm sphere #1                                  1.0001   0.0015   2.17462E-02
heust013    uranium aqueous 32 cm sphere #2                                  0.9969   0.0014   2.28882E-02
heust013    uranium aqueous 32 cm sphere #3                                  0.9941   0.0015   2.39695E-02
heust013    uranium aqueous 32 cm sphere #4                                  0.9937   0.0014   2.45661E-02
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                          218-Group_Low-Enriched_Uranium
Case              Title                                                     k-eff    sigma      EALF
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car01       rocky flats criticals nureg/cr-1071 experiment number 1 (27 g   1.0006   0.0022   3.94999E-01
car02       rocky flats criticals nureg/cr-1071 experiment number 2 (27 g   1.0005   0.0022   3.93085E-01
car03       rocky flats criticals nureg/cr-1071 experiment number 3 (27 g   0.9826   0.0020   1.42251E+00
car04       rocky flats criticals nureg/cr-1071 experiment number 13 (27    1.0075   0.0022   4.47478E-01
car06       rocky flats criticals nureg/cr-0674 experiment number ? (27 g   1.0015   0.0025   5.43776E+02
car07       rocky flats criticals nureg/cr-0674 experiment number ? (27 g   1.0006   0.0034   3.48957E+00
car08       rocky flats criticals nureg/cr-0674 experiment number ? (27 g   0.9920   0.0030   1.75924E+00
car09       rocky flats criticals nureg/cr-0674 experiment number 2 (27 g   1.0035   0.0032   1.76475E+00
car10       rocky flats criticals nureg/cr-0674 concrete reflected (27 gr   1.0020   0.0034   5.05230E+00
car11       rocky flats criticals nureg/cr-1653 experiment a (27 group)     0.9964   0.0025   3.42585E-01
car12       rocky flats criticals nureg/cr-1653 experiment b (27 group)     1.0061   0.0022   9.22813E-01
car14       rocky flats criticals nureg/cr-1653 experiment number ? (27 g   1.0036   0.0033   2.83742E+00
car15       rocky flats criticals nureg/cr-1653 experiment number ? (27 g   0.9923   0.0028   2.95204E+00
car16       rocky flats criticals nureg/cr-1653 experiment number ? (27 g   0.9995   0.0027   1.70924E+00
car17       rocky flats criticals nureg/cr-2500 experiment f (27 group)     0.9959   0.0024   5.88001E-01
car19       rocky flats criticals nureg/cr-2500 experiment number ? (27 g   0.9984   0.0022   3.79885E+00
car20       rocky flats criticals nureg/cr-2500 experiment number ? (27 g   0.9979   0.0025   3.71471E+00
cas04       british handbook of criticality safety u(1.42)f4 & paraffin (   0.9791   0.0018   8.96750E-02
cas05       british handbook of criticality safety u(1.42)f4 & paraffin (   0.9828   0.0019   8.96465E-02
cas06       british handbook of criticality safety u(1.42)f4 & paraffin (   0.9800   0.0019   9.03933E-02
cas11       raffety and malhalczo u(2)f4-1 reflected (case 11)              0.9842   0.0023   1.57178E-01
cas12       raffety and malhalczo u(2)f4-1 unreflected (case12)             0.9877   0.0023   1.89916E-01
cas13       raffety and malhalczo u(2)f4-2 reflected (case 13) no biasing   0.9902   0.0020   8.90524E-02
cas14       raffety and malhalczo u(2)f4-2 unreflected (case 14)            0.9862   0.0023   1.02992E-01
cas15       raffety and malhalczo u(2)f4-3 reflected (case 15)              0.9890   0.0021   6.21983E-02
cas16       raffety and malhalczo u(2)f4-4 reflected (case 16)              0.9912   0.0021   5.18809E-02
cas17       raffety and malhalczo u(2)f4-5 reflected (case 17)              0.9932   0.0020   4.38522E-02
cas18       raffety and malhalczo u(2)f4-5 unreflected (case18)             0.9933   0.0021   4.66593E-02
cas19       raffety and malhalczo u(2)f4-6 reflected (case 19)              0.9846   0.0020   3.32038E-02
cas20       raffety and malhalczo u(2)f4-6 unreflected (case20)             0.9842   0.0016   3.41368E-02
cas21       raffety and milhalczo u(3)f4-1 reflected (case 21) no bias      1.0028   0.0024   1.91295E-01
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cas22    raffety and malhalczo u(3)f4-1 reflected (case 22)            1.0001   0.0025   1.91734E-01
cas23    raffety and malhalczo u(3)f4-1 reflected (case 23)            1.0028   0.0026   1.92158E-01
cas24    raffety and malhalczo u(3)f4-1 reflected (case 24) no biasing 0.9998   0.0021   1.93289E-01
cas25    raffety and malhalczo u(3)f4-1 reflected (case 25)            1.0016   0.0023   1.91741E-01
cas26    raffety and malhalczo u(3)f4-1 unreflected (case 26)          1.0008   0.0029   2.66530E-01
cas27    raffety and malhalczo u(3)f4-1 unreflected (case 27)          1.0020   0.0023   2.64539E-01
cas28    raffety and malhalczo u(3)f4-1 unreflected (case 28)          1.0053   0.0022   2.65378E-01
cas29    raffety and malhalczo u(3)f4-2 reflected (cas29)              1.0040   0.0026   6.97213E-02
cas30    raffety and malhalczo u(3)f4-2 unreflected (case 30)          0.9996   0.0022   8.38485E-02
cas31    raffety and malhalczo u(3)f4-2 unreflected (case 31)          1.0103   0.0021   8.31691E-02
cas32    raffety and malhalczo u(3)f4-2 unreflected (case 32)          1.0033   0.0022   8.35523E-02
cas33    critical reflected cylinder of aqueous u(4.98)o2f2 (case 33)  1.0006   0.0023   4.02568E-02
cas34    critical reflected cylinder of aqueous u(4.98)o2f2 (case 34)  0.9981   0.0023   3.93348E-02
cas35    critical sphere of aqueous u(4.98)o2f2 (case 35)              1.0003   0.0026   3.90638E-02
cas36    critical cylinder of aqueous u(4.98)o2f2 (case 36)            0.9940   0.0022   3.98501E-02


                              218-Group_LWR_Lattices
Case                 Title                                             k-eff    sigma       EALF
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cas01    exp#5, 8.39 cm h2o separating 3 20x16 arrays                  0.9870   0.0021   7.31826E-02
cas02    exp#017, 5.05 cm h2o/boral separating 2 22x16 arrays and 1 20 0.9916   0.0011   7.57345E-02
cas03    exp#28, 6.88 cm h2o/ss separating 3 20x16 arrays              0.9906   0.0014   7.39831E-02
cas04    exp no. 14 8.58 cm h2o/ss separating 3 15x8 arrays            0.9930   0.0017   9.39196E-02
cas05    exp no. 23 7.28 cm h2o/cadmium separating 3 15x8 arrays       0.9962   0.0018   9.37279E-02
cas06    exp no. 31 6.72 cm h2o/boral separating 3 15x8 arrays         0.9919   0.0015   9.46590E-02
cas07    u refl. 1.956 cm from array,     14.11 cm h2o separating 3 19x1 0.9936  0.0017   1.34920E-01
cas08    pb refl. .660 cm from array, 13.72 cm h2o separating 3 19x16  0.9971   0.0014   7.52285E-02
cas09    no refl. 8.31cm h2o separating 19x16 arrays                   0.9886   0.0014   7.31741E-02
cas10    uranium refl. 15.32cm h2o separating 12x8  arrays             0.9944   0.0019   2.28104E-01
cas11    lead refl. 20.78cm h2o separating 13x8  arrays                1.0021   0.0008   9.57944E-02
cas12    2.83cm and 3.60cm separating 4 11x14 arrays                   0.9928   0.0016   2.71025E-01
cas13    2.83cm and 4.94cm separating 2 11x14 + 2 11x16 arrays         0.9939   0.0012   2.71469E-01
cas14    ss refl. 0.66 cm from array, 11.20 cm h2o separating 3 19x16  0.9938   0.0014   7.55889E-02
cas15    steel refl. 15.84cm h2o separating 3 12x16 arrays             0.9938   0.0018   2.45558E-01
cas16    steel refl.  9.83cm h2o separating 3 12x16 arrays  w/borated  0.9924   0.0017   2.54566E-01
cas17    steel refl.  8.30cm h2o separating 3 12x16 arrays  w/boral pl 0.9913   0.0018   2.61571E-01
cas18    steel refl.  8.94cm h2o separating 3 12x16 arrays  w/cd plate 0.9920   0.0012   2.57808E-01
cas19    u refl 1.321 cm from array, 9.50 cm h2o sep. 23x18/2-20x18 ar 0.9846   0.0014   2.72838E-01
cas20    pb refl 0.660 cm from array, 10.11 cm h2o sep. 23x18/2-20x18  0.9955   0.0015   1.32471E-01
cas21    no refl infinite from array, 6.59 cm h2o sep. 23x18/2-20x18 a 0.9861   0.0017   1.26938E-01
cas22    uranium refl. 19.24cm h2o separating 12x16 arrays             0.9940   0.0016   4.29985E-01
cas23    lead refl. 18.18cm h2o separating 12x16 arrays                0.9979   0.0018   2.52231E-01
cas24    no refl. 12.91cm h2o separating 3 12x16 arrays                0.9931   0.0018   2.35292E-01
cas25    pnl-4267 exp. 173 40 x 8.92 array (357 total rods) boron = 0  0.9898   0.0012   2.38528E-01
cas26    pnl-4267 exp.177 40 x 30.92 array 1237 total rods) boron = 2. 0.9928   0.0014   5.33489E-01
cas27    pnl-4267 exp. 178 44 x 11.57array (509 total rods) boron = 0  0.9899   0.0014   4.57461E-01
cas28    pnl-4267 exp. 181 44 x 27.09 array (1192 total rods) boron =  0.9840   0.0013   1.05426E+00
cas29    pnl-4976 4.3-000-194 4.3%uo2 1.598cm-pitch                    0.9894   0.0013   3.22852E+00
cas30    flux trap assembly no. 214r                                   0.9893   0.0016   3.13594E-01
cas31    flux trap assembly no. 214v3                                  0.9889   0.0012   3.14387E-01
cas32    baw-1231 core i 936 rods  boron=1.152 g/l                     0.9841   0.0011   6.42345E-01
cas33    baw-1231 core i 4904 rods  boron=3.389 g/l                    0.9853   0.0010   1.09035E+00
cas34    baw-1273 core xx           2.46 wt%u235   5137 rods           0.9813   0.0015   4.35169E-01
cas35    baw-1484-7 core iv exp 2282  2.46 wt%u235   9 assys 14x14 w/ 8 0.9861  0.0012   1.51773E-01
cas36    baw-1484-7 core ix exp 2321  2.46 wt%u235   9 assys 14x14     0.9873   0.0018   1.09533E-01
cas37    baw-1484-7 core xiii exp 2378  2.46 wt%u235   9 assys 14x14   0.9893   0.0016   1.57662E-01
cas38    baw-1484-7 core xxi exp 2420   2.46 wt%u235   9 assys 14x14   0.9821   0.0014   1.21402E-01
cas39    baw-1645-4 exp,mt=2452  triangular pitch=o.d.    boron=435ppm 0.9826   0.0012   2.07517E+00
cas40    baw-1645-4 exp,mt=2485  pitch=o.d.    boron=886ppm            0.9833   0.0015   1.25336E+00
cas41    baw-1645-4 exp,mt=2500  pitch=1.17*o.d.    boron=1156ppm      0.9862   0.0014   3.49389E-01
cas42    baw-1810 core 12 - 4.02 & 2.46 w/o uo2 1899.3 ppm; no uo2-gd2 0.9880   0.0013   3.05712E-01
cas43    baw-1810 core 14 - 4.02 & 2.46 w/o uo2 1654 ppm; 28 uo2-gd2o3 0.9893   0.0013   2.82602E-01
cas44    baw-1810 core 16 - 4.02 & 2.46 w/o uo2 1579 ppm; 36 uo2-gd2o3 0.9868   0.0012   2.77284E-01
cas45    epri np-196 .615 inch pitch unborated uo2                     0.9855   0.0017   2.09623E-01
cas46    epri np-196 .615 inch pitch borated uo2                       0.9890   0.0016   2.62418E-01
cas47    epri np-196 .75 inch pitch unborated uo2                      0.9916   0.0011   8.84393E-02
cas48    epri np-196 .75 inch pitch borated uo2                        0.9920   0.0010   1.12055E-01
cas49    epri np-196 .87 inch pitch unborated uo2                      0.9959   0.0014   6.29723E-02
cas50    epri np-196 .87 inch pitch borated uo2                        0.9912   0.0013   7.14114E-02
cas51    saxton uo2 5.742 wt% u-235 critical exp. 0.56 inch pitch (wca 0.9898   0.0017   2.52263E-01
cas52    saxton uo2 5.742 wt% u-235 critical exp. 0.792inch pitch (wca 0.9950   0.0014   8.44485E-02
cas53    wcap-3269-39, 2692 fuel rods, 16 ag-in-cd rods,h2o ht=115.55  0.9887   0.0010   5.98311E-01
cas54    wcap-3269-39, 2209 fuel rods, 24 ag-in-cd rods,h2o ht=64.56 c 0.9891   0.0018   3.70456E-01
cas55    wcap-3269-39,  945 fuel rods, 16 ag-in-cd rods,h2o ht=89.75   0.9813   0.0012   2.11051E-01
cas56    4-18x18 array 5.0cm int.,polyethylene powder in box,30.16cm h 0.9918   0.0016   1.84824E-01
cas57    4-18x18 array 5.0cm int.,polyethylene balls in box,30.73cm h2 1.0017   0.0015   1.69951E-01
cas58    4-18x18 array 5.0cm int.,water in box,32.78cm h2o height      1.0042   0.0013   1.61607E-01
cas59    4-18x18 array 5.0cm int.,water without box,31.47cm h2o height 0.9900   0.0014   1.63096E-01


                              218-Group_Mixed_Oxide
Case                 Title                                             k-eff    sigma       EALF
----------  ----------------------------------------------------------  ------   ------   ------------
cas60    epri .70inch pitch unborated plutonium                        0.9885   0.0016   4.93211E-01
cas61    epri .70inch pitch borated plutonium                          0.9903   0.0015   6.69112E-01
cas62    epri .87inch pitch unborated plutonium                        0.9965   0.0012   1.57390E-01
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cas63          epri .87inch pitch borated plutonium                      1.0016  0.0013  2.37628E-01
cas64          epri .99inch pitch unborated plutonium                    1.0030  0.0021  1.12362E-01
cas65          epri .99inch pitch borated plutonium                      1.0009  0.0011  1.50800E-01
cas66          saxton puo2-uo2 critical exp. 0.52 inch pitch (wcap-3385-54)  0.9932  0.0013  8.06082E-01
cas67          saxton puo2-uo2 critical exp. 0.56 inch pitch (wcap-3385-54)  0.9952  0.0020  4.83024E-01
cas68          saxton puo2-uo2 critical exp. 0.56 inch pitch with boron (wca  0.9956  0.0020  5.69167E-01
cas69          saxton puo2-uo2 critical exp. 0.735 inch pitch (wcap-3385-54)  1.0024  0.0019  1.59498E-01
cas70          saxton puo2-uo2 critical exp. 0.792 inch pitch (wcap-3385-54)  0.9996  0.0018  1.31846E-01
cas71          saxton puo2-uo2 critical exp. 01.04 inch pitch (wcap-3385-54)  0.9993  0.0020  8.44048E-02
cas72          pnl4976 exp196 1174 uo2 & 583 mo2 rods to approx. 20,000 mwd/  0.9829  0.0015  3.90997E+00
cas73          exp.no 021(063) pitch=968 (fuel region = pin array + mix 500   1.0071  0.0013  8.09349E-01
cas74          exp.no 032(060) pitch=1.935(fuel region=pin array+mix 500 wit  1.0089  0.0018  9.73447E-02
cas75          exp.no 043(062) pitch=1.242(fuel region=pin array+mix 500 wit  1.0076  0.0013  2.53936E-01
cas76          exp.no 067 pitch=0.761 (fuel region = pin array + mix 500 wit  0.9998  0.0011  2.66626E+00
cas77          exp. no 68r pitch=1.537 (fuel region = pin array + mix 500 wi  1.0109  0.0017  1.43396E-01
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                                  218-Group_Plutonium
Case                    Title                                        k-eff   sigma      EALF
----------   -------------------------------------------------------  ------  ------  ------------
2109_20      benchmark 20, pu sphere with 25.4 cm concrete ref. h/pu=684.3  1.0231  0.0032  5.16629E-02
2109_21      benchmark 21, pu sphere with 10.16 cm concrete ref. h/pu=684.  1.0215  0.0037  4.98331E-02
2109_22      benchmark 22, pu sphere with 10.16 cm concrete ref. h/pu=496   1.0240  0.0034  6.17991E-02
2109_23      benchmark 23, pu sphere with cd shell & 10.16 cm concrete ref  1.0264  0.0037  6.86368E-02
2109_24      benchmark 24, pu sphere with cd shell & 32.00 cm water, h/pu=  1.0221  0.0038  5.87382E-02
2110_05      rectangular parallelpipeds of homogeneous pu(2.2)o2           1.0382  0.0054  3.02218E+01
2110_06      rectangular paralleliped of pu(2.2)o2 reflected with 15cm p    1.0348  0.0055  5.18024E+00
2110_07      benchmark#7 semi-inf homogeneous critical solution of pu-239   1.0179  0.0037  7.12103E-02
2110_08      rectangular parallelipiped of puo2                            1.0067  0.0052  1.48979E+00
2110_09      rectangular parallelipipeds of puo2                           1.0212  0.0050  6.76814E-01
2110_10      rectangular parallelipipeds of puo2                           1.0172  0.0045  6.65798E-01
2110_11      rectangular parallelipipeds of puo2                           1.0166  0.0044  6.42817E-01
2110_12      rectangular parallelipipeds of puo2                           1.0107  0.0053  6.36030E-01
2110_13      sphere described by keno geometry                            0.9942  0.0035  1.22581E+06
2110_14      cylinder described by keno geometry                          1.0080  0.0056  1.20783E+01
2110_15      rectangular parallelipipeds of puo2-h20                       1.0251  0.0042  2.46347E+05
2110_16      rectangular parallelipipeds of puo2-h20                       1.0344  0.0034  9.52307E+05
2110_17      rectangular parallelipipeds of puo2-h20                       1.0343  0.0038  1.70871E+03
2110_18      rectangular parallelipipeds of puo2-h20                       1.0462  0.0037  3.63834E+03
2110_19      rectangular parallelipipeds of puo2-h20                       1.0178  0.0034  4.32956E+03
2110_20      rectangular parallelipipeds of puo2-h20                       1.0252  0.0036  2.16310E+03
2110_21      rectangular parallelipipeds of puo2-h20                       1.0469  0.0043  1.77724E+03
2110_23      rectangular parallelipipeds of puo2-polystyrene               1.0211  0.0056  1.45852E+03
2110_24      rectangular parallelipipeds of puo2-polystyrene               1.0284  0.0032  9.12097E+01
2110_25      rectangular parallelipipeds of puo2-polystyrene               1.0330  0.0037  8.17618E+01
2110_26      rectangular parallelipipeds of puo2-polystyrene               1.0354  0.0036  6.53850E+01
2110_27      rectangular parallelipipeds of puo2-polystyrene               1.0313  0.0034  5.48046E+01
2110_29      cylinder described by keno geometry                          1.0110  0.0035  4.22712E-02
pumf001      read parameters                                             0.9958  0.0020  1.18798E+06
pumf002      pu-met-fast-002                                             0.9993  0.0019  1.21724E+06
pust004      case 1,kvpusolnsphexp,27gp,26.27gpU/L, 0.54w/o240,h2orefl,14i  1.0094  0.0021  4.01972E-02
pust009      case 3a,kvpusolnsphexp,27,9.457gpU/L, 2.5w/o240,bare,48in dia  1.0192  0.0014  2.92598E-02
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                                   218-Group_U-233
Case                    Title                                        k-eff   sigma      EALF
----------   -------------------------------------------------------  ------  ------  ------------
u233mf001    unreflected u233 sphere                                      0.9632  0.0017  9.96415E+05
u233mf002    case 1, 10 kg u233/heu sphere, ref u233-met-fast-002         0.9758  0.0020  9.67456E+05
u233mf002    case 2, 7.6 kg u233/heu sphere, ref u233-met-fast-002        0.9700  0.0019  9.74693E+05
u233mf003    case 1, 10 kg u233 sphere natural uranium reflector, ref u233  0.9700  0.0019  9.60313E+05
u233mf003    case 2, 7.6 kg u233 sphere natural uranium reflector, ref u23  0.9727  0.0019  9.53695E+05
u233mf004    case 1, 10 kg u233 sphere reflected by tungsten              0.9711  0.0023  8.81734E+05
u233mf005    case 1, 10 kg u233 sphere be reflector, ref u233-met-fast-xxx  0.9765  0.0023  8.30195E+05
u233mf006    u-233/nu sphere                                             0.9771  0.0020  9.16551E+05
u233st002    exp 4 simplified model                                      1.0247  0.0035  1.36063E-01
u233st002    exp 5 simplified model                                      1.0011  0.0033  1.03111E-01
u233st002    exp 8 simplified model                                      1.0204  0.0033  7.89818E-02
u233st002    exp 10 simplified model                                     1.0169  0.0030  6.24587E-02
u233st002    exp 11 simplified model                                     1.0221  0.0027  5.37025E-02
u233st002    exp 12 simplified model                                     1.0079  0.0029  4.75664E-02
u233st002    exp 14 simplified model                                     0.9972  0.0028  4.45793E-02
u233st002    exp 15 simplified model                                     1.0055  0.0031  4.07691E-02
u233st002    exp 17 simplified model                                     0.9947  0.0027  3.61638E-02
u233st002    exp 18 simplified model                                     1.0114  0.0029  3.48580E-02
u233st002    exp 19 simplified model                                     1.0176  0.0024  3.21938E-02
u233st002    exp 22 simplified model                                     1.0097  0.0030  2.19634E-01
u233st002    exp 24 simplified model                                     1.0129  0.0030  4.00789E-01
u233st002    exp 34 simplified model                                     1.0158  0.0031  1.07339E-01
u233st002    exp 35 simplified model                                     1.0161  0.0026  7.11225E-02
u233st002    exp 36 simplified model                                     1.0188  0.0026  4.54736E-02
u233st002    exp 38 simplified model                                     1.0180  0.0026  3.81578E-02
u233st004    exp 3 simplified model                                      1.0164  0.0029  1.34418E-01
u233st004    exp 6 simplified model                                      1.0208  0.0030  1.00574E-01
u233st004    exp 20 simplified model                                     1.0198  0.0031  2.17961E-01
u233st004    exp 25 simplified model                                     1.0044  0.0033  4.06822E-01
u233st004    exp 30 simplified model                                     1.0086  0.0033  3.15473E-01
u233st004    exp 27 simplified model                                     1.0240  0.0035  4.03712E-01
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u233st004   exp 28 simplified model                                      1.0237  0.0031  3.10239E-01
u233st004   exp 33 simplified model                                      1.0273  0.0032  1.06955E-01


                             27-Group_High-Enriched_Uranium
Case                   Title                                             k-eff   sigma      EALF
----------  ----------------------------------------------------------  ------  ------  ------------
cas04       keno-5 validation case a-2                                  1.0012  0.0024  8.25177E+05
cas05       keno-5 validation case a-3                                  1.0051  0.0016  2.12729E-02
cas07       keno-5 validation case a-5                                  1.0088  0.0024  1.43238E+03
cas08       keno-5 validation case a-6                                  1.0202  0.0026  1.59606E+05
cas09       keno-5 validation case a-7                                  1.0132  0.0022  7.99182E+05
cas10       keno-5 validation case a-8                                  1.0134  0.0024  4.39491E+03
cas11       keno-5 validation case a-9                                  1.0052  0.0022  1.28208E+04
cas12       keno-5 validation case b-1                                  0.9988  0.0024  9.06663E+05
cas14       keno-5 validation case b-11                                 1.0545  0.0029  3.35277E-01
cas15       keno-5 validation case b-12                                 1.0147  0.0023  3.90048E+04
cas19       keno-5 validation case b-16                                 1.0287  0.0033  4.28583E-01
cas22       keno-5 validation case b-2                                  1.0034  0.0024  9.07820E+05
cas23       keno-5 validation case b-3                                  0.9999  0.0021  9.04580E+05
cas24       keno-5 validation case b-4                                  0.9894  0.0024  9.11988E+05
cas25       keno-5 validation case b-5                                  1.0033  0.0022  8.97214E+05
cas26       keno-5 validation case b-6                                  1.0058  0.0027  8.11693E+03
cas27       keno-5 validation case b-7                                  1.0053  0.0025  6.04371E+03
cas28       keno-5 validation case b-8                                  1.0028  0.0023  5.80892E+04
cas30       93.2% uo2f2 3 in al slab 3x1x1 array 0 in sep room          1.0055  0.0029  3.66423E-02
cas31       93.2% uo2f2 3 in al slab 3x1x1 array 0 in sep h2o refl      0.9956  0.0032  3.37742E-02
cas32       93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep room          0.9875  0.0032  3.70072E-02
cas33       93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep h2o refl      0.9982  0.0033  3.12980E-02
cas34       93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep room          0.9842  0.0028  3.72751E-02
cas35       93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep h2o refl      0.9989  0.0026  3.04115E-02
cas36       93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep room        0.9866  0.0028  3.72423E-02
cas37       93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep h2o refl    1.0051  0.0026  3.07787E-02
cas38       93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep room        0.9890  0.0029  3.73485E-02
cas39       93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep h2o refl    1.0044  0.0027  3.08833E-02
cas40       93.2% uo2f2 3 in al slab 3x1x1 array 6 in sep room          0.9963  0.0028  3.73356E-02
cas41       93.2% uo2f2 3, 6 in al slabs 2x1x1 array 15 in sep          0.9776  0.0029  3.68925E-02
cas42       93.2% uo2f2 3, 6 in al slabs 2x1x1 array 2 in sep           0.9779  0.0031  3.70629E-02
cas43       93.2% uo2f2 3, 6 in al slabs 2x1x1 array 30 in sep          0.9779  0.0026  3.69950E-02
cas44       93.2% uo2f2 3, 6 in al slabs 2x1x1 array 48 in sep          0.9774  0.0029  3.69031E-02
cas45       93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 0 in sep        0.9813  0.0029  3.67765E-02
cas46       93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 10 in sep       0.9761  0.0027  3.72860E-02
cas47       93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 20 in sep       0.9757  0.0030  3.71699E-02
cas48       93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 32 in sep       0.9756  0.0033  3.72024E-02
cas49       93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 12 in sep         0.9812  0.0028  3.70269E-02
cas50       93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 18 in sep         0.9827  0.0029  3.70684E-02
cas51       93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 30 in sep         0.9863  0.0026  3.70451E-02
cas52       93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 6 in sep          0.9849  0.0029  3.70524E-02
cas53       93.2% uo2f2 6 in al slab 2x1x1 array 15 in sep              0.9877  0.0030  3.69003E-02
cas54       93.2% uo2f2 6 in al slab 2x1x1 array 2 in sep               0.9788  0.0029  3.69552E-02
cas55       93.2% uo2f2 6 in al slab 2x1x1 array 20 in sep              0.9833  0.0028  3.69450E-02
cas56       93.2% uo2f2 6 in al slab 2x1x1 array 30 in sep              0.9871  0.0026  3.68452E-02
cas57       93.2% uo2f2 6 in al slab 2x1x1 array 48 in sep              0.9827  0.0032  3.69738E-02
cas58       93.2% uo2f2 6 in al slab 2x1x1 array 6 in sep               0.9831  0.0034  3.69268E-02
cas59       93.2% uo2f2 6 in al slab 2x1x1 array 66 in sep              0.9844  0.0027  3.68209E-02
cas60       uo2(no3)2 279 g U/L 3x3x3 array unrefl. walls, tank, & floor 1.0042 0.0028  1.31018E-01
cas61       uo2(no3)2 279 g U/L 2x2x2 array unrefl. walls, tank, & floor 1.0034 0.0029  1.26948E-01
cas62       uo2(no3)2 415 g U/L 5x5x5 array unrefl. walls, tank, & floor 0.9943 0.0030  2.73618E-01
cas63       uo2(no3)2 415 g U/L 3x3x3 array unrefl. walls, tank, & floor 0.9956 0.0030  2.76888E-01
cas64       uo2(no3)2 415 g U/L 4x4x4 array unrefl. walls, floor, & tank 0.9953 0.0033  2.78316E-01
cas65       uo2(no3)2 415 g U/L 2x2x2 array unrefl.  walls, floor, & tank 1.0015 0.0029 2.71382E-01
cas66       uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p 1.0042 0.0029 2.39237E-01
cas67       uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 2.54 cm p 1.0163 0.0032 2.14582E-01
cas68       uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p 1.0107 0.0028 2.29550E-01
cas69       uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par 5 fc, plex 1 fc  1.0145 0.0030 1.76230E-01
cas70       uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 3.81 cm p 1.0260 0.0028 1.87077E-01
cas71       uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 7.62 cm p 1.0287 0.0031 1.77129E-01
cas72       uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm plexiglass refl.      1.0071 0.0028 2.49885E-01
cas73       uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm paraffin refl.        1.0094 0.0033 2.41178E-01
cas74       uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm paraffin refl.       1.0261 0.0028 1.75409E-01
cas75       uo2(no3)2 415 g U/L 3x3x3 array 3.81 cm paraffin refl.        1.0203 0.0029 1.92302E-01
cas76       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p 1.0178 0.0026 2.31912E-01
cas77       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 11.43 cm  1.0219 0.0029 1.76687E-01
cas78       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 15.24 cm  1.0208 0.0032 1.73787E-01
cas79       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 2.54 cm p 1.0164 0.0034 2.12739E-01
cas80       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 4.45 cm p 1.0216 0.0029 1.91607E-01
cas81       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 6.35 cm p 1.0214 0.0031 1.80898E-01
cas82       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p 1.0106 0.0033 2.27365E-01
cas83       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 3.81 cm p 1.0136 0.0027 1.88998E-01
cas84       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 7.62 cm p 1.0250 0.0029 1.76417E-01
cas85       uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm plexiglass refl.      1.0092 0.0031 2.46337E-01
cas86       uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm paraffin refl.        1.0117 0.0030 2.36859E-01
cas87       uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm paraffin refl.       1.0161 0.0030 1.75556E-01
cas88       uo2(no3)2 415 g U/L 2x2x2 array 3.81 cm paraffin refl.        1.0203 0.0034 1.89939E-01
cas89       uo2(no3)2 415 g U/L 2x2x2 array 7.62 cm paraffin refl.        1.0219 0.0031 1.77361E-01
cas90       uo2(no3)2 415 g U/L 3x3x3 array unrefl. 279 g U/L 5 cent. uni 1.0017 0.0030 2.22231E-01
cas91       uo2(no3)2 63.3 g U/L 3x3x3 array unrefl. walls, floor, & tank 1.0072 0.0033 3.03766E-02
jemima      disks - 15" diam plates 93.15 w% enriched stacked to 3.0258" 0.9985 0.0021 9.11779E+05
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jemima      jemima - ~1/8" x 15" diam u(93.29) plates with 1/16" thk poly      1.0029  0.0022  1.09798E+05
jemima      jemima - ~1/8" thk 15" diam u(93.24) plates with 1/8" thk pol      1.0076  0.0025  1.69595E+04
jemima      jemima - ~1/8" thk 15" diam u(93.24) plates with 1/4" thk pol      0.9939  0.0025  1.65789E+03
jemima      jemima - ~1/8" thk 15" diam u(93.24) plates with 1/2" thk pol      1.0168  0.0031  8.58453E+01
jemima      jemima - ~1/8" thk 15" diam u(93.24) plates with 1" thk poly,      1.0064  0.0028  7.27811E+00
jemima      jemima - ~1/8" x 15" dia u(93) with symetric 1-1/2" thk poly,      1.0187  0.0025  3.27479E+00
jemima      jemima - ~1/8" x 15" dia u(93) with symetric 2" thk poly, pg-      1.0074  0.0026  2.10161E+00
heumf001    read parameters                                                    1.0043  0.0018  9.00065E+05
heumf004    water-reflected heu sphere on hollow plexiglas cylinder            1.0065  0.0018  2.94412E+04
heust001    case 1 heust001                                                    1.0064  0.0021  6.08439E-02
heust001    case 2 heust001                                                    1.0047  0.0026  2.31856E-01
heust001    case 3 heust001                                                    1.0108  0.0023  5.97192E-02
heust001    case 4 heust001                                                    1.0069  0.0029  2.49416E-01
heust001    case 5 heust001                                                    1.0039  0.0019  2.95264E-02
heust001    case 6 heust001                                                    1.0103  0.0021  3.06560E-02
heust001    case 7 heust001                                                    1.0015  0.0024  5.74311E-02
heust001    case 8 heust001                                                    1.0066  0.0026  6.10304E-02
heust001    case 9 heust001                                                    1.0072  0.0025  2.48467E-01
heust001    case 10 heust001                                                   0.9988  0.0022  3.18901E-02
heust007    case 1 , heust007                                                  1.0148  0.0019  3.29526E-02
heust007    case 2 , heust007                                                  1.0147  0.0024  2.23061E-01
heust007    case 3 , heust007                                                  1.0125  0.0021  3.21306E-02
heust007    case 4 , heust007                                                  1.0140  0.0025  1.96752E-01
heust007    case 5 , heust007                                                  1.0113  0.0020  3.52662E-02
heust007    case 6 , heust007                                                  1.0111  0.0024  2.27402E-01
heust007    case 7 , heust007                                                  1.0077  0.0025  3.47670E-02
heust007    case 8 , heust007                                                  1.0060  0.0025  2.25179E-01
heust007    case 9 , heust007                                                  1.0110  0.0021  3.59785E-02
heust007    case 10 , heust007                                                 1.0130  0.0019  3.74407E-02
heust007    case 11 , heust007                                                 1.0124  0.0020  2.12040E-01
heust007    case 12 , heust007                                                 1.0172  0.0020  3.59965E-02
heust007    case 13 , heust007                                                 1.0178  0.0018  1.91280E-01
heust007    case 14 , heust007                                                 1.0127  0.0022  1.97240E-01
heust007    case 15 , heust007                                                 1.0131  0.0023  1.98894E-01
heust007    case 16 , heust007                                                 1.0096  0.0021  2.13028E-01
heust007    case 17 , heust007                                                 1.0147  0.0023  1.97778E-01
heust008    case 1 , heust008                                                  0.9996  0.0023  3.07031E-02
heust008    case 2 , heust008                                                  0.9988  0.0026  1.94851E-01
heust008    case 3 , heust008                                                  1.0027  0.0018  2.96884E-02
heust008    case 4 , heust008                                                  1.0006  0.0022  1.71674E-01
heust008    case 5 , heust008                                                  1.0020  0.0018  3.04500E-02
heust008    case 6 , heust008                                                  1.0061  0.0021  2.11288E-01
heust008    case 7 , heust008                                                  1.0024  0.0021  2.99475E-02
heust008    case 8 , heust008                                                  1.0040  0.0027  2.01170E-01
heust008    case 9 , heust008                                                  1.0041  0.0019  3.04749E-02
heust008    case 10 , heust008                                                 0.9981  0.0024  1.92482E-01
heust008    case 11 , heust008                                                 1.0009  0.0019  2.93566E-02
heust008    case 12 , heust008                                                 0.9937  0.0021  1.67395E-01
heust008    case 13 , heust008                                                 1.0069  0.0023  1.90642E-01
heust008    case 14 , heust008                                                 0.9974  0.0021  1.73162E-01
heust013    uranium aqueous 23 cm sphere #1                                    0.9979  0.0015  2.18895E-02
heust013    uranium aqueous 32 cm sphere #2                                    0.9973  0.0016  2.30049E-02
heust013    uranium aqueous 32 cm sphere #3                                    0.9911  0.0015  2.41103E-02
heust013    uranium aqueous 32 cm sphere #4                                    0.9934  0.0015  2.46565E-02
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                             27-Group_Low-Enriched_Uranium
Case                 Title                                           k-eff   sigma      EALF
----------   -------------------------------------------------------  ------  ------  ------------
car01    rocky flats criticals nureg/cr-1071 experiment number 1 (27 g  1.0045  0.0022  3.87554E-01
car02    rocky flats criticals nureg/cr-1071 experiment number 2 (27 g  0.9999  0.0023  3.91219E-01
car03    rocky flats criticals nureg/cr-1071 experiment number 3 (27 g  0.9936  0.0020  1.35941E+00
car04    rocky flats criticals nureg/cr-1071 experiment number 13 (27   1.0158  0.0022  4.32465E-01
car06    rocky flats criticals nureg/cr-0674 experiment number ? (27 g  1.0057  0.0040  4.55156E+02
car07    rocky flats criticals nureg/cr-0674 experiment number ? (27 g  1.0081  0.0031  3.33012E+00
car08    rocky flats criticals nureg/cr-0674 experiment number ? (27 g  1.0082  0.0033  1.58310E+00
car09    rocky flats criticals nureg/cr-0674 experiment number 2 (27 g  0.9969  0.0027  1.71940E+00
car10    rocky flats criticals nureg/cr-0674 concrete reflected (27 gr  1.0055  0.0032  4.74156E+00
car11    rocky flats criticals nureg/cr-1653 experiment a (27 group)    1.0109  0.0021  3.28500E-01
car12    rocky flats criticals nureg/cr-1653 experiment b (27 group)    1.0134  0.0025  8.64307E-01
car14    rocky flats criticals nureg/cr-1653 experiment number ? (27 g  1.0036  0.0029  2.69715E+00
car15    rocky flats criticals nureg/cr-1653 experiment number ? (27 g  1.0045  0.0029  2.69777E+00
car16    rocky flats criticals nureg/cr-1653 experiment number ? (27 g  1.0078  0.0026  1.63458E+00
car17    rocky flats criticals nureg/cr-2500 experiment f (27 group)    1.0075  0.0022  5.55228E-01
car19    rocky flats criticals nureg/cr-2500 experiment number ? (27 g  1.0060  0.0023  3.27849E+00
car20    rocky flats criticals nureg/cr-2500 experiment number ? (27 g  0.9958  0.0020  3.08323E+00
cas04    british handbook of criticality safety u(1.42)f4 & paraffin (  0.9855  0.0017  8.92388E-02
cas05    british handbook of criticality safety u(1.42)f4 & paraffin (  0.9866  0.0020  8.90776E-02
cas06    british handbook of criticality safety u(1.42)f4 & paraffin (  0.9879  0.0016  8.88506E-02
cas11    raffety and malhalczo u(2)f4-1 reflected (case 11)             0.9932  0.0019  1.55228E-01
cas12    raffety and malhalczo u(2)f4-1 unreflected (case12)            0.9948  0.0017  1.86181E-01
cas13    raffety and malhalczo u(2)f4-2 reflected (case 13) no biasing  0.9978  0.0020  8.79297E-02
cas14    raffety and malhalczo u(2)f4-2 unreflected (case 14)           0.9927  0.0019  1.01576E-01
cas15    raffety and malhalczo u(2)f4-3 reflected (case 15)             0.9962  0.0019  6.15050E-02
cas16    raffety and malhalczo u(2)f4-4 reflected (case 16)             0.9941  0.0018  5.17969E-02
cas17    raffety and malhalczo u(2)f4-5 reflected (case 17)             0.9950  0.0018  4.38689E-02
cas18    raffety and malhalczo u(2)f4-5 unreflected (case18)            0.9977  0.0017  4.62707E-02
cas19    raffety and malhalczo u(2)f4-6 reflected (case 19)             0.9882  0.0015  3.33592E-02
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cas20    raffety and malhalczo u(2)f4-6 unreflected (case20)              0.9873   0.0016   3.40929E-02
cas21    raffety and milhalczo u(3)f4-1 reflected (case 21) no bias       1.0139   0.0022   1.85045E-01
cas22    raffety and malhalczo u(3)f4-1 reflected (case 22)               1.0086   0.0026   1.86574E-01
cas23    raffety and malhalczo u(3)f4-1 reflected (case 23)               1.0087   0.0025   1.87329E-01
cas24    raffety and malhalczo u(3)f4-1 reflected (case 24) no biasing    1.0056   0.0021   1.86411E-01
cas25    raffety and malhalczo u(3)f4-1 reflected (case 25)               1.0064   0.0025   1.86497E-01
cas26    raffety and malhalczo u(3)f4-1 unreflected (case 26)             1.0089   0.0024   2.58533E-01
cas27    raffety and malhalczo u(3)f4-1 unreflected (case 27)             1.0080   0.0020   2.57356E-01
cas28    raffety and malhalczo u(3)f4-1 unreflected (case 28)             1.0083   0.0021   2.57319E-01
cas29    raffety and malhalczo u(3)f4-2 reflected (cas29)                 1.0099   0.0022   6.94461E-02
cas30    raffety and malhalczo u(3)f4-2 unreflected (case 30)             1.0096   0.0024   8.17992E-02
cas31    raffety and malhalczo u(3)f4-2 unreflected (case 31)             1.0127   0.0025   8.18491E-02
cas32    raffety and malhalczo u(3)f4-2 unreflected (case 32)             1.0107   0.0025   8.23629E-02
cas33    critical reflected cylinder of aqueous u(4.98)o2f2 (case 33)     1.0031   0.0024   3.99815E-02
cas34    critical reflected cylinder of aqueous u(4.98)o2f2 (case 34)     0.9986   0.0023   3.90375E-02
cas35    critical sphere of aqueous u(4.98)o2f2 (case 35)                 1.0017   0.0021   3.90282E-02
cas36    critical cylinder of aqueous u(4.98)o2f2 (case 36)               1.0013   0.0023   3.96570E-02
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                                27-Group_LWR_Lattices
Case               Title                                              k-eff   sigma      EALF
----------  -------------------------------------------------------   ------  ------   ------------
cas01    exp#5, 8.39 cm h2o separating 3 20x16 arrays                  0.9936   0.0015   7.32948E-02
cas02    exp#017, 5.05 cm h2o/boral separating 2 22x16 arrays and 1 20 0.9951   0.0012   7.49622E-02
cas03    exp#28, 6.88 cm h2o/ss separating 3 20x16 arrays              0.9954   0.0015   7.40122E-02
cas04    exp no. 14 8.58 cm h2o/ss separating 3 15x8 arrays            0.9950   0.0016   9.33947E-02
cas05    exp no. 23 7.28 cm h2o/cadmium separating 3 15x8 arrays       0.9949   0.0017   9.37307E-02
cas06    exp no. 31 6.72 cm h2o/boral separating 3 15x8 arrays         0.9958   0.0018   9.40061E-02
cas07    u refl. 1.956 cm from array,   14.11 cm h2o separating 3 19x1 0.9981   0.0015   1.35373E-01
cas08    pb refl. .660 cm from array, 13.72 cm h2o separating 3 19x16  0.9990   0.0014   7.48681E-02
cas09    no refl. 8.31cm h2o separating 19x16 arrays                   0.9925   0.0015   7.30107E-02
cas10    uranium refl. 15.32cm h2o separating 12x8  arrays             1.0012   0.0018   2.26990E-01
cas11    lead refl. 20.78cm h2o separating 13x8  arrays                1.0067   0.0009   9.57487E-02
cas12    2.83cm and 3.60cm separating 4 11x14 arrays                   0.9963   0.0020   2.61667E-01
cas13    2.83cm and 4.94cm separating 2 11x14 + 2 11x16 arrays         0.9980   0.0012   2.66483E-01
cas14    ss refl. 0.66 cm from array, 11.20 cm h2o separating 3 19x16  0.9964   0.0014   7.49206E-02
cas15    steel refl. 15.84cm h2o separating 3 12x16 arrays             1.0019   0.0017   2.40167E-01
cas16    steel refl.  9.83cm h2o separating 3 12x16 arrays   w/borated 0.9974   0.0016   2.49256E-01
cas17    steel refl.  8.30cm h2o separating 3 12x16 arrays   w/boral pl 0.9973   0.0016   2.54696E-01
cas18    steel refl.  8.94cm h2o separating 3 12x16 arrays   w/cd plate 0.9988   0.0011   2.53015E-01
cas19    u refl 1.321 cm from array, 9.50 cm h2o sep. 23x18/2-20x18 ar 0.9920   0.0014   2.63682E-01
cas20    pb refl 0.660 cm from array, 10.11 cm h2o sep. 23x18/2-20x18  0.9954   0.0016   1.31238E-01
cas21    no refl infinite from array, 6.59 cm h2o sep. 23x18/2-20x18 a 0.9894   0.0017   1.24163E-01
cas22    uranium refl. 19.24cm h2o separating 12x16 arrays             0.9980   0.0018   4.21807E-01
cas23    lead refl. 18.18cm h2o separating 12x16 arrays                1.0010   0.0019   2.44825E-01
cas24    no refl. 12.91cm h2o separating 3 12x16 arrays                0.9928   0.0017   2.30886E-01
cas25    pnl-4267 exp. 173 40 x 8.92 array (357 total rods) boron = 0  0.9925   0.0014   2.30683E-01
cas26    pnl-4267 exp.177 40 x 30.92 array 1237 total rods) boron = 2. 0.9989   0.0014   5.20775E-01
cas27    pnl-4267 exp. 178 44 x 11.57array (509 total rods) boron = 0  0.9935   0.0011   4.41446E+00
cas28    pnl-4267 exp. 181 44 x 27.09 array (1192 total rods) boron =  0.9898   0.0013   1.00604E+01
cas29    pnl-4976 4.3-000-194 4.3%uo2 1.598cm-pitch                    0.9963   0.0014   3.06248E+00
cas30    flux trap assembly no. 214r                                   0.9922   0.0015   3.08803E-01
cas31    flux trap assembly no. 214v3                                  0.9918   0.0012   3.07797E-01
cas32    baw-1231 core i 936 rods  boron=1.152 g/l                     0.9898   0.0011   6.15731E-01
cas33    baw-1231 core i 4904 rods   boron=3.389 g/l                   0.9904   0.0011   1.03030E+00
cas34    baw-1273 core xx           2.46 wt%u235    5137 rods          0.9903   0.0013   4.26890E-01
cas35    baw-1484-7 core iv exp 2282  2.46 wt%u235   9 assys 14x14 w/ 8 0.9900   0.0011   1.48972E-01
cas36    baw-1484-7 core ix exp 2321  2.46 wt%u235   9 assys 14x14     0.9879   0.0013   1.07245E-01
cas37    baw-1484-7 core xiii exp 2378  2.46 wt%u235   9 assys 14x14   0.9907   0.0014   1.52380E-01
cas38    baw-1484-7 core xxi exp 2420   2.46 wt%u235   9 assys 14x14   0.9859   0.0014   1.19936E-01
cas39    baw-1645-4 exp,mt=2452  triangular pitch=o.d.     boron=435ppm 0.9871   0.0009   2.01240E+00
cas40    baw-1645-4 exp,mt=2485  pitch=o.d.     boron=886ppm           0.9859   0.0015   1.21020E+00
cas41    baw-1645-4 exp,mt=2500  pitch=1.17*o.d.    boron=1156ppm      0.9893   0.0014   3.39788E+00
cas42    baw-1810 core 12 - 4.02 & 2.46 w/o uo2 1899.3 ppm; no uo2-gd2 0.9942   0.0012   2.97288E-01
cas43    baw-1810 core 14 - 4.02 & 2.46 w/o uo2 1654 ppm; 28 uo2-gd2o3 0.9922   0.0012   2.76263E-01
cas44    baw-1810 core 16 - 4.02 & 2.46 w/o uo2 1579 ppm; 36 uo2-gd2o3 0.9913   0.0013   2.69143E-01
cas45    epri np-196 .615 inch pitch unborated uo2                     0.9900   0.0014   2.05086E-01
cas46    epri np-196 .615 inch pitch borated uo2                       0.9945   0.0015   2.53968E-01
cas47    epri np-196 .75 inch pitch unborated uo2                      0.9941   0.0011   8.72283E-02
cas48    epri np-196 .75 inch pitch borated uo2                        0.9959   0.0010   1.10618E-01
cas49    epri np-196 .87 inch pitch unborated uo2                      0.9951   0.0014   6.30229E-02
cas50    epri np-196 .87 inch pitch borated uo2                        0.9954   0.0012   7.14725E-02
cas51    saxton uo2 5.742 wt% u-235 critical exp. 0.56 inch pitch (wca 0.9943   0.0017   2.45481E-01
cas52    saxton uo2 5.742 wt% u-235 critical exp. 0.792inch pitch (wca 0.9980   0.0013   8.36359E-02
cas53    wcap-3269-39, 2692 fuel rods, 16 ag-in-cd rods,h2o ht=115.55  0.9975   0.0010   5.74663E-01
cas54    wcap-3269-39, 2209 fuel rods, 24 ag-in-cd rods,h2o ht=64.56 c 1.0001   0.0015   3.55053E-01
cas55    wcap-3269-39,  945 fuel rods, 16 ag-in-cd rods,h2o ht=89.75   0.9915   0.0012   2.02680E-01
cas56    4-18x18 array 5.0cm int.,polyethylene powder in box,30.16cm h 0.9982   0.0013   1.82579E-01
cas57    4-18x18 array 5.0cm int.,polyethylene balls in box,30.73cm h2 1.0048   0.0012   1.66669E-01
cas58    4-18x18 array 5.0cm int.,water in box,32.78cm h2o height      1.0069   0.0012   1.58953E-01
cas59    4-18x18 array 5.0cm int.,water without box,31.47cm h2o height 0.9929   0.0013   1.59847E-01
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                                27-Group_Mixed_Oxide
Case               Title                                              k-eff   sigma      EALF
----------  -------------------------------------------------------   ------  ------   ------------
cas60    epri .70inch pitch unborated plutonium                        0.9955   0.0015   4.85418E-01
cas61    epri .70inch pitch borated plutonium                          0.9946   0.0015   6.59195E-01
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cas62   epri .87inch pitch unborated plutonium                          1.0018  0.0011  1.58773E-01
cas63   epri .87inch pitch borated plutonium                            1.0065  0.0016  2.37206E-01
cas64   epri .99inch pitch unborated plutonium                          1.0071  0.0017  1.12977E-01
cas65   epri .99inch pitch borated plutonium                            1.0044  0.0010  1.52939E-01
cas66   saxton puo2-uo2 critical exp. 0.52 inch pitch (wcap-3385-54)     0.9991  0.0012  7.89713E-01
cas67   saxton puo2-uo2 critical exp. 0.56 inch pitch (wcap-3385-54)     1.0028  0.0018  4.79583E-01
cas68   saxton puo2-uo2 critical exp. 0.56 inch pitch with boron (wca    1.0004  0.0019  5.65981E-01
cas69   saxton puo2-uo2 critical exp. 0.735 inch pitch (wcap-3385-54)    1.0040  0.0019  1.62447E-01
cas70   saxton puo2-uo2 critical exp. 0.792 inch pitch (wcap-3385-54)    1.0065  0.0017  1.32753E-01
cas71   saxton puo2-uo2 critical exp. 01.04 inch pitch (wcap-3385-54)    1.0052  0.0017  8.57241E-02
cas72   pnl4976 exp196 1174 uo2 & 583 mo2 rods to approx. 20,000 mwd/    0.9891  0.0014  3.75185E+00
cas73   exp.no 021(063) pitch=968 (fuel region = pin array + mix 500     1.0110  0.0011  7.83215E-01
cas74   exp.no 032(060) pitch=1.935(fuel region=pin array+mix 500 wit    1.0134  0.0020  9.81348E-02
cas75   exp.no 043(062) pitch=1.242(fuel region=pin array+mix 500 wit    1.0107  0.0013  2.56284E-01
cas76   exp.no 067 pitch=0.761 (fuel region = pin array + mix 500 wit    1.0037  0.0011  2.61938E+00
cas77   exp. no 68r pitch=1.537 (fuel region = pin array + mix 500 wi    1.0096  0.0018  1.44861E-01
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                            27-Group_Plutonium
Case                   Title                                          k-eff   sigma      EALF
----------  ---------------------------------------------------------  ------  ------  ------------
1727_09     la-3067-msr table iiia1, entry 13, water ref., metal, pu sphe  1.0050  0.0036  7.37764E+04
2109_20     benchmark 20, pu sphere with 25.4 cm concrete ref. h/pu=684.3  1.0296  0.0033  5.29605E-02
2109_21     benchmark 21, pu sphere with 10.16 cm concrete ref. h/pu=684.  1.0261  0.0035  5.08546E-02
2109_22     benchmark 22, pu sphere with 10.16 cm concrete ref. h/pu=496   1.0310  0.0037  6.29458E-02
2109_23     benchmark 23, pu sphere with cd shell & 10.16 cm concrete ref  1.0217  0.0037  6.95508E-02
2109_24     benchmark 24, pu sphere with cd shell & 32.00 cm water, h/pu=  1.0265  0.0039  5.98424E-02
2109_25     pu benchmark 25 from 2109, pu metal sphere reflected with nat  1.0051  0.0043  1.06688E+06
2110_02     benchmark#2 critical pu(no3)4solution, unreflected in a ss(ty  1.0198  0.0038  2.72852E-01
2110_04     sphere described by keno geometry                             1.0249  0.0055  4.92471E-02
2110_05     rectangular parallelpipeds of homogeneous pu(2.2)o2           1.0507  0.0059  2.88407E+01
2110_06     rectangular parallelpiped of pu(2.2)o2 reflected with 15cm p   1.0378  0.0049  5.27143E+00
2110_07     benchmark#7 semi-inf homogeneous critical solution of pu-239   1.0184  0.0039  7.17644E-02
2110_08     rectangular parallelpiped of puo2                             1.0367  0.0046  1.40745E+00
2110_09     rectangular parallelipipeds of pu02                           1.0292  0.0047  6.92776E-01
2110_10     rectangular parallelipipeds of pu02                           1.0228  0.0045  6.42973E-01
2110_11     rectangular parallelipipeds of pu02                           1.0256  0.0048  6.58349E-01
2110_12     rectangular parallelipipeds of pu02                           1.0233  0.0055  6.43369E-01
2110_13     sphere described by keno geometry                             0.9985  0.0038  1.18711E+06
2110_14     cylinder described by keno geometry                           1.0097  0.0056  1.20561E+00
2110_15     rectangular parallelipipeds of puo2-h20                       1.0140  0.0045  2.27778E+05
2110_16     rectangular parallelipipeds of puo2-h20                       1.0324  0.0037  8.93599E+05
2110_17     rectangular parallelipipeds of puo2-h20                       1.0376  0.0036  1.64120E+03
2110_18     rectangular parallelipipeds of puo2-h20                       1.0521  0.0034  3.65901E+03
2110_19     rectangular parallelipipeds of puo2-h20                       1.0159  0.0032  4.26807E+03
2110_20     rectangular parallelipipeds of puo2-h20                       1.0394  0.0033  2.20254E+03
2110_21     rectangular parallelipipeds of puo2-h20                       1.0490  0.0035  1.72756E+03
2110_23     rectangular parallelipipeds of puo2-polystyrene               1.0285  0.0048  1.30875E+03
2110_24     rectangular parallelipipeds of puo2-polystyrene               1.0449  0.0036  8.36567E+01
2110_25     rectangular parallelipipeds of puo2-polystyrene               1.0361  0.0031  7.60241E+01
2110_26     rectangular parallelipipeds of puo2-polystyrene               1.0407  0.0036  6.03526E+01
2110_27     rectangular parallelipipeds of puo2-polystyrene               1.0363  0.0038  5.03329E+01
2110_29     cylinder described by keno geometry                           1.0152  0.0033  4.35008E-02
pumf001     read parameters                                              0.9961  0.0021  1.15483E+06
pumf002     pu-met-fast-002                                              0.9980  0.0021  1.17833E+06
pust004     case 1,kvpusolnsphexp,27gp,26.27gpU/L, 0.54w/o240,h2orefl,14i  1.0144  0.0020  4.16522E-02
pust009     case 3a,kvpusolnsphexp,27,9.457gpU/L, 2.5w/o240,bare,48in dia  1.0315  0.0014  3.08556E-02
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                            27-Group_U-233
Case                   Title                                          k-eff   sigma      EALF
----------  ---------------------------------------------------------  ------  ------  ------------
u233mf001   unreflected u233 sphere                                       0.9606  0.0022  9.53093E+05
u233mf002   case 1, 10 kg u233/heu sphere, ref u233-met-fast-002          0.9800  0.0019  9.20987E+05
u233mf002   case 2, 7.6 kg u233/heu sphere, ref u233-met-fast-002         0.9690  0.0018  9.34208E+05
u233mf003   case 1, 10 kg u233 sphere natural uranium reflector, ref u233 0.9720  0.0022  9.22547E+05
u233mf003   case 2, 7.6 kg u233 sphere natural uranium reflector, ref u23 0.9692  0.0018  9.15874E+05
u233mf004   case 1, 10 kg u233 sphere reflected by tungsten               0.9723  0.0023  8.38232E+05
u233mf005   case 1, 10 kg u233 sphere be reflector, ref u233-met-fast-xxx 0.9804  0.0018  7.55819E+05
u233mf006   u-233/nu sphere                                               0.9720  0.0020  9.05503E+05
u233st002   exp 4 simplified model                                        1.0280  0.0032  1.35803E-01
u233st002   exp 5 simplified model                                        1.0139  0.0029  1.03454E-01
u233st002   exp 8 simplified model                                        1.0228  0.0031  7.89827E-02
u233st002   exp 10 simplified model                                       1.0226  0.0028  6.30183E-02
u233st002   exp 11 simplified model                                       1.0257  0.0028  5.42097E-02
u233st002   exp 12 simplified model                                       1.0115  0.0029  4.79043E-02
u233st002   exp 14 simplified model                                       1.0016  0.0028  4.49952E-02
u233st002   exp 15 simplified model                                       1.0061  0.0029  4.11486E-02
u233st002   exp 17 simplified model                                       0.9979  0.0030  3.65743E-02
u233st002   exp 18 simplified model                                       1.0101  0.0025  3.51384E-02
u233st002   exp 19 simplified model                                       1.0192  0.0024  3.24831E-02
u233st002   exp 22 simplified model                                       1.0212  0.0033  2.21292E-01
u233st002   exp 24 simplified model                                       1.0177  0.0035  4.08451E-01
u233st002   exp 34 simplified model                                       1.0201  0.0030  1.07854E-01
u233st002   exp 35 simplified model                                       1.0245  0.0030  7.11163E-02
u233st002   exp 36 simplified model                                       1.0202  0.0028  4.58427E-02
u233st002   exp 38 simplified model                                       1.0172  0.0032  3.84771E-02
u233st004   exp 3 simplified model                                        1.0284  0.0035  1.35825E-01
u233st004   exp 6 simplified model                                        1.0273  0.0031  1.02251E-01
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u233st004    exp 20 simplified model                                           1.0184   0.0030   2.19344E-01
u233st004    exp 25 simplified model                                           1.0095   0.0033   4.09481E-01
u233st004    exp 30 simplified model                                           1.0162   0.0031   3.16501E-01
u233st004    exp 27 simplified model                                           1.0330   0.0033   4.02504E-01
u233st004    exp 28 simplified model                                           1.0256   0.0033   3.16807E-01
u233st004    exp 33 simplified model                                           1.0244   0.0033   1.06962E-01
```

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                            238-Group_High-Enriched_Uranium
Case                  Title                                                    k-eff    sigma      EALF
----------    ------------------------------------------------------------     ------   ------   -----------
cas04         keno-5 validation case a-2                                       0.9929   0.0026   8.72602E+05
cas05         keno-5 validation case a-3                                       1.0029   0.0022   3.19847E-02
cas07         keno-5 validation case a-5                                       0.9985   0.0023   1.51839E+03
cas08         keno-5 validation case a-6                                       0.9674   0.0021   2.55059E+05
cas09         keno-5 validation case a-7                                       1.0059   0.0027   8.19004E+05
cas10         keno-5 validation case a-8                                       1.0015   0.0022   4.60081E+03
cas11         keno-5 validation case a-9                                       0.9903   0.0023   1.35781E+04
cas12         keno-5 validation case b-1                                       0.9863   0.0023   9.57343E+05
cas14         keno-5 validation case b-11                                      1.0401   0.0028   3.95126E-01
cas15         keno-5 validation case b-12                                      0.9962   0.0022   3.83563E+04
cas19         keno-5 validation case b-16                                      1.0271   0.0031   4.99861E-01
cas22         keno-5 validation case b-2                                       0.9911   0.0028   9.56962E+05
cas23         keno-5 validation case b-3                                       0.9908   0.0022   9.62937E+05
cas25         keno-5 validation case b-5                                       0.9921   0.0023   9.52954E+05
cas26         keno-5 validation case b-6                                       0.9953   0.0026   7.99033E+03
cas27         keno-5 validation case b-7                                       0.9972   0.0023   6.70276E+03
cas28         keno-5 validation case b-8                                       0.9995   0.0025   6.75293E+04
cas30         93.2% uo2f2 3 in al slab 3x1x1 array 0 in sep room               0.9999   0.0030   5.16381E-02
cas32         93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep room               0.9797   0.0034   5.21406E-02
cas33         93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep h2o refl           1.0010   0.0026   4.45316E-02
cas34         93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep room               0.9800   0.0033   5.25296E-02
cas35         93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep h2o refl           0.9925   0.0029   4.35018E-02
cas36         93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep room             0.9870   0.0028   5.27040E-02
cas37         93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep h2o refl         0.9965   0.0026   4.38570E-02
cas38         93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep room             0.9869   0.0031   5.25612E-02
cas39         93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep h2o refl         1.0011   0.0029   4.39968E-02
cas40         93.2% uo2f2 3 in al slab 3x1x1 array 6 in sep room               0.9880   0.0028   5.25405E-02
cas41         93.2% uo2f2 3, 6 in al slabs 2x1x1 array 15 in sep               0.9680   0.0028   5.22359E-02
cas42         93.2% uo2f2 3, 6 in al slabs 2x1x1 array 2 in sep                0.9797   0.0027   5.20680E-02
cas43         93.2% uo2f2 3, 6 in al slabs 2x1x1 array 30 in sep               0.9799   0.0027   5.21397E-02
cas44         93.2% uo2f2 3, 6 in al slabs 2x1x1 array 48 in sep               0.9774   0.0029   5.20884E-02
cas45         93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 0 in sep             0.9871   0.0031   5.18392E-02
cas46         93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 10 in sep            0.9755   0.0031   5.24709E-02
cas47         93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 20 in sep            0.9764   0.0031   5.22873E-02
cas48         93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 32 in sep            0.9753   0.0029   5.23936E-02
cas49         93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 12 in sep              0.9821   0.0031   5.23102E-02
cas50         93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 18 in sep              0.9779   0.0029   5.22187E-02
cas51         93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 30 in sep              0.9837   0.0033   5.21954E-02
cas52         93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 6 in sep               0.9843   0.0031   5.22766E-02
cas53         93.2% uo2f2 6 in al slab 2x1x1 array 15 in sep                   0.9878   0.0030   5.20851E-02
cas54         93.2% uo2f2 6 in al slab 2x1x1 array 2 in sep                    0.9762   0.0036   5.21981E-02
cas55         93.2% uo2f2 6 in al slab 2x1x1 array 20 in sep                   0.9855   0.0035   5.20153E-02
cas56         93.2% uo2f2 6 in al slab 2x1x1 array 30 in sep                   0.9827   0.0032   5.20723E-02
cas57         93.2% uo2f2 6 in al slab 2x1x1 array 48 in sep                   0.9792   0.0028   5.19591E-02
cas58         93.2% uo2f2 6 in al slab 2x1x1 array 6 in sep                    0.9750   0.0026   5.21925E-02
cas59         93.2% uo2f2 6 in al slab 2x1x1 array 66 in sep                   0.9765   0.0029   5.22049E-02
cas60         uo2(no3)2 279 g U/L 3x3x3 array unrefl. walls, tank, & floor     0.9994   0.0036   1.63707E-01
cas61         uo2(no3)2 279 g U/L 2x2x2 array unrefl. walls, tank, & floor     0.9982   0.0028   1.59976E-01
cas62         uo2(no3)2 415 g U/L 5x5x5 array unrefl. walls, tank, & floor     0.9935   0.0029   3.27299E-01
cas63         uo2(no3)2 415 g U/L 3x3x3 array unrefl. walls, tank, & floor     0.9907   0.0031   3.32000E-01
cas64         uo2(no3)2 415 g U/L 4x4x4 array unrefl. walls, floor, & tank     0.9849   0.0027   3.32017E-01
cas65         uo2(no3)2 415 g U/L 2x2x2 array unrefl.  walls, floor, & tank    0.9943   0.0028   3.21700E-01
cas66         uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p    0.9987   0.0031   2.85922E-01
cas67         uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 2.54 cm p    1.0057   0.0028   2.60094E-01
cas68         uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p    1.0098   0.0030   2.74454E-01
cas69         uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par 5 fc, plex 1 fc     1.0098   0.0031   2.13964E-01
cas70         uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 3.81 cm p    1.0136   0.0025   2.29726E-01
cas71         uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 7.62 cm p    1.0174   0.0028   2.16388E-01
cas72         uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm plexiglass refl.         0.9957   0.0029   3.01624E-01
cas73         uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm paraffin refl.           1.0079   0.0030   2.87622E-01
cas74         uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm paraffin refl.          1.0148   0.0033   2.14444E-01
cas75         uo2(no3)2 415 g U/L 3x3x3 array 3.81 cm paraffin refl.           1.0185   0.0029   2.31371E-01
cas76         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p    1.0085   0.0034   2.79851E-01
cas77         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 11.43 cm     1.0162   0.0035   2.09829E-01
cas78         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 15.24 cm     1.0196   0.0034   2.10811E-01
cas79         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 2.54 cm p    1.0061   0.0030   2.57502E-01
cas80         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 4.45 cm p    1.0117   0.0030   2.32547E-01
cas81         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 6.35 cm p    1.0169   0.0034   2.20610E-01
cas82         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p    1.0019   0.0035   2.71412E-01
cas83         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 3.81 cm p    1.0133   0.0029   2.26284E-01
cas84         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 7.62 cm p    1.0096   0.0029   2.13056E-01
cas85         uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm plexiglass refl.         1.0027   0.0032   2.93017E-01
cas86         uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm paraffin refl.           1.0006   0.0031   2.85736E-01
cas87         uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm paraffin refl.          1.0051   0.0030   2.10814E-01
cas88         uo2(no3)2 415 g U/L 2x2x2 array 3.81 cm paraffin refl.           1.0143   0.0030   2.30669E-01
cas89         uo2(no3)2 415 g U/L 2x2x2 array 7.62 cm paraffin refl.           1.0145   0.0032   2.14353E-01
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cas90      uo2(no3)2 415 g U/L 3x3x3 array unrefl. 279 g U/L 5 cent. uni   0.9988  0.0033  2.68293E-01
cas91      uo2(no3)2 63.3 g U/L 3x3x3 array unrefl. walls, floor, & tank   1.0047  0.0028  4.35694E-02
jemima     disks - 15" diam plates 93.15 w% enriched stacked to 3.0258"    0.9901  0.0023  9.54288E+05
jemima     jemima - ~1/8" x 15" diam u(93.29) plates with 1/16" thk poly   0.9856  0.0025  1.29348E+05
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1/8" thk pol   0.9907  0.0022  1.96389E+04
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1/4" thk pol   0.9795  0.0028  1.87563E+03
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1/2" thk pol   1.0033  0.0033  9.10357E+01
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1" thk poly,   0.9961  0.0029  7.84216E+00
jemima     jemima - ~1/8" x 15" dia u(93) with symetric 1-1/2" thk poly,   1.0126  0.0029  3.32451E+00
jemima     jemima - ~1/8" x 15" dia u(93) with symetric 2" thk poly, pg-   1.0030  0.0026  2.15208E+00
heumf001   godiva                                                          0.9947  0.0017  9.46515E+05
heumf004   water-reflected heu sphere on hollow plexiglas cylinder         0.9949  0.0019  3.17230E+04
heust001   case 1 heust001                                                 1.0034  0.0023  8.15659E-02
heust001   case 2 heust001                                                 0.9965  0.0025  2.78903E-01
heust001   case 3 heust001                                                 1.0004  0.0022  8.02241E-02
heust001   case 4 heust001                                                 1.0015  0.0026  2.97525E-01
heust001   case 5 heust001                                                 0.9991  0.0020  4.26179E-02
heust001   case 6 heust001                                                 1.0037  0.0022  4.41837E-02
heust001   case 7 heust001                                                 1.0023  0.0024  7.72749E-02
heust001   case 8 heust001                                                 1.0041  0.0025  8.16412E-02
heust001   case 9 heust001                                                 1.0010  0.0024  2.97578E-01
heust001   case 10 heust001                                                0.9947  0.0024  4.57878E-02
heust007   case 1 , heust007                                               1.0103  0.0020  4.70221E-02
heust007   case 2 , heust007                                               1.0127  0.0025  2.69161E-01
heust007   case 3 , heust007                                               1.0152  0.0020  4.57855E-02
heust007   case 4 , heust007                                               1.0156  0.0021  2.38054E-01
heust007   case 5 , heust007                                               1.0092  0.0024  4.98972E-02
heust007   case 6 , heust007                                               0.9990  0.0025  2.76414E-01
heust007   case 7 , heust007                                               1.0077  0.0021  4.93724E-02
heust007   case 8 , heust007                                               0.9985  0.0023  2.69885E-01
heust007   case 9 , heust007                                               1.0098  0.0020  5.09965E-02
heust007   case 10 , heust007                                              1.0190  0.0018  5.25449E-02
heust007   case 11 , heust007                                              1.0068  0.0025  2.58842E-01
heust007   case 12 , heust007                                              1.0168  0.0019  5.08038E-02
heust007   case 13 , heust007                                              1.0133  0.0024  2.32334E-01
heust007   case 14 , heust007                                              1.0109  0.0023  2.39805E-01
heust007   case 15 , heust007                                              1.0066  0.0024  2.42767E-01
heust007   case 16 , heust007                                              1.0075  0.0020  2.57196E-01
heust007   case 17 , heust007                                              1.0122  0.0022  2.40834E-01
heust008   case 1 , heust008                                               1.0030  0.0021  4.41151E-02
heust008   case 2 , heust008                                               1.0001  0.0022  2.35278E-01
heust008   case 3 , heust008                                               0.9982  0.0022  4.28655E-02
heust008   case 4 , heust008                                               1.0045  0.0024  2.08457E-01
heust008   case 5 , heust008                                               0.9954  0.0020  4.39679E-02
heust008   case 6 , heust008                                               1.0040  0.0023  2.56841E-01
heust008   case 7 , heust008                                               0.9994  0.0021  4.31425E-02
heust008   case 8 , heust008                                               0.9942  0.0027  2.43907E-01
heust008   case 9 , heust008                                               1.0026  0.0019  4.38698E-02
heust008   case 10 , heust008                                              0.9961  0.0021  2.34092E-01
heust008   case 11 , heust008                                              0.9993  0.0019  4.22503E-02
heust008   case 12 , heust008                                              0.9941  0.0026  2.03867E-01
heust008   case 13 , heust008                                              0.9952  0.0022  2.31398E-01
heust008   case 14 , heust008                                              1.0003  0.0024  2.09187E-01
heust013   uranium aqueous 23 cm sphere #1                                 0.9975  0.0014  3.23536E-02
heust013   uranium aqueous 32 cm sphere #2                                 0.9996  0.0015  3.38035E-02
heust013   uranium aqueous 32 cm sphere #3                                 0.9973  0.0016  3.51838E-02
heust013   uranium aqueous 32 cm sphere #4                                 0.9949  0.0018  3.59196E-02
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                          238-Group_Low-Enriched_Uranium
Case              Title                                           k-eff   sigma      EALF
----------   -------------------------------------------------    ------  ------  ------------
car01        rocky flats criticals nureg/cr-1071 experiment number 1 (27 g   1.0120  0.0022  4.49065E-01
car02        rocky flats criticals nureg/cr-1071 experiment number 2 (27 g   1.0037  0.0024  4.62296E-01
car03        rocky flats criticals nureg/cr-1071 experiment number 3 (27 g   0.9906  0.0026  1.57168E+00
car04        rocky flats criticals nureg/cr-1071 experiment number 13 (27    1.0149  0.0022  5.12451E-01
car06        rocky flats criticals nureg/cr-0674 experiment number ? (27 g   0.9855  0.0031  4.07508E+02
car07        rocky flats criticals nureg/cr-0674 experiment number ? (27 g   0.9975  0.0029  4.02812E+00
car08        rocky flats criticals nureg/cr-0674 experiment number ? (27 g   0.9920  0.0035  2.13766E+00
car09        rocky flats criticals nureg/cr-0674 experiment number 2 (27 g   0.9961  0.0032  2.07664E+00
car10        rocky flats criticals nureg/cr-0674 concrete reflected (27 gr   0.9994  0.0033  5.80807E+00
car11        rocky flats criticals nureg/cr-1653 experiment a (27 group)     1.0089  0.0027  3.98382E-01
car12        rocky flats criticals nureg/cr-1653 experiment b (27 group)     1.0185  0.0024  1.01915E+00
car14        rocky flats criticals nureg/cr-1653 experiment number ? (27 g   0.9960  0.0031  3.19301E+00
car15        rocky flats criticals nureg/cr-1653 experiment number ? (27 g   1.0022  0.0026  3.19702E+00
car16        rocky flats criticals nureg/cr-1653 experiment number ? (27 g   1.0022  0.0029  2.02756E+00
car17        rocky flats criticals nureg/cr-2500 experiment f (27 group)     1.0029  0.0025  6.84178E-01
car19        rocky flats criticals nureg/cr-2500 experiment number ? (27 g   0.9979  0.0023  3.88138E+00
car20        rocky flats criticals nureg/cr-2500 experiment number ? (27 g   0.9941  0.0028  3.55597E+00
cas04        british handbook of criticality safety u(1.42)f4 & paraffin (   0.9888  0.0020  1.23327E-01
cas05        british handbook of criticality safety u(1.42)f4 & paraffin (   0.9933  0.0021  1.22794E-01
cas06        british handbook of criticality safety u(1.42)f4 & paraffin (   0.9875  0.0021  1.23536E-01
cas11        raffety and malhalczo u(2)f4-1 reflected (case 11)              1.0009  0.0025  2.03221E-01
cas12        raffety and malhalczo u(2)f4-1 unreflected (case12)             0.9964  0.0025  2.45621E-01
cas13        raffety and malhalczo u(2)f4-2 reflected (case 13) no biasing   1.0057  0.0023  1.19077E-01
cas14        raffety and malhalczo u(2)f4-2 unreflected (case 14)            1.0011  0.0021  1.37058E-01
cas15        raffety and malhalczo u(2)f4-3 reflected (case 15)              0.9975  0.0022  8.68601E-02
cas16        raffety and malhalczo u(2)f4-4 reflected (case 16)              0.9988  0.0021  7.31192E-02
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cas17   raffety and malhalczo u(2)f4-5 reflected (case 17)              0.9990  0.0021  6.32955E-02
cas18   raffety and malhalczo u(2)f4-5 unreflected (case18)             0.9942  0.0024  6.68026E-02
cas19   raffety and malhalczo u(2)f4-6 reflected (case 19)              0.9897  0.0019  4.89725E-02
cas20   raffety and malhalczo u(2)f4-6 unreflected (case20)             0.9938  0.0019  4.99469E-02
cas21   raffety and milhalczo u(3)f4-1 reflected (case 21) no bias      1.0179  0.0024  2.40291E-01
cas22   raffety and malhalczo u(3)f4-1 reflected (case 22)              1.0127  0.0026  2.42018E-01
cas23   raffety and malhalczo u(3)f4-1 reflected (case 23)              1.0123  0.0025  2.40792E-01
cas24   raffety and malhalczo u(3)f4-1 reflected (case 24) no biasing   1.0133  0.0022  2.41798E-01
cas25   raffety and malhalczo u(3)f4-1 reflected (case 25)              1.0142  0.0026  2.38868E-01
cas26   raffety and malhalczo u(3)f4-1 unreflected (case 26)            1.0169  0.0024  3.24076E-01
cas27   raffety and malhalczo u(3)f4-1 unreflected (case 27)            1.0107  0.0028  3.28492E-01
cas28   raffety and malhalczo u(3)f4-1 unreflected (case 28)            1.0121  0.0024  3.27693E-01
cas29   raffety and malhalczo u(3)f4-2 reflected (cas29)                1.0129  0.0026  9.54956E-02
cas30   raffety and malhalczo u(3)f4-2 unreflected (case 30)            1.0121  0.0022  1.12435E-01
cas31   raffety and malhalczo u(3)f4-2 unreflected (case 31)            1.0126  0.0029  1.12253E-01
cas32   raffety and malhalczo u(3)f4-2 unreflected (case 32)            1.0108  0.0026  1.12948E-01
cas33   critical reflected cylinder of aqueous u(4.98)o2f2 (case 33)    0.9993  0.0024  5.65883E-02
cas34   critical reflected cylinder of aqueous u(4.98)o2f2 (case 34)    1.0024  0.0022  5.58962E-02
cas35   critical sphere of aqueous u(4.98)o2f2 (case 35)                1.0023  0.0023  5.59508E-02
cas36   critical cylinder of aqueous u(4.98)o2f2 (case 36)              0.9966  0.0027  5.64167E-02


                             238-Group_LWR_Lattices
Case            Title                                                   k-eff   sigma     EALF
----------  ----------------------------------------------------------  ------  ------  -----------
cas01   exp#5, 8.39 cm h2o separating 3 20x16 arrays                    0.9935  0.0019  9.72779E-02
cas02   exp#017, 5.05 cm h2o/boral separating 2 22x16 arrays and 1 20   0.9963  0.0011  9.99550E-02
cas03   exp#28, 6.88 cm h2o/ss separating 3 20x16 arrays                0.9949  0.0017  9.74634E-02
cas04   exp no. 14 8.58 cm h2o/ss separating 3 15x8 arrays              0.9980  0.0018  1.15539E-01
cas05   exp no. 23 7.28 cm h2o/cadmium separating 3 15x8 arrays         0.9975  0.0018  1.15129E-01
cas06   exp no. 31 6.72 cm h2o/boral separating 3 15x8 arrays           0.9975  0.0017  1.16097E-01
cas07   u refl. 1.956 cm from array,    14.11 cm h2o separating 3 19x1  0.9970  0.0015  1.75684E-01
cas08   pb refl. .660 cm from array, 13.72 cm h2o separating 3 19x16    1.0033  0.0014  9.81849E-02
cas09   no refl. 8.31cm h2o separating 19x16 arrays                     0.9929  0.0018  9.63093E-02
cas10   uranium refl. 15.32cm h2o separating 12x8  arrays               1.0007  0.0015  2.76143E-01
cas11   lead refl. 20.78cm h2o separating 13x8  arrays                  1.0085  0.0009  1.17492E-01
cas12   2.83cm and 3.60cm separating 4 11x14 arrays                     1.0006  0.0018  3.15834E-01
cas13   2.83cm and 4.94cm separating 2 11x14 + 2 11x16 arrays           0.9979  0.0014  3.22608E-01
cas14   ss refl. 0.66 cm from array, 11.20 cm h2o separating 3 19x16    0.9988  0.0017  9.94491E-02
cas15   steel refl. 15.84cm h2o separating 3 12x16 arrays               0.9994  0.0018  2.91242E-01
cas16   steel refl.  9.83cm h2o separating 3 12x16 arrays   w/borated   0.9988  0.0019  3.01840E-01
cas17   steel refl.  8.30cm h2o separating 3 12x16 arrays   w/boral pl  0.9983  0.0017  3.08394E-01
cas18   steel refl.  8.94cm h2o separating 3 12x16 arrays   w/cd plate  0.9971  0.0014  3.05121E-01
cas19   u refl 1.321 cm from array, 9.50 cm h2o sep. 23x18/2-20x18 ar   0.9913  0.0014  3.45496E-01
cas20   pb refl 0.660 cm from array, 10.11 cm h2o sep. 23x18/2-20x18    0.9990  0.0016  1.70965E-01
cas21   no refl infinite from array, 6.59 cm h2o sep. 23x18/2-20x18 a   0.9862  0.0016  1.63154E-01
cas22   uranium refl. 19.24cm h2o separating 12x16 arrays               0.9955  0.0018  5.13386E-01
cas23   lead refl. 18.18cm h2o separating 12x16 arrays                  1.0014  0.0018  2.96916E-01
cas24   no refl. 12.91cm h2o separating 3 12x16 arrays                  0.9968  0.0017  2.81792E-01
cas25   pnl-4267 exp. 173 40 x 8.92 array (357 total rods) boron = 0    0.9927  0.0013  2.81114E-01
cas26   pnl-4267 exp.177 40 x 30.92 array 1237 total rods) boron = 2.   0.9992  0.0014  6.05176E-01
cas27   pnl-4267 exp. 178 44 x 11.57array (509 total rods) boron = 0    0.9944  0.0012  5.26820E-01
cas28   pnl-4267 exp. 181 44 x 27.09 array (1192 total rods) boron =    0.9932  0.0017  1.16687E+00
cas29   pnl-4976 4.3-000-194 4.3%uo2 1.598cm-pitch                      0.9983  0.0015  3.50327E-01
cas30   flux trap assembly no. 214r                                     0.9940  0.0016  3.70966E-01
cas31   flux trap assembly no. 214v3                                    0.9950  0.0012  3.71058E-01
cas32   baw-1231 core i 936 rods  boron=1.152 g/l                       0.9902  0.0012  7.41684E-01
cas33   baw-1231 core i 4904 rods  boron=3.389 g/l                      0.9925  0.0010  1.20418E+00
cas34   baw-1273 core xx          2.46 wt%u235  5137 rods               0.9877  0.0014  5.39135E-01
cas35   baw-1484-7 core iv exp 2282  2.46 wt%u235  9 assys 14x14 w/ 8   0.9917  0.0011  1.91476E-01
cas36   baw-1484-7 core ix exp 2321  2.46 wt%u235  9 assys 14x14        0.9918  0.0015  1.40568E-01
cas37   baw-1484-7 core xiii exp 2378  2.46 wt%u235  9 assys 14x14      0.9971  0.0016  1.96163E-01
cas38   baw-1484-7 core xxi exp 2420  2.46 wt%u235  9 assys 14x14       0.9902  0.0016  1.56510E-01
cas39   baw-1645-4 exp,mt=2452  triangular pitch=o.d.      boron=435ppm 0.9980  0.0011  2.32818E+00
cas40   baw-1645-4 exp,mt=2485  pitch=o.d.      boron=886ppm            0.9956  0.0013  1.43810E+00
cas41   baw-1645-4 exp,mt=2500  pitch=1.17*o.d.      boron=1156ppm      0.9953  0.0013  4.21402E-01
cas42   baw-1810 core 12 - 4.02 & 2.46 w/o uo2 1899.3 ppm; no uo2-gd2   0.9951  0.0014  3.59815E-01
cas43   baw-1810 core 14 - 4.02 & 2.46 w/o uo2 1654 ppm; 28 uo2-gd2o3   0.9973  0.0012  3.40863E-01
cas44   baw-1810 core 16 - 4.02 & 2.46 w/o uo2 1579 ppm; 36 uo2-gd2o3   0.9946  0.0014  3.35341E-01
cas45   epri np-196 .615 inch pitch unborated uo2                       0.9915  0.0015  2.62708E-01
cas46   epri np-196 .615 inch pitch borated uo2                         0.9959  0.0015  3.24378E-01
cas47   epri np-196 .75 inch pitch unborated uo2                        0.9952  0.0011  1.15987E-01
cas48   epri np-196 .75 inch pitch borated uo2                          0.9971  0.0010  1.43469E-01
cas49   epri np-196 .87 inch pitch unborated uo2                        0.9975  0.0015  8.38792E-02
cas50   epri np-196 .87 inch pitch borated uo2                          0.9986  0.0014  9.43365E-02
cas51   saxton uo2 5.742 wt% u-235 critical exp. 0.56 inch pitch (wca   0.9928  0.0019  2.94992E-01
cas52   saxton uo2 5.742 wt% u-235 critical exp. 0.792inch pitch (wca   0.9970  0.0011  1.03491E-01
cas53   wcap-3269-39, 2692 fuel rods, 16 ag-in-cd rods,h2o ht=115.55    0.9967  0.0012  7.02891E-01
cas54   wcap-3269-39, 2209 fuel rods, 24 ag-in-cd rods,h2o ht=64.56 c   0.9969  0.0018  4.35257E-01
cas55   wcap-3269-39,  945 fuel rods, 16 ag-in-cd rods,h2o ht=89.75     0.9922  0.0011  2.59930E-01
cas56   4-18x18 array 5.0cm int.,polyethylene powder in box,30.16cm h   0.9955  0.0014  2.28675E-01
cas57   4-18x18 array 5.0cm int.,polyethylene balls in box,30.73cm h2   1.0081  0.0012  2.07415E-01
cas58   4-18x18 array 5.0cm int.,water in box,32.78cm h2o height        1.0089  0.0014  1.98793E-01
cas59   4-18x18 array 5.0cm int.,water without box,31.47cm h2o height   0.9937  0.0013  1.97221E-01
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                              238-Group_Mixed_Oxide
Case                Title                                               k-eff   sigma      EALF
----------   ------------------------------------------------------   ------  ------  ------------
cas60        epri .70inch pitch unborated plutonium                   0.9950  0.0016  5.79362E-01
cas61        epri .70inch pitch borated plutonium                     0.9937  0.0014  7.73542E-01
cas62        epri .87inch pitch unborated plutonium                   0.9996  0.0012  1.92595E-01
cas63        epri .87inch pitch borated plutonium                     1.0065  0.0013  2.80882E-01
cas64        epri .99inch pitch unborated plutonium                   1.0058  0.0017  1.36046E-01
cas65        epri .99inch pitch borated plutonium                     1.0043  0.0011  1.83063E-01
cas66        saxton puo2-uo2 critical exp. 0.52 inch pitch (wcap-3385-54)  0.9940  0.0013  9.08366E-01
cas67        saxton puo2-uo2 critical exp. 0.56 inch pitch (wcap-3385-54)  0.9958  0.0020  5.56103E-01
cas68        saxton puo2-uo2 critical exp. 0.56 inch pitch with boron (wca  0.9994  0.0017  6.52494E-01
cas69        saxton puo2-uo2 critical exp. 0.735 inch pitch (wcap-3385-54)  1.0002  0.0019  1.87434E-01
cas70        saxton puo2-uo2 critical exp. 0.792 inch pitch (wcap-3385-54)  0.9985  0.0021  1.55424E-01
cas71        saxton puo2-uo2 critical exp. 01.04 inch pitch (wcap-3385-54)  1.0041  0.0017  1.00630E-01
cas72        pnl4976 exp196 1174 uo2 & 583 mo2 rods to approx. 20,000 mwd/  0.9907  0.0016  4.33548E+00
cas73        exp.no 021(063) pitch=968 (fuel region = pin array + mix 500   1.0010  0.0013  8.87803E-01
cas74        exp.no 032(060) pitch=1.935(fuel region=pin array+mix 500 wit  1.0093  0.0018  1.13573E-01
cas75        exp.no 043(062) pitch=1.242(fuel region=pin array+mix 500 wit  1.0010  0.0012  2.89041E-01
cas76        exp.no 067 pitch=0.761 (fuel region = pin array + mix 500 wit  0.9954  0.0012  2.90946E+00
cas77        exp. no 68r pitch=1.537 (fuel region = pin array + mix 500 wi  1.0009  0.0020  1.64627E-01


                              238-Group_Plutonium
Case                Title                                               k-eff   sigma      EALF
----------   ------------------------------------------------------   ------  ------  ------------
1727_09      la-3067-msr table iiia1, entry 13, water ref., metal, pu sphe  0.9941  0.0037  8.74593E+04
2109_20      benchmark 20, pu sphere with 25.4 cm concrete ref. h/pu=684.3  1.0248  0.0033  6.68450E-02
2109_21      benchmark 21, pu sphere with 10.16 cm concrete ref. h/pu=684.  1.0303  0.0030  6.47639E-02
2109_22      benchmark 22, pu sphere with 10.16 cm concrete ref. h/pu=496   1.0284  0.0040  7.80916E-02
2109_23      benchmark 23, pu sphere with cd shell & 10.16 cm concrete ref  1.0207  0.0037  8.61406E-02
2109_24      benchmark 24, pu sphere with cd shell & 32.00 cm water, h/pu=  1.0093  0.0045  7.55822E-02
2109_25      pu benchmark 25 from 2109, pu metal sphere reflected with nat  1.0099  0.0046  1.09881E+06
2110_02      benchmark#2 critical pu(no3)4solution, unreflected in a ss(ty  0.9982  0.0042  3.14377E-01
2110_04      sphere described by keno geometry                         1.0106  0.0054  6.25452E-02
2110_05      rectangular parallelpipeds of homogeneous pu(2.2)o2       1.0215  0.0055  3.25438E+01
2110_06      rectangular parallelpiped of pu(2.2)o2 reflected with 15cm p  1.0324  0.0062  5.75456E+00
2110_07      benchmark#7 semi-inf homogeneous critical solution of pu-239  1.0156  0.0042  8.90235E-02
2110_08      rectangular parallelipiped of puo2                        0.9965  0.0045  1.61025E+00
2110_09      rectangular parallelipipeds of puo2                       1.0129  0.0045  7.49517E-01
2110_10      rectangular parallelipipeds of puo2                       1.0060  0.0044  7.15587E-01
2110_11      rectangular parallelipipeds of puo2                       1.0122  0.0052  6.92043E-01
2110_12      rectangular parallelipipeds of puo2                       1.0138  0.0049  7.04008E-01
2110_13      sphere described by keno geometry                         0.9893  0.0038  1.26282E+06
2110_14      cylinder described by keno geometry                       1.0160  0.0054  1.42869E-01
2110_15      rectangular parallelipipeds of puo2-h2o                   0.9892  0.0047  2.76979E+05
2110_16      rectangular parallelipipeds of puo2-h2o                   1.0306  0.0036  1.01504E+06
2110_17      rectangular parallelipipeds of puo2-h2o                   1.0177  0.0033  1.81528E+03
2110_18      rectangular parallelipipeds of puo2-h2o                   1.0359  0.0035  4.02615E+03
2110_19      rectangular parallelipipeds of puo2-h2o                   1.0036  0.0035  4.90390E+03
2110_20      rectangular parallelipipeds of puo2-h2o                   1.0272  0.0036  2.52214E+03
2110_21      rectangular parallelipipeds of puo2-h2o                   1.0326  0.0033  2.06263E+03
2110_23      rectangular parallelipipeds of puo2-polystyrene           1.0071  0.0045  1.67868E+03
2110_24      rectangular parallelipipeds of puo2-polystyrene           1.0263  0.0030  9.63733E+01
2110_25      rectangular parallelipipeds of puo2-polystyrene           1.0213  0.0034  8.13644E+01
2110_26      rectangular parallelipipeds of puo2-polystyrene           1.0214  0.0032  6.68965E+01
2110_27      rectangular parallelipipeds of puo2-polystyrene           1.0267  0.0036  5.85304E+01
2110_29      cylinder described by keno geometry                       1.0045  0.0042  5.66907E-02
pumf001      read parameters                                          0.9948  0.0022  1.24211E+06
pumf002      pu-met-fast-002                                          0.9970  0.0021  1.26133E+06
pust004      case 1,kvpusolnsphexp,27gp,26.27gpU/L, 0.54w/o240,h2orefl,14i  1.0106  0.0016  5.33603E-02
pust009      case 3a,kvpusolnsphexp,27,9.457gpU/L, 2.5w/o240,bare,48in dia  1.0252  0.0014  4.06586E-02


                              238-Group_U-233
Case                Title                                               k-eff   sigma      EALF
----------   ------------------------------------------------------   ------  ------  ------------
u233mf001    unreflected u233 sphere                                  0.9949  0.0021  1.12624E+06
u233mf002    case 1, 10 kg u233/heu sphere, ref u233-met-fast-002     1.0009  0.0018  1.07140E+06
u233mf002    case 2, 7.6 kg u233/heu sphere, ref u233-met-fast-002    0.9968  0.0019  1.09184E+06
u233mf003    case 1, 10 kg u233 sphere natural uranium reflector, ref u233  0.9973  0.0019  1.08439E+06
u233mf003    case 2, 7.6 kg u233 sphere natural uranium reflector, ref u23  0.9944  0.0021  1.06831E+06
u233mf004    case 1, 10 kg u233 sphere reflected by tungsten          1.0034  0.0021  9.72986E+05
u233mf005    case 1, 10 kg u233 sphere be reflector, ref u233-met-fast-xxx  0.9990  0.0017  9.45442E+05
u233mf006    u-233/nu sphere                                          0.9999  0.0018  1.00260E+06
u233st002    exp 4 simplified model                                   1.0073  0.0029  1.65051E+00
u233st002    exp 5 simplified model                                   0.9880  0.0030  1.27540E-01
u233st002    exp 8 simplified model                                   1.0075  0.0030  9.98798E-02
u233st002    exp 10 simplified model                                  0.9968  0.0030  8.20234E-02
u233st002    exp 11 simplified model                                  1.0062  0.0028  7.17533E-02
u233st002    exp 12 simplified model                                  0.9895  0.0026  6.41775E-02
u233st002    exp 14 simplified model                                  0.9790  0.0028  6.07490E-02
u233st002    exp 15 simplified model                                  0.9948  0.0029  5.59668E-02
u233st002    exp 17 simplified model                                  0.9857  0.0025  5.05877E-02
u233st002    exp 18 simplified model                                  0.9958  0.0026  4.89457E-02
u233st002    exp 19 simplified model                                  1.0082  0.0024  4.56554E-02
u233st002    exp 22 simplified model                                  0.9939  0.0031  2.54080E-01
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u233st002   exp 24 simplified model                                      0.9892  0.0035  4.53345E-01
u233st002   exp 34 simplified model                                      0.9974  0.0032  1.34044E-01
u233st002   exp 35 simplified model                                      1.0059  0.0030  9.20007E-02
u233st002   exp 36 simplified model                                      1.0074  0.0030  6.16613E-02
u233st002   exp 38 simplified model                                      1.0005  0.0025  5.32661E-02
u233st004   exp 3 simplified model                                       1.0034  0.0037  1.61695E-01
u233st004   exp 6 simplified model                                       1.0009  0.0031  1.26983E-01
u233st004   exp 20 simplified model                                      0.9963  0.0034  2.56595E-01
u233st004   exp 25 simplified model                                      0.9835  0.0034  4.49624E-01
u233st004   exp 30 simplified model                                      0.9965  0.0036  3.59591E-01
u233st004   exp 27 simplified model                                      1.0032  0.0032  4.52504E-01
u233st004   exp 28 simplified model                                      0.9970  0.0031  3.55180E-01
u233st004   exp 33 simplified model                                      0.9992  0.0029  1.31412E-01


                            44-Group_High-Enriched_Uranium
Case               Title                                               k-eff   sigma      EALF
----------   ----------------------------------------------------     ------  ------  -----------
cas04        keno-5 validation case a-2                               0.9961  0.0022  8.27402E+05
cas05        keno-5 validation case a-3                               1.0028  0.0021  3.03857E-02
cas07        keno-5 validation case a-5                               1.0055  0.0021  1.43512E+03
cas08        keno-5 validation case a-6                               0.9626  0.0021  2.56420E+05
cas09        keno-5 validation case a-7                               0.9965  0.0025  8.02787E+05
cas10        keno-5 validation case a-8                               1.0102  0.0025  4.68810E+03
cas11        keno-5 validation case a-9                               0.9915  0.0023  1.29666E+04
cas12        keno-5 validation case b-1                               0.9969  0.0024  9.11484E+05
cas14        keno-5 validation case b-11                              1.0541  0.0028  3.83565E-01
cas15        keno-5 validation case b-12                              0.9978  0.0022  3.97055E+04
cas19        keno-5 validation case b-16                              1.0293  0.0035  4.91972E-01
cas22        keno-5 validation case b-2                               0.9957  0.0023  9.12139E+05
cas23        keno-5 validation case b-3                               0.9904  0.0022  9.20083E+05
cas25        keno-5 validation case b-5                               1.0015  0.0023  9.16032E+05
cas26        keno-5 validation case b-6                               1.0039  0.0026  8.46295E+03
cas27        keno-5 validation case b-7                               0.9992  0.0022  6.65054E+03
cas28        keno-5 validation case b-8                               0.9991  0.0028  6.33665E+04
cas30        93.2% uo2f2 3 in al slab 3x1x1 array 0 in sep room       1.0008  0.0029  4.95825E-02
cas31        93.2% uo2f2 3 in al slab 3x1x1 array 0 in sep h2o refl   0.9976  0.0027  4.59142E-02
cas32        93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep room       0.9778  0.0029  5.02354E-02
cas33        93.2% uo2f2 3 in al slab 3x1x1 array 1 in sep h2o refl   0.9993  0.0028  4.26149E-02
cas34        93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep room       0.9792  0.0030  5.06065E-02
cas35        93.2% uo2f2 3 in al slab 3x1x1 array 3 in sep h2o refl   0.9980  0.0025  4.16554E-02
cas36        93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep room     0.9848  0.0030  5.03493E-02
cas37        93.2% uo2f2 3 in al slab 3x1x1 array 4.5 in sep h2o refl 0.9986  0.0023  4.20791E-02
cas38        93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep room     0.9893  0.0028  5.04825E-02
cas39        93.2% uo2f2 3 in al slab 3x1x1 array 5.5 in sep h2o refl 1.0079  0.0028  4.22311E-02
cas40        93.2% uo2f2 3 in al slab 3x1x1 array 6 in sep room       0.9868  0.0027  5.06559E-02
cas41        93.2% uo2f2 3, 6 in al slabs 2x1x1 array 15 in sep       0.9769  0.0030  5.00974E-02
cas42        93.2% uo2f2 3, 6 in al slabs 2x1x1 array 2 in sep        0.9774  0.0028  5.01126E-02
cas43        93.2% uo2f2 3, 6 in al slabs 2x1x1 array 30 in sep       0.9725  0.0029  5.01940E-02
cas44        93.2% uo2f2 3, 6 in al slabs 2x1x1 array 48 in sep       0.9789  0.0033  4.99943E-02
cas45        93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 0 in sep     0.9812  0.0029  4.97176E-02
cas46        93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 10 in sep    0.9722  0.0034  5.05098E-02
cas47        93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 20 in sep    0.9740  0.0028  5.02911E-02
cas48        93.2% uo2f2 3, 6, 3 in al slabs 3x1x1 array 32 in sep    0.9720  0.0031  5.03027E-02
cas49        93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 12 in sep      0.9780  0.0034  5.03063E-02
cas50        93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 18 in sep      0.9806  0.0034  5.03061E-02
cas51        93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 30 in sep      0.9825  0.0028  5.01101E-02
cas52        93.2% uo2f2 6 & 3 in al slabs 2x1x1 array 6 in sep       0.9824  0.0030  5.00571E-02
cas53        93.2% uo2f2 6 in al slab 2x1x1 array 15 in sep           0.9842  0.0030  5.01835E-02
cas54        93.2% uo2f2 6 in al slab 2x1x1 array 2 in sep            0.9772  0.0026  5.02553E-02
cas55        93.2% uo2f2 6 in al slab 2x1x1 array 20 in sep           0.9791  0.0027  4.99922E-02
cas56        93.2% uo2f2 6 in al slab 2x1x1 array 30 in sep           0.9831  0.0027  4.99471E-02
cas57        93.2% uo2f2 6 in al slab 2x1x1 array 48 in sep           0.9815  0.0026  5.00679E-02
cas58        93.2% uo2f2 6 in al slab 2x1x1 array 6 in sep            0.9696  0.0037  5.04142E-02
cas59        93.2% uo2f2 6 in al slab 2x1x1 array 66 in sep           0.9839  0.0032  4.98814E-02
cas60        uo2(no3)2 279 g U/L 3x3x3 array unrefl. walls, tank, & floor  0.9971  0.0030  1.61543E-01
cas61        uo2(no3)2 279 g U/L 2x2x2 array unrefl. walls, tank, & floor  1.0052  0.0027  1.56140E-01
cas62        uo2(no3)2 415 g U/L 5x5x5 array unrefl. walls, tank, & floor  0.9898  0.0033  3.23599E-01
cas63        uo2(no3)2 415 g U/L 3x3x3 array unrefl. walls, tank, & floor  0.9951  0.0034  3.23451E-01
cas64        uo2(no3)2 415 g U/L 4x4x4 array unrefl. walls, floor, & tank  0.9919  0.0033  3.24631E-01
cas65        uo2(no3)2 415 g U/L 2x2x2 array unrefl.  walls, floor, & tank  1.0021  0.0033  3.15319E-01
cas66        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p  0.9969  0.0030  2.81903E-01
cas67        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 2.54 cm p  1.0079  0.0032  2.54614E-01
cas68        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 1.27 cm p  1.0066  0.0030  2.72320E-01
cas69        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par 5 fc, plex 1 fc   1.0187  0.0031  2.07907E-01
cas70        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 3.81 cm p  1.0172  0.0029  2.25525E-01
cas71        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm par. bot., 7.62 cm p  1.0250  0.0030  2.10462E-01
cas72        uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm plexiglass refl.       1.0013  0.0029  2.95021E-01
cas73        uo2(no3)2 415 g U/L 3x3x3 array 1.27 cm paraffin refl.         1.0107  0.0034  2.84036E-01
cas74        uo2(no3)2 415 g U/L 3x3x3 array 15.24 cm paraffin refl.        1.0189  0.0034  2.10003E-01
cas75        uo2(no3)2 415 g U/L 3x3x3 array 3.81 cm paraffin refl.         1.0140  0.0030  2.28122E-01
cas76        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p  1.0058  0.0028  2.76132E-01
cas77        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 11.43 cm   1.0252  0.0031  2.08300E-01
cas78        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 15.24 cm   1.0208  0.0033  2.07481E-01
cas79        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 2.54 cm p  1.0127  0.0029  2.50266E-01
cas80        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 4.45 cm p  1.0191  0.0029  2.28760E-01
cas81        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 6.35 cm p  1.0137  0.0030  2.17799E-01
cas82        uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 1.27 cm p  1.0136  0.0029  2.67261E-01
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cas83      uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 3.81 cm p   1.0169  0.0030  2.24381E-01
cas84      uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm par. bot., 7.62 cm p   1.0136  0.0033  2.09469E-01
cas85      uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm plexiglass refl.        1.0068  0.0031  2.89104E-01
cas86      uo2(no3)2 415 g U/L 2x2x2 array 1.27 cm paraffin refl.          1.0076  0.0030  2.81125E-01
cas87      uo2(no3)2 415 g U/L 2x2x2 array 15.24 cm paraffin refl.         1.0124  0.0032  2.09238E-01
cas88      uo2(no3)2 415 g U/L 2x2x2 array 3.81 cm paraffin refl.          1.0153  0.0029  2.26437E-01
cas89      uo2(no3)2 415 g U/L 2x2x2 array 7.62 cm paraffin refl.          1.0172  0.0032  2.10012E-01
cas90      uo2(no3)2 415 g U/L 3x3x3 array unrefl. 279 g U/L 5 cent. uni   1.0008  0.0035  2.60302E-01
cas91      uo2(no3)2 63.3 g U/L 3x3x3 array unrefl. walls, floor, & tank   1.0108  0.0031  4.17099E-02
jemima     disks - 15" diam plates 93.15 w% enriched stacked to 3.0258"   0.9957  0.0023  9.20645E+05
jemima     jemima - ~1/8" x 15" diam u(93.29) plates with 1/16" thk poly   0.9900  0.0021  1.22180E+05
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1/8" thk pol   0.9968  0.0024  1.77282E+04
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1/4" thk pol   0.9809  0.0025  1.73254E+03
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1/2" thk pol   1.0017  0.0028  8.79715E+01
jemima     jemima - ~1/8" thk 15" diam u(93.24) plates with 1" thk poly,   1.0002  0.0023  7.49203E+00
jemima     jemima - ~1/8" x 15" dia u(93) with symetric 1-1/2" thk poly,   1.0125  0.0024  3.34259E+00
jemima     jemima - ~1/8" x 15" dia u(93) with symetric 2" thk poly, pg-   1.0113  0.0025  2.09217E+00
heumf001   read parameters                                                 1.0026  0.0020  9.05790E+05
heumf004   water-reflected heu sphere on hollow plexiglas cylinder         1.0031  0.0019  3.10106E+04
heust001   case 1 heust001                                                 1.0019  0.0027  7.91224E-02
heust001   case 2 heust001                                                 1.0042  0.0023  2.72577E-01
heust001   case 3 heust001                                                 1.0056  0.0023  7.74878E-02
heust001   case 4 heust001                                                 1.0032  0.0029  2.92934E-01
heust001   case 5 heust001                                                 1.0036  0.0024  4.07241E-02
heust001   case 6 heust001                                                 1.0035  0.0022  4.23172E-02
heust001   case 7 heust001                                                 1.0023  0.0024  7.47451E-02
heust001   case 8 heust001                                                 1.0000  0.0021  7.92721E-02
heust001   case 9 heust001                                                 0.9961  0.0029  2.93771E-01
heust001   case 10 heust001                                                0.9953  0.0023  4.38689E-02
heust007   case 1 , heust007                                               1.0142  0.0020  4.50008E-02
heust007   case 2 , heust007                                               1.0136  0.0022  2.65339E-01
heust007   case 3 , heust007                                               1.0122  0.0020  4.39946E-02
heust007   case 4 , heust007                                               1.0148  0.0022  2.34590E-01
heust007   case 5 , heust007                                               1.0108  0.0022  4.79721E-02
heust007   case 6 , heust007                                               1.0074  0.0024  2.70926E-01
heust007   case 7 , heust007                                               1.0022  0.0023  4.73873E-02
heust007   case 8 , heust007                                               1.0081  0.0023  2.64386E-01
heust007   case 9 , heust007                                               1.0071  0.0020  4.89854E-02
heust007   case 10 , heust007                                              1.0141  0.0020  5.05970E-02
heust007   case 11 , heust007                                              1.0133  0.0023  2.52299E-01
heust007   case 12 , heust007                                              1.0165  0.0023  4.89307E-02
heust007   case 13 , heust007                                              1.0184  0.0022  2.27846E-01
heust007   case 14 , heust007                                              1.0165  0.0024  2.34844E-01
heust007   case 15 , heust007                                              1.0119  0.0022  2.37071E-01
heust007   case 16 , heust007                                              1.0079  0.0021  2.52257E-01
heust007   case 17 , heust007                                              1.0141  0.0021  2.35576E-01
heust008   case 1 , heust008                                               0.9953  0.0021  4.22118E-02
heust008   case 2 , heust008                                               0.9935  0.0024  2.31104E-01
heust008   case 3 , heust008                                               0.9938  0.0020  4.09847E-02
heust008   case 4 , heust008                                               0.9999  0.0022  2.05444E-01
heust008   case 5 , heust008                                               0.9988  0.0018  4.21128E-02
heust008   case 6 , heust008                                               1.0044  0.0024  2.52500E-01
heust008   case 7 , heust008                                               1.0030  0.0020  4.12450E-02
heust008   case 8 , heust008                                               1.0011  0.0021  2.39927E-01
heust008   case 9 , heust008                                               1.0024  0.0018  4.19634E-02
heust008   case 10 , heust008                                              0.9969  0.0022  2.28981E-01
heust008   case 11 , heust008                                              1.0013  0.0019  4.03665E-02
heust008   case 12 , heust008                                              1.0015  0.0024  2.00040E-01
heust008   case 13 , heust008                                              1.0008  0.0022  2.28131E-01
heust008   case 14 , heust008                                              0.9979  0.0020  2.06134E-01
heust013   uranium aqueous 23 cm sphere #1                                 0.9979  0.0017  3.07174E-02
heust013   uranium aqueous 32 cm sphere #2                                 0.9956  0.0015  3.21388E-02
heust013   uranium aqueous 32 cm sphere #3                                 0.9949  0.0015  3.34913E-02
heust013   uranium aqueous 32 cm sphere #4                                 0.9955  0.0017  3.41915E-02
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                         44-Group_Low-Enriched_Uranium
Case              Title                                            k-eff   sigma      EALF
----------  ----------------------------------------------------   ------  ------  -----------
car01      rocky flats criticals nureg/cr-1071 experiment number 1 (27 g   1.0186  0.0026  4.44623E-01
car02      rocky flats criticals nureg/cr-1071 experiment number 2 (27 g   1.0108  0.0022  4.64385E-01
car03      rocky flats criticals nureg/cr-1071 experiment number 3 (27 g   1.0033  0.0022  1.53118E+00
car04      rocky flats criticals nureg/cr-1071 experiment number 13 (27    1.0190  0.0021  5.07803E-01
car06      rocky flats criticals nureg/cr-0674 experiment number ? (27 g   1.0042  0.0035  4.03798E+02
car07      rocky flats criticals nureg/cr-0674 experiment number ? (27 g   1.0090  0.0029  3.85165E+00
car08      rocky flats criticals nureg/cr-0674 experiment number ? (27 g   1.0039  0.0030  2.08837E+00
car09      rocky flats criticals nureg/cr-0674 experiment number 2 (27 g   1.0078  0.0026  2.02702E+00
car10      rocky flats criticals nureg/cr-0674 concrete reflected (27 gr   1.0132  0.0027  5.54167E+00
car11      rocky flats criticals nureg/cr-1653 experiment a (27 group)     1.0128  0.0023  3.90935E-01
car12      rocky flats criticals nureg/cr-1653 experiment b (27 group)     1.0232  0.0026  9.96943E-01
car14      rocky flats criticals nureg/cr-1653 experiment number ? (27 g   1.0124  0.0032  3.06365E+00
car15      rocky flats criticals nureg/cr-1653 experiment number ? (27 g   1.0153  0.0032  3.07174E+00
car16      rocky flats criticals nureg/cr-1653 experiment number ? (27 g   1.0114  0.0030  1.97964E+00
car17      rocky flats criticals nureg/cr-2500 experiment f (27 group)     1.0137  0.0028  6.71267E-01
car19      rocky flats criticals nureg/cr-2500 experiment number ? (27 g   1.0161  0.0031  4.07956E+00
car20      rocky flats criticals nureg/cr-2500 experiment number ? (27 g   1.0024  0.0024  3.38199E+00
cas04      british handbook of criticality safety u(1.42)f4 & paraffin (   0.9893  0.0016  1.18906E-01
cas05      british handbook of criticality safety u(1.42)f4 & paraffin (   0.9966  0.0016  1.17981E-01
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cas06    british handbook of criticality safety u(1.42)f4 & paraffin (   0.9935   0.0018   1.18155E-01
cas11    raffety and malhalczo u(2)f4-1 reflected (case 11)             1.0044   0.0022   1.95339E-01
cas12    raffety and malhalczo u(2)f4-1 unreflected (case12)            1.0032   0.0023   2.36120E-01
cas13    raffety and malhalczo u(2)f4-2 reflected (case 13) no biasing  1.0003   0.0019   1.16287E-01
cas14    raffety and malhalczo u(2)f4-2 unreflected (case 14)           0.9989   0.0020   1.33748E-01
cas15    raffety and malhalczo u(2)f4-3 reflected (case 15)             0.9994   0.0023   8.33167E-02
cas16    raffety and malhalczo u(2)f4-4 reflected (case 16)             1.0025   0.0023   7.00365E-02
cas17    raffety and malhalczo u(2)f4-5 reflected (case 17)             1.0003   0.0020   6.02006E-02
cas18    raffety and malhalczo u(2)f4-5 unreflected (case18)            1.0017   0.0019   6.36542E-02
cas19    raffety and malhalczo u(2)f4-6 reflected (case 19)             0.9932   0.0016   4.66342E-02
cas20    raffety and malhalczo u(2)f4-6 unreflected (case20)            0.9907   0.0014   4.76361E-02
cas21    raffety and milhalczo u(3)f4-1 reflected (case 21) no bias     1.0112   0.0024   2.35639E-01
cas22    raffety and malhalczo u(3)f4-1 reflected (case 22)             1.0178   0.0023   2.33853E-01
cas23    raffety and malhalczo u(3)f4-1 reflected (case 23)             1.0129   0.0022   2.36111E-01
cas24    raffety and malhalczo u(3)f4-1 reflected (case 24) no biasing  1.0161   0.0024   2.35595E-01
cas25    raffety and malhalczo u(3)f4-1 reflected (case 25)             1.0108   0.0022   2.33917E-01
cas26    raffety and malhalczo u(3)f4-1 unreflected (case 26)           1.0166   0.0024   3.18432E-01
cas27    raffety and malhalczo u(3)f4-1 unreflected (case 27)           1.0134   0.0022   3.19981E-01
cas28    raffety and malhalczo u(3)f4-1 unreflected (case 28)           1.0151   0.0023   3.19474E-01
cas29    raffety and malhalczo u(3)f4-2 reflected (cas29)               1.0189   0.0027   9.13878E-02
cas30    raffety and malhalczo u(3)f4-2 unreflected (case 30)           1.0106   0.0025   1.08752E-01
cas31    raffety and malhalczo u(3)f4-2 unreflected (case 31)           1.0146   0.0024   1.08544E-01
cas32    raffety and malhalczo u(3)f4-2 unreflected (case 32)           1.0111   0.0023   1.09087E-01
cas33    critical reflected cylinder of aqueous u(4.98)o2f2 (case 33)   1.0018   0.0024   5.41788E-02
cas34    critical reflected cylinder of aqueous u(4.98)o2f2 (case 34)   0.9998   0.0020   5.37375E-02
cas35    critical sphere of aqueous u(4.98)o2f2 (case 35)               1.0028   0.0024   5.33620E-02
cas36    critical cylinder of aqueous u(4.98)o2f2 (case 36)             0.9999   0.0024   5.40102E-02


                              44-Group_LWR_Lattices
Case                 Title                                             k-eff    sigma       EALF
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cas01    exp#5, 8.39 cm h2o separating 3 20x16 arrays                  0.9972   0.0015   9.38091E-02
cas02    exp#017, 5.05 cm h2o/boral separating 2 22x16 arrays and 1 20 0.9983   0.0012   9.64360E-02
cas03    exp#28, 6.88 cm h2o/ss separating 3 20x16 arrays              0.9960   0.0016   9.51528E-02
cas04    exp no. 14 8.58 cm h2o/ss separating 3 15x8 arrays            0.9987   0.0019   1.13131E-01
cas05    exp no. 23 7.28 cm h2o/cadmium separating 3 15x8 arrays       0.9954   0.0015   1.13879E-01
cas06    exp no. 31 6.72 cm h2o/boral separating 3 15x8 arrays         0.9986   0.0018   1.14574E-01
cas07    u refl. 1.956 cm from array,    14.11 cm h2o separating 3 19x1 0.9999   0.0016   1.70932E-01
cas08    pb refl. .660 cm from array, 13.72 cm h2o separating 3 19x16  1.0044   0.0015   9.61639E-02
cas09    no refl. 8.31cm h2o separating 19x16 arrays                   0.9954   0.0019   9.43868E-02
cas10    uranium refl. 15.32cm h2o separating 12x8  arrays             1.0000   0.0016   2.82370E-01
cas11    lead refl. 20.78cm h2o separating 13x8  arrays                1.0112   0.0009   1.15957E-01
cas12    2.83cm and 3.60cm separating 4 11x14 arrays                   1.0010   0.0016   3.14724E-01
cas13    2.83cm and 4.94cm separating 2 11x14 + 2 11x16 arrays         1.0011   0.0013   3.17311E-01
cas14    ss refl. 0.66 cm from array, 11.20 cm h2o separating 3 19x16  1.0037   0.0014   9.67520E-02
cas15    steel refl. 15.84cm h2o separating 3 12x16 arrays             1.0059   0.0016   2.87059E-01
cas16    steel refl.  9.83cm h2o separating 3 12x16 arrays   w/borated 1.0050   0.0018   2.98164E-01
cas17    steel refl.  8.30cm h2o separating 3 12x16 arrays   w/boral pl 1.0022   0.0017   3.04131E-01
cas18    steel refl.  8.94cm h2o separating 3 12x16 arrays   w/cd plate 1.0025   0.0012   3.01025E-01
cas19    u refl 1.321 cm from array, 9.50 cm h2o sep. 23x18/2-20x18 ar 0.9993   0.0014   3.38900E-01
cas20    pb refl 0.660 cm from array, 10.11 cm h2o sep. 23x18/2-20x18  1.0013   0.0015   1.65840E-01
cas21    no refl infinite from array, 6.59 cm h2o sep. 23x18/2-20x18 a 0.9958   0.0017   1.58234E-01
cas22    uranium refl. 19.24cm h2o separating 12x16 arrays             0.9990   0.0017   5.08130E-01
cas23    lead refl. 18.18cm h2o separating 12x16 arrays                1.0046   0.0018   2.94494E-01
cas24    no refl. 12.91cm h2o separating 3 12x16 arrays                1.0029   0.0019   2.79098E-01
cas25    pnl-4267 exp. 173 40 x 8.92 array (357 total rods) boron = 0  0.9975   0.0012   2.77046E-01
cas26    pnl-4267 exp.177 40 x 30.92 array 1237 total rods) boron = 2. 1.0005   0.0014   6.07987E-01
cas27    pnl-4267 exp. 178 44 x 11.57array (509 total rods) boron = 0  0.9981   0.0012   5.28004E-01
cas28    pnl-4267 exp. 181 44 x 27.09 array (1192 total rods) boron =  0.9942   0.0015   1.16275E+00
cas29    pnl-4976 4.3-000-194 4.3%uo2 1.598cm-pitch                    1.0070   0.0017   3.44375E+00
cas30    flux trap assembly no. 214r                                   1.0022   0.0017   3.63882E-01
cas31    flux trap assembly no. 214v3                                  0.9990   0.0012   3.66500E-01
cas32    baw-1231 core i 936 rods   boron=1.152 g/l                    0.9932   0.0010   7.30419E-01
cas33    baw-1231 core i 4904 rods   boron=3.389 g/l                   0.9954   0.0008   1.20468E+00
cas34    baw-1273 core xx            2.46 wt%u235   5137 rods          0.9974   0.0014   5.19322E-01
cas35    baw-1484-7 core iv exp 2282   2.46 wt%u235   9 assys 14x14 w/ 8 0.9926   0.0010   1.88811E-01
cas36    baw-1484-7 core ix exp 2321   2.46 wt%u235   9 assys 14x14    0.9960   0.0015   1.37543E-01
cas37    baw-1484-7 core xiii exp 2378   2.46 wt%u235   9 assys 14x14  0.9994   0.0015   1.92775E-01
cas38    baw-1484-7 core xxi exp 2420   2.46 wt%u235   9 assys 14x14   0.9941   0.0014   1.50631E-01
cas39    baw-1645-4 exp,mt=2452   triangular pitch=o.d.    boron=435ppm 1.0070   0.0011   2.28086E+00
cas40    baw-1645-4 exp,mt=2485   pitch=o.d.    boron=886ppm           1.0001   0.0015   1.40038E+00
cas41    baw-1645-4 exp,mt=2500   pitch=1.17*o.d.    boron=1156ppm     1.0009   0.0013   4.14787E-01
cas42    baw-1810 core 12 - 4.02 & 2.46 w/o uo2 1899.3 ppm; no uo2-gd2 0.9961   0.0012   3.54751E-01
cas43    baw-1810 core 14 - 4.02 & 2.46 w/o uo2 1654 ppm; 28 uo2-gd2o3 0.9977   0.0013   3.35276E-01
cas44    baw-1810 core 16 - 4.02 & 2.46 w/o uo2 1579 ppm; 36 uo2-gd2o3 1.0003   0.0015   3.32830E-01
cas45    epri np-196 .615 inch pitch unborated uo2                     0.9942   0.0015   2.57054E-01
cas46    epri np-196 .615 inch pitch borated uo2                       0.9982   0.0013   3.15214E-01
cas47    epri np-196 .75 inch pitch unborated uo2                      0.9975   0.0011   1.13283E-01
cas48    epri np-196 .75 inch pitch borated uo2                        0.9986   0.0011   1.41065E-01
cas49    epri np-196 .87 inch pitch unborated uo2                      0.9984   0.0014   8.24161E-02
cas50    epri np-196 .87 inch pitch borated uo2                        0.9965   0.0014   9.24040E-02
cas51    saxton uo2 5.742 wt% u-235 critical exp. 0.56 inch pitch (wca 0.9950   0.0018   2.92580E-01
cas52    saxton uo2 5.742 wt% u-235 critical exp. 0.792inch pitch (wca 0.9984   0.0013   1.02102E-01
cas53    wcap-3269-39, 2692 fuel rods, 16 ag-in-cd rods,h2o ht=115.55  1.0015   0.0012   6.84832E-01
cas54    wcap-3269-39, 2209 fuel rods, 24 ag-in-cd rods,h2o ht=64.56 c 1.0036   0.0018   4.32027E-01
cas55    wcap-3269-39,  945 fuel rods, 16 ag-in-cd rods,h2o ht=89.75   0.9959   0.0012   2.55357E-01
cas56    4-18x18 array 5.0cm int.,polyethylene powder in box,30.16cm h 0.9987   0.0014   2.23525E-01
```

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cas57      4-18x18 array 5.0cm int.,polyethylene balls in box,30.73cm h2   1.0073   0.0013   2.03561E-01
cas58      4-18x18 array 5.0cm int.,water in box,32.78cm h2o height        1.0153   0.0012   1.93742E-01
cas59      4-18x18 array 5.0cm int.,water without box,31.47cm h2o height   0.9965   0.0014   1.95025E-01
```

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                              44-Group_Mixed_Oxide
Case                 Title                                                 k-eff    sigma    EALF
----------   ------------------------------------------------------------  ------   ------   ------------
cas60      epri .70inch pitch unborated plutonium                         0.9967   0.0016   5.74410E-01
cas61      epri .70inch pitch borated plutonium                          0.9993   0.0014   7.68866E-01
cas62      epri .87inch pitch unborated plutonium                         1.0023   0.0013   1.90262E-01
cas63      epri .87inch pitch borated plutonium                          1.0075   0.0014   2.79793E-01
cas64      epri .99inch pitch unborated plutonium                         1.0085   0.0015   1.34765E-01
cas65      epri .99inch pitch borated plutonium                          1.0077   0.0010   1.80510E-01
cas66      saxton puo2-uo2 critical exp. 0.52 inch pitch (wcap-3385-54)   0.9992   0.0013   8.83101E-01
cas67      saxton puo2-uo2 critical exp. 0.56 inch pitch (wcap-3385-54)   0.9982   0.0018   5.40776E-01
cas68      saxton puo2-uo2 critical exp. 0.56 inch pitch with boron (wca  0.9977   0.0016   6.47043E-01
cas69      saxton puo2-uo2 critical exp. 0.735 inch pitch (wcap-3385-54)  1.0035   0.0020   1.85393E-01
cas70      saxton puo2-uo2 critical exp. 0.792 inch pitch (wcap-3385-54)  1.0019   0.0017   1.54707E-01
cas71      saxton puo2-uo2 critical exp. 01.04 inch pitch (wcap-3385-54)  1.0036   0.0016   9.99436E-02
cas72      pnl4976 exp196 1174 uo2 & 583 mo2 rods to approx. 20,000 mwd/  0.9970   0.0013   4.27282E+00
cas73      exp.no 021(063) pitch=968 (fuel region = pin array + mix 500   1.0055   0.0011   8.84044E-01
cas74      exp.no 032(060) pitch=1.935(fuel region=pin array+mix 500 wit  1.0088   0.0016   1.12694E-01
cas75      exp.no 043(062) pitch=1.242 (fuel region=pin array+mix 500 wit 1.0019   0.0013   2.87530E-01
cas76      exp.no 067 pitch=0.761 (fuel region = pin array + mix 500 wit  1.0017   0.0011   2.90665E+00
cas77      exp. no 68r pitch=1.537 (fuel region = pin array + mix 500 wi  1.0058   0.0019   1.65538E-01
```

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                               44-Group_Plutonium
Case                 Title                                                 k-eff    sigma    EALF
----------   ------------------------------------------------------------  ------   ------   ------------
1727_09    la-3067-msr table iiia1, entry 13, water ref., metal, pu sphe  0.9960   0.0032   7.62626E+04
2109_20    benchmark 20, pu sphere with 25.4 cm concrete ref. h/pu=684.3  1.0267   0.0035   6.50197E-02
2109_21    benchmark 21, pu sphere with 10.16 cm concrete ref. h/pu=684.  1.0199   0.0037   6.28530E-02
2109_22    benchmark 22, pu sphere with 10.16 cm concrete ref. h/pu=496.  1.0285   0.0034   7.64713E-02
2109_23    benchmark 23, pu sphere with cd shell & 10.16 cm concrete ref  1.0312   0.0035   8.43735E-02
2109_24    benchmark 24, pu sphere with cd shell & 32.00 cm water, h/pu=  1.0151   0.0037   7.39281E-02
2110_05    rectangular parallelpiped of homogeneous pu(2.2)o2             1.0229   0.0061   3.28214E+01
2110_06    rectangular parallelipiped of pu(2.2)o2 reflected with 15cm p  1.0358   0.0052   5.39858E+00
2110_07    benchmark#7 semi-inf homogeneous critical solution of pu-239   1.0250   0.0036   8.66114E-02
2110_08    rectangular parallelipiped of puo2                            1.0113   0.0049   1.57573E+00
2110_09    rectangular parallelipipeds of pu02                           1.0141   0.0041   7.42683E-01
2110_10    rectangular parallelipipeds of pu02                           1.0089   0.0049   7.09447E-01
2110_11    rectangular parallelipipeds of pu02                           1.0198   0.0051   6.91517E-01
2110_12    rectangular parallelipipeds of pu02                           1.0057   0.0042   6.97871E-01
2110_13    sphere described by keno geometry                             0.9926   0.0036   1.21787E+06
2110_14    cylinder described by keno geometry                           1.0076   0.0050   1.40397E-01
2110_15    rectangular parallelipipeds of puo2-h20                       1.0084   0.0048   2.41605E+05
2110_16    rectangular parallelipipeds of puo2-h20                       1.0265   0.0036   9.23852E+05
2110_17    rectangular parallelipipeds of puo2-h20                       1.0298   0.0035   1.73370E+03
2110_18    rectangular parallelipipeds of puo2-h20                       1.0430   0.0033   3.72166E+03
2110_19    rectangular parallelipipeds of puo2-h20                       1.0130   0.0037   4.52183E+03
2110_20    rectangular parallelipipeds of puo2-h20                       1.0332   0.0037   2.37424E+03
2110_21    rectangular parallelipipeds of puo2-h20                       1.0343   0.0030   1.80538E+03
2110_23    rectangular parallelipipeds of puo2-polystyrene               1.0194   0.0045   1.47668E+03
2110_24    rectangular parallelipipeds of puo2-polystyrene               1.0222   0.0037   8.91457E+01
2110_25    rectangular parallelipipeds of puo2-polystyrene               1.0285   0.0033   8.02661E+01
2110_26    rectangular parallelipipeds of puo2-polystyrene               1.0335   0.0035   6.47283E+01
2110_27    rectangular parallelipipeds of puo2-polystyrene               1.0305   0.0032   5.41442E+01
2110_29    cylinder described by keno geometry                           1.0082   0.0045   5.52232E-02
pumf001    read parameters                                               0.9958   0.0022   1.19898E+06
pumf002    pu-met-fast-002                                               0.9987   0.0024   1.21514E+06
pust004    case 1,kvpusolnsphexp,27gp,26.27gpU/L, 0.54w/o240,h2orefl,14i  1.0100   0.0019   5.17840E-02
pust009    case 3a,kvpusolnsphexp,27,9.457gpU/L, 2.5w/o240,bare,48in dia  1.0264   0.0010   3.92387E-02
```

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                                 44-Group_U-233
Case                 Title                                                 k-eff    sigma    EALF
----------   ------------------------------------------------------------  ------   ------   ------------
u233mf001  unreflected u233 sphere                                        0.9919   0.0021   1.08355E+06
u233mf002  case 1, 10 kg u233/heu sphere, ref u233-met-fast-002           0.9986   0.0019   1.02037E+06
u233mf002  case 2, 7.6 kg u233/heu sphere, ref u233-met-fast-002          1.0000   0.0021   1.04793E+06
u233mf003  case 1, 10 kg u233 sphere natural uranium reflector, ref u233  0.9910   0.0020   1.05216E+06
u233mf003  case 2, 7.6 kg u233 sphere natural uranium reflector, ref u23  0.9894   0.0019   1.04668E+06
u233mf004  case 1, 10 kg u233 sphere reflected by tungsten                1.0034   0.0016   9.34088E+05
u233mf005  case 1, 10 kg u233 sphere be reflector, ref u233-met-fast-xxx  0.9976   0.0020   9.00310E+05
u233mf006  u-233/nu sphere                                                0.9945   0.0020   9.85652E+05
u233st002  exp 4 simplified model                                         1.0119   0.0031   1.60789E-01
u233st002  exp 5 simplified model                                         0.9951   0.0032   1.24082E-01
u233st002  exp 8 simplified model                                         1.0108   0.0034   9.65217E-02
u233st002  exp 10 simplified model                                        1.0075   0.0032   7.87800E-02
u233st002  exp 11 simplified model                                        1.0050   0.0036   6.92738E-02
u233st002  exp 12 simplified model                                        0.9919   0.0031   6.14775E-02
u233st002  exp 14 simplified model                                        0.9807   0.0030   5.85012E-02
u233st002  exp 15 simplified model                                        0.9967   0.0027   5.37426E-02
u233st002  exp 17 simplified model                                        0.9835   0.0030   4.84792E-02
u233st002  exp 18 simplified model                                        0.9974   0.0029   4.67960E-02
u233st002  exp 19 simplified model                                        1.0096   0.0024   4.35886E-02
```

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u233st002   exp 22 simplified model                                    0.9989   0.0033   2.49136E-01
u233st002   exp 24 simplified model                                    1.0004   0.0031   4.43794E-01
u233st002   exp 34 simplified model                                    0.9976   0.0032   1.29027E-01
u233st002   exp 35 simplified model                                    1.0099   0.0031   8.84865E-02
u233st002   exp 36 simplified model                                    1.0030   0.0030   5.95246E-02
u233st002   exp 38 simplified model                                    1.0060   0.0027   5.06776E-02
u233st004   exp 3 simplified model                                     1.0045   0.0031   1.58522E-01
u233st004   exp 6 simplified model                                     1.0019   0.0030   1.22567E-01
u233st004   exp 20 simplified model                                    1.0040   0.0030   2.48265E-01
u233st004   exp 25 simplified model                                    0.9958   0.0036   4.45099E-01
u233st004   exp 30 simplified model                                    0.9968   0.0034   3.51216E-01
u233st004   exp 27 simplified model                                    1.0074   0.0031   4.40937E-01
u233st004   exp 28 simplified model                                    1.0005   0.0029   3.52269E-01
u233st004   exp 33 simplified model                                    1.0095   0.0032   1.27729E-01
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141. M. Rahimi, U.S. Nuclear Regulatory Commission, NMSS/DWM, MS T7 F3, Washington, DC 20555

142. M. Brady Raap, Battelle Pacific Northwest National Lab., P.O. Box 999 / MS K8-34, Richland, WA 99352

143. M. Rahimi, U.S. Nuclear Regulatory Commission, MS T7 F3, Washington, DC 20555-0001

144. T. A. Reilly, Westinghouse Safety Management Solutions, 1993 South Centennial Dr., Aiken, SC 29803

145. R. C. Robinson, Lockheed Martin Energy Systems, P.O. Box 2009, 9110, MS-8238, Oak Ridge, TN 37831-8238

146. C. Rogers, Duke Engineering Services, 10503 W. Williams Road, Benton City, WA 99320

147. C. T. Rombough, CTR Technical Services, Inc., 950 Sugarloaf Rd., Manitou Springs, CO 80829

148. B. Rothleder, U.S. Department of Energy, EH-31, 19901 Germantown Rd., Germantown, MD 20874-1290

149. W. S. Schwink, U.S. Nuclear Regulatory Commission, NMSS/FCSS/FCOB, MS T8 A33, Washington, DC 20555-0001

150. D. A. Seymour, U.S. Nuclear Regulatory Commission, R-II/DNMS, Sam Nunn Atlanta Federal Center, 23 T85, 61 Forsyth Street, S.W., Atlanta, GA 30303-3415

151. M. K. Sheaffer, Lawrence Livermore National Laboratory, P.O. Box 808, L-634, Livermore, CA 94550

152. T. S. Sherr, U.S. Nuclear Regulatory Commission, NMSS/FCSS/FLIB. MS T8 A33, Washington, DC 20555-0001

153. J. A. Smith, U.S. Nuclear Regulatory Commission, NMSS/FCSS, MS T8 A33, Washington, DC 20555-0001

154. J. Stewart, DETR RMTD 2/33, Great Minster House, 76 Marsham Street, LONDON, UK, SW1P 4DR

155. R. G. Taylor, Lockheed Martin Energy Systems, P.O. Box 2009 MS 8238, Oak Ridge, TN 37831-8238

156. T. Taylor, Lockheed Martin Idaho Tech. Co., P.O. Box 1625, MS 3458, Idaho Falls, ID 83415-3458

157. C. Tripp, U.S. Nuclear Regulatory Commission, NMSS/FCSS, MS T8A33, Washington, DC 20555

158. D. A. Thomas, Framatome Cogema Fuels, 1261 Town Center Drive, Las Vegas, NV 89124

159. J. A. Thornton, Duke Engineering & Services, 400 S. Tyrone St., WC26B, P.O. Box 1004, Charlotte, NC 28201-1004

160. P. Ting, U.S. Nuclear Regulatory Commission, NMSS/FCSS/FCOB, MS T8 A33, Washington, DC 20555-0001

161. W. W. Tippl, Siemens AG, Power Generation Group (KWU), Dept. NDM3 Postfach 10 10 63, Berliner Strasse 295-303, D-63010 Offenbach am Main / Germany

162. H. Toffer, Fluor Daniel Northwest, Inc., P.O. Box 1050, MSIN B4-44, 1100 Jadwin Ave., Richland, WA 99352-1050

163. E. F. Trumble, Westinghouse Safety Management Solutions, P.O. Box 5388, 1993 South Centennial Dr., Aiken, SC 29803

164. A. P. Ulses, U.S. Nuclear Regulatory Commission, NRR/DSSA, MS O10 B3, Ulses, Washington, DC 20555-0001

165. M. Wangler, Office of Site Operations, EM-5/CLV-1059, U.S. Department of Energy, 19901 Germantown Road, Germantown, MD 20874-1290

166. M. D. Waters, U.S. Nuclear Regulatory Commission, NMSS/SFPO, MS O13 D13, Washington, DC 20555-0001

167. M. F. Weber, U.S. Nuclear Regulatory Commission, NMSS/FCSS, MS T8 A33, Washington, DC 20555-0001

168. L. Wetzel, BWX Technologies, Inc., Naval Nuclear Fuel, P.O. Box 785, Lynchburg, VA 24505

169. S. A. Whaley, U.S. Nuclear Regulatory Commission, NMSS/SFPO, MS O13 D13, Washington, DC 20555

170. B. H. White IV, U.S. Nuclear Regulatory Commission, NMSS/SFPO, MS O13 D13, Washington, DC 20555

171. D. W. Williams, Westinghouse Electric Corporation, 5801 Bluff Rd, MS#15, Columbia, SC 29209

172. R. E. Wilson, Safe Sites of Colorado, P.O. Box 464, Golden, CO 80420-0464

173. B. E. Wishard, U.S. Nuclear Regulatory Commission, NMSS/FCSS, MS T8 A33, Washington, DC 20555-0001

174-178. C. J. Withee, U.S. Nuclear Regulatory Commission, NMSS/SFPO, MS O13 D13, Washington, DC 20555

179. A. Wong, U.S. Nuclear Regulatory Commission, NMSS/FCSS, MS T8 A33, Washington, DC 20555-0001

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S. M. Bowman, W. C. Jordan, * J. F. Mincey,* C. V. Parks, L. M. Petrie

*Formerly with ORNL

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C. J. Withee, NRC Project Manager

ABSTRACT *(200 words or less)*

This report provides detailed information on the SCALE criticality safety cross-section libraries. Areas covered include the origins of the libraries, the data on which they are based, how they were generated, past experience and validations, and performance comparisons to measured critical experiments and numerical benchmarks.

The performance of the SCALE criticality safety cross-section libraries on various types of fissile systems are examined in detail. Most of the performance areas are demonstrated by examining the performance of the libraries vs critical experiments to show general trends and weaknesses. In areas where directly applicable critical experiments do not exist, performance is examined based on the general knowledge of the strengths and weaknesses of the cross sections. In this case, the experience in the use of the cross sections and comparisons to the results of other libraries on the same systems are relied on for establishing acceptability of application of a particular SCALE library to a particular fissile system.

This report should aid in establishing when a SCALE cross-section library would be expected to perform acceptably and where there are known or suspected deficiencies that would cause the calculations to be less reliable. To determine the acceptability of a library for a particular application, the calculational bias of the library should be established by directly applicable critical experiments.

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