NUREG/CR-6483
ORNL/TM-12834

Guide to Verification and Validation of the SCALE-4 Criticality Safety Software

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Prepared for
U.S. Nuclear Regulatory Commission

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Manuscript Completed: November 1996
Date Published: December 1996

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Prepared for
Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
NRC JCN No. B0009

ABSTRACT

Whenever a decision is made to newly install the SCALE nuclear criticality safety software on a computer system, the user should run a set of verification and validation (V&V) test cases to demonstrate that the software is properly installed and functioning correctly. This report is intended to serve as a guide for this V&V in that it specifies test cases to run and gives expected results. The report describes the V&V that has been performed for the nuclear criticality safety software in a version of SCALE-4.[1]

The verification problems specified by the code developers have been run, and the results compare favorably with those in the SCALE 4.2 baseline.[2] The results reported in this document are from the SCALE 4.2P version which was run on an IBM RS/6000 workstation. These results verify that the SCALE-4 nuclear criticality safety software has been correctly installed and is functioning properly.

A validation has been performed for KENO V.a[3] utilizing the CSAS25 (ref. 4) criticality sequence and the SCALE 27-group cross-section library for ^{233}U, ^{235}U, and ^{239}Pu fissile systems in a broad range of geometries and fissile fuel forms. The experimental models used for the validation were taken from three previous validations of KENO V.a. A statistical analysis of the calculated results was used to determine the average calculational bias and a subcritical k_{eff} criteria for each class of systems validated. Included in the statistical analysis is a means of estimating the margin of subcriticality in k_{eff}. This validation demonstrates that KENO V.a and the 27-group library may be used for nuclear criticality safety computations provided the system being analyzed falls within the range of the experiments used in the validation.

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1 INTRODUCTION

The purpose of this report is to present a guide on verification and validation (V&V) of the SCALE-4 nuclear criticality safety software. This report serves as documentation of the problems used in the V&V of the SCALE-4 system for all releases. The verification problems specified by code developers have been run, and the results compare well with those in the SCALE-4.2 baseline. The SCALE V&V plan[5] describes the methods used for the baseline V&V.

Although there are many definitions of software verification and validation, the SCALE configuration management plan, SCALE-CMP-001,[6] specifies the following:

Verification: Assurance that a computer code correctly performs the operations specified in a numerical model. This is usually accomplished by comparing results to a hand calculation or an analytical solution or approximation.

Validation: Assurance that a model as embodied in a computer code is a correct representation of the process or system for which it is intended. This is usually accomplished by comparing code results to either physical data or a validated code designed to perform the same type of analysis.

These definitions apply in this document.

Verification and validation can be very similar in that both are exercising a code with input for which there is a known result. In some cases the same known system may be used in both the verification and the validation. Verification and validation are different, however, because the end use of the results is different. Verification is intended to demonstrate that the software has been properly coded, installed on a computer, and performs the intended functions for a given set of input. Results of the verification are compared against the standard sample problem results documented in the SCALE-4.2 baseline as required by the SCALE V&V plan. Validation is the process of demonstrating that the software predicts "correct" results for the "systems for which it is intended." The calculated results for systems with a known solution are used to establish the calculational bias. The establishment of the bias defines a range over which the result is acceptably correct. Experimental parameters and physical properties of these systems are used to determine the range of applicability of the validation and define the systems for which the bias applies. Validation is the responsibility of the code user and is specific to an intended application.

This report has been divided into two parts. In Sect. 3, the results of the criticality code verification are presented; in Sect. 4, validation results are presented. The verification results in Sect. 3 have been subdivided into two categories. The first category is the installation verification. The results for the sample problems distributed with SCALE for each module are presented. These problems exercise many of the input options of the codes and are intended to demonstrate that the codes have been properly installed on the computer, are executing properly, and are properly interfacing with the system hardware configuration. The scripts used to execute the codes are also being tested during this phase. The installation verification represents a minimum set of problems which must be run each time the code is newly installed on a computer system. The second verification category is the functional verification. In this phase the functionality of the codes is being tested. The codes are used to solve analytic problems for which the results are known. An intercode comparison between KENO V.a and XSDRNPM[7] is also presented.

The validation presented in Sect. 4 is comprised of critical experiment models collected from previous validations of KENO V.a using the CSAS25 criticality sequence.[8-10] These validation experiments cover a broad range of systems and fissile material types including homogeneous high- and low-enriched ^{235}U systems, heterogeneous low-enriched ^{235}U systems, ^{233}U systems, and ^{239}Pu systems. The SCALE 27-group ENDF/B-IV cross-section library was validated; however, the validation input and the scripts developed to aid in the validation allow easy revalidation using any SCALE cross-section library. The results of the validation have been used to establish a bias for several classes of systems and to develop linear one-sided, closed-interval, uniform-width, lower tolerance bands which may be used in establishing the subcritical acceptance value of k_{eff} and the associated margin of subcriticality in k_{eff}.

2 DESCRIPTION OF THE CODE PACKAGE

The following subsections give a brief description of the program modules which were verified and validated. Each module in SCALE has a version number which is updated whenever the code is revised. This version number is printed out when the module is executed and is also indicated in the documentation distributed with each release. The version numbers of the program modules should be checked when calculations are performed to verify that the correct versions are being used. When a code version changes, the nature of the modifications should be reviewed and test cases should be checked to see if complete verification and/or validation is warranted.

2.1 BONAMI

BONAMI[11] performs resonance shielding through the application of the Bondarenko shielding factor method. BONAMI reads an AMPX[12] master format cross-section library and applies Bondarenko corrections to all nuclides that have Bondarenko data. Input to BONAMI, provided by the CSAS25 control sequence, includes information relating to the physical characteristics (composition of material, size, geometry, temperature) of the system being calculated. BONAMI produces a Bondarenko-corrected master format library which is read by NITAWL-II.[13] For SCALE libraries the Bondarenko technique is used primarily to process unresolved region resonance data and for processing resonance nuclides which were not prepared by XLACS[14] (such as the SCALE 16-group Hansen-Roach library or ENDF/B-VI nuclides processed with NJOY[15]). For the 27-group master cross-section library used in this validation, the primary purpose of the BONAMI functional module is to select the required material cross sections and to create a problem-dependent AMPX master cross-section library to be processed by NITAWL-II. No data processing is performed in BONAMI for the 27-group cross-section library.

2.2 NITAWL-II

NITAWL-II applies the Nordheim Integral Treatment to perform neutron cross-section processing in the resolved resonance range for nuclides that have ENDF/B resonance parameter data. This technique involves the numerical integration of ENDF/B resonance parameters using a calculated flux distribution which is based on the collision density across each resonance, and subsequent weighting of the cross-section to the desired broad group structure. Input data to NITAWL-II, automatically provided by the CSAS25 control sequence, include information relating to the physical and neutronic characteristics of the system being calculated. NITAWL-II uses these data to complete the processing of the problem-dependent master library from BONAMI. NITAWL-II assembles the group-to-group transfer arrays from the elastic and inelastic scattering components, and performs other tasks to produce a problem-dependent, AMPX working format cross-section library which can be used by KENO V.a. The analyst specifies the resonance parameters based on the available options. The options include (1) a homogeneous medium treatment which treats the resonance region of the fissile mixture as if it were an infinite homogeneous media, (2) a finite lump treatment which treats the resonance region as if the fissile mixture were a discrete lump with a 1/E return flux at the boundary. This latter option is for problems where the system is substantially heterogeneous or where reflector effects are important. These options are automatically invoked in the CSAS25 control sequence according to the keywords INFHOMMEDIUM, LATTICECELL, or MULTIREGION. The INFHOMMEDIUM option treats the fissile mixture as an infinite homogeneous medium. The LATTICECELL option utilizes an infinite lattice of a repeated cell for the resonance self-shielding correction. With the MULTIREGION option, a single-cell resonance self-shielding calculation is made.

2.3 ICE[16]

ICE is a cross-section mixing code which will accept cross sections from an AMPX working format library and produce mixed cross sections in the AMPX working format, ANISN format, group independent ANISN format, or the Monte-Carlo processed cross-section library format.

2.4 KENO V.a

KENO V.a is a multigroup Monte Carlo code used to determine k_{eff}. KENO V.a is a substantial revision of KENO IV and includes an enhanced geometry package which allows modeling of a wide variety of complex three-dimensional (3-D) geometries. The geometry package allows nested arrays and "holes" to be placed in the geometry model. The code allows the use of reflector options, including mirror reflection, differential albedo reflection, and an automatic reflector; the latter has the capability of using reflector region-weighting functions which are based on one-dimensional (1-D) adjoint calculations. The reflector options simplify geometry data input and/or reduce the running time of a specific problem. Cross-section input and atom density input are provided by the CSAS25 module. Most of the major KENO parameters have defaults which work for a wide variety of problems, but which can be overridden if the problem or analyst dictates.

2.5 XSDRNPM

XSDRNPM is a general purpose, 1-D discrete-ordinates code used for several purposes in SCALE. In the CSAS1X criticality sequence XSDRN is used to solve the 1-D Boltzmann equation in slab, cylindrical, or spherical geometry. As part of the CSAS2X and CSAS4X sequences, XSDRN is used to solve the 1-D Boltzmann equation for a specified fissile system and to produce spatially averaged (cell-weighted) cross sections for subsequent use in a KENO V.a calculation.

2.6 CSAS CONTROL MODULE

The CSAS control module invokes the following control sequences: CSASI, CSASIX, CSASN, CSAS1X, CSAS25, CSAS2X, CSAS4, and CSAS4X. These control sequences serve similar functions in that they prepare input for the various functional modules depending on which sequence is specified. User-specified data include the cross-section library, specifications for mixtures, information for resonance region cross-section processing of nuclides (size, geometry, and temperature), and geometry models for XSDRN and/or KENO V.a. Physical and neutronics information not supplied explicitly but required by the functional modules (such as theoretical density, molecular weights, average resonance region background cross sections) are supplied by the Standard Composition Library[17] or calculated by the Materials Information Processor.[18] The CSAS25 control sequence was usually utilized in the validation presented in Sect. 4. The CSAS25 control sequence prepares input for and calls BONAMI, NITAWL-II, and KENO V.a.

2.7 THE 27-GROUP NEUTRON CROSS-SECTION LIBRARY

The 27-group ENDF/B-IV AMPX master cross-section library in SCALE is activated in the CSAS25 control sequence by specifying 27GROUPNDF4 or a truncation (e.g., 27GR) as the cross-section library name. The 27-group library is the broad group companion library to the 218-group Criticality Safety Reference Library (CSRL). The CSRL master library, which is based on ENDF/B-IV data, was generated as a pseudo problem-independent fine-group structure library for use in general criticality safety analysis and shipping cask calculations. The 27-group library was collapsed from the 218-group library using a characteristic fission-($1/E\sigma_t$)-Maxwellian spectral flux shape on a nuclide-by-nuclide basis. Explicit ENDF/B-IV resonance parameters are carried for resonance nuclides in both the 27-group and 218-group master libraries. These resonance parameters are used by NITAWL-II in the CSAS25 control sequence for calculating problem-dependent, self-shielded resonance region cross sections.

The 27-group AMPX master format cross-section library was originally created in August 1981. Prior to 1981, the primary cross-section set in use at ORNL was the Knight-Modified Hansen-Roach, 16-group AMPX working format cross-section library. The 27-group set is considered to be an improvement because more thermal neutron groups are available, upscatter is included in the set, and the origin of the base data used to create the data set is better documented.

With the release of SCALE-4.0 the original 27-group library was processed into the new AMPX master library format using CORECTOL.[19] In addition, all of the nuclides were processed with PERFUME.[19] The cross-section libraries distributed with SCALE-4.0 and later versions are not compatible with previous versions of SCALE.

3 VERIFICATION

The purpose of this section is to present code verification results. Verification was accomplished by running the verification problems specified in the SCALE V&V plan and demonstrating that the codes perform consistently with the SCALE-4.2 baseline results. The verification has been subdivided into two categories; installation verification and functional verification. Appendix A describes input files which are available.

Included in Appendix B is a copy of the submit4.2p script which was used to execute the verification and validation problems. The scale4 script, which it references, links appropriate executable code and files that allow SCALE to run. The scale4 script is included in the SCALE distribution. The script submit4.2p allows multiple input files to be sequentially submitted and executed in the same temporary directory. The order in which the files are executed is important for several series of cases used in the verification. Specifically, those requiring that cross-section processing and file manipulation be performed prior to execution of the test cases.

Also included in Appendix B are listings of several FORTRAN programs (READM, READA, READA4, and READK5) which are used to collect the results from some of the calculations. For example, READM, READA, and READA4 all collect results from XSDRNPM and/or KENO, and READK5 collects results from KENO hole-intersection cases. Upon execution, each of these programs prompts the user for the name of an index of the output files to be searched and the name of the output file in which the results are to be stored. READM then prompts the user for the name of the file to be used as input for the statistical analysis of the data (if desired) and the number of groups in the cross-section library that is to be included in the statistical analysis. The other programs also prompt for the number of groups. These programs search for character strings in the output and collect the results from XSDRNPM and/or KENO. READA searches for data specific to comparison of analytic benchmarks for 1- and 2-group cases; and READA4, for 4-group cases.

References to these programs also appear in the sections that describe the edited results produced by each one.

3.1 INSTALLATION VERIFICATION

Installation verification consisted of running the sample problems normally distributed with the modules in the SCALE package and demonstrating that the results were consistent with those in the verification plan. Installation on new hardware may require running the sample problems numerous times as the peculiarities of the system are encountered and ironed out. The sample problems were run to provide a complete documentation of the installation. The sample problems represent a minimum set of calculations which should be run when the codes are installed on new hardware. Table A.1 of Appendix A contains a list of the input file names used.

3.1.1 BONAMI

The BONAMI sample problem results are given in Table 1. The results presented in Table 1 are identical to those in the SCALE-4.2 baseline and verify that BONAMI is correctly installed.

3.1.2 NITAWL-II

The NITAWL-II sample problem results for "res abs" (i.e., resonance absorption), "res fiss" (i.e., resonance fission), and "res scat" (i.e., resonance scattering) for each group are given in Table 2. These results are consistent with the results in the SCALE-4.2 baseline. The results presented in Table 2 verify that NITAWL-II is correctly installed.

Table 1. BONAMI sample problem results

Sample problem for 3-region cylindrical cell in square lattice

shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
10	2.604E+03	6.791E+01	3.792E+01	2.000E+01
11	2.536E+03	7.767E+01	3.921E+01	2.846E+01
12	2.882E+03	7.871E+01	3.115E+01	3.757E+01
13	2.457E+03	4.900E+01	3.000E+01	9.000E+00

edit for material: 92238
zone: 1
position in mix: 2

shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 102 order= 0 offset= 0
8	5.056E+01	1.373E+01	7.340E-01
9	5.131E+01	1.249E+01	1.488E+00
10	5.214E+01	1.320E+01	4.200E+00
11	5.228E+01	1.149E+01	2.494E+00
12	5.207E+01	1.352E+01	4.517E+00

Sample problem for homogeneous option

shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
10	4.605E+03	6.800E+01	3.800E+01	2.000E+01
11	4.526E+03	8.202E+01	4.097E+01	3.105E+01
12	4.914E+03	8.069E+01	3.207E+01	3.863E+01
13	4.460E+03	4.900E+01	3.000E+01	9.000E+00

edit for material: 92238
zone: 1
position in mix: 2

shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 102 order= 0 offset= 0
8	9.777E+01	1.394E+01	9.354E-01
9	9.876E+01	1.317E+01	2.171E+00
10	9.978E+01	1.438E+01	5.378E+00
11	1.000E+02	1.243E+01	3.430E+00
12	1.000E+02	1.519E+01	6.194E+00

Table 2. NITAWL-II sample problem results

```
  uranium-235    endf/b-iv mat 1261      updated 10/12/89     92235     temperature=
293.00
 group        res abs         res fiss        res scat
  12      -2.312891E+00   -1.420647E+00   -5.752800E-02
  13      -7.690681E+00   -3.767564E+00   -1.705856E-01
  14      -5.636110E+00   -3.364578E+00   -3.908945E-02
 excess resonance integrals
                   resolved
 absorption       2.09320E+02
 fission          1.24851E+02

  uranium-238    endf/b-iv mat 1262      updated 10/12/89     92238     temperature=
293.00
 group        res abs         res fiss        res scat
   9      -4.611538E-02    0.000000E+00   -4.567427E-01
  10      -1.135391E+00   -2.312312E-05   -6.877504E+00
  11      -9.870446E+00    0.000000E+00   -2.707627E+01
  12      -4.293667E+01    0.000000E+00   -4.990123E+01
  13      -5.374321E+01    0.000000E+00   -1.763900E+01
  14      -1.040150E+02    0.000000E+00   -6.042653E+00
 excess resonance integrals
                   resolved
 absorption       1.88402E+01
 fission          4.94344E-04
```

3.1.3 ICE

The ICE sample problem cross sections results are given in Table 3. The results presented in Table 3 verify that ICE is correctly installed.

3.1.4 XSDRNPM, KENO V.a, and CSAS25

XSDRNPM, KENO V.a, and CSAS25 sample problem results are presented in Table 4. Table 4 was generated using the FORTRAN utility code READM. The format of the output from READM consists of the results file name followed by a list of the output files scanned. If a string is identified as being from XSDRNPM or KENO V.a the first 20 characters of the title are printed followed by selected output from the modules. If found, the value of k-effective and sigma which appear at the beginning of the KENO V.a plot of k-effective by generation skipped are printed. In addition, if the KENO parameter "nub=yes" was set, the value of the average energy group of the neutron causing fission (AEG) is also printed. The value of "lambda" from XSDRNPM is printed, if found, as is the message that the outer iteration limit was exceeded. The results are consistent with the results in the SCALE-4.2 baseline. Table 5 gives additional results of the XSDRNPM calculation for comparison purposes.

Monte Carlo calculations such as performed in KENO V.a are particularly sensitive to changes in the random sequence. Minor cross section differences and differences in the random number generator between two different computers may lead to seemingly large changes in the results. The deviation in k_{eff} (σ) must be taken into consideration when comparing the code performance between different computer systems. The KENO V.a results are consistent with those in the SCALE-4.2 baseline. Sample problems 26 thru 33 have been added since the SCALE-4.2 baseline was done and have been included here. The results presented in Tables 4 and 5 verify that XSDRN, KENO, and CSAS25 are correctly installed.

3.2 FUNCTIONAL VERIFICATION

Functional verification consists of running problems which have known results. These problems are not part of the sample problems and are normally only run for code verification. The problems include analytic problems for which the results are known and problems which test specific code capabilities for which there is a known code response. See Table A.1 in Appendix A for input file names.

Three non-SCALE programs were utilized in the functional verification. The programs SCOMMAND (see Appendix B), COMET,[12] and AWL are not officially part of SCALE but are required to execute certain of the verification problems. These programs can be soft linked to the program execution area. The SCOMMAND program allows c-shell (csh) commands to be executed under the SCALE driver in SCALE-4.2. This allows files to be manipulated before and/or after execution of SCALE modules. The SHELL program distributed in SCALE-4.3 performs the same function. The COMET program is an AMPX utility program for correcting master interfaces. The AWL program is a utility for converting working libraries back and forth between BCD and binary.

Both KENO V.a and XSDRN solve the Boltzmann equation; KENO V.a by use of the Monte Carlo method and XSDRN by use of 1-D discrete ordinates. Both codes are used to calculate results for systems for which analytic results are known. In addition, both codes are used to calculate the eigenvalue for a range of systems for which physical parameters and/or calculational approximations have been arbitrarily varied. These problems provide additional verification that both KENO V.a and XSDRN yield the same result and are properly solving for the system eigenvalue.

Table 3. ICE sample problem results[a]

```
1 1-d neutron cross sections for mixture[a]     111

0 xsec id       1             27           1099             2            101            201              18            102
  grp.
     1    3.08900E-01    4.04427E-02    2.22343E-02    2.66454E-01    3.70136E-03    5.47546E-01    3.67414E-02    5.01356E-04
     2    3.15399E-01    3.43999E-02    4.35014E-02    2.80999E-01    2.79353E-03    4.89659E-01    3.16064E-02    2.79353E-03
     3    4.84900E-01    1.90600E-02    2.29154E-02    4.65839E-01    5.10230E-03    6.58480E-01    1.39576E-02    5.10230E-03
     4    5.52399E-01    1.90999E-02    2.58635E-02    5.33299E-01    7.09999E-03    6.89763E-01    1.20000E-02    7.09999E-03
     5    7.03799E-01    2.30000E-02    1.32444E-02    6.80799E-01    8.69918E-03    7.99674E-01    1.43008E-02    8.69918E-03
     6    8.64799E-01    4.95000E-02    2.07721E-03    8.15295E-01    2.45000E-02    9.54008E-01    2.50000E-02    2.45000E-02
     7    9.94998E-01    8.30000E-02    1.51471E-04    9.11995E-01    4.10000E-02    1.11120E+00    4.20000E-02    4.10000E-02
     8    1.10220E+00    1.90999E-01    1.12596E-05    9.11195E-01    1.11980E-01    1.41551E+00    7.90203E-02    1.11980E-01
     9    1.54320E+00    7.12000E-01    8.85953E-07    8.31195E-01    5.25000E-01    2.77580E+00    1.87000E-01    5.25000E-01
    10    3.33120E+00    2.58000E+00    6.22384E-08    7.51199E-01    2.20000E+00    5.36804E+00    3.80000E-01    2.20000E+00
    11    3.78120E+00    3.03000E+00    9.88295E-09    7.51199E-01    2.59367E+00    4.60972E+00    4.36326E-01    2.59367E+00
    12    5.89120E+00    5.14000E+00    2.16121E-09    7.51199E-01    4.80286E+00    6.09763E+00    3.37143E-01    4.80286E+00
    13    1.15720E+00    4.06000E-01    1.37221E-09    7.51200E-01    1.06000E-01    1.16951E+00    3.00000E-01    1.06000E-01
    14    1.57320E+00    8.22000E-01    1.14449E-09    7.51199E-01    1.22000E-01    1.61942E+00    7.00000E-01    1.22000E-01
    15    3.03120E+00    2.28000E+00    1.73154E-09    7.51199E-01    4.30000E-01    3.17324E+00    1.85000E+00    4.30000E-01
    16    6.95890E+00    6.20762E+00    1.73154E-09    7.51280E-01    1.04762E+00    7.20121E+00    5.16000E+00    1.04760E+00
0 xsec id     452           1018             16           1452
  grp.
     1    2.84609E+00    2.04000E-01    2.00285E-03    1.04570E-01
     2    2.54631E+00    3.44000E-01    0.00000E+00    8.04797E-02
     3    2.52119E+00    1.68000E-01    0.00000E+00    3.51898E-02
     4    2.49000E+00    1.79999E-01    0.00000E+00    2.98800E-02
     5    2.45999E+00    9.00001E-02    0.00000E+00    3.51798E-02
     6    2.45000E+00    1.40000E-02    0.00000E+00    6.12500E-02
     7    2.45000E+00    0.00000E+00    0.00000E+00    1.02900E-01
     8    2.45000E+00    0.00000E+00    0.00000E+00    1.93600E-01
     9    2.45000E+00    0.00000E+00    0.00000E+00    4.58150E-01
    10    2.45000E+00    0.00000E+00    0.00000E+00    9.31000E-01
    11    2.45000E+00    0.00000E+00    0.00000E+00    1.06900E+00
    12    2.45000E+00    0.00000E+00    0.00000E+00    8.26000E-01
    13    2.45000E+00    0.00000E+00    0.00000E+00    7.35000E-01
    14    2.45000E+00    0.00000E+00    0.00000E+00    1.71500E+00
    15    2.45000E+00    0.00000E+00    0.00000E+00    4.53250E+00
    16    2.45000E+00    0.00000E+00    0.00000E+00    1.26420E+01

1 p- 0 array for mixture     111

0         grp.   1     grp.   2     grp.   3     grp.   4     grp.   5     grp.   6     grp.   7     grp.   8
     1     1001001      1002002      1003003      1004004      1005005      1006006      6007007      7008008
     2  1.31440E-01  1.69820E-01  3.25479E-01  4.61319E-01  6.49839E-01  7.92319E-01  8.88699E-01  8.86700E-01
     3               4.98200E-02  3.16800E-02  1.09660E-01  6.79800E-02  3.09600E-02  2.29799E-02  2.33000E-02
     4                            2.21000E-02  4.51000E-02  2.60000E-02  4.00000E-03
     5                                         3.81000E-02  3.01000E-02  4.70000E-03
     6                                                      2.56000E-02  4.30000E-03
     7                                                                   3.40000E-03
0         grp.   9     grp.  10     grp.  11     grp.  12     grp.  13     grp.  14     grp.  15     grp.  16
     1     8009009      9010010     10011011     11012012     12013013     13014014     14015015     15016016
     2  8.07100E-01  7.17899E-01  7.15180E-01  7.17899E-01  7.15180E-01  7.08459E-01  7.22319E-01  7.51280E-01
     3  2.45000E-02  2.41000E-02  3.33000E-02  3.60200E-02  3.33000E-02  3.60200E-02  4.27400E-02  2.88800E-02
1 1-d neutron cross sections for mixture     222
1 1-d neutron cross sections for mixture     222

0 xsec id       1             27           1099             2            101            201
  grp.
     1    1.25939E-01    1.20000E-03    1.53930E-02    1.24739E-01    1.20000E-03    1.71767E-01
     2    1.63799E-01    0.00000E+00    3.01163E-02    1.63799E-01    0.00000E+00    2.20962E-01
     3    2.99340E-01    0.00000E+00    1.58645E-02    2.99339E-01    0.00000E+00    3.55216E-01
     4    3.55080E-01    0.00000E+00    1.79055E-02    3.55079E-01    0.00000E+00    4.40965E-01
     5    5.06159E-01    0.00000E+00    9.16920E-03    5.06159E-01    0.00000E+00    6.73966E-01
     6    7.99800E-01    0.00000E+00    1.43806E-03    7.99824E-01    0.00000E+00    1.06016E+00
     7    9.61500E-01    0.00000E+00    1.04864E-04    9.61494E-01    0.00000E+00    1.27808E+00
     8    1.00920E+00    6.00000E-05    7.79509E-06    1.00913E+00    6.00000E-05    1.32806E+00
     9    1.00920E+00    2.40000E-04    6.13352E-07    1.00895E+00    2.40000E-04    1.33691E+00
    10    1.00920E+00    4.80000E-04    4.30881E-08    1.00871E+00    4.80000E-04    1.33981E+00
    11    1.00920E+00    8.40000E-04    6.84204E-09    1.00835E+00    8.40000E-04    1.34015E+00
    12    1.00920E+00    1.50000E-03    1.49622E-09    1.00769E+00    1.50000E-03    1.34075E+00
    13    1.00920E+00    2.70000E-03    9.49995E-10    1.00650E+00    2.70000E-03    1.36527E+00
    14    1.18920E+00    4.20000E-03    7.92340E-10    1.18500E+00    4.20000E-03    1.44365E+00
    15    1.60920E+00    7.80000E-03    1.19875E-09    1.60140E+00    7.80000E-03    1.83981E+00
    16    2.80924E+00    1.74060E-02    1.19875E-09    2.79183E+00    1.74060E-02    3.09880E+00
1 p- 0 array for mixture     222

0         grp.   1     grp.   2     grp.   3     grp.   4     grp.   5     grp.   6     grp.   7     grp.   8
     1     1001001      1002002      1003003      1004004      1005005      1006006      2007007      3008008
     2  2.88600E-02  3.52500E-02  8.14197E-02  1.20960E-01  2.51249E-01  3.55109E-01  4.12589E-01  4.23000E-01
     3               5.70600E-02  4.95899E-02  1.33079E-01  1.79759E-01  2.13329E-01  3.68249E-01  4.49970E-01
     4                            1.38599E-02  4.38599E-02  6.35994E-02  4.51200E-02  3.42600E-02  6.26994E-02
     5                                         1.38599E-02  2.63400E-02  1.76400E-02  7.62000E-03  6.00000E-03
     6                                                      8.34000E-03  7.26000E-03  2.94000E-03  1.32000E-03
     7                                                                   2.76000E-03  1.50000E-03  6.60000E-04
0         grp.   9     grp.  10     grp.  11     grp.  12     grp.  13     grp.  14     grp.  15     grp.  16
     1     4009009      5010010      6011011      7012012      8013013      9014014     10015015     11016016
     2  4.24440E-01  2.98680E-01  2.69280E-01  2.85960E-01  2.53980E-01  3.78060E-01  1.29147E+00  2.79183E+00
     3  4.80899E-01  4.11240E-01  4.76820E-01  5.22059E-01  4.85759E-01  4.56959E-01  6.08940E-01  3.09930E-01
     4  8.09400E-02  7.31994E-02  1.15199E-01  1.63140E-01  1.45079E-01  1.41839E-01  2.21039E-01  1.97999E-01
     5  1.12200E-02  1.25400E-02  2.16000E-02  4.07999E-02  4.68000E-02  4.31400E-02  7.09194E-02  7.45200E-02
     6  1.08000E-03  1.80000E-03  3.66000E-03  7.32000E-03  1.15200E-02  1.39200E-02  2.16000E-02  2.32200E-02
     7  3.00000E-04  2.40000E-04  7.50000E-04  1.80000E-03  3.12000E-03  5.76000E-03  9.36000E-03  7.19994E-03
1 p- 1 array for mixture     222
```

Table 3 (continued)

```
0          grp.    1     grp.    2     grp.    3     grp.    4     grp.    5     grp.    6     grp.    7     grp.    8
     1     1001001       1002002       1003003       1004004       1005005       1006006       2007007       4008008
     2  7.20000E-04  2.70000E-03  2.52000E-02  5.02200E-02  3.04740E-01  5.14800E-01  6.15054E-01  6.33060E-01
     3               1.00440E-01  1.02420E-01  2.42459E-01  3.15719E-01  3.27779E-01  6.06954E-01  7.47000E-01
     4                            2.28600E-02  7.66800E-02  8.92800E-02  4.19399E-02  2.28600E-02  4.46400E-02
     5                                         1.71000E-02  2.82600E-02  1.18800E-02  2.88000E-03  1.62000E-03
     6                                                      6.30000E-03  3.78000E-03  9.00000E-04  1.80000E-04
     7                                                                   9.00000E-04  3.60000E-04
0          grp.    9     grp.   10     grp.   11     grp.   12     grp.   13     grp.   14     grp.   15     grp.   16
     1     5009009       6010010       7011011       7012012       8013013       9014014      10015015      11016016
     2  6.37554E-01  3.92400E-01  3.26519E-01  3.44700E-01  2.86920E-01  7.20000E-01  1.80000E+00  2.16000E+00
     3  7.99920E-01  7.19634E-01  8.93514E-01  9.80100E-01  9.13680E-01  8.89554E-01  1.15200E+00  3.60000E-01
     4  5.85000E-02  5.57999E-02  1.14659E-01  1.77659E-01  1.55340E-01  1.61280E-01  2.65320E-01  1.07999E-01
     5  3.42000E-03  4.13999E-03  9.18000E-03  2.30399E-02  2.84400E-02  2.73600E-02  4.82400E-02  2.88000E-02
     6  1.80000E-04  1.80000E-04  7.20000E-04  1.80000E-03  3.60000E-03  5.04000E-03  8.10000E-03  5.04000E-03
     7                                         1.80000E-04  3.60000E-04  1.08000E-03  1.98000E-03  9.00000E-04

 no. of groups=[b]   16 tble length=    21 control=     0 id no.=     1 title=mixed cross sections by ice-the perfect mixer
0psn   grpp  1      grpp  2      grpp  3      grpp  4      grpp  5      grpp  6      grpp  7      grpp  8
     1  2.04000E-01  3.44000E-01  1.68000E-01  1.79999E-01  9.00001E-02  1.40000E-02  0.00000E+00  0.00000E+00
     2  3.67414E-02  3.16064E-02  1.39576E-02  1.20000E-02  1.43008E-02  2.50000E-02  4.20000E-02  7.90203E-02
     3  4.04427E-02  3.43999E-02  1.90600E-02  1.90999E-02  2.30000E-02  4.95000E-02  8.30000E-02  1.90999E-01
     4  1.04570E-01  8.04797E-02  3.51898E-02  2.98800E-02  3.51798E-02  6.12500E-02  1.02900E-01  1.93600E-01
     5  3.08900E-01  3.15399E-01  4.84900E-01  5.52399E-01  7.03799E-01  8.64799E-01  9.94998E-01  1.10220E+00
     6  1.31440E-01  1.69820E-01  3.25479E-01  4.61319E-01  6.49839E-01  7.92319E-01  8.88699E-01  8.86700E-01
     7  0.00000E+00  4.98200E-02  3.16800E-02  1.09660E-01  6.79800E-02  3.09600E-02  2.29799E-02  2.33000E-02
     8  0.00000E+00  0.00000E+00  2.21000E-02  4.51000E-02  2.60000E-02  4.00000E-03  0.00000E+00  0.00000E+00
     9  0.00000E+00  0.00000E+00  0.00000E+00  3.81000E-02  3.01000E-02  4.70000E-03  0.00000E+00  0.00000E+00
    10  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  2.56000E-02  4.30000E-03  0.00000E+00  0.00000E+00
    11  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  3.40000E-03  0.00000E+00  0.00000E+00
    12  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        psn   13 thru psn   21 same as above
0psn   grpp  9      grpp 10      grpp 11      grpp 12      grpp 13      grpp 14      grpp 15      grpp 16
     1  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
     2  1.87000E-01  3.80000E-01  4.36326E-01  3.37143E-01  3.00000E-01  7.00000E-01  1.85000E+00  5.16000E+00
     3  7.12000E-01  2.58000E+00  3.03000E+00  5.14000E+00  4.06000E-01  8.22000E-01  2.28000E+00  6.20762E+00
     4  4.58150E-01  9.31000E-01  1.06900E+00  8.26000E-01  7.35000E-01  1.71500E+00  4.53250E+00  1.26420E+01
     5  1.54320E+00  3.33120E+00  3.78120E+00  5.89120E+00  1.15720E+00  1.57320E+00  3.03120E+00  6.95890E+00
     6  8.07100E-01  7.17899E-01  7.15180E-01  7.17899E-01  7.15180E-01  7.08459E-01  7.22319E-01  7.51280E-01
     7  2.45000E-02  2.41000E-02  3.33000E-02  3.60200E-02  3.33000E-02  3.60200E-02  4.27400E-02  2.88800E-02
     8  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        psn    9 thru psn   21 same as above
 no. of groups=    16 tble length=    21 control=     0 id no.=     2 title=mixed cross sections by ice-the perfect mixer
0psn   grpp  1      grpp  2      grpp  3      grpp  4      grpp  5      grpp  6      grpp  7      grpp  8
     1  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
     2  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
     3  1.20000E-03  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  6.00000E-05
     4  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
     5  1.25939E-01  1.63799E-01  2.99340E-01  3.55080E-01  5.06159E-01  7.99800E-01  9.61500E-01  1.00920E+00
     6  2.88600E-02  3.52500E-02  8.14197E-02  1.20960E-01  2.51249E-01  3.55109E-01  4.12589E-01  4.23000E-01
     7  0.00000E+00  5.70600E-02  4.95899E-02  1.33079E-01  1.79759E-01  2.13329E-01  3.68249E-01  4.49970E-01
     8  0.00000E+00  0.00000E+00  1.38599E-02  4.38599E-02  6.35994E-02  4.51200E-02  3.42600E-02  6.26994E-02
     9  0.00000E+00  0.00000E+00  0.00000E+00  1.38599E-02  2.63400E-02  1.76400E-02  7.62000E-03  6.00000E-03
    10  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  8.34000E-03  7.26000E-03  2.94000E-03  1.32000E-03
    11  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  2.76000E-03  1.50000E-03  6.60000E-04
    12  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        psn   13 thru psn   21 same as above
0psn   grpp  9      grpp 10      grpp 11      grpp 12      grpp 13      grpp 14      grpp 15      grpp 16
     1  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
     2  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
     3  2.40000E-04  4.80000E-04  8.40000E-04  1.50000E-03  2.70000E-03  4.20000E-03  7.80000E-03  1.74060E-02
     4  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
     5  1.00920E+00  1.00920E+00  1.00920E+00  1.00920E+00  1.00920E+00  1.18920E+00  1.60920E+00  2.80924E+00
     6  4.24440E-01  2.98680E-01  2.69280E-01  2.85960E-01  2.53980E-01  3.78060E-01  1.29147E+00  2.79183E+00
     7  4.80899E-01  4.11240E-01  4.76820E-01  5.22059E-01  4.85759E-01  4.56959E-01  6.08940E-01  3.09930E-01
     8  8.09400E-02  7.31994E-02  1.15199E-01  1.63140E-01  1.45079E-01  1.41839E-01  2.21039E-01  1.97999E-01
     9  1.12200E-02  1.25400E-02  2.16000E-02  4.07999E-02  4.68000E-02  4.31400E-02  7.09194E-02  7.45200E-02
    10  1.08000E-03  1.80000E-03  3.66000E-03  7.32000E-03  1.15200E-02  1.39200E-02  2.16000E-02  2.32200E-02
    11  3.00000E-04  2.40000E-04  7.50000E-04  1.80000E-03  3.12000E-03  5.76000E-03  9.36000E-03  7.19994E-03
    12  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        psn   13 thru psn   21 same as above
 no. of groups=    16 tble length=    21 control=     0 id no.=     3 title=mixed cross sections by ice-the perfect mixer
0psn   grpp  1      grpp  2      grpp  3      grpp  4      grpp  5      grpp  6      grpp  7      grpp  8
     1  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        psn    2 thru psn    5 same as above
     6  7.20000E-04  2.70000E-03  2.52000E-02  5.02200E-02  3.04740E-01  5.14800E-01  6.15054E-01  6.33060E-01
     7  0.00000E+00  1.00440E-01  1.02420E-01  2.42459E-01  3.15719E-01  3.27779E-01  6.06954E-01  7.47000E-01
     8  0.00000E+00  0.00000E+00  2.28600E-02  7.66800E-02  8.92800E-02  4.19399E-02  2.28600E-02  4.46400E-02
     9  0.00000E+00  0.00000E+00  0.00000E+00  1.71000E-02  2.82600E-02  1.18800E-02  2.88000E-03  1.62000E-03
    10  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  6.30000E-03  3.78000E-03  9.00000E-04  1.80000E-04
    11  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  9.00000E-04  3.60000E-04  0.00000E+00
    12  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        psn   13 thru psn   21 same as above
0psn   grpp  9      grpp 10      grpp 11      grpp 12      grpp 13      grpp 14      grpp 15      grpp 16
     1  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
        psn    2 thru psn    5 same as above
     6  6.37554E-01  3.92400E-01  3.26519E-01  3.44700E-01  2.86920E-01  7.20000E-01  1.80000E+00  2.16000E+00
     7  7.99920E-01  7.19634E-01  8.93514E-01  9.80100E-01  9.13680E-01  8.89554E-01  1.15200E+00  3.60000E-01
     8  5.85000E-02  5.57999E-02  1.14659E-01  1.77659E-01  1.55340E-01  1.61280E-01  2.65320E-01  1.07999E-01
     9  3.42000E-03  4.13999E-03  9.18000E-03  2.30399E-02  2.84400E-02  2.73600E-02  4.82400E-02  2.88000E-02
    10  1.80000E-04  1.80000E-04  7.20000E-04  1.80000E-03  3.60000E-03  5.04000E-03  8.10000E-03  5.04000E-03
    11  0.00000E+00  0.00000E+00  0.00000E+00  1.80000E-04  3.60000E-04  1.08000E-03  1.98000E-03  9.00000E-04
    12  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
```

Table 3 (continued)

```
       psn   13 thru psn   21 same as above
 no. of groups=     0 tble length=     0 control=     7 id no.=     0 title=mixed cross sections by ice-the perfect mixer


1mixture id number[c]  1111
 id record

       1111         0          0          0         47          0          1          0          0         13
          0         0          0          0          0          0          0          0          0          0
          0         0          0          0          0          0          0          0          0          0
          0         6
 primary
 1d arrays
          1
    .3089E+00   .3154E+00   .4849E+00   .5524E+00   .7038E+00   .8648E+00   .9950E+00   .1102E+01   .1543E+01   .3331E+01
    .3781E+01   .5891E+01   .1157E+01   .1573E+01   .3031E+01   .6959E+01
         27
    .4044E-01   .3440E-01   .1906E-01   .1910E-01   .2300E-01   .4950E-01   .8300E-01   .1910E+00   .7120E+00   .2580E+01
    .3030E+01   .5140E+01   .4060E+00   .8220E+00   .2280E+01   .6208E+01
       1099
    .2223E-01   .4350E-01   .2292E-01   .2586E-01   .1324E-01   .2077E-02   .1515E-03   .1126E-04   .8860E-06   .6224E-07
    .9883E-08   .2161E-08   .1372E-08   .1144E-08   .1732E-08   .1732E-08
          2
    .2665E+00   .2810E+00   .4658E+00   .5333E+00   .6808E+00   .8153E+00   .9120E+00   .9112E+00   .8312E+00   .7512E+00
    .7512E+00   .7512E+00   .7512E+00   .7512E+00   .7512E+00   .7513E+00
        101
    .3701E-02   .2794E-02   .5102E-02   .7100E-02   .8699E-02   .2450E-01   .4100E-01   .1120E+00   .5250E+00   .2200E+01
    .2594E+01   .4803E+01   .1060E+00   .1220E+00   .4300E+00   .1048E+01
        201
    .5475E+00   .4897E+00   .6585E+00   .6898E+00   .7997E+00   .9540E+00   .1111E+01   .1416E+01   .2776E+01   .5368E+01
    .4610E+01   .6098E+01   .1170E+01   .1619E+01   .3173E+01   .7201E+01
         18
    .3674E-01   .3161E-01   .1396E-01   .1200E-01   .1430E-01   .2500E-01   .4200E-01   .7902E-01   .1870E+00   .3800E+00
    .4363E+00   .3371E+00   .3000E+00   .7000E+00   .1850E+01   .5160E+01
        102
    .5014E-03   .2794E-02   .5102E-02   .7100E-02   .8699E-02   .2450E-01   .4100E-01   .1120E+00   .5250E+00   .2200E+01
    .2594E+01   .4803E+01   .1060E+00   .1220E+00   .4300E+00   .1048E+01
        452
    .2846E+01   .2546E+01   .2521E+01   .2490E+01   .2460E+01   .2450E+01   .2450E+01   .2450E+01   .2450E+01   .2450E+01
    .2450E+01   .2450E+01   .2450E+01   .2450E+01   .2450E+01   .2450E+01
       1018
    .2040E+00   .3440E+00   .1680E+00   .1800E+00   .9000E-01   .1400E-01   .0000E+00   .0000E+00   .0000E+00   .0000E+00
    .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00
         16
    .2003E-02   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00
    .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00
       1452
    .1046E+00   .8048E-01   .3519E-01   .2988E-01   .3518E-01   .6125E-01   .1029E+00   .1936E+00   .4582E+00   .9310E+00
    .1069E+01   .8260E+00   .7350E+00   .1715E+01   .4532E+01   .1264E+02
       2002
    .2705E+00   .2810E+00   .4658E+00   .5333E+00   .6808E+00   .8153E+00   .9120E+00   .9112E+00   .8312E+00   .7512E+00
    .7512E+00   .7512E+00   .7512E+00   .7512E+00   .7512E+00   .7513E+00
 mwa pointer array
          1         7         12         16         19         21         23         25         27         29
         31        33         35         37         40         44          6         11         15         18
         20        22         24         26         28         30         32         34         36         39
         43        47          1          2          3          4          5          6          7          8
          9        10         11         12         13         13         13         13
 primary
 p- 0 array
    .4860E+00   .1842E+00   .8171E-01   .1409E+00   .9465E-01   .1257E-01   .6043E+00   .1127E+00   .1605E+00   .1071E+00
    .1530E-01   .6987E+00   .2354E+00   .5581E-01   .1009E-01   .8650E+00   .1275E+00   .7500E-02   .9545E+00   .4548E-01
    .9718E+00   .2819E-01   .9745E+00   .2555E-01   .9731E+00   .2689E-01   .9710E+00   .2899E-01   .9557E+00   .4433E-01
    .9521E+00   .4795E-01   .9557E+00   .4433E-01   .9521E+00   .4795E-01   .0000E+00   .9431E+00   .5690E-01   .0000E+00
    .0000E+00   .9616E+00   .3845E-01   .0000E+00   .0000E+00   .0000E+00   .1000E+01
 angle number  1
    .4860E+00   .1842E+00   .8171E-01   .1409E+00   .9465E-01   .1257E-01   .6043E+00   .1127E+00   .1605E+00   .1071E+00
    .1530E-01   .6987E+00   .2354E+00   .5581E-01   .1009E-01   .8650E+00   .1275E+00   .7500E-02   .9545E+00   .4548E-01
    .9718E+00   .2819E-01   .9745E+00   .2555E-01   .9731E+00   .2689E-01   .9710E+00   .2899E-01   .9557E+00   .4433E-01
    .9521E+00   .4795E-01   .9557E+00   .4433E-01   .9521E+00   .4795E-01   .0000E+00   .9431E+00   .5690E-01   .0000E+00
    .0000E+00   .9616E+00   .3845E-01   .0000E+00   .0000E+00   .0000E+00   .1000E+01
 probability number  1
   -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01
   -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01
   -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01
   -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01
   -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01  -.1000E+01
1mixture id number 2222
 id record

       2222         0          0          0         87          1          1          0          0         13
          0         0          0          0          0          0          0          0          0          0
          0         0          0          0          0          0          0          0          0          0
          0         7
 primary


 1d arrays[d]
          1
    .1259E+00   .1638E+00   .2993E+00   .3551E+00   .5062E+00   .7998E+00   .9615E+00   .1009E+01   .1009E+01   .1009E+01
    .1009E+01   .1009E+01   .1009E+01   .1189E+01   .1609E+01   .2809E+01
         27
    .1200E-02   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .0000E+00   .6000E-04   .2400E-03   .4800E-03
    .8400E-03   .1500E-02   .2700E-02   .4200E-02   .7800E-02   .1741E-01
       1099
    .1539E-01   .3012E-01   .1586E-01   .1791E-01   .9169E-02   .1438E-02   .1049E-03   .7795E-05   .6134E-06   .4309E-07
    .6842E-08   .1496E-08   .9500E-09   .7923E-09   .1199E-08   .1199E-08
          2
```

Table 3 (continued)

```
   .1247E+00  .1638E+00  .2993E+00  .3551E+00  .5062E+00  .7998E+00  .9615E+00  .1009E+01  .1009E+01  .1009E+01
   .1008E+01  .1008E+01  .1006E+01  .1185E+01  .1601E+01  .2792E+01
     101
   .1200E-02  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .6000E-04  .2400E-03  .4800E-03
   .8400E-03  .1500E-02  .2700E-02  .4200E-02  .7800E-02  .1741E-01
     201
   .1718E+00  .2210E+00  .3552E+00  .4410E+00  .6740E+00  .1060E+01  .1278E+01  .1328E+01  .1337E+01  .1340E+01
   .1340E+01  .1341E+01  .1365E+01  .1444E+01  .1840E+01  .3099E+01
      18
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
     102
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
     452
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
    1018
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
      16
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
    1452
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
   .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00  .0000E+00
    2002
   .1247E+00  .1638E+00  .2993E+00  .3551E+00  .5062E+00  .7998E+00  .9615E+00  .1009E+01  .1009E+01  .1009E+01
   .1008E+01  .1008E+01  .1006E+01  .1185E+01  .1601E+01  .2792E+01
 mwa pointer array
       1         7        13        19        25        31        37        43        49        55
      61        67        72        76        80        84         6        12        18        24
      30        36        42        48        54        60        66        71        75        79
      83        87         1         2         3         4         5         6         7         8
       9        10        11        12        13        13        13        13
 primary
 p- 0 array
   .2314E+00  .4574E+00  .1111E+00  .1111E+00  .6686E-01  .2213E-01  .2152E+00  .3027E+00  .2678E+00  .1608E+00
   .4432E-01  .9158E-02  .2720E+00  .4446E+00  .2125E+00  .5893E-01  .9822E-02  .2205E-02  .3407E+00  .5063E+00
   .1271E+00  .2146E-01  .3717E-02  .8449E-03  .4964E+00  .4215E+00  .6769E-01  .1185E-01  .2134E-02  .4742E-03
   .4440E+00  .4604E+00  .7839E-01  .1403E-01  .2250E-02  .9377E-03  .4291E+00  .4680E+00  .8418E-01  .1304E-01
   .3807E-02  .1872E-02  .4192E+00  .4765E+00  .7254E-01  .2140E-01  .7254E-02  .3092E-02  .4207E+00  .4076E+00
   .1142E+00  .4044E-01  .1142E-01  .5709E-02  .2961E+00  .4727E+00  .1617E+00  .4640E-01  .1380E-01  .9279E-02
   .2670E+00  .5177E+00  .1439E+00  .4278E-01  .2142E-01  .7140E-02  .2838E+00  .4820E+00  .1408E+00  .7038E-01
   .2304E-01  .2523E+00  .4540E+00  .2196E+00  .7404E-01  .0000E+00  .3190E+00  .5139E+00  .1671E+00  .0000E+00
   .0000E+00  .8065E+00  .1935E+00  .0000E+00  .0000E+00  .0000E+00  .1000E+01
 p- 1 array
   .2495E-01  .1760E+01  .1649E+01  .1234E+01  .7554E+00  .3261E+00  .7660E-01  .2065E+01  .1748E+01  .1073E+01
   .5207E+00  .2400E+00  .3095E+00  .1822E+01  .1404E+01  .6735E+00  .3061E+00  .0000E+00  .4152E+00  .1756E+01
   .9295E+00  .3780E+00  .1364E+00  .0000E+00  .1213E+01  .1536E+01  .6673E+00  .2700E+00  .1667E+00  .0000E+00
   .1450E+01  .1648E+01  .7120E+00  .3048E+00  .1000E+00  .0000E+00  .1491E+01  .1660E+01  .7228E+00  .3301E+00
   .1967E+00  .1000E+00  .1497E+01  .1663E+01  .7623E+00  .4250E+00  .2459E+00  .1154E+00  .1502E+01  .1750E+01
   .9953E+00  .5647E+00  .3125E+00  .1875E+00  .1314E+01  .1874E+01  .1089E+01  .6077E+00  .3621E+00  .2115E+00
   .1213E+01  .1877E+01  .1071E+01  .6342E+00  .3750E+00  .1250E+00  .1205E+01  .1881E+01  .1137E+01  .6802E+00
   .2171E+00  .1130E+01  .1947E+01  .1200E+01  .3865E+00  .0000E+00  .1904E+01  .1892E+01  .5455E+00  .0000E+00
   .0000E+00  .1394E+01  .1162E+01  .0000E+00  .0000E+00  .0000E+00  .7737E+00
 angle number  1
   .8316E-02  .5868E+00  .5498E+00  .4113E+00  .2518E+00  .1087E+00  .2553E-01  .6884E+00  .5828E+00  .3576E+00
   .1736E+00  .8000E-01  .1032E+00  .6073E+00  .4679E+00  .2245E+00  .1020E+00  .0000E+00  .1384E+00  .5854E+00
   .3098E+00  .1260E+00  .4545E-01  .0000E+00  .4043E+00  .5122E+00  .2224E+00  .9000E-01  .5556E-01  .0000E+00
   .4832E+00  .5494E+00  .2373E+00  .1016E+00  .3333E-01  .0000E+00  .4969E+00  .5534E+00  .2409E+00  .1100E+00
   .6557E-01  .3333E-01  .4989E+00  .5545E+00  .2541E+00  .1417E+00  .8197E-01  .3846E-01  .5007E+00  .5833E+00
   .3318E+00  .1882E+00  .1042E+00  .6250E-01  .4379E+00  .6246E+00  .3630E+00  .2026E+00  .1207E+00  .7051E-01
   .4042E+00  .6258E+00  .3569E+00  .2114E+00  .1250E+00  .4167E-01  .4018E+00  .6270E+00  .3790E+00  .2267E+00
   .7235E-01  .3766E+00  .6489E+00  .4001E+00  .1288E+00  .0000E+00  .6348E+00  .6306E+00  .1818E+00  .0000E+00
   .0000E+00  .4646E+00  .3872E+00  .0000E+00  .0000E+00  .0000E+00  .2579E+00
 probability number  1
   .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01
   .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01 -.1000E+01  .1000E+01  .1000E+01
   .1000E+01  .1000E+01  .1000E+01 -.1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01 -.1000E+01
   .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01 -.1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01
   .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01
   .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01
   .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01
   .1000E+01  .1000E+01  .1000E+01  .1000E+01  .1000E+01 -.1000E+01  .1000E+01  .1000E+01  .1000E+01 -.1000E+01
  -.1000E+01  .1000E+01  .1000E+01 -.1000E+01 -.1000E+01 -.1000E+01  .1000E+01
```

[a]AMPX working format cross sections.
[b]ANISN format cross sections.
[c]MORSE/KENO format cross-section library.

Table 4. XSDRNPM, KENO V.a, and CSAS25 sample problem results

```
install.r1

    case
         title(20 ...)  keno[  k-eff    sigma     AEG    ]  xsdrn[   lambda  ]

bonami.out
nitawl.out
ice.out
xsdrn.out
      93% uo2f2 solution sp ****** outer iteration limit reached   1.00285E+00
kenova.out
      sample problem 1  cas   1.0065    .0047
      sample problem 2  2c8   1.0065    .0047
      sample problem 3  2c8   1.0116    .0053
      sample problem 4  2c8   1.0122    .0054
      sample problem 5  2c8   1.0245    .0036
      sample problem 6  one    .7496    .0037
      sample problem 7  bar   1.0055    .0038
      sample problem 8  inf    .9491    .0041
      sample problem 9  inf   2.2848    .0078
      sample problem 10  ca   1.0065    .0047
      sample problem 11  2c   1.0065    .0047
      sample problem 12 4 a   1.0094    .0055  1.42228E+01
      sample problem 13  tw   1.0030    .0043  1.42228E+01
      sample problem 14  u     .9976    .0049  1.42228E+01
      sample problem 15  sm   1.0122    .0046  1.42228E+01
      sample problem 16 uo2    .9885    .0029  1.42228E+01
      sample problem 17 93%   1.0101    .0164  1.42228E+01
      sample problem 18   1   1.0146    .0073  2.20819E+01
      sample problem 19 4 a   1.0117    .0047  1.40787E+01
      sample problem 20 tri   1.0001    .0063  1.40787E+01
      sample problem 21  pa    .9875    .0034  1.40787E+01
      sample problem 22   c   1.0079    .0048  1.40787E+01
      sample problem 23  ca   1.0048    .0046  1.40787E+01
      sample problem 24  ca   1.0044    .0043  1.40787E+01
      sample problem 25  ca   1.0059    .0043  1.40787E+01
      sample problem 26  ca   1.0070    .0047  1.40787E+01
      sample problem 27  ca   1.0063    .0042  1.40787E+01
      sample problem 28  ca   1.0045    .0045  1.40787E+01
      sample problem 29  ba   1.0023    .0044  1.40787E+01
      sample problem 30   b    .9929    .0046  1.40787E+01
      sample problem 31   b    .9929    .0046  1.40787E+01
      sample problem 32   b    .9929    .0046  1.40787E+01
      sample problem 33   c    .9801    .0021  1.73559E+01
csas25.out
      keno v.a sample probl   1.0040    .0054  9.12134E+00
      storage array of pwr-    .7320    .0061  1.43385E+01
      storage array of pwr-    .3582    .0046  1.04178E+01
      storage array of pwr-    .7445    .0038  1.55533E+01
      storage array of pwr-    .8973    .0048  1.53957E+01
      storage array of pwr-    .9132    .0046  1.52584E+01
      sample problem 3  sam                                        1.33398E+00
      sample square fuel ca    .7111    .0058  1.42171E+01
      sample square fuel ca    .7624    .0043  1.42166E+01
      sample square fuel ca    .6208    .0054  1.41921E+01
      sample square fuel ca    .6432    .0047  1.42196E+01
      critical pitch search    .9626    .0047  1.42196E+01
      critical pitch search    .9270    .0048  1.42196E+01
      critical pitch search   1.0103    .0047  1.42196E+01
      critical pitch search   1.0097    .0042  1.42196E+01
      critical pitch search    .9801    .0050  1.42196E+01
      critical pitch search    .9982    .0042  1.42196E+01
```

Table 5. XSDRNPM sample problem activities by zone

```
        0           activity table
            material        reaction
      1   92235           18
      2   92235           27
      3   92238           27
           0activities by zone
 0zone    act.  1      act.  2      act.  3
    1  4.14319E-01  4.97105E-01  2.71363E-03
    2  4.14319E-01  4.97105E-01  2.71363E-03
        0zone  2 has system totals
         0activities by interval
 0int.    act.  1      act.  2      act.  3
    1  6.12734E-05  7.34642E-05  3.89567E-07
    2  6.11592E-05  7.33283E-05  3.89077E-07
    3  6.08721E-05  7.29840E-05  3.87271E-07
    4  6.04296E-05  7.24537E-05  3.84486E-07
    5  5.98351E-05  7.17409E-05  3.80715E-07
    6  5.90932E-05  7.08515E-05  3.76016E-07
    7  5.82074E-05  6.97895E-05  3.70397E-07
    8  5.71815E-05  6.85596E-05  3.63894E-07
    9  5.60206E-05  6.71678E-05  3.56531E-07
   10  5.47288E-05  6.56190E-05  3.48342E-07
   11  5.33125E-05  6.39211E-05  3.39362E-07
   12  5.17764E-05  6.20794E-05  3.29630E-07
   13  5.01281E-05  6.01033E-05  3.19187E-07
   14  4.83722E-05  5.79984E-05  3.08074E-07
   15  4.65181E-05  5.57756E-05  2.96340E-07
   16  4.45698E-05  5.34400E-05  2.84028E-07
   17  4.25380E-05  5.10043E-05  2.71193E-07
   18  4.04256E-05  4.84721E-05  2.57875E-07
   19  3.82449E-05  4.58581E-05  2.44137E-07
   20  3.59966E-05  4.31631E-05  2.30009E-07
   21  3.36949E-05  4.04044E-05  2.15565E-07
   22  3.13367E-05  3.75781E-05  2.00813E-07
   23  2.89392E-05  3.47048E-05  1.85847E-07
   24  2.64921E-05  3.17724E-05  1.70633E-07
   25  2.40170E-05  2.88068E-05  1.55308E-07
   26  2.14906E-05  2.57800E-05  1.39754E-07
   27  1.89407E-05  2.27259E-05  1.24203E-07
   28  1.63156E-05  1.95824E-05  1.08366E-07
   29  1.36533E-05  1.63961E-05  9.27013E-08
   30  1.08254E-05  1.30136E-05  7.64710E-08
   31  7.89765E-06  9.51682E-06  6.07702E-08
   32  4.34123E-06  5.26946E-06  4.19085E-08
```

3.2.1 BONAMI

The BONAMI analytic problems were set up as follows:

SCOMMAND was executed in front of and following the BONAMI analytical problem to manipulate input and output units and soft link the Hansen-Roach BCD working library into the program execution area. AWL was used to convert the Hansen-Roach BCD working library to a binary library suitable for use by BONAMI.

The BONAMI analytic problems demonstrate that BONAMI is correctly performing the Bondarenko iteration and producing correct cross sections. Table 6 lists the "sigma P" corresponding to each BONAMI zone. The results from the BONAMI output are given in Tables 7 through 12. (The "sigma P" listed in Table 6 for each material and zone is offset from the value of sig0 listed in the BONAMI output because the value edited by BONAMI does not include the contribution to sigma P of the nuclide that it is currently being processed.) The verification input includes a NITAWL-II step after each BONAMI case in order to edit the cross sections for comparison purposes. The results of the NITAWL-II edit are not presented here. The BONAMI results are identical to those in the SCALE-4.2 baseline and to the NITAWL-II edited cross sections, thus verifying that BONAMI is functioning correctly.

3.2.2 NITAWL-II

The NITAWL-II analytic problems verify the consistency of the infinite homogeneous media (0-D), slab (1-D), cylindrical (2-D), and spherical (3-D) options in NITAWL-II. The following messages appear in the output:

this resonance material will be treated as a 0-dimensional object.
this resonance material will be treated as a 1-dimensional object.
this resonance material will be treated as a 2-dimensional object.
this resonance material will be treated as a 3-dimensional object.

The cross-section edits from NITAWL-II have been included in Tables 13 through 16. The values of the cross-section IDs 2, 18 and 102 for groups 9-14 are consistent with those originally reported and included in Appendix C, Tables C.1 through C.4. The results presented in Tables 13 through 16 verify that NITAWL-II is functioning correctly.

3.2.3 KENO V.a

The first series of KENO V.a functional verification problems consists of a series of hole intersection checks, start type checks, and geometric orientation cases. The functional verification against analytic benchmarks and XSDRNPM will be presented in the next section.

The input file for the first KENO V.a hole intersection problem sets up the cross sections that are required by KENO (the cross sections are not used in the calculation but must exist in order for KENO to execute properly). A total of 14 input files are then run. These checks represent a comprehensive set of KENO geometry models where the geometry checking routines in KENO should or should not find geometric inconsistencies. The performance of KENO using these models verifies that the geometry reading and tracking algorithms are performing correctly.

Table 6. Relationship of BONAMI zones to "sigma P" for each nuclide

nuclide	zone	"sigma P"	sig0	nuclide	zone	"sigma P"	sig0
90232	1	40	20	92233	1	20	0.00001
	2	1000	980		2	100	80
	3	3000	2980		3	600	580
	4	6000	5980		4	2000	1980
	5	20000	19980		5	10000	9980
92235	1	20	0.00001	92238	1	15	3
	2	100	80		2	100	88
	3	600	580		3	600	588
	4	2000	1980		4	2000	1988
	5	10000	9980		5	10000	9988
94239	1	20	0.00001	94240	1	50	0.00001
	2	100	80		2	600	550
	3	600	580		3	6000	5950
	4	2000	1980		4	100000	99950
	5	10000	9980		5	1000000	1000000

Table 7. Nuclide 90232

```
     edit for material:      90232
                  zone:          1
        position in mix:         1
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    9   2.000E+01  1.500E+01  3.000E+00
   10   2.000E+01  1.370E+01  1.700E+00
   11   2.000E+01  1.600E+01  4.000E+00
     edit for material:      90232
                  zone:          2
        position in mix:         2
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    9   9.800E+02  2.200E+01  1.000E+01
   10   9.800E+02  1.800E+01  6.000E+00
   11   9.800E+02  2.600E+01  1.400E+01
     edit for material:      90232
                  zone:          3
        position in mix:         3
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    9   2.980E+03  2.500E+01  1.300E+01
   10   2.980E+03  2.100E+01  9.000E+00
   11   2.980E+03  3.300E+01  2.100E+01
    edit for material:       90232
                  zone:          4
        position in mix:         4
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    9   5.980E+03  2.700E+01  1.500E+01
   10   5.980E+03  2.370E+01  1.170E+01
   11   5.980E+03  3.860E+01  2.660E+01
    edit for material:       90232
                  zone:          5
        position in mix:         5
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    9   1.998E+04  2.880E+01  1.680E+01
   10   1.998E+04  2.730E+01  1.530E+01
   11   1.998E+04  4.660E+01  3.460E+01
```

Table 8. Nuclide 92233

```
             edit for material:      92233
                          zone:          1
              position in mix:           1
                              shielded cross sections

                        mt=     1  mt=    18  mt=   102
                         order=  0  order=  0  order=  0
 group    sig0           offset= 0  offset= 0  offset= 0
+_____  __________  __________  __________  __________
   10   1.000E-05  5.660E+01  2.710E+01  1.750E+01
   11   1.000E-05  8.630E+01  6.430E+01  1.000E+01
   12   1.000E-05  9.750E+01  7.250E+01  1.300E+01
   13   1.000E-05  2.263E+02  1.719E+02  4.240E+01
             edit for material:      92233
                          zone:          2
              position in mix:           2
                              shielded cross sections

                        mt=     1  mt=    18  mt=   102
                         order=  0  order=  0  order=  0
 group    sig0           offset= 0  offset= 0  offset= 0
+_____  __________  __________  __________  __________
   10   8.000E+01  5.990E+01  2.880E+01  1.910E+01
   11   8.000E+01  1.019E+02  7.690E+01  1.300E+01
   12   8.000E+01  1.067E+02  8.000E+01  1.470E+01
   13   8.000E+01  2.815E+02  2.145E+02  5.500E+01
             edit for material:      92233
                          zone:          3
              position in mix:           3
                              shielded cross sections

                        mt=     1  mt=    18  mt=   102
                         order=  0  order=  0  order=  0
 group    sig0           offset= 0  offset= 0  offset= 0
+_____  __________  __________  __________  __________
   10   5.800E+02  6.270E+01  3.000E+01  2.070E+01
   11   5.800E+02  1.260E+02  9.600E+01  1.800E+01
   12   5.800E+02  1.205E+02  9.150E+01  1.700E+01
   13   5.800E+02  3.568E+02  2.712E+02  7.360E+01
             edit for material:      92233
                          zone:          4
              position in mix:           4
                              shielded cross sections

                        mt=     1  mt=    18  mt=   102
                         order=  0  order=  0  order=  0
 group    sig0           offset= 0  offset= 0  offset= 0
+_____  __________  __________  __________  __________
   10   1.980E+03  6.300E+01  3.000E+01  2.100E+01
   11   1.980E+03  1.362E+02  1.042E+02  2.000E+01
   12   1.980E+03  1.272E+02  9.700E+01  1.820E+01
   13   1.980E+03  3.946E+02  2.970E+02  8.560E+01
             edit for material:      92233
                          zone:          5
              position in mix:           5
                              shielded cross sections

                        mt=     1  mt=    18  mt=   102
                         order=  0  order=  0  order=  0
 group    sig0           offset= 0  offset= 0  offset= 0
+_____  __________  __________  __________  __________
   10   9.980E+03  6.300E+01  3.000E+01  2.100E+01
   11   9.980E+03  1.420E+02  1.087E+02  2.130E+01
   12   9.980E+03  1.313E+02  1.003E+02  1.900E+01
   13   9.980E+03  4.140E+02  3.100E+02  9.200E+01
```

Table 9. Nuclide 92235

```
          edit for material:      92235
                      zone:          1
             position in mix:          1
                        shielded cross sections

                   mt=     1  mt=    18  mt=   102
                   order=  0  order=  0  order=  0
 group     sig0    offset= 0  offset= 0  offset= 0
+______  _________  _________  _________  _________
   10   1.000E-05  6.250E+01  3.440E+01  1.810E+01
   11   1.000E-05  3.600E+01  1.645E+01  9.551E+00
   12   1.000E-05  3.660E+01  1.229E+01  1.431E+01
   13   1.000E-05  3.560E+01  2.010E+01  5.500E+00
          edit for material:      92235
                      zone:          2
             position in mix:          2
                        shielded cross sections

                   mt=     1  mt=    18  mt=   102
                   order=  0  order=  0  order=  0
 group     sig0    offset= 0  offset= 0  offset= 0
+______  _________  _________  _________  _________
   10   8.000E+01  6.460E+01  3.580E+01  1.880E+01
   11   8.000E+01  4.480E+01  2.212E+01  1.268E+01
   12   8.000E+01  5.030E+01  1.784E+01  2.246E+01
   13   8.000E+01  4.200E+01  2.490E+01  7.100E+00
          edit for material:      92235
                      zone:          3
             position in mix:          3
                        shielded cross sections

                   mt=     1  mt=    18  mt=   102
                   order=  0  order=  0  order=  0
 group     sig0    offset= 0  offset= 0  offset= 0
+______  _________  _________  _________  _________
   10   5.800E+02  6.700E+01  3.720E+01  1.980E+01
   11   5.800E+02  6.190E+01  3.122E+01  2.068E+01
   12   5.800E+02  6.840E+01  2.588E+01  3.252E+01
   13   5.800E+02  4.830E+01  2.940E+01  8.900E+00
          edit for material:      92235
                      zone:          4
             position in mix:          4
                        shielded cross sections

                   mt=     1  mt=    18  mt=   102
                   order=  0  order=  0  order=  0
 group     sig0    offset= 0  offset= 0  offset= 0
+______  _________  _________  _________  _________
   10   1.980E+03  6.780E+01  3.780E+01  2.000E+01
   11   1.980E+03  7.550E+01  3.820E+01  2.730E+01
   12   1.980E+03  7.710E+01  3.024E+01  3.686E+01
   13   1.980E+03  4.900E+01  3.000E+01  9.000E+00
          edit for material:      92235
                      zone:          5
             position in mix:          5
                        shielded cross sections

                   mt=     1  mt=    18  mt=   102
                   order=  0  order=  0  order=  0
 group     sig0    offset= 0  offset= 0  offset= 0
+______  _________  _________  _________  _________
   10   9.980E+03  6.800E+01  3.800E+01  2.000E+01
   11   9.980E+03  8.520E+01  4.237E+01  3.283E+01
   12   9.980E+03  8.220E+01  3.294E+01  3.926E+01
   13   9.980E+03  4.900E+01  3.000E+01  9.000E+00
```

Table 10. Nuclide 92238

```
       edit for material:      92238
                  zone:            1
          position in mix:         1
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    8   3.000E+00  1.338E+01  3.825E-01
    9   3.000E+00  1.159E+01  5.865E-01
   10   3.000E+00  1.148E+01  2.484E+00
   11   3.000E+00  1.027E+01  1.275E+00
   12   3.000E+00  1.135E+01  2.351E+00
       edit for material:      92238
                  zone:            2
          position in mix:         2
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    8   8.800E+01  1.392E+01  9.230E-01
    9   8.800E+01  1.306E+01  2.059E+00
   10   8.800E+01  1.411E+01  5.112E+00
   11   8.800E+01  1.219E+01  3.195E+00
   12   8.800E+01  1.482E+01  5.822E+00
       edit for material:      92238
                  zone:            3
          position in mix:         3
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    8   5.880E+02  1.480E+01  1.800E+00
    9   5.880E+02  1.680E+01  5.800E+00
   10   5.880E+02  2.170E+01  1.270E+01
   11   5.880E+02  1.820E+01  9.200E+00
   12   5.880E+02  2.780E+01  1.880E+01
       edit for material:      92238
                  zone:            4
          position in mix:         4
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    8   1.988E+03  1.500E+01  2.000E+00
    9   1.988E+03  1.880E+01  7.800E+00
   10   1.988E+03  2.830E+01  1.930E+01
   11   1.988E+03  2.420E+01  1.520E+01
   12   1.988E+03  4.020E+01  3.120E+01
       edit for material:      92238
                  zone:            5
          position in mix:         5
                     shielded cross sections

                  mt=     1  mt=   102
                   order=  0  order=  0
 group    sig0     offset= 0  offset= 0
+_____  _________  _________  _________
    8   9.988E+03  1.500E+01  2.000E+00
    9   9.988E+03  2.110E+01  1.010E+01
   10   9.988E+03  4.190E+01  3.290E+01
   11   9.988E+03  3.960E+01  3.060E+01
   12   9.988E+03  7.100E+01  6.200E+01
```

Table 11. Nuclide 94239

edit for material: 94239
zone: 1
position in mix: 1
shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
9	1.000E-05	3.140E+01	1.400E+01	7.400E+00
10	1.000E-05	2.310E+01	8.300E+00	4.800E+00
11	1.000E-05	3.710E+01	1.840E+01	8.700E+00
12	1.000E-05	2.050E+01	7.300E+00	3.200E+00
13	1.000E-05	3.300E+01	2.000E+01	3.000E+00
14	1.000E-05	1.352E+02	8.060E+01	4.460E+01
15	1.000E-05	1.238E+03	7.681E+02	4.599E+02

edit for material: 94239
zone: 2
position in mix: 2
shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
9	8.000E+01	3.370E+01	1.560E+01	8.100E+00
10	8.000E+01	3.090E+01	1.350E+01	7.400E+00
11	8.000E+01	5.330E+01	2.820E+01	1.510E+01
12	8.000E+01	2.420E+01	9.200E+00	5.000E+00
13	8.000E+01	3.300E+01	2.000E+01	3.000E+00
14	8.000E+01	1.554E+02	9.300E+01	5.240E+01
15	8.000E+01	1.270E+03	7.860E+02	4.740E+02

edit for material: 94239
zone: 3
position in mix: 3
shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
9	5.800E+02	3.490E+01	1.630E+01	8.600E+00
10	5.800E+02	4.580E+01	2.110E+01	1.470E+01
11	5.800E+02	8.780E+01	4.810E+01	2.970E+01
12	5.800E+02	3.270E+01	1.350E+01	9.200E+00
13	5.800E+02	3.300E+01	2.000E+01	3.000E+00
14	5.800E+02	1.954E+02	1.164E+02	6.900E+01
15	5.800E+02	1.386E+03	8.540E+02	5.220E+02

edit for material: 94239
zone: 4
position in mix: 4
shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
9	1.980E+03	3.510E+01	1.650E+01	8.600E+00
10	1.980E+03	6.090E+01	2.820E+01	2.270E+01
11	1.980E+03	1.114E+02	6.150E+01	3.990E+01
12	1.980E+03	4.080E+01	1.790E+01	1.290E+01
13	1.980E+03	3.300E+01	2.000E+01	3.000E+00
14	1.980E+03	2.166E+02	1.286E+02	7.800E+01
15	1.980E+03	1.560E+03	9.560E+02	5.940E+02

Table 11 (continued)

```
          edit for material:      94239
                      zone:           5
             position in mix:         5
                            shielded cross sections

                      mt=     1  mt=    18  mt=   102
                      order=  0  order=  0  order=  0
 group     sig0       offset= 0  offset= 0  offset= 0
+______ __________ __________ __________ __________
    9   9.980E+03  3.510E+01  1.650E+01  8.600E+00
   10   9.980E+03  7.960E+01  3.650E+01  3.310E+01
   11   9.980E+03  1.330E+02  7.330E+01  4.970E+01
   12   9.980E+03  4.880E+01  2.210E+01  1.670E+01
   13   9.980E+03  3.300E+01  2.000E+01  3.000E+00
   14   9.980E+03  2.310E+02  1.364E+02  8.460E+01
   15   9.980E+03  1.836E+03  1.112E+03  7.140E+02
```

Table 12. Nuclide 94240

edit for material: 94240
zone: 1
position in mix: 1
shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
10	1.000E-05	2.050E+01	0.000E+00	9.500E+00
11	1.000E-05	2.460E+01	0.000E+00	1.260E+01
12	1.000E-05	3.900E+01	0.000E+00	2.400E+01
13	1.931E-04	3.440E+02	6.667E-02	3.099E+02
14	1.000E-05	1.450E+02	3.000E-02	1.300E+02

edit for material: 94240
zone: 2
position in mix: 2
shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
10	5.500E+02	2.580E+01	0.000E+00	1.480E+01
11	5.500E+02	2.810E+01	0.000E+00	1.610E+01
12	5.500E+02	3.900E+01	0.000E+00	2.400E+01
13	5.500E+02	4.730E+02	9.000E-02	4.299E+02
14	5.500E+02	3.240E+02	6.667E-02	3.039E+02

edit for material: 94240
zone: 3
position in mix: 3
shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
10	5.950E+03	4.710E+01	0.000E+00	3.610E+01
11	5.950E+03	3.600E+01	0.000E+00	2.400E+01
12	5.950E+03	3.900E+01	0.000E+00	2.400E+01
13	5.950E+03	1.258E+03	2.433E-01	1.160E+03
14	5.950E+03	6.230E+02	1.300E-01	5.939E+02

edit for material: 94240
zone: 4
position in mix: 4
shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
10	9.995E+04	6.770E+01	0.000E+00	5.670E+01
11	9.995E+04	4.200E+01	0.000E+00	3.000E+01
12	9.995E+04	3.900E+01	0.000E+00	2.400E+01
13	9.995E+04	4.450E+03	8.700E-01	4.129E+03
14	9.995E+04	8.970E+02	1.900E-01	8.598E+02

edit for material: 94240
zone: 5
position in mix: 5
shielded cross sections

group	sig0	mt= 1 order= 0 offset= 0	mt= 18 order= 0 offset= 0	mt= 102 order= 0 offset= 0
10	1.000E+06	7.100E+01	0.000E+00	6.000E+01
11	1.000E+06	4.300E+01	0.000E+00	3.100E+01
12	1.000E+06	3.900E+01	0.000E+00	2.400E+01
13	1.000E+06	6.654E+03	1.303E+00	6.179E+03
14	1.000E+06	9.360E+02	2.000E-01	8.978E+02

Table 13. NITAWL-II 0-D consistency results

1neutron 1-d cross sections for uranium-238 endf/b-iv mat 1262 updated 10/12/89 id = 92238

0 xsec id grp.	1	2	4	16	18	17	27	101
1	6.47331E+00	3.46587E+00	1.21050E+00	8.43215E-01	9.44658E-01	5.48078E-03	9.48245E-01	3.58692E-03
2	7.79746E+00	4.72139E+00	2.49626E+00	6.65531E-04	5.64925E-01	0.00000E+00	5.79136E-01	1.42103E-02
3	7.46423E+00	4.38785E+00	2.49366E+00	0.00000E+00	5.43171E-01	0.00000E+00	5.82727E-01	3.95560E-02
4	7.03265E+00	4.01940E+00	2.57461E+00	0.00000E+00	3.66818E-01	0.00000E+00	4.38641E-01	7.18229E-02
5	7.07727E+00	4.56522E+00	2.36325E+00	0.00000E+00	4.09193E-02	0.00000E+00	1.48798E-01	1.07880E-01
6	8.07867E+00	6.11930E+00	1.84205E+00	0.00000E+00	2.02359E-03	0.00000E+00	1.17301E-01	1.15277E-01
7	1.03174E+01	9.05783E+00	1.12986E+00	0.00000E+00	7.10000E-05	0.00000E+00	1.29769E-01	1.29698E-01
8	1.31779E+01	1.27085E+01	9.62384E-02	0.00000E+00	5.90640E-05	0.00000E+00	3.73092E-01	3.73033E-01
9	1.61783E+01	1.53133E+01	0.00000E+00	0.00000E+00	3.05779E-05	0.00000E+00	8.64908E-01	8.64877E-01
10	2.19800E+01	1.96440E+01	0.00000E+00	0.00000E+00	3.14814E-04	0.00000E+00	2.33598E+00	2.33566E+00
11	5.18913E+01	4.00804E+01	0.00000E+00	0.00000E+00	1.50924E-08	0.00000E+00	1.18108E+01	1.18108E+01
12	1.08250E+02	6.18384E+01	0.00000E+00	0.00000E+00	1.29848E-08	0.00000E+00	4.64119E+01	4.64119E+01
13	8.40459E+01	2.68903E+01	0.00000E+00	0.00000E+00	2.07583E-08	0.00000E+00	5.71556E+01	5.71556E+01
14	1.25655E+02	1.49380E+01	0.00000E+00	0.00000E+00	3.57114E-08	0.00000E+00	1.10717E+02	1.10717E+02
15	9.01666E+00	8.51209E+00	0.00000E+00	0.00000E+00	5.39731E-08	0.00000E+00	5.04566E-01	5.04566E-01
16	9.17060E+00	8.68621E+00	0.00000E+00	0.00000E+00	6.65200E-08	0.00000E+00	4.84387E-01	4.84386E-01
17	9.26085E+00	8.76022E+00	0.00000E+00	0.00000E+00	7.42999E-08	0.00000E+00	5.00628E-01	5.00628E-01
18	9.31920E+00	8.80382E+00	0.00000E+00	0.00000E+00	7.92970E-08	0.00000E+00	5.15384E-01	5.15384E-01
19	9.34802E+00	8.83951E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	5.08503E-01	5.08503E-01
20	9.51989E+00	8.88285E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6.37022E-01	6.37022E-01
21	9.67281E+00	8.91087E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	7.61957E-01	7.61957E-01
22	9.78755E+00	8.92200E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.65533E-01	8.65533E-01
23	1.00970E+01	8.93650E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.16052E+00	1.16052E+00
24	1.06110E+01	8.94926E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.66175E+00	1.66175E+00
25	1.11314E+01	8.94922E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	2.18219E+00	2.18219E+00
26	1.20526E+01	8.95198E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	3.10069E+00	3.10069E+00
27	1.47971E+01	8.94197E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	5.85514E+00	5.85514E+00

0 xsec id grp.	102	251	252	253	452	1099	1018
1	3.58692E-03	8.08068E-01	1.64030E-03	3.84509E-03	3.53449E+00	7.68845E-01	2.36848E-02
2	1.42103E-02	7.73573E-01	1.92089E-03	3.85576E-03	2.95861E+00	7.67544E+00	1.95789E-01
3	3.95560E-02	6.42278E-01	3.03254E-03	4.35540E-03	2.68421E+00	9.24023E+00	2.16127E-01
4	7.18229E-02	5.52099E-01	3.79385E-03	4.61818E-03	2.57399E+00	5.47884E+00	1.23569E-01
5	1.07880E-01	4.88957E-01	4.33066E-03	4.77056E-03	2.51106E+00	7.40776E+00	1.63493E-01
6	1.15277E-01	3.73533E-01	5.30850E-03	4.86869E-03	2.44152E+00	8.16523E+00	1.76058E-01
7	1.29698E-01	2.16284E-01	6.64037E-03	5.11835E-03	2.36455E+00	4.10471E+00	8.68714E-02
8	3.73033E-01	4.08503E-02	8.12632E-03	5.54290E-03	2.32570E+00	1.77195E+00	1.33721E-02
9	8.64877E-01	3.61991E-03	8.44315E-03	5.63915E-03	2.32146E+00	1.73459E+00	9.70255E-04
10	2.33566E+00	2.82522E-03	8.45049E-03	5.64162E-03	2.31963E+00	1.69644E+00	7.20624E-05
11	1.18108E+01	2.82522E-03	8.45049E-03	5.64162E-03	2.31953E+00	1.70474E+00	5.66937E-06
12	4.64119E+01	2.82523E-03	8.45048E-03	5.64161E-03	2.31951E+00	1.20395E+00	3.98262E-07
13	5.71556E+01	2.82523E-03	8.45047E-03	5.64161E-03	2.31950E+00	1.09861E+00	6.32403E-08
14	1.10717E+02	2.82523E-03	8.45049E-03	5.64161E-03	2.31948E+00	1.18744E+00	1.25325E-08
15	5.04566E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31948E+00	5.44161E-01	1.41632E-09
16	4.84386E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31950E+00	3.08616E-01	4.15882E-10
17	5.00628E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31950E+00	1.40146E-01	1.33933E-10
18	5.15384E-01	2.82523E-03	8.45050E-03	5.64162E-03	2.31950E+00	1.22215E-01	9.58917E-11
19	5.08503E-01	2.82523E-03	8.45050E-03	5.64162E-03	0.00000E+00	2.23143E-01	1.35571E-10
20	6.37022E-01	2.82523E-03	8.45049E-03	5.64162E-03	0.00000E+00	6.93146E-01	2.20454E-10
21	7.61957E-01	2.82523E-03	8.45050E-03	5.64162E-03	0.00000E+00	2.07639E-01	3.22671E-11
22	8.65533E-01	2.82522E-03	8.45049E-03	5.64161E-03	0.00000E+00	3.67723E-01	3.74372E-11
23	1.16052E+00	2.82508E-03	8.45005E-03	5.64132E-03	0.00000E+00	8.98703E-01	3.57942E-11
24	1.66175E+00	2.82551E-03	8.45136E-03	5.64219E-03	0.00000E+00	1.88089E+00	9.74279E-12
25	2.18219E+00	2.82514E-03	8.45022E-03	5.64144E-03	0.00000E+00	1.51608E+00	2.85204E-12
26	3.10069E+00	2.82513E-03	8.45020E-03	5.64142E-03	0.00000E+00	1.61753E+00	1.99985E-12
27	5.85514E+00	2.82522E-03	8.45049E-03	5.64161E-03	0.00000E+00	3.59148E-01	4.76573E-13

Table 14. NITAWL-II 1-D consistency results

1neutron 1-d cross sections for uranium-238 endf/b-iv mat 1262 updated 10/12/89 id = 192238

0 xsec id grp.	1	2	4	16	18	17	27	101
1	6.47331E+00	3.46587E+00	1.21050E+00	8.43215E-01	9.44658E-01	5.48078E-03	9.48245E-01	3.58692E-03
2	7.79746E+00	4.72139E+00	2.49626E+00	6.65531E-04	5.64925E-01	0.00000E+00	5.79136E-01	1.42103E-02
3	7.46423E+00	4.38785E+00	2.49366E+00	0.00000E+00	5.43171E-01	0.00000E+00	5.82727E-01	3.95560E-02
4	7.03265E+00	4.01940E+00	2.57461E+00	0.00000E+00	3.66818E-01	0.00000E+00	4.38641E-01	7.18229E-02
5	7.07727E+00	4.56522E+00	2.36325E+00	0.00000E+00	4.09193E-02	0.00000E+00	1.48798E-01	1.07880E-01
6	8.07867E+00	6.11930E+00	1.84205E+00	0.00000E+00	2.02359E-03	0.00000E+00	1.17301E-01	1.15277E-01
7	1.03174E+01	9.05783E+00	1.12986E+00	0.00000E+00	7.10000E-05	0.00000E+00	1.29769E-01	1.29698E-01
8	1.31779E+01	1.27085E+01	9.62384E-02	0.00000E+00	5.90640E-05	0.00000E+00	3.73092E-01	3.73033E-01
9	1.59743E+01	1.51267E+01	0.00000E+00	0.00000E+00	3.05779E-05	0.00000E+00	8.47426E-01	8.47395E-01
10	1.73048E+01	1.55846E+01	0.00000E+00	0.00000E+00	3.08541E-04	0.00000E+00	1.72021E+00	1.71990E+00
11	2.06898E+01	1.69805E+01	0.00000E+00	0.00000E+00	1.50924E-08	0.00000E+00	3.70918E+00	3.70918E+00
12	2.32580E+01	1.59495E+01	0.00000E+00	0.00000E+00	1.29848E-08	0.00000E+00	7.30876E+00	7.30876E+00
13	1.83346E+01	1.06042E+01	0.00000E+00	0.00000E+00	2.07583E-08	0.00000E+00	7.73034E+00	7.73034E+00
14	2.47897E+01	9.36893E+00	0.00000E+00	0.00000E+00	3.57114E-08	0.00000E+00	1.54208E+01	1.54208E+01
15	9.01666E+00	8.51209E+00	0.00000E+00	0.00000E+00	5.39731E-08	0.00000E+00	5.04566E-01	5.04566E-01
16	9.17060E+00	8.68621E+00	0.00000E+00	0.00000E+00	6.65200E-08	0.00000E+00	4.84387E-01	4.84386E-01
17	9.26085E+00	8.76022E+00	0.00000E+00	0.00000E+00	7.42999E-08	0.00000E+00	5.00628E-01	5.00628E-01
18	9.31920E+00	8.80382E+00	0.00000E+00	0.00000E+00	7.92970E-08	0.00000E+00	5.15384E-01	5.15384E-01
19	9.34802E+00	8.83951E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	5.08503E-01	5.08503E-01
20	9.51989E+00	8.88285E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6.37022E-01	6.37022E-01
21	9.67281E+00	8.91087E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	7.61957E-01	7.61957E-01
22	9.78755E+00	8.92200E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.65533E-01	8.65533E-01
23	1.00970E+01	8.93650E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.16052E+00	1.16052E+00
24	1.06110E+01	8.94926E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.66175E+00	1.66175E+00
25	1.11314E+01	8.94922E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	2.18219E+00	2.18219E+00
26	1.20526E+01	8.95198E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	3.10069E+00	3.10069E+00
27	1.47971E+01	8.94197E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	5.85514E+00	5.85514E+00

0 xsec id grp.	102	251	252	253	452	1099	1018
1	3.58692E-03	8.08068E-01	1.64030E-03	3.84509E-03	3.53449E+00	7.68845E-01	2.36848E-02
2	1.42103E-02	7.73573E-01	1.92089E-03	3.85576E-03	2.95861E+00	7.67544E+00	1.95789E-01
3	3.95560E-02	6.42278E-01	3.03254E-03	4.35540E-03	2.68421E+00	9.24023E+00	2.16127E-01
4	7.18229E-02	5.52099E-01	3.79385E-03	4.61818E-03	2.57399E+00	5.47884E+00	1.23569E-01
5	1.07880E-01	4.88957E-01	4.33066E-03	4.77056E-03	2.51106E+00	7.40776E+00	1.63493E-01
6	1.15277E-01	3.73533E-01	5.30850E-03	4.86869E-03	2.44152E+00	8.16523E+00	1.76058E-01
7	1.29698E-01	2.16284E-01	6.64037E-03	5.11835E-03	2.36455E+00	4.10471E+00	8.68714E-02
8	3.73033E-01	4.08503E-02	8.12632E-03	5.54290E-03	2.32570E+00	1.77195E+00	1.33721E-02
9	8.47395E-01	3.61991E-03	8.44315E-03	5.63915E-03	2.32146E+00	1.73459E+00	9.70255E-04
10	1.71990E+00	2.82522E-03	8.45049E-03	5.64162E-03	2.31963E+00	1.69644E+00	7.20624E-05
11	3.70918E+00	2.82522E-03	8.45049E-03	5.64162E-03	2.31953E+00	1.70474E+00	5.66937E-06
12	7.30876E+00	2.82523E-03	8.45048E-03	5.64161E-03	2.31951E+00	1.20395E+00	3.98262E-07
13	7.73034E+00	2.82523E-03	8.45047E-03	5.64161E-03	2.31950E+00	1.09861E+00	6.32403E-08
14	1.54208E+01	2.82523E-03	8.45049E-03	5.64161E-03	2.31948E+00	1.18744E+00	1.25325E-08
15	5.04566E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31948E+00	5.44161E-01	1.41632E-09
16	4.84386E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31950E+00	3.08616E-01	4.15882E-10
17	5.00628E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31950E+00	1.40146E-01	1.33933E-10
18	5.15384E-01	2.82523E-03	8.45050E-03	5.64162E-03	2.31950E+00	1.22215E-01	9.58917E-11
19	5.08503E-01	2.82523E-03	8.45050E-03	5.64162E-03	0.00000E+00	2.23143E-01	1.35571E-10
20	6.37022E-01	2.82523E-03	8.45049E-03	5.64162E-03	0.00000E+00	6.93146E-01	2.20454E-10
21	7.61957E-01	2.82523E-03	8.45050E-03	5.64162E-03	0.00000E+00	2.07639E-01	3.22671E-11
22	8.65533E-01	2.82522E-03	8.45049E-03	5.64161E-03	0.00000E+00	3.67723E-01	3.74372E-11
23	1.16052E+00	2.82508E-03	8.45005E-03	5.64132E-03	0.00000E+00	8.98703E-01	3.57942E-11
24	1.66175E+00	2.82551E-03	8.45136E-03	5.64219E-03	0.00000E+00	1.88089E+00	9.74279E-12
25	2.18219E+00	2.82514E-03	8.45022E-03	5.64144E-03	0.00000E+00	1.51608E+00	2.85204E-12
26	3.10069E+00	2.82513E-03	8.45020E-03	5.64142E-03	0.00000E+00	1.61753E+00	1.99985E-12
27	5.85514E+00	2.82522E-03	8.45049E-03	5.64161E-03	0.00000E+00	3.59148E-01	4.76573E-13

Table 15. NITAWL-II 2-D consistency results

1neutron 1-d cross sections for uranium-238 endf/b-iv mat 1262 updated 10/12/89 id = 292238

0 xsec id grp.	1	2	4	16	18	17	27	101
1	6.47331E+00	3.46587E+00	1.21050E+00	8.43215E-01	9.44658E-01	5.48078E-03	9.48245E-01	3.58692E-03
2	7.79746E+00	4.72139E+00	2.49626E+00	6.65531E-04	5.64925E-01	0.00000E+00	5.79136E-01	1.42103E-02
3	7.46423E+00	4.38785E+00	2.49366E+00	0.00000E+00	5.43171E-01	0.00000E+00	5.82727E-01	3.95560E-02
4	7.03265E+00	4.01940E+00	2.57461E+00	0.00000E+00	3.66818E-01	0.00000E+00	4.38641E-01	7.18229E-02
5	7.07727E+00	4.56522E+00	2.36325E+00	0.00000E+00	4.09193E-02	0.00000E+00	1.48798E-01	1.07880E-01
6	8.07867E+00	6.11930E+00	1.84205E+00	0.00000E+00	2.02359E-03	0.00000E+00	1.17301E-01	1.15277E-01
7	1.03174E+01	9.05783E+00	1.12986E+00	0.00000E+00	7.10000E-05	0.00000E+00	1.29769E-01	1.29698E-01
8	1.31779E+01	1.27085E+01	9.62384E-02	0.00000E+00	5.90640E-05	0.00000E+00	3.73092E-01	3.73033E-01
9	1.59750E+01	1.51274E+01	0.00000E+00	0.00000E+00	3.05779E-05	0.00000E+00	8.47504E-01	8.47474E-01
10	1.73080E+01	1.55872E+01	0.00000E+00	0.00000E+00	3.08602E-04	0.00000E+00	1.72079E+00	1.72047E+00
11	2.06891E+01	1.69806E+01	0.00000E+00	0.00000E+00	1.50924E-08	0.00000E+00	3.70840E+00	3.70840E+00
12	2.32560E+01	1.59491E+01	0.00000E+00	0.00000E+00	1.29848E-08	0.00000E+00	7.30725E+00	7.30725E+00
13	1.83337E+01	1.06040E+01	0.00000E+00	0.00000E+00	2.07583E-08	0.00000E+00	7.72973E+00	7.72973E+00
14	2.47884E+01	9.36865E+00	0.00000E+00	0.00000E+00	3.57114E-08	0.00000E+00	1.54198E+01	1.54198E+01
15	9.01666E+00	8.51209E+00	0.00000E+00	0.00000E+00	5.39731E-08	0.00000E+00	5.04566E-01	5.04566E-01
16	9.17060E+00	8.68621E+00	0.00000E+00	0.00000E+00	6.65200E-08	0.00000E+00	4.84387E-01	4.84386E-01
17	9.26085E+00	8.76022E+00	0.00000E+00	0.00000E+00	7.42999E-08	0.00000E+00	5.00628E-01	5.00628E-01
18	9.31920E+00	8.80382E+00	0.00000E+00	0.00000E+00	7.92970E-08	0.00000E+00	5.15384E-01	5.15384E-01
19	9.34802E+00	8.83951E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	5.08503E-01	5.08503E-01
20	9.51989E+00	8.88285E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6.37022E-01	6.37022E-01
21	9.67281E+00	8.91087E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	7.61957E-01	7.61957E-01
22	9.78755E+00	8.92200E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.65533E-01	8.65533E-01
23	1.00970E+01	8.93650E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.16052E+00	1.16052E+00
24	1.06110E+01	8.94926E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.66175E+00	1.66175E+00
25	1.11314E+01	8.94922E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	2.18219E+00	2.18219E+00
26	1.20526E+01	8.95198E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	3.10069E+00	3.10069E+00
27	1.47971E+01	8.94197E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	5.85514E+00	5.85514E+00

0 xsec id grp.	102	251	252	253	452	1099	1018
1	3.58692E-03	8.08068E-01	1.64030E-03	3.84509E-03	3.53449E+00	7.68845E-01	2.36848E-02
2	1.42103E-02	7.73573E-01	1.92089E-03	3.85576E-03	2.95861E+00	7.67544E+00	1.95789E-01
3	3.95560E-02	6.42278E-01	3.03254E-03	4.35540E-03	2.68421E+00	9.24023E+00	2.16127E-01
4	7.18229E-02	5.52099E-01	3.79385E-03	4.61818E-03	2.57399E+00	5.47884E+00	1.23569E-01
5	1.07880E-01	4.88957E-01	4.33066E-03	4.77056E-03	2.51106E+00	7.40776E+00	1.63493E-01
6	1.15277E-01	3.73533E-01	5.30850E-03	4.86869E-03	2.44152E+00	8.16523E+00	1.76058E-01
7	1.29698E-01	2.16284E-01	6.64037E-03	5.11835E-03	2.36455E+00	4.10471E+00	8.68714E-02
8	3.73033E-01	4.08503E-02	8.12632E-03	5.54290E-03	2.32570E+00	1.77195E+00	1.33721E-02
9	8.47474E-01	3.61991E-03	8.44315E-03	5.63915E-03	2.32146E+00	1.73459E+00	9.70255E-04
10	1.72047E+00	2.82522E-03	8.45049E-03	5.64162E-03	2.31963E+00	1.69644E+00	7.20624E-05
11	3.70840E+00	2.82522E-03	8.45049E-03	5.64162E-03	2.31953E+00	1.70474E+00	5.66937E-06
12	7.30725E+00	2.82523E-03	8.45048E-03	5.64161E-03	2.31951E+00	1.20395E+00	3.98262E-07
13	7.72973E+00	2.82523E-03	8.45047E-03	5.64161E-03	2.31950E+00	1.09861E+00	6.32403E-08
14	1.54198E+01	2.82523E-03	8.45049E-03	5.64161E-03	2.31948E+00	1.18744E+00	1.25325E-08
15	5.04566E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31948E+00	5.44161E-01	1.41632E-09
16	4.84386E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31950E+00	3.08616E-01	4.15882E-10
17	5.00628E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31950E+00	1.40146E-01	1.33933E-10
18	5.15384E-01	2.82523E-03	8.45050E-03	5.64162E-03	2.31950E+00	1.22215E-01	9.58917E-11
19	5.08503E-01	2.82523E-03	8.45050E-03	5.64162E-03	0.00000E+00	2.23143E-01	1.35571E-10
20	6.37022E-01	2.82523E-03	8.45049E-03	5.64162E-03	0.00000E+00	6.93146E-01	2.20454E-10
21	7.61957E-01	2.82523E-03	8.45050E-03	5.64162E-03	0.00000E+00	2.07639E-01	3.22671E-11
22	8.65533E-01	2.82522E-03	8.45049E-03	5.64161E-03	0.00000E+00	3.67723E-01	3.74372E-11
23	1.16052E+00	2.82508E-03	8.45005E-03	5.64132E-03	0.00000E+00	8.98703E-01	3.57942E-11
24	1.66175E+00	2.82551E-03	8.45136E-03	5.64219E-03	0.00000E+00	1.88089E+00	9.74279E-12
25	2.18219E+00	2.82514E-03	8.45022E-03	5.64144E-03	0.00000E+00	1.51608E+00	2.85204E-12
26	3.10069E+00	2.82513E-03	8.45020E-03	5.64142E-03	0.00000E+00	1.61753E+00	1.99985E-12
27	5.85514E+00	2.82522E-03	8.45049E-03	5.64161E-03	0.00000E+00	3.59148E-01	4.76573E-13

Table 16. NITAWL-II 3-D consistency results

1neutron 1-d cross sections for uranium-238 endf/b-iv mat 1262 updated 10/12/89 id = 392238

0 xsec id grp.	1	2	4	16	18	17	27	101
1	6.47331E+00	3.46587E+00	1.21050E+00	8.43215E-01	9.44658E-01	5.48078E-03	9.48245E-01	3.58692E-03
2	7.79746E+00	4.72139E+00	2.49626E+00	6.65531E-04	5.64925E-01	0.00000E+00	5.79136E-01	1.42103E-02
3	7.46423E+00	4.38785E+00	2.49366E+00	0.00000E+00	5.43171E-01	0.00000E+00	5.82727E-01	3.95560E-02
4	7.03265E+00	4.01940E+00	2.57461E+00	0.00000E+00	3.66818E-01	0.00000E+00	4.38641E-01	7.18229E-02
5	7.07727E+00	4.56522E+00	2.36325E+00	0.00000E+00	4.09193E-02	0.00000E+00	1.48798E-01	1.07880E-01
6	8.07867E+00	6.11930E+00	1.84205E+00	0.00000E+00	2.02359E-03	0.00000E+00	1.17301E-01	1.15277E-01
7	1.03174E+01	9.05783E+00	1.12986E+00	0.00000E+00	7.10000E-05	0.00000E+00	1.29769E-01	1.29698E-01
8	1.31779E+01	1.27085E+01	9.62384E-02	0.00000E+00	5.90640E-05	0.00000E+00	3.73092E-01	3.73033E-01
9	1.59975E+01	1.51479E+01	0.00000E+00	0.00000E+00	3.05779E-05	0.00000E+00	8.49526E-01	8.49495E-01
10	1.76412E+01	1.58720E+01	0.00000E+00	0.00000E+00	3.09473E-04	0.00000E+00	1.76917E+00	1.76886E+00
11	2.13779E+01	1.74651E+01	0.00000E+00	0.00000E+00	1.50924E-08	0.00000E+00	3.91271E+00	3.91271E+00
12	2.42178E+01	1.64540E+01	0.00000E+00	0.00000E+00	1.29848E-08	0.00000E+00	7.76405E+00	7.76405E+00
13	1.90605E+01	1.07814E+01	0.00000E+00	0.00000E+00	2.07583E-08	0.00000E+00	8.27903E+00	8.27903E+00
14	2.59722E+01	9.43120E+00	0.00000E+00	0.00000E+00	3.57114E-08	0.00000E+00	1.65411E+01	1.65411E+01
15	9.01666E+00	8.51209E+00	0.00000E+00	0.00000E+00	5.39731E-08	0.00000E+00	5.04566E-01	5.04566E-01
16	9.17060E+00	8.68621E+00	0.00000E+00	0.00000E+00	6.65200E-08	0.00000E+00	4.84387E-01	4.84386E-01
17	9.26085E+00	8.76022E+00	0.00000E+00	0.00000E+00	7.42999E-08	0.00000E+00	5.00628E-01	5.00628E-01
18	9.31920E+00	8.80382E+00	0.00000E+00	0.00000E+00	7.92970E-08	0.00000E+00	5.15384E-01	5.15384E-01
19	9.34802E+00	8.83951E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	5.08503E-01	5.08503E-01
20	9.51989E+00	8.88285E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6.37022E-01	6.37022E-01
21	9.67281E+00	8.91087E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	7.61957E-01	7.61957E-01
22	9.78755E+00	8.92200E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	8.65533E-01	8.65533E-01
23	1.00970E+01	8.93650E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.16052E+00	1.16052E+00
24	1.06110E+01	8.94926E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.66175E+00	1.66175E+00
25	1.11314E+01	8.94922E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	2.18219E+00	2.18219E+00
26	1.20526E+01	8.95198E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	3.10069E+00	3.10069E+00
27	1.47971E+01	8.94197E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	5.85514E+00	5.85514E+00

0 xsec id grp.	102	251	252	253	452	1099	1018
1	3.58692E-03	8.08068E-01	1.64030E-03	3.84509E-03	3.53449E+00	7.68845E-01	2.36848E-02
2	1.42103E-02	7.73573E-01	1.92089E-03	3.85576E-03	2.95861E+00	7.67544E+00	1.95789E-01
3	3.95560E-02	6.42278E-01	3.03254E-03	4.35540E-03	2.68421E+00	9.24023E+00	2.16127E-01
4	7.18229E-02	5.52099E-01	3.79385E-03	4.61818E-03	2.57399E+00	5.47884E+00	1.23569E-01
5	1.07880E-01	4.88957E-01	4.33066E-03	4.77056E-03	2.51106E+00	7.40776E+00	1.63493E-01
6	1.15277E-01	3.73533E-01	5.30850E-03	4.86869E-03	2.44152E+00	8.16523E+00	1.76058E-01
7	1.29698E-01	2.16284E-01	6.64037E-03	5.11835E-03	2.36455E+00	4.10471E+00	8.68714E-02
8	3.73033E-01	4.08503E-02	8.12632E-03	5.54290E-03	2.32570E+00	1.77195E+00	1.33721E-02
9	8.49495E-01	3.61991E-03	8.44315E-03	5.63915E-03	2.32146E+00	1.73459E+00	9.70255E-04
10	1.76886E+00	2.82522E-03	8.45049E-03	5.64162E-03	2.31963E+00	1.69644E+00	7.20624E-05
11	3.91271E+00	2.82522E-03	8.45049E-03	5.64162E-03	2.31953E+00	1.70474E+00	5.66937E-06
12	7.76405E+00	2.82523E-03	8.45048E-03	5.64161E-03	2.31951E+00	1.20395E+00	3.98262E-07
13	8.27903E+00	2.82523E-03	8.45047E-03	5.64161E-03	2.31950E+00	1.09861E+00	6.32403E-08
14	1.65411E+01	2.82523E-03	8.45049E-03	5.64161E-03	2.31948E+00	1.18744E+00	1.25325E-08
15	5.04566E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31948E+00	5.44161E-01	1.41632E-09
16	4.84386E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31950E+00	3.08616E-01	4.15882E-10
17	5.00628E-01	2.82523E-03	8.45049E-03	5.64162E-03	2.31950E+00	1.40146E-01	1.33933E-10
18	5.15384E-01	2.82523E-03	8.45050E-03	5.64162E-03	2.31950E+00	1.22215E-01	9.58917E-11
19	5.08503E-01	2.82523E-03	8.45050E-03	5.64162E-03	0.00000E+00	2.23143E-01	1.35571E-10
20	6.37022E-01	2.82523E-03	8.45049E-03	5.64162E-03	0.00000E+00	6.93146E-01	2.20454E-10
21	7.61957E-01	2.82523E-03	8.45050E-03	5.64162E-03	0.00000E+00	2.07639E-01	3.22671E-11
22	8.65533E-01	2.82522E-03	8.45049E-03	5.64161E-03	0.00000E+00	3.67723E-01	3.74372E-11
23	1.16052E+00	2.82508E-03	8.45005E-03	5.64132E-03	0.00000E+00	8.98703E-01	3.57942E-11
24	1.66175E+00	2.82551E-03	8.45136E-03	5.64219E-03	0.00000E+00	1.88089E+00	9.74279E-12
25	2.18219E+00	2.82514E-03	8.45022E-03	5.64144E-03	0.00000E+00	1.51608E+00	2.85204E-12
26	3.10069E+00	2.82513E-03	8.45020E-03	5.64142E-03	0.00000E+00	1.61753E+00	1.99985E-12
27	5.85514E+00	2.82522E-03	8.45049E-03	5.64161E-03	0.00000E+00	3.59148E-01	4.76573E-13

Verification

The results are verified by summarizing the KENO V.a error messages (k5-91, k5-92, k5-166, k5-169, k5-179, k5-100, and k5-133) and the system messages (STOP 129, STOP (this is an unlabeled STOP)) and comparing the results to the earlier verifications included in Appendix C.

Messages k5-91, k5-92, k5-166, k5-169 and k5-179 are printed on a separate page between the Geometry Description and the Volumes table of the KENO output (*.out). Message k5-133 is the last message printed on the last page of each KENO V.a case that did not contain any error messages and attempted to run zero generations. k5-100 is the last message printed on the last page of each KENO V.a case that contained other error messages. The system message STOP 129 and the unlabeled STOP appear in the message file (*.msgs) which is generated for each case. The unlabeled STOP has been taken as the equivalent of the USER 0000 completion code in the results in Table C.5 of Appendix C.

A FORTRAN utility program, READK5, was used to collect the message totals for each case and edit them in table format. A copy of the FORTRAN utility is included in Appendix B. When executed, READK5 prompts for an index file and an output file. The format of the index file is a list of the file names without the .out qualifier. The program assumes that there will be two files, name.out and name.msgs, for each name in the list. The results file is given in Table 17. Although the results are not given in detail, the message totals for each case suffice to verify that KENO is functioning properly.

The message summaries for each case in Table 17 are the same as those presented in Table C.5 of Appendix C except for the case k5shape. There are 28 individual KENO sample problems contained within k5shape. Sample problem 15 failed with a memory fault during execution. The cause of the failure was determined by the code developer to be a code error where an "if" test was being performed. A corrected "if" test was patched into the code to verify that the problem had been correctly identified and solved. It was determined by the code developer that the inappropriate evaluation of the "if" test could occur without causing the problem to fail. If the problem did not fail, the program logic remained correct. This minor code error has been corrected. Alternatively, the sample problem can be run if a core boundary card is included in the KENO input data.

The start option case is a model of an analytic 1-group problem where k_{eff} is 1.0000. The geometry is a 2.0 cm radius sphere and the cross sections have p1 scattering. Each of the seven KENO start types (start types 0 through 6) were verified using this geometry model and cross sections. The results are listed in order of increasing start type in Table 18. These results statistically are consistent with those included in Table C.6 of Appendix C and verify that the KENO start options are functioning correctly.

The output from the geometric orientation verification was reviewed and is consistent with the plot orientation figures presented in Table C.7 and Fig. C.1 in Appendix C. The actual output plots are not conducive to presentation in this report. The summary of the orientation results is included in Table 19 which refers to Figures 1 through 6. The label "hemi shape" refers to a hemicylindrical or hemispherical shape and the w refers to the orientation of the curved surface opposite the chord. For example, +w has the curved surface to the right of the chord, and -w has the curved surface to the left of the chord. These figures were created at the same resolution as the printer plots which accounts for the uneven appearance of the surfaces. The plot cases verify that the geometry input is correctly interpreted by KENO and produce the expected results.

Table 17. Summary of KENO V.a hole intersection messages

k5.r1

case	KENO V.a messages k5-91	k5-92	k5-166	k5-169	k5-179	k5-100	k5-133	SYSTEM stop 129	stop
k5case1h	0	0	0	0	0	0	45	0	45
k5case1i	135	0	90	45	0	45	0	45	0
k5case1o	135	0	45	90	0	45	0	45	0
k5case2h	0	0	0	0	0	0	27	0	27
k5case2i	81	0	54	27	0	27	0	27	0
k5case2o	81	0	27	54	0	27	0	27	0
k5case3h	0	0	0	0	0	0	36	0	36
k5case3i	252	0	216	36	0	36	0	36	0
k5case3o	252	0	108	144	0	36	0	36	0
k5case4h	0	0	0	0	0	0	5	0	5
k5case4i	40	0	40	0	0	5	0	5	0
k5case4o	40	0	0	40	0	5	0	5	0
k5intrs	600	4	4	12	582	15	0	15	0
k5shape	0	0	0	0	0	0	0	0	27

Table 18. KENO V.a start options results

k5start.r1

case title(20 ...)	keno[k-eff	sigma	AEG]	xsdrn[lambda]
k5start.out				
test problem 1 group	.9950	.0036		
test problem 1 group	1.0041	.0033		
test problem 1 group	1.0049	.0033		
test problem 1 group	1.0030	.0026		
test problem 1 group	1.0108	.0033		
test problem 1 group	.9981	.0035		
test problem 1 group	1.0039	.0034		

Table 19. KENO V.a geometric orientation results

Plot No.	Figure	Plot No.	Figure	Plot No.	Figure
1	1	17	6	30	2
2-5	4	18	2	31	5
6	2	19	5	32	3
7	5	20	3	33	6
8	3	21	6	34	2
9	6	22	2	35	5
10	2	23	5	36	3
11	5	24	3	37	6
12	3	25	6	38	2
13	6	26	2	39	5
14	2	27	5	40	3
15	5	28	3	41	6
16	3	29	6		

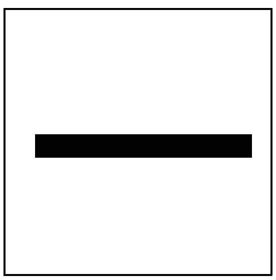

Figure 1 Cuboid

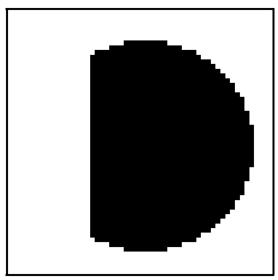

Figure 2 Hemishape +w/+chord

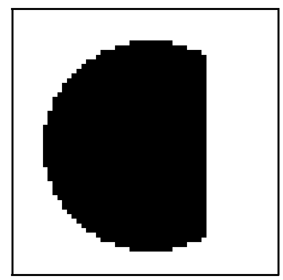

Figure 3 Hemishape -w/+chord

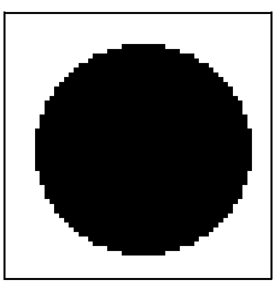

Figure 4 Sphere/cylinder

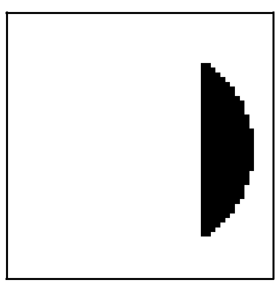

Figure 5 Hemishape +w/-chord

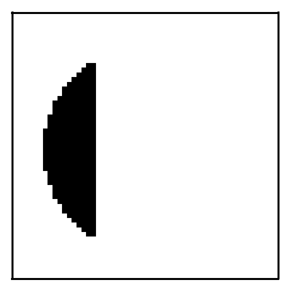

Figure 6 Hemishape -w/-chord

3.2.4 XSDRNPM/KENO V.a Comparison

The XSDRNPM/KENO V.a comparison is comprised of three series of calculations. In the first series both XSDRN and KENO are used to calculate 1-group analytic benchmarks which have a k_{eff} = 1. In the second series both codes are used to calculate 2-group analytic benchmarks which have a k_{eff} = 1. In both these series, the calculated k_{eff} may be compared directly with 1, as well as comparing KENO and XSDRN results. The third series is a comparison of XSDRN and KENO for a range of systems where the geometry model, materials, and modeling approximations have been arbitrarily varied over a range. These calculations are based on a 4-group library so that phenomena such as downscatter and upscatter may be verified. The agreement between XSDRN and KENO on these cases demonstrates that both codes are solving the same eigenvalue problem and verifying the functionality of the codes.

The output for the 1- and 2-group analytic cases was edited using the FORTRAN utility READA which scans output files supplied in an index file for specific XSDRN and KENO output and edits them into a results file. The index file is assumed to have a list of output file names without the .out qualifier. It is also assumed that there are two files, namex.out for the XSDRN cases and name.out for the KENO cases. A copy of the FORTRAN source for READA is provided in Appendix B.

The output for the 4-group comparison cases was edited using the FORTRAN utility READA4 which is a modified version of READA. It is assumed that each output file contains an XSDRN case followed by the equivalent KENO case. A copy of the FORTRAN source for READA4 is given in Appendix B.

Several of the cases in the keno1x and keno1 1-group input files were modified from those in the original verification. This was done in order to directly compare equivalent calculations. The parameter ISCT in XSDRN is the order of the Legendre expansion used for the cross sections. The parameter SCT in KENO is the number of scattering angles that are used for cross-section representation. For the cases to be equivalent, ISCT = (2 * SCT) - 1. The 1-group cross sections are p1 cross sections. Calculations at p0 represent a truncation of the cross-section data and calculations above p1 represent an artificial cross-section expansion. In XSDRN, the cross-section expansion is performed by padding higher order terms with zero. The effect is that every calculation above p1 has the same result. In KENO the cross sections are expanded by calculating moments which satisfy the original cross-section expansion. When SCT is changed in KENO, the cross section is actually different.

The results of the 1- and 2-group analytic problems are presented in Tables 20 and 21, respectively. In addition to presenting the λ or k_{eff} for each case, the calculated absorption and leakage are presented. The column entitled "Deviation" represents the number of KENO standard deviations between the KENO k_{eff} and a k_{eff} = 1.0000. Ideally this deviation would be 0, but because of the statistical nature of the KENO calculation there is some uncertainty in the KENO result. The columns entitled "Fract. Abs. Dev." and "Fract. Leak Dev." are the difference between the XSDRN and KENO calculated results normalized to the XSDRN results. The small fractional deviations verify that XSDRN and KENO are independently calculating the same quantities and are functioning correctly.

The results for the 4-group XSDRN/KENO comparison are presented in Table 22. In addition to presenting the λ or k_{eff} for each case, the calculated absorption and leakage are presented. The column entitled "Deviation" represents the number of KENO standard deviations between the KENO k_{eff} and the XSDRN λ. The columns entitled "Fract. Abs. Dev." and "Fract. Leak Dev." are the difference between the XSDRN and KENO calculated results normalized to the XSDRN results. The small fractional deviations verify that XSDRN and KENO are independently calculating the same quantities and are functioning correctly. Cases ic3xk3 and iic3xk3 have specular reflective boundary conditions and should have no leakage. The leakage predicted by XSDRN is small, being on the order of 10^{-7}, and the leakage predicted by KENO is zero. The nonzero leakage predicted by XSDRN gives rise to the unusual fractional deviation in the leakage for these cases. Table C.8 of Appendix C contains the original verification results for the four-group comparison.

Table 20. Results for the XSDRN and KENO V.a 1-group analytic cases

1group.r1

		XSDRN					KENO						
Case	ISCT	Lambda	Absorption	Leakage	Case	SCT	K-eff	dev	Abs1	Leak1	Deviation[a]	Fract.[b] Abs. Dev.	Fract.[c] Leak Dev.
keno1x	0	1.000180	.432875	.567125	keno1	0	.9994	.0011	.432468	.567324	-.5454	-.00094	.00035
	1	1.000220	.391034	.608966		1	1.0021	.0012	.391786	.608249	1.7500	.00192	-.00118
	3	1.000220	.391034	.608966		2	1.0000	.0012	.390875	.609145	.0000	-.00041	.00029
	5	1.000220	.391034	.608966		3	.9992	.0012	.390652	.609409	-.6667	-.00098	.00073
	15	1.000220	.391034	.608966		8	.9994	.0011	.390731	.609431	-.5454	-.00077	.00076
keno1x	22	1.000220	.391034										
					keno1	12	1.0024	.0012	.391873	.608000	2.0000		
	23	1.000220	.391034	.608966		12	1.0024	.0012	.391873	.608000	2.0000	.00215	-.00159
kenox	0	1.000090	.716463	.283537	keno	0	1.0003	.0009	.716658	.283342	.3334	.00027	-.00069
	0	1.000180	.432875	.567125		0	.9985	.0012	.432138	.567822	-1.2500	-.00170	.00123
	1	1.000220	.391034	.608966		1	.9988	.0011	.390462	.609566	-1.0909	-.00146	.00099
kenox	2	1.000220	.391034										
					keno	2	.9999	.0012	.390923	.609138	-.0833		
kenowx	0	1.000030	.972627	.027372	kenow	0	.9976	.0026	.969802	.028360	-.9231	-.00290	.03610
kenow2x	0	1.000040	.684094	.315906	kenow2	0	1.0049	.0031	.686361	.316391	1.5806	.00331	.00154
					kenoa	0	1.0008	.0009	.716975	.283025	.8889		

[a]Number of KENO standard deviations between KENO results and k_{eff} = 1.0000.
[b]Difference in fraction absorptions between XSDRN and KENO normalized to the XSDRN results.
[c]Difference in fraction leakage between XSDRN and KENO normalized to the XSDRN results.

Table 21. Results for the XSDRN and KENO V.a 2-group analytic cases

2group.r1

		XSDRN					KENO						
Case	ISCT	Lambda	Absorption	Leakage	Case	SCT	K-eff	dev	Abs1	Leak1	Deviation[a]	Fract.[b] Abs. Dev.	Fract.[c] Leak Dev.
keno2x	0	1.000160	.444400	.555600	keno2	0	1.0006	.0012	.444612	.555555	.5000	.00048	-.00008
keno2zx	0	.999883	.732651	.267347	keno2z	0	1.0009	.0037	.733419	.267112	.2433	.00105	-.00088
refl1x	0	.999924	.743552	.256446	refl1	0	1.0029	.0033	.745986	.254747	.8788	.00327	-.00663
refl2x	0	.999950	.770152	.229846	refl2	0	.9994	.0035	.770277	.230632	-.1714	.00016	.00342
refl5x	0	.999982	.884644	.115354	refl5	0	.9997	.0032	.885217	.114585	-.0937	.00065	-.00667
refl5x	8	.999982	.884644	.115354									

[a]Number of KENO standard deviations between KENO results and k_{eff} = 1.0000.
[b]Difference in fraction absorptions between XSDRN and KENO normalized to the XSDRN results.
[c]Difference in fraction leakage between XSDRN and KENO normalized to the XSDRN results.

Table 22. Results for the XSDRN and KENO V.a 4-group comparison cases

4group.r1

	XSDRN				KENO							
Case	ISCT	Lambda	Absorption	Leakage	SCT	K-eff	dev	Abs1	Leak1	Deviation[a]	Fract.[b] Abs. Dev.	Fract.[c] Leak Dev.
ia1xk0	0	1.097200	.511193	.490542	0	1.0981	.0011	.511588	.490438	.8181	.00077	-.00021
ia1xk1	1	1.020600	.475509	.526104	1	1.0192	.0010	.474844	.526804	-1.4000	-.00140	.00133
ia1xk2	3	1.020600	.475509	.526104	2	1.0195	.0010	.475003	.526551	-1.0999	-.00106	.00085
ia1xk3	5	1.020600	.475509	.526104	3	1.0189	.0010	.474713	.527002	-1.6999	-.00167	.00171
ia2xk3	5	1.061960	.787151	.212419	3	1.0644	.0029	.786435	.212704	.8414	-.00091	.00134
ia3xk0	0	1.201310	.653638	.355841	0	1.2001	.0010	.652932	.356843	-1.2101	-.00108	.00282
ia3xk1	1	1.094110	.597896	.410946	1	1.0944	.0010	.597864	.410912	.2900	-.00005	-.00008
ia3xk2	3	1.094350	.598103	.410747	2	1.0952	.0010	.598185	.410781	.8500	.00014	.00008
ia3xk3	5	1.094350	.598103	.410747	3	1.0929	.0010	.597138	.411538	-1.4499	-.00161	.00193
ia4xk0	0	.533308	.248471	.752373	0	.5320	.0008	.247868	.752969	-1.6350	-.00243	.00079
ia4xk1	1	.506174	.235833	.764967	1	.5057	.0007	.235582	.765211	-.6772	-.00106	.00032
ia4xk2	3	.506174	.235833	.764967	2	.5052	.0007	.235381	.765428	-1.3914	-.00192	.00060
ia4xk3	5	.506174	.235833	.764967	3	.5052	.0008	.235357	.765439	-1.2175	-.00202	.00062
ib1xk0	0	1.085910	.505933	.495784	0	1.0848	.0010	.505432	.496001	-1.1100	-.00099	.00044
ib1xk1	1	1.018650	.474597	.527014	1	1.0180	.0010	.474347	.527351	-.6500	-.00053	.00064
ib1xk2	3	1.018650	.474597	.527014	2	1.0179	.0011	.474195	.527452	-.6819	-.00085	.00083
ib1xk3	5	1.018650	.474597	.527014	3	1.0180	.0010	.474316	.527395	-.6500	-.00059	.00072
ib3xk3	5	1.076840	.838410	.160859	3	1.0821	.0030	.838386	.160679	1.7533	-.00003	-.00112
ic1xk0	0	.933080	.434727	.566749	0	.9320	.0010	.434203	.567352	-1.0800	-.00121	.00106
ic1xk1	1	.891261	.415246	.586163	1	.8911	.0009	.415079	.586116	-.1789	-.00040	-.00008
ic1xk2	3	.891261	.415246	.586163	2	.8911	.0010	.415129	.586394	-.1610	-.00028	.00039
ic1xk3	5	.891261	.415246	.586163	3	.8912	.0009	.415243	.586069	-.0678	-.00001	-.00016
ic3xk3	5	1.134620	.998255	.000000	3	1.1367	.0030	.997551	.000000	.6934	-.00071	-1.00000
iia1xk0	0	1.205360	.644426	.354710	0	1.2044	.0015	.643971	.355332	-.6401	-.00071	.00175
iia1xk1	1	.923587	.494457	.504903	1	.9241	.0015	.494767	.504777	.3420	.00063	-.00025
iia1xk2	3	.923587	.494457	.504903	2	.9237	.0015	.494441	.505271	.0753	-.00003	.00073
iia1xk3	5	.923587	.494457	.504903	3	.9211	.0015	.493124	.505945	-1.6580	-.00270	.00206
iia3xk3	5	.842322	.547453	.451259	3	.8446	.0021	.546947	.452046	1.0848	-.00092	.00174
iib1xk0	0	1.179680	.630779	.368376	0	1.1805	.0015	.631237	.368444	.5467	.00073	.00018
iib1xk1	1	.913565	.489153	.510215	1	.9132	.0014	.488973	.510297	-.2607	-.00037	.00016
iib1xk2	3	.913565	.489153	.510215	2	.9126	.0014	.488780	.510008	-.6893	-.00076	-.00041
iib1xk3	5	.913565	.489153	.510215	3	.9142	.0014	.489524	.509770	.4536	.00076	-.00087
iib3xk3	5	.592546	.365717	.633459	3	.5959	.0017	.367750	.631741	1.9729	.00556	-.00271
iic1xk0	0	1.006900	.538880	.460407	0	1.0092	.0014	.540087	.459094	1.6429	.00224	-.00285
iic1xk1	1	.780369	.418322	.581149	1	.7821	.0014	.419277	.580309	1.2365	.00228	-.00145
iic1xk2	3	.780369	.418322	.581149	2	.7825	.0013	.419535	.579557	1.6393	.00290	-.00274
iic1xk3	5	.780369	.418322	.581149	3	.7855	.0013	.421034	.578734	3.9469	.00648	-.00416
iic3xk3	5	.948322	.996462	.000000	3	.9537	.0036	.996080	.000000	1.4939	-.00038	-1.00000

[a]Number of KENO standard deviations between KENO results and k_{eff} = 1.0000.
[b]Difference in fraction absorptions between XSDRN and KENO normalized to the XSDRN results.
[c]Difference in fraction leakage between XSDRN and KENO normalized to the XSDRN results.

4 VALIDATION

4.1 PREFACE

The purpose of this section is to present the results of a validation of KENO V.a and the 27-group SCALE cross-section library run under the CSAS25 control sequence. Results for several benchmark calculations using XSDRNPM run under the CSAS1X sequence are also presented.

The models of critical experiments used for the validation were taken from previously documented validations. The experiments modeled cover a broad range of systems and fissile material types including homogeneous high- and low-enriched ^{235}U systems, heterogeneous low-enriched ^{235}U systems, ^{233}U systems, and ^{239}Pu systems. No descriptions or discussions of the critical experiments will be given in this report; however, input files for the calculational models are available (see Appendix A). Prior to applying the results of this validation, the analyst must become familiar with the particular series of experiments that he is comparing against and ascertain that the range of the validation critical experiments spans the type of system being analyzed.

The large number and variety of critical experiments included in this validation make the validation very general. The bias and calculational acceptance k_{eff}'s presented in this section may be overly restrictive for specific applications. In this situation the analyst should consider selecting a more appropriate subset of the validation cases for establishing the bias and acceptance criteria.

Several of the groupings of experiments presented overlap in that they include the same critical experiments as are included in one or more of the other groups. The different groupings should not be combined without reviewing the experiments included in the groups and ensuring that the same critical experiment is not being included multiple times.

4.2 INTRODUCTION

The validation results for KENO V.a using the 27-group SCALE cross-section library run under the CSAS25 control sequence are presented in this section. The purpose of validation is to demonstrate that the codes and cross sections may be used for a specific application. The "bias" and "margin of subcriticality" in calculated k_{eff} must be determined in order to use the codes for nuclear criticality safety purposes. In this report the "bias" is taken to be all the sources of bias which prevent code and cross sections from calculating the experimental value (k_{eff} = 1 for critical systems). Using this definition, each calculation has a "bias;" the quantity of interest becomes the "average bias" of the group of experiments being analyzed. The margin of subcriticality in k_{eff} is determined through a statistical analysis of the validation results. A statistical approach is used to establish a lower tolerance band of k_{eff} for which there is a high degree of confidence that the band encompasses all similar critical systems. This band is then used to determine the margin of subcriticality in k_{eff}. A more detailed discussion of the statistical treatment and the interpretation of the results is given later. The results of this validation indicates that KENO V.a and the 27-group library run under the CSAS25 control sequence in SCALE-4 may be used for criticality safety evaluations for a broad range of critical systems.

In Sect. 4.3 the sources of the critical experiment models are given. The calculations are grouped for easy cross reference to the original reports. The calculational results and statistical analyses of the data are presented in Sect. 4.4.

4.3 PROBLEM DESCRIPTION

The critical experiment validation models were taken from three reports[8-10] which included validation of KENO V.a. The models were obtained from the authors of the reports and were used unaltered with the following exceptions. The models from Ref. 9 were originally set up for the SCALE 16-group Hansen-Roach library. The cross-section library specification was modified in the input to use the 27-group library. In addition, references to specific cross sections available in the 16-group library but not in the 27-group library [e.g., X(e) hydrogen] were changed to equivalent materials in the 27-group library. The models from Ref. 10 were originally set up to use a new 44-group ENDF/B-V library available at ORNL. The cross-section library specification was changed to use the 27-group library. In addition, several element specifications which have individual isotope evaluations in ENDF/B-V were changed to the equivalent natural element evaluations in order to use the 27-group library (the authors of Ref. 10 provided several of these modified models).

The models were organized to correspond to the organization in the original reports to allow easy cross referencing. A brief description is given for each group of models.

Models taken from Ref. 8 correspond to those described in Tables 1 through 6 of the reference report. The models from Tables 1 through 3 are for low-enriched ^{235}U systems. The models from Tables 1 and 3 are primarily for homogeneous water-moderated single units and arrays of large units. The models from Table 2 are arrays of large low-enriched uranium metal billets moderated and reflected by water. The models from Tables 4 through 6 are for highly enriched ^{235}U systems with several ^{233}U systems included in Table 6. The criticals from Ref. 8 cover a broad range of geometry, fissile fuel mixture, moderator, and reflector combinations with a broad range of neutron spectra. These models validate ^{235}U, ^{238}U, water cross sections, and many materials of construction used in the critical systems.

Models taken from Ref. 9 correspond to those discussed in Appendices C, D, and E of the reference report. The models from Appendix C are for ^{233}U systems. Included are ^{233}U metal systems, water-moderated systems at various concentrations, and arrays of large units. The models from Appendix D are for highly enriched ^{235}U systems. The models in Appendix D were primarily extracted from Tables 4 and 5 of Ref. 8. The selection process was intended to exclude highly thermal systems in order to validate harder thermal, epithermal, and fast systems. The models from Appendix E are for ^{239}Pu systems. Systems with variable ^{240}Pu content were analyzed as well as systems with a range of fissile material form, geometry and moderation level. Several arrays of large units were also included in the validation. These experiment models validate the codes and cross sections for harder spectra over a broad range of fissile materials and materials of construction.

Models taken from Ref. 10 correspond to those discussed in Tables 3 and 4 of the reference report. The models from Table 3 are CSAS1X/XSDRNPM calculations, primarily of CSEWG fast and thermal benchmarks. The fast benchmarks include ^{233}U, ^{235}U, and ^{239}Pu systems in 1-D geometry representations in a variety of unreflected and water- and metal-reflected systems. Graphite-moderated systems and UH_3 systems have also been included. The thermal benchmarks include highly enriched ^{235}U water-moderated systems, low-enriched ^{235}U lattices, and water-moderated ^{239}Pu systems. Although these experiments were not modeled using KENO V.a, it has been shown that KENO V.a and XSDRNPM calculate the same results when using the same geometry, cross sections, and approximations. Therefore, the expected performance of KENO V.a may be gauged from the XSDRNPM results. The models from Table 4 are primarily of low-enriched light-water-reactor (LWR) reactor lattices. These cases provide significant testing of the SCALE resonance cross-section processing methodology for heterogeneous systems. Both UO_2 and mixed-oxide UO_2-PuO_2 lattices have been included. Several fast-reactor mixed-oxide lattices and homogeneous ^{235}U systems were also included. These experiments are useful for validating the code and cross sections for analysis of LWR fresh and spent fuel storage and for fuel shipping cask analysis.

4.4 RESULTS AND DISCUSSION

The FORTRAN utility READM was used to scan the output files for XSDRN and/or KENO output and edit the results (the READM utility was discussed in Sect. 3). The results of the validation calculations are presented in Tables 23 through 33.

The results for the Ref. 8 Tables 1 through 6 cases are presented in Tables 23 through 28, respectively. The results in Tables 23, 24, and 25 are for low-enriched ^{235}U systems. The results in Tables 26, 27, and 28 are for highly enriched ^{235}U systems. Several ^{233}U systems are included in Table 28. Several of the cases presented in Table 25 (Ref. 8, Table 3, cases) have multiple KENO outputs. This is because the original cases were set up for both 27-group and 16-group Hansen-Roach calculations. The second KENO result presented in Table 25 is the 16-group result.

The results for the Ref. 9 Appendices C, D, and E cases are presented in Tables 29 through 31, respectively. The Table 29 results are for ^{233}U systems; in Table 30, for highly enriched ^{235}U systems; and Table 31, for ^{239}Pu systems. Several of the cases in Table 29 (Ref. 9, Appendix C) and Table 31 (Ref. 9, Appendix E) are XSDRN cases. For some of the cases only an XSDRN was run; for others, both XSDRN and KENO were run for the same (or similar equivalent) geometry.

The results for Ref. 10 Tables 3 and 4 cases are presented in Tables 32 and 33, respectively. The results in Table 32 (Ref. 10, Table 3) are CSAS1X/XSDRNPM results for the CSEWG benchmarks. The results in Table 33 (Ref. 10, Table 4) are primarily LWR lattice results with several fast-reactor lattice and homogeneous systems included. Several of the calculations presented in Table 33 were run using the CSAS2X sequence. In this sequence, an XSDRN calculation is performed prior to the KENO calculation to create a flux- and volume-weighted homogeneous mixture which represents the heterogeneous lattice specification. This cell-weighted mixture is designated mixture 500 and is passed to KENO to be used in lieu of the heterogeneous lattice.

A statistical analysis was performed on the KENO results presented in Tables 23 through 33. The experiments in Tables 27 and 29 were subdivided into low and high average energy group causing fission (AEG) because of significant trends in the results. Table 34 presents the mean k_{eff} and the standard deviation of the mean k_{eff} for each set of results, treating the data as a single group. Also presented are (1) estimates of the lower 95% confidence bound of k_{eff} and (2) the lower 95% confidence on 99.9% of future calculations bound of k_{eff} when the data are treated as a group. The lower 95% confidence bound of k_{eff} may be interpreted as that value of k_{eff} that one would expect to calculate above, 95% of the time, if the system being analyzed is a critical system. The lower 95% confidence bound on 99.9% of future calculations may be interpreted as the value of k_{eff} for which a critical system similar to those validated would calculate above for 99.9% of the estimates of k_{eff} at the 95% confidence level.

In establishing the confidence bounds of k_{eff}, the variability of the KENO calculations has been included in the estimate of the total standard deviation (this is the sample variance listed in Table 34). In general, this is appropriate because while each estimate of k_{eff} is that of a critical system, each estimate is a single estimate of a different physical arrangement of fissile material which has imbedded an individual uncertainty. In specific instances where all of the estimates of k_{eff} are for a specific system or very similar systems, this treatment will overestimate the variability and be slightly conservative.

The results presented in Table 34 indicate that a calculated k_{eff} of less than 0.95 would be considered subcritical at the 95% confidence level. With the exception of the Table 27, Table 27 high AEG, Table 29, and Table 29 low AEG groupings, a calculated k_{eff} of less than 0.95 would be considered subcritical 99.9% of the time at the 95% confidence level. The Table 27 results for highly enriched ^{235}U systems have a large total standard deviation due to the bias in

Table 23. Results from Table 1 of Ref. 8

t1.r1

case	title(20 ...)	keno[k-eff	sigma	AEG]	xsdrn[lambda]
caa01.out	libby exp. 4.89% rods	.9965	.0031	2.11960E+01	
caa02.out	libby h2o refl. case	.9958	.0033	2.17662E+01	
caa03.out	libby h2o refl. case	.9903	.0032	2.28962E+01	
caa04.out	libby h2o refl. case	.9917	.0037	2.31278E+01	
caa05.out	libby h2o refl. case	.9878	.0030	2.32222E+01	
caa06.out	libby h2o refl. case	1.0027	.0039	2.11287E+01	
caa07.out	libby h2o refl. case	.9851	.0032	2.13701E+01	
caa08.out	libby h2o refl. case	.9927	.0033	2.28425E+01	
caa09.out	libby h2o refl. case	.9925	.0031	2.27466E+01	
caa10.out	libby h2o refl. case	1.0058	.0034	2.09263E+01	
caa11.out	libby h2o refl. case	.9976	.0027	2.09526E+01	
caa12.out	libby rods in uo2f2 s	.9759	.0026	2.40233E+01	
caa13.out	libby rods in uo2f2 s	.9868	.0023	2.43977E+01	
caa14.out	libby rods in uo2f2 s	.9891	.0027	2.44810E+01	
caa15.out	libby rods in uo2f2 s	.9911	.0022	2.41695E+01	
caa16.out	libby rods in uo2f2 s	.9919	.0023	2.41751E+01	
caa17.out	libby rods in uo2f2 s	.9866	.0022	2.42439E+01	
caa18.out	libby rods in uo2f2 s	.9908	.0023	2.43162E+01	
caa19.out	4.89% green blocks un	.9844	.0034	2.33537E+01	
caa20.out	4.89% green blocks un	1.0039	.0036	2.40014E+01	
caa21.out	4.89% green blocks un	1.0032	.0028	2.45617E+01	
caa22.out	4.89% green blocks un	.9936	.0031	2.42503E+01	
caa23.out	4.89% green blocks re	.9785	.0039	2.33851E+01	
caa24.out	4.89% green blocks re	.9917	.0033	2.36610E+01	
caa25.out	4.89% green blocks re	.9896	.0033	2.41745E+01	
caa26.out	4.89% green blocks re	1.0022	.0028	2.46252E+01	
caa27.out	4.89% green blocks re	.9864	.0029	2.28531E+01	
caa28.out	4.89% green blocks re	.9672	.0032	2.16016E+01	
caa29.out	4.89% green blocks re	.9901	.0027	2.43757E+01	
caa30.out	4.89% uo2f2 20 in dia	.9883	.0030	2.42837E+01	

Table 23 (continued)

```
caa31.out
      4.89% uo2f2 20x20 in      .9986    .0032  2.42923E+01
caa32.out
      4.89% uo2f2 20 in dia     .9995    .0027  2.45405E+01
caa33.out
      4.89% uo2f2 27.3 in d     .9963    .0027  2.47160E+01
caa34.out
      4.89% uo2f2 30 in dia     .9895    .0025  2.47084E+01
caa35.out
      4.89% uo2f2 15 in dia    1.0030    .0025  2.43637E+01
caa36.out
      4.89% uo2f2 20x20 in     1.0085    .0031  2.43906E+01
caa37.out
      4.89% uo2f2 15 in dia     .9928    .0028  2.45762E+01
caa38.out
      4.89% uo2f2 27.3 in d     .9993    .0024  2.47847E+01
caa39.out
      4.89% uo2f2 20 in dia     .9953    .0023  2.47310E+01
```

Table 24. Results from Table 2 of Ref. 8

```
t2.r1

    case
         title(20 ...)  keno[  k-eff    sigma     AEG    ]  xsdrn[   lambda  ]

cab01.out
      case ebj.1 u(3.85) 15   1.0070    .0027  1.44716E+01
cab02.out
      case ebj.2x  restart    1.0106    .0026  1.58857E+01
cab03.out
      case ebj.3x              .9979    .0031  1.67454E+01
cab04.out
      case ebj.3q same as c   1.0032    .0028  1.67538E+01
cab05.out
      case ebj.3a use 123gp    .9572    .0032  8.50215E+01
cab06.out
      case ebj.3k use 16gp     .9777    .0029  1.11853E+01
cab07.out
      case ebj.4 u(3.85) 16    .9969    .0026  1.34117E+01
cab08.out
      case ebj.5x              .9989    .0028  1.56167E+01
cab09.out
      case ebj.6x              .9991    .0029  1.71174E+01
cab10.out
      case ebj.8 u(3.85) 6    1.0089    .0029  1.68408E+01
cab11.out
      case ebj.9 u(3.85) 16   1.0034    .0028  1.71134E+01
cab12.out
      case ebj.10 u(3.85) 2   1.0125    .0027  1.75552E+01
cab13.out
      case ebj.11 u(3.85) 8   1.0095    .0027  1.58942E+01
cab14.out
      case ebj.12 u(3.85) 2   1.0159    .0031  1.70717E+01
cab15.out
      case ebj.13 u(3.85) 1   1.0043    .0027  1.85057E+01
cab16.out
      case ebj.14 u(3.85) 2   1.0013    .0028  1.97054E+01
```

Table 25. Results from Table 3 of Ref. 8

```
t4.r1

    case
         title(20 ...)  keno[  k-eff    sigma     AEG    ]  xsdrn[   lambda  ]

car01.out
      rocky flats criticals   1.0044    .0029  2.13759E+01
car02.out
      rocky flats criticals   1.0053    .0033  2.13434E+01
car03.out
      rocky flats criticals    .9895    .0029  1.96136E+01
car04.out
      rocky flats criticals   1.0135    .0030  2.12094E+01
car05.out
      rocky flats criticals    .9986    .0025  1.91183E+01
car06.out
      rocky flats criticals   1.0029    .0038  1.26369E+01
car07.out
      rocky flats criticals   1.0050    .0035  1.82894E+01
car08.out
      rocky flats criticals    .9970    .0036  1.92472E+01
car09.out
      rocky flats criticals    .9982    .0032  1.92553E+01
car10.out
      rocky flats criticals   1.0091    .0027  1.77648E+01
car11.out
      rocky flats criticals   1.0047    .0031  2.15406E+01
car12.out
      rocky flats criticals   1.0085    .0030  2.01709E+01
car13.out
      rocky flats criticals   1.0137    .0027  2.01735E+01
car14.out
      rocky flats criticals   1.0048    .0033  1.85443E+01
car15.out
      rocky flats criticals    .9975    .0035  1.84995E+01
car16.out
      rocky flats criticals   1.0060    .0035  1.92180E+01
car17.out
      rocky flats criticals   1.0039    .0028  2.07603E+01
car18.out
      rocky flats criticals   1.0102    .0029  2.18609E+01
car19.out
      rocky flats criticals   1.0093    .0033  1.82604E+01
car20.out
      rocky flats criticals    .9982    .0029  1.83503E+01
cas04.out
      british handbook of c    .9878    .0021  2.32711E+01
cas05.out
      british handbook of c    .9839    .0019  2.32669E+01
cas06.out
      british handbook of c    .9889    .0023  2.32739E+01
      british handbook of c   1.0001    .0019  1.48553E+01
cas11.out
      raffety and malhalczo    .9957    .0028  2.24939E+01
      raffety and malhalczo   1.0045    .0028  1.45011E+01
cas12.out
      raffety and malhalczo    .9924    .0024  2.22333E+01
      raffety and malhalczo   1.0002    .0028  1.43499E+01
cas13.out
      raffety and malhalczo    .9995    .0023  2.32374E+01
      raffety and malhalczo   1.0025    .0023  1.48785E+01
cas14.out
      raffety and malhalczo    .9935    .0024  2.30234E+01
      raffety and malhalczo    .9992    .0025  1.47610E+01
```

Table 25 (continued)

cas15.out				
	raffety and malhalczo	.9919	.0025	2.36804E+01
	raffety and malhalczo	.9990	.0030	1.51144E+01
cas16.out				
	raffety and malhalczo	.9939	.0022	2.38964E+01
	raffety and malhalczo	.9960	.0026	1.52315E+01
cas17.out				
	raffety and malhalczo	.9987	.0023	2.41130E+01
	raffety and malhalczo	.9907	.0025	1.53388E+01
cas18.out				
	raffety and malhalczo	.9973	.0026	2.40333E+01
	raffety and malhalczo	.9900	.0024	1.52917E+01
cas19.out				
	raffety and malhalczo	.9848	.0022	2.44582E+01
	raffety and malhalczo	.9895	.0022	1.55176E+01
cas20.out				
	raffety and malhalczo	.9848	.0018	2.44249E+01
	raffety and malhalczo	.9858	.0020	1.55020E+01
cas21.out				
	raffety and milhalczo	1.0092	.0030	2.22122E+01
	raffety and milhalczo	1.0083	.0030	1.44129E+01
cas22.out				
	raffety and malhalczo	1.0055	.0029	2.22087E+01
	raffety and malhalczo	1.0119	.0035	1.44071E+01
cas23.out				
	raffety and malhalczo	1.0076	.0030	2.22172E+01
	raffety and malhalczo	1.0127	.0034	1.44059E+01
cas24.out				
	raffety and malhalczo	1.0081	.0029	2.22029E+01
	raffety and malhalczo	1.0121	.0026	1.44090E+01
cas25.out				
	raffety and malhalczo	1.0076	.0032	2.21924E+01
	raffety and malhalczo	1.0141	.0031	1.44099E+01
cas26.out				
	raffety and malhalczo	1.0091	.0034	2.17703E+01
	raffety and malhalczo	1.0099	.0028	1.41555E+01
cas27.out				
	raffety and malhalczo	1.0061	.0029	2.17688E+01
	raffety and malhalczo	1.0008	.0023	1.41444E+01
cas28.out				
	raffety and malhalczo	1.0089	.0030	2.17645E+01
	raffety and malhalczo	1.0015	.0032	1.41448E+01
cas29.out				
	raffety and malhalczo	1.0053	.0033	2.35214E+01
	raffety and malhalczo	.9999	.0033	1.50654E+01
cas30.out				
	raffety and malhalczo	1.0094	.0029	2.32731E+01
	raffety and malhalczo	.9918	.0029	1.49272E+01
cas31.out				
	raffety and malhalczo	1.0092	.0031	2.32836E+01
	raffety and malhalczo	1.0043	.0030	1.49374E+01
cas32.out				
	raffety and malhalczo	1.0088	.0029	2.32820E+01
	raffety and malhalczo	.9955	.0033	1.49305E+01
cas33.out				
	critical reflected cy	1.0026	.0027	2.42211E+01
	critical reflected cy	.9848	.0028	1.54414E+01
cas34.out				
	critical reflected cy	.9981	.0029	2.42301E+01
	critical reflected cy	.9893	.0026	1.54473E+01
cas35.out				
	critical sphere of aq	.9980	.0028	2.42335E+01
	critical sphere of aq	.9915	.0030	1.54494E+01
cas36.out				
	critical cylinder of	.9946	.0035	2.42248E+01
	critical cylinder of	.9789	.0029	1.54434E+01

Table 26. Results from Table 4 of Ref. 8

```
t4.r1

    case
         title(20 ...)  keno[  k-eff    sigma     AEG    ]  xsdrn[   lambda  ]

caa01.out
      uo2f2 soln h/u-235=11   1.0061    .0029  2.49379E+01
caa02.out
      uo2f2 soln h/u-235=13   1.0047    .0023  2.49995E+01
caa03.out
      uo2(no3)2 soln h/u-23    .9982    .0021  2.49940E+01
caa04.out
      uo2f2 soln h/u-235=76    .9972    .0043  2.25483E+01
caa05.out
      uo2f2 soln h/u-235=12   1.0046    .0044  2.34138E+01
caa06.out
      uo2f2 soln h/u-235=12   1.0061    .0025  2.49963E+01
caa07.out
      uo2f2 soln h/u-235=26   1.0076    .0036  2.42536E+01
caa08.out
      uo2f2 soln h/u-235=51   1.0187    .0033  2.46826E+01
caa09.out
      uo2f2 soln h/u-235=20   1.0073    .0037  2.37384E+01
caa10.out
      uo2f2 soln h/u-235=23   1.0283    .0042  2.41583E+01
caa11.out
      uo2f2 soln h/u-235=46   1.0370    .0036  2.46336E+01
caa12.out
      rocky flats uo2(no3)2   1.0147    .0040  2.36138E+01
caa13.out
      rocky flats uo2(no3)2   1.0100    .0045  2.15994E+01
caa14.out
      rocky flats uo2(no3)2   1.0168    .0040  2.45725E+01
caa15.out
      rocky flats uo2(no3)2   1.0102    .0044  2.36663E+01
caa16.out
      rocky flats uo2(no3)2   1.0105    .0038  2.15893E+01
caa17.out
      rocky flats uo2(no3)2   1.0141    .0045  2.36172E+01
caa18.out
      rocky flats uo2(no3)2   1.0137    .0040  2.18693E+01
caa19.out
      rocky flats uo2(no3)2   1.0077    .0040  2.36208E+01
caa20.out
      rocky flats uo2(no3)2   1.0116    .0046  2.18803E+01
caa21.out
      rocky flats uo2(no3)2   1.0117    .0040  2.36356E+01
caa22.out
      rocky flats uo2(no3)2   1.0123    .0036  2.19989E+01
caa23.out
      rocky flats uo2(no3)2   1.0078    .0039  2.35989E+01
caa24.out
      rocky flats uo2(no3)2   1.0052    .0043  2.18110E+01
caa25.out
      rocky flats uo2(no3)2    .9981    .0042  2.35953E+01
caa26.out
      rocky flats uo2(no3)2   1.0067    .0044  2.18085E+01
caa27.out
      rocky flats uo2(no3)2   1.0093    .0039  2.36707E+01
caa28.out
      rocky flats uo2(no3)2   1.0070    .0042  2.20303E+01
caa29.out
      rocky flats uo2(no3)2    .9964    .0034  2.44580E+01
caa30.out
      rocky flats uo2(no3)2    .9985    .0037  2.19362E+01
```

Table 26 (continued)

```
caa31.out
      rocky flats uo2(no3)2   1.0071    .0036  2.43012E+01
caa32.out
      rocky flats uo2(no3)2   1.0137    .0040  2.19680E+01
caa33.out
      rocky flats uo2(no3)2   1.0085    .0035  2.43540E+01
caa34.out
      rocky flats uo2(no3)2   1.0039    .0040  2.17201E+01
caa35.out
      rocky flats uo2(no3)2   1.0121    .0038  2.18842E+01
caa36.out
      rocky flats uo2(no3)2   1.0090    .0047  2.19254E+01
caa37.out
      rocky flats uo2(no3)2    .9960    .0037  2.45613E+01
caa38.out
      rocky flats uo2(no3)2    .9955    .0040  2.21449E+01
caa39.out
      rocky flats uo2(no3)2   1.0037    .0034  2.45827E+01
caa40.out
      rocky flats uo2(no3)2    .9999    .0041  2.21841E+01
caa41.out
      rocky flats uo2(no3)2    .9925    .0038  2.45516E+01
caa42.out
      rocky flats uo2(no3)2    .9987    .0038  2.18799E+01
caa43.out
      rocky flats uo2(no3)2    .9952    .0037  2.21149E+01
```

Table 27. Results from Table 5 of Ref. 8

```
t5.r1

    case
         title(20 ...)  keno[  k-eff    sigma     AEG    ]  xsdrn[   lambda  ]

cas01.out
      keno-5 validation cas   1.0053    .0031  4.86677E+00
cas02.out
      keno-5 validation cas    .9972    .0033  8.54903E+00
cas03.out
      keno-5 validation cas   1.0089    .0037  2.16918E+01
cas04.out
      keno-5 validation cas   1.0007    .0031  4.99863E+00
cas05.out
      keno-5 validation cas   1.0013    .0025  2.50015E+01
cas06.out
      keno-5 validation cas    .9994    .0023  2.49950E+01
cas07.out
      keno-5 validation cas   1.0015    .0031  1.16874E+01
cas08.out
      keno-5 validation cas   1.0104    .0031  6.38872E+00
cas09.out
      keno-5 validation cas   1.0099    .0027  4.90171E+00
cas10.out
      keno-5 validation cas   1.0128    .0031  1.05388E+01
cas11.out
      keno-5 validation cas   1.0003    .0032  9.36769E+00
cas12.out
      keno-5 validation cas    .9954    .0033  4.83922E+00
cas13.out
      keno-5 validation cas    .9905    .0030  2.45319E+01
cas14.out
      keno-5 validation cas   1.0577    .0042  2.11553E+01
cas15.out
      keno-5 validation cas   1.0123    .0031  8.34174E+00
cas16.out
      keno-5 validation cas    .9905    .0046  2.13794E+01
cas17.out
      keno-5 validation cas   1.0330    .0040  2.21024E+01
cas18.out
      keno-5 validation cas   1.0109    .0039  2.15955E+01
cas19.out
      keno-5 validation cas   1.0366    .0054  2.08049E+01
cas20.out
      keno-5 validation cas   1.0269    .0038  2.22462E+01
cas21.out
      keno-5 validation cas   1.0307    .0041  2.19453E+01
cas22.out
      keno-5 validation cas   1.0053    .0032  4.84842E+00
cas23.out
      keno-5 validation cas    .9957    .0031  4.83846E+00
cas24.out
      keno-5 validation cas    .9945    .0030  4.83438E+00
cas25.out
      keno-5 validation cas   1.0027    .0027  4.85042E+00
cas26.out
      keno-5 validation cas   1.0095    .0035  1.01296E+01
cas27.out
      keno-5 validation cas   1.0059    .0034  1.02628E+01
cas28.out
      keno-5 validation cas   1.0149    .0036  7.74995E+00
cas29.out
      keno-5 validation cas    .9824    .0042  2.14080E+01
cas30.out
      93.2% uo2f2 3 in al s   1.0031    .0040  2.42782E+01
```

Table 27 (continued)

cas31.out	93.2% uo2f2 3 in al s	.9959	.0037	2.43962E+01
cas32.out	93.2% uo2f2 3 in al s	.9846	.0039	2.42615E+01
cas33.out	93.2% uo2f2 3 in al s	1.0032	.0031	2.45135E+01
cas34.out	93.2% uo2f2 3 in al s	.9875	.0043	2.42528E+01
cas35.out	93.2% uo2f2 3 in al s	.9971	.0031	2.45396E+01
cas36.out	93.2% uo2f2 3 in al s	.9867	.0037	2.42462E+01
cas37.out	93.2% uo2f2 3 in al s	.9987	.0032	2.45292E+01
cas38.out	93.2% uo2f2 3 in al s	.9835	.0034	2.42490E+01
cas39.out	93.2% uo2f2 3 in al s	.9986	.0031	2.45213E+01
cas40.out	93.2% uo2f2 3 in al s	.9863	.0038	2.42449E+01
cas41.out	93.2% uo2f2 3, 6 in a	.9816	.0036	2.42575E+01
cas42.out	93.2% uo2f2 3, 6 in a	.9817	.0038	2.42651E+01
cas43.out	93.2% uo2f2 3, 6 in a	.9796	.0037	2.42627E+01
cas44.out	93.2% uo2f2 3, 6 in a	.9749	.0043	2.42536E+01
cas45.out	93.2% uo2f2 3, 6, 3 i	.9822	.0031	2.42703E+01
cas46.out	93.2% uo2f2 3, 6, 3 i	.9732	.0038	2.42500E+01
cas47.out	93.2% uo2f2 3, 6, 3 i	.9798	.0037	2.42540E+01
cas48.out	93.2% uo2f2 3, 6, 3 i	.9731	.0036	2.42579E+01
cas49.out	93.2% uo2f2 6 & 3 in	.9904	.0039	2.42589E+01
cas50.out	93.2% uo2f2 6 & 3 in	.9783	.0040	2.42578E+01
cas51.out	93.2% uo2f2 6 & 3 in	.9759	.0037	2.42644E+01
cas52.out	93.2% uo2f2 6 & 3 in	.9858	.0038	2.42591E+01
cas53.out	93.2% uo2f2 6 in al s	.9829	.0042	2.42630E+01
cas54.out	93.2% uo2f2 6 in al s	.9795	.0034	2.42614E+01
cas55.out	93.2% uo2f2 6 in al s	.9848	.0039	2.42639E+01
cas56.out	93.2% uo2f2 6 in al s	.9861	.0042	2.42683E+01
cas57.out	93.2% uo2f2 6 in al s	.9894	.0042	2.42705E+01
cas58.out	93.2% uo2f2 6 in al s	.9863	.0036	2.42626E+01
cas59.out	93.2% uo2f2 6 in al s	.9857	.0040	2.42704E+01
cas60.out	uo2(no3)2 279 g u/l 3	.9967	.0034	2.25047E+01
cas61.out	uo2(no3)2 279 g u/l 2	1.0070	.0046	2.25339E+01
cas62.out	uo2(no3)2 415 g u/l 5	1.0057	.0042	2.14388E+01

Table 27 (continued)

```
cas63.out
      uo2(no3)2 415 g u/l 3   1.0025    .0043  2.14367E+01
cas64.out
      uo2(no3)2 415 g u/l 4    .9945    .0043  2.14357E+01
cas65.out
      uo2(no3)2 415 g u/l 2   1.0120    .0046  2.14774E+01
cas66.out
      uo2(no3)2 415 g u/l 3   1.0067    .0038  2.16672E+01
cas67.out
      uo2(no3)2 415 g u/l 3   1.0194    .0043  2.18190E+01
cas68.out
      uo2(no3)2 415 g u/l 3   1.0113    .0041  2.17255E+01
cas69.out
      uo2(no3)2 415 g u/l 3   1.0129    .0044  2.20919E+01
cas70.out
      uo2(no3)2 415 g u/l 3   1.0213    .0038  2.20046E+01
cas71.out
      uo2(no3)2 415 g u/l 3   1.0284    .0039  2.21044E+01
cas72.out
      uo2(no3)2 415 g u/l 3   1.0033    .0042  2.15773E+01
cas73.out
      uo2(no3)2 415 g u/l 3   1.0133    .0036  2.16259E+01
cas74.out
      uo2(no3)2 415 g u/l 3   1.0283    .0039  2.20901E+01
cas75.out
      uo2(no3)2 415 g u/l 3   1.0228    .0040  2.19967E+01
cas76.out
      uo2(no3)2 415 g u/l 2   1.0105    .0045  2.16806E+01
cas77.out
      uo2(no3)2 415 g u/l 2   1.0283    .0043  2.21221E+01
cas78.out
      uo2(no3)2 415 g u/l 2   1.0292    .0047  2.21173E+01
cas79.out
      uo2(no3)2 415 g u/l 2   1.0081    .0044  2.18287E+01
cas80.out
      uo2(no3)2 415 g u/l 2   1.0265    .0035  2.19702E+01
cas81.out
      uo2(no3)2 415 g u/l 2   1.0272    .0046  2.20593E+01
cas82.out
      uo2(no3)2 415 g u/l 2   1.0173    .0042  2.17473E+01
cas83.out
      uo2(no3)2 415 g u/l 2   1.0237    .0042  2.20151E+01
cas84.out
      uo2(no3)2 415 g u/l 2   1.0194    .0037  2.21053E+01
cas85.out
      uo2(no3)2 415 g u/l 2   1.0029    .0042  2.16011E+01
cas86.out
      uo2(no3)2 415 g u/l 2   1.0108    .0042  2.16703E+01
cas87.out
      uo2(no3)2 415 g u/l 2   1.0219    .0040  2.21442E+01
cas88.out
      uo2(no3)2 415 g u/l 2   1.0154    .0044  2.19822E+01
cas89.out
      uo2(no3)2 415 g u/l 2   1.0240    .0042  2.21292E+01
cas90.out
      uo2(no3)2 415 g u/l 3    .9980    .0043  2.17411E+01
cas91.out
      uo2(no3)2 63.3 g u/l    1.0166    .0035  2.45340E+01
```

Table 28. Results from Table 6 of Ref. 8

```
t6.r1

    case
         title(20 ...)  keno[  k-eff    sigma     AEG    ]  xsdrn[   lambda  ]

cae01.out
      eta experiments  # 1     .9956    .0025  2.49952E+01
cae02.out
      eta experiments  # 2    1.0005    .0022  2.49316E+01
cae03.out
      eta experiments  # 3     .9916    .0021  2.48673E+01
cae04.out
      eta experiments  # 4     .9940    .0024  2.48368E+01
cae05.out
      eta experiments  # 5    1.0051    .0022  2.46287E+01
cae06.out
      eta experiments  # 6     .9999    .0026  2.45981E+01
cae07.out
      eta experiments  # 7     .9980    .0024  2.45668E+01
cae08.out
      eta experiments  # 8     .9993    .0022  2.45439E+01
cae09.out
      eta experiments  # 9    1.0041    .0021  2.45170E+01
cae10.out
      eta experiments  # 10    .9981    .0015  2.50617E+01
cae11.out
      eta experiments  # 11    .9966    .0019  2.47259E+01
cae12.out
      eta experiments  # 12    .9921    .0019  2.50312E+01
cae13.out
      eta experiments  # 13    .9875    .0021  2.50349E+01
cae14.out
      eta experiments  # 14    .9999    .0018  2.50602E+01
cae15.out
      eta experiments  # 15    .9972    .0014  2.50704E+01
cae16.out
      eta experiments  # 16    .9877    .0014  2.50760E+01
cae17.out
      eta experiments  # 17    .9971    .0018  2.46955E+01
cae18.out
      eta experiments  # 18    .9947    .0018  2.47065E+01
cae19.out
      eta experiments  # 19    .9993    .0017  2.47296E+01
cae20.out
      eta experiments  # 20    .9935    .0015  2.47456E+01
cae21.out
      eta experiments  # 21    .9964    .0014  2.50746E+01
cae22.out
      eta experiments  # 22    .9946    .0014  2.50783E+01
cae23.out
      eta experiments  # 23    .9987    .0013  2.50836E+01
```

Table 29. Results from Appendix C of Ref. 9

appndxc.r1

case	title(20 ...)	keno[k-eff	sigma	AEG]	xsdrn[lambda]
111_1.out	expt. 111- 1	1.0238	.0049	2.03970E+01	
111_2.out	expt. 111- 2	1.0343	.0044	2.08243E+01	
111_3.out	expt. 111- 3	1.0311	.0042	2.24888E+01	
111_4.out	expt. 111- 4	1.0148	.0042	2.04386E+01	
111_5.out	expt. 111- 5	1.0123	.0043	2.13753E+01	
111_6.out	expt. 111- 6	1.0334	.0045	2.21296E+01	
111_7.out	expt. 111- 7	1.0207	.0044	2.24630E+01	
111_8.out	expt. 111- 8	1.0086	.0042	2.25538E+01	
111_9.out	expt. 111- 9	1.0239	.0042	2.29734E+01	
111_10.out	expt. 111-10	1.0401	.0039	2.31067E+01	
111_11.out	expt. 111-11	1.0247	.0040	2.33134E+01	
111_12.out	expt. 111-12	1.0265	.0038	2.35493E+01	
111_13.out	expt. 111-13	1.0096	.0040	2.37460E+01	
111_14.out	expt. 111-14	1.0247	.0037	2.37973E+01	
111_15.out	expt. 111-15	.9899	.0039	2.38349E+01	
111_16.out	expt. 111-16	1.0119	.0035	2.39799E+01	
111_17.out	expt. 111-17	1.0005	.0039	2.41473E+01	
111_18.out	expt. 111-18	.9999	.0034	2.42060E+01	
111_19.out	expt. 111-19	1.0040	.0037	2.43355E+01	
111_20.out	expt. 111-20				1.01417E+00
111_21.out	expt. 111-21	1.0477	.0042	2.25973E+01	
111_22.out	expt. 111-22	1.0162	.0031	2.43549E+01	
111_23.out	expt. 111-23	1.0216	.0038	2.38810E+01	
111_24.out	expt. 111-24	1.0342	.0033	2.38038E+01	
111_25.out	expt. 111-25				1.02694E+00
111_26.out	expt. 111-26	1.0159	.0041	2.35262E+01	
111_27.out	expt. 111-27	1.0331	.0039	2.33521E+01	
111_28.out	expt. 111-28	1.0363	.0038	2.36722E+01	
111_29.out	expt. 111-29	1.0270	.0041	2.38508E+01	
111_30.out	expt. 111-30	1.0242	.0034	2.40791E+01	

Table 29 (continued)

```
111_31.out
      expt. 111-31            1.0309    .0047  2.18448E+01
114_05.out
      eta experiments  # 5    1.0051    .0022  2.46287E+01
114_06.out
      eta experiments  # 6     .9999    .0026  2.45981E+01
114_07.out
      eta experiments  # 7     .9980    .0024  2.45668E+01
114_08.out
      eta experiments  # 8     .9993    .0022  2.45439E+01
114_09.out
      eta experiments  # 9    1.0041    .0021  2.45170E+01
114_11.out
      eta experiments  # 11    .9966    .0019  2.47259E+01
114_17.out
      eta experiments  # 17    .9971    .0018  2.46955E+01
114_18.out
      eta experiments  # 18    .9947    .0018  2.47065E+01
114_19.out
      eta experiments  # 19    .9993    .0017  2.47296E+01
114_20.out
      eta experiments  # 20    .9935    .0015  2.47456E+01
1211_1.out
      expt. 1211- 1           1.0348    .0045  1.96380E+01
1211_2.out
      expt. 1211- 2           1.0178    .0045  1.95837E+01
1211_3.out
      expt. 1211- 3           1.0367    .0041  2.09208E+01
1211_4.out
      expt. 1211- 4           1.0367    .0041  2.08846E+01
1211_5.out
      expt. 1211- 5            .9875    .0047  2.11194E+01
1211_6.out
      expt. 1211- 6            .9884    .0044  2.10918E+01
1211_7.out
      expt. 1211- 7           1.0225    .0040  2.20710E+01
1211_8.out
      expt. 1211- 8           1.0098    .0044  2.20608E+01
1211_9.out
      expt. 1211- 9           1.0917    .0044  1.97734E+01
1211_10.out
      expt. 1211-10           1.0508    .0049  2.13266E+01
1211_11.out
      expt. 1211-11           1.0366    .0047  2.13072E+01
1211_12.out
      expt. 1211-12           1.0191    .0048  2.12824E+01
1211_13.out
      expt. 1211-13           1.0406    .0046  2.23923E+01
1211_14.out
      expt. 1211-14           1.0370    .0041  2.24393E+01
1211_15.out
      expt. 1211-15           1.0316    .0044  2.24242E+01
1211_16.out
      expt. 1211-16           1.0132    .0045  2.23863E+01
1211_17.out
      expt. 1211-17           1.0442    .0044  2.29149E+01
1211_18.out
      expt. 1211-18           1.0504    .0049  2.29310E+01
1211_19.out
      expt. 1211-19           1.0245    .0043  2.29023E+01
1211_20.out
      expt. 1211-20           1.0351    .0043  2.34039E+01
1211_21.out
      expt. 1211-21           1.0323    .0042  2.34171E+01
```

Table 29 (continued)

1211_22.out					
	expt. 1211-22	1.0175	.0044	2.34082E+01	
1211_23.out					
	expt. 1211-23	1.0376	.0041	2.40004E+01	
1211_24.out					
	expt. 1211-24	1.0195	.0038	2.40069E+01	
1211_25.out					
	expt. 1211-25	1.0114	.0041	2.28794E+01	
1211_26.out					
	expt. 1211-26	1.0304	.0043	2.27998E+01	
1211_27.out					
	expt. 1211-27	1.0160	.0040	2.28333E+01	
1211_28.out					
	expt. 1211-28	1.0191	.0040	2.28726E+01	
1211_29.out					
	expt. 1211-29	1.0064	.0037	2.33557E+01	
1211_30.out					
	expt. 1211-30	1.0200	.0042	2.33516E+01	
1211_31.out					
	expt. 1211-31	1.0188	.0035	2.33833E+01	
1211_32.out					
	expt. 1211-32	1.0056	.0033	2.40747E+01	
1211_33.out					
	expt. 1211-33	1.0084	.0033	2.40584E+01	
1211_34.out					
	expt. 1211-34	.9785	.0036	2.40949E+01	
1250_6.out					
	expt. 1250- 6 sourc	1.0431	.0043	2.11048E+01	
1250_7.out					
	expt. 1250- 7 sourc	1.0319	.0041	2.11507E+01	
1250_8.out					
	expt. 1250-8 source	1.0448	.0040	2.13653E+01	
1250_9.out					
	expt. 1250- 9 sourc	1.0524	.0042	2.14648E+01	
1250_10.out					
	expt. 1250-10 sourc	1.0434	.0042	2.15027E+01	
1250_11.out					
	expt. 1250-11 sourc	1.0567	.0039	2.16108E+01	
1250_12.out					
	expt. 1250-12 sourc	1.0448	.0044	2.11295E+01	
1727_01.out					
	la-3067-msr table iv,				9.67175E-01
	la-3067-ms rev 1, tab	.9629	.0032	4.73967E+00	
1727_02.out					
	la-3067-msr table iv,				9.81062E-01
	la-3067-msr table iv,	.9775	.0031	4.74621E+00	
1727_03.out					
	la-3067-msr table iv,				9.79288E-01
	la-3067-msr table iv,	.9812	.0029	4.77633E+00	
1727_04.out					
	la-3067-msr table iv,				9.76009E-01
	la-3067-msr table iv,	.9763	.0030	4.78629E+00	
1727_05.out					
	la-3067-msr table iv,				9.76744E-01
	la-3067-msr table iv,	.9724	.0034	5.07137E+00	
1727_06.out					
	la-3067-msr table iv,				9.76411E-01
	la-3067-msr table iv,	.9729	.0033	4.94768E+00	
1727_07.out					
	la-3067-msr table iv,				9.96293E-01
	la-3067-msr table iv,	.9900	.0034	5.28849E+00	
1727_08.out					
	la-3067-msr table iv,				9.84006E-01
	la-3067-msr table iv,	.9869	.0031	5.02266E+00	

Table 29 (continued)

1727_14.out					
1727-14, la-3067-msr					9.76296E-01
1727-14, la-3067-msr		.9748	.0034	4.79005E+00	
1727_15.out					
1727-15, la-3067-msr					9.82589E-01
1727-15, la-3067-msr		.9786	.0031	4.79793E+00	
mod_111_.out					
expt. 111-15	c	.9998	.0039	2.38350E+01	

Table 30. Results from Appendix D of Ref. 9

```
appndxd.r1

    case
         title(20 ...)  keno[  k-eff    sigma     AEG    ]  xsdrn[   lambda  ]

caa_04.out
      uo2f2 soln h/u-235=76    .9972    .0043  2.25483E+01
caa_05.out
      uo2f2 soln h/u-235=12   1.0046    .0044  2.34138E+01
caa_12.out
      rocky flats uo2(no3)2   1.0147    .0040  2.36138E+01
caa_13.out
      rocky flats uo2(no3)2   1.0096    .0034  2.16010E+01
caa_16.out
      rocky flats uo2(no3)2   1.0105    .0038  2.15893E+01
caa_18.out
      rocky flats uo2(no3)2   1.0078    .0039  2.18657E+01
caa_20.out
      rocky flats uo2(no3)2   1.0116    .0046  2.18803E+01
caa_22.out
      rocky flats uo2(no3)2   1.0123    .0036  2.19989E+01
caa_24.out
      rocky flats uo2(no3)2   1.0052    .0043  2.18110E+01
caa_26.out
      rocky flats uo2(no3)2   1.0067    .0044  2.18085E+01
caa_28.out
      rocky flats uo2(no3)2   1.0137    .0036  2.20409E+01
caa_30.out
      rocky flats uo2(no3)2    .9985    .0037  2.19362E+01
caa_32.out
      rocky flats uo2(no3)2   1.0137    .0040  2.19680E+01
caa_34.out
      rocky flats uo2(no3)2   1.0039    .0040  2.17201E+01
caa_35.out
      rocky flats uo2(no3)2   1.0121    .0038  2.18842E+01
caa_36.out
      rocky flats uo2(no3)2   1.0090    .0047  2.19254E+01
caa_38.out
      rocky flats uo2(no3)2    .9955    .0040  2.21449E+01
caa_40.out
      rocky flats uo2(no3)2    .9999    .0041  2.21841E+01
caa_42.out
      rocky flats uo2(no3)2    .9987    .0038  2.18799E+01
caa_43.out
      rocky flats uo2(no3)2    .9952    .0037  2.21149E+01
cas_01.out
      cas.01 validation cas   1.0053    .0031  4.86677E+00
cas_02.out
      cas.02 validation cas    .9972    .0033  8.54903E+00
cas_03.out
      cas.03 validation cas   1.0089    .0037  2.16918E+01
cas_04.out
      cas.04 validation cas   1.0007    .0031  4.99863E+00
cas_07.out
      cas.07 validation cas   1.0015    .0031  1.16874E+01
cas_08.out
      cas.08 validation cas   1.0104    .0031  6.38872E+00
cas_09.out
      cas.09 validation cas   1.0099    .0027  4.90171E+00
cas_10.out
      cas.10 validation cas   1.0128    .0031  1.05388E+01
cas_11.out
      cas.11 validation cas   1.0003    .0032  9.36769E+00
cas_12.out
      cas.12 validation cas   1.0030    .0029  4.84282E+00
```

Table 30 (continued)

```
cas_14.out
      cas.14 validation cas   1.0577    .0042  2.11553E+01
cas_15.out
      cas.15 validation cas   1.0123    .0031  8.34174E+00
cas_16.out
      cas.16 validation cas    .9905    .0046  2.13794E+01
cas_17.out
      cas.17 validation cas   1.0330    .0040  2.21024E+01
cas_18.out
      cas.18 validation cas   1.0109    .0039  2.15955E+01
cas_19.out
      cas.19 validation cas   1.0366    .0054  2.08049E+01
cas_20.out
      cas.20 validation cas   1.0269    .0038  2.22462E+01
cas_21.out
      cas.21 validation cas   1.0307    .0041  2.19453E+01
cas_22.out
      cas.22 validation cas   1.0053    .0032  4.84842E+00
cas_23.out
      cas.23 validation cas    .9957    .0031  4.83846E+00
cas_24.out
      cas.24 validation cas    .9945    .0030  4.83438E+00
cas_25.out
      cas.25 validation cas   1.0027    .0027  4.85042E+00
cas_26.out
      cas.26 validation cas   1.0095    .0035  1.01296E+01
cas_27.out
      cas.27 validation cas   1.0116    .0028  1.03403E+01
cas_28.out
      cas.28 validation cas   1.0149    .0036  7.74995E+00
cas_29.out
      cas.29 validation cas    .9824    .0042  2.14080E+01
cas_60.out
      uo2(no3)2 279 g u/l 3    .9967    .0034  2.25047E+01
cas_61.out
      uo2(no3)2 279 g u/l 2   1.0070    .0046  2.25339E+01
cas_62.out
      uo2(no3)2 415 g u/l 5   1.0057    .0042  2.14388E+01
cas_63.out
      uo2(no3)2 415 g u/l 3    .9999    .0033  2.14427E+01
cas_64.out
      uo2(no3)2 415 g u/l 4    .9945    .0043  2.14357E+01
cas_65.out
      uo2(no3)2 415 g u/l 2   1.0120    .0046  2.14774E+01
cas_66.out
      uo2(no3)2 415 g u/l 3   1.0067    .0038  2.16672E+01
cas_67.out
      uo2(no3)2 415 g u/l 3   1.0194    .0043  2.18190E+01
cas_68.out
      uo2(no3)2 415 g u/l 3   1.0113    .0041  2.17255E+01
cas_69.out
      uo2(no3)2 415 g u/l 3   1.0234    .0036  2.21003E+01
cas_70.out
      uo2(no3)2 415 g u/l 3   1.0213    .0038  2.20046E+01
cas_71.out
      uo2(no3)2 415 g u/l 3   1.0284    .0039  2.21044E+01
cas_72.out
      uo2(no3)2 415 g u/l 3   1.0033    .0042  2.15773E+01
cas_73.out
      uo2(no3)2 415 g u/l 3   1.0133    .0036  2.16259E+01
cas_74.out
      uo2(no3)2 415 g u/l 3   1.0283    .0039  2.20901E+01
cas_75.out
      uo2(no3)2 415 g u/l 3   1.0228    .0040  2.19967E+01
```

Table 30 (continued)

cas_76.out				
	uo2(no3)2 415 g u/l 2	1.0105	.0045	2.16806E+01
cas_77.out				
	uo2(no3)2 415 g u/l 2	1.0283	.0043	2.21221E+01
cas_78.out				
	uo2(no3)2 415 g u/l 2	1.0292	.0047	2.21173E+01
cas_79.out				
	uo2(no3)2 415 g u/l 2	1.0081	.0044	2.18287E+01
cas_80.out				
	uo2(no3)2 415 g u/l 2	1.0265	.0035	2.19702E+01
cas_81.out				
	uo2(no3)2 415 g u/l 2	1.0272	.0046	2.20593E+01
cas_82.out				
	uo2(no3)2 415 g u/l 2	1.0173	.0042	2.17473E+01
cas_83.out				
	uo2(no3)2 415 g u/l 2	1.0237	.0042	2.20151E+01
cas_84.out				
	uo2(no3)2 415 g u/l 2	1.0194	.0037	2.21053E+01
cas_85.out				
	uo2(no3)2 415 g u/l 2	1.0029	.0042	2.16011E+01
cas_86.out				
	uo2(no3)2 415 g u/l 2	1.0108	.0042	2.16703E+01
cas_87.out				
	uo2(no3)2 415 g u/l 2	1.0219	.0040	2.21442E+01
cas_88.out				
	uo2(no3)2 415 g u/l 2	1.0154	.0044	2.19822E+01
cas_89.out				
	uo2(no3)2 415 g u/l 2	1.0240	.0042	2.21292E+01
cas_90.out				
	uo2(no3)2 415 g u/l 3	.9980	.0043	2.17411E+01

Table 31. Results from Appendix E of Ref. 9

```
appndxe.r1

    case
        title(20 ...)  keno[  k-eff    sigma     AEG    ]  xsdrn[   lambda  ]

1727_09.out
      la-3067-msr table iii                                        1.00709E+00
      la-3067-msr table iii   1.0002    .0034  7.42094E+00
1727_10.out
      1727-10, la-3067-msr                                         1.00112E+00
      1727-10, la-3067-msr     .9930    .0034  4.57873E+00
2109_20.out
      benchmark 20, pu sphe   1.0258    .0031  2.39187E+01
2109_21.out
      benchmark 21, pu sphe   1.0335    .0032  2.39619E+01
2109_22.out
      benchmark 22, pu sphe   1.0291    .0032  2.36681E+01
2109_23.out
      benchmark 23, pu sphe   1.0317    .0033  2.35295E+01
2109_24.out
      benchmark 24, pu sphe   1.0211    .0035  2.37292E+01
2109_25.out
      pu benchmark 25 from                                         1.01055E+00
      pu benchmark 25 from    1.0010    .0034  4.50991E+00
2110_01.out
      benchmark#1 infinite                                         1.00486E+00
      benchmark#1 infinite    1.0093    .0012  2.47248E+01
2110_02.out
      benchmark#2 critical                                         1.01617E+00
      benchmark#2 critical    1.0212    .0035  2.15532E+01
2110_03.out
      benchmark#3 critical                                         1.01669E+00
      benchmark#3 critical    1.0194    .0032  2.42619E+01
2110_04.out
      benchmark#4 critical                                         1.01852E+00
      sphere described by k   1.0269    .0051  2.40351E+01
2110_05.out
      rectangular parallelp   1.0444    .0054  1.48333E+01
2110_06.out
      rectangular paralleli   1.0316    .0047  1.73092E+01
2110_07.out
      benchmark#7 semi-inf                                         1.01999E+00
      benchmark#7 semi-inf    1.0235    .0038  2.34928E+01
2110_08.out
      rectangular paralleli   1.0239    .0057  1.90540E+01
2110_09.out
      rectangular paralleli   1.0188    .0052  2.02330E+01
2110_10.out
      rectangular paralleli   1.0301    .0044  2.02497E+01
2110_11.out
      rectangular paralleli   1.0279    .0050  2.02729E+01
2110_12.out
      rectangular paralleli   1.0244    .0047  2.02771E+01
2110_13.out
      sphere described by k    .9998    .0036  4.44609E+00
2110_14.out
      cylinder described by   1.0165    .0046  2.27433E+01
2110_15.out
      rectangular paralleli   1.0172    .0048  5.91243E+00
2110_16.out
      rectangular paralleli   1.0316    .0035  4.76177E+00
2110_17.out
      rectangular paralleli   1.0300    .0034  1.13165E+01
2110_18.out
      rectangular paralleli   1.0357    .0035  1.06580E+01
```

Table 31 (continued)

2110_19.out				
rectangular paralleli	1.0125	.0034	1.03409E+01	
2110_20.out				
rectangular paralleli	1.0353	.0034	1.11215E+01	
2110_21.out				
rectangular paralleli	1.0380	.0037	1.13667E+01	
2110_23.out				
rectangular paralleli	1.0357	.0044	1.03951E+01	
2110_24.out				
rectangular paralleli	1.0376	.0034	1.40582E+01	
2110_25.out				
rectangular paralleli	1.0320	.0033	1.41790E+01	
2110_26.out				
rectangular paralleli	1.0327	.0032	1.44461E+01	
2110_27.out				
rectangular paralleli	1.0308	.0031	1.47105E+01	
2110_29.out				
cylinder described by	1.0142	.0032	2.41539E+01	
2110_30.out				
benchmark#15a soln of				1.01804E+00
sphere described by k	1.0217	.0047	2.43122E+01	
2110_32.out				
benchmark#15b soln of				1.01618E+00
sphere described by k	1.0051	.0044	2.42763E+01	
2110_34.out				
sphere described by k	.9990	.0034	4.45337E+00	

Table 32. Results from Table 3 of Ref. 10

```
table3.r1

    case
         title(20 ...)  keno[  k-eff    sigma     AEG    ]  xsdrn[   lambda  ]

bapl1.out
           bapl-1 lattice,  ****** outer iteration limit reached   1.00883E+00
           bapl-1 lattice,  ****** outer iteration limit reached   9.89130E-01
bapl2.out
           bapl-2 lattice,  ****** outer iteration limit reached   1.01266E+00
           bapl-2 lattice,  ****** outer iteration limit reached   9.91187E-01
bapl3.out
           bapl-3 lattice,  ****** outer iteration limit reached   1.01471E+00
           bapl-3 lattice,  ****** outer iteration limit reached   9.93697E-01
big10.out
       big-10  s-16, p-3,                                          1.00153E+00
flat25.out
       flattop-25  s-16, p-                                        1.00885E+00
godiva.out
       godiva  s-16, p-3,                                          1.00622E+00
h2ox1.out
       k-calc&react rates f                                        1.00869E+00
hi240r.out
       hi-240  s-08/p-3,                                           1.00417E+00
jezb23.out
       jezb23  s-16, p-3,                                          9.64754E-01
jezbel.out
       jezebel  s-16, p-3,                                         9.95579E-01
jezbpu.out
       jezebel-pu(20.1)  s-                                        9.97672E-01
l7csb.out
       l7-csb  s-08/p-3,                                           1.01014E+00
l8csb.out
       L-8CSB  s-08/p-3,                                           1.00664E+00
l9csb.out
       L-9CSB  s-08/p-3,                                           1.00236E+00
l10csb.out
       l10csb  s-08/p-3,                                           1.01049E+00
l11csb.out
       l11csb  s-08/p-3,                                           1.00095E+00
ornl1.out
       ornl-1  s-8, p-3,                                           9.98044E-01
ornl2.out
       ornl-2  s-8, p-3,                                           9.97878E-01
ornl3.out
       ornl-3  s-8, p-3,                                           9.94922E-01
ornl4.out
       ornl-4  s-8, p-3,                                           9.96437E-01
ornl10.out
       ornl-10 s-8, p-3,                                           9.95918E-01
pnl3.out
       pnl3fg  s-08/p-3,                                           1.00057E+00
pnl6b.out
       pnl6fg  s-08/p-3,                                           1.01678E+00
pnl11.out
      cylinder described by   1.0134    .0016
trx1.out
           trx-1 lattice,-  ****** outer iteration limit reached   1.01237E+00
           trx-1 lattice, - ****** outer iteration limit reached   9.83880E-01
trx2.out
           trx-2 lattice,-  ****** outer iteration limit reached   1.01804E+00
           trx-2 lattice, - ****** outer iteration limit reached   9.89364E-01
uh3ni.out
       UH3-NI  s-16/p-3,                                           1.06144E+00
```

Table 32 (continued)

```
uh3ur.out
       UH3-UR  s-08/p-3,                                         1.02171E+00
zpr66a.out
       zpr-6/6a k-calculati                                      1.01792E+00
zpr67.out
       zpr-6/7 k-calculatio                                      1.02638E+00
zpr311.out
       zpr-3/11 k-calculati                                      1.00693E+00
zpr312.out
       zpr-3/12 k-calculati                                      1.01285E+00
```

Table 33. Results from Table 4 of Ref. 10

table4.r1

case	title(20 ...)	keno[k-eff	sigma	AEG]	xsdrn[lambda]
cas01.out	exp#5, 8.39 cm h2o se	.9955	.0014	2.35852E+01	
cas02.out	exp#017, 5.05 cm h2o/	.9937	.0010	2.35386E+01	
cas03.out	exp#28, 6.88 cm h2o/s	.9961	.0013	2.35643E+01	
cas04.out	exp no. 14 8.58 cm h2	.9954	.0015	2.33052E+01	
cas05.out	exp no. 23 7.28 cm h2	.9973	.0016	2.33144E+01	
cas06.out	exp no. 31 6.72 cm h2	.9969	.0015	2.33036E+01	
cas07.out	u refl. 1.956 cm from	.9992	.0013	2.28349E+01	
cas08.out	pb refl. .660 cm from	.9960	.0013	2.35565E+01	
cas09.out	no refl. 8.31cm h2o s	.9937	.0014	2.35845E+01	
cas10.out	uranium refl. 15.32cm	1.0013	.0014	2.22302E+01	
cas11.out	lead refl. 20.78cm h2	1.0044	.0008	2.32732E+01	
cas12.out	2.83cm and 3.60cm sep	.9982	.0015	2.18581E+01	
cas13.out	2.83cm and 4.94cm sep	.9988	.0011	2.18505E+01	
cas14.out	ss refl. 0.66 cm from	.9947	.0013	2.35284E+01	
cas15.out	steel refl. 15.84cm h	.9977	.0016	2.19896E+01	
cas16.out	steel refl. 9.83cm h	.9965	.0016	2.19370E+01	
cas17.out	steel refl. 8.30cm h	.9983	.0016	2.19118E+01	
cas18.out	steel refl. 8.94cm h	.9968	.0011	2.19233E+01	
cas19.out	u refl 1.321 cm from	.9965	.0013	2.19501E+01	
cas20.out	pb refl 0.660 cm from	.9964	.0014	2.27882E+01	
cas21.out	no refl infinite from	.9901	.0014	2.28753E+01	
cas22.out	uranium refl. 19.24cm	.9946	.0015	2.13211E+01	
cas23.out	lead refl. 18.18cm h2	1.0017	.0016	2.19703E+01	
cas24.out	no refl. 12.91cm h2o	.9944	.0016	2.20626E+01	
cas25.out	1.890 cm pitch lattic	1.46436E+00			
	pnl-4267 exp. 173 40	.9955	.0011	2.20475E+01	
cas26.out	1.890 cm pitch lattic				1.15187E+00
	pnl-4267 exp.177 40 x	.9965	.0012	2.08970E+01	
cas27.out	1.715 cm pitch lattic				1.40635E+00
	pnl-4267 exp. 178 44	.9925	.0011	2.11411E+01	
cas28.out	1.715 cm pitch lattic				1.19608E+00
	pnl-4267 exp. 181 44	.9927	.0012	2.00094E+01	

Table 33 (continued)

cas29.out				
pnl-4976 4.3-000-194	.9945	.0014	1.84847E+01	
cas30.out				
1.891 cm pitch lattic				1.46170E+00
flux trap assembly no	.9944	.0016	2.16485E+01	
cas31.out				
1.891 cm pitch lattic				1.46170E+00
flux trap assembly no	.9918	.0011	2.16327E+01	
cas32.out				
baw-1231 core i 936 r	.9884	.0009	2.06518E+01	
cas33.out				
baw-1231 core i 4904	.9915	.0007	1.99255E+01	
cas34.out				
baw-1273 core xx	.9915	.0011	2.12156E+01	
cas35.out				
baw-1484-7 core iv ex	.9892	.0010	2.26317E+01	
cas36.out				
baw-1484-7 core ix ex	.9864	.0013	2.30638E+01	
cas37.out				
baw-1484-7 core xiii	.9946	.0014	2.25886E+01	
cas38.out				
baw-1484-7 core xxi e	.9861	.0013	2.29260E+01	
cas39.out				
baw-1645-4 exp,mt=245	.9875	.0008	1.92277E+01	
cas40.out				
baw-1645-4 exp,mt=248	.9868	.0012	1.98621E+01	
cas41.out				
baw-1645-4 exp,mt=250	.9957	.0011	2.15404E+01	
cas42.out				
baw-1810 core 12 - 4.	.9945	.0011	2.16928E+01	
cas43.out				
baw-1810 core 14 - 4.	.9929	.0010	2.17746E+01	
cas44.out				
baw-1810 core 16 - 4.	.9923	.0010	2.18106E+01	
cas45.out				
epri np-196 .615 inch	.9896	.0014	2.22118E+01	
cas46.out				
epri np-196 .615 inch	.9951	.0012	2.19169E+01	
cas47.out				
epri np-196 .75 inch	.9925	.0010	2.33370E+01	
cas48.out				
epri np-196 .75 inch	.9965	.0009	2.30243E+01	
cas49.out				
epri np-196 .87 inch	.9943	.0013	2.37618E+01	
cas50.out				
epri np-196 .87 inch	.9957	.0012	2.36222E+01	
cas51.out				
saxton uo2 5.742 wt%	.9940	.0016	2.19129E+01	
cas52.out				
saxton uo2 5.742 wt%	.9971	.0012	2.34240E+01	
cas53.out				
wcap-3269-39, table i				1.23297E+00
wcap-3269-39, 2692 fu	.9980	.0009	2.07672E+01	
cas54.out				
wcap-3269-39, table v				1.28040E+00
wcap-3269-39, 2209 fu	.9965	.0014	2.13992E+01	
cas55.out				
wcap-3269-39, 945 fu	.9893	.0010	2.21940E+01	
cas56.out				
4-18x18 array 5.0cm i	.9967	.0013	2.23420E+01	
cas57.out				
4-18x18 array 5.0cm i	1.0051	.0011	2.24672E+01	
cas58.out				
4-18x18 array 5.0cm i	1.0071	.0013	2.25353E+01	

Table 33 (continued)

cas59.out				
4-18x18 array 5.0cm i	.9942	.0012	2.25420E+01	
cas60.out				
epri .70inch pitch un	.9985	.0014	2.11025E+01	
cas61.out				
epri .70inch pitch bo	.9946	.0013	2.06714E+01	
cas62.out				
epri .87inch pitch un	1.0037	.0010	2.26164E+01	
cas63.out				
epri .87inch pitch bo	1.0068	.0012	2.20748E+01	
cas64.out				
epri .99inch pitch un	1.0053	.0014	2.30803E+01	
cas65.out				
epri .99inch pitch bo	1.0069	.0009	2.26803E+01	
cas66.out				
saxton puo2-uo2 criti	1.0013	.0012	2.03420E+01	
cas67.out				
saxton puo2-uo2 criti	1.0041	.0017	2.10532E+01	
cas68.out				
saxton puo2-uo2 criti	1.0040	.0016	2.08000E+01	
cas69.out				
saxton puo2-uo2 criti	1.0068	.0018	2.25817E+01	
cas70.out				
saxton puo2-uo2 criti	1.0011	.0017	2.28420E+01	
cas71.out				
saxton puo2-uo2 criti	1.0068	.0017	2.34692E+01	
cas72.out				
pnl4976 exp196 1174 u	.9724	.0012	1.81477E+01	
cas73.out				
exp.no 021(063) pitch				1.47451E+00
exp.no 021(063) pitch	1.0081	.0010	2.02083E+01	
cas74.out				
exp.no 032(060) pitch				1.48052E+00
exp.no 032(060) pitch	1.0102	.0015	2.32637E+01	
cas75.out				
exp.no 043(062) pitch				1.54278E+00
exp.no 043(062) pitch	1.0098	.0011	2.18680E+01	
cas76.out				
exp.no 067 pitch=0.76				1.55675E+00
exp.no 067 pitch=0.76	1.0052	.0010	1.85580E+01	
cas77.out				
exp.no 68r pitch=1.53				1.54120E+00
exp. no 68r pitch=1.5	1.0089	.0016	2.27021E+01	
cas78.out				
rocky flats criticals	1.0138	.0011	2.13553E+01	
cas79.out				
rocky flats criticals	1.0061	.0011	2.15561E+01	
cas80.out				
rocky flats criticals	1.0067	.0011	1.91766E+01	
cas81.out				
rocky flats criticals	1.0138	.0011	2.18363E+01	
cas82.out				
raffety and malhalczo	.9963	.0013	2.30359E+01	
cas83.out				
raffety and malhalczo	.9968	.0013	2.36786E+01	
cas84.out				
raffety and malhalczo	1.0065	.0015	2.22080E+01	
cas85.out				
raffety and malhalczo	1.0078	.0013	2.17704E+01	
cas86.out				
uo2f2 soln h/u-235=11	1.0064	.0015	2.49362E+01	
cas87.out				
uo2f2 soln h/u-235=12	1.0030	.0013	2.49949E+01	
cas88.out				
rocky flats uo2(no3)2	1.0121	.0021	2.36089E+01	

Table 33 (continued)

cas89.out				
	rocky flats uo2(no3)2	1.0067	.0021	2.20264E+01
cas90.out				
	4.89% uo2f2 20 in dia	.9865	.0015	2.42842E+01
cas91.out				
	4.89% uo2f2 20x20 in	1.0076	.0011	2.43966E+01
cas92.out				
	4.89% uo2f2 20 in dia	.9976	.0009	2.47334E+01
cas93.out				
	ttc-5 pnl-6838 1264 f	.9000	.0017	2.18215E+01

Table 34. Statistical estimates for grouped data

Grouping	No. of observations	Mean k_{eff}	Standard deviation	Minimum value	Maximum value	Sample variance	Total standard deviation	Lower 95% bound	Lower 95% bound on 99.9%
Table 23	39	0.9926	8.2977-3	0.9672	1.0085	8.8562-6	8.8914-3	0.9765	0.9583
Table 24	14	1.0050	5.9088-3	0.9969	1.0159	7.8628-6	6.7114-3	0.9908	0.9733
Table 25	49	1.0013	7.8934-3	0.9839	1.0137	8.4347-6	8.1328-3	0.9856	0.9694
Table 26	43	1.0073	8.6190-3	0.9925	1.0370	1.4929-5	9.4963-3	0.9907	0.9710
Table 27	91	1.0031	1.7045-2	0.9731	1.0577	1.4541-5	1.7368-2	0.9731	0.9408
Table 27 Low AEG	17	1.0044	6.5559-3	0.9945	1.0149	9.9929-6	7.1367-3	0.9904	0.9711
Table 27 High AEG	74	1.0029	1.8663-2	0.9731	1.0577	1.5586-5	1.4107-2	0.9787	0.9336
Table 28	23	0.9966	4.3776-3	0.9875	1.0051	3.7452-6	4.3785-3	0.9875	0.9762
Table 29	91	1.0168	2.2988-2	0.9629	1.0917	1.4904-5	2.0417-2	0.9811	0.9337
Table 29 Low AEG	10	0.9773	7.6619-3	0.9629	0.9900	1.0205-5	7.4151-3	0.9598	0.9311
Table 29 High AEG	81	1.0217	1.9213-2	0.9785	1.0917	1.5484-5	1.6814-2	0.9925	0.9511
Table 30	77	1.0109	1.2296-2	0.9824	1.0577	1.5233-5	1.2569-2	0.9891	0.9643
Table 31	38	1.0227	1.2683-2	0.9930	1.0444	1.5381-5	1.3074-2	0.9995	0.9708
Table 33	92	0.9980	7.2006-3	0.9724	1.0138	1.7240-6	7.2496-3	0.9854	0.9720

linear uniform-width band that encompasses the 95% confidence band for a single future calculation may be interpreted as the k_{eff} value that, for a critical system similar to those validated, one would calculate above for a single future estimate of k_{eff} at 95% confidence. Any calculated k_{eff} above this band is considered critical. The values of k_{eff} represented by the 95% confidence closed-interval, uniform-width, lower tolerance band on 99.9% proportion of the population band may be interpreted as the k_{eff} value that, for a critical system similar to those validated, one would expect to calculate above for 99.9% of the estimates of k_{eff} at 95% confidence. Any calculated k_{eff} below this band is considered to belong to the group of systems that is subcritical. The lower-tolerance band is taken to be the subcritical acceptance criteria for k_{eff}. The difference between the two confidence bands is taken to be the margin of calculated subcriticality. With the exception of Fig. 14 (Table 28 results) and Fig. 20 (Table 33 results), this margin is in excess of 0.02 Δk. The margins for Figs. 14 and 20 are 0.015 and 0.018 Δk, respectively.

The broad range of AEG for which there are no observations causes the lower-tolerance band to be especially low for the results presented in Fig. 11 (Table 27 results). Figures 12 and 13 are based on the same results subdivided into low AEG (fast systems) and high AEG (thermal systems). There appears to be a strong trend in the high AEG cases presented in Fig. 13. Figure 18 (Table 30 results) includes experiments from both Tables 26 and 27, except that the highly thermalized systems have been omitted. There does not appear to be a strong trend in these results and the lower-tolerance band does not appear overly restrictive. Subdividing the experiments into groups by AEG or filtering experiments for a specific application are both means of restricting the validation results to specific applications. In doing so, a more realistic subcritical k_{eff} acceptance criteria is obtained.

The results presented in Fig. 15 (Table 29 results) for ^{233}U systems show a strong trend as a function of AEG. The subcritical acceptance criteria is below 0.90 for fast systems and as high as 0.94 for the thermal systems. This low subcritical acceptance criteria is due to both the large range of AEG for which there are no observations and the strong trends in the results. Figures 16 and 17 present the same results divided into low AEG and high AEG. The subcritical acceptance criteria for the low AEG cases is improved, but not to a great extent, because of the small number of observations. The high AEG cases show a large spread in calculated results with a trend that has a negative slope. The large spread in k_{eff} and the presence of significant trends in the ^{233}U results suggests a deficiency in the 27-group ENDF/B-IV ^{233}U cross sections. The reversal of the slope as a function of AEG when only the high AEG experiments are considered (as compared to the full range of AEG) is similar to that seen for the ^{235}U results presented in Figs. 11 and 13. This type of trend may suggest a deficiency in the hydrogen cross sections, which is the most significant moderator in these cases.

The results for the ^{239}Pu systems are presented in Fig. 19 (Table 30 results). An unusual characteristic of the experiments that make up this group is that there are experiments across the full range of AEG. There appears to be a nonlinear trend which is characterized by low k_{eff} at low AEG with a positive bias in the intermediate AEG range and a negative slope as a function of AEG at high AEG. This type of nonlinear trend is suggested in both the ^{233}U and ^{235}U results, but cannot be substantiated because of the lack of experiments which yield an AEG in the intermediate range. The subcritical acceptance criteria predicted by the statistical treatment appears realistically acceptable.

The results of the statistical analysis presented in Table 34 in which the data were treated as a single group may be compared to those presented in Figs. 7 through 20. When there is an absence of trends and when the range of AEG has been adequately sampled, the results compare well. For example, Table 23 results indicate a lower 95% confidence on 99.9% proportion of the population of 0.958 when treated as a single group and Figure 7 indicates a range of subcritical acceptance criteria from about 0.948 to 0.952. This indicates that either method (treating the results as a single group or considering the results as a function of AEG) will yield a realistic subcritical acceptance criteria which may be used to establish the safety of a system. On the other hand, when there are trends in the data and/or large ranges of AEG which have not been sampled, the results from treating the data as a single group are significantly less

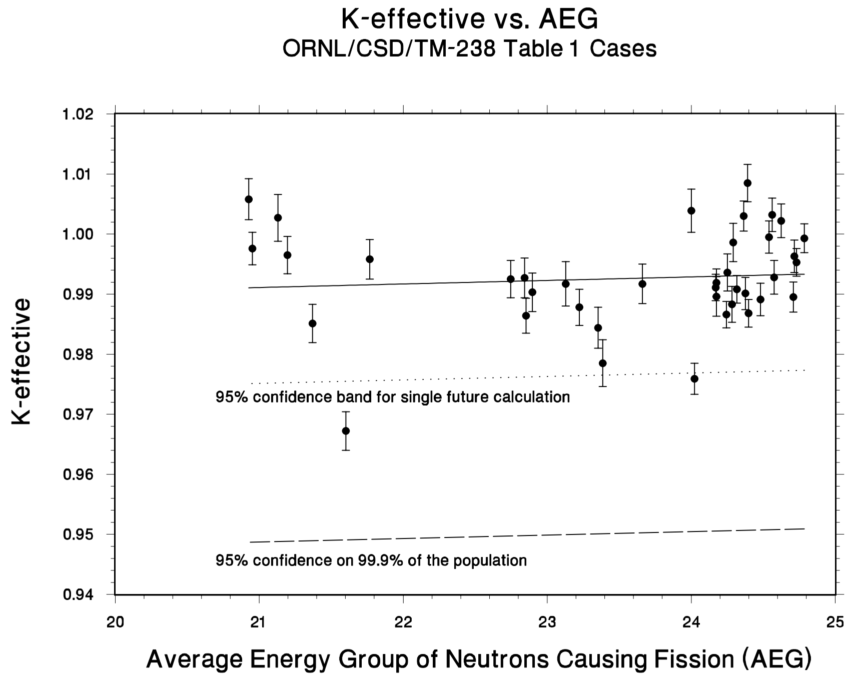

Figure 7. Results from Table 1 of Ref. 8

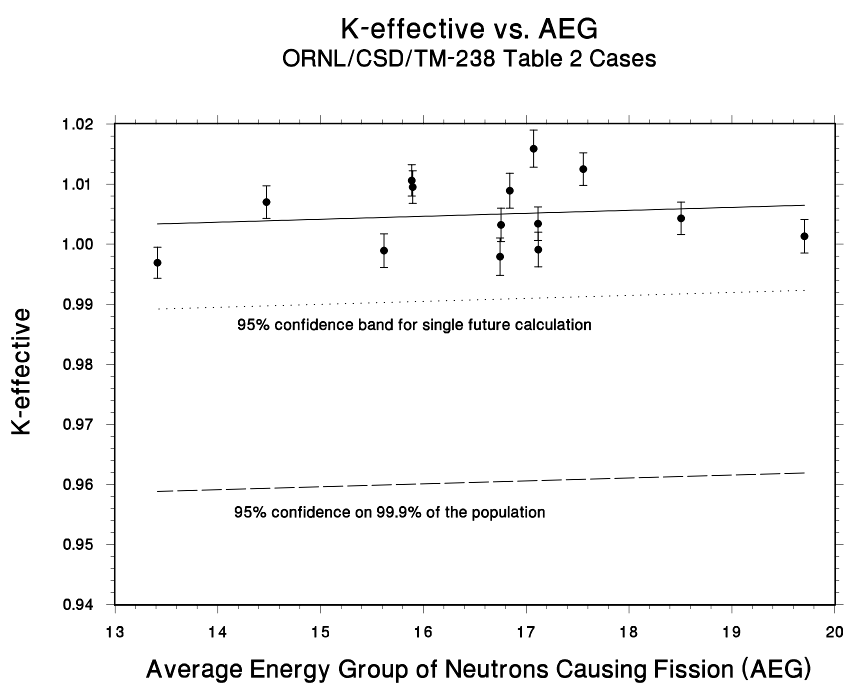

Figure 8. Results from Table 2 of Ref. 8

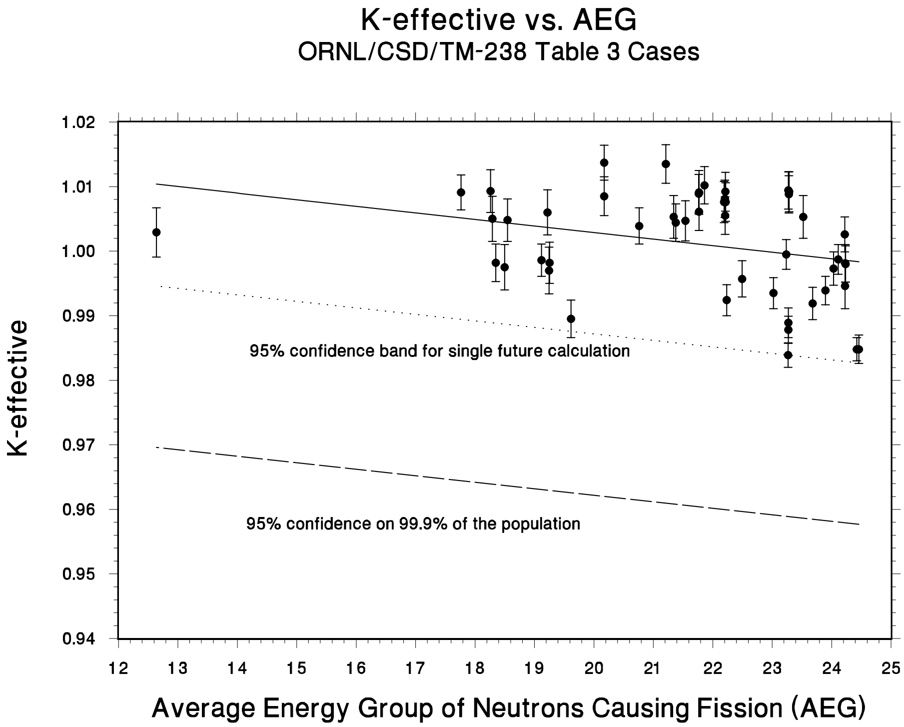

Figure 9. Results from Table 3 of Ref. 8

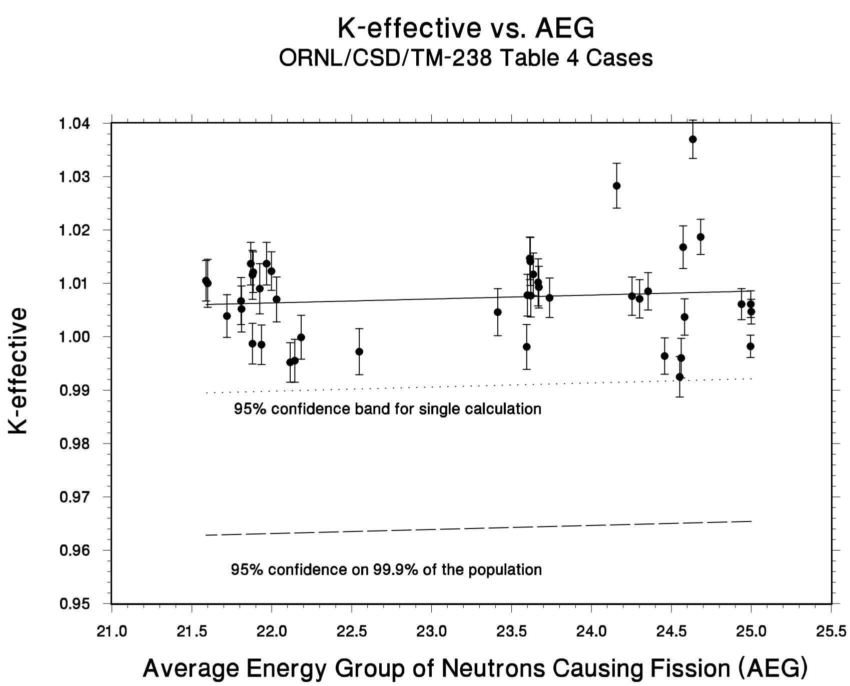

Figure 10. Results from Table 4 of Ref. 8

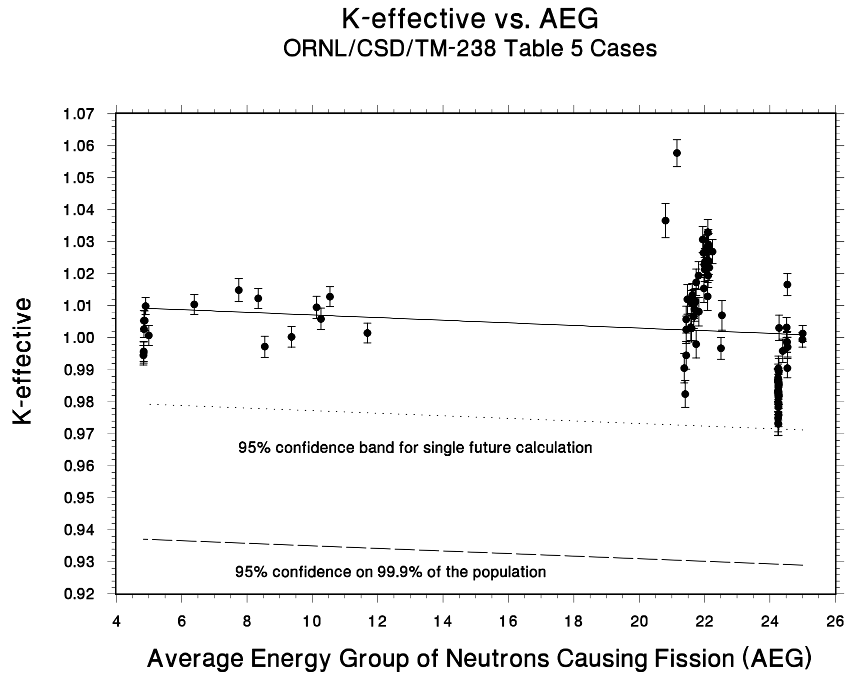

Figure 11. Results from Table 5 of Ref. 8

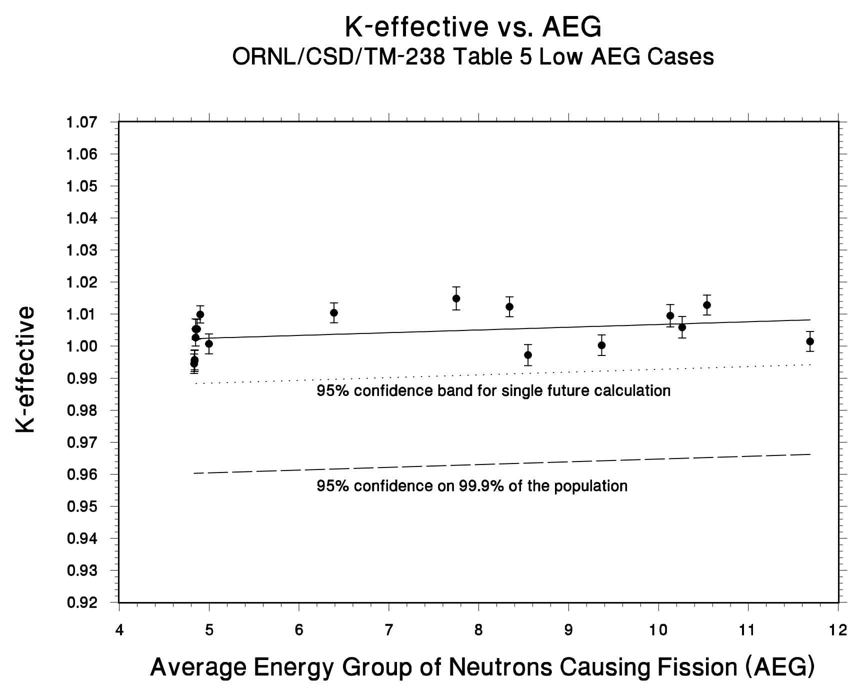

Figure 12. Results from Table 5 Low AEG of Ref. 8

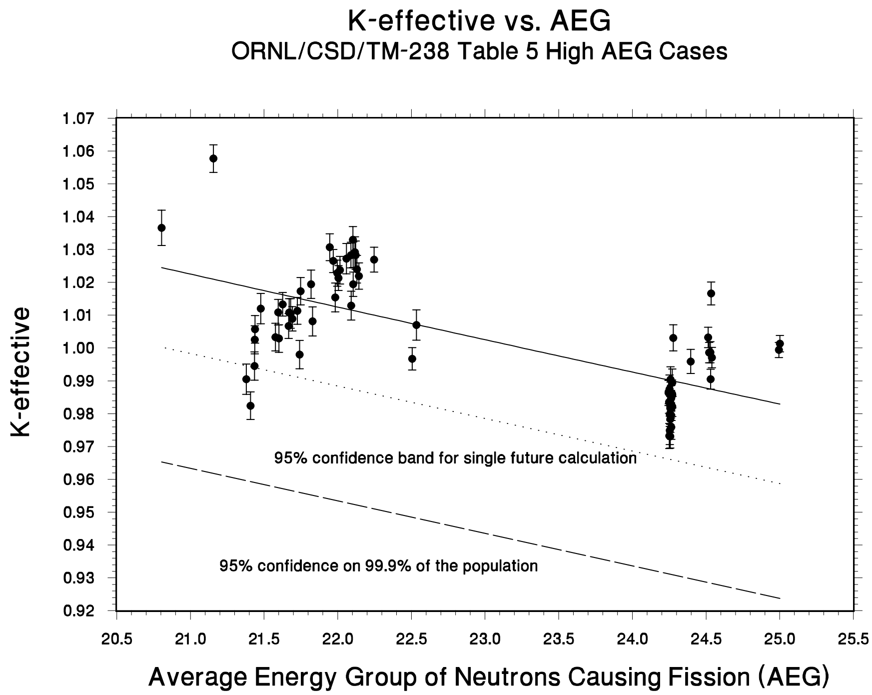

Figure 13. Results from Table 5 High AEG of Ref. 8

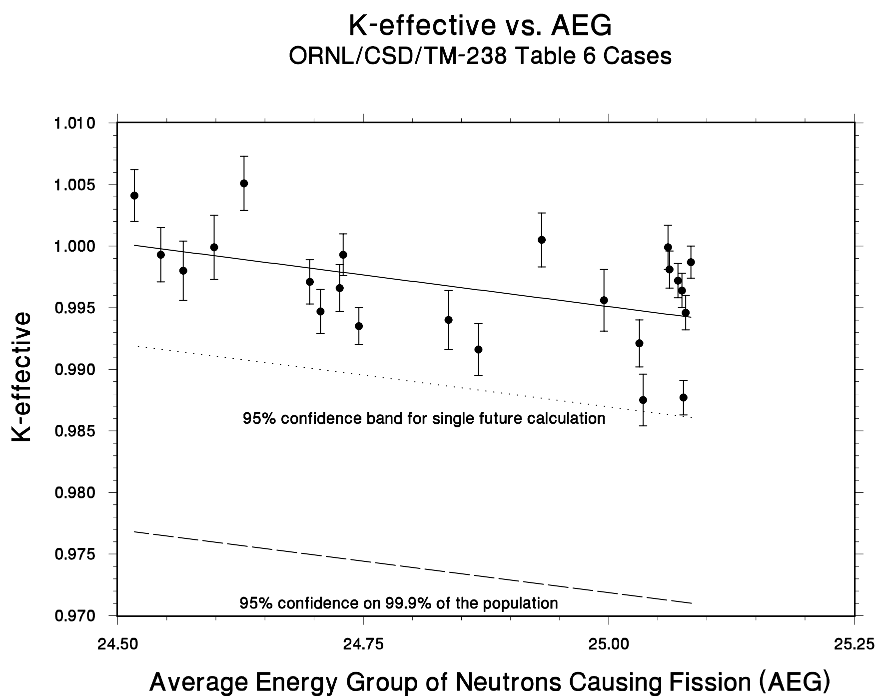

Figure 14. Results from Table 6 of Ref. 8

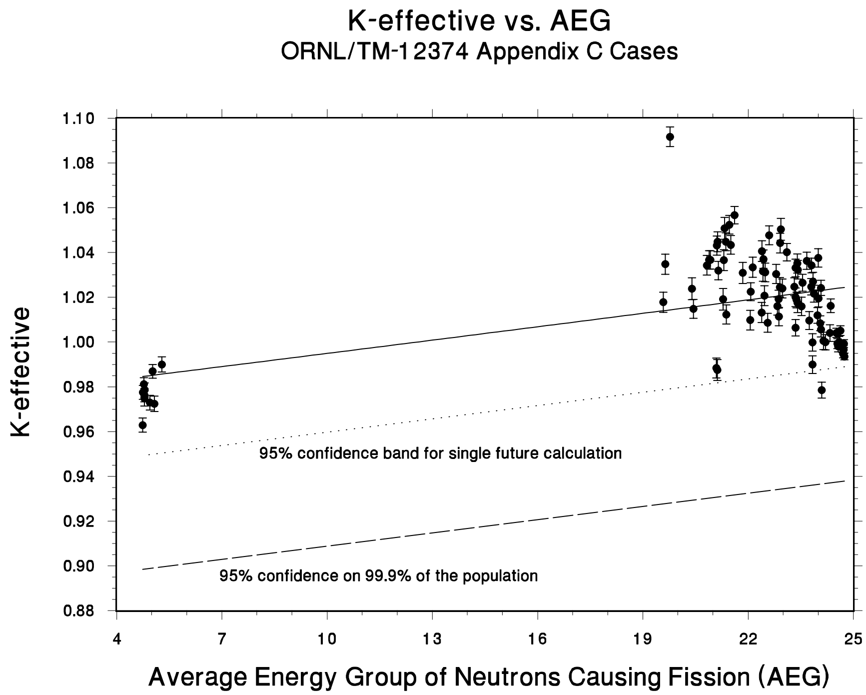

Figure 15. Results from Appendix C of Ref. 9

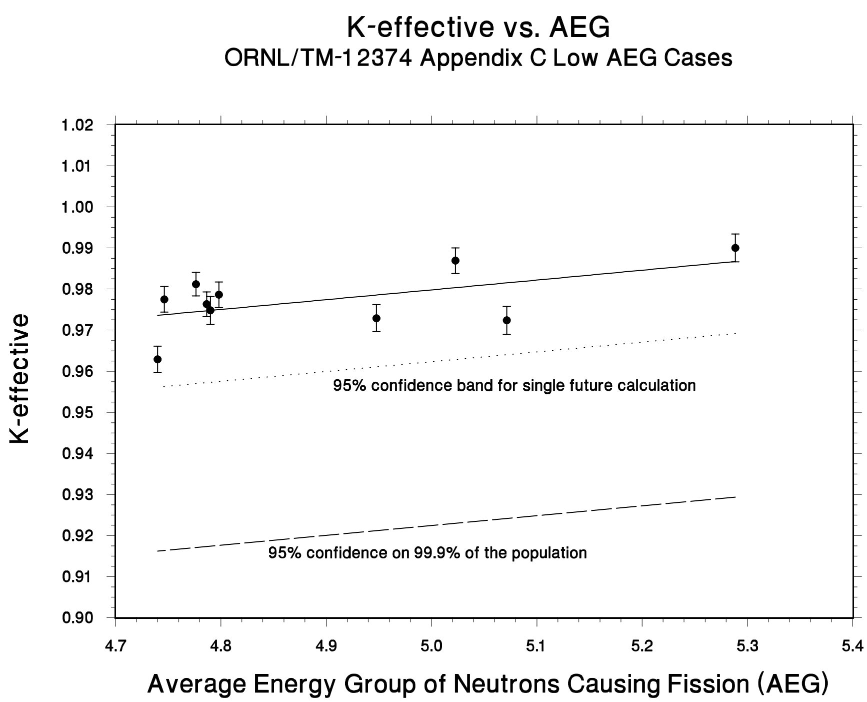

Figure 16. Results from Appendix C Low AEG of Ref. 9

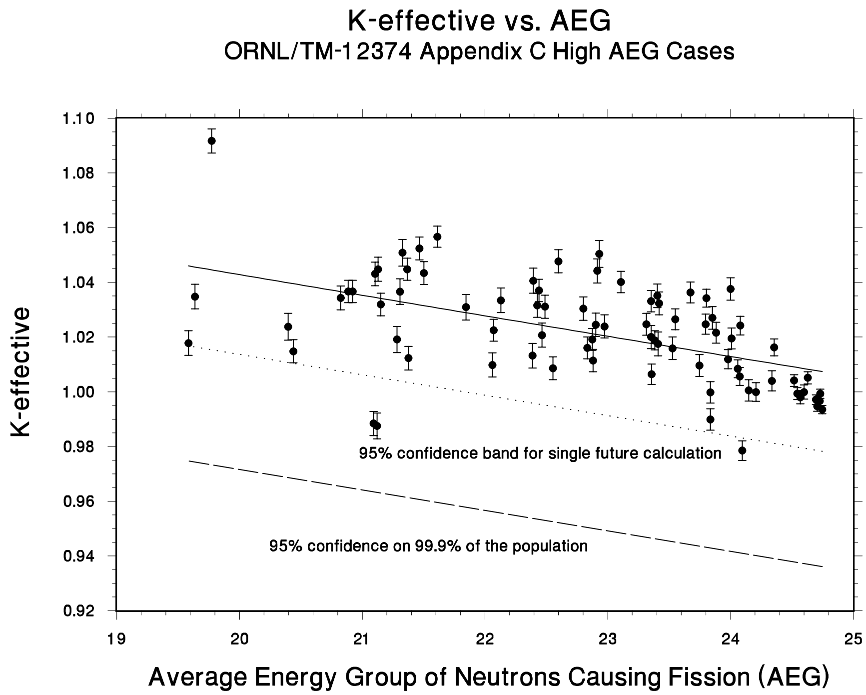

Figure 17. Results from Appendix C High AEG of Ref. 9

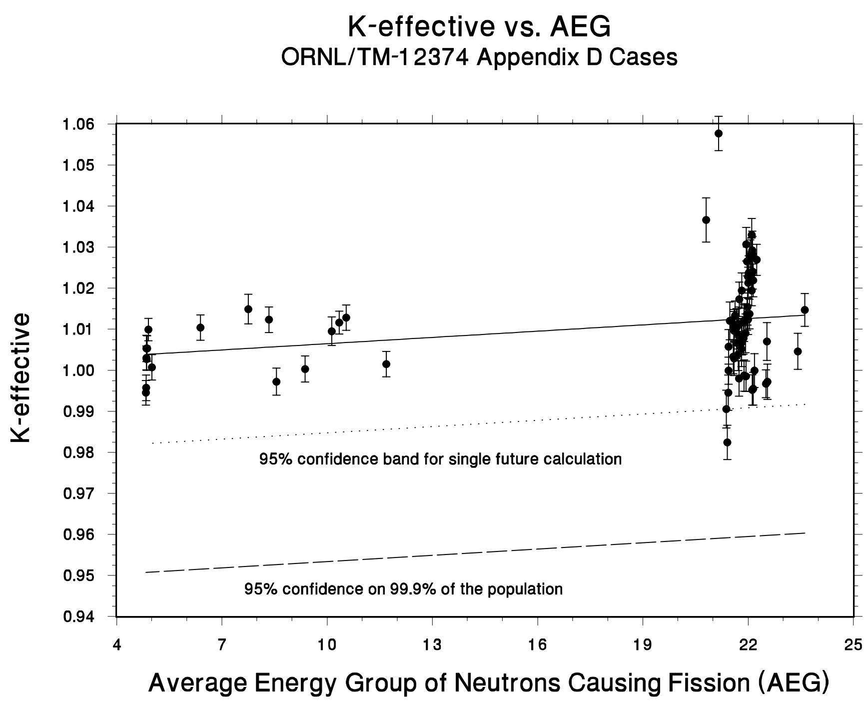

Figure 18. Results from Appendix D of Ref. 9

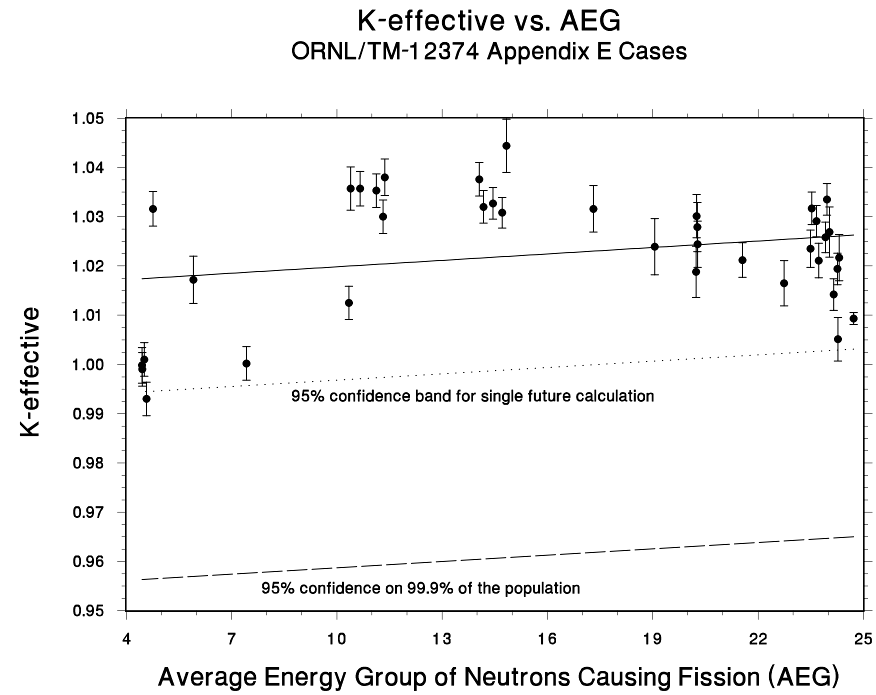

Figure 19. Results from Appendix E of Ref. 9

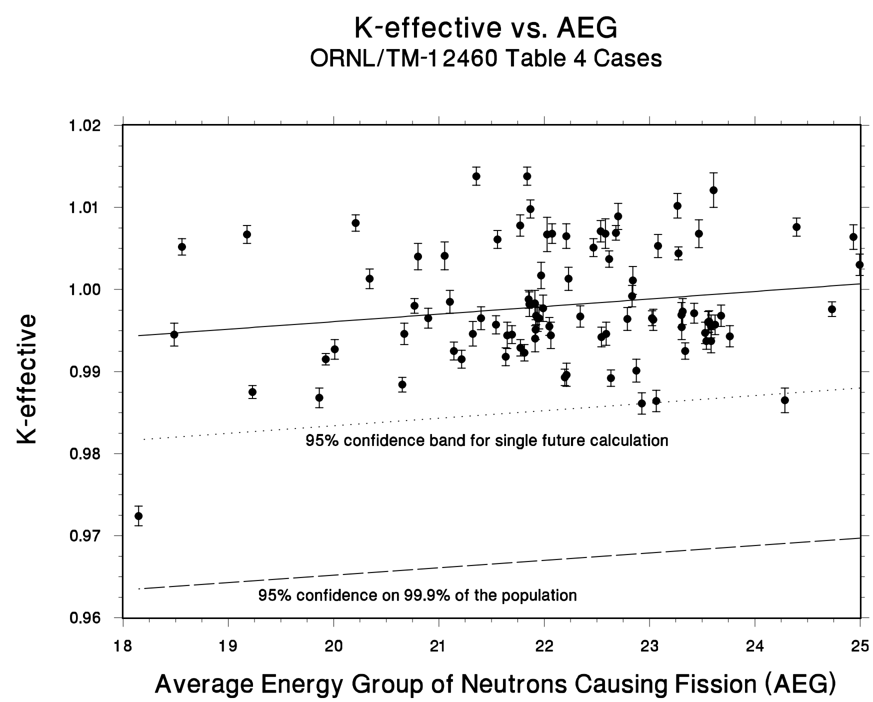

Figure 20. Results from Table 4 of Ref. 10

conservative than when these trends and lack of data are taken into account. An example is the result presented in Table 34 for the Table 29 experiments which indicate that a k_{eff} = 0.933 for 95% confidence on 99.9% proportion of the population as compared to Fig. 15 which indicates a range of subcritical k_{eff} of about 0.895 to 0.94.

4.5 CONCLUSIONS

A broad range of ^{233}U, ^{235}U, and ^{239}Pu critical systems have been validated using KENO V.a in SCALE-4. The CSAS25 criticality sequence and the SCALE 27-group library were utilized. The results indicate that for low-enriched ^{235}U systems there is an average bias that ranges from approximately -0.01 to +0.01 Δk depending on the systems being analyzed. The results for highly enriched ^{235}U systems indicate an average bias ranging from -0.02 to +.025 Δk depending on the system being analyzed. The results for ^{233}U systems indicate an average bias ranging from -0.02 to +0.045 Δk and for ^{239}Pu systems, a range of approximately +0.01 to +0.035 Δk, depending on the system being analyzed with many individual systems calculating nearly unbiased.

A statistical analysis of the validation results was performed where the AEG was used as the independent variable. The results of this analysis are presented graphically in Figs. 7 through 20. In each of these figures the 95% confidence band for a single future calculation (of systems similar to those analyzed) and the 95% confidence closed-interval, uniform width, lower tolerance band on 99.9% proportion of the population are presented. The lower confidence band presented in Figures 7 through 20 may be safely used as the subcritical k_{eff} acceptance criteria for systems similar to those validated. The margin of subcriticality for each group of experiments is defined as the difference between the two tolerance bands presented.

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APPENDIX A

VERIFICATION/VALIDATION INPUT

In order for users to perform the verification and/or validation described in this report, the input files for the problems must be available. This appendix contains two tables that correlate input files with the results presented in this document. Table A.1 provides information on the verification problems; Table A.2 does likewise for the validation problems. Users should refer to the SCALE homepage on the World Wide Web which can be accessed from http://www.cad.ornl.gov for additional information on accessing these input files.

Table A.1 Input files for SCALE criticality safety code verification

File Names	Description
INSTALL/	
BONAMI.INP	BONAMI Sample Problems
NITAWL.INP	NITAWL Sample Problems
XSDRN.INP	XSDRNPM Sample Problems
ICE.INP	ICE Sample Problems
CSAS25.INP	CSAS25 Sample Problems
KENOVA.INP	KENOVA Sample Problems
FUNCTION/	
VERBON1.INP	AWL, BONAMI, NITAWL (Tables 6-12)
NITAWLC.INP	NITAWL Cases for Tables 13-16
K5CSASI.1ST	Cross Sections for Table 17 Cases
K5CASE1H.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE1I.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE1O.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE2H.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE2I.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE2O.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE3H.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE3I.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE3O.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE4H.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE4I.INP	KENOV.a Hole Inter. Case for Table 17
K5CASE4O.INP	KENOV.a Hole Inter. Case for Table 17
K5INTRS.INP	KENOV.a Hole Inter. Case for Table 17
K5SHAPE.INP	KENOV.a Hole Inter. Case for Table 17
FUNCTION/1GROUP	
K5START.INP	KENOV.a Start Opt Cases for Table 18
K5PLOTS.INP	KENOV.a Geom. Orient. Cases for Table 19
KENO.INP	KENOV.a Cases for Table 20
KENOX.INP	XSDRN Cases for Table 20
KENO1.INP	KENOV.a Cases for Table 20
KENO1X.INP	XSDRN Cases for Table 20
KENOW.INP	KENOV.a Case for Table 20
KENOWX.INP	XSDRN Case for Table 20
KENOW2.INP	KENOV.a Case for Table 20
KENOW2X.INP	XSDRN Case for Table 20
KENOA.INP	KENOV.a Case for Table 20
FUNCTION/2GROUP	
KENO2.INP	KENOV.a 2 Gp Case for Table 21
KENO2X.INP	XSDRN 2 Gp Case for Table 21
KENO2Z.INP	KENOV.a 2 Gp Case for Table 21
KENO2ZX.INP	XSDRN 2 Gp Case for Table 21
REFL1.INP	KENOV.a 2 Gp Case for Table 21
REFL1X.INP	XSDRN 2 Gp Case for Table 21
REFL2.INP	KENOV.a 2 Gp Case for Table 21
REFL2X.INP	XSDRN 2 Gp Case for Table 21
REFL5.INP	KENOV.a 2 Gp Case for Table 21
REFL5X.INP	XSDRN 2 Gp Cases for Table 21

Table A.1 (continued)

File Names	DESCRIPTION
FUNCTION/4GROUP	
IA1XK0.INP	XSDRN/KENO 4 Gp Case for Table 22
IA1XK1.INP	XSDRN/KENO 4 Gp Case for Table 22
IA1XK2.INP	XSDRN/KENO 4 Gp Case for Table 22
IA1XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IA2XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IA3XK0.INP	XSDRN/KENO 4 Gp Case for Table 22
IA3XK1.INP	XSDRN/KENO 4 Gp Case for Table 22
IA3XK2.INP	XSDRN/KENO 4 Gp Case for Table 22
IA3XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IA4XK0.INP	XSDRN/KENO 4 Gp Case for Table 22
IA4XK1.INP	XSDRN/KENO 4 Gp Case for Table 22
IA4XK2.INP	XSDRN/KENO 4 Gp Case for Table 22
IA4XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IB1XK0.INP	XSDRN/KENO 4 Gp Case for Table 22
IB1XK1.INP	XSDRN/KENO 4 Gp Case for Table 22
IB1XK2.INP	XSDRN/KENO 4 Gp Case for Table 22
IB1XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IB3XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IC1XK0.INP	XSDRN/KENO 4 Gp Case for Table 22
IC1XK1.INP	XSDRN/KENO 4 Gp Case for Table 22
IC1XK2.INP	XSDRN/KENO 4 Gp Case for Table 22
IC1XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IC3XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IIA1XK0.INP	XSDRN/KENO 4 Gp Case for Table 22
IIA1XK1.INP	XSDRN/KENO 4 Gp Case for Table 22
IIA1XK2.INP	XSDRN/KENO 4 Gp Case for Table 22
IIA1XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IIA3XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IIB1XK0.INP	XSDRN/KENO 4 Gp Case for Table 22
IIB1XK1.INP	XSDRN/KENO 4 Gp Case for Table 22
IIB1XK2.INP	XSDRN/KENO 4 Gp Case for Table 22
IIB1XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IIB3XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IIC1XK0.INP	XSDRN/KENO 4 Gp Case for Table 22
IIC1XK1.INP	XSDRN/KENO 4 Gp Case for Table 22
IIC1XK2.INP	XSDRN/KENO 4 Gp Case for Table 22
IIC1XK3.INP	XSDRN/KENO 4 Gp Case for Table 22
IIC3XK3.INP	XSDRN/KENO 4 Gp Case for Table 22

Table A.2 Input files for SCALE criticality safety code validation

File Names	Description
TM238/LOWENR	
CAAxx.INP	CSAS25 lowen ^{235}U Cases for Table 23
CABxx.INP	CSAS25 lowen ^{235}U Cases for Table 24
CARxx.INP	CSAS25 lowen ^{235}U Cases for Table 25
CASxx.INP	CSAS25 lowen ^{235}U Cases for Table 25
TM238/HGHENR	
CAAxx.INP	CSAS25 highe ^{235}U Cases for Table 26
CASxx.INP	CSAS25 highe ^{235}U Cases for Table 27
CAExx.INP	CSAS25 highe ^{235}U Cases for Table 28
TM12374/APPNDXC	
111_xx.INP	CSAS25 ^{233}U Cases for Table 29
114_xx.INP	CSAS25 ^{233}U Cases for Table 29
1211_xx.INP	CSAS25 ^{233}U Cases for Table 29
1250_xx.INP	CSAS25 ^{233}U Cases for Table 29
1727_xx.INP	CSAS25 ^{233}U Cases for Table 29
MOD_111_.INP	CSAS25 ^{233}U Case for Table 29
TM12374/APPNDXD	
CAA_xx.INP	CSAS25 ^{235}U Cases for Table 30
CAS_xx.INP	CSAS25 ^{235}U Cases for Table 30
TM12374/APPNDXE	
1727_xx.INP	CSAS ^{239}Pu Cases for Table 31
2109_xx.INP	CSAS ^{239}Pu Cases for Table 31
2110_xx.INP	CSAS ^{239}Pu Cases for Table 31
TM12460/	
BAPLx.INP	CSAS/XSDRN Cases for Table 32
BIG10.INP	CSAS/XSDRN Case for Table 32
FLAT25.INP	CSAS/XSDRN Case for Table 32
GODIVA.INP	CSAS/XSDRN Case for Table 32
H2OX1.INP	CSAS/XSDRN Case for Table 32
HI240R.INP	CSAS/XSDRN Case for Table 32
JEZBxx.INP	CSAS/XSDRN Cases for Table 32
LxxCSB.INP	CSAS/XSDRN Cases for Table 32
ORNLx.INP	CSAS/XSDRN Cases for Table 32
PNLxx.INP	CSAS/XSDRN Cases for Table 32
TRXx.INP	CSAS/XSDRN Cases for Table 32
UH3xx.INP	CSAS/XSDRN Cases for Table 32
ZPRxx.INP	CSAS/XSDRN Cases for Table 32
CASxx.INP	CSAS LWR Cases for Table 33

APPENDIX B

UTILITY CODE LISTINGS

This appendix contains a listing of four computer programs (READM, READA, READA4, and READK5) that process outputs to produce some of the tables printed in this report. These programs are not operable on Personal Computers; they were written to process output from the workstations. In addition to these four programs, a listing of two scripts used to run the problems are included in this appendix.

The following is a list of the computer program READM used to process outputs from the XSDRN and KENO programs.

```
      program readm
      character iline*132,iline0*132,icase*12,aeg*11,keff*6,sigma*6
      character index*12,results*40,plots*40,title*21,lambda*11
      character stats*12,error*36,lib*3,grps*3
      logical iflag
      integer ipt*1
cwcj
c    This program scans the file list in the INDEX file for certain
c    keno and xsdrn output.  The findings are edited into several
c    output files.
cwcj
c
c 'INDEX' has a list of output files that are to be scanned
c    (max length filename = 12).
c
      write(*,'(1x,a\)') 'enter the index file name ---> '
      read(*,'(a)') index
c
c 'RESULTS' contains an edit of the casename, title, and keno or xsdrn
c    results only if a string is found to contain a search string.
c
      write(*,'(1x,a\)') 'enter the results file name ---> '
      read(*,'(a)') results
c
c 'PLOTS' contains an edit of the keno k-eff by generation skipped.
c    this option generates a large amount of output and has been dissabled.
c      write(*,'(1x,a\)') 'enter the plots file name ---> '
c      read(*,'(a)') plots
c      write(*,'(1x,a\)') 'enter the plot table # ---> '
c      read(*,'(i1)') ipt
c
c
c   read STATS output file name
c
      write(*,'(1x,a\)') 'enter the stats file name ---> '
      read(*,'(a)') stats
        grps = ' '
        is = 0
        if(stats.ne.' ') then
c   read # of groups in lib
          write(*,'(1x,a\)') 'enter # of groups in lib ---> '
          read(*,'(a)') grps
    1     if(grps(1:1).eq.' ') then
            grps = grps(2:)
            goto 1
          end if
          is =1
          open(11,file=stats)
          write(11,1000) stats
          write(11,1001)
```

```
 1000     format(t2,a,' statistical analysis input data')
 1001     format(t2,'0.999 0.95 0.95 #of_obs 0.0 0.0 -1')
        end if
      open(7,file=index)
      open(8,file=results)
      write(8,'(1x,a,/)') results
      write(8,2000)
 2000 format(5x,'case',/,t11,'title(20 ...)',2x,'keno[',2x,'k-eff',4x,
     * 'sigma',5x,'AEG',4x,']',2x,'xsdrn[',3x,'lambda',2x,']',/)
c      open(9,file=plots)
c      write(9,'(1x,a,/)') plots
c
c    ik and ix are counters to help in editing files with multiple outputs.
c
      ik     = 0
      ix     = 0
c    outer control loop
   10 continue
        read(7,'(a12)',end=40) icase
        ilib   = 0
        title  = ' '
        aeg    = ' '
        keff   = ' '
        sigma  = ' '
        lambda = ' '
        iline  = ' '
        iline0 = ' '
        error  = ' '
        write(*,'(1x,a)') icase
        inquire(file=icase,exist=iflag)
        if(iflag) then
          write(8,'(1x,a)') icase
          open(10,file=icase,err=41)
   20     iline0 = iline
          read(10,'(a)',end=42) iline
c check for xsdrn stuff
          if(iline(21:26).eq.'lambda') then
c    we found some xsdrn stuff
            lambda = iline(29:39)
c    now get the title
            read(10,'(a)') iline
c    check iteration limit
            if(iline(10:14).eq.'outer') then
              error = iline(3:39)
              write(*,'(1x,a)') error
              read(10,'(a)') iline
            end if
            read(10,'(a)') iline
            title = iline(24:44)
c    go ahead and print it and skip the counter check
            write(8,'(t8,a,t30,a,t69,a)') title,error,lambda
            title  = ' '
            error  = ' '
            lambda = ' '
            goto 20
          end if
c    check for keno stuff
c    set ilib flag to 1 if # of groups is GRPS

          if(iline(20:42).eq.'number of energy groups') then
            lib = iline(56:58)
    2       if(lib(1:1).eq.' ') then
              lib = lib(2:)
              goto 2
            end if
            if(lib.eq.grps) ilib = 1
          end if
```

```
          if(iline(52:72).eq.'average fission group') then
            aeg=iline(77:87)
c    we found some stuff from NUB=YES in keno
            goto 20
          end if
          if(iline(62:67).eq.'ion sk') then
c    we found 'THE ANSWER' in keno
            title = iline0(28:48)
c            write(9,'(//,t50,a,i1,a,a,a,/)') 'Table ',ipt,' ( ',
c     *                                              icase(1:5),' )'
c            write(9,'(a)') iline0(2:133)
c            write(9,'(a)') iline(2:133)
            read(10,'(a)') iline
            keff  = iline(35:40)
            sigma = iline(50:55)
c            write(9,'(a)') iline(2:133)
c            do 25 i=1,101
c              read(10,'(a)') iline
c              write(9,'(a)') iline(2:133)
c   25       continue
c
c    go ahead and print it
            write(8,'(t8,a,t32,a,t41,a,t49,a)')
     *                title,keff,sigma,aeg
c
c    write out file for statistical analysis if ilib is set
c
            if(ilib.eq.1) then
              ik    = ik +1
              if(is.eq.1) write(11,'(1x,a,4x,a,1x,a)') aeg,keff,sigma
              title = ' '
              keff  = ' '
              sigma = ' '
              aeg   = ' '
              ilib  = 0
            end if
          end if
          goto 20
        end if
      goto 10
   41 write(*,'(1x,a)') 'file not found'
      goto 10
   42 write(*,'(1x,a)') 'EOF in output'
      close(10)
      goto 10
   40 write(*,'(1x,a)') 'EOF in index'
      close(8)
      close(9)
      close(10)
      if(is.eq.1) then
        write(11,1002) ik
 1002 format(/,t2,'#of_obs = ',i3)
        close(11)
      end if
      stop 40
      end
```

Appendix B

The following is a list of the computer program READA used to process output from XSDRN and KENO programs for 1- and 2-group cases.

```
      program reada
      character iline*132,icase*8,icasex*12,icase1*12,keff*6,sigma*6
      character index*12,results*40,title*21,lambda*11
      character error*36,lib*3,grps*3
      logical iflag
      integer ipt*1,isct(20),sct(20)
      dimension rlambda(20),abs(20),rleak(20),
     * rkeff(20),dev(20),abs1(20),rleak1(20)
cwcj
c    This program scans the file list in the INDEX file for certain
c    keno and xsdrn output specific to the comparison of the analytic
c    benchmarks.  The findings are edited into an
c    output files.
cwcj
c
c 'INDEX' has a list of output files that are to be scanned
c    (max length filename = 8).
c
      write(*,'(1x,a\)') 'enter the index file name ---> '
      read(*,'(a)') index
c
c 'RESULTS' contains an edit of the casename, title, and keno or xsdrn
c    results only if a string is found to contain a search string.
c
      write(*,'(1x,a\)') 'enter the results file name ---> '
      read(*,'(a)') results
      grps = ' '
c   read # of groups in lib
      write(*,'(1x,a\)') 'enter # of groups in lib ---> '
      read(*,'(i3)') igrp
      open(7,file=index)
      open(8,file=results)
      write(8,'(1x,a,/)') results
      write(8,1000)
 1000 format(5x,t20,'XSDRN',t63,'KENO',/,
     * t1,'Case',t9,'ISCT',t14,'Lambda',t22,'Absorption',t36,'Leakage',
     *t46,'Case',t52,'SCT',t57,'K-eff',t65,'dev',t75,'Abs1',t83,'Leak1',
     *t92,'Deviation*',t105,'Fract.**',t117,'fract.***',/
     *t104,'Abs. Dev.',t116,'Leak Dev.')
c
c    outer control loop
   10 continue
        read(7,'(a8)',end=40) icase
c    ik and ix are counters to help in editing files with multiple outputs.
c
        ik     = 0
        ix     = 0
        do 11 i=1,20
          isct(i)    = 0
          rlambda(i) = 0
          abs(i)     = 0
          rleak(i)   = 0
          sct(i)     = 0
          rkeff(i)   = 0
          dev(i)     = 0
          abs1(i)    = 0
          rleak1(i)  = 0
   11   continue
        ilib   = 0
        title  = ' '
        aeg    = ' '
        keff   = ' '
        sigma  = ' '
```

```
        lambda = ' '
        iline  = ' '
        iline0 = ' '
        write(*,'(1x,a)') icase
c this program assumes that the icase is an extensionless file name
c   and that the actual file name is icasex.out for xsdrn output
c   and icase.out for keno output
c   read xsdrn stuff first
        il = 8
        do 15 i = 1,8
          if(icase(i:i).eq.' ') il = il -1
   15   continue
        icasex = icase(1:il)//'x.out '
        write(*,'(1x,a)') icasex
        inquire(file=icasex,exist=iflag)
        if(iflag) then
          open(10,file=icasex,err=41)
   20     iline0 = iline
          read(10,'(a)',end=42) iline
c check for xsdrn stuff
          if(iline(52:55).eq.'isct') then
c    we found some xsdrn stuff
            ix = ix + 1
            read(iline,100) isct(ix)
          end if
  100     format(t92,i2)
          if(iline(21:26).eq.'lambda') then
c    we found lambda
            read(iline,101) rlambda(ix)
  101       format(t28,f12.0)
            lambda = iline(29:39)
c    now get the title
            read(10,'(a)') iline
c    check iteration limit
            if(iline(10:14).eq.'outer') then
              error = iline(3:39)
              write(*,'(1x,a)') error
              read(10,'(a)') iline
            end if
            read(10,'(a)') iline
            title = iline(24:44)
          end if
c    check for system totals
          if(iline(2:19).eq.'fine group summary') then
            do 16 i=1,igrp+2
   16         read(10,'(a)') iline
c    get the system absorbtions and leakage
            read(iline,102) abs(ix),rleak(ix)
  102       format(t73,f12.0,t86,f12.0)
            if(ix.eq.20) stop
          end if
          goto 20
        end if
   42   continue
        close(10)
c    at the end of the xsdrn file. now get the keno stuff
        icase1 = icase(1:il)//'.out '
        write(*,'(1x,a)') icase1
        inquire(file=icase1,exist=iflag)
        if(iflag) then
          open(10,file=icase1,err=41)
   30     iline0 = iline
          read(10,'(a)',end=43) iline
c    check for keno stuff
          if(iline(43:62).eq.'number of scattering') then
c    we found SCT
            ik = ik + 1
```

```
            read(iline,200) sct(ik)
  200       format(t73,i2)
          end if
          if(iline(62:67).eq.'ion sk') then
c    we found 'THE ANSWER' in keno
            read(10,'(a)') iline
            read(iline,201) rkeff(ik),dev(ik)
  201       format(t35,f6.0,t50,f6.0)
          end if
          if(iline(2:15).eq.'system total =') then
c    we found the system totals. read abs1 and rleak1
            read(iline,202) abs1(ik),rleak1(ik)
  202       format(t61,f12.0,t90,f12.0)
          end if
          if(ik.eq.10) stop
          goto 30
        end if
  43    continue
c    we have all the keno and xsdrn stuff for icase. now print it
        ic = max(ix,ik)

        do 50 i=1,ic
            if(isct(i).eq.max(0,2*sct(i)-1) .and.
     *         ix.ne.0 .and. ic.ne.0) then
c    isct and sct are equal
              if(dev(i)*abs(i)*rleak(i).eq.0.) goto 99
              if(i.eq.1) then
                write(8,2000) (icase(1:il)//'x'//icase(il+1:8)),
     *  isct(i),rlambda(i),abs(i), rleak(i),
     *  icase,sct(i),rkeff(i),dev(i),abs1(i),rleak1(i),
     *  (rkeff(i)-1.)/dev(i),(abs1(i)-abs(i))/abs(i),
     *  (rleak1(i)-rleak(i))/rleak(i)
 2000   format(t1,a8,t9,i2,t13,f8.6,t22,f9.6,t35,f9.6,
     * t46,a8,t53,i2,t57,f6.4,t64,f5.4,t71,f9.6,t80,f9.6,
     * t93,f7.4,t104,f8.5,t116,f8.5)
              else
                write(8,2001) isct(i),rlambda(i),abs(i),rleak(i),
     *  sct(i),rkeff(i),dev(i),abs1(i),rleak1(i),
     *  (rkeff(i)-1.)/dev(i),(abs1(i)-abs(i))/abs(i),
     *  (rleak1(i)-rleak(i))/rleak(i)
 2001   format(t9,i2,t13,f8.6,t22,f9.6,t35,f9.6,
     * t53,i2,t57,f6.4,t64,f5.4,t71,f9.6,t80,f9.6,
     * t93,f7.4,t104,f8.5,t116,f8.5)
               end if
             else
               if(i.le.ix .and. i.le.ik) then
                 write(8,2002) (icase(1:il)//'x'//icase(il+1:8)),
     *  isct(i),rlambda(i),abs(i)
 2002   format(t1,a8,t9,i2,t13,f8.6,t22,f9.6,t35,f9.6)
                 write(8,2003) icase,sct(i),rkeff(i),
     *  dev(i),abs1(i),rleak1(i),(rkeff(i)-1.)/dev(i)
 2003   format(t46,a8,t53,i2,t57,f6.4,t64,f5.4,t71,f9.6,t80,f9.6,
     * t93,f7.4)
               else
                 if (i.le.ix)
     *             write(8,2002) (icase(1:il)//'x'//icase(il+1:8)),
     *  isct(i),rlambda(i),abs(i), rleak(i)
                 if (i.le.ik) write(8,2003) icase,sct(i),rkeff(i),
     *  dev(i),abs1(i),rleak1(i),(rkeff(i)-1.)/dev(i)
               end if
             end if
  50    continue
      goto 10
  99    write(8,2000) icase,isct(i),rlambda(i),abs(i), rleak(i),
     *  sct(i),rkeff(i),dev(i),abs1(i),rleak1(i),(rkeff(i)-1.)/dev(i)
      goto 10
   41 write(*,'(1x,a)') 'file not found'
```

```
   goto 10
40 write(*,'(1x,a)') 'EOF in index'
   close(8)
   close(9)
   close(10)
   stop 40
   end
```

Appendix B

The following is a list of the computer program READA4 (a modified version of READA) used to process output from XSDRN and KENO programs for the 4-group case.

```
      program reada4
      character iline*132,icase*8,icase1*12,keff*6,sigma*6
      character index*12,results*40,title*21,lambda*11
      character error*36,lib*3,grps*3
      logical iflag
      integer ipt*1,isct(20),sct(20)
      dimension rlambda(20),abs(20),rleak(20),
     * rkeff(20),dev(20),abs1(20),rleak1(20)
cwcj
c    This program scans the file list in the INDEX file for certain
c    keno and xsdrn output specific to the comparison of the 4 group
c    analytic benchmarks.  The findings are edited into an
c    output files.
cwcj
c
c 'INDEX' has a list of output files that are to be scanned
c    (max length filename = 12).
c
      write(*,'(1x,a\)') 'enter the index file name ---> '
      read(*,'(a)') index
c
c 'RESULTS' contains an edit of the casename, title, and keno or xsdrn
c    results only if a string is found to contain a search string.
c
      write(*,'(1x,a\)') 'enter the results file name ---> '
      read(*,'(a)') results
      grps = ' '
c   read # of groups in lib
      write(*,'(1x,a\)') 'enter # of groups in lib ---> '
      read(*,'(i3)') igrp
      open(7,file=index)
      open(8,file=results)
      write(8,'(1x,a,/)') results
      write(8,1000)
 1000 format(5x,t20,'XSDRN',t63,'KENO',/,
     * t1,'Case',t9,'ISCT',t14,'Lambda',t22,'Absorption',t36,'Leakage',
     * t52,'SCT',t57,'K-eff',t65,'dev',t75,'Abs1',t83,'Leak1',
     * t92,'Deviation*',t105,'Fract.**',t117,'fract.***',/
     * t104,'Abs. Dev.',t116,'Leak Dev.')
c
c    outer control loop
   10 continue
        read(7,'(a8)',end=40) icase
c    ik and ix are counters to help in editing files with multiple outputs.
c
        ik     = 0
        ix     = 0
        do 11 i=1,20
          isct(i)    = 0
          rlambda(i) = 0
          abs(i)     = 0
          rleak(i)   = 0
          sct(i)     = 0
          rkeff(i)   = 0
          dev(i)     = 0
          abs1(i)    = 0
          rleak1(i)  = 0
   11   continue
        ilib   = 0
        title  = ' '
        aeg    = ' '
        keff   = ' '
        sigma  = ' '
```

```
        lambda = ' '
        iline  = ' '
        iline0 = ' '
        write(*,'(1x,a)') icase
c this program assumes that the icase is an extensionless file name
c   and that the actual file name is icase.out with one xsdrn and
c   one keno output
c   read xsdrn stuff first
        il = 8
        do 15 i = 1,8
          if(icase(i:i).eq.' ') il = il -1
   15   continue
        icase1 = icase(1:il)//'.out '
        write(*,'(1x,a)') icase1
        inquire(file=icase1,exist=iflag)
        if(iflag) then
          open(10,file=icase1,err=41)
   20     iline0 = iline
          read(10,'(a)',end=42) iline
c check for xsdrn stuff
          if(iline(52:55).eq.'isct') then
c    we found some xsdrn stuff
            ix = ix + 1
            read(iline,100) isct(ix)
          end if
  100     format(t92,i2)
          if(iline(21:26).eq.'lambda') then
c    we found lambda
            read(iline,101) rlambda(ix)
  101       format(t28,f12.0)
            lambda = iline(29:39)
c    now get the title
            read(10,'(a)') iline
c    check iteration limit
            if(iline(10:14).eq.'outer') then
              error = iline(3:39)
              write(*,'(1x,a)') error
              read(10,'(a)') iline
            end if
            read(10,'(a)') iline
            title = iline(24:44)
          end if
c    check for system totals
          if(iline(2:30).eq.'fine group summary for system') then
            do 16 i=1,igrp+2
   16         read(10,'(a)') iline
c    get the system absorbtions and leakage
            read(iline,102) abs(ix),rleak(ix)
  102       format(t73,f12.0,t86,f12.0)
            goto 42
          end if
          goto 20
   42   continue
c    at the end of the xsdrn info. now get the keno stuff
   30     iline0 = iline
          read(10,'(a)',end=43) iline
c    check for keno stuff
          if(iline(43:62).eq.'number of scattering') then
c    we found SCT
            ik = ik + 1
            read(iline,200) sct(ik)
  200       format(t73,i2)
          end if
          if(iline(62:67).eq.'ion sk') then
c    we found 'THE ANSWER' in keno
            read(10,'(a)') iline
            read(iline,201) rkeff(ik),dev(ik)
```

```
  201       format(t35,f6.0,t50,f6.0)
          end if
          if(iline(2:15).eq.'system total =') then
c    we found the system totals. read abs1 and rleak1
            read(iline,202) abs1(ik),rleak1(ik)
  202       format(t61,f12.0,t90,f12.0)
          end if
          if(ik.eq.10) stop
          goto 30
        end if
  43    continue
c    we have all the keno and xsdrn stuff for icase. now print it
        ic = max(ix,ik)

        do 50 i=1,ic
            if(isct(i).eq.max(0,2*sct(i)-1) .and.
     *         ix.ne.0 .and. ic.ne.0) then
c    isct and sct are equal
              if(dev(i)*abs(i)*rleak(i).eq.0.) goto 99
              if(i.eq.1) then
                write(8,2000) icase,
     *  isct(i),rlambda(i),abs(i), rleak(i),
     *  sct(i),rkeff(i),dev(i),abs1(i),rleak1(i),
     *  (rkeff(i)-rlambda(i))/dev(i),(abs1(i)-abs(i))/abs(i),
     *  (rleak1(i)-rleak(i))/rleak(i)
 2000   format(t1,a8,t9,i2,t13,f8.6,t22,f9.6,t35,f9.6,
     * t53,i2,t57,f6.4,t64,f5.4,t71,f9.6,t80,f9.6,
     * t93,f7.4,t104,f8.5,t116,f8.5)
              else
                write(8,2001) isct(i),rlambda(i),abs(i),rleak(i),
     *  sct(i),rkeff(i),dev(i),abs1(i),rleak1(i),
     *  (rkeff(i)-rlambda(i))/dev(i),(abs1(i)-abs(i))/abs(i),
     *  (rleak1(i)-rleak(i))/rleak(i)
 2001   format(t9,i2,t13,f8.6,t22,f9.6,t35,f9.6,
     * t53,i2,t57,f6.4,t64,f5.4,t71,f9.6,t80,f9.6,
     * t93,f7.4,t104,f8.5,t116,f8.5)
               end if
             else
               if(ix.gt.ik) then
                 write(8,2002) icase,
     *  isct(i),rlambda(i),abs(i), rleak(i)
 2002   format(t1,a8,t9,i2,t13,f8.6,t22,f9.6,t35,f9.6)
               else
                write(8,2003) icase,sct(i),rkeff(i),dev(i),
     *  abs1(i),rleak1(i)
 2003   format(t46,a8,t53,i2,t57,f6.4,t64,f5.4,t71,f9.6,t80,f9.6)
               end if
             end if
  50    continue
      goto 10
  99    write(8,2000) icase,isct(i),rlambda(i),abs(i), rleak(i),
     *  sct(i),rkeff(i),dev(i),abs1(i),rleak1(i)
      goto 10
   41 write(*,'(1x,a)') 'file not found'
      goto 10
   40 write(*,'(1x,a)') 'EOF in index'
      close(8)
      close(9)
      close(10)
      stop 40
      end
```

The following is a list of the computer program READK5 used to process output from the KENO program.

```
      program readk5
      character iline*132,iline0*132,icase*12,icase1*13
      character index*12,results*40
      logical*4 iflag
cwcj
c    This program scans KENOV.a hole intersection output cases in
c    the file list in the INDEX file for certain
c    keno messages.  The findings are tallied and edited an
c    output file.
cwcj
c
c 'INDEX' has a list of output files that are to be scanned
c    (max length filename = 12).
c
      write(*,'(1x,a\)') 'enter the index file name ---> '
      read(*,'(a)') index
c
c 'RESULTS' contains an edit of the summary of the KENOV.a hole
c    intersection messages.  The total number of k5 messages for
c    91, 92, 166, 169, 179, 100, and 133 are tallied for each file
c    in INDEX.  In addition, stop 129 system messages are tallied.
c
      write(*,'(1x,a\)') 'enter the results file name ---> '
      read(*,'(a)') results
c
      open(7,file=index)
      open(8,file=results)
      write(8,'(1x,a,/)') results
      write(8,2000)
 2000 format(t21,'KENO V.a messages',t53,'SYSTEM',/,
     *  5x,'case',/,t16,7(1x,'k5-',1x),t51,'stop',1x,'stop',/,
     *  t16,'  91   92  166  169  179  100  133  129     ',//)
c    outer control loop
   10 continue
        k91   = 0
        k92   = 0
        k166  = 0
        k169  = 0
        k179  = 0
        k100  = 0
        k133  = 0
        kstp0 = 0
        kstp1 = 0
        read(7,'(a12)',end=40) icase
        write(*,'(1x,a)') icase
c this program assumes that the icase is an extensionless file name
c   and that the actual file name is icase.out or icase.msgs
        il = 8
        do 15 i = 1,8
          if(icase(i:i).eq.' ') il = il -1
   15   continue
        icase1 = icase(1:il)//'.out '
        write(*,'(1x,a)') icase1
        inquire(file=icase1,exist=iflag)
        if(iflag) then
          open(10,file=icase1,err=41)
   20     iline0 = iline
          read(10,'(a)',end=42) iline
c check for a k5 message
          if(iline(2:20).eq.'keno message number') then
c    we found one. now check the message and tally the result
            if(iline(25:27).eq.'91 ') k91   = k91  + 1
            if(iline(25:27).eq.'92 ') k92   = k92  + 1
            if(iline(25:27).eq.'166') k166  = k166 + 1
            if(iline(25:27).eq.'169') k169  = k169 + 1
```

```
            if(iline(25:27).eq.'179') k179  = k179 + 1
            if(iline(25:27).eq.'133') k133  = k133 + 1
          end if
          if(iline(28:46).eq.'keno message number') then
            if(iline(51:53).eq.'100') k100  = k100 + 1
          end if
          goto 20
        end if
c    check stop codes. note that the stop codes are found in the
c    output file with the extension msgs as opposed to the .out file.
   42   continue
        write(*,'(1x,a)') 'EOF in output'
        close(10)
        icase1=icase(1:il)//'.msgs'
        write(*,'(1x,a)') icase1
        inquire(file=icase1,exist=iflag)
        if(iflag) then
          open(10,file=icase1,err=41)
   30       read(10,'(a)',end=43) iline
            if(iline(1:8).eq.'STOP 129') kstp1 = kstp1 + 1
            if(iline(1:8).eq.'STOP    ') kstp0 = kstp0 + 1
          goto 30
        end if
   43   continue
        write(*,'(1x,a)') 'EOF in output'
        close(10)
c we have all the data we are going to get so print it
        write(8,1000) icase,k91,k92,k166,k169,k179,k100,k133,
     *                    kstp1,kstp0
 1000   format(t3,a,9(1x,i3,1x))
      goto 10
   41 write(*,'(1x,a)') 'file not found'
      goto 10
   40 write(*,'(1x,a)') 'EOF in index'
      close(8)
      close(9)
      close(10)
      stop 40
      end
```

The following is the script referred to as submit4.2p.

```
#!/bin/csh
#
# This script sequentially executes scale4 jobs using the input argument
# list.  It is assumed that the directory /var/tmp exists.  A TMPDIR is
# created under a USER subdirectory and is used for execution.  An extension
# is required on the input file (eq. name.inp).  Two output files are created
# (name.out and name.msgs).  TMPDIR is used for each job in the input list
# and is then removed after completion of all jobs.
#
if (!(-e /var/tmp/$USER))  mkdir /var/tmp/$USER
setenv TMPDIR /var/tmp/$USER/$USER.$$
mkdir $TMPDIR
ln -s /home/wcj/scale/bin/scommand $TMPDIR/scommand
ln -s /home/wcj/scale/bin/comet    $TMPDIR/comet
ln -s /home/wcj/scale/bin/awl      $TMPDIR/awl
foreach name ($argv[*])
  echo $name ' ==> ' $name:r.out $name:r.msgs
  /scale4.2p/cmds/scale4 $name $name:r.out >& $name:r.msgs
  rm $TMPDIR/print $TMPDIR/_*
end
rm -r $TMPDIR
```

Appendix B

The following is Perl Script scommand referred to by the script submit4.2p

```
#!/usr/local/bin/perl
  open(INPUT, "input") || die "no input commands\n";

  while(<INPUT>) {
    system $_ ;
  }
exit;
```

APPENDIX C

ORIGINAL FUNCTIONAL VERIFICATION RESULTS

This appendix contains tables of results from an earlier functional verification of NITAWL and KENO V.a. These results were independently verified for the Nuclear Criticality Safety System at ORNL. Tables C.1 through C.4 contain the results from the NITAWL-II computer program. Tables C.5 through C.7 contain results from a series of KENO V.a problems. Table C.5 is a summary of results for hole intersection checks; Table C.6 contains results for start option checks; and Table C.7 contains geometric orientation results. Table C.8 contains a comparison of XSDRNPM and KENO V.a results for a series of problems.

Appendix C

Table C.1. Original NITAWL-II 0-D consistency results

neutron 1-d cross sections for uranium-238 endf/b-iv mat 1262 updated 10/12/89
id = 92238

xsec id / grp.	1	2	4	16	18	17	27	101
1	6.47332e+00	3.46587e+00	1.21051e+00	8.43215e-01	9.44658e-01	5.48078e-03	9.48245e-01	3.58692e-03
2	7.79746e+00	4.72140e+00	2.49626e+00	6.65531e-04	5.64925e-01	0.00000e+00	5.79136e-01	1.42103e-02
3	7.46424e+00	4.38786e+00	2.49366e+00	0.00000e+00	5.43171e-01	0.00000e+00	5.82727e-01	3.95560e-02
4	7.03265e+00	4.01940e+00	2.57461e+00	0.00000e+00	3.66818e-01	0.00000e+00	4.38641e-01	7.18229e-02
5	7.07728e+00	4.56523e+00	2.36325e+00	0.00000e+00	4.09193e-02	0.00000e+00	1.48799e-01	1.07880e-01
6	8.07867e+00	6.11931e+00	1.84206e+00	0.00000e+00	2.02359e-03	0.00000e+00	1.17301e-01	1.15277e-01
7	1.03175e+01	9.05783e+00	1.12986e+00	0.00000e+00	7.10000e-05	0.00000e+00	1.29769e-01	1.29698e-01
8	1.31779e+01	1.27086e+01	9.62384e-02	0.00000e+00	5.90640e-05	0.00000e+00	3.73092e-01	3.73033e-01
9	1.61783e+01	1.53133e+01	0.00000e+00	0.00000e+00	3.05779e-05	0.00000e+00	8.64908e-01	8.64877e-01
10	2.19800e+01	1.96440e+01	0.00000e+00	0.00000e+00	3.14814e-04	0.00000e+00	2.33598e+00	2.33567e+00
11	5.18913e+01	4.00804e+01	0.00000e+00	0.00000e+00	1.50924e-08	0.00000e+00	1.18108e+01	1.18108e+01
12	1.08250e+02	6.18384e+01	0.00000e+00	0.00000e+00	1.29848e-08	0.00000e+00	4.64119e+01	4.64119e+01
13	8.40459e+01	2.68903e+01	0.00000e+00	0.00000e+00	2.07583e-08	0.00000e+00	5.71556e+01	5.71556e+01
14	1.25656e+02	1.49381e+01	0.00000e+00	0.00000e+00	3.57114e-08	0.00000e+00	1.10718e+02	1.10718e+02
15	9.01667e+00	8.51210e+00	0.00000e+00	0.00000e+00	5.39731e-08	0.00000e+00	5.04566e-01	5.04566e-01
16	9.17060e+00	8.68621e+00	0.00000e+00	0.00000e+00	6.65200e-08	0.00000e+00	4.84387e-01	4.84386e-01
17	9.26085e+00	8.76022e+00	0.00000e+00	0.00000e+00	7.42999e-08	0.00000e+00	5.00628e-01	5.00628e-01
18	9.31920e+00	8.80382e+00	0.00000e+00	0.00000e+00	7.92970e-08	0.00000e+00	5.15384e-01	5.15384e-01
19	9.34802e+00	8.83951e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	5.08503e-01	5.08503e-01
20	9.51989e+00	8.88286e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	6.37022e-01	6.37022e-01
21	9.67282e+00	8.91087e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	7.61958e-01	7.61958e-01
22	9.78755e+00	8.92201e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	8.65534e-01	8.65534e-01
23	1.00970e+01	8.93650e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	1.16052e+00	1.16052e+00
24	1.06110e+01	8.94926e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	1.66175e+00	1.66175e+00
25	1.11314e+01	8.94923e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	2.18220e+00	2.18220e+00
26	1.20527e+01	8.95198e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	3.10069e+00	3.10069e+00
27	1.47971e+01	8.94198e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	5.85514e+00	5.85514e+00

xsec id / grp.	102	251	252	253	452	1099	1018
1	3.58692e-03	8.08068e-01	1.64030e-03	3.84509e-03	3.53449e+00	7.68845e-01	2.36848e-02
2	1.42103e-02	7.73573e-01	1.92089e-03	3.85576e-03	2.95861e+00	7.67545e+00	1.95789e-01
3	3.95560e-02	6.42278e-01	3.03254e-03	4.35540e-03	2.68421e+00	9.24023e+00	2.16127e-01
4	7.18229e-02	5.52100e-01	3.79385e-03	4.61818e-03	2.57399e+00	5.47885e+00	1.23569e-01
5	1.07880e-01	4.88957e-01	4.33066e-03	4.77056e-03	2.51106e+00	7.40776e+00	1.63493e-01
6	1.15277e-01	3.73533e-01	5.30850e-03	4.86869e-03	2.44153e+00	8.16524e+00	1.76058e-01
7	1.29698e-01	2.16284e-01	6.64037e-03	5.11835e-03	2.36455e+00	4.10472e+00	8.68714e-02
8	3.73033e-01	4.08503e-02	8.12632e-03	5.54290e-03	2.32570e+00	1.77195e+00	1.33721e-02
9	8.64877e-01	3.61991e-03	8.44315e-03	5.63915e-03	2.32146e+00	1.73459e+00	9.70255e-04
10	2.33567e+00	2.82522e-03	8.45049e-03	5.64162e-03	2.31964e+00	1.69644e+00	7.20624e-05
11	1.18108e+01	2.82522e-03	8.45049e-03	5.64162e-03	2.31954e+00	1.70474e+00	5.66937e-06
12	4.64119e+01	2.82523e-03	8.45048e-03	5.64161e-03	2.31951e+00	1.20396e+00	3.98262e-07
13	5.71556e+01	2.82523e-03	8.45047e-03	5.64161e-03	2.31950e+00	1.09861e+00	6.32403e-08
14	1.10718e+02	2.82523e-03	8.45049e-03	5.64161e-03	2.31949e+00	1.18744e+00	1.25325e-08
15	5.04566e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31949e+00	5.44161e-01	1.41632e-09
16	4.84386e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31950e+00	3.08616e-01	4.15882e-10
17	5.00628e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31950e+00	1.40146e-01	1.33933e-10
18	5.15384e-01	2.82523e-03	8.45050e-03	5.64162e-03	2.31950e+00	1.22215e-01	9.58917e-11
19	5.08503e-01	2.82523e-03	8.45050e-03	5.64162e-03	0.00000e+00	2.23143e-01	1.35571e-10
20	6.37022e-01	2.82523e-03	8.45049e-03	5.64162e-03	0.00000e+00	6.93146e-01	2.20454e-10
21	7.61958e-01	2.82523e-03	8.45050e-03	5.64162e-03	0.00000e+00	2.07639e-01	3.22671e-11
22	8.65534e-01	2.82522e-03	8.45049e-03	5.64161e-03	0.00000e+00	3.67724e-01	3.74372e-11
23	1.16052e+00	2.82508e-03	8.45005e-03	5.64132e-03	0.00000e+00	8.98703e-01	3.57942e-11
24	1.66175e+00	2.82551e-03	8.45136e-03	5.64219e-03	0.00000e+00	1.88090e+00	9.74279e-12
25	2.18220e+00	2.82514e-03	8.45022e-03	5.64144e-03	0.00000e+00	1.51609e+00	2.85204e-12
26	3.10069e+00	2.82513e-03	8.45020e-03	5.64142e-03	0.00000e+00	1.61753e+00	1.99986e-12
27	5.85514e+00	2.82522e-03	8.45049e-03	5.64161e-03	0.00000e+00	3.59148e-01	4.76573e-13

Table C.2. Original NITAWL-II 1-D consistency results

neutron 1-d cross sections for uranium-238 endf/b-iv mat 1262 updated 10/12/89 id = 192238

xsec id grp.	1	2	4	16	18	17	27	101
1	6.47332e+00	3.46587e+00	1.21051e+00	8.43215e-01	9.44658e-01	5.48078e-03	9.48245e-01	3.58692e-03
2	7.79746e+00	4.72140e+00	2.49626e+00	6.65531e-04	5.64925e-01	0.00000e+00	5.79136e-01	1.42103e-02
3	7.46424e+00	4.38786e+00	2.49366e+00	0.00000e+00	5.43171e-01	0.00000e+00	5.82727e-01	3.95560e-02
4	7.03265e+00	4.01940e+00	2.57461e+00	0.00000e+00	3.66818e-01	0.00000e+00	4.38641e-01	7.18229e-02
5	7.07728e+00	4.56523e+00	2.36325e+00	0.00000e+00	4.09193e-02	0.00000e+00	1.48799e-01	1.07880e-01
6	8.07867e+00	6.11931e+00	1.84206e+00	0.00000e+00	2.02359e-03	0.00000e+00	1.17301e-01	1.15277e-01
7	1.03175e+01	9.05783e+00	1.12986e+00	0.00000e+00	7.10000e-05	0.00000e+00	1.29769e-01	1.29698e-01
8	1.31779e+01	1.27086e+01	9.62384e-02	0.00000e+00	5.90640e-05	0.00000e+00	3.73092e-01	3.73033e-01
9	1.59741e+01	1.51267e+01	0.00000e+00	0.00000e+00	3.05779e-05	0.00000e+00	8.47417e-01	8.47386e-01
10	1.73007e+01	1.55810e+01	0.00000e+00	0.00000e+00	3.08542e-04	0.00000e+00	1.71973e+00	1.71943e+00
11	2.06355e+01	1.69376e+01	0.00000e+00	0.00000e+00	1.50924e-08	0.00000e+00	3.69785e+00	3.69785e+00
12	2.31973e+01	1.59059e+01	0.00000e+00	0.00000e+00	1.29848e-08	0.00000e+00	7.29143e+00	7.29143e+00
13	1.83596e+01	1.06055e+01	0.00000e+00	0.00000e+00	2.07583e-08	0.00000e+00	7.75406e+00	7.75406e+00
14	2.48217e+01	9.37088e+00	0.00000e+00	0.00000e+00	3.57114e-08	0.00000e+00	1.54508e+01	1.54508e+01
15	9.01667e+00	8.51210e+00	0.00000e+00	0.00000e+00	5.39731e-08	0.00000e+00	5.04566e-01	5.04566e-01
16	9.17060e+00	8.68621e+00	0.00000e+00	0.00000e+00	6.65200e-08	0.00000e+00	4.84387e-01	4.84386e-01
17	9.26085e+00	8.76022e+00	0.00000e+00	0.00000e+00	7.42999e-08	0.00000e+00	5.00628e-01	5.00628e-01
18	9.31920e+00	8.80382e+00	0.00000e+00	0.00000e+00	7.92970e-08	0.00000e+00	5.15384e-01	5.15384e-01
19	9.34802e+00	8.83951e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	5.08503e-01	5.08503e-01
20	9.51989e+00	8.88286e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	6.37022e-01	6.37022e-01
21	9.67282e+00	8.91087e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	7.61958e-01	7.61958e-01
22	9.78755e+00	8.92201e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	8.65534e-01	8.65534e-01
23	1.00970e+01	8.93650e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	1.16052e+00	1.16052e+00
24	1.06110e+01	8.94926e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	1.66175e+00	1.66175e+00
25	1.11314e+01	8.94923e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	2.18220e+00	2.18220e+00
26	1.20527e+01	8.95198e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	3.10069e+00	3.10069e+00
27	1.47971e+01	8.94198e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	5.85514e+00	5.85514e+00

xsec id grp.	102	251	252	253	452	1099	1018
1	3.58692e-03	8.08068e-01	1.64030e-03	3.84509e-03	3.53449e+00	7.68845e-01	2.36848e-02
2	1.42103e-02	7.73573e-01	1.92089e-03	3.85576e-03	2.95861e+00	7.67545e+00	1.95789e-01
3	3.95560e-02	6.42278e-01	3.03254e-03	4.35540e-03	2.68421e+00	9.24023e+00	2.16127e-01
4	7.18229e-02	5.52100e-01	3.79385e-03	4.61818e-03	2.57399e+00	5.47885e+00	1.23569e-01
5	1.07880e-01	4.88957e-01	4.33066e-03	4.77056e-03	2.51106e+00	7.40776e+00	1.63493e-01
6	1.15277e-01	3.73533e-01	5.30850e-03	4.86869e-03	2.44153e+00	8.16524e+00	1.76058e-01
7	1.29698e-01	2.16284e-01	6.64037e-03	5.11835e-03	2.36455e+00	4.10472e+00	8.68714e-02
8	3.73033e-01	4.08503e-02	8.12632e-03	5.54290e-03	2.32570e+00	1.77195e+00	1.33721e-02
9	8.47386e-01	3.61991e-03	8.44315e-03	5.63915e-03	2.32146e+00	1.73459e+00	9.70255e-04
10	1.71943e+00	2.82522e-03	8.45049e-03	5.64162e-03	2.31964e+00	1.69644e+00	7.20624e-05
11	3.69785e+00	2.82522e-03	8.45049e-03	5.64162e-03	2.31954e+00	1.70474e+00	5.66937e-06
12	7.29143e+00	2.82523e-03	8.45048e-03	5.64161e-03	2.31951e+00	1.20396e+00	3.98262e-07
13	7.75406e+00	2.82523e-03	8.45047e-03	5.64161e-03	2.31950e+00	1.09861e+00	6.32403e-08
14	1.54508e+01	2.82523e-03	8.45049e-03	5.64161e-03	2.31949e+00	1.18744e+00	1.25325e-08
15	5.04566e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31949e+00	5.44161e-01	1.41632e-09
16	4.84386e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31950e+00	3.08616e-01	4.15882e-10
17	5.00628e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31950e+00	1.40146e-01	1.33933e-10
18	5.15384e-01	2.82523e-03	8.45050e-03	5.64162e-03	2.31950e+00	1.22215e-01	9.58917e-11
19	5.08503e-01	2.82523e-03	8.45050e-03	5.64162e-03	0.00000e+00	2.23143e-01	1.35571e-10
20	6.37022e-01	2.82523e-03	8.45049e-03	5.64162e-03	0.00000e+00	6.93146e-01	2.20454e-10
21	7.61958e-01	2.82523e-03	8.45050e-03	5.64162e-03	0.00000e+00	2.07639e-01	3.22671e-11
22	8.65534e-01	2.82522e-03	8.45049e-03	5.64161e-03	0.00000e+00	3.67724e-01	3.74372e-11
23	1.16052e+00	2.82508e-03	8.45005e-03	5.64132e-03	0.00000e+00	8.98703e-01	3.57942e-11
24	1.66175e+00	2.82551e-03	8.45136e-03	5.64219e-03	0.00000e+00	1.88090e+00	9.74279e-12
25	2.18220e+00	2.82514e-03	8.45022e-03	5.64144e-03	0.00000e+00	1.51609e+00	2.85204e-12
26	3.10069e+00	2.82513e-03	8.45020e-03	5.64142e-03	0.00000e+00	1.61753e+00	1.99986e-12
27	5.85514e+00	2.82522e-03	8.45049e-03	5.64161e-03	0.00000e+00	3.59148e-01	4.76573e-13

Table C.3. Original NITAWL-II 2-D consistency results

neutron 1-d cross sections for uranium-238 endf/b-iv mat 1262 updated 10/12/89 id = 292238

xsec id grp.	1	2	4	16	18	17	27	101
1	6.47332e+00	3.46587e+00	1.21051e+00	8.43215e-01	9.44658e-01	5.48078e-03	9.48245e-01	3.58692e-03
2	7.79746e+00	4.72140e+00	2.49626e+00	6.65531e-04	5.64925e-01	0.00000e+00	5.79136e-01	1.42103e-02
3	7.46424e+00	4.38786e+00	2.49366e+00	0.00000e+00	5.43171e-01	0.00000e+00	5.82727e-01	3.95560e-02
4	7.03265e+00	4.01940e+00	2.57461e+00	0.00000e+00	3.66818e-01	0.00000e+00	4.38641e-01	7.18229e-02
5	7.07728e+00	4.56523e+00	2.36325e+00	0.00000e+00	4.09193e-02	0.00000e+00	1.48799e-01	1.07880e-01
6	8.07867e+00	6.11931e+00	1.84206e+00	0.00000e+00	2.02359e-03	0.00000e+00	1.17301e-01	1.15277e-01
7	1.03175e+01	9.05783e+00	1.12986e+00	0.00000e+00	7.10000e-05	0.00000e+00	1.29769e-01	1.29698e-01
8	1.31779e+01	1.27086e+01	9.62384e-02	0.00000e+00	5.90640e-05	0.00000e+00	3.73092e-01	3.73033e-01
9	1.59748e+01	1.51273e+01	0.00000e+00	0.00000e+00	3.05779e-05	0.00000e+00	8.47496e-01	8.47465e-01
10	1.73039e+01	1.55836e+01	0.00000e+00	0.00000e+00	3.08603e-04	0.00000e+00	1.72031e+00	1.72000e+00
11	2.06349e+01	1.69377e+01	0.00000e+00	0.00000e+00	1.50924e-08	0.00000e+00	3.69708e+00	3.69708e+00
12	2.31954e+01	1.59055e+01	0.00000e+00	0.00000e+00	1.29848e-08	0.00000e+00	7.28987e+00	7.28987e+00
13	1.83588e+01	1.06053e+01	0.00000e+00	0.00000e+00	2.07583e-08	0.00000e+00	7.75345e+00	7.75345e+00
14	2.48205e+01	9.37061e+00	0.00000e+00	0.00000e+00	3.57114e-08	0.00000e+00	1.54499e+01	1.54499e+01
15	9.01667e+00	8.51210e+00	0.00000e+00	0.00000e+00	5.39731e-08	0.00000e+00	5.04566e-01	5.04566e-01
16	9.17060e+00	8.68621e+00	0.00000e+00	0.00000e+00	6.65200e-08	0.00000e+00	4.84387e-01	4.84386e-01
17	9.26085e+00	8.76022e+00	0.00000e+00	0.00000e+00	7.42999e-08	0.00000e+00	5.00628e-01	5.00628e-01
18	9.31920e+00	8.80382e+00	0.00000e+00	0.00000e+00	7.92970e-08	0.00000e+00	5.15384e-01	5.15384e-01
19	9.34802e+00	8.83951e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	5.08503e-01	5.08503e-01
20	9.51989e+00	8.88286e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	6.37022e-01	6.37022e-01
21	9.67282e+00	8.91087e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	7.61958e-01	7.61958e-01
22	9.78755e+00	8.92201e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	8.65534e-01	8.65534e-01
23	1.00970e+01	8.93650e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	1.16052e+00	1.16052e+00
24	1.06110e+01	8.94926e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	1.66175e+00	1.66175e+00
25	1.11314e+01	8.94923e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	2.18220e+00	2.18220e+00
26	1.20527e+01	8.95198e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	3.10069e+00	3.10069e+00
27	1.47971e+01	8.94198e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	5.85514e+00	5.85514e+00

xsec id grp.	102	251	252	253	452	1099	1018
1	3.58692e-03	8.08068e-01	1.64030e-03	3.84509e-03	3.53449e+00	7.68845e-01	2.36848e-02
2	1.42103e-02	7.73573e-01	1.92089e-03	3.85576e-03	2.95861e+00	7.67545e+00	1.95789e-01
3	3.95560e-02	6.42278e-01	3.03254e-03	4.35540e-03	2.68421e+00	9.24023e+00	2.16127e-01
4	7.18229e-02	5.52100e-01	3.79385e-03	4.61818e-03	2.57399e+00	5.47885e+00	1.23569e-01
5	1.07880e-01	4.88957e-01	4.33066e-03	4.77056e-03	2.51106e+00	7.40776e+00	1.63493e-01
6	1.15277e-01	3.73533e-01	5.30850e-03	4.86869e-03	2.44153e+00	8.16524e+00	1.76058e-01
7	1.29698e-01	2.16284e-01	6.64037e-03	5.11835e-03	2.36455e+00	4.10472e+00	8.68714e-02
8	3.73033e-01	4.08503e-02	8.12632e-03	5.54290e-03	2.32570e+00	1.77195e+00	1.33721e-02
9	8.47465e-01	3.61991e-03	8.44315e-03	5.63915e-03	2.32146e+00	1.73459e+00	9.70255e-04
10	1.72000e+00	2.82522e-03	8.45049e-03	5.64162e-03	2.31964e+00	1.69644e+00	7.20624e-05
11	3.69708e+00	2.82522e-03	8.45049e-03	5.64162e-03	2.31954e+00	1.70474e+00	5.66937e-06
12	7.28987e+00	2.82523e-03	8.45048e-03	5.64161e-03	2.31951e+00	1.20396e+00	3.98262e-07
13	7.75345e+00	2.82523e-03	8.45047e-03	5.64161e-03	2.31950e+00	1.09861e+00	6.32403e-08
14	1.54499e+01	2.82523e-03	8.45049e-03	5.64161e-03	2.31949e+00	1.18744e+00	1.25325e-08
15	5.04566e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31949e+00	5.44161e-01	1.41632e-09
16	4.84386e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31950e+00	3.08616e-01	4.15882e-10
17	5.00628e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31950e+00	1.40146e-01	1.33933e-10
18	5.15384e-01	2.82523e-03	8.45050e-03	5.64162e-03	2.31950e+00	1.22215e-01	9.58917e-11
19	5.08503e-01	2.82523e-03	8.45050e-03	5.64162e-03	0.00000e+00	2.23143e-01	1.35571e-10
20	6.37022e-01	2.82523e-03	8.45049e-03	5.64162e-03	0.00000e+00	6.93146e-01	2.20454e-10
21	7.61958e-01	2.82523e-03	8.45050e-03	5.64162e-03	0.00000e+00	2.07639e-01	3.22671e-11
22	8.65534e-01	2.82522e-03	8.45049e-03	5.64161e-03	0.00000e+00	3.67724e-01	3.74372e-11
23	1.16052e+00	2.82508e-03	8.45005e-03	5.64132e-03	0.00000e+00	8.98703e-01	3.57942e-11
24	1.66175e+00	2.82551e-03	8.45136e-03	5.64219e-03	0.00000e+00	1.88090e+00	9.74279e-12
25	2.18220e+00	2.82514e-03	8.45022e-03	5.64144e-03	0.00000e+00	1.51609e+00	2.85204e-12
26	3.10069e+00	2.82513e-03	8.45020e-03	5.64142e-03	0.00000e+00	1.61753e+00	1.99986e-12
27	5.85514e+00	2.82522e-03	8.45049e-03	5.64161e-03	0.00000e+00	3.59148e-01	4.76573e-13

Table C.4. Original NITAWL-II 3-D consistency results

neutron 1-d cross sections for uranium-238 endf/b-iv mat 1262 updated 10/12/89 id = 392238

xsec id / grp.	1	2	4	16	18	17	27	101
1	6.47332e+00	3.46587e+00	1.21051e+00	8.43215e-01	9.44658e-01	5.48078e-03	9.48245e-01	3.58692e-03
2	7.79746e+00	4.72140e+00	2.49626e+00	6.65531e-04	5.64925e-01	0.00000e+00	5.79136e-01	1.42103e-02
3	7.46424e+00	4.38786e+00	2.49366e+00	0.00000e+00	5.43171e-01	0.00000e+00	5.82727e-01	3.95560e-02
4	7.03265e+00	4.01940e+00	2.57461e+00	0.00000e+00	3.66818e-01	0.00000e+00	4.38641e-01	7.18229e-02
5	7.07728e+00	4.56523e+00	2.36325e+00	0.00000e+00	4.09193e-02	0.00000e+00	1.48799e-01	1.07880e-01
6	8.07867e+00	6.11931e+00	1.84206e+00	0.00000e+00	2.02359e-03	0.00000e+00	1.17301e-01	1.15277e-01
7	1.03175e+01	9.05783e+00	1.12986e+00	0.00000e+00	7.10000e-05	0.00000e+00	1.29769e-01	1.29698e-01
8	1.31779e+01	1.27086e+01	9.62384e-02	0.00000e+00	5.90640e-05	0.00000e+00	3.73092e-01	3.73033e-01
9	1.59973e+01	1.51478e+01	0.00000e+00	0.00000e+00	3.05779e-05	0.00000e+00	8.49518e-01	8.49487e-01
10	1.76371e+01	1.58684e+01	0.00000e+00	0.00000e+00	3.09473e-04	0.00000e+00	1.76870e+00	1.76839e+00
11	2.13201e+01	1.74196e+01	0.00000e+00	0.00000e+00	1.50924e-08	0.00000e+00	3.90044e+00	3.90044e+00
12	2.41437e+01	1.64038e+01	0.00000e+00	0.00000e+00	1.29848e-08	0.00000e+00	7.73988e+00	7.73988e+00
13	1.90806e+01	1.07816e+01	0.00000e+00	0.00000e+00	2.07583e-08	0.00000e+00	8.29900e+00	8.29900e+00
14	2.60055e+01	9.43297e+00	0.00000e+00	0.00000e+00	3.57114e-08	0.00000e+00	1.65725e+01	1.65725e+01
15	9.01667e+00	8.51210e+00	0.00000e+00	0.00000e+00	5.39731e-08	0.00000e+00	5.04566e-01	5.04566e-01
16	9.17060e+00	8.68621e+00	0.00000e+00	0.00000e+00	6.65200e-08	0.00000e+00	4.84387e-01	4.84386e-01
17	9.26085e+00	8.76022e+00	0.00000e+00	0.00000e+00	7.42999e-08	0.00000e+00	5.00628e-01	5.00628e-01
18	9.31920e+00	8.80382e+00	0.00000e+00	0.00000e+00	7.92970e-08	0.00000e+00	5.15384e-01	5.15384e-01
19	9.34802e+00	8.83951e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	5.08503e-01	5.08503e-01
20	9.51989e+00	8.88286e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	6.37022e-01	6.37022e-01
21	9.67282e+00	8.91087e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	7.61958e-01	7.61958e-01
22	9.78755e+00	8.92201e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	8.65534e-01	8.65534e-01
23	1.00970e+01	8.93650e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	1.16052e+00	1.16052e+00
24	1.06110e+01	8.94926e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	1.66175e+00	1.66175e+00
25	1.11314e+01	8.94923e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	2.18220e+00	2.18220e+00
26	1.20527e+01	8.95198e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	3.10069e+00	3.10069e+00
27	1.47971e+01	8.94198e+00	0.00000e+00	0.00000e+00	0.00000e+00	0.00000e+00	5.85514e+00	5.85514e+00

xsec id / grp.	102	251	252	253	452	1099	1018
1	3.58692e-03	8.08068e-01	1.64030e-03	3.84509e-03	3.53449e+00	7.68845e-01	2.36848e-02
2	1.42103e-02	7.73573e-01	1.92089e-03	3.85576e-03	2.95861e+00	7.67545e+00	1.95789e-01
3	3.95560e-02	6.42278e-01	3.03254e-03	4.35540e-03	2.68421e+00	9.24023e+00	2.16127e-01
4	7.18229e-02	5.52100e-01	3.79385e-03	4.61818e-03	2.57399e+00	5.47885e+00	1.23569e-01
5	1.07880e-01	4.88957e-01	4.33066e-03	4.77056e-03	2.51106e+00	7.40776e+00	1.63493e-01
6	1.15277e-01	3.73533e-01	5.30850e-03	4.86869e-03	2.44153e+00	8.16524e+00	1.76058e-01
7	1.29698e-01	2.16284e-01	6.64037e-03	5.11835e-03	2.36455e+00	4.10472e+00	8.68714e-02
8	3.73033e-01	4.08503e-02	8.12632e-03	5.54290e-03	2.32570e+00	1.77195e+00	1.33721e-02
9	8.49487e-01	3.61991e-03	8.44315e-03	5.63915e-03	2.32146e+00	1.73459e+00	9.70255e-04
10	1.76839e+00	2.82522e-03	8.45049e-03	5.64162e-03	2.31964e+00	1.69644e+00	7.20624e-05
11	3.90044e+00	2.82522e-03	8.45049e-03	5.64162e-03	2.31954e+00	1.70474e+00	5.66937e-06
12	7.73988e+00	2.82523e-03	8.45048e-03	5.64161e-03	2.31951e+00	1.20396e+00	3.98262e-07
13	8.29900e+00	2.82523e-03	8.45047e-03	5.64161e-03	2.31950e+00	1.09861e+00	6.32403e-08
14	1.65725e+01	2.82523e-03	8.45049e-03	5.64161e-03	2.31949e+00	1.18744e+00	1.25325e-08
15	5.04566e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31949e+00	5.44161e-01	1.41632e-09
16	4.84386e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31950e+00	3.08616e-01	4.15882e-10
17	5.00628e-01	2.82523e-03	8.45049e-03	5.64162e-03	2.31950e+00	1.40146e-01	1.33933e-10
18	5.15384e-01	2.82523e-03	8.45050e-03	5.64162e-03	2.31950e+00	1.22215e-01	9.58917e-11
19	5.08503e-01	2.82523e-03	8.45050e-03	5.64162e-03	0.00000e+00	2.23143e-01	1.35571e-10
20	6.37022e-01	2.82523e-03	8.45049e-03	5.64162e-03	0.00000e+00	6.93146e-01	2.20454e-10
21	7.61958e-01	2.82523e-03	8.45050e-03	5.64162e-03	0.00000e+00	2.07639e-01	3.22671e-11
22	8.65534e-01	2.82522e-03	8.45049e-03	5.64161e-03	0.00000e+00	3.67724e-01	3.74372e-11
23	1.16052e+00	2.82508e-03	8.45005e-03	5.64132e-03	0.00000e+00	8.98703e-01	3.57942e-11
24	1.66175e+00	2.82551e-03	8.45136e-03	5.64219e-03	0.00000e+00	1.88090e+00	9.74279e-12
25	2.18220e+00	2.82514e-03	8.45022e-03	5.64144e-03	0.00000e+00	1.51609e+00	2.85204e-12
26	3.10069e+00	2.82513e-03	8.45020e-03	5.64142e-03	0.00000e+00	1.61753e+00	1.99986e-12
27	5.85514e+00	2.82522e-03	8.45049e-03	5.64161e-03	0.00000e+00	3.59148e-01	4.76573e-13

Table C.5. Summary of KENO V.a hole intersection messages

k5.r1

case	KENO V.a messages							SYSTEM		
	k5-91	k5-92	k5-166	k5-169	k5-179	k5-100	k5-133	stop 129	user 0129	user 0000
k5case1h	0	0	0	0	0	0	45	0	0	45
k5case1i	135	0	90	45	0	45	0	45	45	0
k5case1o	135	0	45	90	0	45	0	45	45	0
k5case2h	0	0	0	0	0	0	27	0	0	27
k5case2i	81	0	54	27	0	27	0	27	27	0
k5case2o	81	0	27	54	0	27	0	27	27	0
k5case3h	0	0	0	0	0	0	36	0	0	36
k5case3i	252	0	216	36	0	36	0	36	36	0
k5case3o	252	0	108	144	0	36	0	36	36	0
k5case4h	0	0	0	0	0	0	5	0	0	5
k5case4i	40	0	40	0	0	5	0	5	5	0
k5case4o	40	0	0	40	0	5	0	5	5	0
k5intrs	600	4	4	12	582	15	0	15	15	0
k5shape	0	0	0	0	0	0	0	0	0	28

Table C.6. KENO V.a start options results

Start type	k-effective	Deviation
0	1.0067	0.0039
1	0.9965	0.0037
2	1.0050	0.0035
3	1.0033	0.0036
4	1.0006	0.0029
5	1.0071	0.0034
6	1.0073	0.0033

Table C.7. KENO V.a geometric orientation results

Plot No.	Figure C.1	Plot No.	Figure C.1	Plot No.	Figure C.1
1	1	17	6	30	2
2-5	4	18	2	31	5
6	2	19	5	32	3
7	5	20	3	33	6
8	3	21	6	34	2
9	6	22	2	35	5
10	2	23	5	36	3
11	5	24	3	37	6
12	3	25	6	38	2
13	6	26	2	39	5
14	2	27	5	40	3
15	5	28	3	41	6
16	3	29	6		

Table C.8. Comparative results for XSDRN and KENO V.a

	XSDRN			KENO						
Case	Lambda	Absorption	Leakage	k_{eff}	Dev.	Abs1	Leak1	Deviation[a]	Fract.[b] abs. dev.	Fract.[c] leak dev.
IA1xk0	1.09720	.511193	0.490543	1.0964	.0011	.510764	0.491045	-0.7273	-.00084	.00102
IA1xk1	1.02060	.475509	0.526105	1.0184	.0010	.474417	0.526901	-0.2000	-.00230	.00151
IA1xk2	1.02060	.475509	0.526105	1.0212	.0010	.475790	0.525904	0.6000	.00059	-.00038
IA1xk3	1.02060	.475509	0.526105	1.0211	.0010	.475742	0.525947	0.5000	.00049	-.00030
IA2xk3	1.06196	.787136	0.212415	1.0619	.0024	.784903	0.214511	-0.0250	-.00284	.00987
IA3xk0	1.20131	.653637	0.355844	1.2005	.0011	.653095	0.356379	-0.7364	-.00083	.00150
IA3xk1	1.09410	.597894	0.410948	1.0936	.0010	.597693	0.411005	-0.5000	-.00034	.00014
IA3xk2	1.09436	.598102	0.410750	1.0931	.0010	.597563	0.411589	-1.2600	-.00090	.00204
IA3xk3	1.09436	.598102	0.410750	1.0935	.0010	.597588	0.411238	-0.8600	-.00086	.00119
IA4xk0	0.533307	.248470	0.752372	0.5328	.0008	.248241	0.752577	-0.6338	-.00092	.00027
IA4xk1	0.506174	.235832	0.764967	0.5067	.0007	.236086	0.764704	0.7514	.00108	-.00034
IA4xk2	0.506174	.235832	0.764967	0.5060	.0007	.235751	0.765090	-0.2486	-.00034	.00016
IA4xk3	0.506174	.235832	0.764967	0.5075	.0007	.236456	0.764365	1.8943	.00265	-.00079
IB1xk0	1.08591	.505932	0.495781	1.0882	.0010	.507011	0.494835	2.2900	.00213	-.00191
IB1xk1	1.01864	.474596	0.527011	1.0173	.0010	.473962	0.527572	-1.3400	-.00134	.00106
IB1xk2	1.01864	.474596	0.527011	1.0187	.0010	.474627	0.527105	0.0600	.00007	.00018
IB1xk3	1.01864	.474596	0.527011	1.0184	.0010	.474540	0.526919	-0.2400	-.00012	-.00017
IB3xk3	1.07683	.838382	0.160853	1.0841	.0034	.839726	0.159802	2.1382	.00160	-.00653
IC1xk0	0.933080	.434725	0.566747	0.9329	.0009	.434672	0.566834	-0.2000	-.00012	.00015
IC1xk1	0.891261	.415245	0.586162	0.8924	.0009	.415782	0.585654	1.2656	.00129	-.00080
IC1xk2	0.891261	.415245	0.586162	0.8904	.0009	.414809	0.586675	-0.9578	-.00105	.00095
IC1xk3	0.891261	.415245	0.586162	0.8905	.0009	.414888	0.586604	-0.8456	-.00086	.00083
IC3xk3	1.13461	.998221	2.12-6	1.1372	.0031	.997727	0.0	0.8355	-.00049	---
IIA1xk0	1.20537	.644433	0.354711	1.2044	.0015	.643859	0.355198	-0.6467	-.00089	.00137
IIA1xk1	0.923599	.494462	0.504905	0.9230	.0014	.494179	0.505180	-0.4279	-.00057	.00054
IIA1xk2	0.923599	.494462	0.504905	0.9234	.0015	.494300	0.505252	-0.1327	-.00033	.00069
IIA1xk3	0.923599	.494462	0.504905	0.9226	.0014	.493742	0.505489	-0.7136	-.00146	.00116
IIA3xk3	0.842331	.547456	0.451261	0.8404	.0021	.546618	0.451947	-0.9195	-.00153	.00152
IIB1xk0	1.17969	.630784	0.368374	1.1794	.0014	.630605	0.368590	-0.2071	-.00028	.00059
IIB1xk1	0.913573	.489156	0.510212	0.9140	.0014	.489469	0.510200	0.3050	.00064	-.00002
IIB1xk2	0.913573	.489156	0.510212	0.9130	.0014	.488820	0.510571	-0.4093	-.00069	.00070
IIB1xk3	0.913573	.489156	0.510212	0.9145	.0014	.489622	0.509789	0.6621	.00095	-.00083
IIB3xk3	0.592549	.365717	0.633458	0.5952	.0017	.367206	0.632214	1.5594	.00407	-.00196
IIC1xk0	1.00691	.538886	0.460406	1.0075	.0015	.539157	0.460165	0.3933	.00050	-.00052
IIC1xk1	0.780377	.418326	0.581147	0.7822	.0014	.419398	0.579709	1.3021	.00256	-.00247
IIC1xk2	0.780377	.418326	0.581147	0.7840	.0014	.420265	0.579410	2.5879	.00464	-.00299
IIC1xk3	0.780377	.418326	0.581147	0.7845	.0014	.420373	0.578786	2.9450	.00489	-.00406
IIC3xk3	0.948306	.996428	3.88649-7	0.9532	.0039	.997170	0.0	1.2549	.00074	---

[a] Number of KENO standard deviations between KENO results and k_{eff} = 1.0000.
[b] Difference in fraction absorptions between XSDRN and KENO normalized to the XSDRN results.
[c] Difference in fraction leakage between XSDRN and KENO normalized to the XSDRN results.

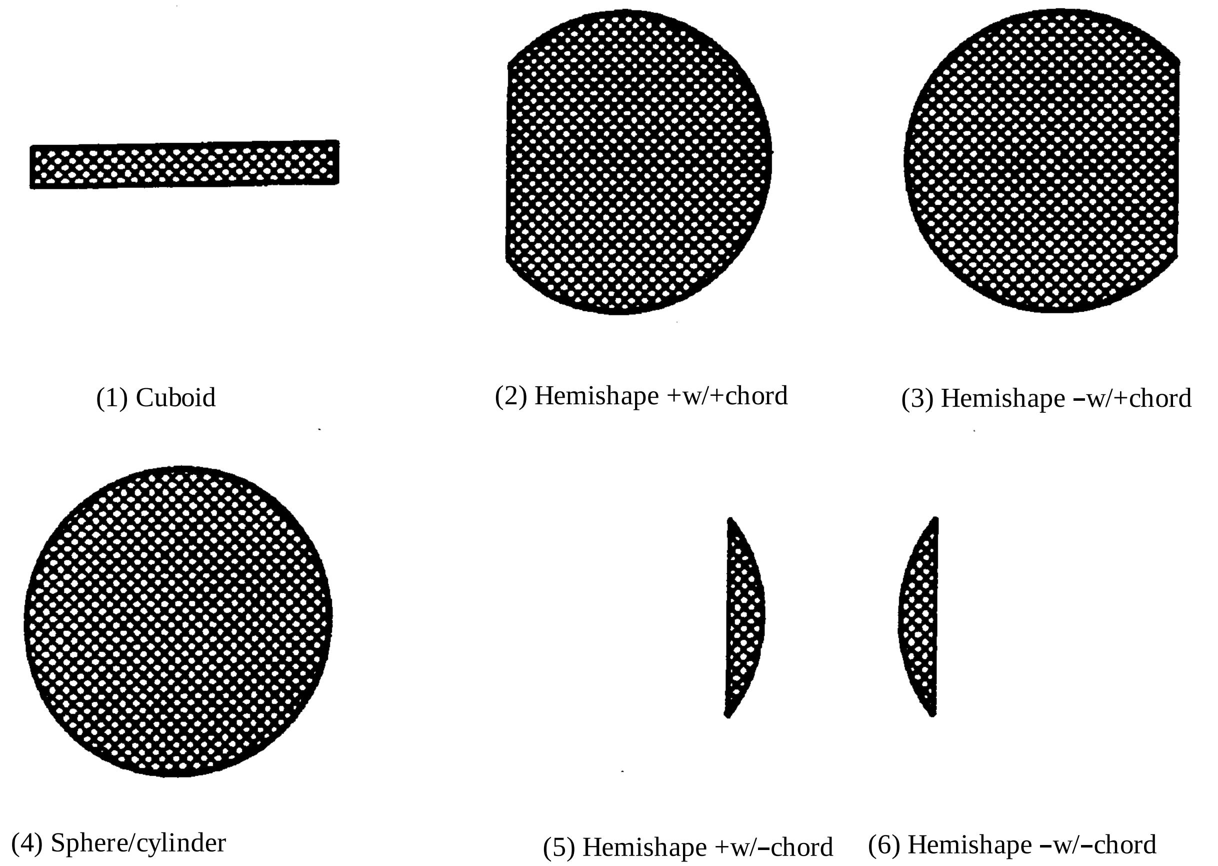

Figure C.1. Plots of geometric orientation

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NRC FORM 335 (2-89) NRCM 1102 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

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(See instructions on the reverse)

1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-6483
ORNL/TM-12834

2. TITLE AND SUBTITLE

Guide to Verification and Validation of the SCALE-4 Criticality Safety Software

3. DATE REPORT PUBLISHED

MONTH	YEAR
December	1996

4. FIN OR GRANT NUMBER

B0009

5. AUTHOR(S)

M. B. Emmett, W. C. Jordan

6. TYPE OF REPORT

Technical

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION — NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

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9. SPONSORING ORGANIZATION — NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Regulatory Commission, and mailing address.)*

Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

10. SUPPLEMENTARY NOTES

C. J. Withee, NRC Project Manager ***(Revised 4/11/2000)***

11. ABSTRACT *(200 words or less)*

Whenever a decision is made to newly install the SCALE nuclear criticality safety software on a computer system, the user should run a set of verification and validation (V&V) test cases to demonstrate that the software is properly installed and functioning correctly. This report is intended to serve as a guide for this V&V in that it specifies test cases to run and gives expected results. The report describes the V&V that has been performed for the nuclear criticality safety software in a version of SCALE-4.[1]

The verification problems specified by the code developers have been run, and the results compare favorably with those in the SCALE 4.2 baseline.[2] The results reported in this document are from the SCALE 4.2P version which was run on an IBM RS/6000 workstation. These results verify that the SCALE-4 nuclear criticality safety software has been correctly installed and is functioning properly.

A validation has been performed for KENO V.a[3] utilizing the CSAS25 (ref. 4) criticality sequence and the SCALE 27-group cross-section library for ^{233}U, ^{235}U, and ^{239}Pu fissile systems in a broad range of geometries and fissile fuel forms. The experimental models used for the validation were taken from three previous validations of KENO V.a. A statistical analysis of the calculated results was used to determine the average calculational bias and a subcritical k_{eff} criteria for each class of systems validated. Included in the statistical analysis is a means of estimating the margin of subcriticality in k_{eff}. This validation demonstrates that KENO V.a and the 27-group library may be used for nuclear criticality safety computations provided the system being analyzed falls within the range of the experiments used in the validation.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

SCALE, criticality safety, radiation shielding, verification, validation

13. AVAILABILITY STATEMENT

unlimited

14. SECURITY CLASSIFICATION

(This Page) unclassified

(This Report) unclassified

15. NUMBER OF PAGES

16. PRICE