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COMPUTER SCIENCES DIVISION

SCALE: A Modular Code System For Performing Standardized Computer Analyses For Licensing Evaluation

SCALE System Criticality Safety Analysis Modules CSAS1 and CSAS2

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FOREWORD

The SCALE "system" contains:

1. A number of large, well-established, stand-alone computer codes for neutronic and heat transfer analysis (denoted here as "functional modules").
2. A number of new, well-documented computer codes (denoted here as "control modules"), which read highly simplified sets of input data and invoke one or more of the functional modules in a pre-established sequence to perform a very specific type of criticality, shielding, or heat transfer analysis for a given problem.
3. A driver package which interfaces with the local computer system to provide the software and operating environment in which the various control modules may be executed.
4. A number of data libraries containing nuclear cross section data, material properties, thermal constants, etc.

While each of the functional modules (NITAWL, XSDRNPM, ORIGEN, MORSE, KENO, HEATING, etc.) may still be used separately to model different aspects of a given problem, the heart of the SCALE "system" lies in the various control modules. The control modules read a highly simplified set of input describing a given problem, perform a number of auxiliary calculations formerly required of the user, and run the necessary functional modules (sometimes in an iterative fashion) to achieve the desired solution. The high degree of automation provided by the control modules, as well as the use of well-established data libraries, is intended to provide the type of standardization required for the licensing process.

The development of the SCALE system has been due to the efforts of numerous people over a period of several years. It is expected that documentation for each component of the SCALE sysem will be released as it becomes available. Except for the functional modules, all necessary documentation will be developed by the individual responsible for the particular module.

This document describes the CSAS1 and CSAS2 criticality safety analysis sequences and some of the associated data libraries. A special "tutorial" on the use of KENO-IV geometry has been included as Appendix C. Appendix D, which will be issued in the near future, is intended to provide some supplementary notes on the resonance self-shielding techniques currently used in the SCALE system. This document, like the control modules described herein, has been prepared by J. A. Bucholz. The routines which calculate the Dancoff factor, and portions of the Material Information Processor, were supplied by J. R. Knight. Appreciation for the over-all guidance provided by L. M. Petrie is also acknowledged.

– R. M. Westfall – (12/10/79)

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Inspiration, guidance and computational assistance for this project have been provided by several individuals meriting special acknowledgement. The concept of a Material Information Processor using alphanumeric material specifications was originally proposed by R. M. Westfall, and developed by him in some detail. Using that conceptual outline, J. R. Knight developed the Standard Composition Library and many of the associated data processing routines. Special routines to calculate the Dancoff factor and other resonance parameters were also supplied by J. R. Knight. Lastly, the author is especially indebted to L. M. Petrie who developed the driver package for the SCALE system and who has provided many helpful comments throughout the course of this project.

The SCALE system CSAS1 and CSAS2 control modules have been available for internal use at ORNL for some time. Indeed, draft documentation for these control modules has been available for over two years. During that time numerous people have reviewed the documentation and have used one or the other control module. Their comments and suggestions have led to many improvements in both the code and the documentation. The text, for example, now contains many more examples than it previously did. Likewise, the code itself will generate many more self-explanatory error messages designed to help the novice user. For this type of careful review, the author is deeply indebted to: R. M. Westfall, L. M. Petrie, J. R. Knight, O. W. Hermann, N. F. Landers, W. King, B. R. Diggs, P. B. Fox, M. W. Waddell, J. S. Tang and various members of the NRC staff sponsoring this work.

Lastly, the author would like to acknowledge the various secretaries who have patiently contributed their skills and talents towards the final preparation of this document. In particular, the efforts of Billie Ferguson, Theresa Judd, Brenda Neeley, Cathy Oldham, and Pam Young are gratefully acknowledged.

– J. A. Bucholz – (12 18 79)

ABSTRACT

Under contract with the Nuclear Regulatory Commission, the Computer Sciences Division at Oak Ridge National Laboratory has developed the SCALE system for performing Standardized Computer Analyses for Licensing Evaluation of nuclear systems. The SCALE system includes a number of selected data libraries as well as various calculational modules for performing criticality, shielding and heat transfer analyses.

This document describes the CSAS1 and CSAS2 control modules which shield the group-averaged cross-section data for the given situation and perform a one-dimensional discrete ordinates or multidimensional Monte Carlo calculation to obtain the effective neutron multiplication factor (k-eff) for the configuration described by the user.

PROCEDURE FOR MAKING REVISIONS

This document, ORNL/NUREG/CSD-2 VOLUME 1, describes the "SCALE System Control Modules CSAS1 and CSAS2." Documentation for subsequent control modules will eventually be released as VOLUME 2, VOLUME 3, etc. Each volume is expected to describe a relatively large body of new information – such as the description of one or more control modules, one or more functional modules, etc. While VOLUME 1, describing the CSAS1 and CSAS2 control modules, is currently being issued in its own oversized loose-leaf binder, future volumes describing additional control modules may be inserted in the same binder as space permits. Each volume would, of course, have its own cover page (with appropriate subtitle), and each could be referenced separately as "ORNL/NUREG/CSD-2 VOLUME n." This scheme allows each volume to be issued independently over a period of time while still providing a mechanism for minor revisions within each volume as necessary.

Minor revisions within each volume may be necessary from time-to-time. Each revision should be issued with a cover letter listing any old pages to be deleted and/or any new pages to be inserted. It should also contain a brief description outlining the nature of each change. The cover letter accompanying each formal revision should then be inserted in this section (of the appropriate volume) so as to provide a permanent record of what changes were made and when. Future license applicants could then say, for example, that they used the CSAS2 control module as described in "ORNL/NUREG/CSD-2, VOLUME 1, REV. 1 through 4," etc.

SCALE SYSTEM CRITICALITY SAFETY ANALYSIS MODULES
CSAS1 and CSAS2: INDEX

1. INTRODUCTION TO CSAS1

Criticality Safety Analysis Sequence No. 1 (CSAS1) is used to calculate the effective neutron multiplication factor (k-eff) for one-dimensional systems. Unit cell calculations or larger "multiregion" calculations may be performed in slab, cylindrical or spherical geometry. Infinite homogeneous media calculations may also be performed.

This simple analytic sequence consists of two cross section processing codes (NITAWL[1] and BONAMI[6]) followed by a one-dimensional transport code (XSDRNPM[2]). The CSAS1 control module reads a single unified set of input and, after massaging that input and performing several auxiliary calculations, calls each of the functional modules*[1] in turn. The "auxiliary calculations" performed by the control module include a) the calculation of number densities for each nuclide in the system, b) the determination of Dancoff factors for the resonance self-shielding calculation,*[2] c) the determination of a satisfactory mesh spacing in each material zone, and d) establishing binary input files for each of the functional modules.

Any one of several multigroup cross section libraries may be selected in the input stream for a given problem. These master libraries include anisotropic scattering data and allow some temperature dependence for the resonance nuclides. On a given master library, a resonance nuclide will either have a full set of Bondarenko "shielding factors" for that group structure [$f_x^x(T,\sigma_0)$, $f_\gamma^x(T,\sigma_0)$,etc.] or a set of group-independent resonance parameters (E_0, Γ, etc.). Because of this data, the master libraries tend to be more problem-independent.

In the calculational sequence defined by CSAS1, the master cross section library selected will first be processed by the BONAMI code[6] which will perform a resonance self-shielding calculation for those nuclides which have Bondarenko data in lieu of resonance parameters. The self-shielded data for these nuclides, along with the original data for all the other nuclides, will then be stored "on-line" in the same format as the original master library. Data for non-resonance nuclides and data for nuclides with resonance parameters will essentially be copied onto this library (unchanged) from the original library. The NITAWL code[1] will then read this second master library, perform a resonance self-shielding calculation for those nuclides having resonance parameters, and collect the results into a "working" library which may be used by XSDRNPM. This working library has the same number of energy groups and the same group structure as the original master library selected

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*[1] When describing the various control modules such as CSAS1, the large stand-alone codes such as BONAMI, NITAWL, XSDRNPM, etc., are frequently referred to as "functional modules."

*[2] See Sect. 3.4 and/or Ref. 3 for details.

by the user. Unlike the original master library, it contains the self-shielded, group-averaged cross section data for the given physical situation.*3,*4

The XSDRNPM code[2] is a one-dimensional discrete-ordinates transport code. It is used by CSAS1 to determine the effective neutron multiplication factor (k-eff) of the given system. It uses multigroup cross sections from the working library produced by NITAWL.

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*3As noted below (c.f., Sect. 3.2 and 3.3), BONAMI uses the Bondarenko Method[5] to self-shield the group-averaged cross section data for the given physical situation while NITAWL uses the Nordheim Integral Method.[4] The mathematical details of each method are presented in Appendix D.

*4To the extent that this cross section library may be saved by the user for future use (c.f., Sect. 4 for the appropriate I/O unit), the CSAS1 control module might also be viewed as a convenient way of generating self-shielded, group-averaged cross section data with a minimal amount of effort.

2. INTRODUCTION TO CSAS2

Criticality Safety Analysis Sequence No. 2 (CSAS2) is used to calculate the effective neutron multiplication factor (k-eff) for multi-dimensional systems which can be described in KENO geometry.*1 Multiregion calculations involving either homogeneous fuel mixtures or heterogeneous fuel assemblies may be performed. As an option, a preliminary 1-D unit cell calculation may be performed to obtain homogenized cell-weighted cross sections for a fuel assembly. In the multi-dimensional calculation, each material (i.e., the individual components of each fuel pin) may be represented explicitly or the homogenized cell-weighted cross sections may be used.

The optional 1-D calculation referred to above allows the user to describe a unit cell in a fuel assembly, perform a 1-D eigenvalue calculation of the unit cell to determine the spatially dependent flux spectrum, cell-weight the microscopic cross section data with this spatially dependent spectrum, homogenize the nuclide number densities in the unit cell (i.e., in the fuel assembly), and then use these homogenized cell-weighted cross sections in a subseqent multidimensional KENO calculation. While the user must provide input describing the materials in the fuel, clad and moderator, the control module internally defines the homogenized cell-weighted cross sections as mixture No. 500. The user is then free to assign mixture 500 anywhere in the KENO input describing the multidimensional configuration. Although the user is still free to model each constituent part of each fuel pin in the multidimensional configuration (i.e., not use mixture 500 at all), it is frequently a great convenience to have this homogenized cell-weighted mixture available.

This analysis sequence consists of two cross section processing codes (NITAWL[1] and BONAMI[6]), a 1-D transport code for cell-weighting cross section data (XSDRNPM[2]), and a three-dimensional Monte Carlo code (KENO-IV[7]) for calculating the effective neutron multiplication factor (k-eff) for the entire system. The CSAS2 control module reads a single unified set of input and, after massaging that input and performing several auxiliary calculations, calls each of the functional modules in turn. It should be noted here that the execution path actually includes XSDRNPM only when one specifically uses mixture 500 in the multidimensional problem description. If it is not used anywhere, the XSDRNPM step is skipped and the cross section data produced by NITAWL is used in KENO-IV directly. (See below for additional details.)

The "auxiliary calculations" performed by the control module include a) the calculation of number densities for each nuclide in the system, b) the determination of Dancoff factors for the resonance self-shielding calculation,*2 c) the determination of a satisfactory mesh spacing in each material zone (if necessary), and d) establishing binary input files for each of the functional modules.

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*1 KENO geometry is three-dimensional and allows for the simultaneous use of cuboids, spheres, hemispheres, cylinders, hemicylinders and an imbedded array of such bodies. Thus, for example, an array of fuel assemblies imbedded in a cylindrical shipping cask may be represented exactly. See Sect. 6 and/or Appendix C for further details.

*2 See Sect. 3.4 and/or Ref. 3 for details.

Any one of several multigroup cross section libraries may be selected in the input stream for a given problem. These master libraries include anisotropic scattering data and allow some temperature dependence for the resonance nuclides. On a given master library, a resonance nuclide will have either a full set of Bondarenko "shielding factors" for that group structure [$f_x^g(T, \sigma_0)$, $f_\gamma^g(T, \sigma_0)$, etc.] or a set of group-independent resonance parameters (E_0, Γ, etc.). Because of this data, the master libraries tend to be more problem-independent.

In the calculational sequence defined by CSAS2, the master cross section library selected will first be processed by the BONAMI code[6] which will perform a resonance self-shielding calculation for those nuclides which have Bondarenko data in lieu of resonance parameters. The self-shielded data for these nuclides, along with the original data for all the other nuclides, will then be stored "on-line" in the same format as the original master library. Data for non-resonance nuclides and data for nuclides with resonance parameters will essentially be copied onto this library (unchanged) from the original library. The NITAWL code[1] will then read this second master library, perform a resonance self-shielding calculation for those nuclides having resonance parameters, and collect the results into a "working" library which may be used by XSDRNPM or KENO-IV. This working library has the same number of energy groups and the same group structure as the original master library selected by the user. Unlike the original master library, it contains the self-shielded, group-averaged cross section data for the given physical situation.*

XSDRNPM[2] is a one-dimensional discrete-ordinates transport code used by CSAS2 (when necessary) to obtain cell-weighted microscopic cross sections, $\overline{\sigma}_g(j)$, as defined by:

$$\overline{N}(j)\,\overline{\sigma}_g(j)\,\overline{\phi}_g\,V = \sum_i N(i,j)\,\sigma_g(i,j)\,\phi_g(i)\,V_i \qquad (1)$$

where $N(i,j)$ and $\sigma_g(i,j)$ represent the number density and cross section of nuclide j in the i^{th} spatial mesh interval, $\overline{N}(j)$ is the homogenized number density for the nuclide in the unit cell:

$$\overline{N}(j) = \frac{\sum_i N(i,j)\,V_i}{V} \qquad (2)$$

and $\overline{\phi}_g$ is the cell averaged flux for group g:

$$\overline{\phi}_g = \frac{\sum_i \phi_g(i)\,V_i}{V} \qquad (3)$$

To obtain the spatially dependent flux spectrum $\phi_g(i)$ used in Eqs. (1) and (3), XSDRNPM will perform a one-dimensional eigenvalue calculation for the unit cell. To insure good resolution, the control module will automatically determine the number of spatial mesh intervals to be used in each

*As noted below (c.f., Sect. 3.2 and 3.3), BONAMI uses the Bondarenko Method[5] to self-shield the group-averaged cross section data for the given physical situation while NITAWL uses the Nordheim Integral Method.[4] The mathematical details of each method are presented in Appendix D.

material zone. The cell-weighted "working" library produced by XSDRNPM will then have the same number of groups and the same group structure as the original master library selected by the user. Cross sections for the user-defined mixtures not found in the fuel assembly (such as the structural and shielding materials in a shipping cask) are effectively copied from the NITAWL working library to the XSDRNPM working library without change (i.e., without any cell-weighting).*4

KENO-IV[7] is a multigroup Monte Carlo code used by CSAS2 to determine the effective neutron multiplication factor (k-eff) of the multidimensional system specified by the user. KENO geometry is three- dimensional and allows for the simultaneous use of cuboids, spheres, hemispheres, cylinders, hemicylinders and an imbedded array of such bodies (see Sect. 6 and/or Appendix C for further details). The control module supplies KENO-IV with multigroup cross sections from the working library produced by XSDRNPM (if mixture 500 is used) or NITAWL (if mixture 500 is not used).*5

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*4To accomplish this, the control module actually inserts trace amounts (1×10^{-20} atoms/barn-cm) of each such nuclide into each zone of the XSDRNPM calculation. (Such small amounts will have no effect on the resulting flux distribution). Since σ_g (i,j) is constant and $\bar{N}(j) = N(i,j)$ is constant, they may be pulled out of the summation in Eq. (1), yielding:

$$\bar{N}(j)\,\bar{\sigma}_g(j)\,\bar{\phi}_g\,V = N(i,j)\,\sigma_g(i,j)\sum \phi_g(i)\,V, \tag{4}$$

$$\bar{\sigma}_g(j)\,\bar{\phi}_g\,V = \sigma_g(i,j)\,\bar{\phi}_g\,V \tag{5}$$

$$\bar{\sigma}_g(j) = \sigma_g(i,j) \tag{6}$$

*5To the extent that either cross section library may be saved by the user for future use (c.f., Sect. 4 for the appropriate I/O unit), the CSAS2 control module might also be viewed as a convenient way of generating self- shielded, group-averaged, cell-weighted cross section data with a minimal amount of effort.

3. AUXILIARY CALCULATIONS AND THEIR APPLICABILITY

3.1 Determination of Number Densities

To simplify the input and to eliminate the chance for human error, the control module internally applies a standardized procedure to calculate the number density for each nuclide in the system. It also creates the necessary mixing table(s) for use in XSDRNPM and/or KENO.

In the input stream (c.f., Sect. 6), the user describes all material mixtures found in his problem in terms of various "standard compositions"* and other engineering-type specifications such as their associated volume fraction or the percent theoretical density (grams/liter and acid molarity in the case of solutions), temperature (if the standard composition contains a resonance material), and isotopic distribution (if required). For each "standard composition," subroutine SETUPB scans the Standard Composition Library to determine: the theoretical density (grams/cc), the number of elements in the standard composition, whether or not any of the elements have more than one isotope, whether or not any of the nuclides require a resonance treatment, and whether the "standard composition" is a compound, alloy or solution.

In the case of solutions, subroutine SLNS will first decompose the solution into three standard compositions, each with an associated volume fraction. These correspond to the heavy metal compound, acid, and water components of the solution. Given the density of the fuel (ρ) in grams/liter, the acid molarity (m) and the volume fraction of the solution (all specified on the input card), each of the three associated volume fractions will be calculated using Eqs. (7-9). These equations are based on empirical fits to experimental data.[8] Each of the three standard composition components will then be treated in the appropriate fashion.

$$V[UO2F2]/V[SOLNUO2F2] = (0.203697)\rho \tag{7a}$$

$$V[HF]/V[SOLNUO2F2] = (0.0200063)m \tag{7b}$$

$$V[H2O]/V[SOLNUO2F2] = (1.00327) - (0.16596)\rho - (0.01)m \tag{7c}$$

$$V[UO2(NO3)2]/V[SOLNUO2(NO3)2] = (0.751439)\rho \tag{8a}$$

$$V[HNO3]/V[SOLNUO2(NO3)2] = (0.0630128)m \tag{8b}$$

$$V[H2O]/V[SOLNUO2(NO3)2] = (1.3012) - (0.32072)\rho - (0.03205)m \tag{8c}$$

$$V[PU(NO3)4]/V[SOLNPU(NO3)4] = (0.832750)\rho \tag{9a}$$

$$V[HNO3]/V[SOLNPU(NO3)4] = (0.0630128)m \tag{9b}$$

$$V[H2O]/V[SOLNPU(NO3)4] = (1.0000) - (0.3620)\rho - (0.0331)m \tag{9c}$$

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*See Table A.1 for a list of the standard compositions (UO_2, SS304, etc.) that are in the Standard Composition Library and available for use.

From the Standard Composition Library, SETUPB also determines the number of atoms per molecule (if the standard composition is a compound) or the wt % of each element (if the standard composition is an alloy). It also determines the atomic mass of each nuclide in the standard composition, the I.D. number corresponding to each of these nuclides on the master cross section library, and other miscellaneous data. For elements with more than one isotope, SETUPB will read the isotopic distribution specified by the user (wt %) or default to the naturally occurring abundances (wt %) stored in the Isotope Distribution Table.*

To calculate the nuclide number densities in a compound where one of the elements has two or more isotopes (like (UO_2), it is necessary to know the number fraction (i.e., atom %) of each isotope in the element. While the wt % may be calculated easily given the atom %, the inverse determination requires the solution of a set of N linear equations in N unknowns, where N is the number of isotopes in the element. This task is handled by subroutines NOFRAC and WTINV.

Given that an element (EL) may have one or more isotopes (I), the number density of each isotope (N_I) is calculated using

$$N_I = \rho V A_0 (w_{EL/AL})(w_{I/EL})/M_I \tag{10}$$

if the standard composition is an alloy, and

$$N_I = \rho V A_0 \left[\frac{n_{I/EL} \; N_{EL/mol}}{\sum_{J} \sum_{i \in J} (n_{i \in J} \; N_{el/mol} \; M_i)} \right] \tag{11}$$

if the standard composition is a compound. Here,

N_I = no. density of isotope "I" in atoms/(barn-cm)

ρ = theoretical density in grams/cc

V = volume fraction (or % theoretical density) of this standard composition in the specified mixture

A_0 = Avagadro's number divided by 10^{24} ($A_0 = 0.602252$)

$w_{EL/AL}$ = wt. fraction of the element (EL) in the alloy

*See Table A.3.

$w_{I/EL}$ = wt. fraction of the isotope (I) in the element (EL)

$n_{I/EL}$ = no. fraction of the isotope (I) in the element (EL)

$n_{i/el}$ = no. fraction of isotope "i" in element "el"

$N_{EL/mol}$ = no. of atoms of the element (EL) per molecule

$N_{el/mol}$ = no. of atoms of element "el" per molecule

M_I = atomic mass of the isotope (I)

M_i = atomic mass of isotope "i"

$\sum_{el}$ denotes a summation over all elements (el) in the standard composition (i.e., in the compound)

and

$\sum_{i/el}$ denotes a summation over all isotopes (i) in the particular element (el).

Subroutine MIXTAB uses the above equations and the informaion extracted by SETUPB from the Standard Composition Library to calculate the number density for each nuclide in each mixture specified by the user. It then sets up the necessary mixing table(s) as required by XSDRNPM and/or KENO. Other information (including some resonance data and an array of alias nuclide I.D.'s) is also passed back for use in BONAMI and NITAWL.

3.2 Applicability of the Nordheim Method

The Nordheim Integral Method[4] is the most accurate of the three self-shielding approximations available in the NITAWL code[1] and the only one that will be used here. Nevertheless, it does have some limitations that merit attention.

When calculating the group-averaged cross sections for a particular resonance nuclide, NITAWL calculates the energy dependent collision density using a single integral equation in which the slowing-down integrals for the absorber nuclide and at most two moderating nuclides (in the fuel lump) are explicitly represented. An asymptotic term representing the slowing-down source from adjacent zones is also included. This expression for $\Sigma_t(E)\phi(E)$ is then evaluated*1 for each resonance, with the asymptotic form of the flux being assumed between resonances. As always, the flux is assumed to have no spatial dependence.

Failure to account for the presence of more than one resonance nuclide at a time means that the multigroup cross sections for each resonance nuclide will be weighted with a slightly different flux spectrum even though they are in the same spatial zone. This may cause some inaccuracies whenever the resonances of two or more nuclides overlap (c.f., the resonances of ^{232}Th ^{233}U ^{235}U ^{238}U in an advanced thorium convertor, or the resonances of ^{235}U ^{238}U ^{239}Pu ^{240}Pu ^{241}Pu ^{242}Pu in an LMFBR). Failure to account for resonance nuclides in adjacent zones may cause other inaccuracies when, for example, the resonances in the fuel overlap with the Mn resonances in the clad. In such a case, it may be a poor premise to assume an asymptotic contribution from the adjacent zone.

Even in the case of a single resonance nuclide in a single spatial zone, the present coding does not properly account for the overlap between two resonances. This limitation becomes a real problem when attempting to produce good, self-shielded cross section data for ^{233}U or ^{241}Pu.*2 In its present form, NITAWL solves the Nordheim Integral Equation by expanding the slowing-down integral(s) in a three-point formula corresponding to Simpson's Rule; it then marches from the highest to the lowest energy, developing a numerical value for the energy dependent flux and collision density as it goes. For computational efficiency, it does not carry out this process over all energy but instead: 1) it assumes the resonances are well isolated; 2) it uses the asymptotic solution for the flux between resonances; and 3) it assumes the asymptotic value for the flux [$\phi_\infty = 1/(\overline{\xi\Sigma}_p E)$] at the upper end of a resonance, over which it will calculate $\phi(E)$ in the fashion described above.

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*1 For the derivation of the Nordheim Integral Equation and a mathematical discussion of the various approximations, the interested reader is referred to Appendix D.

*2 Unlike most nuclides, ^{233}U and ^{241}Pu each exhibit a great deal of self-overlap such that when calculating the collision density at energy E underneath one resonance, the range E to E/α will nearly always include another resonance.

Since NITAWL treats only one resonance at a time, it assumes this asymptotic value [ϕ_∞] at the top of each resonance when, if the resonances are overlapped, the actual flux [ϕ(E)] may be quite different. Thus, the calculated collision density at any lower energy does not include the scattering sources from the higher energy resonances. The other difficulty, of course, lies in the assumption that the cross section, σ(E), is well represented by the Breit-Wigner formula for an isolated resonance when, if the resonances are overlapped, the actual cross section near the wings of the resonance may be quite different.

To arrive at the single integral equation solved by NITAWL, it was necessary to decouple the integral neutron balance equations for each zone by assuming that the energy loss per collision with nuclides in all zones other than the one of interest is always large compared with the practical width of the resonance (c.f., Appendix D). Replacing ϕ(E) in these other zones with the asymptotic flux [ϕ_∞] and assuming constant potential scattering, the slowing-down sources from these zones can be shown to be asymptotic (1/E). Normally, this is quite good. However, when performing a resonance calculation for a nuclide in the clad (such as the Mn component of SS-316), the substantial amounts of heavy metal in the adjacent fuel zone may cause the average ΔE there to be much smaller than the practical width of the resonance.

In order to compute the energy dependent flux using the Nordheim Integral Equation, NITAWL must (at each energy) calculate the escape probability from the zone of interest. The geometry dependent algorithms for calculating these probabilities*$_3$ are all based on a "flat flux approximation" in which the flux is assumed to be independent of position within each zone. This is not a very good assumption since the flux, particularly at resonance energies, drops sharply within the interior of the fuel and may be far from flat in the moderator. Certainly this would not be a good assumption for a thick, depleted-uranium shield of a shipping cask where the flux may drop by several orders of magnitude.

The Nordheim integral method was originally developed using a simple 2-zone, 1-D model representing the fuel and the moderator. Thus, it is not surprising that there are certain configurations that can be handled poorly at best. While the Nordheim method (using the appropriate Dancoff correction factor) can perform a quite adequate self-shielding calculation for a fuel pin in a reasonably uniform PWR lattice, it may be held suspect if applied to the fuel pins in a BWR lattice where strong two-dimensional effects may be present.*$_4$ In other cases, the user may have to approximate the physical system to account for a double level of heterogeneity.For example, the pyrolytic graphite coating on an HTGR fuel pellet might be homogenized with the fuel, while the large graphite blocks containing the pellets could be considered as the external moderator.

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*$_3$Escape probabilities for annular zones (i.e., concentric spheres or cylinders) are calculated as in slab geometry while the inner-most zone is treated in the appropriate fashion.

*$_4$BWR lattices typically have some fuel pins of high, medium and low enrichment, some fuel pins with gadolinium poisoning, water slots (where pins have been removed), control blades and structural material.

In its present form, NITAWL solves the Nordheim Integral Equation by expanding the slowing-down integral(s) in a three-point formula corresponding to Simpson's Rule; it then marches from the highest to the lowest energy, developing a numerical value for the energy dependent flux and collision density as it goes. This is normally a quite satisfactory procedure. It does not, however, account for any thermal upscatter into the resonance range – a phenomena which may be particularly important for ^{239}Pu and ^{240}Pu due to their respective low-energy resonances at 0.3 eV and 1.0 eV.*[5] The importance of accounting for this thermal upscatter is, of course, increased whenever the moderating nuclide is bound in a crystalline lattice such as graphite or beryllium.

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*[5]At 550°K, hydrogen may, for example, supply the 0.3 eV ^{239}Pu resonance with ~40% as many neutrons via upscatter as via downscatter. Indeed, incoherent scattering with hydrogen may scatter neutrons up as high as 2.0 eV.

3.3 Applicability of the Bondarenko Method

The Bondarenko Method,[5] also known as the "shielding-factor method," is an alternate scheme for obtaining group-averaged self-shielded cross section data for the various nuclides in a given mixture. It differs from the Nordheim Method in that one does not explicitly calculate the flux [ϕ(E)] or the energy dependent collision density. Instead, one multiplies the infinitely dilute cross section data by a pre-tabulated shielding factor [$f_\lambda^{g,j}$ (T,σ_0),$f_1^{g,j}$ (T,σ_0), etc.] which depends on the temperature and the "background cross section" of the mixture to obtain the group-averaged self-shielded cross section data. With that data for each nuclide "in hand," one updates the estimate of the background cross section for the mixture (σ_0) and repeats the process until it converges. The presence of the external moderator (c.f., the water surrounding a fuel pin) is accounted for via the Dancoff factor (C) which, together with the mean chord length of the fuel lump ($\bar{\ell}$), is used to calculate the escape cross section (σ_{es}) for the fuel. This "escape cross section" is related to the escape probability from the fuel and is used to account for the slowing-down sources from the external moderator. The background cross section (σ_0) depends on the escape cross section, the potential scattering cross section of the moderating nuclide(s) inside the fuel lump (c.f., the oxygen in UO_2), and the group-averaged cross sections of the other resonance nuclides in the fuel lump.*$_1$

To determine the applicability of the method in various situations it is necessary to examine the underlying assumptions of the method and the approximations used in tabulating the Bondarenko f-factors.*$_2$ As shown in Appendix D, one may start with the Nordheim Integral Equation, apply the narrow resonance (NR) or the narrow resonance-infinite mass (NRIM) approximation for all nuclides in the fuel lump, and obtain an explicit expression for the flux [ϕ(E)] underneath a resonance. Assuming that the resonances in the fuel mixture are "widely spaced" (that is: "isolated in energy"), it is then possible to tabulate the group-averaged cross section data for a given nuclide in terms of a single variable (σ_0). To partially account for the fact that resonances of various nuclides frequently overlap, one can readjust the background cross section based on the group-averaged values. This last step gives rise to the iterative procedure described above.

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*$_1$For the derivation of the Bondarenko Method and a mathematical discussion of the various approximations, the interested reader is referred to Appendix D.

*$_2$The procedure of applying f-factors to obtain self-shielded group-averaged cross section data has, in a very narrow sense, been referred to as "the Bondarenko shielding factor method" by some people. In that sterile sense it is independent of the various approximations described below. Typically, however, most people consider the generation of the f-factors to be an integral part of the method even though it is a separate calculational step.

Because the Bondarenko Method and the form of the various shielding factors derive from an approximate solution of the Nordheim Integral Equation, the present method shares all the limitations imposed by the Nordheim Method: 1) Because of the simple two-zone model used in the original formulation, the method is not valid where one has strong 2-D effects (as in BWR fuel assemblies) and cannot handle double levels of heterogeneity (as required for the fuel grains in some HTGR fuels); 2) The assumption of a spatially flat flux is not good – especially at $E=E_{res}$; 3) Since the NR approximation has been used for the flux in the adjacent zones where Σ_A was assumed to be negligible and Σ_S was assumed to be constant, one cannot account for the presence of resonance nuclides in the adjacent zones; 4) The method cannot account for thermal upscatter into the resonance range. This difficulty may be important for the 0.3 eV resonance in ^{239}Pu and/or the 1.0 eV resonance in ^{240}Pu.*$_3$ Upscatter effects are also important whenever the moderating nuclide is bound in a crystalline lattice such as graphite or beryllium.

To calculate the shielding factors used in the Bondarenko method, it was necessary to make some assumptions regarding the flux spectrum $[\phi(E)]$.*$_4$ Typically, the spectrum used is based upon the narrow resonance approximation which assumes that the scattering density underneath a resonance depends primarily on the asymptotic (1/E) flux at energies above the resonance. The introduction of light nuclides into the fuel broadens the range of the respective slowing-down integrals into regions where significant absorption may occur due to the other nuclides. For the flux to actually be 1/E at energies above the resonance requires that there be little or no absorption in the fuel between energy E and E/α', where $\alpha' = (A-1)^2/(A+1)^2$. While this assumption may be valid for U-metal fuel, it is somewhat approximate in the case of UO_2 fuel where a good deal of the elastic slowing down occurs due to the oxygen. In the case of a homogeneous fuel/water solution this assumption is clearly violated by the presence of the hydrogen. (Fortunately other factors such as the diluteness of the fuel diminish the impact of this particular approximation). While the assumption that there is little or no absorption in the fuel between E and E/α' is not bad in many instances,

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*$_3$At 550°K, hydrogen may, for example, supply the 0.3 eV ^{239}Pu resonance with ~40% as many neutrons via upscatter as via downscatter. Indeed, incoherent scattering with hydrogen may scatter neutrons up as high as 2.0 eV.

*$_4$Historically, the Bondarenko method has been based upon the narrow resonance approximation and the assumption that the resonances are widely spaced. Likewise, the f-factors in the present Hansen-Roach library are also based upon these two assumptions.[22] For that reason, much of the discussion below centers on these two assumptions. It should be noted, however, that other methods and/or approximations may be used to obtain somewhat better f-factors. For example, one may use the narrow resonance-infinite mass approximation or intermediate resonance theory[27] for the flux $[\phi(E)]$ in those groups having broad thermal resonances. Likewise, a numerical determination of the flux for ^{233}U systems may yield f-factors that account for various degrees of self-overlap between the various resonances. Such a formulation, however, would require a more exotic expression for the background cross section. Thus, while the shielding factor method may be made very general, the discussion here focuses primarily on the basic method as currently implemented.

there are two nuclides for which this is certainly not true. Unlike most resonance nuclides, ^{233}U and ^{241}Pu each exhibit a great deal of self-overlap such that when calculating the collision density at energy E underneath one resonance, the range E to E/α^1 will nearly always include another resonance. Thus the Bondarenko Method (or for that matter, the Nordheim Method as implemented in NITAWL) does poorly when processing the cross section data for either of these isotopes. In advanced thorium convertors such an error may become significant.

Having used the NR approximation to obtain an expression for the flux, it is possible to tabulate the various shielding factors as a function of the number density of each constituent nuclide in the fuel. Assuming that the resonances are "widely spaced" such that, within a given energy group, the resonances of one nuclide do not overlap the resonances of another nuclide, it is possible to show that the various shielding factors may be tabulated as a function of a single variable (σ_0). Whereas this assumption is fairly good for ^{235}U ^{238}U systems which have overlapping resonances only at 6.4 eV and 21 eV, ^{235}U ^{238}U ^{239}Pu systems have a number of overlapping resonances. Likewise, ^{232}Th ^{233}U ^{235}U ^{238}U systems typical of advanced thorium converters and ^{235}U ^{238}U ^{239}Pu ^{240}Pu ^{241}Pu ^{242}Pu systems typical of LMFBR's both have a large number of overlapping resonances. While the cross section data for the predominant isotope may be relatively unaffected, the cross section data for other isotopes may be off considerably.*$_5$ Typically, the Bondarenko method will overestimate the multigroup cross sections for absorption, fission, etc. For fissile nuclides the reactivity effect of this is minimal since the method tends to overestimate both the absorption and the fission rate. For fertile nuclides, the overall effect is to underestimate the reactivity of the system.*$_6$ Advanced systems whose conversion ratio or breeding ratio depend critically on the shielded cross section data for the various individual processes should be analyzed with more advanced techniques which account for resonance overlap.[28]

Since the f-factors in the present Hansen-Roach library were based on the NR approximation, it is necessary to insert a final note of caution regarding their use in highly thermalized systems.

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*$_5$These comments must, of course, be kept in proper perspective. In the case of LMFBR fuel, for example, it is true that the multigroup data in the resolved energy range is poorly shielded by the Bondarenko method. The saving feature is that the flux spectrum is relatively hard, thus diminishing the importance of the data in that portion of the resolved energy range where resonance overlap is a problem.

*$_6$Fortunately resonance overlap is minimal in ^{235}U ^{238}U systems. It should also be noted that the SCALE Hansen-Roach library uses the Knight-modified data in which the ^{238}U f-factors have been altered to yield good agreement with a wide range of critical experiments (see Appendix D).

Typically, the NR approximation is considered valid with respect to a given nuclide whenever the practical width of the resonance (Γ_P) is much less than the average energy lost in an elastic collision [$0.5(1-\alpha_F)\ E_{res}$]. Fortunately, the NR appoximation is quite good for all but a few broad low-energy resonances. Even then the NR approximation for the slowing-down source is valid for all but the heaviest nuclides where $\alpha_i \rightarrow 1$ (c.f., Appendix D). Some of the more outstanding examples of where the NR approximation is not applicable would include the 21.78 and 23.43 eV resonances in ^{232}Th; the 1.79 and 10.37 eV resonances in ^{233}U; the 6.67, the 20.9 and the 36.8 eV resonances in ^{238}U; and the 1.056 and 20.46 eV resonances in ^{240}Pu. Although not available at the present time, future cross section data sets will almost certainly contain somewhat better f-factors based on intermediate resonance theory.[27] BONAMI will, of course, then be modified to calculate σ_0 in a consistent manner for those energy groups having broad thermal resonances.

3.4 The Dancoff Factor

The Dancoff Factor (C) is the probability that a neutron emitted isotropically from the surface of one absorber lump will pass through the external media and enter a nearby absorber lump. It is used in the NITAWL resonance self-shielding calculations to reduce the effective escape probability from the fuel in a heterogeneous lattice. To determine the Dancoff factor for loosely packed lattices, it was previously necessary to obtain the sum

$$C = \sum_i C_i \tag{12}$$

of the lump-to-lump Dancoff factors for all surrounding lumps. To determine each C_i, one could use the extensive tables found in ANL-5800[9], the Bell approximation[10] or the Hummel approximation:[11]

$$C_i = 1 - \gamma_B \qquad \text{(Bell)} \tag{13}$$

$$C_i = 1 - \gamma_B - \gamma_B^4 + \gamma_B^5 \qquad \text{(Hummel)} \tag{14}$$

where

$$\gamma_B = \frac{\bar{\ell}_m \Sigma_{t\,m}}{1 + \bar{\ell}_m \Sigma_{t\,m}} \quad , \qquad \bar{\ell}_m = (4 V_m / S_F) \tag{15}$$

More recently, Sauer[12] has developed an approximation for C which accounts for the partial overshadowing of one neighboring lump by another in a closely packed lattice. Separate approximations are available for both square and hexagonal lattices.

Still more recently, Knight has written the SUPERDAN program[13] which uses a double numerical integration to analytically determine the Dancoff factor for spheres, cylinders and slabs. In each case, the program accounts for any cladding that might be present. For cylindrical fuel pins, SUPERDAN will also calculate the total Dancoff factor (C) for both square and hexagonal lattices. The overshadowing of one neighboring lump by another is accounted for analytically. The summation indicated by Eq. 12 is taken over all nearest and second nearest neighbors as shown in Fig. 1a and 1b.

To simplify the input and reduce the chance for human error, the determination of the Dancoff factor is now treated as one of the internal auxiliary calculations performed by the control module. This calculation is actually performed in subroutine DANCOF (c.f., Sect. 4) which has all of the analytic features found in SUPERDAN.

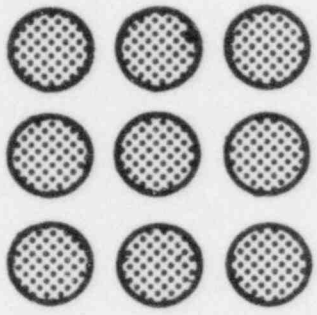

Fig. 1(a). Nearest and Second Nearest Neighbors in a Square Lattice. The Summation, $C = \sum_{i=1}^{8} C_i$, is taken over all pins partially visible from the central pin.

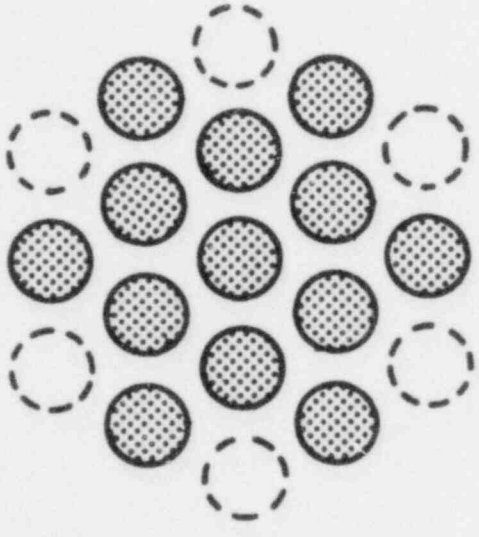

Fig. 1(b). Nearest and Second Nearest Neighbors in a Hexagonal Lattice. The summation, $C = \sum_{i=1}^{12} C_i$, is taken over all pins partially visible from the central pin.

3.5 Automatic Mesh Generator

To simplify the input, the control module also determines the number and location of mesh boundaries within a zone using an internal algorithm based on the total epithermal cross section and asymptotic diffusion length in each mixture. Through a single (optional) control parameter, the user may increase or decrease the mesh size to assure that a sufficiently small mesh is used for any given problem.

Within a particular material zone, the scheme used to determine the location of the mesh boundaries is logarithmically symmetric about the mid-point of the zone as shown in Fig. 2.

Fig. 2. Mesh Spacing Scheme Used in Material Zone.

If there are a total of N mesh intervals in the zone, then the size of each mesh interval (Δr_n) is given by:

$$\Delta r_n = 0.5(r_o - r_i)\log_{10}\{[N + 18(n)]/[N + 18(n-1)]\} \ , \ n=1,2,\ldots,N/2 \tag{16}$$

This type of logarithmically symmetric distribution has the advantage of providing more mesh intervals near the material zone interfaces where one would expect greater flux gradients. To determine N, we require that the size of the largest mesh interval be less than some specified number of mean free paths or asymptotic diffusion lengths. Specifically, N is determined by applying the requirement that

$$(\Delta r_{max}) \leq \left\{ \begin{array}{l} (SZF)(0.06)(\lambda_T) \quad \text{for LATTICECELL calculations} \\ (SZF)(0.15)(L) \quad \text{for MULTIREGION calculations} \end{array} \right\} \tag{17}$$

where the size factor (SZF) is an optional control parameter that may be specified by the user, and L is the asymptotic diffusion length for the mixture as defined by

$$(1/L)^2 = 3\Sigma_A \ \Sigma_S \ (1-\bar{\mu})(1- \ 4\Sigma_A/5\,\Sigma_T) \tag{18}$$

The asymptotic diffusion length is computed internally within the program using epithermal cross section data stored in the Standard Composition Library. The constants, (0.06) and (0.15), were chosen so that an adequate mesh size is normally obtained when the size factor (SZF) is allowed to

assume its default value (1.0). The user may, however, increase or decrease the size of the largest mesh interval at will by adjusting this factor (SZF). For latticecell calculations, the above prescription yields:

$$N = 18/(10^{X} - 1) \tag{19a}$$

where

$$x = 2(0.06)\ (\lambda_T)\ (SZF)/(\ r_o - r_i) \tag{19b}$$

A similar expression is obtained for the multiregion case. For optically thin regions (such as voids or thin cladding), N is assigned a value of 4 whenever the above equation would yield something less. For an infinite-homogeneous-media calculation (where the user specifies the material composition of a single zone), N is always defaulted to a value of 1.

3.6 Automatic Quadrature Generator

As in any discrete ordinate code, XSDRNPM solves for the angular flux (ψ_m) in a number of discrete directions ($\vec{\Omega}_m = \mu_m \vec{i} + \eta_m \vec{j} + \xi_m \vec{k}$) in each spatial mesh. The scalar flux in each mesh (ϕ) is then computed using a numerical quadrature of the form:

$$\phi = \sum_m W_m \psi_m \tag{20}$$

where W_m is the weight associated with direction $\vec{\Omega}_m$.*1

Early versions of XSDRN required that the user specify the actual set of directions and weights to be used for each problem. These quadrature sets are, of course, geometry dependent and must satisfy a number of other requirements [14-16]. Quadrature sets of higher order include more discrete directions and provide for better resolution of the angular flux.

To simplify the input and reduce the associated errors, XSDRNPM now automatically calculates the direction cosines and the associated weights for the specified geometry. The number of discrete directions (MM) generated for a quadrature of order ISN is given by:

$$MM = ISN + 1 \qquad \text{for slab or spherical geometry} \tag{21}$$

and

$$MM = ISN*(ISN + 4)/4 \qquad \text{for cylindrical geometry.} \tag{22}$$

In spherical geometry, the directions and weights calculated correspond to those of a simple Gaussian quadrature set of order ISN.*2 In slab geometry, XSDRNPM calculates a Gaussian quadrature set of order ISN/2, compresses it from 180° down to 90° (for symmetry), and uses this compressed quadrature in combination with its mirror image.*3 (In both slab and spherical geometry one additional direction having an associated weight of 0.0 is also included). In cylindrical geometry the polar angles (θ) correspond to the positive angles of a Gaussian quadrature of order ISN while the azimuthal angles (ϕ) are equally spaced as shown in Fig. 3.*4

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*1 The theory behind various quadrature schemes has been widely discussed in the literature[14-16] and will not be reviewed here.

*2 More precisely: $\mu_i = \pm x_i$ where $\{x_i\}$ are the (m/2) positive roots of $P_m(x) = 0.0$ where m = ISN; and $w_i = W_i/2$ where $\{W_i\}$ are the Gaussian weights associated with $\{x_i\}$. The starting direction, $\mu_0 = -1$, is assigned a zero weight.

*3 More precisely: $\mu_i = \pm(1 \pm x_i)/2$ where $\{x_i\}$ are the (m/2) positive roots of $P_m(x) = 0.0$ where m = ISN/2; and $w_i = W_i/4$ where $\{W_i\}$ are the Gaussian weights associated with $\{x_i\}$. The starting direction, $\mu_0 = -1$, is assigned a zero weight.

*4 More precisely: $\eta_i = \cos(\theta_i)$ are the (m/2) positive roots of $P_m(\eta) = 0.0$ where m = ISN; $\mu_{i,j} = \pm\sqrt{1-\eta_i^2}\cos[\pi(j-0.5)/2i]$ where j = 1, 2, ..., i; and $w_{i,j} = W_i/(2i)$ where $\{W_i\}$ are the Gaussian weights associated with $\{\eta_i\}$. The starting directions, $\mu_{i,0} = -\sqrt{1-\eta_i^2}$, are assigned a zero weight.

This equal spacing of the azimuthal angles corresponds to a Chebyschev quadrature in ϕ. Note that one additional angular direction having an associated weight of 0.0 is also included for each of the polar angles (θ).

The quadrature order (ISN) is an optional control parameter that may be specified by the user. The SCALE criticality safety analysis sequences normally default to ISN = 8. The user may, however, increase or decrease the quadrature order to verify the accuracy of a particular calculation. ISN = 8 has been found to be more than satisfactory for most LATTICECELL calculations. In MULTIREGION calculations having a reflector, ISN = 8 will generally be adequate, although the user may wish to compare the resulting k-eff and/or scalar fluxes with those of another calculation using ISN = 12. Accurate determination of the scalar fluxes deep in a thick shield may, for example, require ISN = 16.

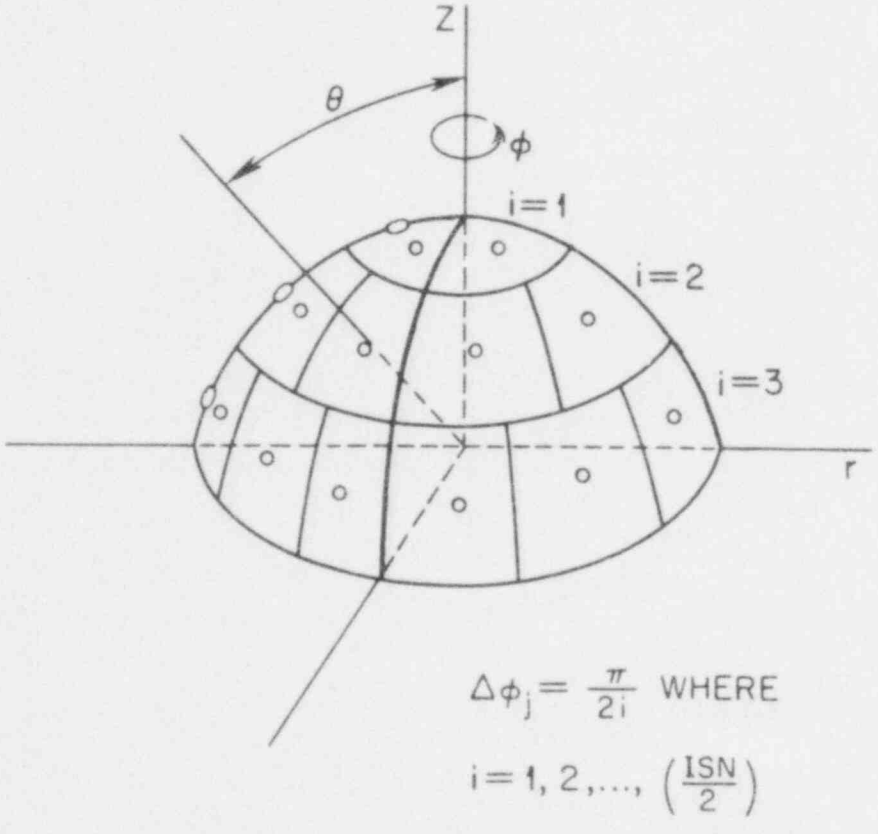


Fig. 3. Angular Directions Associated with an S_n Gauss-Chebyschev Quadrature Set for Cylindrical Geometry.

3.7 The 1-D Approximation with/without Buckling

The obvious approximation associated with the CSAS1 analytic sequence is the assumption that the physical system may be adequately represented in one dimension. For most lattice-cell calculations this is not a bad approximation since the leakage out the ends of a fuel rod is almost negligible and the effect of neighboring fuel rods may be accounted for by using the appropriate boundary condition. For multiregion calculations, however, the implications of the approximation should be examined more carefully. In one-dimensional calculations, cylinders are assumed to be infinitely long and slabs are assumed to be of infinite extent in both of the transverse directions. Hence, a true 1-D calculation in these geometries would tend to overestimate the k-eff of the physical system.

To partially alleviate this difficulty, it is possible to use a buckling correction which accounts for the leakage out of the system in the transverse direction(s). To do this, the leakage in each group is calculated as $D_g B_g^2 \phi_g$ and treated as an absorption term in the transport equation. Here D_g is the diffusion coefficient

$$D_g = 1/(3\Sigma_{TR}^g) \tag{22}$$

and the buckling, B_g, is given by:

$$B_g^2 = (\pi/DY_g^*)^2 + (\pi/DZ_g^*)^2 \quad \text{in slab geometry and} \tag{23}$$

$$B_g^2 = (\pi/DY_g^*)^2 \quad \text{in cylindrical geometry.} \tag{24}$$

DY_g^* and DZ_g^* are the extrapolated dimensions of the assembly defined by:

$$DY_g^* = DY + 2d^g \tag{25a}$$

$$DZ_g^* = DZ + 2d^g \tag{25b}$$

where DY and DZ are the actual dimensions of the assembly and d^g is the extrapolation distance from the surface of the assembly. For a semi-infinite system in planar geometry, the analytic solution to the Milne problem yields $d = (.710446)\ \lambda_{TR}$. For smaller systems, d can be shown to lie between $(.7104)\lambda_{TR}$ and $(1.3333)\lambda_{TR}$.[17] Within the XSDRNPM code, d is calculated as

$$d^g = (1/2)(BKL)\lambda_{TR}^g = (1/2)(BKL)(1/\Sigma_{TR}^g) \doteq (1/2)(BKL)(1/\Sigma_t^g) \tag{26}$$

where BKL is an optional parameter which the user may supply. A default value of

BKL = 1.420892 is normally supplied by the control module. While it is true that underestimating the extrapolation distance (i.e., using a value of BKL that is too small) will cause a buckling-corrected transport calculation to underestimate k-eff by a slight amount, that is nearly always a second or third order effect. In systems with transverse dimensions small enough for d to be much greater than $(.7104)\lambda_{TR}$, the 1-D approximation is no longer valid and a 2-D model of the physical system is probably required.

3.8 Convergence Criteria

The convergence criteria for the XSDRNPM calculation are availabe to the user as optional control parameters (EPS and PTC). Terms useful in describing the convergence criteria are defined below:

$Q \equiv$ total fixed source in system

$F \equiv$ total fission neutron source

$D \equiv$ total outscatter $= \sum_i \sum_g \sum_{g' \neq g} \phi_{i,g} \sigma_{g \to g'} V_i$

$\phi_{i,g} \equiv$ scalar flux in group g, interval i

$V_i \equiv$ volume of interval i

$\sigma_{g \to g'} \equiv$ group g to group g' transfer cross section

$IGM \equiv$ number of energy groups

$q_g \equiv$ fixed source in group g

$f_g \equiv$ fission source in group g

$\epsilon_g' \equiv \left(\frac{q_g + f_g}{IGM}\right) EPS$

$k \equiv$ outer iteration number (do not confuse with the multiplication factor)

$\lambda_k \equiv \frac{Q + F_k}{Q + F_{k-1}}$ (LAMBDA1 in output)

$G_k \equiv \frac{D_k}{Q + F_k}$

$\lambda_k' \equiv \frac{G_{k-1}}{G_k}$ (LAMBDA2 in output)

$U_k \equiv$ total upscatter rate $= \sum_i \sum_g \sum_{g' < g} \phi_{i,g} \sigma_{g \to g'} V_i$

An inner iteration consists of sweeping one time through the entire spatial mesh and calculating the flux for all the S_n angles in one energy group. A sweep through all energy groups is called an outer iteration.

When the fluxes for a particular group are being calculated, the inner iterations will continue until (a) the number of inner iterations in this outer exceeds IIM (the inner iteration maximum), or (b) until the following criteria are met:

1) $$\sum_i \left| (\phi_{i,g}^k - \phi_{i,g}^{k-1}) \right| \sigma_{g \to g} \nabla_i \leq \epsilon_g'$$

2) $$\sum_i \left| (\phi_{i,g}^k - \phi_{i,g}^{k-1}) \right| (\sigma_t - \sigma_{g \to g}) \nabla_i \leq \epsilon_g'$$

If PTC, the point flux convergence criterion, is greater than zero, XSDRNPM also requires

3) $$\max_i \left| \frac{\phi^k_{i,g} - \phi^{k-1}_{i,g}}{\phi^k_{i,g}} \right| \leq \text{PTC}$$

At the end of an outer iteration, the following checks are made:

4) $$|1.0 - \lambda_k| \leq \text{EPS}$$

5) $$R|1.0 - \lambda^c_k| \leq \text{EPS}$$

6) $$R\left| 1.0 - \frac{U_{k-1}}{U_k} \right| \leq \text{EPS}$$

R is a convergence relaxation factor which is automatically set to 0.5 within XSDRNPM. If all the convergence criteria are met or if the maximum allowed number of outer iterations is reached, the XSDRNPM calculation will terminate with full output. Otherwise, another outer iteration will be started.

4. LOGICAL PROGRAM FLOW AND DESCRIPTION OF SUBROUTINES

Figures 4 through 6 are intended to show the logical flow of information through the CSAS1 and CSAS2 analytic sequences. Following each figure is a brief description of each subroutine and its function. Note that the key difference between the CSAS1 and CSAS2 sequence is shown in Figs. 4 and 5. In both cases, subroutine NITXSD reads all the necessary input, performs the auxiliary calculations previously described, and writes the binary files for each of the functional modules.

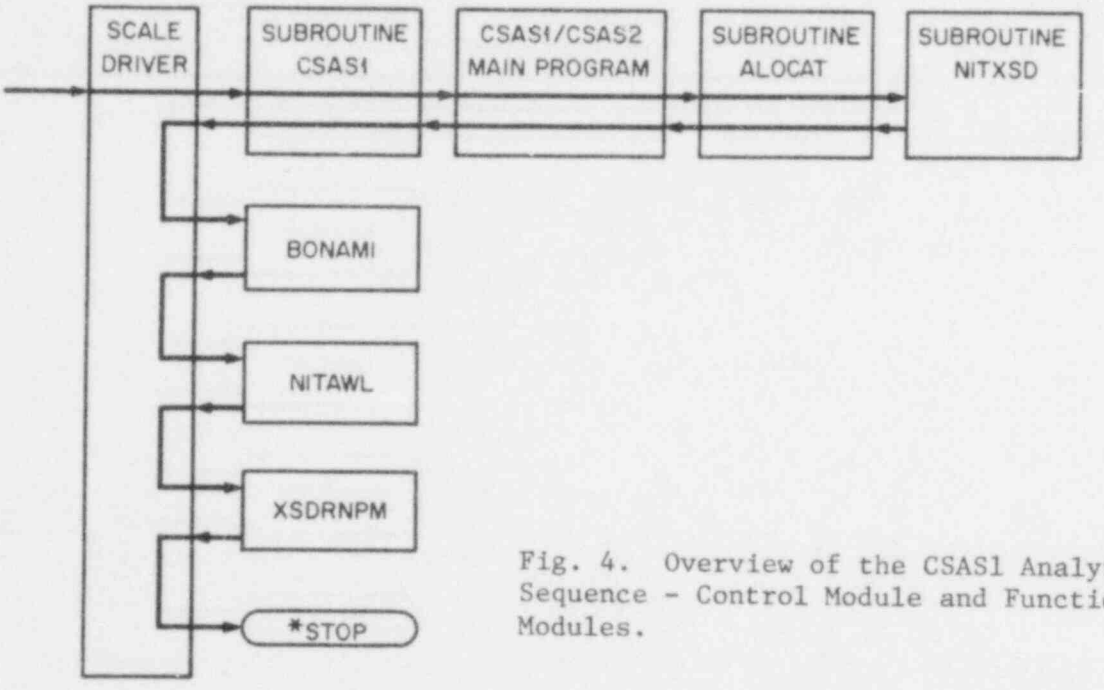


Fig. 4. Overview of the CSAS1 Analytic Sequence - Control Module and Functional Modules.

CSAS1 — dummy subroutine which serves as an entry point for the control module's main program; sets flag [IC(14) = 1] indicating entry point was CSAS1.

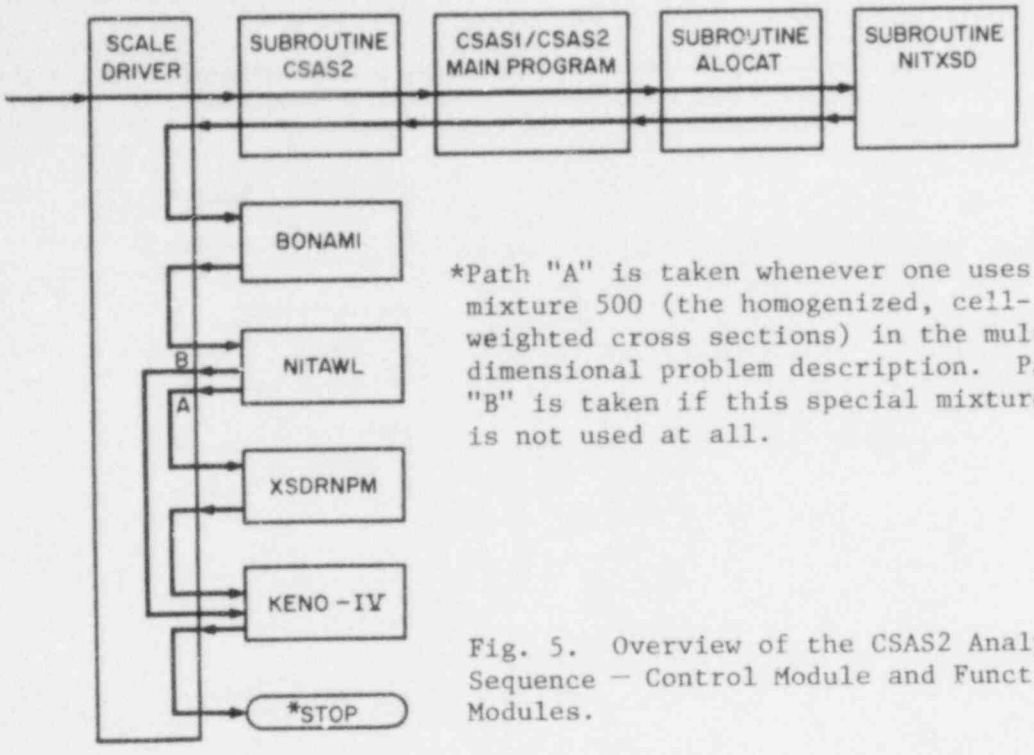
MAIN PROGRAM — places BONAMI, NITAWL, and XSDRNPM modules in the execution list; opens necessary buffers.

ALOCAT — determines amount of core storage available in system and allocates it for use in subroutine NITXSD.

NITXSD — workhorse of the CSAS1 and CSAS2 control modules; reads all necessary input; performs auxiliary calculations (see Fig. 6a); writes binary files for each of the functional modules.

BONAMI, NITAWL, XSDRNPM – functional modules; described separately.

*STOP — flow path is actually as follows: driver calls CSAS1 again; it calls main program which implements wrap-up procedures and returns to driver; driver checks input queue and stops if there are no more cases.



*Path "A" is taken whenever one uses mixture 500 (the homogenized, cell-weighted cross sections) in the multi-dimensional problem description. Path "B" is taken if this special mixture is not used at all.

Fig. 5. Overview of the CSAS2 Analytic Sequence – Control Module and Functional Modules.

CSAS2 — dummy subroutine which serves as an entry point for the control module's main program; sets flag [IC(14) = 2] indicating entry point was CSAS2.

MAIN PROGRAM — places BONAMI, NITAWL, XSDRNPM and KENO-IV modules in the execution list if mixture 500 is used; places BONAMI, NITAWL and KENO-IV modules in the execution list if mixture 500 is not used; opens necessary buffers.

ALOCAT — determines amount of core storage available in system and allocates it for use in subroutine NITXSD.

NITXSD — workhorse of the CSAS1 and CSAS2 control modules; reads all necessary input; performs auxiliary calculations (see Fig. 6a); writes binary files for each of the functional modules.

BONAMI, NITAWL, XSDRNPM, KENO-IV – functional modules; described separately.

*STOP — flow path is actually as follows: driver calls CSAS2 again; it calls main program which implements wrap-up procedures and returns to driver; driver checks input queue and stops if there are no more cases.

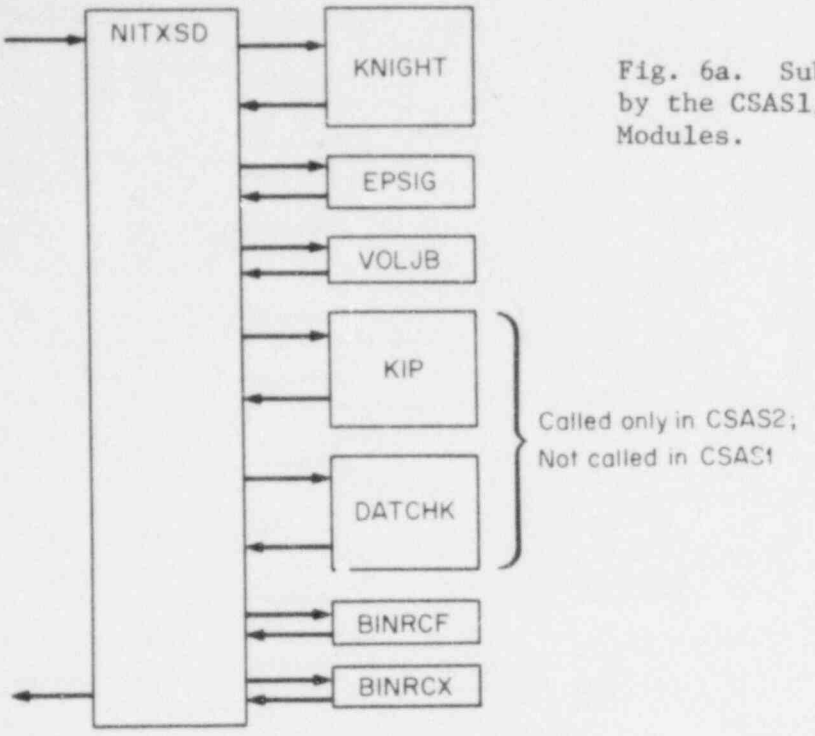


Fig. 6a. Subroutines Used by the CSAS1/CSAS2 Control Modules.

NITXSD — calls KNIGHT; calls EPSIG; calls VOLJB; sets-up binary input files for BONAMI, NITAWL, XSDRNPM; computes the number of spatial mesh intervals required in the XSDRNPM transport calculation and assigns zone numbers to each mesh interval; establishes three special versions of the mixing table: one for BONAMI, one for XSDRNPM and one for KENO-IV; calls KIP to process KENO-IV input (required only in CSAS2 analytic sequence – skipped in CSAS1 sequence); writes binary input file for BONAMI on tape 96; writes binary input file for NITAWL on tape 97; writes binary input file for XSDRNPM on tape 98; writes binary input file for KENO-IV on tape 95 (required only in CSAS2 analytic sequence – skipped in CSAS1 sequence); calls DATCHK to read and check the binary input file for KENO-IV (required only in CSAS2 analytic sequence – skipped in CSAS1 sequence).

KNIGHT — reads all of the input required by CSAS1; establishes a basic version of the nuclide mixing table (including the automatic calculation of necessary number densities); establishes the resonance parameters for NITAWL; see Fig. 6b for further details.

EPSIG	calculates the total epithermal cross section and the corresponding asymptotic relaxation factor (κ) for use in determining the number of spatial mesh intervals.
VOLJB	function subroutine used for calculating volume fractions.
KIP	reads all of the KENO input required by the CSAS2 analytic sequence (not used in the CSAS1 sequence).
DATCHK	reads the binary input file for KENO-IV and performs numerous checks on the 3-D geometry data; see Fig. 6e; required only in the CSAS2 analytic sequence (not used in the CSAS1 sequence).

BINRCF, BINRCX – short routines for writing many of the binary interface files.

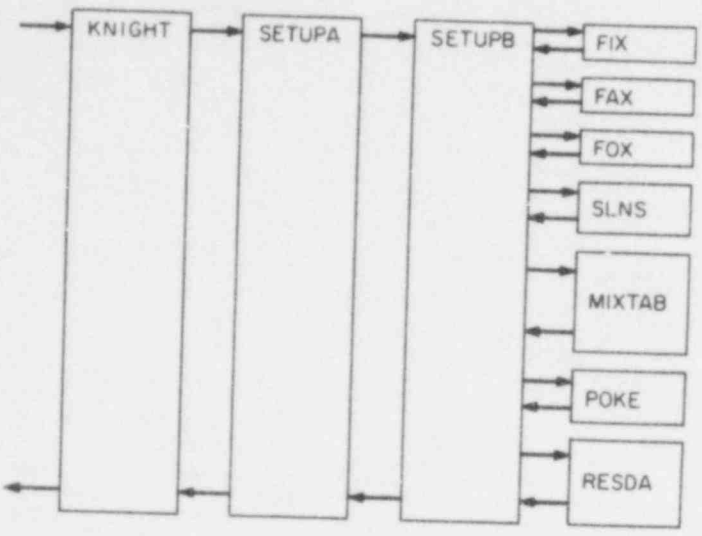


Fig. 6b. Subroutines Used by the CSAS1/CSAS2 Control Modules.

KNIGHT — reads the standard composition directory, the isotope distribution directory and the isotope distribution table from the standard composition library mounted on unit 89; places this information in various arrays and sets up pointers; then calls SETUPA; further details described below.

SETUPA — reads the CSAS1 title card and the first seven parameters; sets up pointers for subsequent data arrays; then calls SETUPB.

SETUPB — reads rest of the CSAS1 input data (i.e., the standard composition specifications, the geometry description and the optional control parameters); calls routines shown above, roughly in that order; they: a) read in the rest of the standard composition library; b) calculate number densities for each nuclide in each mixture; c)establish the resonance parameters required for NITAWL.

FIX — used only when an "arbitrary material" is encountered in the CSAS1 input stream; transfers the information on the "arbitrary material" specification card into the arrays it would have been in had the material been a standard composition.

FAX — used by SETUPB to read the rest of the standard composition library mounted on unit 89.

FOX — looks up the nuclide I.D's and corresponding natural abundances (wt %) for those elements having more than one isotope; used only when the user does not specify the isotopic distribution.

SLNS — calculates the volume fraction corresponding to the water, acid, and heavy metal compound in each of several commonly encountered solutions; uses accurate empirical formulas.

MIXTAB	calculates the number densities for each nuclide in each mixture and establishes an XSDRN-like mixing table; see Fig. 6c for further details.
POKE	determines the outer boundary for each zone and the mixture number for each zone.
RESDA	determines the 15 NITAWL resonance parameters for each nuclide having resonance information on the master cross section library; see Fig. 6d for further details.

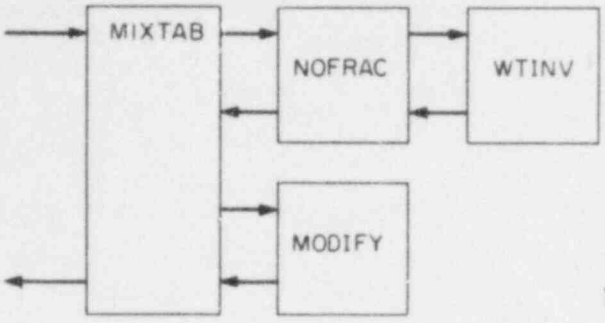


Fig. 6c. Subroutines Used by the CSAS1/CSAS2 Control Modules.

MIXTAB — uses the information from the standard composition library to calculate the number density for each nuclide in each mixture; establishes an XSDRN-like mixing table; establishes unique nuclide I.D.'s to be placed on the working cross-section library by NITAWL (see description of subroutine MODIFY).

NOFRAC — calculates the number fraction for each of the isotopes in an element, given the weight fractions and respective masses.

WTINV — matrix inversion routine used by NOFRAC to solve a set of coupled linear equations.

MODIFY — modifies the mixing table's nuclide I.D. array so as to provide unique I.D.'s for each appearance of a resonance nuclide and/or a nuclide for which multiple sets of thermal scattering data are available.

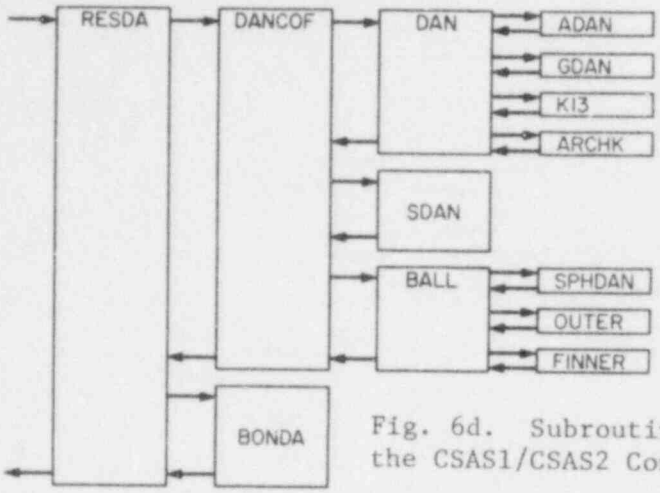


Fig. 6d. Subroutines Used by the CSAS1/CSAS2 Control Modules.

RESDA — determines the 15 NITAWL resonance parameters for each nuclide having resonance information on the master cross-section library; calls DANCOF (described below); calls BONDA for each nuclide having Bondarenko factors on the master cross-section library (only the 16-group library has Bondarenko factors at present).

BONDA — establishes the additional input arrays that would be required by BONAMI if it (i.e., BONAMI) is to perform the resonance self-shielding analysis using the Bondarenko method.

DANCOF — computes Dancoff factors for resonance materials in a lattice-cell calculation; calls DAN, SDAN, or BALL, depending on the type of geometry.

DAN — computes Dancoff factors in cylindrical geometry.

SDAN — computes Dancoff factors in slab geometry.

BALL — computes Dancoff factors in spherical geometry.

ADAN — performs the outer integral required in the evaluation of the Dancoff factor in cylindrical geometry; calls GAUSS and/or AGAUSS (described below).

GDAN — performs the inner integral required in the evaluation of the Dancoff factor in cylindrical geometry; calls GAUSS and/or AGAUSS (described below).

KI3 — evaluates the third order Bickley function using several (very accurate) piecewise approximations.

ARCHK — utility routine to correct for roundoff errors before using any of the arc-trig functions.

SPHDAN	sets up the double integration required in the evaluation of the Dancoff factor in spherical geometry.
OUTER	performs the outer integral required in the evaluation of the Dancoff factor in spherical geometry; calls GAUSS and/or AGAUSS (described below).
FINNER	performs the inner integral required in the evaluation of the Dancoff factor in spherical geometry; calls GAUSS and/or AGAUSS (described below).
GAUSS	evaluates the integral of a function using a Gaussian quadrature; called by ADAN, GDAN, OUTER or FINNER.
AGAUSS	evaluates the integral of a function using a Gaussian quadrature; called by ADAN, GDAN, OUTER, or FINNER.

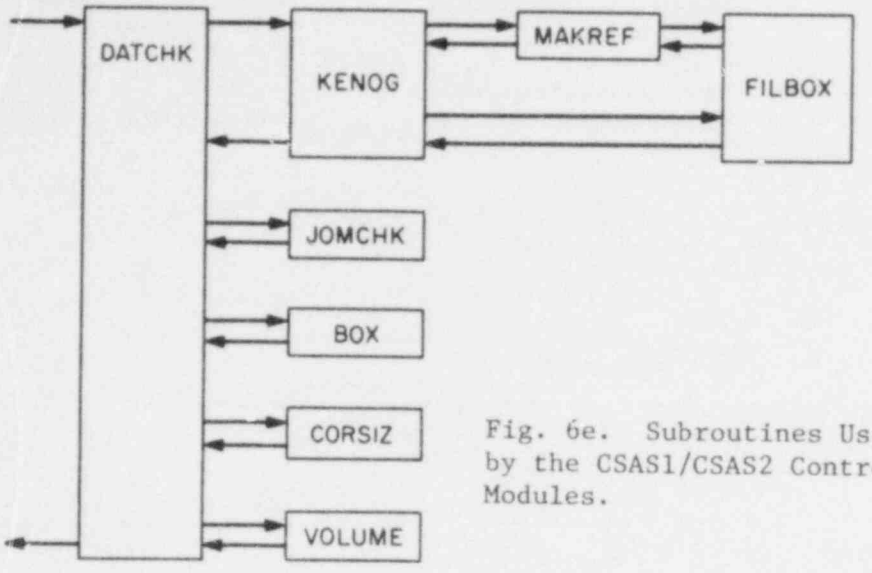


Fig. 6e. Subroutines Used by the CSAS1/CSAS2 Control Modules.

DATCHK — reads the data stored on the binary KENO input tape and performs numerous checks on the 3-D geometry data; repeats this for each KENO case submitted by the user; calls routines shown in Fig. 6e; required only in CSAS2 sequence – skipped in CSAS1 sequence.

KENOG — reads and edits the data for a given KENO case as stored on the binary KENO input tape; checks to make sure that each alphanumeric geometry word encountered is a valid one; prints out the multigroup weights for each region; calls MAKREF if automatic reflector option has been invoked.

MAKREF — automatically supplies a number of CUBOID regions (each with appropriate dimensions and an appropriate set of multigroup weights) whenever the automatic reflector option is invoked.

FILBOX — reads the mixed box orientation data for a given KENO case as stored on the binary KENO input tape.

JOMCHK — checks to be sure that regions within a given box type do not contain intersecting surfaces and that regions within the reflector do not contain intersecting surfaces.

BOX — checks the mixed box orientation data for errors and prints a 2-D map of the array layout at each axial level.

CORSIZ — checks to make sure that the tangent faces of adjacent boxes are always the same size.

VOLUME — performs checks to insure that the dimensions of certain regions were entered in the proper order and to insure that, within a given box type or within the reflector, each KENO region fully encloses all previous ones; this routine also checks to make sure that each box type contains at least one region and that the last geometry region in every box type is a CUBE or CUBOID.

OTHER ROUTINES USED BY CSAS1/CSAS2

GAUSS	evaluates the integral of a function using a Gaussian quadrature; called by ADAN, GDAN, OUTER or FINNER.
AGAUSS	evaluates the integral of a function using a Gaussian quadrature; called by ADAN, GDAN, OUTER or FINNER.
STOCHK	determines whether or not there is adequate space left in core to append a new array onto the end of the large, flexibly dimensioned D array; prints error message and corrective action to be taken if space left is insufficient; called from KNIGHT, SETUPA, SETUPB, MIXTAB, NITXSD, KIP, DATCHK.
AREAD	reads alphanumeric data from cards.
IREAD	reads integer data from cards; actually, this is an entry point in the AREAD subroutine.
FREAD	reads floating point data from cards; actually, this is an entry point in the AREAD subroutine.
SCANON, SCANOF	– subroutines which after being called, enable/disable AREAD, IREAD, FREAD to scan ahead and tell whether the characters "END" follow the data item being read.
MESAGE	used to print header pages; calls DATIM and FHLPR.
DATIM	machine language program to determine the date and time.
FHLPR	prints eight "block letter" characters across a page.
OPENDA	opens I/O buffers.
CLOSDA	closes I/O buffers.

5. INPUT/OUTPUT UNITS USED BY CSAS1/CSAS2

1 AMPX master library (produced by BONAMI)
3 AMPX weighted library (produced by XSDRNPM)
4 AMPX working library (produced by NITAWL)
5 Card Input
6 Printed output (BONAMI, NITAWL, XSDRNPM, and KENO-IV functional modules)
8 Scratch (Used by XSDRNPM for external cross section storage)
9 Scratch (Used by XSDRNPM for mixing and weighting operations; also used by NITAWL)
10 Scratch (Used by XSDRNPM for external storage of flux moments)
16 Forward angular fluxes (calculated by XSDRNPM)
18 Scratch (Used by BONAMI, XSDRNPM and KENO-IV)
19 Scratch (Used by NITAWL and XSDRNPM)
43 Master KENO library of space/energy dependent weights for automatic reflector option
81 HANSEN-ROACH Master Cross Section Library
82 27GROUPNDF4 Master Cross Section Library
83 123GROUPGMTH Master Cross Section Library
84 218GROUPNDF4 Master Cross Section Library
89 Standard Composition Library
95 Binary input for KENO-IV (produced by CSAS2 control module)
96 Binary input for BONAMI (produced by CSAS1 or CSAS2 control module)
97 Binary input for NITAWL (produced by CSAS1 or CSAS2 control module)
98 Binary input for XSDRNPM (produced by CSAS1 or CSAS2 control module)
99 Printed Output (produced by CSAS1 or CSAS2 control module)

6. Input Instructions for CSAS1/CSAS2

The input for the CSAS1/CSAS2 analytic sequence(s) has been formulated in engineering terms and includes only the detail necessary to properly define the system. A convenient free-form input processor has been adopted which simplifies the entry of input data. (The free-form format is described below in more detail.) Alphanumeric keywords describing the system, as well as numeric data are used where appropriate. Commonly used values of many of the parameters may be obtained by default or easily changed as needed.

The input is divided into three main parts. First, the problem parameters are read. This provides a general description of the system. Next, a description of each material composition is read. As many entries as needed may be used to fully describe any material mixture. Finally, the geometry description for the problem is read. In the CSAS2 analytic sequence, several additional blocks of data are required to describe the three-dimensional KENO geometry.

The material composition of each zone is assumed to be a mixture of one or more standard compositions. The alphanumeric identifiers for these standard compositions 1) may be taken from the list of elements, compounds and alloys found in the Standard Composition Library (e.g., UO2, SS304, H2O, etc. – see Table A.1), or 2) they may be taken from the Table of Available Solutions (e.g., SOLNUO2(NO3)2 – see Table A.2), or 3) they may designate an arbitrary material for which the user will supply additional information (e.g., ARBMTL1, ARBMTL2, etc.). An invalid standard composition name will cause an error message to be printed and the calculation to be terminated. For standard compositions taken from the Standard Composition Library, the user will have to enter the volume fraction or theoretical density of the standard composition in the mixture, and other engineering type data. For those standard compositions, the user will have to consult the Standard Composition Library (see Table A.1) to determine if any of the associated cross sections require a resonance self-shielding calculation. For standard compositions containing more than one isotope of an element (such as UO2), the user is free to specify the weight percent for each isotope so long as they total 100%. For solutions, the user will have to specify the density of the heavy metal in solution and the acid molarity of the solution. For arbitrary materials specified by the user (ARBMTL1, ARBMTL2, etc.), the user will have to input all the information that would normally be found in the Standard Composition Library. Any number of arbitrary standard compositions may be used in a given problem.

The free-form input processor implemented herein allows alphanumeric data, floating point data and integer data to be entered in an unformatted manner. All 80 columns of any card may be used and data, with certain exceptions noted below, can start or end in any column.

Any alphanumeric data entry must be followed by two or more blanks. Any numeric data entry must be followed by one or more blanks. Integers may be used for floating values if the particular item has no decimal value (i.e., 10 will be interpreted as 10.0). Likewise, 1+4, 1.0+4, 1.0E+4 or 10000.0 will all be interpreted as 1.0×10^4. Note that imbedded blanks are not allowed within the representation for a given number. The only exception to this is that a single blank may precede an unsigned exponent in a floating point number. Thus, for example, 1.0E 04 would be correctly interpreted as 1.0×10^4.

This free-form processor has provisions for multiple entries of the same data value. This is done by entering the number of repeats, followed by either R, *, or $, followed by the data value to be repeated. For example, 5R2 or 5*2 enters five successive 2's in the input data. There should be no blanks between the number of repeats and the repeat flag(R, *, or $), but each multiple entry must be separated from the rest of the data by one or more blanks. Multiple zeros may be specified as nZ where n is the number of zeros to be repeated. There should not be any blanks between the n and the Z, but the nZ must be separated from the rest of the data by one or more blanks.

The actual input for the CSAS1/CSAS2 analytic sequence(s) is divided into 14 "mini-blocks":

1. Analytic Sequence Specification Card
2. Title Card
3. Parameter Card
4. Standard Composition Specification Cards
5. Geometry Description Card
6. Multiregion Zone Description Card
7. Optional Control Parameters
8. END Card for the CSAS1 Analytic Sequence
9. KENO Title Card
10. KENO Parameter Card
11. Boundary Condition Specifications
12. Multidimensional Geometry Specification Cards
13. Mixed Box Orientation Data
14. END Card for the CSAS2 Analytic Sequence

(1–8: required for CSAS1; 1–14: required for CSAS2)

Each of these "mini-blocks" will now be described in detail.

1. Analytic Sequence Specification Card

The appropriate Criticality Safety Analysis Sequence is specified by punching the six characters =CSAS1 or =CSAS2 in columns 1 through 6.

2. Title Card

All 80 columns may be used for a descriptive title.

3. Parameter Card

1. LIB — Alphanumeric description of the cross-section library to be used, for example: HANSEN-ROACH, 123GROUPGMTH, etc. See Table A.4 for a complete list of available cross-section libraries. Note that the alphanumeric description must be followed by two or more blanks before any additional data is entered.

MXX Number of material mixtures to be defined by mixing the various standard compositions. [See items (1a) and (2a) on the Standard Composition Specification Card for further explanation.]

Note: MXX represents the total number of mixtures the user intends to define. If a single material is used in more than one spatial zone (as may be the case in a MULTIREGION calculation), separate mixtures should be defined with identical specifications. (This will, for example, allow NITAWL to produce separate working libraries based on the appropriate number of external moderators and the actual mean chord length for each zone.) In the CSAS2 sequence, some mixtures may be used in the 1-D calculation while the same and/or other mixtures may be used in the multidimensional calculation.

3. MSC Number of Standard Composition Specifications the user intends to enter. (See below.)

4. IZM Number of material zones to be used in the XSDRNPM calculation. Typically IZM=2, 3 or 4 for a LATTICECELL calculation (fuel/moderator; fuel/clad/moderator; fuel/gap/clad/moderator). For an infinite homogeneous media (INFHOMMEDIUM), set IZM=1. For a MULTIREGION calculation, one should have IZM $\geq$ 1. In the configuration shown in Fig. 7, one would have IZM=5 and MXX=4.

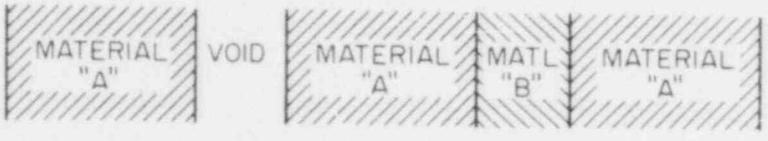


Fig. 7. Graphic Explanation of IZM and MXX.

Note that each spatial region is considered a "zone" even though it may contain a void. Note also that a void (which is internally defined as mixture number 0) does not count as a material mixture to be defined by the user.

5. GE Alphanumeric description of the type of calculation to be performed. Any one of the following alphanumeric descriptions may be used:
LATTICECELL – for a lattice cell calculation. For an array of cylindrical fuel rods or an array of spherical fuel pellets, white (i.e., isotropic) return will be used as the boundary condition on the outside surface. In slab geometry, mirror-like reflection will be used on both surfaces.
INFHOMMEDIUM – for an infinite homogeneous media.

MULTIREGION – for a multiregion calculation. For this type of calculation, the user may enter the boundary conditions (and other descriptive information) as described below.

Note: The alphanumeric description must be followed by two or more blanks before any additional data is entered.

Note: In the CSAS1 analytic sequence, the type of calculation required (LATTICECELL, INFHOMMEDIUM, MULTIREGION) is defined by the problem at hand. In the CSAS2 analytic sequence, however, the question may not be as straightforward. The next two paragraphs provide guidelines for the users of the CSAS2 analytic sequence.

In 3-D KENO calculations involving any sort of fuel assembly, the individual components of each fuel pin may be represented explicitly, or the homogenized cell-weighted cross sections for the assembly may be used (c.f., Section 2). In either case, the user should define this as a LATTICECELL calculation even though the fuel assembly may be a small part of the complete 3-D KENO problem. The self-shielding calculations for those resonance materials found in the unit cell will be performed using the geometry data supplied on the Geometry Description Card (below) and the appropriate Dancoff factor (computed internally). [In practice, the user may also describe the unit cell using the MULTIREGION option. In addition to the information on the Geometry Description Card, he would also have to enter the information on the Multiregion Zone Description Card (below). This would allow him to specify the number of external moderators (0, 1 or 2) the absorber lump sees, but it would also cause a Dancoff factor of 0.0 to be used in the resonance self-shielding calculation.] A separate self-shielding calculation will then be performed for each material defined by the user but not found in the unit cell. Each of these calculations will be performed as if that single material were of infinite extent (i.e., an infinite-homogeneous-media). Note, however, that each of these calculations will account for the presence of only those moderating nuclides within the material in question. These self-shielded cross sections are then used in KENO.

If the 3-D KENO calculation does not involve any sort of fuel assembly and/or if there is no convenient way of modeling the fissile portion of the problem in 1-D, the user should define this as an INFHOMMEDIUM calculation. A separate self-shielding calculation will then be performed for each material defined by the user. Each of these calculations will be performed as if that single material were of infinite extent (i.e., an

infinite-homogeneous-media). Note, however, that each of these calculations will account for the presence of only those moderating nuclides within the material in question. These self-shielded cross sections are then used in KENO.

6. MORE Flag used to signal whether or not the user wishes to read any of the Optional Control Parameters described below. Set MORE=1 if any of the optional control parameters are to be read; set MORE=0 if none of the optional control parameters are to be read.

7. MSLN Number of Standard Composition Specification Cards which designate a solution as the standard composition [c.f., item (1a) below]. Some common fissile solutions are SOLNUO2(NO3)2, SOLNPU(NO3)4 and SOLNUO2F2. For a complete listing, see the Table of Available Solutions (Table A.2).

4. Standard Composition Specification Cards

Note: The user should enter as many of these "Standard Composition Specifications" as necessary. (Item 3 on the Parameter Card, MSC, is the number of Standard Composition Specifications the user intends to enter.) The data for any Standard Composition Specification may extend over as many punched cards as necessary. Each Standard Composition Specification should begin with item (1a) as the first item of a new card. Despite the lengthy elucidation which follows, many mixtures can be described briefly, and only require that the user enter items (1a) and (2a), followed by item (7).

(1a) SC Alphanumeric description of the standard composition (i.e., U-235, SS304, SOLNUO2(NO3)2, ARBMTL1, etc.). A list of available isotopes, elements, compounds, solutions and alloys may be found in the Standard Composition Library (Table A.1) or the Table of Available Solutions (Table A.2). ARBMTL1, ARBMTL2, etc., may always be used to designate an arbitrary material for which the user will supply information normally found in the standard composition library.

Note: The arbitrary material option has been provided so that one can use the elements and isotopes in the Standard Composition Library to build other compounds and/or alloys not found there. (See discussion below.)

Note: The alphanumeric description of the standard compostion must be followed by two or more blanks before any additional data is entered.

If an arbitrary material is specified (i.e., ARBMTL1, ARBMTL2, etc.), items (1b) through (1h) must be included next, otherwise they should be skipped.

Example of When and How to Specify an Arbitrary Material:

The input parameters on the Standard Composition Specification Card should be straightforward and should not have to be "calculated" by the user. Using the isotopes, elements, compounds, solutions and alloys in the Standard Composition Library (Table A.1) or the Table of Available Solutions (Table A.2), and the associated volume fractions [see discussion of item (3) below], the user can generally describe almost any mixture in a "straightforward" manner. Occasionally, however, a special mixture will be encountered for which the determination of the component volume fractions [item (3)] will not be straightforward. Consider a mixture of Boral having 35 wt % B_4C, 65 wt % Al and an overall density of 2.64 gm/cc. Assume that the user had to represent such a mixture but that neither BORAL nor B4C was in the Standard Composition Library. If one used BORON, C and AL (all elements in the Standard Compostion Library) to describe the BORAL mixture, the corresponding volume fractions [item (3)] would have to be calculated as in Appendix B. A more straightforward approach would be to define both B_4C and Al as "arbitrary materials," each with a density of 2.64 gm/cc and with respective volume fractions of 0.35 and 0.65. The resulting standard composition specifications would look like:

ARBMTL-B4C 2.64 2 1 1 0 5000 4 6012 1 1 0.35 END

ARBMTL-AL 2.64 1 0 0 0 13027 100.0 1 0.65 END

Note that this type of specification does not require the user to calculate anything. The various data items shown are described below.

Note: If the user intends to enter an arbitrary material, item (1a) need not be ARBMTL1, ARBMTL2, ARBMTL3, etc. Indeed, the user may use up to 12 characters in the alphanumeric description as long as 1) there are no imbedded blanks, and 2) the first four characters are ARBM. Hence, ARBMTL-B4C and ARBMTL-AL are valid entries. The alphanumeric description must, of course, be followed by two or more blanks before any additional data is entered.

(1b) ROTH — Theoretical density of the material in gm/cc.

(1c) NEL — Number of elements in the material.

(1d) IVIS — Set IVIS=0 if none of the elements in the material have more than one isotope; set IVIS=1 if one of the elements (i.e., the first one listed below) has more than one isotope. Note: Each user supplied arbitrary material (ARBMTL1, ARBMTL2, etc.) can have, at most, one element with more than one isotope. If necessary, two or more arbitrary materials may be used to define a single mixture.

(1e) ICP — Set ICP=0 if the material is not a compound; set ICP=1 if the material is a compound. For alloys like SS-316 or mixtures like concrete, one would, for example, set ICP=0.

(1f) IRS — Set IRS=0 if none of the nuclides in this material have resonance data in the cross section library; set IRS=1 if any of the nuclides in this material

have resonance data in the cross section library. Table A.1 may be used to determine the availability of resonance data for each of the constituent nuclides entered below ($NCZA_1$, $NCZA_2$, etc.).

Items (1g) and (1h) should be entered (in the order shown) once for each element in the "arbitrary material."

(1g.1) $NCZA_1$ "ZA" ID number for the first element in this material. Generally NCZA = A + 1000*Z where Z and A are the charge and mass numbers for the nuclide (i.e., 1001 for Hydrogen and 8016 for Oxygen, etc.). For elements with more than one isotope, it is simply NCZA = 1000*Z (i.e., 92000 for Uranium).

Note: Each user supplied arbitrary material (ARBMTL1, ARBMTL2, etc.) can have, at most, one element with more than one isotope. That element must be specified as the first element in the material – i.e., it must be described by ($NCZA_1$, $ATPM_1$), not ($NCZA_2$, $ATPM_2$) or ($NCZA_3$, $ATPM_3$), etc. Furthermore, such an element can be specified only if it is currently listed in the Isotope Distribution Table (c.f., Table A.3). All other elements must, of course, be listed in the Standard Composition Library (c.f., Table A.1).

(1h.1) $ATPM_1$ If ICP=1, ATPM = number of atoms of the first element per molecule. If ICP=0, ATPM = weight percent of the first element in this material.

(1g.2) $NCZA_2$ "ZA" ID number for the second element in this material.

(1h.2) $ATPM_2$ Number of atoms of the second element per molecule, or the weight percent of the second element in this material.

.
.
.

Note: If this "arbitrary material" is an alloy, i.e., if ICP=0, the ATPM.'s should sum to 100.0.

2a) MX Mixture ID number. The standard composition specified by item (1a) will become a constituent part of this mixture. Must have $1 \leq MX \leq MXX$ where MXX was specified as item (2) on the Parameter Card.

If item (1a) denotes a solution [i.e., SOLNUO2F2, SOLNUO2(NO3)2, SOLNPU(NO3)4, etc.], items (2b) and (2c) must be included next, otherwise they should be skipped.

(2b) FD Fuel density (i.e., grams of heavy metal per liter of solution).

(2c) AML Acid molarity of the solution.

The remaining input data for this standard composition may be defaulted by entering item (7) next.

(3) VF

VF may be interpreted as 1) the volume fraction of this standard composition in the mixture, or as 2) the fractional theoretical density of the standard composition (i.e., the density of the standard composition in this application divided by the theoretical density listed in the Standard Composition Library), or 3) a product of (1) and (2).

Several examples might be in order: a) A homogenized mixture representing the coolant and the cladding around a fuel pin may be described using H2O, ZIRCALLOY and the appropriate volume fractions; b) A homogenized mixture representing a known solution diluted with water may be described using the appropriate volume fractions; c) For UO_2 fuel at 95% theoretical density, the user would enter VF = 0.95; and d) For the coolant water in an operating PWR, the user might enter VF = 0.71 (c.f., Table A.6).

To describe a mixed oxide fuel pin which has a density of 10.50 gm/cc and is 17.8 wt % PuO_2 and 82.2 wt % UO_2, requires two standard composition specification cards: one for the PuO_2 component and one for the UO_2 component. From the standard composition library, it may be seen that the theoretical density of PuO_2 is 11.46 gm/cc while that of UO_2 is 10.96 gm/cc. Thus, on the PuO_2 standard composition specification card, one would use VF = (0.178)(10.50/11.46) = 0.1631; and on the UO_2 standard composition card, one would use VF = (0.822)(10.50/10.96) = 0.7875.

Occasionally, a special mixture will be desired for which the determination of the component volume fractions will not be as straightforward as the ordinary situation illustrated above. Consider a mixture of Boral having 35 wt % B_4C, 65 wt % Al and an overall density of 2.64 gm/cc. Assume a user had to represent such a mixture but that neither BORAL nor B4C was in the Standard Composition Library. The volume fractions corresponding to BORON, C and AL may be computed as illustrated in Appendix B. Note that the calculation is complicated by the fact that B_4C is a compound and the fact that Boron has two isotopes. In this particular case, a more straightforward approach might be to enter B_4C and Al as "Arbitrary Materials." See previous example.

Note: If this parameter (VF) is not entered, the code assumes a default value of 1.0.

Note: If item (1a) denotes a single nuclide (such as U-235) and if the user would prefer to personally calculate and enter the number density (atoms/barn-cm) for that nuclide in this mixture, then he should set VF = 0.0.

If VF > 0.0, the remaining input for this standard composition may be defaulted by entering item (7) next.

If VF = 0.0, item (4) must be included next; otherwise, it should be skipped.

(4) ADEN Atomic number density (atoms/barn-cm) for the nuclide [c.f., item (1a)] in the mixture [c.f., item (2a)].

The remaining input for this standard composition may be defaulted by entering item (7) next.

(5) TEMP Temperature of the material (in deg. K). This will be used for Doppler Broadening and/or for the selection of the proper set of thermal scattering data (see more detailed note below).

The resonance self-shielding calculation performed by NITAWL uses the Nordheim Integral Method[4] and can account for Doppler Broadening of the resonances at any specified temperature. If this material is known to contain a resonance nuclide, the user may (and probably should) enter a rough estimate of the temperature of the material. To determine whether resonance data is available for any of the nuclides in this material:

a) Check Table A.1 if item (1a) denotes an isotope, element, compound or alloy found in the Standard Composition Library (SS304, etc.).

b) Check Table A.2 if item (1a) denotes a solution [SOLNUO2(NO3)2, etc.].

c) Check item (1f) if item (1a) denotes a user-specified "arbitrary material" (ARBMTL1, etc.).

For each of the light nuclides ($A \lesssim 20$ a.m.u.), the master cross section library selected may contain one or more sets of thermal scattering data, each set corresponding to a different temperature. Scattering matrices for nuclides in media at elevated temperatures are generally fuller than those at lower temperatures. Tables A.1 and A.2 indicate the isotopes, elements, compounds, solutions and alloys for which multiple sets of thermal scattering data are currently available. If multiple sets of thermal scattering data are available, the user may (and probably should) enter a rough estimate of the temperature of the material. The code will then use the set of cross section data which is most appropriate.

Note: One may always enter TEMP, even if it is not needed.

Note: If TEMP is not entered, the code assumes a default value of 293°K.

The remaining input for this standard composition may be defaulted by entering item (7) next.

If VF = 0.0 [c.f., item (3)], items (6a) and (6b) should be skipped.

If none of the elements in this material [c.f., item (1a)] have more than one isotope, items (6a) and (6b) should be skipped. To determine whether the material in item (1a) has an element with more than one isotope, the user may look up that material in the Standard Composition Library (c.f., Table A.1). That table contains a complete list of the isotopes in each material and the corresponding "ZA" nuclide ID numbers.

If one of the elements in this material has more than one isotope, the user may specify the isotopic distribution by entering items (6a) and (6b) as many times as necessary. Alternately, the user may skip items (6a) and (6b) and allow the code to assume the default values shown in the Isotope Distribution Table (c.f., Table A.3).

(6a.1) IZA_1 Isotope's "ZA" ID number.

(6b.1) WTP_1 Weight percent of this isotope (IZA_1) in the element [for example: $WTP_1 = (100)(\text{kg } ^{235}\text{U/kg U})$ in UO_2].

(6a.2) IZA_2 Another isotope's "ZA" ID number.

(6b.2) WTP_2 Weight percent of this isotope (IZA_2) in the element.

•
•
•

Note: The user need not enter a (IZA_n, WTP_n) pair for each isotope listed in the Isotope Distribution Table. If he enters this data at all (i.e., if he does not take the default values), the only requirement is that the sum of the WTP_n's entered must equal 100.0. Hence, (92235 3.2 92238 96.8) would constitute a complete specification for uranium even though other isotopes are listed in the Isotope Distribution Table.

(7) END The word END should be punched to indicate the end of the input data for this Standard Composition Specification.

5. Geometry Description Card

Note that the data for the "Geometry Description Card" may extend over as many punched cards as necessary.

If item 5 on the Parameter Card (GE) designates this as an INFHOMMEDIUM calculation, the Geometry Description Card should not be included at all.

If item (5) on the Parameter Card (GE) designates this as a MULTIREGION calculation, items (1) through (6) should be skipped. For LATTICECELL calculations:

(1) CTP Alphanumeric description of the lattice cell. Any one of the following alphanumeric descriptions may be used. (Note that the alphanumeric description must be followed by two or more blanks before any additional data is entered.)

SQUAREPITCH - for an array of cylindrical fuel rods arranged in a square lattice.

TRIANGPITCH - for an array of cylindrical fuel rods arranged in a triangular lattice.

SPHSQUAREP - for an array of spherical fuel pellets arranged in a cubic lattice.

SPHTRIANGP - for an array of spherical fuel pellets arranged in a bi-centered or face-centered hexagonal close-packed lattice. (In this configuration, each layer of fuel pellets forms a hexagonal array, with alternate layers being rotated with respect to each other so as to form a close-packed arrangement.)

SYMMSLABCELL - for a symmetric array of slabs as illustrated in Fig. 8.

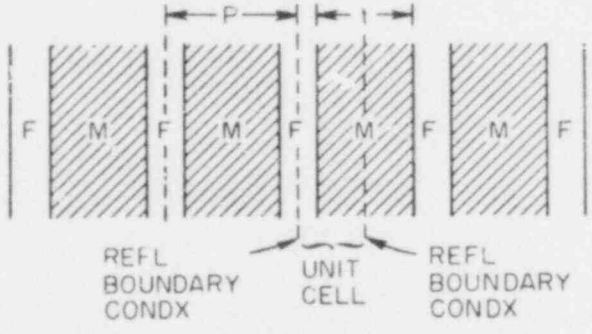


Fig. 8. Arrangement of Materials in a Symmetric Slab Cell. Here, one has (F,M), (F,M), (F,M), (F,M), etc.

ASYMSLABCELL - for a periodic but asymmetric array of slabs as illustrated in Fig. 9. For such an asymmetric LATTICECELL calculation, one should have IZM = [illegible] or 7 depending on the materials present (i.e., fuel/moderator; fuel/clad/moderator; fuel/gap/clad/moderator). Check item 4 on the Parameter Card (IZM)

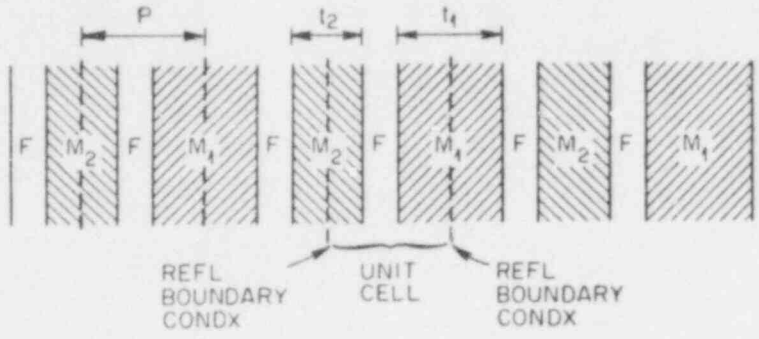


Fig. 9. Arrangement of Materials in an Asymmetric Slab Cell. Here, one has (F,M_2,F,M_1), (F,M_2,F,M_1), etc.

(2) PITCH — For an asymmetric slab cell calculation, PITCH is the distance from the center of one moderator to the center of the other moderator (see Fig. 9). For all other lattice cell calculations, PITCH is center-to-center spacing between fuel lumps (rods, pellets, or slabs).

(3a) FUELOD — Outside diameter of the fuel in cm. (In slab geometry, enter its thickness.)

(3b) MFUEL — Mixture number representing the fuel.

(4a) MMOD — Mixture number representing the moderator (M_1).

If item (1) denotes an asymmetric slab cell calculation (i.e., ASYMSLABCELL), items (4b) and (4c) must be entered next; otherwise, they should be skipped.

(4b) MMOD2 — Mixture number representing the second moderator (M_2).

(4c) TKMOD2 — Thickness of the second moderator in cm.

If there is clad around the fuel, items (5a) and (5b) should be entered next; if there is no clad, item (13) should be entered next.

(5a) CLADOD — Outside diameter of the clad in cm. (In slab geometry, CLADOD = $t_{fuel} + 2t_{gap} + 2t_{clad}$.)

(5b) MCLAD — Mixture number representing the clad.

If there is a gap between the fuel and the clad, items (6a) and (6b) should be entered next; if there is no gap, item (13) should be entered next.

(6a) CLADID — Inside diameter of the clad in cm. (In slab geometry, CLADID = $t_{fuel} + 2t_{gap}$.)

(6b) MGAP — Mixture number representing the gap. (Mixture number zero is often used. It is internally defined as a void.)

If item 5 on the Parameter Card (GE) designates this as a LATTICECELL calculation, skip items (7) through (12), and enter item (13) next.

For MULTIREGION calculations:

(7) CS — Alphanumeric description of the geometry. Any one of the following alphanumeric descriptions may be used:

SLAB – for slab geometry.

CYLINDRICAL – for cylindrical geometry.

SPHERICAL – for spherical geometry.

BUCKLEDSLAB – for slab geometry, with a buckling correction for the two transverse directions.

BUCKLEDCYL – for cylindrical geometry, with a buckling correction in the axial direction.

Note: This alphanumeric description must be followed by two or more blanks before any additional data is entered.

If item (7) designates SLAB, CYLINDRICAL or SPHERICAL geometry, items (8), (9), and (10) may be skipped and allowed to assume their default values. Alternately, the user may enter item (8) only, items (8) and (9), or items (8), (9), and (10). For BUCKLEDSLAB and BUCKLEDCYL calculations, all three parameters must be entered.

(8) ER — Alphanumeric description of the right/outside boundary condition. Any one of the following alphanumeric descriptions may be used: VACUUM, REFLECTED, PERIODIC, WHITE.

Note: The alphanumeric description must be followed by two or more blanks before any additional data is entered.

Note: If this parameter (BR) is not entered, the code assumes a VACUUM boundary condition on the right/outside boundary.

Note: The WHITE boundary condition corresponds to isotropic return of all particles which otherwise would have left the system.[18]

Note: A REFLECTED or PERIODIC right boundary condition should not be used in cylindrical or spherical geometry.[18]

(9) BL — Alphanumeric description of the left boundary condition. Any one of the following alphanumeric descriptions may be used: VACUUM, REFLECTED, PERIODIC, WHITE.

Note: The alphanumeric description must be followed by two or more blanks before any additional data is entered.

Note: If this parameter (BL) is not entered, the code assumes a REFLECTED boundary condition on the left boundary. In cylindrical or spherical geometry, this is the only boundary condition that makes sense since the left boundary then corresponds to the centerline.

(10) ORGN — Location of the left boundary on the x-axis (in cm).

Note: If this parameter (ORGN) is not entered, the code assumes ORGN = 0.0 cm. In cylindrical or spherical geometry, this is the only value allowed.

If item (7) denotes a BUCKLEDSLAB or BUCKLEDCYL calculation, item (11) should be included next; otherwise, it should be skipped.

(11) DY — Buckling height (in cm). This corresponds to one of the transverse dimensions of an actual 3-D assembly or the length of a finite cylinder.

If item (7) denotes a BUCKLEDSLAB calculation, item (12) should be included next; otherwise, it should be skipped.

(12) [illegible] — Buckling depth (in cm). This corresponds to the second transverse dimension of an actual 3-D assembly.

For MULTIREGION calculations or LATTICECELL calculations:

(13) END — The word END should be punched to indicate the end of the input data for the Geometry Description Card.

6. Multiregion Zone Description Card

If item 5 on the Parameter Card (GE) designates this as an INFHOMMEDIUM calculation or a LATTICECELL calculation, the Multiregion Zone Description Card should not be included at all.

Items (1a), (1b) and (1c) should be entered once for each zone, as shown below. Note that the number of zones (IZM) was specified as item 4 on the Parameter Card. The data for the "Multiregion Zone Description Card" may extend over as many punched cards as necessary. Each punched card may contain data for one or more zones.

(1a.1) MXZ_1 — Mixture number for the material in zone one. These "mixtures" are those previously defined by the user [c.f., item (2a) on the Standard Composition Specification Cards]. A zero may be entered for a void; otherwise, one must have $1 \leq MXZ_1 \leq MXX$ (c.f., item 2 on the Parameter Card).

(1b.1) RZ_1 — Outside radius of zone one (in cm). In slab geometry, RZ is the location of the zone's right boundary on the x-axis.

(1c.1) $XMOD_1$ — External moderator index for zone one. Any one of the following alphanumeric descriptions may be used:

NOEXTERMOD – no moderating materials in the zones immediately adjacent to this zone.

ONEEXTERMOD – moderating material in one of the zones immediately adjacent to this zone.

TWOEXTERMOD – moderating materials in both of the zones immediately adjacent to this zone.

Note that the alphanumeric description must be followed by two or more blanks before any additional data is entered.

(1a.2) MXZ_2 Mixture number for the material in zone two.

(1b.2) RZ_2 Outside radius of zone two (in cm).

(1c.2) $XMOD_2$ External moderator index for zone two.

•

•

•

7. Optional Control Parameters

If item 6 on the Parameter Card (MORE) equals zero, the Optional Control Parameter Card should not be included at all.

If MORE = 1, one or more of the parameters may be entered in any order. The default values shown in brackets will be used for those parameters not entered. Each parameter is entered by spelling its name, followed immediately by an equal sign (=) and the value to be entered (e.g., ISN=6). There should not be a blank between the parameter name and the equal sign. Each parameter specification must be separated from the rest by one or more blanks.

If the user elects to enter any of the optional control parameters, then the last entry should be followed by one or more blanks, the three characters 'END,' and one or more additional blanks.

The optional control parameters available to the user are:

ISN Order of angular quadrature (8). ISN may be made less than 8 for a lower order angular quadrature or greater than 8 for a higher order angular quadrature. See Section 3.6 for details.

SZF Spatial mesh size factor (1.0). SZF may be made less than 1.0 for a finer spatial mesh or greater than 1.0 for a coarser spatial mesh. See Section 3.5 for details.

IIM Maximum number of inner iterations allowed (20).

ICM Maximum number of outer iterations allowed (25).

EPS Overall problem convergence criteria (0.0001). See Section 3.8 for details.

PTC Pointwise convergence criteria for the scalar flux (0.0001). See Section 3.8 for details.

BKL Buckling factor (1.420892). This parameter is not even used unless this is a MULTIREGION calculation for a BUCKLEDSLAB or a BUCKLEDCYL. Even then, 1.420892 is quite good for most (large) systems. See Section 3.7 for additional details.

IUS Upscatter scaling switch (0). If IUS=0, upscatter scaling is not used in the XSDRNPM multigroup iteration procedure. If IUS=1, upscatter scaling is used to accelerate the solution and/or force convergence. Some problems will not converge with it, and some problems will not converge without it. No a priori guidelines exist for determining when it is needed and when it will fail. Most problems, however, will work with IUS=0.

8. END Card for the CSAS1 Analytic Sequence

For the CSAS1 analytic sequence, the user should include a final card with END punched in columns 1 through 3. No additional input is required for the CSAS1 sequence.

For the CSAS2 analytic sequence, the END card should not be included and, in its place, the following KENO input should follow immediately. Having processed the necessary cross section data using NITAWL and XSDRNPM, it is possible to use that data in one or more KENO cases. One set of KENO input data should be entered for each case.

9. KENO Title Card

All 80 columns may be used for a descriptive title.

10. KENO Parameter Card

(1) TMAX Maximum computer time (in min) to be allowed for this problem.

(2) NGEN Number of generations desired (typically 100).

(3) NSTART Number of neutrons started per generation (typically 300).

(4) NSKIP Number of generations to be skipped before calculating k_{eff} (typically 4).

(5) NBOX Number of box types to be described by user.

To model many physical situations in KENO geometry, the user must mentally subdivide a problem (or a portion of it) into an "array of boxes." Rules for doing this are described in Appendix C along with assorted examples. Such an array would be composed of a specified number of boxes in the x-direction (NBXMAX), a specified number of boxes in the y-direction (NBYMAX), and a specified number of boxes in the z-direction (NBZMAX). All "boxes" would not necessarily have to be the same. Indeed, the internal geometry description, the material specifications or the external dimensions of each box may vary (c.f., Appendix C). The user must, however, tell the code the number of different "box types" he intends to use (NBOX).

NOTE: If the physical situation being modeled is simple enough that it need not be subdivided into an array of boxes, set NBOX equal to zero. A large isolated tank containing a fissile solution might be one such example. See Appendix C for additional examples.

(6) NBXMAX Number of boxes in the x-direction. See note under NBOX for explanation. If NBOX=0, set NBXMAX=0.

(7) NBYMAX Number of boxes in the y-direction. See note under NBOX for explanation. If NBOX=0, set NBYMAX=0.

(8) NBZMAX Number of boxes in the z-direction. See note under NBOX for explanation. If NBOX=0, set NBZMAX=0.

(9) NXX Flag used to signal whether or not the user wishes to read any of the Boundary Condition Specifications described below. Set NXX=1 if perfect mirror-like reflection is to be prescribed on one or more of the external surfaces; otherwise, set NXX=0.

Whenever the physical situation being modeled by the user can be represented as an "array of boxes," perfect mirror-like reflection may be prescribed for one or more of the surfaces. To determine k_{eff} of an infinite array of fuel pins, for example, the user might actually describe a segment of a single unit cell using a $1 \times 1 \times 1$ array. The fuel, gap, clad and moderator could all be represented explicitly within a single box. Perfect mirror-like reflection could then be applied to all six surfaces of the array to determine k_{eff} of an infinite array of infinitely long fuel pins, or to four surfaces to determine k_{eff} of an infinite array of finite fuel pins. For that reason, NXX=1 has been called the "k_∞ option."

Reflective boundary conditions may also be used in conjunction with the automatic reflector card, or whenever a CUBE or CUBOID card is used to describe the outermost region beyond the array boundary. To model a symmetric reactor with a reflector of thickness (t), for example, the user may use an array of boxes to describe a single octant, the automatic reflector card to describe the reflector, and the Boundary Condition Specifications to describe the symmetry. He might, for example, set TX2=TY2=TZ2=t and TX1=TY1=TZ1=0.0 on the REFLECTOR card, and prescribe mirror-like reflection on the $-x$, $-y$ and $-z$ surfaces. While he could have described the entire reactor explicitly, this scheme requires him to enter a somewhat smaller amount of Mixed Box Orientation Data.

Fig. 10 shows the upper half of a (symmetric) spent fuel shipping cask. Enclosing the upper half of the cask with a CUBOID (as shown) and prescribing mirror-like reflection on the lower surface reduces the amount of Mixed Box Orientation Data the user must enter. Alternately, he could have described the entire cask explicitly with little additional effort.

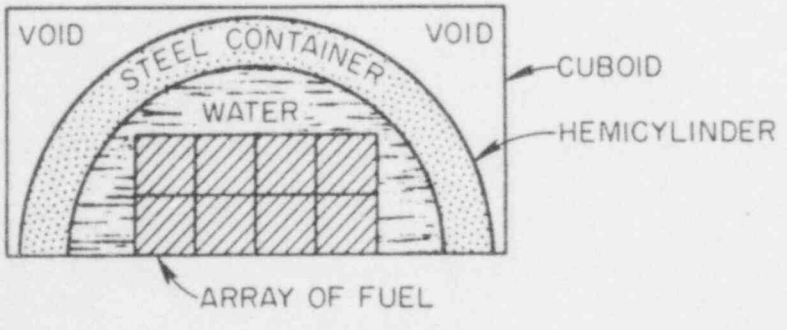


Fig. 10. Upper half of a (Symmetric) Spent Fuel Shipping Cask.

Lastly, it should be noted that mirror-like reflection should be used with caution on those surfaces immediately adjacent to a moderately thick reflecting material. Fig. 11 shows a large, water-filled fuel storage area where the individual fuel assemblies are moderately well-separated. (If they were close together, this could be treated as an infinite array of fuel pins; if the assemblies were far apart, one could model this as a single fuel assembly with an infinite water reflector.) In this case, one could certainly describe a single fuel assembly as an array of boxes, and use one or more CUBOID cards to describe the water beyond the array boundary, with mirror-like reflection on the various surfaces of the outermost CUBOID. Depending on the dimensions, use of reflective boundary conditions in this situation may cause some uncertainty in the selection of appropriate, spatially dependent multigroup weights for the water. Alternately, one could use the automatic reflector card to describe the water beyond the array boundary and still specify mirror-like reflection on the outermost surface of the reflector region. Again, depending on the dimensions, the use of water weights automatically secured from the library may be questionable for this situation.

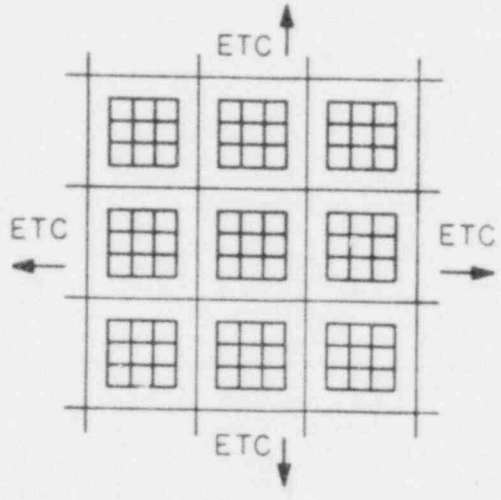


Fig. 11. Large Water-Filled Fuel Storage Area.

11. Boundary Condition Specifications

This data card should be entered only if NXX=1 [c.f., item (9) of the KENO Parameter Card].

(1) MLRX2 Enter 1 for perfect mirror-like reflection on the outermost surface in the +x direction; enter 0 otherwise.

(2) MLRX1 Enter 1 for perfect mirror-like reflection on the outermost surface in the −x direction; enter 0 otherwise.

(3) MLRY2 Enter 1 for perfect mirror-like reflection on the outermost surface in the +y direction; enter 0 otherwise.

(4) MLRY1 Enter 1 for perfect mirror-like reflection on the outermost surface in the −y direction; enter 0 otherwise.

(5) MLRZ2 Enter 1 for perfect mirror-like reflection on the outermost surface in the +z direction; enter 0 otherwise.

(6) MLRZ1 Enter 1 for perfect mirror-like reflection on the outermost surface in the −z direction; enter 0 otherwise.

12. Multidimensional Geometry Specification Cards

KENO geometry is three-dimensional and allows the user to model a large variety of frequently encountered physical situations. To be more precise, it allows for the simultaneous use of cuboids, spheres, hemispheres, cylinders, hemicylinders and an imbedded array of such bodies. Appendix C, "The Rudiments of KENO-IV Geometry," explains "how" one would model a large variety of physical situations – starting with the most elementary configuration and extending through to the most complex. It attempts to explain "why" a particular problem should be modeled one way as opposed to another. Lastly, it illustrates the way in which the selection of spatially dependent multigroup weights can often determine the best geometric model for a particular problem. While Table 1 and the subsequent discussion serve as "quick reminders" of how the geometry input data is to be structured, the novice user is strongly encouraged to read Appendix C before proceeding further.

The Multidimensional Geometry Specification Data is composed of 25 Basic Geometry Description Cards plus 4 "special" cards: the BOX TYPE cards, the ARRAY BOUNDARY card, the REFLECTOR card, and the END GEOMETRY card. The function of each card is described in Appendix C, and the placement of each card in the input stream is summarized in Table 1. Note that the Basic Geometry Description Cards may be used to describe an entire problem, the contents of each "box type," or the region(s) beyond the array boundary (c.f., Appendix C).

Table 1. Location of Various Geometry Cards in the Input Stream

BOX TYPE 1	←"Box type" card needed only if NBOX > 1
Basic Geometry Description (of Box Type 1)	
BOX TYPE 2	←"Box type" card needed only if NBOX > 1
Basic Geometry Description (of Box Type 2)	
ARRAY BOUNDARY	←"Array boundary" card needed only if one uses the basic geometry description to describe regions outside the array
Basic Geometry Description of Regions Surrounding the Array	←Optional, but only makes sense if NBXMAX * NBYMAX * NBZMAX > 1
REFLECTOR	←"Reflector" card is almost always optional. May be entered even if one uses the basic geometry description to describe regions outside the array. May even be used if NBXMAX * NBYMAX * NBZMAX = 1. Must not be used only if NBOX = 0
END GEOMETRY	←Always required

12a. BOX TYPE Cards

BOX TYPE cards should be entered only if NBOX > 1 [c.f., item (5) on the KENO Parameter Card]. When required, the user will enter a BOX TYPE Card followed by a set of Basic Geometry Description Cards describing the box type. He will then enter a second BOX TYPE Card followed by a set of Basic Geometry Description Cards describing the second box type, and so on, until all box types have been fully described. BOX TYPE cards can be entered in either of two formats:

BOX TYPE 1
BOX TYPE 2
BOX TYPE 3
.
.
.

} where BOX TYPE is punched in columns 1 through 8 with a single blank between the two words

or

BOX 1
BOX 2
BOX 3
.
.
.

} where BOX is punched in columns 1 through 3

In each case, the box type number must be proceeded by two or more blanks. Box types must be numbered sequentially, starting with 1.

Note that the last Basic Geometry Description Card describing each box type should be a CUBE or CUBOID.

12b. Basic Geometry Description Cards

There are 25 basic geometry description cards that this verion of KENO-IV will recognize. Each of these are described below. Basically, each has the same format: Starting in column 1 on a new card, the user should enter the alphanumeric geometry word (CUBOID, CYLINDER, etc.), followed by at least two blanks. The user should then enter the appropriate mixture number, the dimensions, and the weights for that region, with data entries separated by one or more blanks. This data may extend over as many punched cards as necessary.

The user is generally free to use mixture numbers 1 through MXX in any of the 3-D KENO geometry regions.*[1] He is also free to use mixture number 0 to represent a void. He should note, however, that any mixture previously used on the Geometry Description Card (describing a LATTICECELL configuration) or on the Multiregion Zone Description Card (describing a MULTIREGION configuration), will have had its cross section data self-shielded using the information entered on those cards. All other mixtures containing resonance nuclides will be self-shielded using an infinite homogeneous media approximation for each.

In many 3-D KENO calculations, it is convenient to use homogenized cell-weighted cross sections to represent a fuel assembly. The CSAS2 analytic sequence has provisions for internally calculating such cross sections. Thus, in addition to using mixture number 0 to represent a void, the user is also free to use mixture number 500 to represent the homogenized cell-weighted cross sections corresponding to the LATTICECELL (or MULTIREGION) configuration described on the Geometry Description Card (or the Multiregion Zone Description Card). If the user elects to take advantage of this option and assigns mixture number 500 to one or more of the KENO geometry regions, he should be careful not to re-assign any of the mixtures used in the unit cell (i.e., on the Geometry Description Card or the Multiregion Zone Description Card) to any of the KENO geometry regions.*[2]

If, for example, stainless steel and water are components of a unit cell and they also represent structural and shielding components of a shipping cask being modeled in three-dimensional KENO geometry, the user should use the Standard Composition Cards to define at least five mixture numbers: 1) the fuel, 2) the stainless steel clad, 3) the water in the unit cell, 4) the water in the shipping cask (exterior to the fuel assemblies), and 5) the stainless steel used for the structural material in the cask. If each fuel pin is to be modeled explicitly in 3-D KENO geometry, the user may use mixtures 0, 1, 2, 3, 4 and 5 in his 3-D geometry description. (In this case, mixture numbers

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*[1] MXX is the number of material mixtures defined by the user [c.f., item on the (CSAS2) Parameter Card]

*[2] Mixture number 0 is, of course, an exception and may be used in the unit cell and in any of the KENO geometry regions.

3 and 4 are redundant and may be used interchangeably.) If, on the other hand, he wishes to use homogenized cell-weighted cross sections for the entire fuel assembly, he should use mixtures 0, 4, 5 and 500 in his 3-D geometry description. (In this case, the cross section data for mixture 3 will be cell-weighted and cannot be used interchangeably with mixture 4.)

Lastly, the user should note that he is required to enter an appropriate set of multigroup weights for every spatial region. This data is usually entered as the last string of data items on each geometry card. As a matter of convenience, the user may punch a single entry of −0.5 as a flag to tell the code that (in the given region) a weight of 0.5 is to be used for all energy groups. Indeed, a weight of 0.5 should be used for all energy groups in any region containing a large amount of fissile material, in the clad and moderator surrounding a fuel pin in a fuel assembly, or whenever "something better" is not available (c.f., Appendix C). If, however, the geometry card describes a reflector region, it may be computationally more efficient to use a set of spatially dependent multigroup weights that have been pre-calculated. Weights for some commonly used reflector materials are given in ORNL-TM-4660 (see Ref. 19). Appendix C gives multiple examples of how such weights might be used.

(12b.1)	CUBOID	Six character alphanumeric geometry word
	MIXNO	Mixture number to be assigned to this region
	X2	Location of the +x surface of the cuboid
	X1	Location of the −x surface of the cuboid
	Y2	Location of the +y surface of the cuboid
	Y1	Location of the −y surface of the cuboid
	Z2	Location of the +z surface of the cuboid
	Z1	Location of the −z surface of the cuboid Note that the CUBOID described here need not be centered at the origin, or even enclose it.
	WTS	Multigroup weights to be assigned to this region
(12b.2)	CYLINDER	Eight character alphanumeric geometry word
	MIXNO	Mixture number to be assigned to this region
	RXY	Radius of the cylinder in the xy plane (Note that the cylinder is centered at x=y=0.)
	Z2	Location of the +z end of the cylinder
	Z1	Location of the −z end of the cylinder
	WTS	Multigroup weights to be assigned to this region
(12b.3)	SPHERE	Six character alphanumeric geometry word
	MIXNO	Mixture number to be assigned to this region
	R	Radius of the sphere (Note that the sphere is centered at x=y=z=0.)
	WTS	Multigroup weights to be assigned to this region

(12b.4)	CUBE	Four character alphanumeric geometry word
	MIXNO	Mixture number to be assigned to this region
	S2	Location of the +x, +y and +z surfaces of the cube (s × s × s, where s = S2 − S1).
	S1	Location of the −x, −y and −z surfaces of the cube (s × s × s, where s = S2 − S1). Note that the CUBE described here need not be centered at the origin, or even enclose it.
	WTS	Multigroup weights to be assigned to this region
(12b.5)	XCYLINDER	Nine character alphanumeric geometry word
	MIXNO	Mixture number to be assigned to this region
	RYZ	Radius of the cylinder in the yz plane (Note that the cylinder is centered at y=z=0.)
	X2	Location of the +x end of the cylinder
	X1	Location of the −x end of the cylinder
	WTS	Multigroup weights to be assigned to this region
(12b.6)	YCYLINDER	Nine character alphanumeric geometry word
	MIXNO	Mixture number to be assigned to this region
	RXZ	Radius of the cylinder in the xz plane (Note that the cylinder is centered at x=z=0.)
	Y2	Location of the +y end of the cylinder
	Y1	Location of the −y end of the cylinder
	WTS	Multigroup weights to be assigned to this region
(12b.7)	XHEMICYL+Y	Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the XCYLINDER for which $y > 0$. See Fig. 12.)
	MIXNO	Mixture number to be assigned to this region
	RYZ	Radius of the hemicylinder in the yz plane (Note that the cylinder of which this is a part would be centered at y=z=0.)
	X2	Location of the +x end of the hemicylinder
	X1	Location of the −x end of the hemicylinder
	WTS	Multigroup weights to be assigned to this region
(12b.8)	XHEMICYL−Y	Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the XCYLINDER for which $y < 0$. See Fig. 12.)
	MIXNO	Mixture number to be assigned to this region
	RYZ	Radius of the hemicylinder in the yz plane (Note that the cylinder of which this is a part would be centered at y=z=0.)

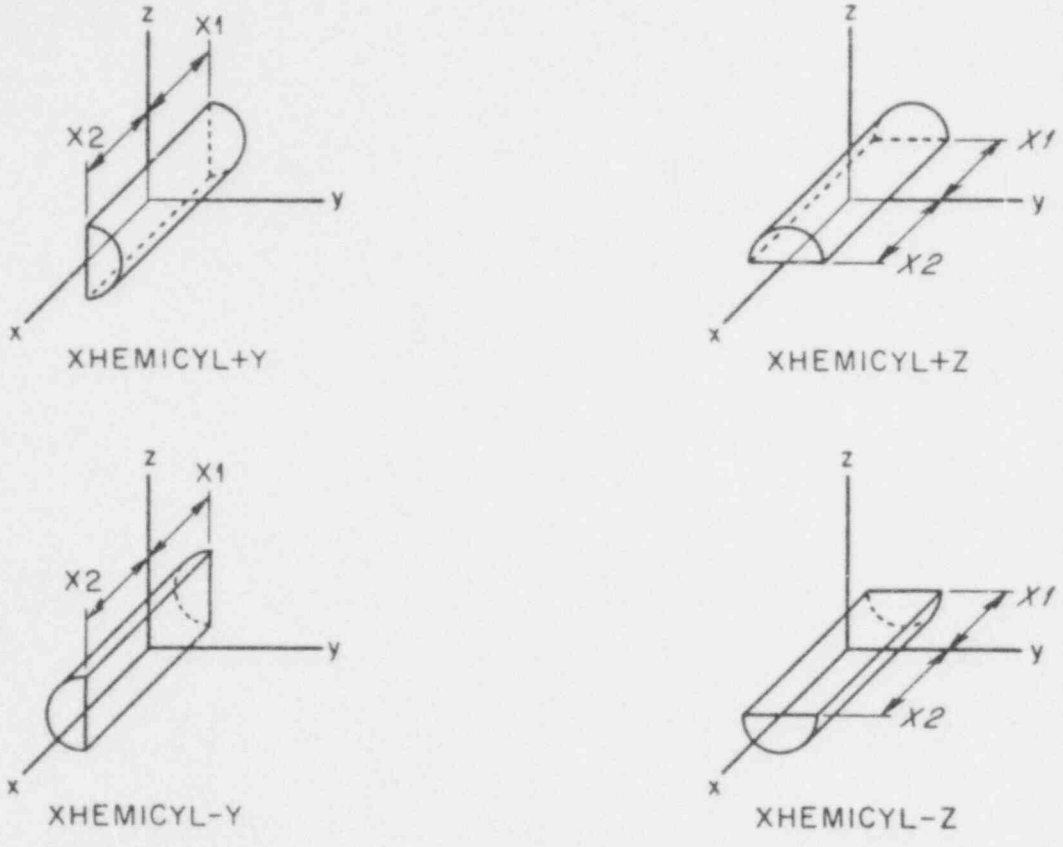


Fig. 12. Graphic Definition of XHEMICYL+Y, XHEMICYL-Y, XHEMICYL+Z and XHEMICYL-Z. Note that YHEMICYL+X, YHEMICYL-X, YHEMICYL+Z, YHEMICYL-Z and ZHEMICYL+X, ZHEMICYL-X, ZHEMICYL+Y, ZHEMICYL-Y are all defined in a similar fashion, with the first character denoting the axis and the last two characters denoting which "half" of the cylinder is intended.

	X2	Location of the +x end of the hemicylinder
	X1	Location of the −x end of the hemicylinder
	WTS	Multigroup weights to be assigned to this region
(12b.9)	XHEMICYL+Z	Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the XCYLINDER for which $z > 0$. See Fig. 12.)
	MIXNO	Mixture number to be assigned to this region
	RYZ	Radius of the hemicylinder in the yz plane (Note that the cylinder of which this is a part would be centered at $y=z=0$.)
	X2	Location of the +x end of the hemicylinder
	X1	Location of the −x end of the hemicylinder
	WTS	Multigroup weights to be assigned to this region
(12b.10)	XHEMICYL−Z	Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the XCYLINDER for which $z < 0$. See Fig. 12.)
	MIXNO	Mixture number to be assigned to this region
	RYZ	Radius of the hemicylinder in the yz plane (Note that the cylinder of which this is a part would be centered at $y=z=0$.)
	X2	Location of the +x end of the hemicylinder
	X1	Location of the −x end of the hemicylinder
	WTS	Multigroup weights to be assigned to this region
(12b.11)	YHEMICYL+X	Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the YCYLINDER for which $x > 0$. See Fig. 12.)
	MIXNO	Mixture number to be assigned to this region
	RXZ	Radius of the hemicylinder in the xz plane (Note that the cylinder of which this is a part would be centered at $x=z=0$.)
	Y2	Location of the +y end of the hemicylinder
	Y1	Location of the −y end of the hemicylinder
	WTS	Multigroup weights to be assigned to this region
(12b.12)	YHEMICYL−X	Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the YCYLINDER for which $x < 0$. See Fig. 12.)
	MIXNO	Mixture number to be assigned to this region
	RXZ	Radius of the hemicylinder in the xz plane (Note that the cylinder of which this is a part would be centered at $x=z=0$.)
	Y2	Location of the +y end of the hemicylinder
	Y1	Location of the −y end of the hemicylinder
	WTS	Multigroup weights to be assigned to this region

(12b.13) YHEMICYL+Z — Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the YCYLINDER for which $z > 0$. See Fig. 12.)

- MIXNO — Mixture number to be assigned to this region
- RXZ — Radius of the hemicylinder in the xz plane (Note that the cylinder of which this is a part would be centered at $x=z=0$.)
- Y2 — Location of the +y end of the hemicylinder
- Y1 — Location of the −y end of the hemicylinder
- WTS — Multigroup weights to be assigned to this region

(12b.14) YHEMICYL−Z — Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the YCYLINDER for which $z < 0$. See Fig. 12.)

- MIXNO — Mixture number to be assigned to this region
- RXZ — Radius of the hemicylinder in the xz plane (Note that the cylinder of which this is a part would be centered at $x=z=0$.)
- Y2 — Location of the +y end of the hemicylinder
- Y1 — Location of the −y end of the hemicylinder
- WTS — Multigroup weights to be assigned to this region

(12b.15) ZHEMICYL+X — Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the CYLINDER for which $x > 0$. See Fig. 12.)

- MIXNO — Mixture number to be assigned to this region
- RXY — Radius of the hemicylinder in the xy plane (Note that the cylinder of which this is a part would be centered at $x=y=0$.)
- Z2 — Location of the +z end of the hemicylinder
- Z1 — Location of the −z end of the hemicylinder
- WTS — Multigroup weights to be assigned to this region

(12b.16) ZHEMICYL−X — Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the CYLINDER for which $x < 0$. See Fig. 12.)

- MIXNO — Mixture number to be assigned to this region
- RXY — Radius of the hemicylinder in the xy plane (Note that the cylinder of which this is a part would be centered at $x=y=0$.)
- Z2 — Location of the +z end of the hemicylinder
- Z1 — Location of the −z end of the hemicylinder
- WTS — Multigroup weights to be assigned to this region

(12b.17) ZHEMICYL+Y — Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the CYLINDER for which $y > 0$. See Fig. 12.)

MIXNO	Mixture number to be assigned to this region
RXY	Radius of the hemicylinder in the xy plane (Note that the cylinder of which this is a part would be centered at x=y=0.)
Z2	Location of the +z end of the hemicylinder
Z1	Location of the −z end of the hemicylinder
WTS	Multigroup weights to be assigned to this region

(12b.18) ZHEMICYL−Y Ten character alphanumeric geometry word (Note that this "hemicylinder" corresponds to that half of the CYLINDER for which $y < 0$. See Fig. 12.)

MIXNO	Mixture number to be assigned to this region
RXY	Radius of the hemicylinder in the xy plane (Note that the cylinder of which this is a part would be centered at x=y=0.)
Z2	Location of the +z end of the hemicylinder
Z1	Location of the −z end of the hemicylinder
WTS	Multigroup weights to be assigned to this region

(12b.19) HEMISPHERE Ten character alphanumeric geometry word [Note that this "hemisphere" corresponds to that half of the SPHERE (centered at x=y=z=0) for which $z > 0$.]

MIXNO	Mixture number to be assigned to this region
RXY	Radius of the hemisphere in the xy plane
WTS	Multigroup weights to be assigned to this region

(12b.20) HEMISPHE+Z Ten character alphanumeric geometry word [Note that this "hemisphere" corresponds to that half of the SPHERE (centered at x=y=z=0) for which $z > 0$.]

MIXNO	Mixture number to be assigned to this region
RXY	Radius of the hemisphere in the xy plane
WTS	Multigroup weights to be assigned to this region

(12b.21) HEMISPHE−Z Ten character alphanumeric geometry word [Note that this "hemisphere" corresponds to that half of the SPHERE (centered at x=y=z=0) for which $z < 0$.]

MIXNO	Mixture number to be assigned to this region
RXY	Radius of the hemisphere in the xy plane
WTS	Multigroup weights to be assigned to this region

(12b.22) HEMISPHE+X Ten character alphanumeric geometry word [Note that this "hemisphere" corresponds to that half of the SPHERE (centered at x=y=z=0) for which $x > 0$.]

MIXNO	Mixture number to be assigned to this region
RYZ	Radius of the hemisphere in the yz plane
WTS	Multigroup weights to be assigned to this region

(12b.23)	HEMISPHE-X	Ten character alphanumeric geometry word [Note that this "hemisphere" corresponds to that half of the SPHERE (centered at x=y=z=0) for which $x < 0$.]
	MIXNO	Mixture number to be assigned to this region
	RYZ	Radius of the hemisphere in the yz plane
	WTS	Multigroup weights to be assigned to this region
(12b.24)	HEMISPHE+Y	Ten character alphanumeric geometry word [Note that this "hemisphere" corresponds to that half of the SPHERE (centered at x=y=z=0) for which $y > 0$.]
	MIXNO	Mixture number to be assigned to this region
	RXZ	Radius of the hemisphere in the xz plane
	WTS	Multigroup weights to be assigned to this region
(12b.25)	HEMISPHE-Y	Ten character alphanumeric geometry word [Note that this "hemisphere" corresponds to that half of the SPHERE (centered at x=y=z=0) for which $y < 0$.]
	MIXNO	Mixture number to be assigned to this region
	RXZ	Radius of the hemisphere in the xz plane
	WTS	Multigroup weights to be assigned to this region

12c. The ARRAY BOUNDARY Card

If NBOX=0 [c.f., item (5) of the KENO Parameter Card], the ARRAY BOUNDARY card should not be entered.

If NBOX > 0 [c.f., item (5) of the KENO Parameter Card], the ARRAY BOUNDARY card is required only if one uses the Basic Geometry Description Cards to describe regions outside the array.

The ARRAY BOUNDARY card, when required, should be placed immediately after the last Basic Geometry Description Card for the last "box type" and immediately before the first Basic Geometry Description Card for the region(s) outside the array.

Seasoned KENO users will recognize the "array boundary card" as the "core boundary card." Indeed, the CSAS2 control module will recognize and accept this card in any of the following formats:

ARRAY BOUNDARY m, X_2, X_1, Y_2, Y_1, Z_2, Z_1, w

ARRAY m, X_2, X_1, etc.
ARRAY BDY m, X_2, X_1, etc.
ARRAY BOUND m, X_2, X_1, etc.

CORE m, X_2, X_1, etc.
CORE BDY m, X_2, X_1, etc.
CORE BOUND m, X_2, X_1, etc.
CORE BOUNDARY m, X_2, X_1, etc.

The word ARRAY or the word CORE must begin in column 1. If two words (such as ARRAY BOUNDARY) are used, they must be separated by a single blank. In each case, two or more blanks must be used to separate the alphanumeric keyword(s) from the remaining numeric data:

m Dummy constant. User should enter 0 in all cases.
X_2 Location of the +x surface of the array
X_1 Location of the −x surface of the array
Y_2 Location of the +y surface of the array
Y_1 Location of the −y surface of the array
Z_2 Location of the +z surface of the array
Z_1 Location of the −z surface of the array
w Dummy constant. User should enter −0.5 in all cases.

Note that the array dimensions $\Delta X_A = X_2 - X_1$, $\Delta Y_A = Y_2 - Y_1$, $\Delta Z_A = Z_2 - Z_1$ must exactly equal the sum of the corresponding dimensions of the boxes in each of the three directions. (Check the dimensions of the various "box types" and the arrangement of these boxes in the array as described by the Mixed Box Orientation Data entered below.)

12d. The REFLECTOR Card

If NBOX=0 [c.f., item (5) of the KENO Parameter Card], the REFLECTOR Card should not be entered. If NBOX > 0, the REFLECTOR Card is optional.

The REFLECTOR Card (also known as the "automatic reflector card") often provides a convenient mechanism for modeling a large homogeneous medium outside the array. Correct usage of this card is described in Appendix C. When used, it should be placed immediately before the END GEOMETRY card. It has the following form:

REFLECTOR MAT, TX2, TX1, TY2, TY1, TZ2, TZ1, IDWT

The word REFLECTOR must begin in column 1 and be separated by two or more blanks from the remaining numeric data:

MAT Mixture number the user has established for the reflector material. (See previous remarks.)
TX2 Thickness of the reflector on the +x face of the array
TX1 Thickness of the reflector on the −x face of the array
TY2 Thickness of the reflector on the +y face of the array
TY1 Thickness of the reflector on the −y face of the array
TZ2 Thickness of the reflector on the +z face of the array
TZ1 Thickness of the reflector on the −z face of the array
IDWT ID number corresponding to the set of pre-calculated weights for the reflector material. See Table A.5 for a list of ID numbers to be used with selected materials. For other materials, see comments in Appendix C.

Note that TX2, TX1, etc., must each be greater than or equal to zero since they represent the "thickness" of the reflector in various directions rather than the "location" of various surfaces.

Note: In general, one should describe the region surrounding the array using the Basic Geometry Description Cards or the automatic reflector card, but not both. In special cases both can be used, but the user should exercise caution in selecting weights for those basic geometry regions between the array and the automatic reflector (c.f., Appendix C). In such cases, the outermost region described by a Basic Geometry Description Card must be a CUBE or CUBOID and TX2, TX1, etc., will represent the thickness of the reflector on the respective faces of the CUBE or CUBOID.

12e. The END GEOMETRY Card

This card signals the end of the Multidimensional Geometry Specification Data and is always required. The words END GEOMETRY should be punched in columns 1 through 12 with a single blank imbedded between the two words.

13. Mixed Box Orientation Data

As noted in Appendix C, KENO-IV allows the user to describe all or part of the geometric configuration as an "array of boxes." If the user employs that aspect of the geometry package and if (in the Multidimensional Geometry Specification Data) he has defined more than one "box type," then he must include the Mixed Box Orientation Data to describe the position of each "box type" in the array.

Two schemes presently exist for entering the Mixed Box Orientation Data. The first scheme requires that the user explicitly describe the position of each "box type" in the array. That is, for every position (i, j, k) in the array,* the user must enter a number (n) designating the associated "box type." This scheme has two or three distinct advantages: First, there is a clear and obvious one-to-one correspondence between a sketch of the array as superimposed over the physical system and the data entries as they are punched on the input cards. This makes preparation of the data very straightforward and reduces the chances of making an error. Secondly, the user must keypunch only one number for each position in the array. For small arrays having a large number of box types interspersed in a relatively random fashion, this feature is particularly attractive. The second input scheme requires that the user implicitly describe the position of each "box type" in the array. That is: the user enters one or more sets of instructions, with each set of instructions telling the code to assign a particular "box type" to one or more positions in the array. The first set of instructions may, for example, assign one box type to every position in the array. Subsequent instructions may redefine the box type associated with any portion of the array. This scheme is especially convenient whenever one has a large array with relatively few "box types" arranged in isolated clumps or distributed in a reasonably periodic fashion.

Note: The user is free to use either the first input scheme or the second input scheme, but not both.

---

*i = 1 to NBXMAX; j = 1 to NBYMAX; k = 1 to NBZMAX.

13a. Point-by-Point Input of the Mixed Box Orientation Data

Note: Mixed Box Orientation Data should be entered only if NBOX > 1 [c.f., item (5) on the KENO Parameter Card]. If required, the first item (IBGN) should be the first item of a new card. The remaining data may extend over as many punched cards as necessary.

The Point-by-Point input scheme requires (2+NBXMAX*NBYMAX*NBZMAX) entries. They are:

IBGN
(((N(i, j, k), i = 1, NBXMAX), j = 1, NBYMAX), k = 1, NBZMAX)
IEND

IBGN and IEND are dummy flags used by the input processor. The user should enter an integer zero for each of these. N(i, j, k) represents the "box type" associated with position (i, j, k) in the array. They are read in a free-form format using the implied do-loop shown above. For those not familiar with FORTRAN, the ordering of the input should correspond to Table 2 as read from left to right.

This first input scheme is most convenient whenever one has a small array or a relatively large number of box types interspersed in a semi-random fashion. Thus, the Mixed Box Orientation Data required to represent the experimental configuration illustrated in Fig. C.2 (c.f., Appendix C) may be written quite simply as:

0 1 2 3 4 5 6 0

Likewise, the Mixed Box Orientation Data for the BWR fuel assembly shown in Fig. C.4 (c.f., Appendix C) may be written as:

0 3 2 2 2 3 3 4
1 1 1 5 1 2 3
1 1 1 1 1 1 3
1 5 1 1 1 5 2
1 1 1 1 1 1 2
1 1 1 5 1 1 2
2 1 1 1 1 1 3 0

Note that it is convenient (but not necessary) to "spread the data out" over seven data cards so as to maintain a "clear and obvious" one-to-one correspondence between each data entry and each fuel pin in the assembly. Note also that Fig. C.4 uses a left-handed coordinate system to describe the fuel assembly. For a given problem, the user may use either a right-handed system or a left-handed system provided he is consistent throughout. That is: the orientation of the coordinate system used to describe the geometry within each box must be the same as the orientation of the coordinate system used to describe the Mixed Box Orientation Data, which must be the same as the orientation of the coordinate system used to describe the reflector surrounding the array (if any). As a final example of when this input scheme is most convenient, the user is referred to the shipping cask

Table 2. Order in which the point-by-point mixed box orientation data is to be entered. (Read row-by-row, left-to-right.)

N(1,1,1)	N(2,1,1)	N(3,1,1)	....	N(I,1,1)
N(1,2,1)	N(2,2,1)	N(3,2,1)	....	N(I,2,1)
N(1,3,1)	N(2,3,1)	N(3,3,1)	....	N(I,3,1)
⋮	⋮	⋮		⋮
N(1,J,1)	N(2,J,1)	N(3,J,1)	....	N(I,J,1)
N(1,1,2)	N(2,1,2)	N(3,1,2)	....	N(I,1,2)
N(1,2,2)	N(2,2,2)	N(3,2,2)	....	N(I,2,2)
N(1,3,2)	N(2,3,2)	N(3,3,2)	....	N(I,3,2)
⋮	⋮	⋮		⋮
N(1,J,2)	N(2,J,2)	N(3,J,2)	....	N(I,J,2)
N(1,1,3)	N(2,1,3)	N(3,1,3)	....	N(I,1,3)
N(1,2,3)	N(2,2,3)	N(3,2,3)	....	N(I,2,3)
N(1,3,3)	N(2,3,3)	N(3,3,3)	....	N(I,3,3)
⋮	⋮	⋮		⋮
N(1,J,3)	N(2,J,3)	N(3,J,3)	....	N(I,J,3)
⋮				
N(1,1,K)	N(2,1,K)	N(3,1,K)	....	N(I,1,K)
N(1,2,K)	N(2,2,K)	N(3,2,K)	....	N(I,2,K)
N(1,3,K)	N(2,3,K)	N(3,3,K)	....	N(I,3,K)
⋮	⋮	⋮		⋮
N(1,J,K)	N(2,J,K)	N(3,J,K)	....	N(I,J,K)

where I = NBXMAX, J = NBYMAX, K = NBZMAX

problem illustrated in Figs. 15 and 16 (c.f., Section 8). The array corresponding to the "core" of the shipping cask measures 19 × 11 × 1 and has 19 unique box types. The Mixed Box Orientation Data for that array is most conveniently written as:

```
0  6  5  2  3  2  4  2  3  2  1  2  3  2  4  2  3  2  5  6
  13 12  8  9 10 11 10  9  8  7  8  9 10 11 10  9  8 12 13
   6  5  2  3  2  4  2  3  2  1  2  3  2  4  2  3  2  5  6
  15 17 15 16 15 14 15 16 15 14 15 16 15 14 15 16 15 17 15
   2 18  2  3  2  1  2  3  2  4  2  3  2  1  2  3  2 18  2
   8 19 10  9  8  7  8  9 10 11 10  9  8  7  8  9 10 19  8
   2 18  2  3  2  1  2  3  2  4  2  3  2  1  2  3  2 18  2
  15 17 15 16 15 14 15 16 15 14 15 16 15 14 15 16 15 17 15
   6  5  2  3  2  4  2  3  2  1  2  3  2  4  2  3  2  5  6
  13 12  8  9 10 11 10  9  8  7  8  9 10 11 10  9  8 12 13
   6  5  2  3  2  4  2  3  2  1  2  3  2  4  2  3  2  5  6 0
```

As noted before, this data string must begin and end with a zero when the point-by-point input mode is being used.

13b. Implicit Definition of the Mixed Box Orientation Data

Note: Mixed Box Orientation Data should be entered only if NBOX > 1 [see item (5) on the KENO Parameter Card]. If required, the Mixed Box Orientation Data should begin on a new card. It may extend over as many punched cards as necessary.

With this input scheme, the user enters one or more "sets of instructions," with each set of instructions telling the code to assign a particular "box type" to one or more positions in the array. Each "set of instructions" contains eleven items:

LTYPE, IX1, IX2, INCX, IY1, IY2, INCY, IZ1, IZ2, INCZ, IENDD

LTYPE — Number corresponding to the particular box type. Note that one must have $1 \leq \text{LTYPE} \leq \text{NBOX}$ where NBOX was specified as item (5) on the KENO Parameter Card.

IX1, IX2, INCX — Do-loop indices which determine the frequency of occurrence of the particular box type in the X direction (see explanation below). Note that one must have $1 \leq \text{IX1} \leq \text{NBXMAX}$, $\text{IX1} \leq \text{IX2} \leq \text{NBXMAX}$, and $1 \leq \text{INCX}$ where NBXMAX was specified as item (6) on the KENO Parameter Card.

IY1, IY2, INCY — Do-loop indices which determine the frequency of occurrence of the particular box type in the Y direction (see explanation below). Note that one must have $1 \leqslant IY1 \leqslant NBYMAX$, $IY1 \leqslant IY2 \leqslant NBYMAX$, and $1 \leqslant INCY$ where NBYMAX was specified as item (7) on the KENO Parameter Card.

IZ1, IZ2, INCZ — Do-loop indices which determine the frequency of occurrence of the particular box type in the Z direction (see explanation below). Note that one must have $1 \leqslant IZ1 \leqslant NBZMAX$, $IZ1 \leqslant IZ2 \leqslant NBZMAX$, and $1 \leqslant INCZ$ where NBZMAX was specified as item (8) on the KENO Parameter Card.

IENDD — Flag that signals the end of the Mixed Box Orientation Data. Enter a 1 (or any non-zero integer constant) if this "set of instructions" represents the end of the Mixed Box Orientation Data. Enter a 0 if more instructions are to follow.

Each set of instructions causes the code to assign the specified "box type" to one or more positions in the array as follows:

```
2  READ (n, m)  LTYPE, IX1, . . . , IENDD
   DO 3  K = IZ1, IZ2, INCZ
   DO 3  J = IY1, IY2, INCY
   DO 3  I = IX1, IX2, INCX
3  IPOSN (I, J, K) = LTYPE
   IF (IENDD.EQ.0) GO TO 2
```

For those not familiar with FORTRAN, each "set of instructions" effectively assigns the specified box type to each of the array positions (i, j, k) listed in Table 3.

This second input scheme is most convenient whenever one has a large array with relatively few "box types" arranged in isolated clumps or distributed in a reasonably periodic fashion. Thus, the Mixed Box Orientation Data required to represent the situation illustrated in Fig. 13 may be written as:

```
2  1  9  1  1  10  1  1  1  1  0
1  1  5  1  1   5  1  1  1  1  1
```

and the Mixed Box Orientation Data required to represent the situation illustrated in Fig. 14 may be written as:

```
1  1  15  1  1  11  1  1  1  1  0
2  2  14  3  2  10  2  1  1  1  0
3  3  12  3  3   9  2  1  1  1  0
3  4  13  3  3   9  2  1  1  1  1
```

Table 3. Positions in the "array" defined by a single set of instructions

POSN(i_1,j_1,k_1)	POSN(i_A,j_1,k_1)	POSN(i_B,j_1,k_1)	.....	POSN(i_2,j_1,k_1)
POSN(i_1,j_A,k_1)	POSN(i_A,j_A,k_1)	POSN(i_B,j_A,k_1)	.....	POSN(i_2,j_A,k_1)
POSN(i_1,j_B,k_1)	POSN(i_A,j_B,k_1)	POSN(i_B,j_B,k_1)	.....	POSN(i_2,j_B,k_1)
⋮	⋮	⋮		⋮
POSN(i_1,j_2,k_1)	POSN(i_A,j_2,k_1)	POSN(i_B,j_2,k_1)	.....	POSN(i_2,j_2,k_1)
POSN(i_1,j_1,k_A)	POSN(i_A,j_1,k_A)	POSN(i_B,j_1,k_A)	.....	POSN(i_2,j_1,k_A)
POSN(i_1,j_A,k_A)	POSN(i_A,j_A,k_A)	POSN(i_B,j_A,k_A)	.....	POSN(i_2,j_A,k_A)
POSN(i_1,j_B,k_A)	POSN(i_A,j_B,k_A)	POSN(i_B,j_B,k_A)	.....	POSN(i_2,j_B,k_A)
⋮	⋮	⋮		⋮
POSN(i_1,j_2,k_A)	POSN(i_A,j_2,k_A)	POSN(i_B,j_2,k_A)	.....	POSN(i_2,j_2,k_A)
POSN(i_1,j_1,k_B)	POSN(i_A,j_1,k_B)	POSN(i_B,j_1,k_B)	.....	POSN(i_2,j_1,k_B)
POSN(i_1,j_A,k_B)	POSN(i_A,j_A,k_B)	POSN(i_B,j_A,k_B)	.....	POSN(i_2,j_A,k_B)
POSN(i_1,j_B,k_B)	POSN(i_A,j_B,k_B)	POSN(i_B,j_B,k_B)	.....	POSN(i_2,j_B,k_B)
⋮	⋮	⋮		⋮
POSN(i_1,j_2,k_B)	POSN(i_A,j_2,k_B)	POSN(i_B,j_2,k_B)	.....	POSN(i_2,j_2,k_B)
.				
.				
.				
.				
.				
POSN(i_1,j_1,k_2)	POSN(i_A,j_1,k_2)	POSN(i_B,j_1,k_2)	.....	POSN(i_2,j_1,k_2)
POSN(i_1,j_A,k_2)	POSN(i_A,j_A,k_2)	POSN(i_B,j_A,k_2)	.....	POSN(i_2,j_A,k_2)
POSN(i_1,j_B,k_2)	POSN(i_A,j_B,k_2)	POSN(i_B,j_B,k_2)	.....	POSN(i_2,j_B,k_2)
⋮	⋮	⋮		⋮
POSN(i_1,j_2,k_2)	POSN(i_A,j_2,k_2)	POSN(i_B,j_2,k_2)	.....	POSN(i_2,j_2,k_2)

i_1 = IX1, i_2 = IX2, Δi = INCX; $i_A = i_1 + \Delta i$, $i_B = i_1 + 2\Delta i$, etc.
j_1 = IY1, j_2 = IY2, Δj = INCY; $j_A = j_1 + \Delta j$, $j_B = j_1 + 2\Delta j$, etc.
k_1 = IZ1, k_2 = IZ2, Δk = INCZ; $k_A = k_1 + \Delta k$, $k_B = k_1 + 2\Delta k$, etc.

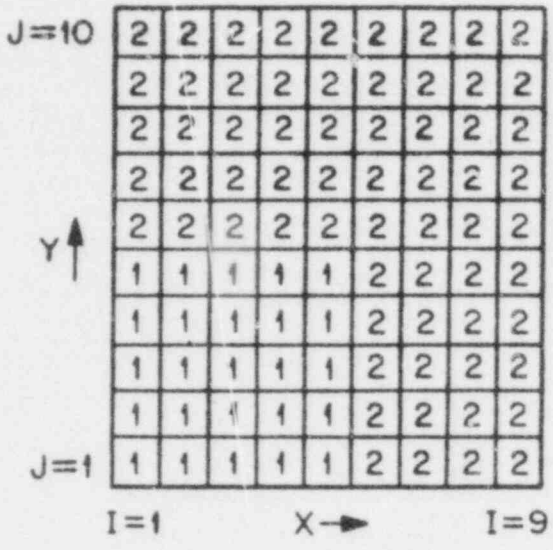


Fig. 13. An "array of boxes" with relatively few "box types" arranged in isolated clumps.

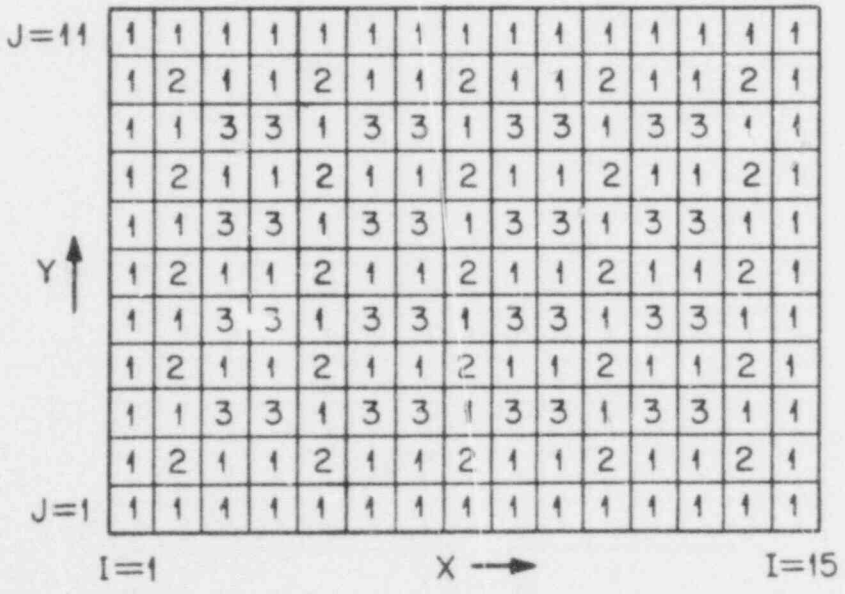


Fig. 14. An "array of boxes" with relatively few "box types" arranged in a reasonably periodic fashion.

14. END Card for the CSAS2 Analytic Sequence

If several KENO cases are to be run back-to-back, the data for the next KENO case should be entered here.

After the last card of the last case, the user should terminate the CSAS2 analytic sequence by including a final card with END punched in columns 1 through 3.

7. CSAS1 SAMPLE PROBLEMS

Listed below is the input for three sample problems and the output for the third. The first case is a lattice cell calculation for a square assembly. The UO_2 fuel pin is clad with zircalloy and surrounded by water at 0.718 gm/cc. This density corresponds to a typical PWR at operating temperature and pressure. Other parameters such as the enrichment of the fuel, the temperature of the various materials, and the dimensions of the unit cell, may all be inferred from the input data listed below. [Pitch = 1.430 cm, Dia(UO_2) = 0.9296 cm, Clad (ID) = 0.94844 cm, Clad (OD) = 1.07188 cm].

The second case is a multiregion problem in slab geometry. It features a dense uranyl-fluoride solution inside a plexiglass container immersed in water. The fissile solution contains 570.8 grams of heavy metal per liter and has no excess acid. (Uranyl-fluoride, unlike other fissile solutions, typically has no excess acid. For that reason one normally enters AML = 0 for this particular solution). Experimental results show the critical thickness of the fuel to be 5.384 cm, or t/2 = 2.692 cm. This half-thickness is used in the present model along with mirror-like reflection on the left hand boundary. To account for the finite dimensions in the other two directions, the experiment was modeled as a buckled slab (DY = 71.58 cm, DZ = 147.32 cm).

The third case is a multiregion problem in spherical geometry. It features a plutonium-nitrate solution inside a stainless steel tank surrounded by water. The fuel in this experiment consisted of a 0.52 molar nitric acid solution of plutonium-nitrate, containing 24.4 grams of heavy metal per liter of solution. To illustrate the use of the Optional Control Parameters, an S_4 calculation was specified in lieu of the standard S_8 calculation. The output for this problem has also been included below. A number of pertinent comments have been written directly on the printed output. It is hoped that this approach will make the task of interpreting the output somewhat easier.

Table 4. Input for CSAS1 Sample Problem No. 1

```
=CSAS1
LATTICECELL CALCULATION FOR A WESTINGHOUSE 15*15 PWR AT OPER. T&P
218GROUPNDF4   3 3 4 LATTICECELL   0 0
UO2   1 0.95 1000.0 92235 3.3 92238 96.7 END
ZIRCALLOY   2 1.0 605.0 END
H2O   3 0.719 581.0 END
SQUAREPITCH   1.430 0.92964 1 3 1.07188 2 0.94844 0 END
END
```

Table 5. Input for CSAS1 Sample Problem No. 2

```
=CSAS1
CRITICAL SLAB EXPERIMENT USING URANYL-FLORIDE SOLUTION
123GROUPGMTH   3 3 3 MULTIREGION   0 1
SOLNUO2F2   1 570.8 0 1 295 92235 93.2 92238 6.8 END
PLEXIGLASS   2 1   END
H2O   3 1   END
BUCKLEDSLAB   VACUUM   REFLECTED   0 71.58 147.32   END
1 2.692 ONEEXTERMOD
2 4.597 NOEXTERMOD
3 24.917 NOEXTERMOD
END
```

Table 6. Input for CSAS1 Sample Problem No. 3

```
=CSAS1
CRITICAL PU(NO3)4 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER
HANSEN-ROACH   3 3 3 MULTIREGION   1 1
SOLNPU(NO3)4   1 24.4 .52 1 295 94239 95.4 94240 4.6 END
SS304   2 1.0   END
H2O   3 1   END
SPHERICAL   VACUUM   REFLECTED   0   END
1 19.304 ONEEXTERMOD   2 19.426 ONEEXTERMOD   3 39.746 NOEXTERMOD
ISN=4 SZF=1.5 END
END
```

```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - JULY 6,1978)

MODULE CSAS1    WILL BE CALLED  TIME OF DAY 12.45.47  DATE 78.245

  CRITICAL PU(NO3)4 SOLUTION IN A 55 SPHERICAL TANK REFLECTED BY WATER
  HANSEN-ROACH  3 3 3 MULTIREGION  1 1
  SOLNPU(NO3)4   1 24.4 .52 1 2.5 94239 95.4 94240 4.6 END
  SS304  2 1.0  END
  H2O  3 1  END
  SPHERICAL   VACUUM   REFLECTED   0   END
  1 19.304 ONEEXTERMOD   2 19.426 ONEEXTERMOD   3 39.746 NOEXTERMOD
  ISN=4 SZF=1.5 END
  END

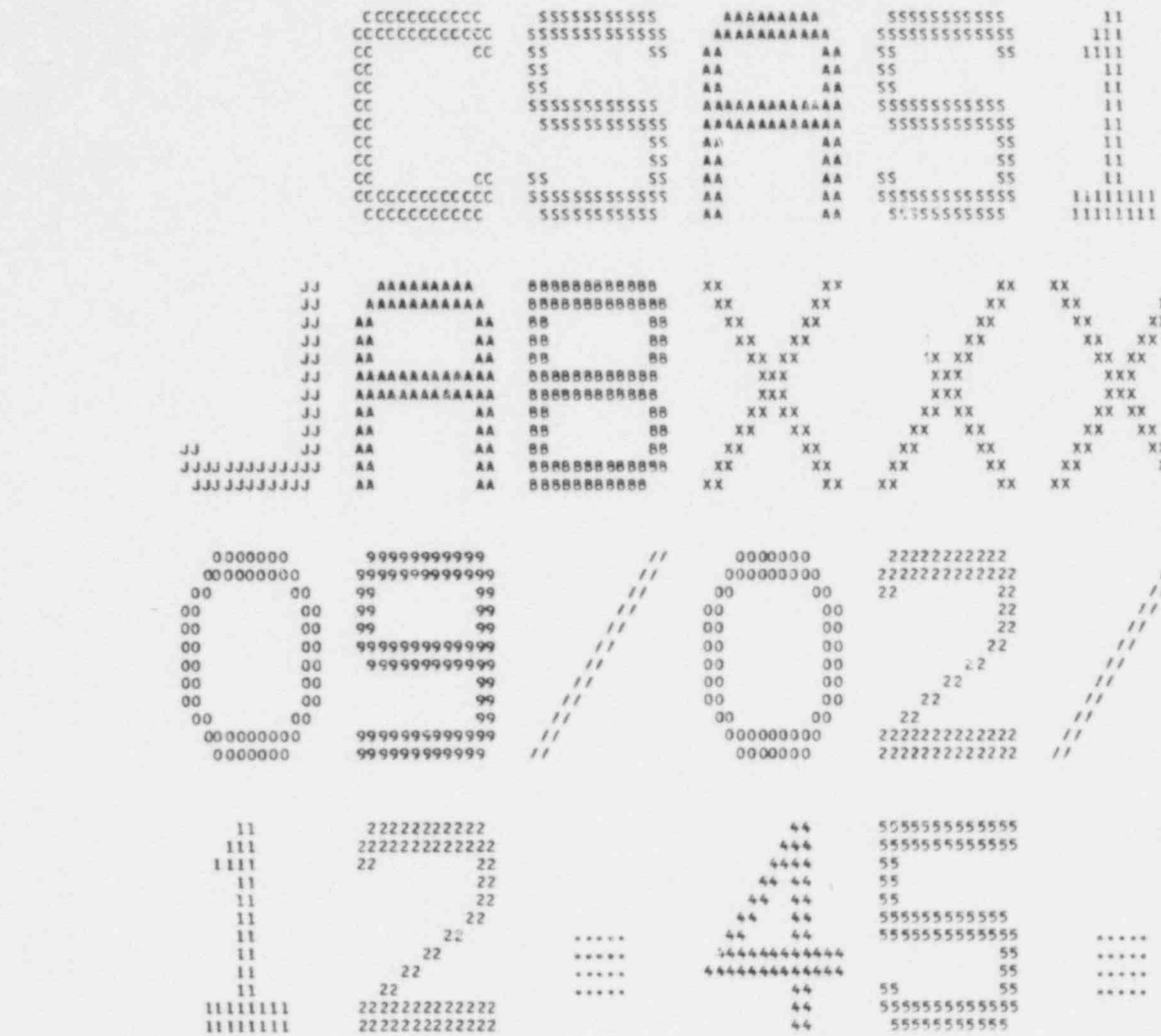
MODULE CSAS1    IS FINISHED.  USER COMPLETION CODE  0000. CPU TIME USED    25.25 (SECONDS). I/O'S USED    2227
```

THE SCALE DRIVER PRINTS EVERYTHING ON THIS PAGE.*
ONE OR MORE CONTROL MODULES MAY BE ACCESSED MULTIPLE TIMES IN A SINGLE RUN AND THIS PAGE PROVIDES A LOG OF WHAT WAS DONE.

THE SCALE DRIVER AUTOMATICALLY PRINTS A COPY OF THE INPUT DECK EXACTLY AS IT WAS SUBMITTED.

COMPLETION CODE 0000 INDICATES THAT ALL PROGRAMS CALLED BY THIS CONTROL MODULE WERE SUCCESSFULLY EXECUTED.

* THIS "FIRST PAGE" OF OUTPUT WILL BE PRINTED BY THE DRIVER ON A UNIT CALLED SYSOUT. THE CONTROL MODULE (CSAS1) WILL PRINT ITS OUTPUT ON FT99 AND THE FUNCTIONAL MODULES (BONAMI, NITAWL, XSDRNPM) WILL PRINT THEIR OUTPUT ON FT06. SUBJECT TO THE ORDER IN WHICH THESE THREE UNITS ARE PRINTED, THIS MAY OR MAY NOT BE "THE FIRST PAGE" ACTUALLY PRINTED AT ANOTHER INSTALLATION.



C1.84

```
CRITICAL PU(NO3)4 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER


**** PROBLEM PARAMETERS ****

LIB HANSEN-ROACH LIBRARY
MXX              3 MIXTURES
MSC              3 COMPOSITION SPECIFICATIONS
IZM              3 MATERIAL ZONES
GE   MULTIREGION  GEOMETRY
MORE             1 0/1 DO NOT READ/READ SPECIAL PARAMETERS
MSLN             1 FUEL SOLUTIONS


**** PROBLEM COMPOSITION DESCRIPTION ****

SC   SOLNPU(NO3)4 STANDARD COMPOSITION
MX               1 MIXTURE NO.
FD         24.4000 SOLUTION FUEL DENSITY
AML         0.5200 ACID MOLARITY
VF          1.0000 VOLUME FRACTION
TEMP         295.0 DEG KELVIN
            94239 95.40%
            94240  4.60%
END

SC   SS304          STANDARD COMPOSITION
MX               2 MIXTURE NO.
VF          1.0000 VOLUME FRACTION
END

SC   H2O            STANDARD COMPOSITION
MX               3 MIXTURE NO.
VF          1.0000 VOLUME FRACTION
END


**** PROBLEM GEOMETRY ****

CS     SPHERICAL     COORDINATE SYSTEM
BR     VACUUM        RIGHT BOUNDARY
BL     REFLECTED     LEFT BOUNDARY
ORGN           0.0   CM LEFT BOUNDARY LOCATION
DY             0.0   CM BUCKLING HEIGHT
DZ             0.0   CM BUCKLING DEPTH
END

ZONE NUMBER      1
MZX              1 MIXTURE NO.
RZ           19.30 CM RIGHT BOUNDARY LOCATION
XMOD ONEEXTERMOD   EXTERNAL MODERATOR INDE

ZONE NUMBER      2
MZX              2 MIXTURE NO.
RZ           19.43 CM RIGHT BOUNDARY LOCATION
XMOD ONEEXTERMOD   EXTERNAL MODERATOR INDEX

ZONE NUMBER      3
MZX              3 MIXTURE NO.
RZ           39.75 CM RIGHT BOUNDARY LOCATION
XMOD NOEXTERMOD    EXTERNAL MODERATOR INDEX
```

INPUT SUPPLIED BY THE USER, AS "INTERPRETED" BY THE CONTROL MODULE

```
**** SPECIAL PARAMETERS ****

ISN             4 ORDER OF ANGULAR QUADRITURE
IIM            20 INNER ITERATION MAXIMUM
OCM            25 OUTER ITERATION MAXIMUM
SZF  1.50000E 00 SIZE FACTOR FOR SPATIAL MESH
EPS  1.00000E-04 OVERALL PROBLEM CONVERGENCE
PTC  1.00000E-04 SCALAR FLUX CONVERGENCE
BKL  1.42089E 00 BUCKLING FACTOR
IUS             0 THERMAL UPSCATTER SCALING

**** XSDRN MESH INTERVALS ****

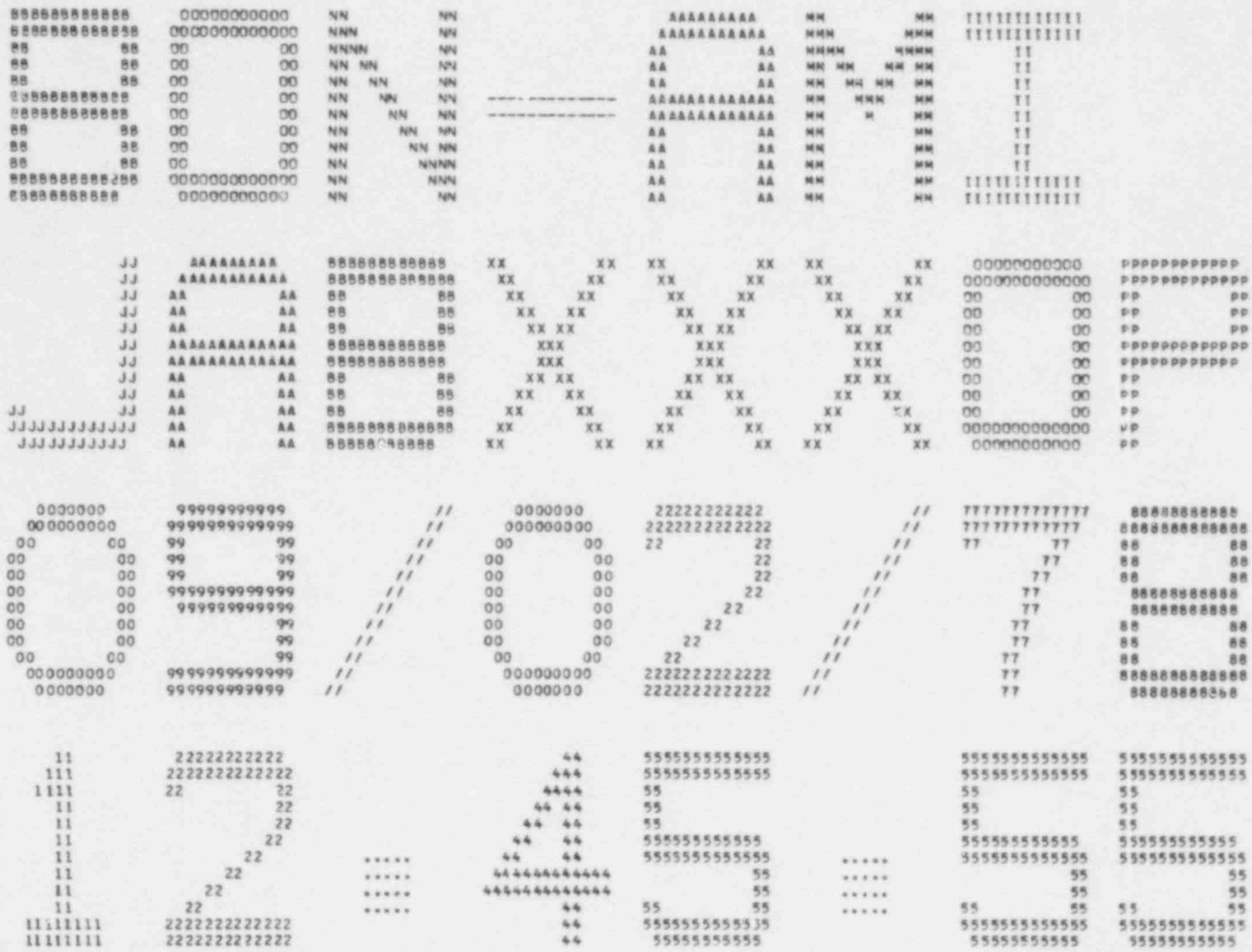
  22 MESH INTERVALS IN ZONE  1
   4 MESH INTERVALS IN ZONE  2
  14 MESH INTERVALS IN ZONE  3

MODULE CSAS1     MADE     3 SUCCESSFUL ACCESSES.
```

ALTHOUGH THE USER MAY HAVE INPUT ONLY ONE OR TWO OF THE PARAMETERS, THE CONTROL MODULE LISTS ALL THE OPTIONAL CONTROL PARAMETERS, INCLUDING THOSE SUPPLIED BY DEFAULT.

THESE MESH INTERVALS ARE AUTOMATICALLY DETERMINED BY THE CONTROL MODULE AND PRINTED HERE FOR YOUR INSPECTION AND APPROVAL. THE SIZE OF THE SPATIAL MESH INTERVALS MAY BE INCREASED OR DECREASED USING THE SZF PARAMETER LISTED ABOVE.

MEANS THAT CSAS1 CALLED AND SUCCESSFULLY EXECUTED BONAMI, NITAWL, AND XSDRNPM



LOGICAL ASSIGNMENTS

MASTER LIBRARY 81
WORKING LIBRARY 0
SCRATCH FILE 18
NEW LIBRARY 1

P R O B L E M D E S C R I P T I O N

IGR--GEOMETRY (0/1/2/3--INF MED/SLAB/CYL/SPHERE 3

IZM--NUMBER OF ZONES OR MATERIAL REGIONS 3

MS--MIXING TABLE LENGTH 11

IBL- -LEFT BOUNDARY CONDITION (0/1--VAC/REFL) 1

IBR--RIGHT BOUNDARY CONDITION (0/1--VAC/REFL) 0

ISSOPT--CELL DESCRIPTION FOR DANCOFF CORRECTION 0

CONVERGENCE CRITERION 1.00000E-03

WIGNER CONSTANT 1.35000E 00

3Q ARRAY HAS 11 ENTRIES.

4Q ARRAY HAS 11 ENTRIES.

5Q ARRAY HAS 11 ENTRIES.

6Q ARRAY HAS 3 ENTRIES.

7Q ARRAY HAS 3 ENTRIES.

8Q ARRAY HAS 3 ENTRIES.

9Q ARRAY HAS 3 ENTRIES.

10Q ARRAY HAS 11 ENTRIES.

11Q ARRAY HAS 3 ENTRIES.

INPUT DATA FOR BONAMI AS READ OFF THE BINARY INPUT TAPE PREPARED BY THE CONTROL MODULE

M I X I N G T A B L E

ENTRY	MIXTURE	ISOTOPE	NUMBER DENSITY	NEW IDENTIFIER
1	1	94239	5.86641E-05	94239
2	1	94240	2.81686E-06	94240
3	1	7014	5.59175E-04	7014
4	1	8016	3.41878E-02	8016
5	3	8016	3.33797E-02	5
6	1	1001	6.53338E-02	1001
7	3	1001	6.67593E-02	7
8	2	24304	1.74249E-02	24304
9	2	25055	1.73644E-03	25055
10	2	26304	5.93560E-02	26304
11	2	28304	7.72081E-03	28304

THESE NO. DENSITIES ARE CALCULATED BY THE CONTROL MODULE AND PASSED ON TO BONAMI. THIS TABLE, WHICH IS OFTEN VERY USEFUL, IS USUALLY PRINTED IN THE FIRST 2 OR 3 SECONDS OF EXECUTION.

OCCASIONALLY, ONE MAY WISH TO RUN A SHORT "DUMMY CASE" JUST TO OBTAIN THIS TABLE AND THEN RESUBMIT A LARGE JOB WITH AN ADDITIONAL NUCLIDE HAVING A CONCENTRATION BASED ON ONE OR MORE OF THESE. FOR EXAMPLE: ONE MAY WISH TO INCLUDE SO MANY "PARTS PER MILLION" BORON IN THE WATER REFLECTOR.

GEOMETRY AND MATERIAL DESCRIPTION

ZONE	MIXTURE	OUTER DIMENSION	TEMPERATURE	EXTRA XS	TYPE (0/1--FUEL/MOD)
1	1	1.93040E 01	2.95000E 02	3.99537E-02	0
2	2	1.94260E 01	2.93000E 02	2.37050E 00	0

```
  3      3          3.97460E 01    2.93000E 02    0.0                    0
THIS CALCULATION REQUIRES    1421 LOCATIONS OF 99840 AVAILABLE TO THIS MODULE

  ELAPSED TIME   0.01 MIN.

  ELAPSED TIME   0.01 MIN.
```

BONDARENKO ITERATION STATISTICS

ITERATION	MT	MAX CHANGE	GROUP	ZONE	NEW VALUE	NUCLIDE	SIGO
1	1	-7.913E-02	10	1	8.564E 01	94239	1.96001E 04
1	18	-7.058E-02	10	1	3.904E 01	94239	1.96001E 04
1	102	-1.072E-01	10	1	3.661E 01	94239	1.96001E 04
1	1	-1.510E-01	13	1	6.070E 03	94240	4.08890E 05
1	18	-1.522E-01	13	1	1.187E 00	94240	4.08890E 05
1	102	-1.513E-01	13	1	5.636E 03	94240	4.08890E 05
2	1	-3.563E-07	10	1	8.564E 01	94239	1.96000E 04
2	18	0.0	0	0	0.0	94239	1.96000E 04
2	102	0.0	0	0	0.0	94239	1.96000E 04
2	1	0.0	0	0	0.0	94240	1.96000E 04
2	18	0.0	0	0	0.0	94240	1.96000E 04
2	102	0.0	0	0	0.0	94240	1.96000E 04

THIS ITERATION ON THE BACKGROUND CROSS-SECTION WOULD BE SKIPPED IF NONE OF THE NUCLIDES HAD BONDARENKO DATA

ELAPSED TIME 0.01 MIN.

PU-239 HANSEN ROACH IDENTIFIER 94239

GROUP	TOTAL	ELASTIC	FISSION	N-GAMMA	TRANSPORT
1	4.25000E 00	2.32000E 00	1.90300E 00	2.99997E-02	0.0
2	4.50000E 00	2.50000E 00	1.95016E 00	4.98381E-02	0.0
3	4.80000E 00	2.90000E 00	1.83010E 00	6.98996E-02	0.0
4	5.70000E 00	3.89000E 00	1.70000E 00	1.10000E-01	0.0
5	8.40000E 00	6.56000E 00	1.67014E 00	1.69861E-01	0.0
6	1.32000E 01	1.09000E 01	1.91993E 00	3.80070E-01	0.0
7	1.35000E 01	1.00000E 01	2.50000E 00	1.00000E 00	0.0
8	1.67000E 01	1.00000E 01	4.20000E 00	2.50000E 00	0.0
9	3.51000E 01	1.00000E 01	1.65000E 01	8.60001E 00	0.0
10	8.56411E 01	1.00000E 01	3.90358E 01	3.66053E 01	0.0
11	1.36917E 02	1.00000E 01	7.52616E 01	5.16558E 01	0.0
12	5.06541E 01	1.00000E 01	2.29792E 01	1.76749E 01	0.0
13	3.30000E 01	1.00000E 01	2.00000E 01	3.00000E 00	0.0
14	2.32952E 02	1.00000E 01	1.37935E 02	8.50169E 01	0.0
15	1.94843E 03	1.00000E 01	1.17896E 03	7.59475E 02	0.0
16	9.90000E 02	1.00000E 01	7.05000E 02	2.75000E 02	0.0

THE SELF-SHIELDED CROSS-SECTIONS WOULD NOT BE LISTED IF NONE OF THE NUCLIDES HAD BONDARENKO DATA IN THE CROSS SECTION LIBRARY. THIS EDIT WOULD NOT APPEAR, FOR EXAMPLE, HAD WE USED THE 27GROUPNDF4 LIBRARY.

PU-240 HANSEN ROACH IDENTIFIER 94240

GROUP	TOTAL	ELASTIC	FISSION	N-GAMMA	TRANSPORT
1	4.25000E 00	2.60000E 00	1.60000E 00	5.00002E-02	0.0
2	4.50000E 00	2.88000E 00	1.54006E 00	7.99417E-02	0.0
3	4.65000E 00	3.15000E 00	1.39000E 00	1.10001E-01	0.0
4	5.45000E 00	4.53000E 00	7.69969E-01	1.50031E-01	0.0
5	8.20000E 00	7.92000E 00	5.00000E-02	2.30000E-01	0.0
6	1.14500E 01	1.10000E 01	0.0	4.50000E-01	0.0
7	1.17000E 01	1.10000E 01	0.0	7.00000E-01	0.0
8	1.30000E 01	1.10000E 01	0.0	2.00000E 00	0.0
9	2.20600E 01	1.10000E 01	0.0	1.10000E 01	0.0
10	7.04358E 01	1.10000E 01	0.0	5.94358E 01	0.0
11	4.27153E 01	1.20000E 01	0.0	3.07153E 01	0.0
12	3.90000E 01	1.50000E 01	0.0	2.40000E 01	0.0
13	6.07007E 03	5.08000E 02	1.18692E 00	5.63563E 03	0.0
14	9.32172E 02	3.80000E 01	1.98273E-01	8.93949E 02	0.0
15	1.51000E 02	1.10000E 01	0.0	1.40000E 02	0.0
16	2.63030E 02	1.10000E 01	3.00000E-02	2.52000E 02	0.0

SEE NOTE ABOVE

TAPE ID	4321	NUMBER OF NUCLIDES	86
NUMBER OF NEUTRON GROUPS	16	NUMBER OF GAMMA GROUPS	0
FIRST THERMAL GROUP	13		

TABLE OF CONTENTS

WHILE ONLY THE RESONANCE NUCLIDES USED IN THIS PARTICULAR PROBLEM WILL BE SELF-SHIELDED, BONAMI COPIES THE ENTIRE CROSS-SECTION LIBRARY (AS A MASTER LIBRARY) AND PASSES IT ON TO NITAWL WHICH MAY SELF-SHIELD OTHER NUCLIDES HAVING RESONANCE DATA. NITAWL WILL THEN PRODUCE A MUCH SMALLER WORKING LIBRARY.

NOTE THAT NUCLIDES #7 AND #5 REPRESENT THE HYDROGEN AND OXYGEN IN MIXTURE NO. 3 WHEREAS 1001 AND 8016 REPRESENT THE HYDROGEN AND OXYGEN IN MIXTURE NO. 1 (THE PLUTONIUM NITRATE SOLUTION). SEPARATE SETS OF CROSS SECTION DATA FOR THESE "NEW NUCLIDES" WILL ALSO BE AVAILABLE ON THE MASTER CROSS SECTION LIBRARY PASSED TO NITAWL.

```
 GADOLINIUM ENDF/B-IV MAT 1030                                    10     64000
 DYSPROSIUM-164 ENDF/B-IV MAT 1031                                10     66164
 LUTETIUM-175 ENDF/B-IV MAT 1032                                  10     71175
 LUTETIUM-176 ENDF/B-IV MAT 1033                                  10     71176
 HAFNIUM ENDF/B-IV MAT 1034                                       10     72000
TANTALUM                                HANSEN ROACH              10     73181
 TUNGSTEN-182 ENDF/B-IV MAT 1128                                  10     74182
 TUNGSTEN-183 ENDF/B-IV MAT 1129                                  10     74183
 TUNGSTEN-184 ENDF/B-IV MAT 1130                                  10     74184
 TUNGSTEN-186 ENDF/B-IV MAT 1131                                  10     74186
 RHENIUM-185 ENDF/B-IV MAT 1083                                   10     75185
 RHENIUM-187 ENDF/B-IV MAT 1084                                   10     75187
 GOLD-197 ENDF/B-IV MAT 1283                                      10     79197
 LEAD ENDF/B-IV MAT 1288                                          10     82000
TH-232  INFINITE DILUTION               HANSEN ROACH              10     90232
 PROTACTINIUM-233 ENDF/B-IV MAT 1297                              10     91233
U-233                                   HANSEN ROACH              10     92233
 U-234 ENDF/B-IV MAT 1043                                         10     92234
U-235 YR                                HANSEN ROACH              10     92235
 U-236 ENDF/B-IV MAT 1163                                         10     92236
U-238 Y                                 HANSEN ROACH              10     92238
 NP-237 ENDF/B-IV MAT 1263                                        10     93237
PU-238                                  HANSEN ROACH              10     94238
PU-238 Y                                PERSINMON                 10     94338
PU-239                                  HANSEN ROACH              10     94239
PU-240                                  HANSEN ROACH              10     94240
 PU-241 ENDF/B-IV MAT 1266                                        10     94241
 PU-242 ENDF/B-IV MAT 1161                                        10     94242
 AM-241 ENDF/B-IV MAT 1056                                        10     95241
 AM-243 ENDF/B-IV MAT 1057                                        10     95243
 CM-244 ENDF/B-IV MAT 1162                                        10     96244
1/V CROSS SECTIONS NORMALIZED TO 1.0 AT 0.0253 EV                 10     99999

  TAPE COPY USED    434 I/O'S, AND TOOK    2.13 SECONDS

ELAPSED TIME   0.11 MIN.
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← THIS IS NOW #999 IN THE MORE RECENT HANSEN-ROACH LIBRARY. (THAT CHANGE BECAME EFFECTIVE IN OCT. 1978, WHILE THIS JOB WAS EXECUTED IN JULY, 1978).

C1.94

C1.95

OQ ARRAY HAS 9 ENTRIES.

1Q ARRAY HAS 12 ENTRIES.

MSCM	NOT USED	0
MMT	NUMBER OF NUCLIDES FROM MASTER LIBRARY	11
MWT	NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LOG 2)	0
MXT	NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LOG 3)	0
MCR	OUTPUT SENSITIVITY TAPE 0/1 - NO/YES	0
MXX	NOT USED	0
MS	NOT USED	0
IRES	NUMBER OF RESONANCE CALCULATIONS	3
IQM	NOT USED	0
IPM	NOT USED	0
IPP	OUTPUT OPTION TRIGGER	-1
IFG	NOT USED	0

THE STORAGE ALLOCATED FOR THIS CASE IS 94208 WORDS

INPUT DATA FOR NITAWL AS READ OFF THE BINARY INPUT TAPE PREPARED BY THE CONTROL MODULE

2Q ARRAY HAS 11 ENTRIES.

3Q ARRAY HAS 45 ENTRIES.

4Q ARRAY HAS 11 ENTRIES.

GENERAL INFORMATION CONCERNING CROSS SECTION LIBRARY

TAPE IDENTIFICATION NUMBER	4321
NUMBER OF NUCLIDES ON TAPE	86
NUMBER OF NEUTRON ENERGY GROUPS	16
FIRST THERMAL NEUTRON ENERGY GROUP	13
NUMBER OF GAMMA ENERGY GROUPS	0

DIRECT ACCESS UNIT NUMBER 9 REQUIRES 74 BLOCKS OF LENGTH 160 WORDS

XSDRN TAPE 4321

NUCLIDES FROM XSDRN TAPE

1	HYDROGEN DE/E	HANSEN ROACH	1001
2	HYDROGEN DE/E	HANSEN ROACH	7
3	NITROGEN	HANSEN ROACH	7014
4	OXYGEN	HANSEN ROACH	8016
5	OXYGEN	HANSEN ROACH	8
6	CHROMIUM ENDF/B-IV MAT 1191 SS-304 WT		24304
7	MANGANESE-55 ENDF/B-IV MAT 1197		25055
8	IRON ENDF/B-IV MAT 1192 SS-304 WT		26304
9	NICKEL ENDF/B-IV MAT 1190 SS-304 WT		28304
10	PU-239	HANSEN ROACH	94239
11	PU-240	HANSEN ROACH	94240

HYDROGEN DE/E	HANSEN ROACH	1001	TEMPERATURE=	295.00
HYDROGEN DE/E	HANSEN ROACH	7	TEMPERATURE=	293.00
NITROGEN	HANSEN ROACH	7014	TEMPERATURE=	295.00

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OXYGEN                          HANSEN ROACH                              8016    TEMPERATURE=  295.00

OXYGEN                          HANSEN ROACH                                 5    TEMPERATURE=  293.00

 CHROMIUM ENDF/B-IV MAT 1191 SS-304 WT                                    24304    TEMPERATURE=  293.00

 MANGANESE-55 ENDF/B-IV MAT 1197                                          25055    TEMPERATURE=  293.00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)          =    54.466        TEMPERATURE(KELVIN)      =   293.000

POTENTIAL SCATTER SIGMA=      2.590        LUMPED NUCLEAR DENSITY   = 0.1736442E-02

SPIN FACTOR (G)          =    14.448        LUMP DIMENSION (A-BAR)   = 0.2440186E 00

SIGMA-M(EFFECTIVE)       = 0.1687816E 04    DANCOFF CORRECTION (C)   = 0.0

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHO

MASS OF MODERATOR-1      =    55.850        SIGMA(PER ABSORBER ATOM)= 0.3896812E 03

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2      =    58.690        SIGMA(PER ABSORBER ATOM)= 0.7736621E 02

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 1-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP        RES ABS          RES FISS        RES SCAT
  6      1.117060E-02     0.0             7.335182E 00
  7      2.464616E-02     0.0             2.240529E 01
  8      6.313215E-01     0.0             1.043083E 02
  9      3.810507E 00     0.0             1.579850E 02

EXCESS RESONANCE INTEGRALS

                 RESOLVED       UNRESOLVED          TOTAL

ABSORPTION       0.75309E 01    0.0             0.75309E 01
FISSION          0.0            0.0             0.0

  ELAPSED TIME   0.09 MIN.

 IRON ENDF/B-IV MAT 1192 SS-304 WT                                        26304    TEMPERATURE=  293.00

 NICKEL ENDF/B-IV MAT 1190 SS-304 WT                                      28304    TEMPERATURE=  293.00

PU-239                          HANSEN ROACH                              94239    TEMPERATURE=  295.00

PU-240                          HANSEN ROACH                              94240    TEMPERATURE=  295.00

  ELAPSED TIME   0.10 MIN.
```

THE Mn^{55} FOUND IN THE STAINLESS STEEL IS A RESONANCE NUCLIDE.

THE HANSEN-ROACH LIBRARY USED HERE CONTAINS NO BONDARENKO DATA FOR THIS NUCLIDE AND HENCE, BONAMI DID NOT PERFORM A SELF-SHIELDING CALCULATION FOR THIS NUCLIDE.

FORTUNATELY, THE HANSEN-ROACH LIBRARY DOES CONTAIN LEVEL WIDTHS AND OTHER RESONANCE DATA FOR Mn^{55}. AS A RESULT, THE CROSS SECTION DATA FOR THIS NUCLIDE WILL BE SELF-SHIELDED HERE BY NITAWL USING THE NORDHEIM INTEGRAL METHOD.

THIS XSDRN WORKING TAPE WAS CREATED 09/02/78 AT 12.46.37
THE TITLE OF THE PARENT CASE IS AS FOLLOWS

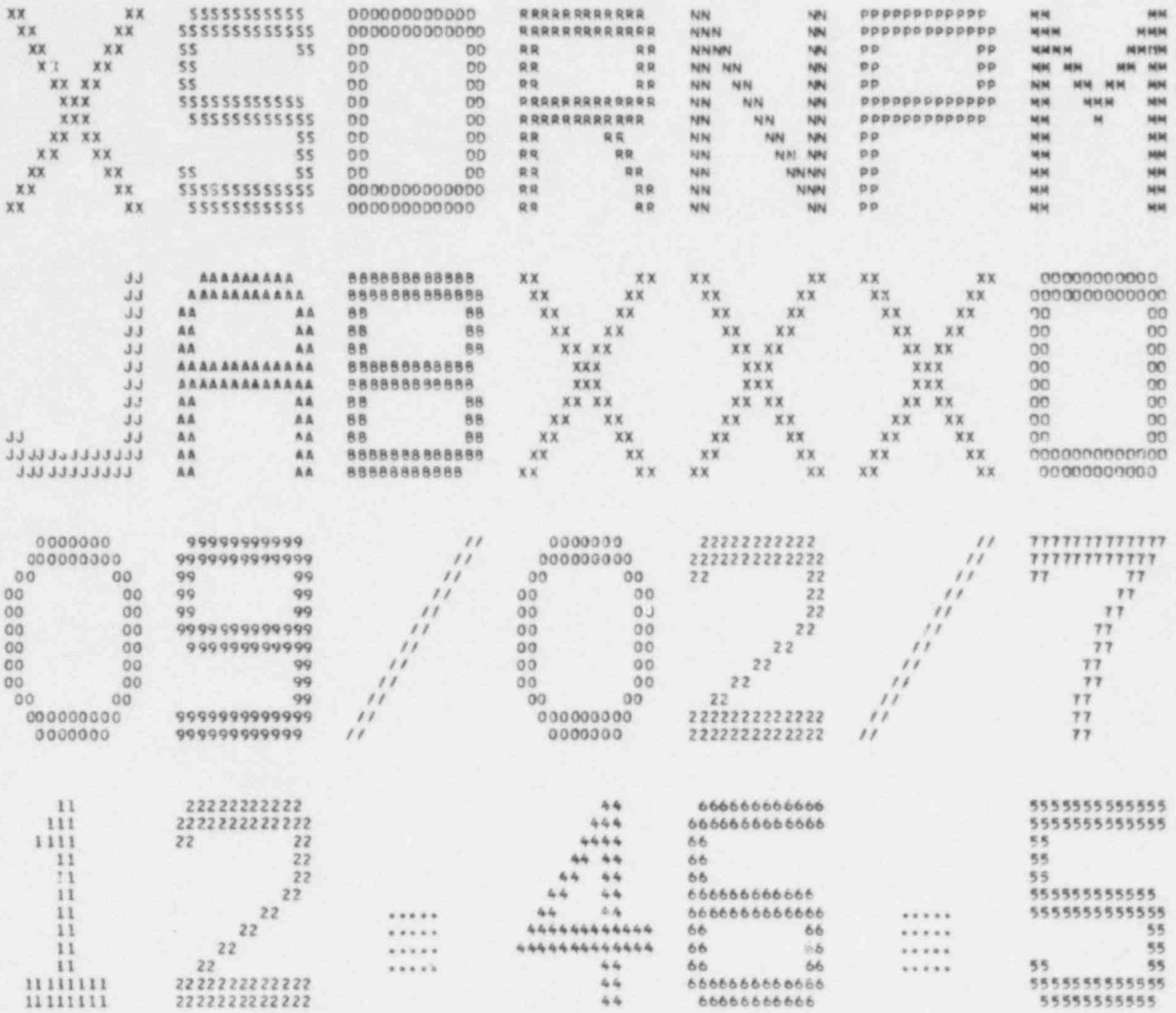
TAPE ID	4321	NUMBER OF NUCLIDES	11
NUMBER OF NEUTRON GROUPS	16	NUMBER OF GAMMA GROUPS	0
FIRST THERMAL GROUP	13		

TABLE OF CONTENTS

HYDROGEN DE/E	HANSEN ROACH	ID	1001
HYDROGEN DE/E	HANSEN ROACH	ID	7
NITROGEN	HANSEN ROACH	ID	7014
OXYGEN	HANSEN ROACH	ID	8016
OXYGEN	HANSEN ROACH	ID	5
CHROMIUM ENDF/B-IV MAT 1191 SS-304 WT		ID	24304
MANGANESE-55 ENDF/B-IV MAT 1197		ID	25055
IRON ENDF/B-IV MAT 1192 SS-304 WT		ID	26304
NICKEL ENDF/B-IV MAT 1190 SS-304 WT		ID	28304
PU-239	HANSEN ROACH	ID	94239
PU-240	HANSEN ROACH	ID	94240

AN AMPX WORKING LIBRARY CONTAINING CROSS-SECTION DATA FOR THESE NUCLIDES WILL NOT BE PASSED TO XSDRNPM.

TAPE COPY USED 86 I/O'S, AND TOOK 0.28 SECONDS



C1.99

CRITICAL PU(NO3)4 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER

1Q ARRAY HAS 15 ENTRIES.

2Q ARRAY HAS 10 ENTRIES.

3Q ARRAY HAS 12 ENTRIES.

4Q ARRAY HAS 9 ENTRIES.

5Q ARRAY HAS 12 ENTRIES.

DIRECT ACCESS UNIT 9 REQUIRES 6 BLOCKS OF LENGTH 288 FOR CROSS SECTION MIXING.

GENERAL PROBLEM DESCRIPTION DATA BLOCK

GENERAL PROBLEM DATA

IGE	1/2/3 = PLANE/CYLINDER/SPHERE	3	ISN	QUADRATURE ORDER	4
IZM	NUMBER OF ZONES	3	ISCT	ORDER OF SCATTERING	1
IM	NUMBER OF SPACIAL INTERVALS	40	IEVT	0/1/2/3/4/5/6=Q/K/ALPHA/C/Z/R/H	1
IBL	0/1/2/3 = VACUUM/REFL/PER/WHITE	1	IIM	INNER ITERATION MAXIMUM	20
IBR	RIGHT BOUNDARY CONDITION	0	ICM	OUTER ITERATION MAXIMUM	25
MXX	NUMBER OF MIXTURES	3	ICLC	-1/0/N--FLAT RES/SN/OPT	0
MS	MIXING TABLE LENGTH	11	ITH	0/1 = FORWARD/ADJOINT	0
IGM	NUMBER OF ENERGY GROUPS	16	IFLU	0/1/2/3/4=L-S/L/S/W/L-W	0
NNG	NUMBER OF NEUTRON GROUPS	16	IPRT	-2/-1/0/N=MIXTURE XSEC PRINT	-1
NGG	NUMBER OF GAMMA GROUPS	0	IDI	0/1/2/3=NO/PRT NO/PCH N/BOTH	0
IFTG	NUMBER OF FIRST THERMAL GROUP	13	IPBT	-1/0/1=NONE/FINE/ALL BAL. PRT	0

SPECIAL OPTIONS

IFG	0/1 = NONE/WEIGHTING CALCULATION	0	IPN	DUMMY PARAMETER	0
IQM	VOLUMETRIC SOURCES (0/N=NO/YES)	0	IDFM	0/1 = NONE/DENSITY FACTORS 38*	0
IPM	BOUNDARY SOURCES (0/N=NO/YES)	0	IAZ	0/N = NONE/N ACTIVITIES BY ZONE	0
IFN	0/1/2 = INPUT 33*/34*/USE LAST	0	IAI	0/1=NONE/ACTIVITIES BY INTERVAL	0
ITMX	MAXIMUM TIME (MINUTES)	0	IFCT	0/1=NO/YES UPSCATTER SCALING	0
IDT1	0/1/2/3=NO/XSECT/SRCE/FLUX--OUT	0	IPVT	0/1/2=NO/K/ALPHA PARAMETRIC SRCH	0

FLOATING POINT PARAMETERS

EV	EIGENVALUE GUESS	0.0	PV	IPVT=1/2--K/ALPHA	1.00000E 00
EVM	EIGENVALUE MODIFIER	0.0	EPS	OVERALL CONVERGENCE	1.00000E-04
BF	BUCKLING FACTOR=1.420892	1.42089E 00	PTC	POINT CONVERGENCE	1.00000E-04
DY	CYL/PLA HT FOR BUCKLING	0.0	XNF	NORMALIZATION FACTOR	1.00000E 00
DZ	PLANE DEPTH FOR BUCKLING	0.0	EQL	EV CHANGE EPS FOR SEARCH	1.00000E-03
VSC	VOID STREAMING CORRECTION	0.0	XNPM	NEW PARAM MOD FOR SEARCH	7.50000E-01

THIS CASE WILL REQUIRE 1424 LOCATIONS FOR MIXING

THIS CASE HAS BEEN ALLOCATED 107008 LOCATIONS

INPUT DATA FOR XSDRNPM AS READ OFF THE BINARY INPUT TAPE PREPARED BY THE CONTROL MODULE

CRITICAL PU(NO3)4 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER

13Q ARRAY HAS 11 ENTRIES.

14Q ARRAY HAS 11 ENTRIES.

15Q ARRAY HAS 11 ENTRIES.

DATA BLOCK 2 (MIXING TABLE, ETC.)

	NUCLIDES ON TAPE	CCCC IDENTIFICATION	MIXTURE	MIXING TABLE COMPONENT	ATOM DENSITY	EXTRA XSECT ID'S
1	1001		1	94239	5.86641E-05	
2	7		1	94240	2.81686E-06	
3	7014		1	7014	5.59175E-04	
4	8016		1	8016	3.41878E-02	
5	5		3	5	3.33797E-02	
6	24304		1	1001	6.53338E-02	
7	25055		3	7	6.67593E-02	
8	26304		2	24304	1.74249E-02	
9	28304		2	25055	1.73644E-03	
10	94235		2	26304	5.93560E-02	
11	94240		2	28304	7.72081E-03	

MACROSCOPIC 1-D CROSS SECTIONS FOR MIXTURE 1

		GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
DIFFCOEF	1	3.89984E 00	3.18404E 00	1.67710E 00	1.35821E 00	1.02502E 00	7.32544E-01	6.16911E-01	5.89654E-01
$\Sigma_{N,2N}$	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	2.25000E-01	3.47000E-01	1.61000E-01	1.70000E-01	8.40001E-02	1.30000E-02	0.0	0.0
Σ_F	5	1.15969E-04	1.18743E-04	1.11277E-04	1.01898E-04	9.81180E-05	1.12631E-04	1.46660E-04	2.46389E-04
	6	1.62518E-03	1.83401E-04	1.38054E-04	1.31140E-04	1.09849E-04	1.37313E-04	2.09533E-04	4.68490E-04
$\nu\Sigma_F$	7	4.04653E-04	3.68346E-04	3.33931E-04	2.99211E-04	2.82622E-04	3.22124E-04	4.19448E-04	7.04673E-04
	8	1.41007E-01	1.83547E-01	3.27268E-01	3.95167E-01	5.70198E-01	8.79704E-01	1.05731E 00	1.10999E 00

		GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
	1	5.87729E-01	5.8398 E-01	5.80988E-01	5.76081E-01	5.59636E-01	5.52247E-01	3.04639E-01	1.42112E-01
Σ_{UPSCAT}	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
χ(SPEC)	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5	9.67956E-04	2.29000 -03	4.41515E-03	1.34806E-03	1.17662E-03	8.09239E-03	6.91624E-02	4.13583E-02
Σ_A	6	1.77541E-03	5.14987 -03	8.48583E-03	4.15298E-03	2.02904E-02	2.03726E-02	1.22962E-01	7.60882E-02
	7	2.76835E-03	6.54940 -03	1.26273E-02	3.85544E-03	3.36561E-03	2.31443E-02	1.97805E-01	1.18285E-01
Σ_T	8	1.11132E 00	1.11489E 00	1.11796E 00	1.11292E 00	1.12914E 00	1.32227E 00	1.87820E 00	3.12958E 00

MACROSCOPIC 1-D CROSS SECTIONS FOR MIXTURE 2

	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	2.08147E 00	1.62385E 00	1.92499E 00	1.64380E 00	1.25065E 00	8.14859E-01	3.81287E-01	3.60060E-01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.32885E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.01129E-02	6.38783E-04	3.67509E-04	4.45968E-04	5.21979E-04	1.06152E-03	2.08429E-03	4.65588E-03
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	2.67770E-01	2.70003E-01	2.20467E-01	2.54655E-01	2.89926E-01	4.18622E-01	8.91989E-01	9.40052E-01

	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	2.90554E-01	3.74511E-01	3.73197E-01	3.70028E-01	3.60159E-01	3.52139E-01	3.36434E-01	2.92432E-01
2	0.0	0.0	0.0	0.0	0.0	4.32726E-03	4.78253E-03	1.08418E-02
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	9.48549E-03	5.95556E-03	1.03143E-02	1.81948E-02	3.22283E-02	5.33004E-02	9.75204E-02	2.46571E-01
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.16113E 00	9.00869E-01	9.03980E-01	9.11589E-01	9.25516E-01	9.46597E-01	9.90783E-01	1.13987E 00

MACROSCOPIC 1-D CROSS SECTIONS FOR MIXTURE 3

	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	3.94709E 00	3.20479E 00	1.69371E 00	1.36871E 00	1.02844E 00	7.31048E-01	6.15515E-01	5.88597E-01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.33519E-03	0.0	0.0	0.0	0.0	0.0	0.0	6.67593E-05
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.41156E-01	1.84589E-01	3.28122E-01	3.96550E-01	5.74464E-01	8.89901E-01	1.06982E 00	1.12289E 00

	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	5.88042E-01	5.87973E-01	5.88111E-01	5.77767E-01	5.76966E-01	5.66106E-01	3.36914E-01	1.43394E-01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	2.67037E-04	5.34074E-04	9.34630E-04	1.66898E-03	3.00417E-03	4.67315E-03	8.67870E-03	1.93669E-02
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	1.12289E 00	1.12289E 00	1.12289E 00	1.12289E 00	1.12289E 00	1.32317E 00	1.79048E 00	3.12571E 00

ELAPSED TIME 0.01 MIN.

7889 LOCATIONS WILL BE USED

33Q ARRAY HAS 1280 ENTRIES.

35Q ARRAY HAS 41 ENTRIES.

36Q ARRAY HAS 40 ENTRIES.

39Q ARRAY HAS 3 ENTRIES.

40Q ARRAY HAS 3 ENTRIES.

CRITICAL PUENO314 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER
NEUTRON GROUP PARAMETERS

GP	ENERGY BOUNDARIES	LETHARGY BOUNDARIES	MID PT VELOCITIES	BROAD GP NUMBERS	CALC TYPE	RIGHT ALBEDO	LEFT ALBEDO
1	1.50000E 07	-4.05465E-01	3.58233E 09	0	0		
2	3.00000E 06	1.20397E 00	1.98004E 09	0	0		
3	1.40000E 06	1.96611E 00	1.46540E 09	0	0		
4	9.00000E 05	2.40795E 00	1.07137E 09	0	0		
5	4.00000E 05	3.21888E 00	6.18554E 08	0	0		
6	1.00000E 05	4.60517E 00	2.80850E 08	0	0		
7	1.70000E 04	6.37713E 00	1.16884E 08	0	0		
8	3.00000E 03	8.11173E 00	4.95716E 07	0	0		
9	5.50000E 02	9.80818E 00	2.11814E 07	0	0		
10	1.00000E 02	1.15129E 01	1.02363E 07	0	0		
11	3.00000E 01	1.27169E 01	5.75629E 06	0	0		
12	1.00000E 01	1.38155E 01	3.23700E 06	0	0		
13	3.00000E 00	1.50195E 01	1.82031E 06	0	0		
14	1.00000E 00	1.61181E 01	1.09997E 06	0	0		
15	4.00000E-01	1.70344E 01	6.18556E 05	0	0		
16	1.00000E-01	1.84207E 01	1.38314E 05	0	0		
17	1.00000E-03	2.30258E 01					

CRITICAL PU(NO3)4 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER

	MIXTURE BY ZONE	ORDER P(L) BY ZONE
1	1	1
2	2	1
3	3	1
4		
5		

ACTIVITY TABLE

MATL NO.	REACTION

QUADRATURE CONSTANTS

	WEIGHTS	DIRECTIONS	REFL DIREC	WT X COS
1	0	-1.00000E 00	5	0
2	1.73927E-01	-8.61136E-01	5	-1.49775E-01
3	3.26073E-01	-3.39981E-01	4	-1.10858E-01
4	3.26073E-01	3.39981E-01	3	1.10858E-01
5	1.73927E-01	8.61136E-01	2	1.49775E-01

CONSTANTS FOR P(L) SCATTERING

ANGL	SET 1
1	-1.00000E 00
2	-8.61136E-01
3	-3.39981E-01
4	3.39981E-01
5	8.61136E-01

INT	RADII	MID PTS	ZONE NO.	AREAS	VOLUMES	DENS FACT	RADIUS MOD	SPEC(INT)
1	0	1.78906E-01	1	0	1.91892E-01		0	
2	3.57813E-01	5.53428E-01	1	1.60887E 00	1.56850E 00		0	
3	7.49043E-01	9.64813E-01	1	7.05056E 00	5.13212E 00		0	
4	1.18058E 00	1.42154E 00	1	1.75147E 01	1.23272E 01			
5	1.66170E 00	1.93349E 00	1	3.46989E 01	2.57047E 01			
6	2.20528E 00	2.51765E 00	1	6.11137E 01	5.00165E 01			
7	2.83001E 00	3.19722E 00	1	1.00644E 02	9.47555E 01			
8	3.56443E 00	4.00994E 00	1	1.59658E 02	1.80782E 02			
9	4.45545E 00	5.02195E 00	1	2.49455E 02	3.60599E 02			
10	5.58845E 00	6.36722E 00	1	3.92438E 02	7.97450E 02			
11	7.14598E 00	8.39898E 00	1	6.41701E 02	2.23799E 03			
12	9.65199E 00	1.09050E 01	1	1.17070E 03	3.76142E 03			
13	1.21580E 01	1.29368E 01	1	1.85752E 03	3.27960E 03			
14	1.37155E 01	1.42820E 01	1	2.36393E 03	2.90569E 03			
15	1.48485E 01	1.52940E 01	1	2.77062E 03	2.61977E 03			
16	1.57356E 01	1.61038E 01	1	3.11311E 03	2.39465E 03			
17	1.64740E 01	1.67863E 01	1	3.41041E 03	2.21238E 03			
18	1.70987E 01	1.73705E 01	1	3.67397E 03	2.06124E 03			
19	1.76423E 01	1.78828E 01	1	3.91128E 03	1.93358E 03			
20	1.81234E 01	1.83392E 01	1	4.12752E 03	1.82394E 03			
21	1.85549E 01	1.87505E 01	1	4.32642E 03	1.72856E 03			
22	1.89462E 01	1.91251E 01	1	4.51079E 03	1.64473E 03			
23	1.93040E 01	1.93119E 01	2	4.68278E 03	7.42.91E 01			
24	1.93158E 01	1.93424E 01	2	4.69046E 03	2.12354E 02			
25	1.93650E 01	1.93876E 01	2	4.71242E 03	2.13250E 02			
26	1.94101E 01	1.94181E 01	2	4.73442E 03	7.51250E 01			
27	1.94260E 01	1.97296E 01	3	4.74216E 03	2.97050E 03			
28	2.00332E 01	2.03854E 01	3	5.04326E 03	3.67862E 03			
29	2.07376E 01	2.11569E 01	3	5.40413E 03	4.71743E 03			
30	2.15761E 01	2.20942E 01	3	5.85002E 03	6.35762E 03			
31	2.26124E 01	2.32907E 01	3	6.42541E 03	9.25118E 03			
32	2.39651E 01	2.49537E 01	3	7.21960E 03	1.54169E 04			
33	2.59383E 01	2.77621E 01	3	8.45460E 03	3.53799E 04			
34	2.95860E 01	3.14098E 01	3	1.09997E 04	4.52733E 04			
35	3.32336E 01	3.42182E 01	3	1.38792E 04	2.89826E 04			
36	3.52029E 01	3.58812E 01	3	1.55728E 04	2.19531E 04			
37	3.65596E 01	3.70777E 01	3	1.67963E 04	1.79024E 04			
38	3.75958E 01	3.80151E 01	3	1.77619E 04	1.52291E 04			
39	3.84344E 01	3.87865E 01	3	1.85631E 04	1.33161E 04			
40	3.91387E 01	3.94424E 01	3	1.92497E 04	1.18717E 04			
41	3.97460E 01			1.98516E 04				

ELAPSED TIME 0.02 MIN.

OUTER ITER	INNER ITERS	1 - BALANCE	EIGENVALUE	1 - SOURCE RATIO	1 - SCATTER RATIO	1 - UPSCAT RATIO	TIME (MIN)
1	129	-9.63114E-07	9.47938E-01	5.20680E-02	1.00000E 00	-1.94067E-01	0.0460
2	215	-9.34442E-07	9.85029E-01	-3.91249E-02	5.34327E-05	5.00042E-02	0.0675
3	293	-9.22974E-07	9.99145E-01	-1.43315E-02	1.49343E-05	2.18987E-02	0.0872
4	365	-9.18322E-07	1.00481E 00	-5.67224E-03	6.06372E-06	9.32250E-03	0.1052
5	427	-9.16365E-07	1.00713E 00	-2.30225E-03	2.41903E-06	3.87630E-03	0.1210
6	469	-9.15522E-07	1.00807E 00	-9.42884E-04	9.42276E-07	1.65321E-03	0.1333
7	500	-9.15265E-07	1.00836E 00	-2.87885E-04	3.77068E-07	4.73235E-04	0.1430
8	531	-9.15155E-07	1.00849E 00	-1.22620E-04	5.83020E-08	1.82084E-04	0.1525
9	561	-9.15101E-07	1.00855E 00	-6.21725E-05	3.32679E-08	8.45150E-05	0.1618

THESE NUMBERS SHOULD ALL BECOME SMALL AS THE PROBLEM CONVERGES

GROUP	INNER ITERS	MED INT.	MAX. FLUX DIFFERENCE	MSF INT.	MAX. SCALE FACTOR	COARSE MESH
1	2	11	1.38904D-05	40	9.99999E-01	5
2	2	10	1.59850D-05	9	1.00000E 00	7
3	2	8	1.33883D-05	40	1.00000E 00	11
4	2	10	1.53073D-05	6	1.00000E 00	13
5	2	14	9.49504D-06	5	1.00000E 00	16
6	2	9	1.03988D-05	8	1.00000E 00	20
7	2	8	5.78431D-06	10	1.00000E 00	24
8	2	8	5.54305D-06	10	1.00000E 00	24
9	2	8	5.38025D-06	10	1.00000E 00	24
10	2	25	3.57343D-06	10	1.00000E 00	24
11	2	25	3.58782D-06	10	1.00000E 00	24
12	2	25	3.42026D-06	10	1.00000E 00	24
13	2	22	3.51842D-06	10	1.00000E 00	25
14	2	25	2.36370D-06	10	1.00000E 00	26
15	1	1	6.36633D-05	2	1.00018E 00	32
16	1	36	5.99478D-05	7	1.00040E 00	36

10	591	-9.15068E-07	1.00859E 00	-3.79921E-05	2.78528E-08	5.50218E-05	0.1722

FINAL MONITOR

LAMBDA 1.00858E 00

ANGULAR FLUX ON 16

ELAPSED TIME 0.17 MIN.

THE ANSWER

K_{EFF} = 1.00858 FOR THIS SYSTEM

CRITICAL PU(NO3)4 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER

INT.	ZONE NUMBER	RADIUS	INT. MIDPOINT	AREA	VOLUME	PROD DENSITY
1	1	0.0	1.78906E-01	0.0	1.91892E-01	1.17547D-05
2	1	3.57813E-01	5.53428E-01	1.60887E 00	1.56850E 00	9.60319D-05
3	1	7.49043E-01	9.64813E-01	7.05056E 00	5.13212E 00	3.13719D-04
4	1	1.18058E 00	1.42114E 00	1.75147E 01	1.23272E 01	7.51406D-04
5	1	1.66170E 00	1.93349E 00	3.46989E 01	2.57047E 01	1.55972D-03
6	1	2.20528E 00	2.51765E 00	6.11137E 01	5.00165E 01	3.01392D-03
7	1	2.83001E 00	3.19722E 00	1.00644E 02	9.47555E 01	5.65049D-03
8	1	3.56443E 00	4.00994E 00	1.59658E 02	1.80782E 02	1.06107D-02
9	1	4.45545E 00	5.02195E 00	2.49455E 02	3.60599E 02	2.06425D-02
10	1	5.58845E 00	6.36722E 00	3.92458E 02	7.97450E 02	4.37543D-02
11	1	7.14598E 00	8.39898E 00	6.41701E 02	2.23799E 03	1.12743D-01
12	1	9.65199E 00	1.09050E 01	1.17070E 03	3.76142E 03	1.64555D-01
13	1	1.21580E 01	1.29368E 01	1.85752E 03	3.27960E 03	1.23470D-01
14	1	1.37155E 01	1.42820E 01	2.36393E 03	2.90569E 03	9.69680D-02
15	1	1.48485E 01	1.52940E 01	2.77062E 03	2.61977E 03	7.91345D-02
16	1	1.57396E 01	1.61068E 01	3.11311E 03	2.39465E 03	6.86369D-02
17	1	1.64740E 01	1.67863E 01	3.41041E 03	2.21238E 03	5.76595D-02
18	1	1.70987E 01	1.73705E 01	3.67357E 03	2.06124E 03	5.11433D-02
19	1	1.76423E 01	1.78828E 01	3.91128E 03	1.93358E 03	4.66389D-02
20	1	1.81234E 01	1.83392E 01	4.12752E 03	1.82394E 03	4.31152D-02
21	1	1.85549E 01	1.87505E 01	4.32642E 03	1.72856E 03	4.09184D-02
22	1	1.89462E 01	1.91251E 01	4.51079E 03	1.64473E 03	3.93933D-02
23	2	1.93040E 01	1.93119E 01	4.68278E 03	7.42291E 01	0.0
24	2	1.93198E 01	1.93424E 01	4.69046E 03	2.12354E 02	0.0
25	2	1.93650E 01	1.93876E 01	4.71242E 03	2.13250E 02	0.0
26	2	1.94101E 01	1.94181E 01	4.73442E 03	7.51250E 01	0.0
27	3	1.94260E 01	1.97296E 01	4.74216E 03	2.97050E 03	0.0
28	3	2.00332E 01	2.03854E 01	5.04326E 03	3.67862E 03	0.0
29	3	2.07376E 01	2.11569E 01	5.40413E 03	4.71743E 03	0.0
30	3	2.15761E 01	2.20942E 01	5.85002E 03	6.35762E 03	0.0
31	3	2.26124E 01	2.32907E 01	6.42541E 03	9.25118E 03	0.0
32	3	2.39691E 01	2.49537E 01	7.21960E 03	1.54169E 04	0.0
33	3	2.59383E 01	2.77621E 01	8.45460E 03	3.53799E 04	0.0
34	3	2.95860E 01	3.14098E 01	1.09997E 04	4.52733E 04	0.0
35	3	3.32336E 01	3.42182E 01	1.38792E 04	2.89826E 04	0.0
36	3	3.52029E 01	3.58812E 01	1.55728E 04	2.19531E 04	0.0
37	3	3.65596E 01	3.70777E 01	1.67963E 04	1.79024E 04	0.0
38	3	3.75958E 01	3.80151E 01	1.77619E 04	1.52291E 04	0.0
39	3	3.84344E 01	3.87865E 01	1.85631E 04	1.33161E 04	0.0
40	3	3.91387E 01	3.94424E 01	1.92497E 04	1.18717E 04	0.0
41		3.97460E 01		1.98516E 04		

CRITICAL PU(NO3)4 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER

TOTAL FLUX

INT.	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	9.56447E-05	1.66394E-04	7.47372E-05	1.06237E-04	1.07728E-04	7.80742E-05	6.15775E-05	5.63129E-05
2	9.57496E-05	1.66560E-04	7.47788E-05	1.06280E-04	1.07752E-04	7.80754E-05	6.15699E-05	5.63022E-05
3	9.5543E-05	1.66362E-04	7.46793E-05	1.06134E-04	1.07600E-04	7.79612E-05	6.14779E-05	5.62170E-05
4	9.54025E-05	1.65941E-04	7.44812E-05	1.05850E-04	1.07308E-04	7.77474E-05	6.13082E-05	5.60612E-05
5	9.49916E-05	1.65220E-04	7.41508E-05	1.05378E-04	1.06828E-04	7.73997E-05	6.10338E-05	5.58100E-05
6	9.43567E-05	1.64110E-04	7.36464E-05	1.04660E-04	1.06099E-04	7.68720E-05	6.06176E-05	5.54294E-05
7	9.34011E-05	1.62442E-04	7.28919E-05	1.03586E-04	1.05012E-04	7.60843E-05	5.99966E-05	5.48616E-05
8	9.19615E-05	1.59933E-04	7.17594E-05	1.01976E-04	1.03380E-04	7.49026E-05	5.90649E-05	5.40096E-05
9	8.97331E-05	1.56053E-04	7.00098E-05	9.94880E-05	1.00858E-04	7.30760E-05	5.76246E-05	5.26923E-05
10	8.60664E-05	1.49671E-04	6.71323E-05	9.53947E-05	9.67068E-05	7.00673E-05	5.52508E-05	5.05204E-05
11	7.91033E-05	1.37562E-04	6.16782E-05	8.76362E-05	8.88357E-05	6.43607E-05	5.07477E-05	4.63998E-05
12	6.87860E-05	1.19628E-04	5.36075E-05	7.61537E-05	7.71830E-05	5.59109E-05	4.40782E-05	4.02944E-05
13	5.92531E-05	1.03058E-04	4.61460E-05	6.55288E-05	6.63860E-05	4.80731E-05	3.78854E-05	3.46208E-05
14	5.24740E-05	9.12707E-05	4.08284E-05	5.79381E-05	5.86451E-05	4.24373E-05	3.34230E-05	3.05273E-05
15	4.72525E-05	8.21949E-05	3.67295E-05	5.20670E-05	5.26273E-05	3.80385E-05	2.99327E-05	2.73247E-05
16	4.30011E-05	7.48195E-05	3.34022E-05	4.72852E-05	4.77002E-05	3.44125E-05	2.70615E-05	2.46941E-05
17	3.93762E-05	6.85562E-05	3.05870E-05	4.32320E-05	4.35107E-05	3.13706E-05	2.46189E-05	2.24653E-05
18	3.61480E-05	6.30123E-05	2.81074E-05	3.96686E-05	3.98354E-05	2.86412E-05	2.24920E-05	2.05377E-05
19	3.31474E-05	5.78578E-05	2.58262E-05	3.64157E-05	3.65182E-05	2.62251E-05	2.06100E-05	1.88483E-05
20	3.02407E-05	5.29818E-05	2.36236E-05	3.33223E-05	3.34404E-05	2.40250E-05	1.89280E-05	1.73566E-05
21	2.73163E-05	4.80688E-05	2.13849E-05	3.02491E-05	3.05031E-05	2.19948E-05	1.74203E-05	1.60366E-05
22	2.42783E-05	4.29879E-05	1.89948E-05	2.70590E-05	2.76192E-05	2.01062E-05	1.60802E-05	1.48732E-05
23	2.26358E-05	4.02336E-05	1.76972E-05	2.53529E-05	2.61200E-05	1.91509E-05	1.53996E-05	1.42861E-05
24	2.23146E-05	3.96510E-05	1.75028E-05	2.51027E-05	2.58877E-05	1.89828E-05	1.51972E-05	1.41189E-05
25	2.18448E-05	3.87937E-05	1.72136E-05	2.47302E-05	2.55434E-05	1.87361E-05	1.49011E-05	1.38709E-05
26	2.15311E-05	3.82180E-05	1.70174E-05	2.44772E-05	2.53104E-05	1.85708E-05	1.47034E-05	1.37029E-05
27	1.91153E-05	3.40875E-05	1.50042E-05	2.18148E-05	2.29825E-05	1.71310E-05	1.36952E-05	1.27684E-05
28	1.48720E-05	2.68335E-05	1.15313E-05	1.71225E-05	1.86855E-05	1.43193E-05	1.16812E-05	1.09455E-05
29	1.13950E-05	2.08350E-05	8.80784E-06	1.32701E-05	1.48190E-05	1.15409E-05	9.55358E-06	9.04503E-06
30	8.52146E-06	1.57931E-05	6.58147E-06	9.99554E-06	1.13114E-05	8.89072E-06	7.43553E-06	7.10560E-06
31	6.10875E-06	1.14587E-05	4.69212E-06	7.13940E-06	8.12470E-06	6.41266E-06	5.39566E-06	5.19279E-06
32	4.03155E-06	7.62594E-06	3.04470E-06	4.61396E-06	5.24754E-06	4.14173E-06	3.49140E-06	3.37267E-06
33	2.17132E-06	4.10888E-06	1.58003E-06	2.36841E-06	2.67551E-06	2.10280E-06	1.76771E-06	1.70599E-06
34	9.21314E-07	1.72060E-06	6.29325E-07	9.25801E-07	1.03203E-06	8.04100E-07	6.70718E-07	6.43047E-07
35	4.65965E-07	8.53491E-07	3.05593E-07	4.44488E-07	4.91227E-07	3.80547E-07	3.15580E-07	3.00725E-07
36	3.22829E-07	5.85560E-07	2.08503E-07	3.01588E-07	3.31443E-07	2.55584E-07	2.10986E-07	2.00145E-07
37	2.49095E-07	4.47953E-07	1.58529E-07	2.27657E-07	2.48202E-07	1.89931E-07	1.55562E-07	1.46425E-07
38	2.03055E-07	3.61573E-07	1.26674E-07	1.79965E-07	1.93941E-07	1.46643E-07	1.18564E-07	1.10264E-07
39	1.70984E-07	3.00494E-07	1.03173E-07	1.43947E-07	1.52053E-07	1.12786E-07	8.93475E-08	8.16534E-08
40	1.46927E-07	2.53442E-07	8.34216E-08	1.12433E-07	1.13255E-07	7.94363E-08	6.03198E-08	5.37975E-08

INT.	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	5.56637E-05	3.86431E-05	3.48608E-05	3.71891E-05	3.30295E-05	2.72531E-05	6.44882E-05	3.93037E-04
2	5.56516E-05	3.86343E-05	3.48526E-05	3.71801E-05	3.30214E-05	2.72461E-05	6.44628E-05	3.92815E-04
3	5.55669E-05	3.85753E-05	3.47992E-05	3.71232E-05	3.29708E-05	2.72043E-05	6.43631E-05	3.92190E-04
4	5.54125E-05	3.84680E-05	3.47024E-05	3.70198E-05	3.28790E-05	2.71285E-05	6.41832E-05	3.91072E-04
5	5.51641E-05	3.82955E-05	3.45467E-05	3.68537E-05	3.27313E-05	2.70067E-05	6.38949E-05	3.89289E-04
6	5.47878E-05	3.80341E-05	3.43109E-05	3.66020E-05	3.25078E-05	2.68222E-05	6.34581E-05	3.86585E-04
7	5.42264E-05	3.76443E-05	3.39591E-05	3.62267E-05	3.21743E-05	2.65470E-05	6.28065E-05	3.82552E-04
8	5.33841E-05	3.70594E-05	3.34314E-05	3.56635E-05	3.16739E-05	2.61340E-05	6.18284E-05	3.76508E-04
9	5.20815E-05	3.61549E-05	3.26150E-05	3.47923E-05	3.08999E-05	2.54951E-05	6.03155E-05	3.67190E-04
10	4.99336E-05	3.46630E-05	3.12687E-05	3.33554E-05	2.96231E-05	2.44411E-05	5.78196E-05	3.51923E-04
11	4.58573E-05	3.18313E-05	2.87126E-05	3.06268E-05	2.71981E-05	2.24390E-05	5.30790E-05	3.23132E-04
12	3.98153E-05	2.76326E-05	2.49217E-05	2.65793E-05	2.36007E-05	1.94690E-05	4.60479E-05	2.80696E-04
13	3.41970E-05	2.37273E-05	2.13954E-05	2.28148E-05	2.02556E-05	1.67081E-05	3.95167E-05	2.41761E-04
14	3.01420E-05	2.09092E-05	1.88522E-05	2.01020E-05	1.78473E-05	1.47223E-05	3.48292E-05	2.14686E-04
15	2.65727E-05	1.87097E-05	1.68701E-05	1.79910E-05	1.59763E-05	1.31818E-05	3.12088E-05	1.94943E-04
16	2.43771E-05	1.69128E-05	1.52543E-05	1.62738E-05	1.44572E-05	1.19334E-05	2.82978E-05	1.80479E-04

17	2.21882E-05	1.54025E-05	1.38996E-05	1.48372E-05	1.31893E-05	1.08933E-05	2.59057E-05	1.70212E-06
18	2.03069E-05	1.41091E-05	1.27424E-05	1.36124E-05	1.21107E-05	1.00103E-05	2.39228E-05	1.63520E-04
19	1.86659E-05	1.29872E-05	1.17408E-05	1.25539E-05	1.11806E-05	9.25049E-06	2.22842E-05	1.60029E-04
20	1.72344E-05	1.20048E-05	1.08650E-05	1.16289E-05	1.03703E-05	8.59000E-06	2.09552E-05	1.59484E-04
21	1.59656E-05	1.11370E-05	1.00926E-05	1.08125E-05	9.65913E-06	8.01090E-06	1.99339E-05	1.61859E-04
22	1.48507E-05	1.03609E-05	9.40596E-06	1.00824E-05	9.03339E-06	7.49684E-06	1.93374E-05	1.65568E-04
23	1.42759E-05	9.96696E-06	9.05955E-06	9.71223E-06	8.71975E-06	7.23659E-06	1.91625E-05	1.67373E-04
24	1.40888E-05	9.86777E-06	8.97325E-06	9.62115E-06	8.64063E-06	7.17141E-06	1.91295E-05	1.67730E-04
25	1.38144E-05	9.72183E-06	8.84686E-06	9.48840E-06	8.52621E-06	7.07826E-06	1.90870E-05	1.68685E-04
26	1.36308E-05	9.62386E-06	8.76239E-06	9.40013E-06	8.45077E-06	7.01760E-06	1.90627E-05	1.69618E-04
27	1.27603E-05	9.02146E-06	8.24234E-06	8.85361E-06	8.00537E-06	6.66795E-06	1.88274E-05	1.86720E-04
28	1.10564E-05	7.82999E-06	7.19368E-06	7.75182E-06	7.07011E-06	5.92154E-06	1.76876E-05	2.09994E-04
29	9.21630E-06	6.56372E-06	6.05688E-06	6.55378E-06	6.00767E-06	5.05560E-06	1.55943E-05	2.17641E-04
30	7.30650E-06	5.23659E-06	4.85727E-06	5.28072E-06	4.86541E-06	4.11355E-06	1.29921E-05	2.11802E-04
31	5.38268E-06	3.88242E-06	3.62064E-06	3.95704E-06	3.66518E-06	3.11356E-06	1.00028E-05	1.89898E-04
32	3.51552E-06	2.54870E-06	2.38832E-06	2.62345E-06	2.44259E-06	2.08469E-06	6.78751E-06	1.50981E-04
33	1.78012E-06	1.29311E-06	1.21484E-06	1.33878E-06	1.25114E-06	1.07168E-06	3.52351E-06	9.32109E-05
34	6.67270E-07	4.83011E-07	4.52781E-07	4.98297E-07	4.65410E-07	3.98674E-07	1.31426E-06	4.16857E-05
35	3.09849E-07	2.22908E-07	2.07762E-07	2.27269E-07	2.10975E-07	1.79757E-07	5.86099E-07	1.90993E-05
36	2.05259E-07	1.47129E-07	1.36716E-07	1.49095E-07	1.37987E-07	1.17250E-07	3.79750E-07	1.18662E-05
37	1.49040E-07	1.06250E-07	9.83160E-08	1.06816E-07	9.85262E-08	8.34890E-08	2.68238E-07	7.87408E-06
38	1.11061E-07	7.86220E-08	7.23942E-08	7.83205E-08	7.19871E-08	6.08192E-08	1.92623E-07	5.19842E-06
39	8.11706E-08	5.70225E-08	5.22493E-08	5.62906E-08	5.15711E-08	4.35621E-08	1.34548E-07	3.17533E-06
40	5.27981E-08	3.68538E-08	3.36425E-08	3.60915E-08	3.30040E-08	2.78735E-08	7.97256E-08	1.46100E-06

ELAPSED TIME 0.17 MIN.

FINE GROUP SUMMARY FOR ZONE 1 BY GROUP INCLUDING SUM FOR ALL GROUPS IN LINE 17

GRP.	FIX	SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0		2.25000E-01	0.0	4.62053E-02	1.64651E-01	2.45859E-03	5.78872E-02	1.00001E 00
2	0.0		3.47000E-01	9.82331E-02	1.32821E-01	3.50346E-01	4.83267E-04	9.44021E-02	1.00000E 00
3	0.0		1.61000E-01	1.60202E-01	9.96559E-02	2.85824E-01	1.62680E-04	3.52128E-02	1.00000E 00
4	0.0		1.70000E-01	3.17471E-01	2.16621E-01	4.43496E-01	2.19141E-04	4.37535E-02	1.00000E 00
5	0.0		8.39998E-02	5.09383E-01	4.06139E-01	5.57149E-01	1.85615E-04	3.60465E-02	1.00000E 00
6	0.0		1.30000E-02	5.98541E-01	4.82256E-01	5.92300E-01	1.67755E-04	1.94701E-02	1.00000E 00
7	0.0		0.0	5.87983E-01	4.41557E-01	5.76112E-01	2.01717E-04	1.16674E-02	1.00000E 00
8	0.0		0.0	5.72049E-01	4.14132E-01	5.62496E-01	4.12376E-04	9.13981E-03	1.00000E 00
9	0.0		0.0	5.64485E-01	4.10995E-01	5.54623E-01	1.54511E-03	8.31616E-03	1.00000E 00
10	0.0		0.0	4.76669E-01	2.02666E-01	4.67940E-01	3.11204E-03	5.61483E-03	1.00000E 00
11	0.0		0.0	4.49147E-01	1.65443E-01	4.39609E-01	4.62775E-03	4.90755E-03	1.00000E 00
12	0.0		0.0	4.65654E-01	1.87204E-01	4.58110E-01	2.41708E-03	5.12625E-03	1.00000E 00
13	0.0		0.0	4.39414E-01	1.49025E-01	4.24553E-01	1.04957E-02	4.36534E-03	1.00000E 00
14	0.0		0.0	3.88204E-01	1.80067E-01	3.75945E-01	8.70073E-03	3.55917E-03	9.99999E-01
15	0.0		0.0	4.72299E-01	1.44156E 00	3.44485E-01	1.25120E-01	2.69436E-03	1.00000E 00
16	0.0		0.0	4.97528E-01	2.00142E 01	0.0	5.12167E-01	-1.46450E-02	1.00001E 00
17	0.0		9.99998E-01	6.59766E 00	2.49905E 01	6.59763E 00	6.72477E-01	3.27518E-01	1.00000E 00

GRP.	RT BDY FLUX	RT LEAKAGE	LFT BDY FLUX	LFT LEAKAGE	N2N RATE	FISS RATE	FLUX*DB**2	TOTAL FLUX
1	2.27199E-05	5.78872E-02	9.55095E-05	0.0	0.0	1.75439E-04	0.0	1.51281E 00
2	4.03856E-05	9.44021E-02	1.66173E-04	0.0	0.0	3.12891E-04	0.0	2.63503E 00
3	1.77474E-05	3.52128E-02	7.46650E-05	0.0	0.0	1.31126E-04	0.0	1.17838E 00
4	2.54176E-05	4.37535E-02	1.06148E-04	0.0	0.0	1.70275E-04	0.0	1.67104E 00
5	2.61802E-05	3.60465E-02	1.07654E-04	0.0	0.0	1.65792E-04	0.0	1.68972E 00
6	1.91947E-05	1.94701E-02	7.80361E-05	0.0	0.0	1.37600E-04	0.0	1.22169E 00
7	1.34526E-05	1.16674E-02	6.15549E-05	0.0	0.0	1.41190E-04	0.0	9.62699E-01
8	1.43294E-05	9.13981E-03	5.62954E-05	0.0	0.0	2.16878E-04	0.0	8.80226E-01
9	1.43249E-05	8.31616E-03	5.56476E-05	0.0	0.0	8.42398E-04	0.0	8.70286E-01
10	9.99283E-06	5.61483E-03	3.86323E-05	0.0	0.0	1.38383E-03	0.0	6.04294E-01
11	9.08214E-06	4.90755E-03	3.48512E-05	0.0	0.0	2.40781E-03	0.0	5.45351E-01
12	9.73614E-06	5.12625E-03	3.71790E-05	0.0	0.0	7.84582E-04	0.0	5.82011E-01
13	8.74065E-06	4.36534E-03	3.30208E-05	0.0	0.0	6.08636E-04	0.0	5.17274E-01
14	7.25396E-06	3.55917E-03	2.72461E-05	0.0	0.0	3.45610E-03	0.0	4.27080E-01
15	1.91720E-05	2.69436E-03	6.64803E-05	0.0	0.0	7.03763E-02	0.0	1.01755E 00
16	1.67335E-04	-1.46450E-02	3.93050E-04	0.0	0.0	2.71262E-01	0.0	6.55883E 00
17	4.27063E-04	3.27516E-01	1.43014E-03	0.0	0.0	3.52573E-01	0.0	2.28743E 01

* FINE GROUP EDITS BY ZONE AND FINE GROUP EDIT FOR SYSTEM (BELOW) SHOULD ALWAYS BE INSPECTED TO VERIFY THAT THE SOLUTION WAS ADEQUATELY CONVERGED

* THE VALUE OF K_{EFF} WAS ALREADY PRINTED, SEVERAL PAGES CLOSER TO THE FRONT.

FINE GROUP SUMMARY FOR ZONE 2 BY GROUP INCLUDING SUM FOR ALL GROUPS IN LINE 17

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0	0.0	0.0	2.27375E-03	1.16574E-03	1.28381E-04	-1.12552E-03	1.00028E 00
2	0.0	0.0	5.89785E-04	4.73426E-03	1.33909E-03	1.44048E-05	-7.64608E-04	1.00076E 00
3	0.0	0.0	9.22909E-04	1.83382E-03	3.62690E-04	3.66761E-06	5.56551E-04	1.00000E 00
4	0.0	0.0	9.24398E-04	3.47281E-03	1.68764E-04	6.38856E-06	7.49256E-04	9.99994E-01
5	0.0	0.0	5.31425E-04	4.21253E-03	6.62387E-05	7.71735E-06	4.57462E-04	1.00001E 00
6	0.0	0.0	1.25588E-04	4.37773E-03	1.49967E-04	1.15103E-05	-3.58783E-05	9.99957E-01
7	0.0	0.0	1.57834E-04	7.40456E-03	2.95356E-04	1.80343E-05	-1.55546E-04	9.99967E-01
8	0.0	0.0	2.95838E-04	7.37787E-03	1.48362E-04	3.74614E-05	1.10041E-04	9.99956E-01
9	0.0	0.0	1.48429E-04	9.07166E-03	1.66196E-04	7.60873E-05	-9.38475E-05	9.99975E-01
10	0.0	0.0	1.66206E-04	9.89060E-03	1.49058E-04	3.35386E-05	-1.63950E-05	1.00001E 00
11	0.0	0.0	1.49061E-04	4.42984E-03	1.48273E-04	5.28387E-05	-5.20460E-05	9.99984E-01
12	0.0	0.0	1.48274E-04	4.76113E-03	1.46817E-04	9.99552E-05	-9.84892E-05	9.99971E-01
13	0.0	0.0	1.64544E-04	4.26066E-03	1.47908E-04	1.59053E-04	-1.42403E-04	9.99958E-01
14	0.0	0.0	2.00454E-04	3.49321E-03	1.66338E-04	2.18355E-04	-1.84226E-04	9.99967E-01
15	0.0	0.0	1.19763E-03	9.32739E-03	4.86910E-04	1.07146E-03	-3.60788E-04	1.00002E 00
16	0.0	0.0	4.34365E-04	8.53835E-02	1.04902E-03	2.38574E-02	-2.44728E-02	1.00084E 00
17	0.0	0.0	6.15672E-03	1.61305E-01	6.15672E-03	2.57962E-02	-2.56293E-02	1.00014E 00

GRP.	RT BDY FLUX	RT LEAKAGE	LFT BDY FLUX	LFT LEAKAGE	N2N RATE	FISS RATE	FLUX*DB**2	TOTAL FLUX
1	2.14503E-05	5.67617E-02	2.27192E-05	5.78872E-02	1.68695E-04	0.0	0.0	1.26948E-02
2	3.80650E-05	9.36315E-02	4.03856E-05	9.44021E-02	0.0	0.0	0.0	2.25505E-02
3	1.69662E-05	3.57694E-02	1.77474E-05	3.52128E-02	0.0	0.0	0.0	9.97965E-03
4	2.44111E-05	4.45028E-02	2.54176E-05	4.37535E-02	0.0	0.0	0.0	1.43251E-02
5	2.52458E-05	3.65039E-02	2.61802E-05	3.60465E-02	0.0	0.0	0.0	1.47848E-02
6	1.85281E-05	1.94342E-02	1.91947E-05	1.94701E-02	0.0	0.0	0.0	1.08432E-02
7	1.46525E-05	1.15118E-02	1.54526E-05	1.16674E-02	0.0	0.0	0.0	8.65[illegible]52E-03
8	1.36591E-05	9.24985E-03	1.43294E-05	9.13981E-03	0.0	0.0	0.0	8[illegible]34E-03
9	1.35834E-05	8.22231E-03	1.43249E-05	8.31616E-03	0.0	0.0	0.0	8.[illegible]44E-03
10	9.59852E-06	5.59843E-03	9.99283E-06	5.61483E-03	0.0	0.0	0.0	5.63147E-03
11	8.74062E-06	4.85551E-03	9.08214E-06	4.90755E-03	0.0	0.0	0.0	5.12285E-03
12	9.37745E-06	5.02776E-03	9.73614E-06	5.12625E-03	0.0	0.0	0.0	5.49360E-03
13	8.43152E-06	4.22294E-03	8.74065E-06	4.36534E-03	0.0	0.0	0.0	4.93521E-03
14	7.00227E-06	3.37494E-03	7.25396E-06	3.55917E-03	0.0	0.0	0.0	4.09668E-03
15	1.90572E-05	2.[illegible]3357E-03	1.91720E-05	2.69436E-03	0.0	0.0	0.0	1.00870E-02
16	1.69916E-04	-3.[illegible]1178E-02	1.67335E-04	-1.46450E-02	0.0	0.0	0.0	9.67568E-02
17	4.18692E-04	3.[illegible]1887E-01	4.27063E-04	3.27516E-01	1.68695E-04	0.0	0.0	2.42921E-01

FINE GROUP SUMMARY FOR ZONE 3 BY GROUP INCLUDING SUM FOR ALL GROUPS IN LINE 17

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0	0.0	0.0	1.44557E-02	5.39069E-02	6.52627E-04	-5.45596E-02	0.0
2	0.0	0.0	3.20114E-02	4.45506E-02	1.22248E-01	0.0	-9.02386E-02	1.00002E 00
3	0.0	0.0	5.51848E-02	2.99792E-02	9.00093E-02	0.0	-3.48262E-02	1.00002E 00
4	0.0	0.0	1.04279E-01	6.90873E-02	1.47584E-01	0.0	-4.33062E-02	1.00001E 00
5	0.0	0.0	1.69263E-01	1.44935E-01	2.04655E-01	0.0	-3.53928E-02	1.00000E 00
6	0.0	0.0	2.15426E-01	1.86979E-01	2.34144E-01	0.0	-1.87195E-02	1.00000E 00
7	0.0	0.0	2.28977E-01	1.80378E-01	2.39971E-01	0.0	-1.09960E-02	1.00000E 00
8	0.0	0.0	2.35581E-01	1.76344E-01	2.44353E-01	2.50133E-05	-8.79867E-03	1.00000E 00
9	0.0	0.0	2.42887E-01	1.81945E-01	2.50564E-01	1.02881E-04	-7.78160E-03	1.00000E 00
10	0.0	0.0	2.13435E-01	9.19456E-02	2.10577E-01	1.47763E-04	-5.29122E-03	1.00000E 00
11	0.0	0.0	2.07151E-01	7.70537E-02	2.11484E-01	2.40364E-04	-4.57521E-03	1.00000E 00
12	0.0	0.0	2.20935E-01	8.92245E-02	2.25194E-01	4.68026E-04	-4.72782E-03	1.00000E 00
13	0.0	0.0	2.13726E-01	7.32036E-02	2.16895E-01	7.78212E-04	-3.94843E-03	1.00000E 00
14	0.0	0.0	1.95063E-01	9.23814E-02	1.97181E-01	1.02630E-03	-3.14435E-03	1.00000E 00
15	0.0	0.0	2.43698E-01	9.97675E-01	2.39424E-01	6.02257E-03	-1.75129E-03	1.00000E 00
16	0.0	0.0	3.18590E-01	4.36852E 01	0.0	2.72361E-01	4.62211E-02	1.00001E 00
17	0.0	0.0	2.89620E 00	4.61353E 01	2.89619E 00	2.81827E-01	-2.81836E-01	1.00000E 00

GRP.	RT BDY FLUX	RT LEAKAGE	LFT BDY FLUX	LFT LEAKAGE	N2N RATE	FISS RATE	FLUX*DB**2	TOTAL FLUX
1	1.36414E-07	2.20210E-03	2.14503E-05	5.67617E-02	0.0	0.0	0.0	4.88792E-01
2	2.32453E-07	3.39891E-03	3.80690E-05	9.36375E-02	0.0	0.0	0.0	9.03631E-01
3	7.40709E-08	9.43179E-04	1.69662E-05	3.57694E-02	0.0	0.0	0.0	3.65688E-01
4	9.71315E-08	1.19658E-03	2.44111E-05	4.45028E-02	0.0	0.0	0.0	5.46396E-01
5	9.36377E-08	1.11110E-03	2.52498E-05	3.65039E-02	0.0	0.0	0.0	6.08553E-01
6	6.17145E-08	7.14671E-04	1.85281E-05	1.94342E-02	0.0	0.0	0.0	4.73227E-01
7	4.48137E-08	5.15881E-04	1.46525E-05	1.15118E-02	0.0	0.0	0.0	3.92917E-01
8	3.91539E-08	4.51176E-04	1.36591E-05	9.24985E-03	0.0	0.0	0.0	3.74679E-01
9	3.81396E-08	4.40709E-04	1.35834E-05	8.22231E-03	0.0	0.0	0.0	3.85268E-01
10	2.65351E-08	3.07210E-04	9.59852E-06	5.59843E-03	0.0	0.0	0.0	2.76672E-01
11	2.41785E-08	2.80295E-04	8.74062E-06	4.85551E-03	0.0	0.0	0.0	2.57176E-01
12	2.58538E-08	2.99932E-04	9.37745E-06	5.02776E-03	0.0	0.0	0.0	2.80426E-01
13	2.36368E-08	2.74509E-04	8.43152E-06	4.22294E-03	0.0	0.0	0.0	2.59044E-01
14	1.98744E-08	2.30587E-04	7.00227E-06	3.37494E-03	0.0	0.0	0.0	2.19616E-01
15	5.07322E-08	5.82277E-04	1.90572E-05	2.33357E-03	0.0	0.0	0.0	6.94296E-01
16	6.17273E-07	7.10337E-03	1.69916E-04	-3.91179E-02	0.0	0.0	0.0	1.40632E 01
17	1.60565E-06	2.00524E-02	4.18692E-04	3.01887E-01	0.0	0.0	0.0	2.05896E 01

FINE GROUP SUMMARY FOR SYSTEM

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0	2.25000E-01	0.0	6.29347E-02	2.19724E-01	3.23960E-03	2.20210E-03	1.00001E 00
2	0.0	3.47000E-01	1.30834E-01	1.82106E-01	4.73933E-01	4.97672E-04	3.39891E-03	1.00000E 00
3	0.0	1.61000E-01	2.16310E-01	1.31469E-01	3.76196E-01	1.66348E-04	9.43179E-04	1.00000E 00
4	0.0	1.70000E-01	4.22675E-01	2.89181E-01	5.91249E-01	2.25530E-04	1.19658E-03	1.00000E 00
5	0.0	8.39998E-02	6.79178E-01	5.55286E-01	7.61870E-01	1.93332E-04	1.11110E-03	1.00000E 00
6	0.0	1.30000E-02	8.14492E-01	6.73613E-01	8.26594E-01	1.79265E-04	7.14471E-04	1.00000E 00
7	0.0	0.0	8.17117E-01	6.29338E-01	8.16378E-01	2.19751E-04	5.15881E-04	1.00000E 00
8	0.0	0.0	8.07925E-01	5.97853E-01	8.06997E-01	4.74851E-04	4.51176E-04	1.00000E 00
9	0.0	0.0	8.07521E-01	6.02011E-01	8.05354E-01	1.72408E-03	4.40709E-04	1.00000E 00
10	0.0	0.0	6.90270E-01	2.99503E-01	6.86666E-01	3.29334E-03	3.07210E-04	1.00000E 00
11	0.0	0.0	6.56447E-01	2.46927E-01	6.51242E-01	4.92095E-03	2.80295E-04	1.00000E 00
12	0.0	0.0	6.86737E-01	2.81189E-01	6.83451E-01	2.98506E-03	2.99932E-04	1.00000E 00
13	0.0	0.0	6.53304E-01	2.26489E-01	6.41596E-01	1.14329E-02	2.74509E-04	1.00000E 00
14	0.0	0.0	5.83468E-01	2.75942E-01	5.73292E-01	9.94539E-03	2.30587E-04	1.00000E 00
15	0.0	0.0	7.17195E-01	2.44856E 00	5.84396E-01	1.32217E-01	5.82277E-04	1.00000E 00
16	0.0	0.0	8.16553E-01	6.37847E 01	1.04902E-03	8.08385E-01	7.10337E-03	1.00001E 00
17	0.0	9.99998E-01	9.50001E 00	7.12869E 01	9.49997E 00	9.80100E-01	2.00525E-02	1.00000E 00

GRP.	RT BDY FLUX	RT LEAKAGE	LFT BDY FLUX	LFT LEAKAGE	N2N RATE	FISS RATE	FLUX*DB**2	TOTAL FLUX
1	1.36414E-07	2.20210E-03	9.55095E-05	0.0	1.68695E-04	1.75439E-04	0.0	2.01430E 00
2	2.32453E-07	3.39891E-03	1.66173E-04	0.0	0.0	3.12891E-04	0.0	3.56121E 00
3	7.40709E-08	9.43179E-04	7.46650E-05	0.0	0.0	1.31126E-04	0.0	1.55404E 00
4	9.71315E-08	1.19658E-03	1.06148E-04	0.0	0.0	1.70275E-04	0.0	2.23176E 00
5	9.36377E-08	1.11110E-03	1.07654E-04	0.0	0.0	1.65792E-04	0.0	2.31306E 00
6	6.17145E-08	7.14671E-04	7.80361E-05	0.0	0.0	1.37600E-04	0.0	1.70576E 00
7	4.48137E-08	5.15801E-04	6.15549E-05	0.0	0.0	1.41190E-04	0.0	1.36427E 00
8	3.91539E-08	4.51176E-04	5.62954E-05	0.0	0.0	2.16878E-04	0.0	1.26295E 00
9	3.81396E-08	4.40709E-04	5.56476E-05	0.0	0.0	8.42398E-04	0.0	1.26357E 00
10	2.65351E-08	3.07210E-04	3.86323E-05	0.0	0.0	1.38383E-03	0.0	8.86598E-01
11	2.41785E-08	2.80295E-04	3.48512E-05	0.0	0.0	2.40781E-03	0.0	8.07649E-01
12	2.58538E-08	2.99932E-04	3.71790E-05	0.0	0.0	7.84582E-04	0.0	8.67931E-01
13	2.36368E-08	2.74509E-04	3.30208E-05	0.0	0.0	6.08636E-04	0.0	7.81253E-01
14	1.98744E-08	2.30587E-04	2.72461E-05	0.0	0.0	3.45610E-03	0.0	6.50793E-01
15	5.07322E-08	5.82277E-04	6.44803E-05	0.0	0.0	7.03763E-02	0.0	1.72283E 00
16	6.17273E-07	7.10337E-03	3.93050E-04	0.0	0.0	2.71262E-01	0.0	2.07188E 01
17	1.60565E-06	2.00524E-02	1.43014E-03	0.0	1.68695E-04	3.52573E-01	0.0	4.37066E 01

ELAPSED TIME 0.18 MIN.

8. CSAS2 SAMPLE PROBLEM

Figure 15 shows a typical spent fuel shipping cask to be analyzed. Structurally the cask consists of an inside and outside shell of stainless steel with 10 cm of depleted uranium as the interstitial shielding material. The water-filled cask contains seven fuel assemblies, each surrounded by a sheath of Boral (an alloy of B_4C and aluminum weighing ~2.64 gm/cc). The key dimensions for the cask are shown in Fig. 15.

In the KENO calculation described below, the fuel assemblies are represented as homogenized zones measuring 21.42 cm by 21.42 cm. Homogenized, cell-weighted cross-section data for the materials in that zone will be produced by XSDRNPM which will perform a preliminary 1-D unit cell calculation for a typical fuel pin. The materials present in the unit cell, and the associated dimensions, may all be inferred from the input data listed below [Pitch = 1.26 cm, Dia(UO_2) = 0.819 cm, Clad (ID) = 0.[illegible]cm, Clad (OD) = 0.950 cm].

The Boral sheath around each fuel assembly serves as a neutron absorber in this design. The Boral selected for this application consists of 1.5 wt % B_4C and 98.5 wt % aluminum. Appendix B describes how the user may "create" such a mixture using the information already available in the Standard Composition Library.

The KENO geometry description requires that the seven fuel assemblies be enclosed by an artificial "CORE BOUNDARY" as shown in Fig. 16. To fully describe the geometry, this artificial "CORE" must be partitioned into 19 intervals in the x-direction and 11 intervals in the y-direction. This partitioning results in a total of 209 "boxes." After studying Fig. 16 and making note of the dimensions, orientation, and material corresponding to each box, the user should be able to identify 19 unique "box types." Table 7 shows a map of the 19 "box types" found in Fig. 16. This information is required as part of the multidimensional geometry description for KENO. The user may, if he wishes, enter a separate "Mixed Box Orientation Card" for each of the 209 boxes. Alternately, the information from Table 7 may be entered in a much more compact fashion as shown below in Table 8.

Often one may wish to run several variations of a given problem. In this particular case, for example, one may wish to determine k-eff of an infinite homogeneous media, a single bare fuel assembly, or a single fuel assembly reflected by water. The input data for these additional KENO cases is listed in Table 9. If any of these calculations are desired, the corresponding data should be included in the input deck as noted in Table 8. After the cross-section data has been properly processed, the control module will execute each of the KENO cases back-to-back.

The output for this sample problem has been included below. A number of pertinent comments have been written directly on the printed output. It is hoped that this approach will make the task of interpreting the output somewhat easier.

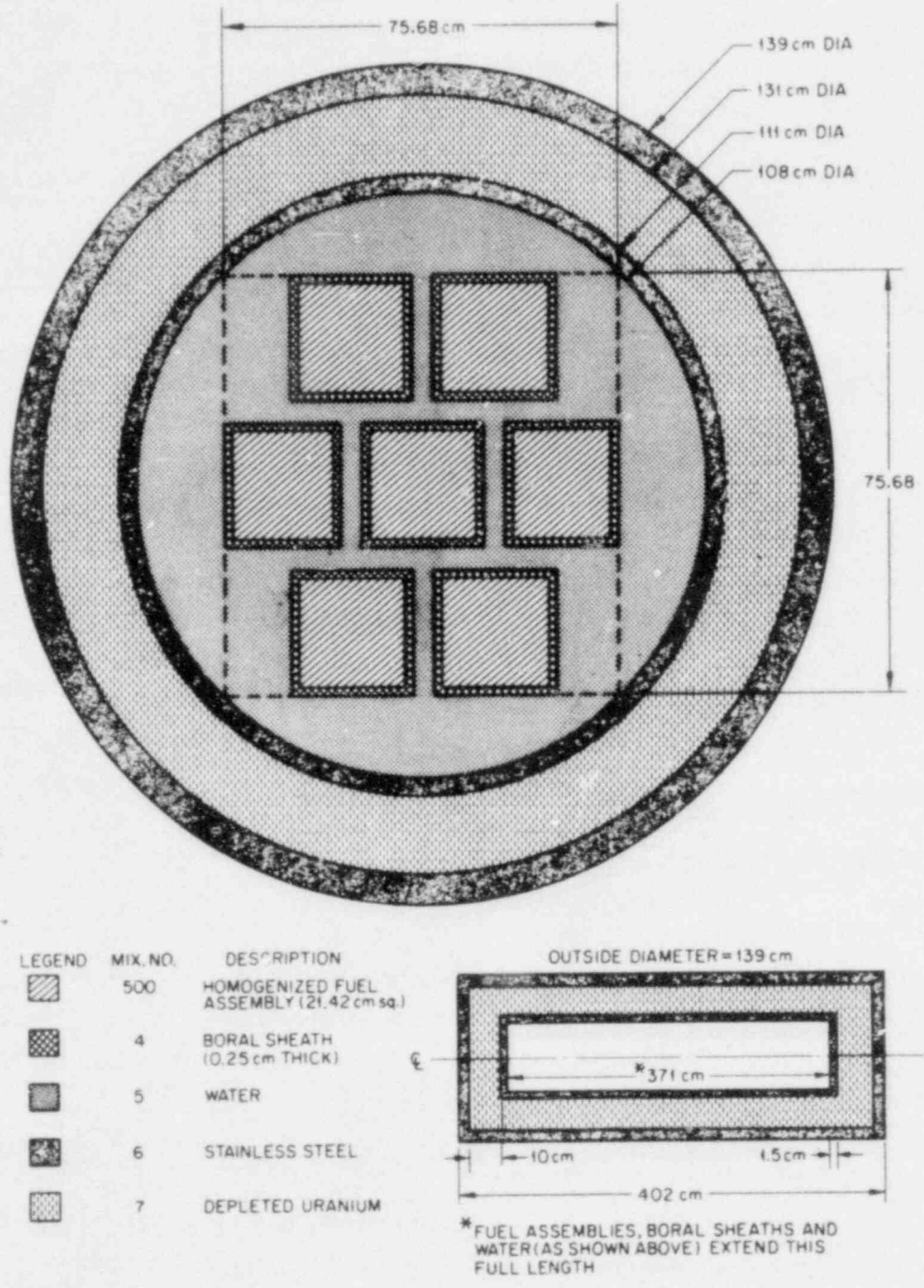


Fig. 15. Model of typical spent fuel shipping cask.

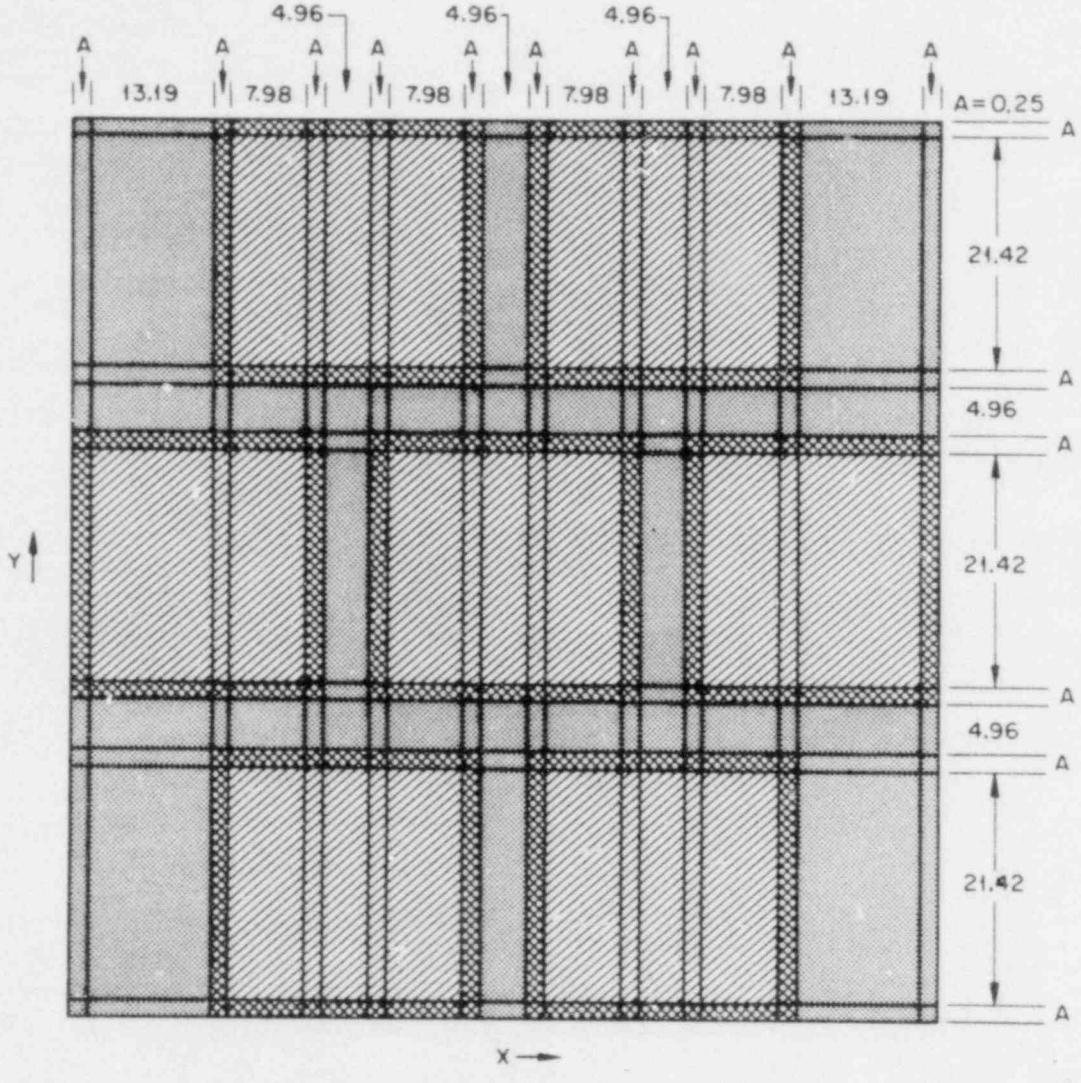


Fig. 16. KENO description of the "core" of the shipping cask. Note that there are 19 boxes in the X-direction and 11 boxes in the Y-direction. Also note that there are 19 unique "box types." All dimensions shown here are in centimeters.

Table 7. Location of Each "Box Type" in the KENO Description

This table shows the location of each of the 19 "box types" in the 19 x 11 grid defined by Fig. 16.

	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6
	13	12	8	9	10	11	10	9	8	7	8	9	10	11	10	9	8	12	13
	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6
	15	17	15	16	15	14	15	16	15	14	15	16	15	14	15	16	15	17	15
	2	18	2	3	2	1	2	3	2	4	2	3	2	1	2	3	2	18	2
Y	8	19	10	9	8	7	8	9	10	11	10	9	8	7	8	9	10	19	8
	2	18	2	3	2	1	2	3	2	4	2	3	2	1	2	3	2	18	2
	15	17	15	16	15	14	15	16	15	14	15	16	15	14	15	16	15	17	15
	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6
	13	12	8	9	10	11	10	9	8	7	8	9	10	11	10	9	8	12	13
	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	

X →

Table 8. Input for CSAS2 Sample Problem.

```
=CSAS2
SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP
27GROUPNDF4   7 8 4 LATTICECELL   0 0
UO2   1   0.95    293.       92235 3.2       92238 96.8       END
ZIRCALLOY   2   1.0   END
H2O   3   1.0   END
ARBMTL-B4C    2.64   2   1   1   0   5000   4   6012   1   4   0.015   END
ARBMTL-AL    2.64   1   0   0   0   13027   100.0   4   0.985   END
H2O      5   1.0   END
SS304   6   1.0   END
UO2     7   0.90   293.       92235 0.2       92238 99.8       END
SQUAREPITCH   1.26 0.819 1 3 0.950 2 0.836 0 END
```

Input data for additional KENO cases may be inserted here. See next page.

```
REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK  (KENO IV GEOMETRY)
 10.0    100   300   4   19   19   11   1   0
BOX TYPE   1
CUBOID   5      4.96   0.      .25            0.      370.84   0.         -0.5
BOX TYPE   2
CUBOID   4      .25   0.      .25             0.      370.84   0.         -0.5
BOX TYPE   3
CUBOID   4      7.98   0.      .25            0.      370.84   0.         -0.5
BOX TYPE   4
CUBOID   4      4.96   0.      .25            0.      370.84   0.         -0.5
BOX TYPE   5
CUBOID   5      13.19   0.      .25           0.      370.84   0.         -0.5
BOX TYPE   6
CUBOID   5      .25   0.      .25             0.      370.84   0.         -0.5
BOX TYPE   7
CUBOID   5      4.96   0.      21.42          0.      370.84   0.         -0.5
BOX TYPE   8
CUBOID   4      .25   0.      21.42           0.      370.84   0.         -0.5
BOX TYPE   9
CUBOID   500      7.98   0.      21.42        0.      370.84   0.         -0.5
BOX TYPE   10
CUBOID   500      .25   0.      21.42         0.      370.84   0.         -0.5
BOX TYPE   11
CUBOID   500      4.96   0.      21.42        0.      370.84   0.         -0.5
BOX TYPE   12
CUBOID   5      13.19   0.      21.42         0.      370.84   0.         -0.5
BOX TYPE   13
CUBOID   5      .25   0.      21.42           0.      370.84   0.         -0.5
BOX TYPE   14
CUBOID   5      4.96   0.      4.96           0.      370.84   0.         -0.5
BOX TYPE   15
CUBOID   5      .25   0.      4.96            0.      370.84   0.         -0.5
BOX TYPE   16
CUBOID   5      7.98   0.      4.96           0.      370.84   0.         -0.5
BOX TYPE   17
CUBOID   5      13.19   0.      4.96          0.      370.84   0.         -0.5
BOX TYPE   18
CUBOID   4      13.19   0.      .25           0.      370.84   0.         -0.5
BOX TYPE   19
CUBOID   500      13.19   0.      21.42       0.      370.84   0.         -0.5
ARRAY BOUNDARY   0 37.84 -37.84 37.84 -37.84 185.42 -185.42 -0.5
CYLINDER   5   54.0   185.5   -185.5          -0.5
CYLINDER   6   55.5   187.0   -187.0          -0.5
CYLINDER   7   65.5   197.0   -197.0          -0.5
CYLINDER   8   69.5   201.0   -201.0          -0.5
END GEOMETRY
      0   6   5   2   3   2   4   2   3   2   1   2   3   2   4   2   3   2   5   6
         13  12   8   9  10  11  10   9   8   7   8   9  10  11  10   9   8  12  13
          6   5   2   3   2   4   2   3   2   1   2   3   2   4   2   3   2   5   6
         15  17  15  16  15  14  15  16  15  14  15  16  15  14  15  16  15  17  15
          2  18   2   3   2   1   2   3   2   4   2   3   2   1   2   3   2  18   2
          8  19  10   9   8   7   8   9  10  11  10   9   8   7   8   9  10  19   8
          2  18   2   3   2   1   2   3   2   4   2   3   2   1   2   3   2  18   2
         15  17  15  16  15  14  15  16  15  14  15  16  15  14  15  16  15  17  15
          6   5   2   3   2   4   2   3   2   1   2   3   2   4   2   3   2   5   6
         13  12   8   9  10  11  10   9   8   7   8   9  10  11  10   9   8  12  13
          6   5   2   3   2   4   2   3   2   1   2   3   2   4   2   3   2   5   6   0
END
```

Table 9. Data for Additional KENO Cases.

```
INFINITE HOMOGENEOUS MEDIA
0.5 100 300 4 5*1
6*1
CUBE  500 1.0 0.0 -0.5
END GEOMETRY
SINGLE BARE FUEL ASSEMBLY (HOMOGENIZED)
0.5 100 300 4 4*1 0
CUBOID  500 21.42 0. 21.42 0. 370.84 0. -0.5
END GEOMETRY
SINGLE FUEL ASSEMBLY REFLECTED BY WATER
0.5 100 300 4 4*1 0
CUBOID  500 21.42 0. 21.42 0. 370.84 0. -0.5
REFLECTOR  5 6*33.0 500
END GEOMETRY
```

```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - JULY 6,1978)

MODULE CSAS2    WILL    CALLED  TIME OF DAY 12.49.08  DATE 78.245

  SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP
  27GROUPNDF4  7 8 4 LATTICECELL  0 0
  U02  1  0.95   293.      92235 3.2      92238 96.8      END
  ZIRCALLOY  2  1.0  END
  H20  3  1.0  END
  ARBMTL-B4C  2.64  2  1  1  0  5000  4  6012  1  4  0.015  END
  ARBMTL-AL  2.64  1  0  0  0  13027  100.0  4  0.985  END
  H20    5  1.0  END
  SS304  6  1.0  END
  U02    7  0.90  293.     92235 0.2      92238 99.8      END
  SQUAREPITCH  1.26 0.819 1 3 0.950 2 0.836 0 END
  INFINITE HOMOGENEOUS MEDIA
  0.5 100 300 4 5*1
  A*1
   UBE  500 1.0 0.0 -0.5
  END GEOMETRY
  SINGLE BARE FUEL ASSEMBLY (HOMOGENIZED)
  0.5 100 300 4 4*1 0
  CUBOID  500 21.42 0. 21.42 0. 370.84 0. -0.5
  END GEOMETRY
  SINGLE FUEL ASSEMBLY REFLECTED BY WATER
  0.5 100 300 4 4*1 0
  CUBOID  500 21.42 0. 21.42 0. 370.84 0. -0.5
  REFLECTOR  5 6*33.0 500
  END GEOMETRY
  REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK  (KENO-IV GEOMETRY)
  10.0   100  300  4  19  19  11  1  0
  BOX TYPE  1
  CUBOID  5    4.96  0.    .25        0.    370.84  0.      -0.5
  BOX TYPE  2
  CUBOID  4    .25  0.    .25        0.    370.84  0.      -0.5
  BOX TYPE  3
  CUBOID  4    7.98  0.    .25        0.    370.84  0.      -0.5
  BOX TYPE  4
  CUBOID  4    4.96  0.    .25        0.    370.84  0.      -0.5
  BOX TYPE  5
  CUBOID  5    13.19  0.    .25       0.    370.84  0.      -0.5
  BOX TYPE  6
  CUBOID  5    .25  0.    .25        0.    370.84  0.      -0.5
  BOX TYPE  7
  CUBOID  5    4.96  0.    21.42      0.    370.84  0.      -0.5
  BOX TYPE  8
  CUBOID  4    .25  0.    21.42      0.    370.84  0.      -0.5
  BOX TYPE  9
  CUBOID  500    7.98  0.    21.42    0.    370.84  0.      -0.5
  BOX TYPE  10
  CUBOID  500    .25  0.    21.42     0.    370.84  0.      -0.5
  BOX TYPE  11
  CUBOID  500    4.96  0.    21.42     0.    370.84  0.      -0.5
  BOX TYPE  12
  CUBOID  5    13.19  0.    21.42      0.    370.84  0.      -0.5
  BOX TYPE  13
  CUBOID  5    .25  0.    21.42        0.    370.84  0.      -0.5
  BOX TYPE  14
  CUBOID  5    4.96  0.    4.96        0.    370.84  0.      -0.5
  BOX TYPE  15
  CUBOID  5    .25  0.    4.96         0.    370.84  0.      -0.5
  BOX TYPE  16
  CUBOID  5    7.98  0.    4.96        0.    370.84  0.      -0.5
```

THE SCALE DRIVER PRINTS EVERYTHING ON THIS PAGE. ONE OR MORE CONTROL MODULES MAY BE ACCESSED MULTIPLE TIMES IN A SINGLE RUN AND THIS PAGE PROVIDES A LOG OF WHAT WAS DONE

DESCRIPTION OF THE MATERIALS USED IN THIS PROBLEM

DESCRIPTION OF THE LATTICE CELL CALCULATION USED TO SELF-SHIELD AND (IN THIS CASE) CELL-AVERAGE THE CROSS SECTION DATA.

THESE THREE "EXTRA" KENO CALCULATIONS WERE INCLUDED AT THE LAST MINUTE. DATA FOR AS MANY KENO CASES AS DESIRED MAY BE STACKED BACK-TO-BACK. NOTE THAT MIXTURE NO. 500 REPRESENTS THE HOMOGENIZED CELL-AVERAGED CROSS SECTION DATA RESULTING FROM THE XSDRNPM LATTICE-CELL CALCULATION.

NINETEEN "BOX TYPES" ARE REQUIRED TO FAITHFULLY MODEL THE FUEL ASSEMBLIES INSIDE THIS PARTICULAR SHIPPING CASK. GEOMETRY CARDS DESCRIBING EACH "BOX TYPE" FOLLOW IMMEDIATELY.

THE SCALE DRIVER AUTOMATICALLY PRINTS A COPY OF THE INPUT DECK EXACTLY AS IT WAS SUBMITTED.

```
BOX TYPE  17
CUBOID  5     13.19  0.     4.96         0.     370.84  0.       -0.5
BOX TYPE  18
CUBOID  4     13.19  0.     .25          0.     370.84  0.       -0.5
BOX TYPE  19
CUBOID  500     13.19  0.     21.42      0.     370.84  0.       -0.5
ARRAY BOUNDARY   0 37.84 -37.84 37.84 -37.84 185.42 -185.42 -0.5
CYLINDER  5   54.0   185.5   -185.5       -0.5
CYLINDER  6   55.5   187.0   -187.0       -0.5
CYLINDER  7   65.5   197.0   -197.0       -0.5
CYLINDER  8   69.5   201.0   -201.0       -0.5
END GEOMETRY
     0  6  5  2  3  2  4  2  3  2  1  2  3  2  4  2  3  2  5  6
       13 12  8  9 10 11 10  9  8  7  8  9 10 11 10  9  8 12 13
        6  5  2  3  2  4  2  3  2  1  2  3  2  4  2  3  2  5  6
       15 17 15 16 15 14 15 16 15 14 15 16 15 14 15 16 15 17 15
        2 18  2  3  2  1  2  3  2  4  2  3  2  1  2  3  2 18  2
        8 19 10  9  8  7  8  9 10 11 10  9  8  7  8  9 10 19  8
        2 18  2  3  2  1  2  3  2  4  2  3  2  1  2  3  2 18  2
       15 17 15 16 15 14 15 16 15 14 15 16 15 14 15 16 15 17 15
        6  5  2  3  2  4  2  3  2  1  2  3  2  4  2  3  2  5  6
       13 12  8  9 10 11 10  9  8  7  8  9 10 11 10  9  8 12 13
        6  5  2  3  2  4  2  3  2  1  2  3  2  4  2  3  2  5  6  0
END
```

BASIC GEOMETRY DESCRIPTION CARDS USED TO DESCRIBE THAT PORTION OF THE CASK OUTSIDE THE ARRAY BOUNDARY.

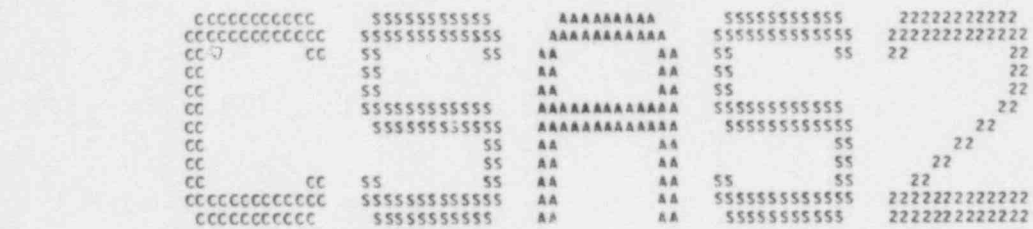
MIXED BOX ORIENTATION DATA FOR THE SHIPPING CASK PROBLEM. THIS DATA IS USED TO DESCRIBE THE LOCATION OF THE VARIOUS "BOX TYPES" WITHIN THE ARRAY.

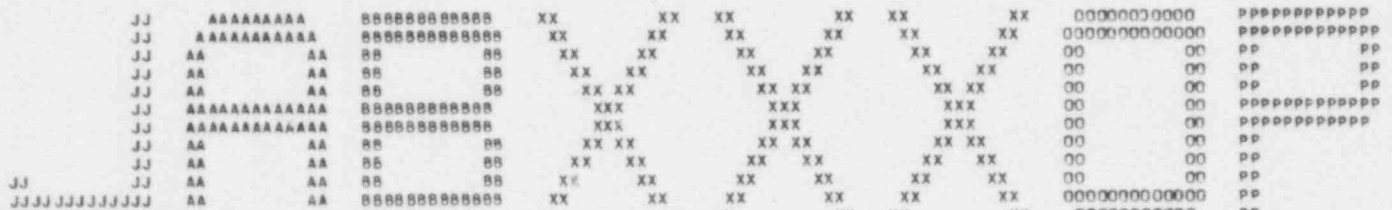
DATA FOR ADDITIONAL KENO CASES COULD BE INSERTED HERE IF DESIRED.

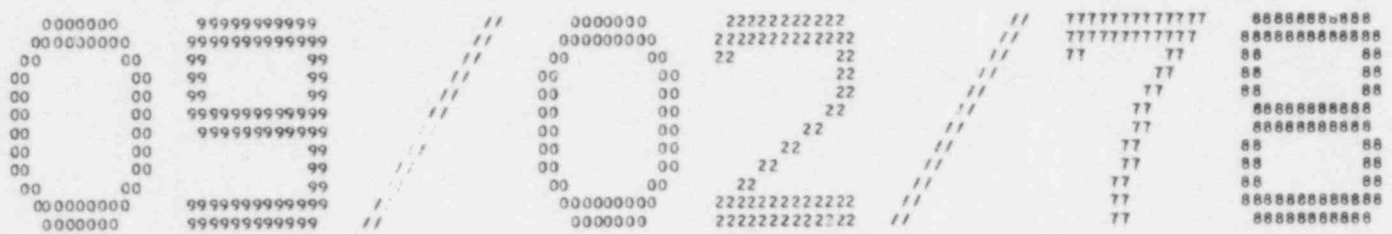
```
MODULE CSAS2    IS FINISHED.  USER COMPLETION CODE  0000.  CPU TIME USED   888.38 (SECONDS).  I/O'S USED    7367
```

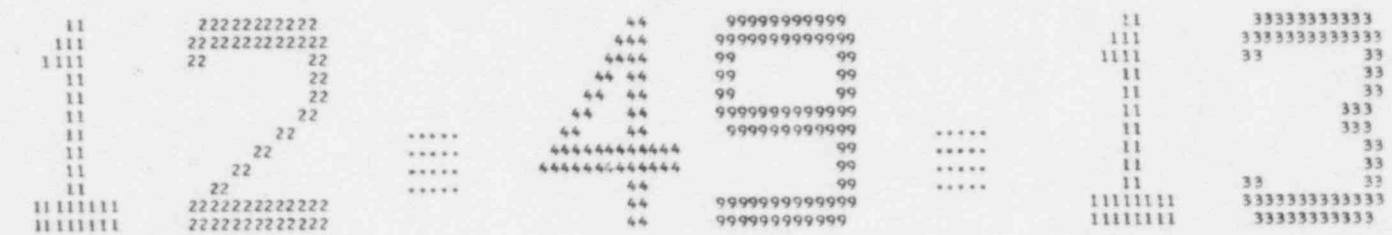
COMPLETION CODE 0000 INDICATES THAT ALL PROGRAMS CALLED BY THIS CONTROL MODULE WERE SUCCESSFULLY EXECUTED.

* THE OUTPUT SHOWN ABOVE WILL BE PRINTED BY THE DRIVER ON A UNIT CALLED SYSOUT. THE CONTROL MODULE (CSAS2) WILL PRINT ITS OUTPUT ON FT99 AND THE FUNCTIONAL MODULES (BONAMI, NITAWL, XSDRNPM, KENO-IV) WILL PRINT THEIR OUTPUT ON FT06. SUBJECT TO THE ORDER IN WHICH THESE THREE UNITS ARE PRINTED, THIS MAY OR MAY NOT BE "THE FIRST PAGE" ACTUALLY PRINTED AT ANOTHER INSTALLATION.









C1.123

```
SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP

**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX              7 MIXTURES
MSC              8 COMPOSITION SPECIFICATIONS
IZM              4 MATERIAL ZONES
GE   LATTICECELL  GEOMETRY
MORE             0 0/1 DO NOT READ/READ SPECIAL PARAMETERS
MSLN             0 FUEL SOLUTIONS

**** PROBLEM COMPOSITION DESCRIPTION ****

SC   UO2           STANDARD COMPOSITION
MX               1 MIXTURE NO.
V"          0.9500 VOLUME FRACTION
TEMP         293.0 DEG KELVIN
             92235  3.20%
             92238 96.80%        WT%
END

SC   ZIRCALLOY     STANDARD COMPOSITION
MX               2 MIXTURE NO.
VF          1.0000 VOLUME FRACTION
END

SC   H2O           STANDARD COMPOSITION
MX               3 MIXTURE NO.
VF          1.0000 VOLUME FRACTION
END

SC   ARBMTL-B4C    STANDARD COMPOSITION
MX               4 MIXTURE NO.
VF          0.0150 VOLUME FRACTION
ROTH        2.6400 DENSITY
NEL              2 NO. ELEMENTS
IVIS             1 0/1 NO VARIABLE ISOTOPE/VARIABLE ISOTOPE
ICP              1 0/1 MIXTURE/COMPOUND
IRS              0 0/1 NO RESONANCE MTL./RESONANCE MTL.

              5000   4.00
              6012   1.00
END

SC   ARBMTL-AL     STANDARD COMPOSITION
MX               4 MIXTURE NO.
VF          0.9850 VOLUME FRACTION
ROTH        2.6400 DENSITY
NEL              1 NO. ELEMENTS
IVIS             0 0/1 NO VARIABLE ISOTOPE/VARIABLE ISOTOPE
ICP              0 0/1 MIXTURE/COMPOUND
IRS              0 0/1 NO RESONANCE MTL./RESONANCE MTL.

             13027 100.00
END

SC   H2O           STANDARD COMPOSITION
MX               5 MIXTURE NO.
VF          1.0000 VOLUME FRACTION
```

INPUT SUPPLIED BY THE USER, AS "INTERPRETED" BY THE CONTROL MODULE.

NOTE THAT MIXTURE NO. 4 HAS A DENSITY OF 2.64 GM/CC AND IS 1.5 WT% B_4C AND 98.5 WT% AL. THIS PARTICULAR BORAL MIXTURE WAS CONVENTIENTLY DESCRIBED USING TWO STANDARD COMPOSITION SPECIFICATION CARDS.

NOTE THAT MIXTURE NO. 5 IS THE SAME AS MIXTURE NO. 3. TWO OR MORE MIXTURES HAVING IDENTICAL SPECIFICATIONS SHOULD BE DEFINED WHENEVER ONE IS INSIDE THE LATTICE CELL AND THE OTHERS ARE NOT.

```
END

SC  SS304          STANDARD COMPOSITION
MX                6 MIXTURE NO.
VF          1.0000 VOLUME FRACTION
END

SC  UO2            STANDARD COMPOSITION
MX                7 MIXTURE NO.
VF          0.9000 VOLUME FRACTION
TEMP         293.0 DEG KELVIN
             92235  0.20%
             92238 99.80%
END

**** PROBLEM GEOMETRY ****

CTP SQUAREPITCH  CELL TYPE
PITCH       1.2600 CM CENTER TO CENTER SPACING
FUELOD      0.8190 CM FUEL ROD DIAMETER OR SLAB THICKNESS
MFUEL             1 MIXTURE NO. OF FUEL
MMOD              3 MIXTURE NO. OF MODERATOR
CLADOD      0.9500 CM CLAD OUTER DIAMETER
MCLAD             2 MIXTURE NO. OF CLAD
GAPOD       0.8360 CM GAP OUTER DIAMETER
MGAP              0 MIXTURE NO. OF GAP
END

**** XSDRN MESH INTERVALS ****

   6 MESH INTERVALS IN ZONE  1
   4 MESH INTERVALS IN ZONE  2
   4 MESH INTERVALS IN ZONE  3
  14 MESH INTERVALS IN ZONE  4
```

wt%

THIS DATA WILL BE USED FOR THE RESONANCE SELF-SHIELDING CALCULATION IN NITAWL AND FOR THE SPATIAL SELF-SHIELDING (I.E. THE CELL-AVERAGING) CALCULATION IN XSDRNPM.

THESE MESH INTERVALS ARE AUTOMATICALLY DETERMINED BY THE CONTROL MODULE AND PRINTED HERE FOR YOUR INSPECTION AND APPROVAL. THE SIZE OF THE SPATIAL MESH INTERVALS MAY BE INCREASED OR DECREASED USING THE SZF PARAMETER (I.E., ONE OF THE OPTIONAL CONTROL PARAMETERS).

IF MIXTURE No. 500 (REPRESENTING THE HOMOGENIZED, CELL-AVERAGED CROSS SECTION DATA FOR THE LATTICE CELL) IS NOT USED ANYWHERE IN THE 3-D KENO DESCRIPTION OF THE PROBLEM, THE XSDRNPM CALCULATION FOR THE LATTICE CELL WILL BE BYPASSED. NEVERTHELESS, THE CONTROL MODULE WILL STILL ALLOCATE STORAGE FOR THIS MANY MESH INTERVALS EVEN THOUGH THEY'RE NEVER USED. IF MIXTURE No. 500 IS NOT USED ANYWHERE IN THE 3-D KENO INPUT, THE USER MAY WISH TO SET SZF=100.

```
KENO INFORMATION PROCESSOR CALLED
**********************************
PARAMETER CARD WILL BE READ NEXT
PARAMETER CARD SUCCESSFULLY READ
BOUNDARY CONDX. WILL BE READ NEXT
BOUNDARY CONDX. SUCCESSFULLY READ
GEOMETRY DATA WILL BE READ NEXT
GEOMETRY DATA SUCCESSFULLY READ
**********************************
PARAMETER CARD WILL BE READ NEXT
PARAMETER CARD SUCCESSFULLY READ
GEOMETRY DATA WILL BE READ NEXT
GEOMETRY DATA SUCCESSFULLY READ
**********************************
PARAMETER CARD WILL BE READ NEXT
PARAMETER CARD SUCCESSFULLY READ
GEOMETRY DATA WILL BE READ NEXT
GEOMETRY DATA SUCCESSFULLY READ
**********************************
PARAMETER CARD WILL BE READ NEXT
PARAMETER CARD SUCCESSFULLY READ
GEOMETRY DATA WILL BE READ NEXT
GEOMETRY DATA SUCCESSFULLY READ
MIXED BOX DATA WILL BE READ NEXT
MIXED BOX DATA SUCCESSFULLY RE
**********************************

A DETAILED DESCRIPTION OF THE GEOMETRY
DATA FOR EA H KENO CASE IS GIVEN BELOW.

NUMBER OF KENO CASES ENTERED = 4
```

THIS BLOCK OF OUTPUT IS ALSO PRODUCED BY THE CSAS2 CONTROL MODULE. AT THIS POINT IT HAS BEGUN CHECKING THE 3-D KENO INPUT.

IF THE OUTPUT WERE TO MYSTERIOUSLY STOP AT THIS POINT, FOR EXAMPLE, IT WOULD INDICATE A GROSS ERROR IN THE GEOMETRY DATA FOR THE FOURTH KENO CASE. ANY ERROR MESSAGES PRINTED AT THIS POINT WOULD HAVE BEEN GENERATED BY SUBROUTINE KIP.

IF THE PROGRAM MAKES IT THIS FAR, THERE WERE NO "GROSS" ERRORS IN THE KENO INPUT. THE CONTROL MODULE WILL NOW BEGIN CHECKING THE INPUT CORRESPONDING TO EACH KENO CASE FOR ERRORS OF A MORE SUBTLE NATURE. SEVERAL DOZEN TYPES OF CHECKS WILL BE MADE. IF AN ERROR SHOULD BE FOUND, A DESCRIPTIVE DIAGNOSTIC WILL BE PRINTED.

INFINITE HOMOGENEOUS MEDIA

THE PARAMETERS FOR THIS PROBLEM ARE

NUMBER OF ENERGY GROUPS	27
NUMBER OF MIXTURES	8
NUMBER OF GEOMETRY CARDS	1
NUMBER OF BOX TYPES	1
NUMBER OF UNITS IN X DIRECTION	1
NUMBER OF UNITS IN Y DIRECTION	1
NUMBER OF UNITS IN Z DIRECTION	1

THE DATA FOR THIS KENO CASE WILL NOW BE CHECKED.

FOR BREVITY, THE NEXT 4 PAGES OF OUTPUT HAVE NOT BEEN INCLUDED HERE.

SINGLE BARS FUEL ASSEMBLY (HOMOGENIZED)

THE PARAMETERS FOR THIS PROBLEM ARE

NUMBER OF ENERGY GROUPS	27
NUMBER OF MIXTURES	8
NUMBER OF GEOMETRY CARDS	1
NUMBER OF BOX TYPES	1
NUMBER OF UNITS IN X DIRECTION	1
NUMBER OF UNITS IN Y DIRECTION	1
NUMBER OF UNITS IN Z DIRECTION	1

THE DATA FOR THIS KENO CASE WILL NOW BE CHECKED.

FOR BREVITY, THE NEXT [illegible] PAGES OF OUTPUT HAVE NOT BEEN INCLUDED HERE

SINGLE FUEL ASSEMBLY REFLECTED BY WATER

THE PARAMETERS FOR THIS PROBLEM ARE

NUMBER OF ENERGY GROUPS	27
NUMBER OF MIXTURES	8
NUMBER OF GEOMETRY CARDS	13
NUMBER OF BOX TYPES	1
NUMBER OF UNITS IN X DIRECTION	1
NUMBER OF UNITS IN Y DIRECTION	1
NUMBER OF UNITS IN Z DIRECTION	1

THE DATA FOR THIS KENO CASE WILL NOW BE CHECKED.

FOR BREVITY, THE NEXT 9 PAGES OF OUTPUT HAVE NOT BEEN INCLUDED HERE.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

THE DATA FOR THIS KENO CASE WILL NOW BE CHECKED.

THE PARAMETERS FOR THIS PROBLEM ARE

NUMBER OF ENERGY GROUPS	27
NUMBER OF MIXTURES	8
NUMBER OF GEOMETRY CARDS	24
NUMBER OF BOX TYPES	19
NUMBER OF UNITS IN X DIRECTION	19
NUMBER OF UNITS IN Y DIRECTION	11
NUMBER OF UNITS IN Z DIRECTION	1

WHILE THE USER DEFINED 7 MIXTURES, MIXTURE NO. 500 IS THE 8TH. INDEED, THE CONTROL MODULE INTERNALLY SUBSTITUTES MIXTURE NO. 8 EVERYWHERE THE USER ENTERED MIXTURE NO. 500. THIS SUBSTITUTION WILL BE NOTED IN THE KENO MIXING TABLE (SHOWN BELOW) AND IN THE EDIT OF THE GEOMETRY DATA (ALSO SHOWN BELOW). HAD THE USER DEFINED N MIXTURES, MIXTURE NO. 500 WOULD BECOME NUMBER N + 1.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-'V GEOMETRY)

KENO MIXING TABLE -----

1	-92235	7.523545E-04
8	-92235	2.496543E-04
7	-2	4.455683E-05
1	92238	2.247093E-02
8	92238	7.456549E-03
7	4	2.194902E-02
1	8016	4.644658E-02
8	8016	1.541241E-02
3	6	3.337968E-02
8	6	1.847651E-02
5	7	3.337968E-02
7	8	4.398715E-02
2	40302	4.251811E-02
8	40302	4.282616E-03
3	1001	6.675929E-02
8	1001	3.695298E-02
5	11	6.675929E-02
4	5010	3.227338E-04
4	5011	1.393936E-03
4	6012	4.291674E-04
4	13027	5.804319E-02
6	24304	1.742489E-02
6	25055	1.736442E-03
6	26304	5.535605E-02
6	28304	7.720906E-03

* NMAT=19 MATT= 8 NMIX=25

* THESE NO. DENSITIES ARE CALCULATED BY THE CONTROL MODULE. THIS TABLE, WHICH IS OFTEN VERY USEFUL, IS USUALLY PRINTED IN THE FIRST 2 OR 3 SECONDS OF EXECUTION.

* OCCASIONALLY, ONE MAY WISH TO RUN A SHORT "DUMMY CASE" JUST TO OBTAIN THIS TABLE AND THEN RESUBMIT A LONGER JOB WITH AN ADDITIONAL NUCLIDE HAVING A CONCENTRATION BASED ON ONE OR MORE OF THESE. FOR EXAMPLE: ONE MAY WISH TO INCLUDE SO MANY "PARTS PER MILLION" BORON IN THE WATER.

THE NEGATIVE NUCLIDE I.D. NUMBERS FLAG THE PRIMARY FISSILE ISOTOPE IN THE GIVEN MIXTURE. THE FISSION SPECTRUM FOR THAT PARTICULAR NUCLIDE WILL BE USED BY KENO IN EACH OF THE RESPECTIVE MIXTURES.

NUCLIDE NUMBER 8016, 6, 7, AND 8 ALL REPRESENT OXYGEN IN EACH OF SEVERAL DIFFERENT MIXTURES. LIKEWISE NUCLIDE 1001 AND 11 BOTH REPRESENT HYDROGEN IN EACH OF TWO DIFFERENT MIXTURES. (IN THE CASE OF MIXTURE NO. 8, THE TOTAL OXYGEN CONTENT EQUALS THE NO. DENSITY FOR NUCLIDE #8016 PLUS THE NO. DENSITY FOR NUCLIDE #6).

AS NOTED PREVIOUSLY, MIXTURE NO. 8 NOW REPRESENTS THE HOMOGENIZED CELL-AVERAGED CROSS-SECTION DATA FOR THE LATTICE-CELL.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

GEOMETRY DESCRIPTION

HERE, THE CONTROL MODULE SCANS THE GEOMETRY DATA AND CHECKS FOR SYNTAX ERRORS, THE IMPROPER USE OF THE ARRAY BOUNDARY CARD, ETC. ANY ERROR MESSAGES PRINTED AT THIS POINT WOULD HAVE BEEN GENERATED BY SUBROUTINE KENOG. USERS ARE ENCOURAGED TO CHECK THIS EDIT AND VERIFY THAT ALL DATA IS CORRECT.

BOX TYPE 1

REGION

1 CUBOID 5 +X = 4.9600E 00 -X = 0.0 +Y = 2.5000E-01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 2

REGION

1 CUBOID 4 +X = 2.5000E-01 -X = 0.0 +Y = 2.5000E-01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 3

REGION

1 CUBOID 4 +X = 7.9800E 00 -X = 0.0 +Y = 2.5000E-01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 4

REGION

1 CUBOID 4 +X = 4.9600E 00 -X = 0.0 +Y = 2.5000E-01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 5

REGION

1 CUBOID 5 +X = 1.3190E 01 -X = 0.0 +Y = 2.5000E-01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 6

REGION

1 CUBOID 5 +X = 2.5000E-01 -X = 0.0 +Y = 2.5000E-01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 7

REGION

1 CUBOID 5 +X = 4.9600E 00 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 8

REGION

1 CUBOID 4 +X = 2.5000E-01 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 9

REGION

1 CUBOID 8 +X = 7.9800E 00 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 10

REGION

1 CUBOID 8 +X = 2.5000E-01 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 11

REGION

1 CUBOID 8 +X = 4.9600E 00 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 12

REGION

1 CUBOID 5 +X = 1.3190E 01 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 13

REGION

1 CUBOID 5 +X = 2.5000E-01 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 14

REGION

1 CUBOID 5 +X = 4.9600E 00 -X = 0.0 +Y = 4.9600E 00 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 15

REGION

1 CUBOID 5 +X = 2.5000E-01 -X = 0.0 +Y = 4.9600E 00 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 16

REGION

```
  1 CUBOID      5      +X = 7.9800E 00   -X = 0.0          +Y = 4.9600E 00   -Y = 0.0          +Z = 3.7084E 02   -Z = 0.0

BOX TYPE  17
REGION
  1 CUBOID      5      +X = 1.3190E 01   -X = 0.0          +Y = 4.9600E 00   -Y = 0.0          +Z = 3.7084E 02   -Z = 0.0

BOX TYPE  18
REGION
  1 CUBOID      4      +X = 1.3190E 01   -X = 0.0          +Y = 2.5000E-01   -Y = 0.0          +Z = 3.7084E 02   -Z = 0.0

BOX TYPE  19
REGION
  1 CUBOID      8      +X = 1.3190E 01   -X = 0.0          +Y = 2.1420E 01   -Y = 0.0          +Z = 3.7084E 02   -Z = 0.0

REFLECTOR
REGION
  1 CORE        0      +X = 3.7840E 01   -X =-3.7840E 01   +Y = 3.7840E 01   -Y =-3.7840E 01   +Z = 1.8542E 02   -Z =-1.8542E 02
  2 CYLINDER    5  RADIUS = 5.4000E 01   +Z = 1.8550E 02   -Z =-1.8550E 02
  3 CYLINDER    6  RADIUS = 5.5500E 01   +Z = 1.8700E 02   -Z =-1.8700E 02
  4 CYLINDER    7  RADIUS = 6.5500E 01   +Z = 1.9700E 02   -Z =-1.9700E 02
  5 CYLINDER    6  RADIUS = 6.9500E 01   +Z = 2.0100E 02   -Z =-2.0100E 02
```

MIXTURE No. 8 NOW REPRESENTS THE HOMOGENIZED CELL-AVERAGED DATA FOR THE LATTICE CELL (PREVIOUSLY CALLED MIXTURE No. 500).

THE CORE REGION NOW CORRESPONDS TO THAT REGION INSIDE THE ARRAY BOUNDARY.

BELOW, THESE ARE REFERRED TO AS GEOMETRY CARDS #20-24.

BELOW, THIS IS REFERRED TO AS GEOMETRY CARD #19. NOTE THAT GEOMETRY CARD 19 DOESN'T ALWAYS HAVE TO BE IN BOX TYPE #19. THAT WAS THE CASE HERE ONLY BECAUSE WE HAD ONE REGION PER BOX.

THESE GEOMETRY CARDS DESCRIBE THE REGION(S) OUTSIDE THE ARRAY BOUNDARY. BECAUSE THEY WERE DESCRIBED EXPLICITLY BY THE USER, THESE GEOMETRY CARDS SHOULD CORRESPOND TO THE USER'S INPUT. IN SOME OTHER PROBLEM WHERE ONE USES THE AUTOMATIC REFLECTOR CARD, THE CODE WILL AUTOMATICALLY GENERATE AND PRINT OUT A NUMBER OF CUBOID CARDS NOT FOUND IN THE USER'S DECK. THE CODE WILL ALSO SUPPLY APPROPRIATE MULTIGROUP WEIGHTS FOR THESE "EXTRA" GEOMETRY REGIONS.

IN THIS PARTICULAR CASE, THE FOUR REGIONS OUTSIDE THE ARRAY BOUNDARY CORRESPOND TO THE WATER INSIDE THE CASK, THE INNER STEEL LINER, THE DEPLETED UO_2 SHIELD, AND THE OUTER STEEL SHELL OF THE CASK.

```
REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK  (KENO-IV GEOMETRY)

WEIGHTING FUNCTION

BOX TYPE   1                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD   1
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE   2                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD   2
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE   3                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD   3
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE   4                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD   4
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE   5                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD   5
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE   6                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD   6
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE   7                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD   7
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE   8                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD   8
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE   9                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD   9
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  10                                        GROUP   WTLOW    WT AVG    WT HI
        REGION   1 DEFINED BY GEOMETRY CARD  10
                                                      1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE
```

WHILE SCANNING THE GEOMETRY DATA, THE CONTROL MODULE ALSO PRINTS THIS EDIT OF THE SPATIALLY DEPENDENT MULTIGROUP WEIGHTS FOR EACH REGION.

DATA LISTED UNDER WT AVG WAS SUPPLIED BY THE USER OR GENERATED INTERNALLY USING THE AUTOMATIC REFLECTOR CARD.

USERS ARE ENCOURAGED TO CHECK THIS EDIT AND VERIFY THAT ALL DATA IS CORRECT.

THERE MAY BE ONE OR MORE REGIONS INSIDE ANY GIVEN BOX. FOR MORE THAN ONE REGION, THE USER WOULD NEED MORE THAN ONE BASIC GEOMETRY DESCRIPTION CARD. FOR THIS PARTICULAR PROBLEM, A SIMPLE CUBOID ADEQUATELY DESCRIBED EACH BOX TYPE.

```
BOX TYPE  11                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  11

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  12                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  12

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  13                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  13

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  14                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  14

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  15                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  15

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  16                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  16

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  17                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  17

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  18                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  18

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  19                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  19

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

REFLECTOR

        REGION   1 DEFINED BY GEOMETRY CARD  20

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

        REGION   2 DEFINED BY GEOMETRY CARD  21

                                                     1     0.167     0.500     1.500
                                                  GROUPS 2 TO   27 SAME AS ABOVE

        REGION   3 DEFINED BY GEOMETRY CARD  22
```

```
                                        1      0.167      0.500      1.500
                                   GROUPS 2 TO   27 SAME AS ABOVE

 REGION    4 DEFINED BY GEOMETRY CARD  23
                                        1      0.167      0.500      1.500
                                   GROUPS 2 TO   27 SAME AS ABOVE

 REGION    5 DEFINED BY GEOMETRY CARD  24
                                        1      0.167      0.500      1.500
                                   GROUPS 2 TO   27 SAME AS ABOVE
```

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

ARRAY DESCRIPTION

Z = 1

J=11:	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6
J=10:	13	12	8	5	10	11	10	9	8	7	8	9	10	11	10	9	8	12	13
J=9:	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6
J=8:	15	17	15	16	15	14	15	16	15	14	15	16	15	14	15	16	15	17	15
J=7:	2	18	2	3	2	1	2	3	2	4	2	3	2	1	2	3	2	18	2
J=6:	8	19	10	9	8	7	8	9	10	11	10	9	8	7	8	9	10	19	8
J=5:	2	18	2	3	2	1	2	3	2	4	2	3	2	1	2	3	2	18	2
J=4:	15	17	15	16	15	14	15	16	15	14	15	16	15	14	15	16	15	17	15
J=3:	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6
J=2:	13	12	8	5	10	11	10	9	8	7	8	9	10	11	10	9	8	12	13
J=1:	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6

I=1 I=3 I=5 I=7 I=9 I=11 I=13 I=15 I=17 I=19

THIS EDIT SHOWS THE "BOX TYPE" THAT WAS ULTIMATELY PRESCRIBED FOR EACH LOCATION (I, J, K) IN THE ARRAY.

THE USER IS STRONGLY ENCOURAGED TO CHECK THIS EDIT AND VERIFY THAT THE DATA WAS CORRECTLY ENTERED--ESPECIALLY IF HE DID NOT USE THE POINT-BY-POINT INPUT SCHEME FOR THE MIXED BOX ORIENTATION DATA.

THE CONTROL MODULE WILL CHECK THE MIXED BOX ORIENTATION DATA FOR VARIOUS TYPES OF INCONSISTENCIES. IT WILL VERIFY THAT ADJACENT FACES OF ADJACENT BOXES ARE THE SAME SIZE AND THAT THE OVERALL DIMENSIONS OF THE ARRAY DO CORRESPOND TO THOSE SHOWN ON THE ARRAY BOUNDARY CARD. ANY ERROR MESSAGES PRINTED AT THIS POINT WOULD HAVE BEEN GENERATED BY SUBROUTINES BOX, FIXBOX, AND CORSIZ.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

THE CONTROL MODULE NOW CAREFULLY CHECKS THE GEOMETRY DATA INSIDE EACH "BOX TYPE". ANY ERROR MESSAGE PRINTED AT THIS POINT WOULD HAVE BEEN GENERATED BY SUBROUTINES JOPCHK OR VOLUME

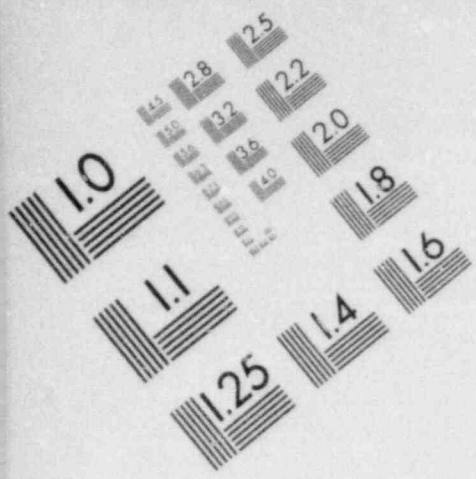
VOLUMES

BOX TYPE 1	REGION DEFINED BY GEOMETRY CARD	1	VOLUME = 4.59841E 02 CM**3	CUMULATIVE VOLUME =	4.59841E 02 CM**3
BOX TYPE 2	REGION DEFINED BY GEOMETRY CARD	2	VOLUME = 2.31775E 01 CM**3	CUMULATIVE VOLUME =	2.31775E 01 CM**3
BOX TYPE 3	REGION DEFINED BY GEOMETRY CARD	3	VOLUME = 7.39825E 02 CM**3	CUMULATIVE VOLUME =	7.39825E 02 CM**3
BOX TYPE 4	REGION DEFINED BY GEOMETRY CARD	4	VOLUME = 4.59841E 02 CM**3	CUMULATIVE VOLUME =	4.59841E 02 CM**3
BOX TYPE 5	REGION DEFINED BY GEOMETRY CARD	5	VOLUME = 1.22284E 03 CM**3	CUMULATIVE VOLUME =	1.22284E 03 CM**3
BOX TYPE 6	REGION DEFINED BY GEOMETRY CARD	6	VOLUME = 2.31775E 01 CM**3	CUMULATIVE VOLUME =	2.31775E 01 CM**3
BOX TYPE 7	REGION DEFINED BY GEOMETRY CARD	7	VOLUME = 3.93992E 04 CM**3	CUMULATIVE VOLUME =	3.93992E 04 CM**3
BOX TYPE 8	REGION DEFINED BY GEOMETRY CARD	8	VOLUME = 1.98585E 03 CM**3	CUMULATIVE VOLUME =	1.98585E 03 CM**3
BOX TYPE 9	REGION DEFINED BY GEOMETRY CARD	9	VOLUME = 6.33882E 04 CM**3	CUMULATIVE VOLUME =	6.33882E 04 CM**3
BOX TYPE 10	REGION DEFINED BY GEOMETRY CARD	10	VOLUME = 1.98585E 03 CM**3	CUMULATIVE VOLUME =	1.98585E 03 CM**3
BOX TYPE 11	REGION DEFINED BY GEOMETRY CARD	11	VOLUME = 3.93992E 04 CM**3	CUMULATIVE VOLUME =	3.93992E 04 CM**3
BOX TYPE 12	REGION DEFINED BY GEOMETRY CARD	12	VOLUME = 1.04773E 05 CM**3	CUMULATIVE VOLUME =	1.04773E 05 CM**3
BOX TYPE 13	REGION DEFINED BY GEOMETRY CARD	13	VOLUME = 1.98585E 03 CM**3	CUMULATIVE VOLUME =	1.98585E 03 CM**3
BOX TYPE 14	REGION DEFINED BY GEOMETRY CARD	14	VOLUME = 9.12324E 03 CM**3	CUMULATIVE VOLUME =	9.12324E 03 CM**3
BOX TYPE 15	REGION DEFINED BY GEOMETRY CARD	15	VOLUME = 4.59841E 02 CM**3	CUMULATIVE VOLUME =	4.59841E 02 CM**3
BOX TYPE 16	REGION DEFINED BY GEOMETRY CARD	16	VOLUME = 1.46781E 04 CM**3	CUMULATIVE VOLUME =	1.46781E 04 CM**3
BOX TYPE 17	REGION DEFINED BY GEOMETRY CARD	17	VOLUME = 2.42612E 04 CM**3	CUMULATIVE VOLUME =	2.42612E 04 CM**3
BOX TYPE 18	REGION DEFINED BY GEOMETRY CARD	18	VOLUME = 1.22284E 03 CM**3	CUMULATIVE VOLUME =	1.22284E 03 CM**3
BOX TYPE 19	REGION DEFINED BY GEOMETRY CARD	19	VOLUME = 1.04773E 05 CM**3	CUMULATIVE VOLUME =	1.04773E 05 CM**3
REFLECTOR VOLUMES - GEOMETRY CARD 20 IS THE CORE BOUNDARY CARD	REGION DEFINED BY GEOMETRY CARD	21	VOLUME = 1.27472E 06 CM**3	CUMULATIVE VOLUME =	3.39869E 06 CM**3

ACTUAL VOLUME OF A GIVEN REGION INSIDE A PARTICULAR BOX TYPE

VOLUME OF A GIVEN REGION PLUS THAT OF ALL PREVIOUS REGIONS INSIDE THE PARTICULAR BOX

VOLUME OF ARRAY =(3.39869E+06)-(1.27472E+06)



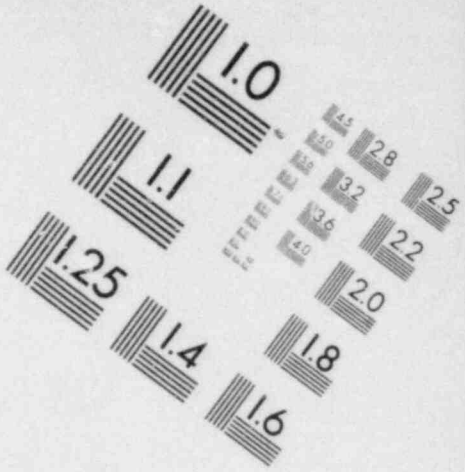
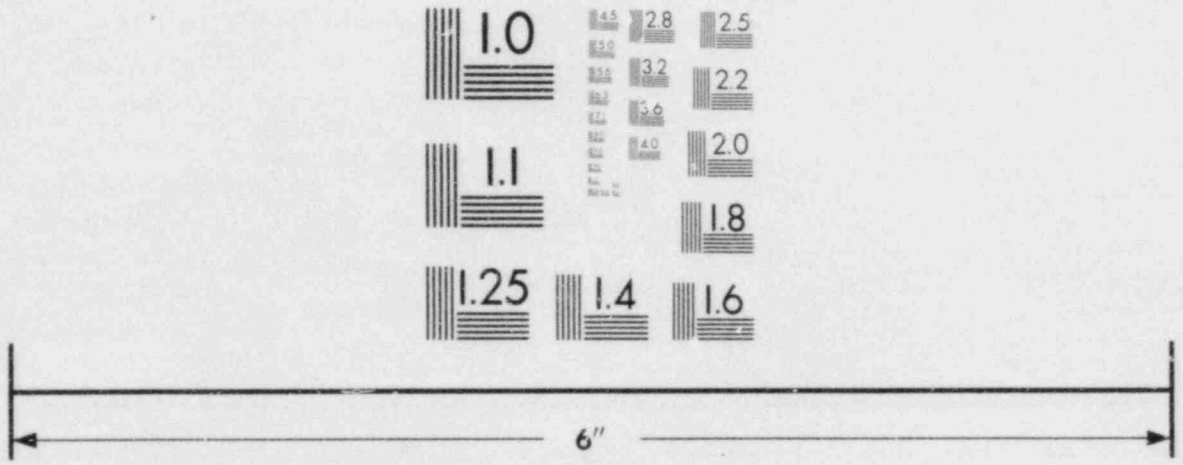
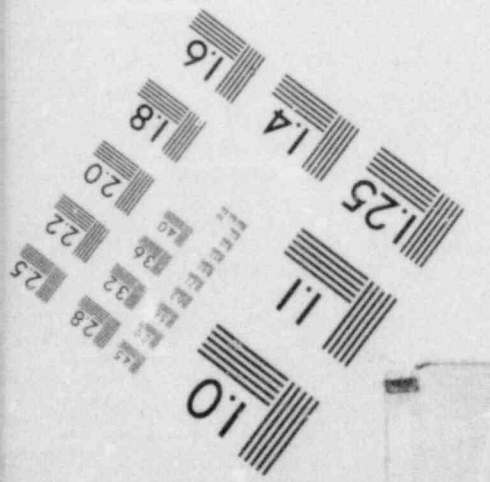
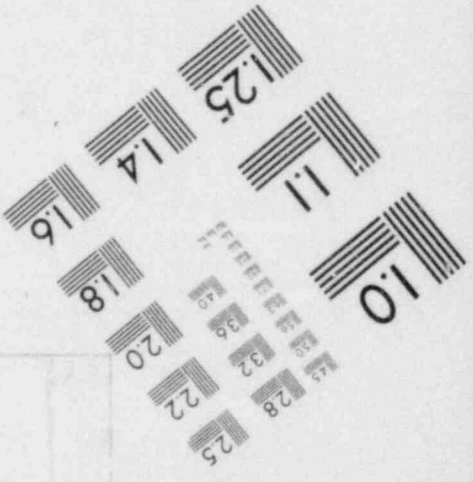


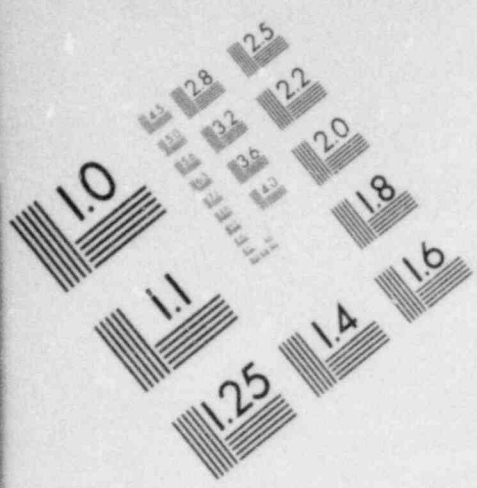
IMAGE EVALUATION
TEST TARGET (MT-3)



MICROCOPY RESOLUTION TEST CHART







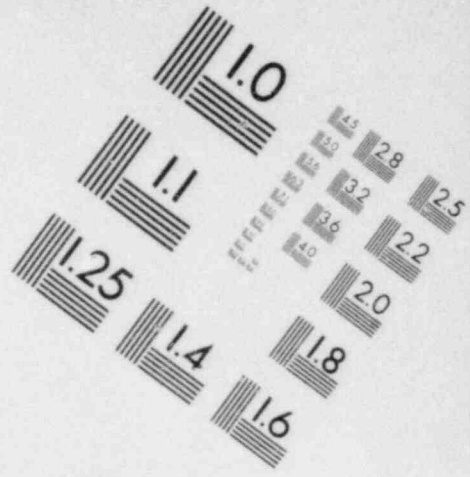
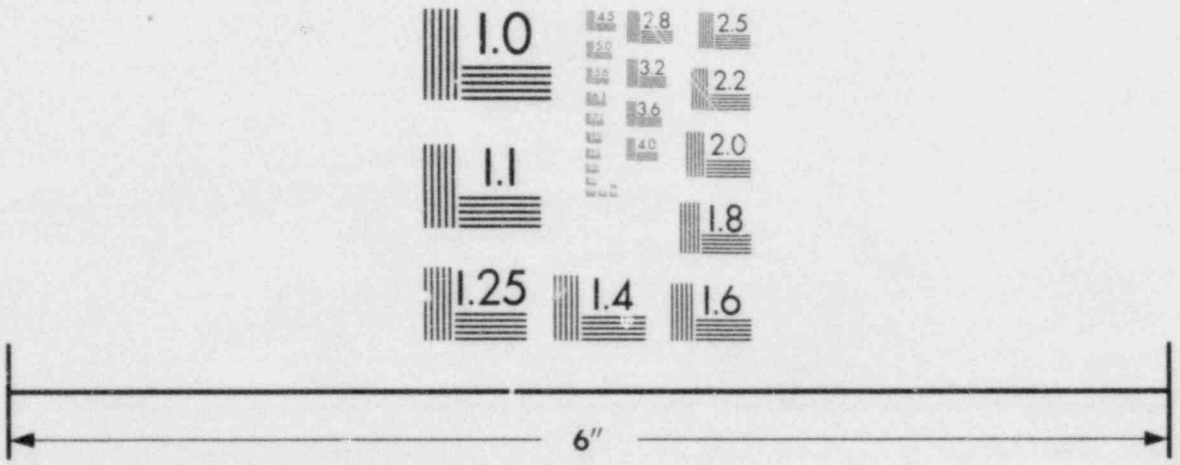
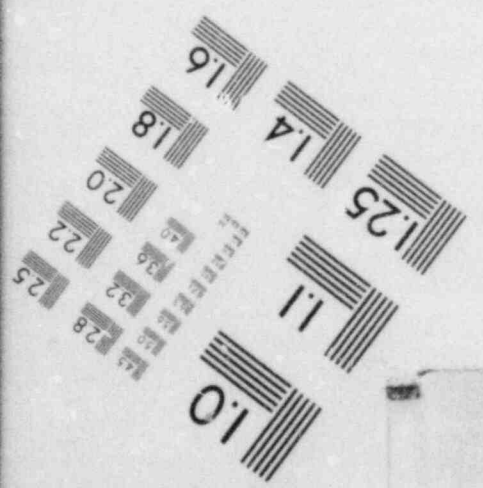
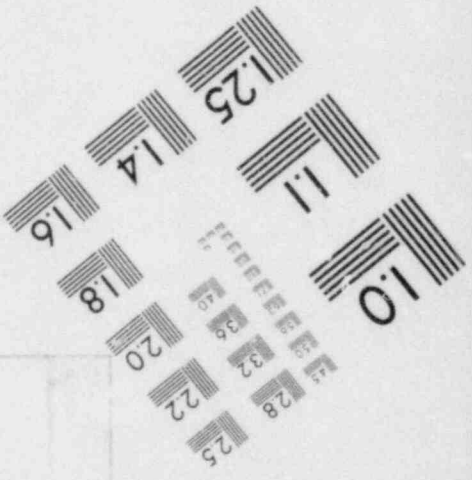


IMAGE EVALUATION
TEST TARGET (MT-3)



MICROCOPY RESOLUTION TEST CHART





```
          REGION DEFINED BY GEOMETRY CARD     22   VOLUME =     2.20469E 05 CM**3        CUMULATIVE VOLUME =     3.61916E 06 CM**3
          REGION DEFINED BY GEOMETRY CARD     23   VOLUME =     1.69126E 06 CM**3        CUMULATIVE VOLUME =     5.31042E 06 CM**3
          REGION DEFINED BY GEOMETRY CARD     24   VOLUME =     7.49802E 05 CM**3        CUMULATIVE VOLUME =     6.10022E 06 CM**3

TOTAL VOLUMES
   1        3.67873E 03
   2        1.20523E 03
   3        1.77558E 04
   4        4.59841E 03
   5        9.78275E 03
   6        1.85420E 02
   7        1.41491E 05
   8        2.78018E 04
   9        7.60658E 05
  10        2.38301E 04
  11        1.96996E 05
  12        4.19093E 05
  13        7.94338E 03
  14        5.47395E 04
  15        9.19681E 03
  16        1.17425E 05
  17        5.70448E 04
  18        4.89138E 03
  19        2.09546E 05

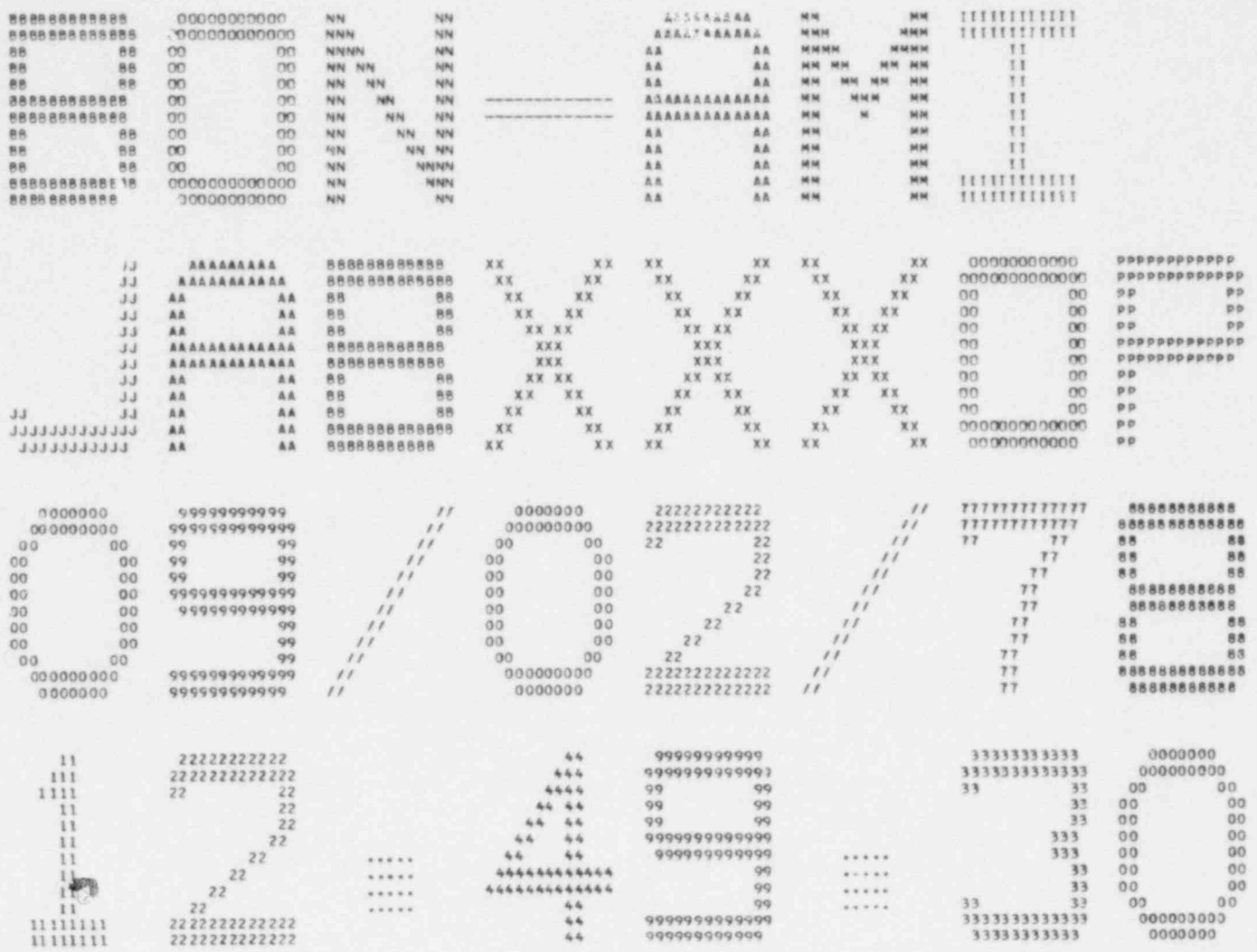
MODULE C S2     MADE     4 SUCCESSFUL ACCESSES.
```

(TOTAL VOLUME OF REGION 7 INSIDE THE ARRAY) = (VOLUME OF REGION 7 INSIDE BOX TYPE M) X (NO. OF TIMES BOX TYPE M IS FOUND IN THE ARRAY)

NOTE: "REGION 7" IS ALWAYS "DEFINED BY GEOMETRY CARD 7." IN THIS PARTICULAR CASE IT IS FOUND IN BOX TYPE 7 BECAUSE WE HAD ONLY ONE REGION PER BOX. IN GENERAL, ONE MAY HAVE TWO OR MORE REGIONS IN A GIVEN BOX.

MEANS THAT CSAS2 CALLED AND SUCCESSFULLY EXECUTED BONAMI, NITAWL, XSDRNPM AND KENO-IV.

HAD WE NOT USED THE HOMOGENIZED CELL-AVERAGED CROSS SECTION DATA TO REPRESENT THE FUEL ASSEMBLY (I.E., HAD WE NOT USED MIXTURE No. 500 IN THE 3-D KENO INPUT), THE CONTROL MODULE WOULD HAVE CALLED BONAMI, NITAWL, AND KENO-IV. HOPEFULLY IT WOULD THEN HAVE MADE 3 SUCCESSFUL ACCESSES INSTEAD OF 4.



LOGICAL ASSIGNMENTS

MASTER LIBRARY 82
WORKING LIBRARY 0
SCRATCH FILE 18
NEW LIBRARY 1

P R O B L E M D E S C R I P T I O N

IGM--GEOMETRY (0/1/2/3--INF MED/SLAB/CYL/SPHERE 2

IZM--NUMBER OF ZONES OR MATERIAL REGIONS 8

MS--MIXING TABLE LENGTH 20

IBL--LEFT BOUNDARY CONDITION (0/1--VAC/REFL) 1

IBR--RIGHT BOUNDARY CONDITION (0/1--VAC/REFL) 1

ISSOPT--CELL DESCRIPTION FOR DANCOFF CORRECTION 0

CONVERGENCE CRITERION 1.00000E-03

WIGNER CONSTANT 1.35000E 00

3Q ARRAY HAS 20 ENTRIES.

4Q ARRAY HAS 20 ENTRIES.

5Q ARRAY HAS 20 ENTRIES.

6Q ARRAY HAS 8 ENTRIES.

7Q ARRAY HAS 8 ENTRIES.

8Q ARRAY HAS 8 ENTRIES.

9Q ARRAY HAS 8 ENTRIES.

10Q ARRAY HAS 20 ENTRIES.

11Q ARRAY HAS 8 ENTRIES.

INPUT DATA FOR BONAMI AS READ OFF THE BINARY INPUT TAPE PREPARED BY THE CONTROL MODULE

M I X I N G T A B L E

ENTRY	MIXTURE	ISOTOPE	NUMBER DENSITY	NEW IDENTIFIER
1	1	92235	7.52355E-04	92235
2	7	92235	4.45568E-05	2
3	1	92238	2.24709E-02	92238
4	7	92238	2.19490E-02	4
5	1	8016	4.64466E-02	8016
6	3	8016	3.33797E-02	6
7	5	8016	3.33797E-02	7
8	7	8016	4.39871E-02	8
9	2	40302	4.25181E-02	40302
10	3	1001	6.67593E-02	1001
11	5	1001	6.67593E-02	11
12	4	5010	3.22734E-04	5010
13	4	5011	1.39394E-03	5011
14	4	6012	4.29167E-04	6012
15	4	13027	5.80432E-02	13027
16	6	24304	1.74249E-02	24304
17	6	25055	1.73644E-03	25055

THESE NO. DENSITIES ARE CALCULATED BY THE CONTROL MODULE AND PASSED ON TO BONAMI. WHILE THIS TABLE IS OFTEN VERY USEFUL, THE PROGRAM WILL NOT GET THIS FAR IF THE USER HAPPENED TO MAKE ANY SORT OF ERROR IN HIS KENO INPUT. FOR THAT REASON, THE USER IS REFERRED TO THE MORE LENGTHY MIXING TABLE PRINTED DIRECTLY BY THE CONTROL MODULE AS IT CHECKS AND EDITS THE KENO DATA. (ABOVE)

18	6	26304	5.93560E-02	26304
19	A	28304	7.72081E-03	28304
20	(8)	28304	1.00000E-20	20

← IF THE USER DEFINED N MIXTURES (7 IN THIS CASE), THE BONAMI INPUT MAY SHOW MIXTURE N+1 AS A "DUMMY MIXTURE." IT DOES NOT CORRESPOND TO MIXTURE NO. 8 IN THE KENO EDIT.

GEOMETRY AND MATERIAL DESCRIPTION

ZONE	MIXTURE	OUTER DIMENSION	TEMPERATURE	EXTRA XS	TYPE (0/1--FUEL/MOD)
1	1	4.0[illegible]E-01	2.93000E 02	1.21831E 00	0
2	8	4.186[illegible]E-01	2.93000E 02	0.0	0
3	2	4.75000E-01	2.93000E 02	5.03554E 00	0
4	3	7.10878E-01	2.93000E 02	0.0	0
5	4	5.71088E 00	2.93000E 02	0.0	0
6	5	1.07109E 01	2.93000E 02	0.0	0
7	6	1.57109E 01	2.93000E 02	0.0	0
8	7	2.07109E 01	2.93000E 02	0.0	0

NOTE: SINCE NONE OF THE NUCLIDES ON THE 27GROUP[illegible] LIBRARY HAVE F-FACTOR DATA, A DONDARENKO SELF-SHIELDING CALCULATION WAS NOT PERFORMED. IN THIS CASE, BONAMI IS SIMPLY USED TO COPY THE MASTER CROSS SECTION LIBRARY FROM ONE LOGICAL UNIT TO ANOTHER FOR USE IN NITAWL.

TAPE ID 4321 NUMBER OF NUCLIDES 87
NUMBER OF NEUTRON GROUPS 27 NUMBER OF GAMMA GROUPS 0
FIRST THERMAL GROUP 15

TABLE OF CONTENTS

HERE BONAMI IS COPYING THE MASTER CROSS SECTION LIBRARY FROM ONE LOGICAL UNIT TO ANOTHER FOR USE IN NITAWL.

NITAWL WILL THEN SELF-SHIELD THOSE NUCLIDES HAVING RESONANCE DATA AND PRODUCE A MUCH SMALLER WORKING LIBRARY.

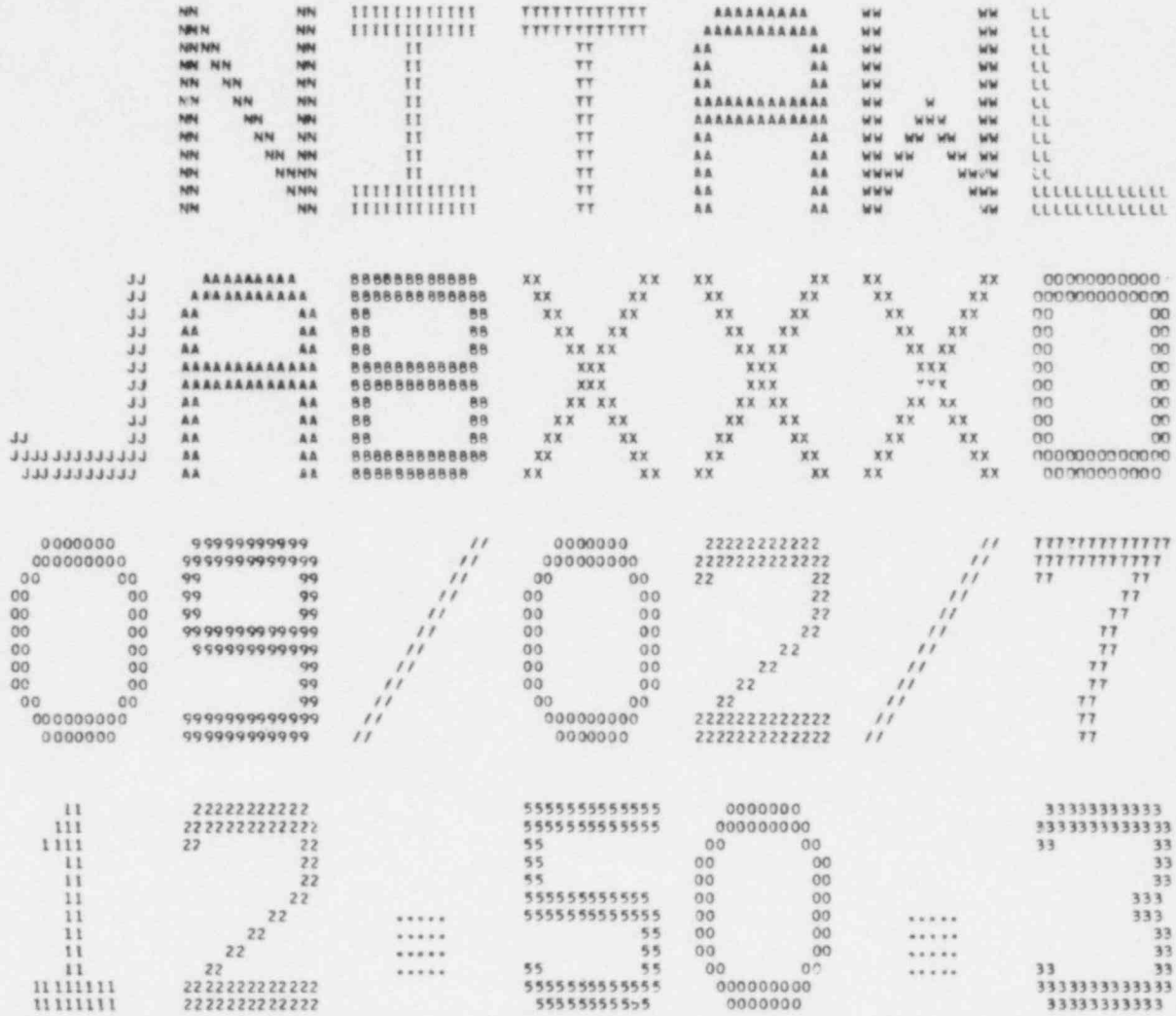
ALL THE NUCLIDES SHOWN HERE WILL BE AVAILABLE ON THE MASTER LIBRARY PASSED TO NITAWL.

NOTE THAT NUCLIDES #6, 7, AND 8 REPRESENT OXYGEN IN MIXTURES No. 3, 5, AND 7 WHEREAS NUCLIDE #8016 REPRESENTS OXYGEN IN MIXTURE No. 1. SEPARATE SETS OF CROSS SECTION DATA FOR THESE "NEW NUCLIDES" WILL ALSO BE AVAILABLE ON THE MASTER LIBRARY PASSED TO NITAWL. (SEPARATE SETS OF DATA WILL ALSO BE AVAILABLE FOR NUCLIDES No. 2, 4, 11 AND 20).

```
BA-138 7040 218NGP WT 1/EST 042375 P3 293K                          ID     56138
GD (1030) SIGP=5+4 NEWXLACS 293K 9-20-77 1/E WT.                    ID     64000
DY-164 1031 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     66164
LU-175 1032 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     71175
LU-176 1033 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     71176
HF(NAT) 1034 218NGP WT 1/S P-3 SIGP=5+4 293K RF(042375)             ID     72000
TA-181 1285 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     73181
W-182  1128 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     74182
W-183  1129 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     74183
W-184  1130 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     74184
W-186  1131 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     74186
RE-185 1083 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     75185
RE-187 1084 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     75187
AU-197 1283 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     79197
PB   1288 218NGP 042375 P-3 293K                                    ID     82000
TH-232 1296 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     90232
PA-233 1297 218 GP WT F-1/E-M 090376 P3 293K                        ID     91233
U-233  1260 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     92233
U-234 1043 SIGD=5+4 NEWXLACS P-3 293K F-1/E-M(1.+5)                 ID     92234
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)                     ID     92235
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(7)                     ID          2
U-236 1163 SIGD=5+4 NEWXLACS P-3 293K F-1/E-M(1.+5)                 ID     92236
U-238 1262 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)                     ID     92238
U-238 1262 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)                     ID          4
NP-237 1263 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     93237
PU-238 1050 SIGD=5+4 NEWXLACS P-3 293K F-1/E-M(1.+5)                ID     94238
PU-239 1264 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     94239
PU-240 1265 SIGP=5+4 NEWXLACS 218NGP P-3 273K                       ID     94240
PU-241 1266 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     94241
PU-242 1161 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     94242
AM-241 1056 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     95241
AM-243 1057 218 GP WT F-1/E-M 090376 P3 293K                        ID     95243
CM-244 1162 SIGP=5+4 NEWXLACS 218NGP P-3 293K                       ID     96244

  TAPE COPY USED    937 I/O'S, AND TOOK    4.07 SECONDS

ELAPSED TIME   0.27 MIN.
```



OQ ARRAY HAS 9 ENTRIES.

1Q ARRAY HAS 12 ENTRIES.

MSCM	NOT USED	0
MMT	NUMBER OF NUCLIDES FROM MASTER LIBRARY	19
MWT	NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LOG 2)	0
MXT	NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LOG 3)	0
MCR	OUTPUT SENSITIVITY TAPE 0/1 - NO/YES	0
MXX	NOT USED	0
MS	NOT USED	0
IRES	NUMBER OF RESONANCE CALCULATIONS	6
IQM	NOT USED	0
IPM	NOT USED	0
IPP	OUTPUT OPTION TRIGGER	-1
IFG	NOT USED	0

INPUT DATA FOR NITAWL AS READ OFF THE BINARY INPUT TAPE PREPARED BY THE CONTROL MODULE

THE STORAGE ALLOCATED FOR THIS C .. IS 94208 WORDS

2Q ARRAY HAS 19 ENTRIES.

3Q ARRAY HAS 90 ENTRIES.

4Q ARRAY HAS 19 ENTRIES.

GENERAL INFORMATION CONCERNING CROSS SECTION LIBRARY

TAPE IDENTIFICATION NUMBER	4321
NUMBER OF NUCLIDES ON TAPE	87
NUMBER OF NEUTRON ENERGY GROUPS	27
FIRST THERMAL NEUTRON ENERGY GROUP	15
NUMBER OF GAMMA ENERGY GROUPS	0

DIRECT ACCESS UNIT NUMBER 9 REQUIRES 146 BLOCKS OF LENGTH 484 WORDS

SDRN TAPE 4321

NUCLIDES FROM XSDRN TAPE

1	H 1269 F, 1002 T 218 GP 032475(2)	1001
2	H 1269 F, 1002 T 218 GP 032475(2)	11
3	B-10 1273 218NGP 042375 P-3 293K	5010
4	B-11 1160 WT 1/EST 218NGP P-3 293K RE(042375)	5011
5	C-12 1274F,1065T 218 GP 030476(7)	6012
6	O-16 1276 218 GP 030476(7)	8016
7	O-16 1276 218 GP 030476(7)	6
8	O-16 1276 218 GP 030476(7)	7
9	O-16 1276 218 GP 030476(7)	8
10	AL-27 1193 218 GP 040375(5)	13027
11	CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'	24304
12	MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K	25055
13	FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'	26304
14	NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'	28304
15	ZR-2(1284) SIGP=5+4 NEWXLACS 293K 9-20-77 I/E WT.	40302
16	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	92235
17	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	2
18	U-238 1262 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	92238

```
H 1269 F. 1002 T 218 GP 032475(2)                                    1001    TEMPERATURE=   293.00
                        THERMAL SCATTERING MATRIX NUMBER   1 AT A TEMPERATURE OF   293.00 WAS SELECTED.

H 1269 F. 1002 T 218 GP 032475(2)                                      11    TEMPERATURE=   293.00
                        THERMAL SCATTERING MATRIX NUMBER   1 AT A TEMPERATURE OF   293.00 WAS SELECTED.

B-10 1273 218NGP 042375 P-3 293K                                     5010    TEMPERATURE=   293.00
                        THERMAL SCATTERING MATRIX NUMBER   1 AT A TEMPERATURE OF   293.00 WAS SELECTED.

B-11 1160 WT 1/EST 218NGP P-3 293K RE(042375)                        5011    TEMPERATURE=   293.00
                        THERMAL SCATTERING MATRIX NUMBER   1 AT A TEMPERATURE OF   293.00 WAS SELECTED.

C-12 1274F,1065T 218 GP 030476(7)                                    6012    TEMPERATURE=   293.00
                        THERMAL SCATTERING MATRIX NUMBER   1 AT A TEMPERATURE OF   293.00 WAS SELECTED.

O-16 1276 218 GP 030476(7)                                           8016    TEMPERATURE=   293.00

O-16 1276 218 GP 030476(7)                                              6    TEMPERATURE=   293.00

O-16 1276 218 GP 030476(7)                                              7    TEMPERATURE=   293.00

O-16 1276 218 GP 030476(7)                                              8    TEMPERATURE=   293.00

AL-27 1195 218 GP 040375(5)                                         13027    TEMPERATURE=   293.00

CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'                    24304    TEMPERATURE=   293.00

MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K                        25055    TEMPERATURE=   293.00

 GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS   0.0

 RESONANCE DATA FOR THIS NUCLIDE

 MASS NUMBER (A)        =    54.466          TEMPERATURE(KELVIN)     =   293.000
 POTENTIAL SCATTER SIGMA=     2.590          LUMPED NUCLEAR DENSITY  = 0.1736442E-02
 SPIN FACTOR (G)        =    14.448          LUMP DIMENSION (A-BAR)  = 0.0
 SIGMA-M(EFFECTIVE)     = 0.5078032E 03      DANCOFF CORRECTION (C)  = 0.0
 THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.
 MASS OF MODERATOR-1    =    55.850          SIGMA(PER ABSORBER ATOM)= 0.3896812E 03
 MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.
 MASS OF MODERATOR-2    =    58.690          SIGMA(PER ABSORBER ATOM)= 0.7736621E 02
 MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.
 THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.
 VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

 GROUP        RES ABS          RES FISS         RES SCAT
   8      1.067007E-02      0.0             6.954503E 00
   9      2.032253E-02      0.0             1.791673E 01
  10      4.270282E-01      0.0             9.538618E 01
  11      2.232624E 00      0.0             9.449124E 01

 EXCESS RESONANCE INTEGRALS
                  RESOLVED       UNRESOLVED          TOTAL
```

I.E. TREATED AS INFINITE HOMOGENEOUS MEDIA SINCE MIXTURE NO. 6 WAS NOT IN THE LATTICE CELL

THE Mn^{55} FOUND IN THE STAINLESS STEEL PORTIONS OF THE SHIPPING CASK IS A RESONANCE NUCLIDE.

THE 27GROUPNDF4 LIBRARY DOES CONTAIN LEVEL WIDTHS AND OTHER RESONANCE DATA FOR Mn^{55}. THE CROSS-SECTION DATA FOR THIS NUCLIDE WILL BE SELF-SHIELDED BY NITAWL USING THE NORDHEIM INTEGRAL METHOD.

SINCE THE STAINLESS STEEL CONTAINING THE Mn^{55} IS NOT PART OF THE LATTICE CELL, IT WILL BE TREATED AS AN INFINITE HOMOGENEOUS MEDIA IN THE RESONANCE SELF-SHIELDING CALC.

```
ABSORPTION        0.11260E 01   0.0           0.11260E 01
FISSION           0.0           0.0           0.0

  ELAPSED TIME   0.11 MIN.

FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(423751)'                    26304    TEMPERATURE=  293.00

NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(423751)'                    28304    TEMPERATURE=  293.00

ZR-2 1284) SIGP=5+4 NEWXLACS 293K 9-20-77 1/E WT.                    40302    TEMPERATURE=  293.00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)        =    90.436          TEMPERATURE(KELVIN)     =   293.000

POTENTIAL SCATTER SIGMA=     6.385          LUMPED NUCLEAR DENSITY  = 0.4251811E-01

SPIN FACTOR (G)        =     1.236 USED TO CALCULATE ESCAPE PROBABILITY  LUMP DIMENSION (A-BAR)  = 0.5699998E-01

SIGMA-M(EFFECTIVE)     = 0.2125106E 03          DANCOFF CORRECTION (C)  = 0.2926325E 00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 1-DIMENSIONAL OBJECT. I.E. TREATED AS INFINITE SHEET RATHER THAN HOLLOW CYLINDRICAL TUBING

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP        RES ABS          RES FISS        RES SCAT
  8       3.100896E-03     0.0             1.639970E 00
  9       9.592324E-02     0.0             1.972286E 00
 10       1.463274E-01     0.0             9.866779E-01
 11       2.576579E-01     0.0             2.490104E-01

EXCESS RESONANCE INTEGRALS

                 RESOLVED        UNRESOLVED          TOTAL

ABSORPTION       0.85914E 00     0.0             0.85914E 00
FISSION          0.0             0.0             0.0

  ELAPSED TIME   0.31 MIN.

U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)                      92235    TEMPERATURE=  293.00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)        =   233.025          TEMPERATURE(KELVIN)     =   293.000

POTENTIAL SCATTER SIGMA=    11.500          LUMPED NUCLEAR DENSITY  = 0.7523545E-03

SPIN FACTOR (G)        = 15171.172 USED TO CALCULATE ESCAPE PROBABILITY  LUMP DIMENSION (A-BAR)  = 0.4094999E 00

SIGMA-M(EFFECTIVE)     = 0.2112813E 04          DANCOFF CORRECTION (C)  = 0.2569973E 00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1    =    15.994 OXYGEN IN THE UO2          SIGMA(PER ABSORBER ATOM)= 0.2315061E 03

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2    =   238.125 U238 IN THE UO2           SIGMA(PER ABSORBER ATOM)= 0.2479000E 03

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.
```

RESONANCE SELF-SHIELDING CALCULATION FOR THE ZR FOUND IN THE CLAD

NOTE THAT A NON-ZERO ESCAPE PROBABILITY WILL BE USED FOR THE CLAD SINCE IT IS A COMPONENT OF THE LATTICE CELL.

RESONANCE SELF-SHIELDING CALCULATION FOR THE U^{235} IN THE FUEL PIN

```
THIS RE. .ANCE MAT (IAL WILL BE TREATED AS A 2-DIMENSIONAL OBJECT.
VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP        RES ABS          RES FISS         RES SCAT
 12       5.023253E 01     3.331773E 01     7.694799E-01
 13       7.054924E 01     4.013507E 01     9.154034E-01
 14       5.492482E 01     3.150560E 01    -7.074153E-02
 15       2.219584E 00     1.640677E 00    -1.065593E-01
 16       3.583099E-02     3.035408E-02    -4.467450E-03

EXCESS RESONANCE INTEGRALS

                 RESOLVED        UNRESOLVED          TOTAL

ABSORPTION       0.20257E 03     0.0              0.20257E 03
FISSION          0.12141E 03     0.0              0.12141E 03

  ELAPSED TIME   0.64 MIN.

U-235 1261 SIGP=5+4 NEWXLACS 218NGP 9-3 293K(3                    2      TEMPERATURE=   293.00

GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS   0.0

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)          =   233.025          TEMPERATURE(KELVIN)      =   293.000

POTENTIAL SCATTER SIGMA=    11.500            LUMPED NUCLEAR DENSITY   = 0.4455683E-04

SPIN FACTOR (G)          = 15171.172          LUMP DIMENSION (A-BAR)   = 0.0

SIGMA-M(EFFECTIVE)       = 0.7801191E 04      DANCOFF CORRECTION (C)   = 0.0

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1      =    15.994          SIGMA(PER ABSORBER ATOM)= 0.3702054E 04

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2      =   238.125          SIGMA(PER ABSORBER ATOM)= 0.4088638E 04

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.
VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP        RES ABS          RES FISS         RES SCAT
 12       5.191139E 01     3.432713E 01     8.364310E-01
 13       7.595088E 01     4.296509E 01     1.122274E 00
 14       6.496239E 01     3.805876E 01     6.802690E-02
 15       2.460058E 00     1.820542E 00    -1.124660E-01
 16       4.038153E-02     3.077363E-02    -4.528701E-03

EXCESS RESONANCE INTEGRALS

                 RESOLVED        UNRESOLVED          TOTAL

ABSORPTION       0.19503E 03     0.0              0.19503E 03
FISSION          0.11595E 03     0.0              0.11595E 03

  ELAPSED TIME   0.94 MIN.
```

I.E. THE FUEL WILL BE TREATED AS A FINITE CIRCULAR CYLINDER

DESCRIPTION OF NUCLIDE

NUCLIDE I.D. NUMBER

OXYGEN IN THE UO_2

U^{238} IN THE UO_2

I.E. TREATED AS AN INFINITE HOMOGENEOUS MEDIA SINCE MIXTURE 7 WAS NOT IN THE LATTICE CELL

NOTE THAT A NON-ZERO ESCAPE PROBABILITY WILL BE USED FOR THE FUEL SINCE IT IS A COMPONENT OF THE LATTICE CELL.

RESONANCE SELF-SHIELDING CALCULATION FOR THE U^{235} IN MIXTURE 7--THE DEPLETED URANIUM SHIELD.

SINCE THE DEPLETED URANIUM SHIELD IS NOT PART OF THE LATTICE CELL, IT WILL BE TREATED AS AN INFINITE HOMOGENEOUS MEDIA IN THE RESONANCE SELF-SHIELDING CALCULATION.

U-238 1262 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3) 92238 TEMPERATURE= 293.00

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A) = 236.006 TEMPERATURE(KELVIN) = 293.000

POTENTIAL SCATTER SIGMA= 10.599 LUMPED NUCLEAR DENSITY = 0.2247093E-01

SPIN FACTOR (G) = 656.527 (USED TO CALCULATE ESCAPE PROBABILITY) LUMP DIMENSION (A-BAR) = 0.4094999E 00

SIGMA-M(EFFECTIVE) = 0.7073956E 02 DANCOFF CORRECTION (C) = 0.2569973E 00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1 = 15.994 (OXYGEN IN THE UO_2) SIGMA(PER ABSORBER ATOM)= 0.7751109E 01

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2 = 235.11 (U^{235} IN THE UO_2) SIGMA(PER ABSORBER ATOM)= 0.3515528E 00

MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 2-DIMENSIONAL OBJECT (I.E. THE FUEL WILL BE TREATED AS A FINITE CIRCULAR CYLINDER)

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP	RES ABS	RES FISS	RES SCAT
9	9.535164E-0	0.0	4.760277E-01
10	8.982153E-01	2.895517E-04	2.541608E 00
11	1.748782E 00	0.0	3.113667E 00
12	3.237837E 00	0.0	2.452176E 00
13	3.C16409E 00	0.0	5.717494E-01
14	6.181414E 00	0.0	3.791194E-02

EXCESS RESONANCE INTEGRALS

	RESOLVED	UNRESOLVED	TOTAL
ABSORPTION	0.17981E 02	0.0	0.17981E 02
FISSION	0.49119E-03	0.0	0.49119E-03

ELAPSED TIME 1.38 MIN.

RESONANCE SELF-SHIELDING CALCULATION FOR THE U^{238} IN THE FUEL PIN

NOTE THAT A NON-ZERO ESCAPE PROBABILITY WILL BE USED FOR THE FUEL SINCE IT IS A COMPONENT OF THE LATTICE CELL.

U-238 12 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3) ← DESCRIPTION OF NUCLIDE TEMPERATURE= 293.00

GEOMETRY HAS BEEN SET TO HOMOGENEOUS AS LBAR IS 0.0

NUCLIDE I.D. NUMBER

RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A) = 236.006 TEMPERATURE(KELVIN) = 293.000

POTENTIAL SCATTER SIGMA= 10.599 LUMPED NUCLEAR DENSITY = 0.2194902E-01

SPIN FACTOR (G) = 656.527 LUMP DIMENSION (A-BAR) = 0.0

SIGMA-M(EFFECTIVE) = 0.1583654E 02 DANCOFF CORRECTION (C) = 0.0

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1 = 15.994 (OXYGEN IN THE UO_2) SIGMA(PER ABSORBER ATOM)= 0.7515225E 01

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-2 = 235.11 (U^{235} IN THE UO_2) SIGMA(PER ABSORBER ATOM)= 0.2131515E-01

RESONANCE SELF-SHIELDING CALCULATION FOR THE U^{238} IN MIXTURE 7--THE DEPLETED URANIUM SHIELD

```
MODERATOR-2 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 0-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

GROUP        RES ABS          RES FISS         RES SCAT
  9       6.317377E-02     0.0              1.656010E-01
 10       5.155309E-01     2.383229E-04     4.928886E-01
 11       9.174617E-01     0.0              1.233217E 00
 12       1.378881E 00     0.0              1.431486E 00
 13       1.694891E 00     0.0              1.141171E 00
 14       3.436260E 00     0.0              1.680072E 00

EXCESS RESONANCE    EGRALS

                  RESOLVED        UNRESOLVED          TOTAL

ABSORPTION        0.55630E 01     0.0             0.55630E 01
FISSION           0.40267E-03     0.0             0.40267E-03

  ELAPSED TIME   1.79 MIN.

  ELAPSED TIME   1.80 MIN.
```

I.E. TREATED AS AN INFINITE HOMOGENEOUS MEDIA SINCE MIXTURE 7 WAS NOT IN THE LATTICE-CELL

SINCE THE DEPLETED URANIUM SHIELD IS NOT PART OF THE LATTICE-CELL, IT WILL BE TREATED AS AN INFINITE HOMOGENEOUS MEDIA.

THIS XSDRN WORKING TAPE WAS CREATED 09/02/78 AT 12.50.39
THE TITLE OF THE PARENT CASE IS AS FOLLOWS

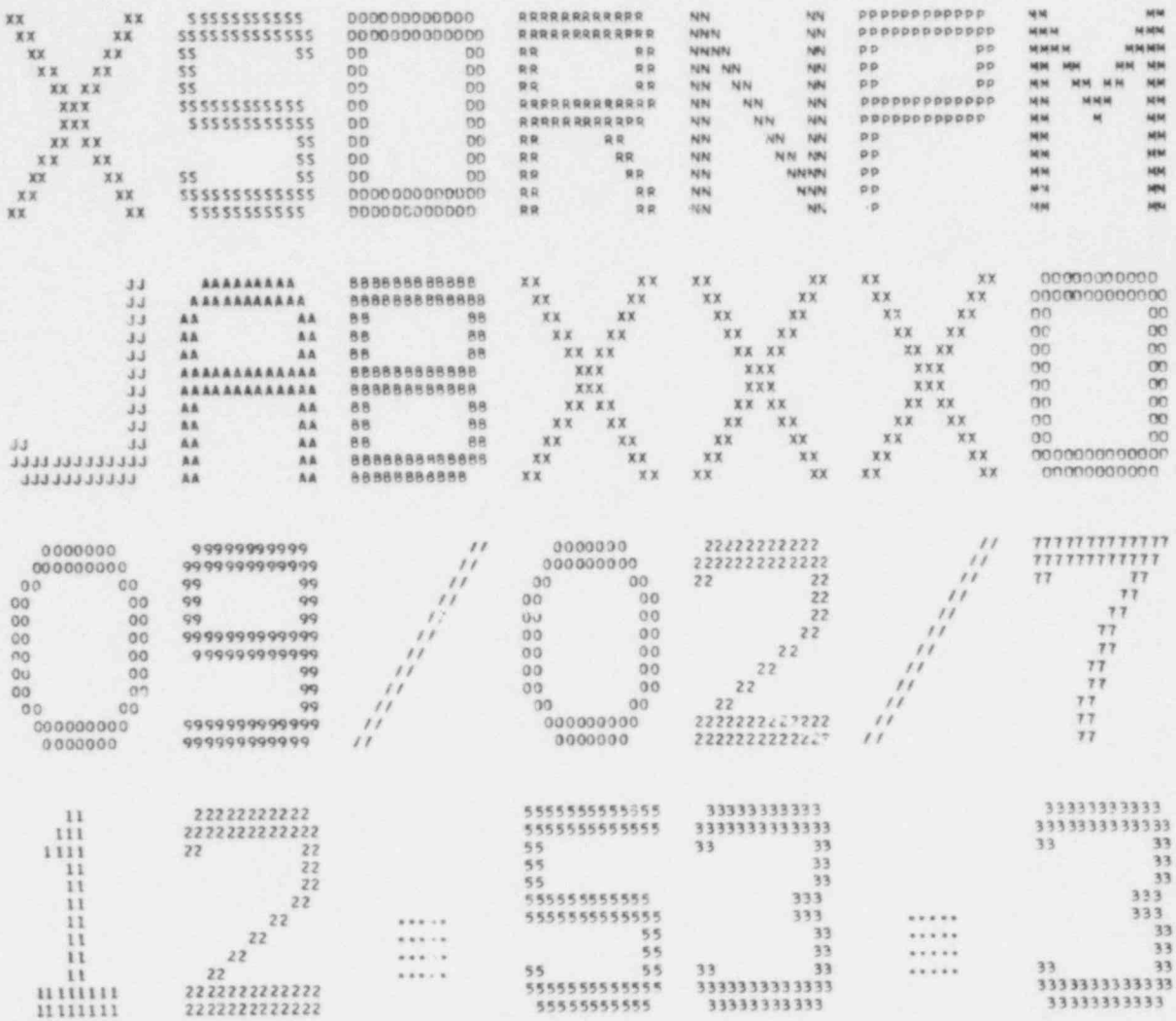
TAPE ID	4321	NUMBER OF NUCLIDES	19
NUMBER OF NEUTRON GROUPS	27	NUMBER OF GAMMA GROUPS	0
FIRST THERMAL GROUP	15		

TABLE OF CONTENTS

H 1269 F, 1002 T 218 GP 032475(2)	ID	1001
H 1269 F, 1002 T 218 GP 032475(2)	ID	11
B-10 1273 218NGP 042375 P-3 293K	ID	5010
B-11 1160 WT 1/EST 218NGP P-3 293K RE(042375)	ID	5011
C-12 1274F,1065T 218 GP 030476(7)	ID	6012
O-16 1276 218 GP 030476(7)	ID	8016
O-16 1276 218 GP 030476(7)	ID	6
O-16 1276 218 GP 030476(7)	ID	7
O-16 1276 218 GP 030476(7)	ID	8
AL-27 1193 218 GP 040375(5)	ID	13027
CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)*	ID	24304
MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K	ID	25055
FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)*	ID	26304
NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)*	ID	28304
ZR-2(1284) SIGP=5+4 NEWXLACS 293K 9-20-77 1/E WT.	ID	40302
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	ID	92235
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	ID	2
U-238 1262 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	ID	92238
U-238 1262 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	ID	4

TAPE COPY USED 157 I/O'S, AND TOOK 0.45 SECONDS

AN AMPX WORKING LIBRARY CONTAINING CROSS-SECTION DATA FOR THESE NUCLIDES WILL NOW BE PASSED TO XSDRNPM.



SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP ← THIS LINE SHOWS WHATEVER THE USER ENTERED ON THE CSAS2 TITLE CARD.

1Q ARRAY HAS 15 ENTRIES.

2Q ARRAY HAS 10 ENTRIES.

3Q ARRAY HAS 12 ENTRIES.

4Q ARRAY HAS 9 ENTRIES.

5Q ARRAY HAS 12 ENTRIES.

DIRECT ACCESS UNIT 9 REQUIRES 12 BLOCKS OF LENGTH 704 FOR CROSS SECTION MIXING.

GENERAL PROBLEM DESCRIPTION DATA BLOCK

GENERAL PROBLEM DATA

IGE	1/2/3 = PLANE/CYLINDER/SPHERE	2	ISN	QUADRATURE ORDER	8
IZM	NUMBER OF ZONES	4	ISCT	ORDER OF SCATTERING	3
IM	NUMBER OF SPACIAL INTERVALS	28	IEVT	0/1/2/3/4/5/6=Q/K/ALPHA/C/Z/R/H	1
IBL	0/1/2/3 = VACUUM/REFL/PER/WHITE	1	IIM	INNER ITERATION MAXIMUM	20
IBR	RIGHT BOUNDARY CONDITION	3	ICM	OUTER ITERATION MAXIMUM	25
MXX	NUMBER OF MIXTURES	3	ICLC	-1/0/N--FLAT RES/SN/OPT	0
MS	MIXING TABLE LENGTH	45	ITH	0/1 = FORWARD/ADJOINT	0
IGM	NUMBER OF ENERGY GROUPS	27	IFLU	0/1/2/3/4=L-S/L/S/W/L-W	0
NNG	NUMBER OF NEUTRON GROUPS	27	IPRT	-2/-1/0/N=MIXTURE XSEC PRINT	-1
NGG	NUMBER OF GAMMA GROUPS	0	IDI	0/1/2/3=NO/PRT ND/PCH N/BOTH	0
IFTG	NUMBER OF FIRST THERMAL GROUP	15	IPBT	-1/0/1=NONE/FINE/ALL BAL. PRT	0

INPUT DATA FOR XSDRNPM AS READ OFF THE BINARY INPUT TAPE PREPARED BY THE CONTROL MODULE

SPECIAL OPTIONS

IFG	0/1 = NONE/WEIGHTING CALCULATION	1	IPN	DUMMY PARAMETER	0
IQM	VOLUMETRIC SOURCES (0/N=NO/YES)	0	IDEN	0/1 = NONE/DENSITY FACTORS 38*	1
IPM	BOUNDARY SOURCES (0/N=NO/YES)	0	IAZ	0/N = NONE/N ACTIVITIES BY ZONE	0
IFN	0/1/2 = INPUT 33*/34*/USE LAST	0	IAI	0/1=NONE/ACTIVITIES BY INTERVAL	0
ITMX	MAXIMUM TIME (MINUTES)	0	IFCT	0/1=NO/YES UPSCATTER SCALING	0
IDT1	0/1/2/3=NO/XSECT/SRCE/FLUX--OUT	0	IPVT	0/1/2=NO/K/ALPHA PARAMETRIC SRCH	0

DESPITE WHAT THE TITLE CARD MAY INDICATE, THIS IS A K_{EFF} CALCULATION FOR THE LATTICE CELL DESCRIBED BY THE USER. THAT SPACE & ENERGY DEPENDENT FLUX SPECTRUM WILL THEN BE USED TO PRODUCE HOMOGENIZED CELL-AVERAGED MICROSCOPIC CROSS SECTION DATA FOR THE FUEL ASSEMBLY. THE RESULTING CROSS SECTION DATA WILL THEN BE PASSED TO KENO.

WEIGHTING DATA (IFG=1)

ICON	-1/0/1=CELL/ZONE/REGION WEIGHT	-1	IHTF	TOTAL XSECT PSN IN BRD GP TABLES	3
IGMF	NUMBER OF BROAD GROUPS	27	NOSF	PSN G-G OR FILE NUMBER	4
ITP	0/10/20/30/40 0/C/E/AC/A	0	NUSF	TABLE LENGTH OR MAX ORDER	4
IPP	-2/-1/0/N=WGTED XSECT PRINT	-1	MSCM	EXTRA 1-D X-SECT POSITIONS	0
IAP	-1/N ANISN XSECT PRINT	-1			

FLOATING POINT PARAMETERS

EV	EIGENVALUE GUESS	0.0	PV	IPVT=1/. -K/ALPHA	1.00000E 00
EVM	EIGENVALUE MODIFIER	0.0	EPS	OVERALL CONVERGENCE	1.00000E-04
BF	BUCKLING FACTOR=1.420892	1.42089E 00	PTC	POINT CONVERGENCE	1.00000E-04
DY	CYL/PLA HT FOR BUCKLING	0.0	XNF	NORMALIZATION FACTOR	1.00000E 00
DZ	PLANE DEPTH FOR BUCKLING	0.0	EQL	EV CHANGE EPS FOR SEARCH	1.00000E-03
VSC	VOID STREAMING CORRECTION	0.0	XNPM	NEW PARAM MOD FOR SEARCH	7.50000E-01

THIS CASE WILL REQUIRE 2625 LOCATIONS FOR MIXING
THIS CASE HAS BEEN ALLOCATED 105984 LOCATIONS

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP

13Q ARRAY HAS 45 ENTRIES.

14Q ARRAY HAS 45 ENTRIES.

15Q ARRAY HAS 45 ENTRIES.

DATA BLOCK 2 (MIXING TABLE, ETC.)

	NUCLIDES ON TAPE	CCCC IDENTIFICATION	MIXTURE	MIXING TABLE COMPONENT	ATOM DENSITY	EXTRA XSECT ID'S
1	1001		1	92235	7.52355E-04	
2	11		1	2	1.00000E-20	
3	5010		2	2	1.00000E-20	
4	5011		3	2	1.00000E-20	
5	6012		1	92238	2.24709E-02	
6	8016		1	4	1.00000E-20	
7	6		2	4	1.00000E-20	
8	7		3	4	1.00000E-20	
9	8		1	8016	4.64466E-02	
10	13027		3	6	3.33797E-02	
11	24304		1	7	1.00000E-20	
12	25055		2	7	1.00000E-20	
13	26304		3	7	1.00000E-20	
14	28304		1	8	1.00000E-20	
15	40302		2	8	1.00000E-20	
16	92235		3	8	1.00000E-20	
17	2		2	40302	4.25181E-02	
18	92238		3	1001	6.67593E-02	
19	4		1	11	1.00000E-20	
20			2	11	1.00000E-20	
21			3	11	1.00000E-20	
22			1	501	1.00000E-20	
23			2	5010	1.00000E-20	
24			3	5010	1.00000E-20	
25			1	5011	1.00000E-20	
26			2	5011	1.00000E-20	
27			3	5011	1.00000E-20	
28			1	6012	1.00000E-20	
29			2	6012	1.00000E-20	
30			3	6012	1.00000E-20	
31			1	13027	1.00000E-20	
32			2	13027	1.00000E-20	
33			3	13027	1.00000E-20	
34			1	24304	1.00000E-20	
35			2	24304	1.00000E-20	
36			3	24304	1.00000E-20	
37			1	25055	1.00000E-20	
38			2	25055	1.00000E-20	
39			3	25055	1.00000E-20	
40			1	26304	1.00000E-20	
41			2	26304	1.00000E-20	
42			3	26304	1.00000E-20	
43			1	28304	1.00000E-20	
44			2	28304	1.00000E-20	
45			3	28304	1.00000E-20	

THOSE NUCLIDES NOT ACUTALLY IN THE LATTICE CELL ARE SHOWN HERE AS HAVING A DENSITY OF 1.0E-20. SUCH LOW DENSITIES WILL HAVE NO EFFECT ON THE RESULTING FLUX SOLUTION AND SHOULD NOT CONCERN THE USER. THEIR USE IN THIS FASHION IS SIMPLY A MECHANICAL CONTRIVANCE USED TO GET THE ASSOCIATED CROSS-SECTION DATA PUT ON THE LIBRARY PASSED TO KENO-IV. MICROSCOPIC CROSS SECTION DATA FOR THESE NUCLIDES WILL BE UNAFFECTED BY THE "CELL AVERAGING" SINCE THEY HAVE BEEN ASSIGNED A DENSITY OF 1.0E-20 IN EACH ZONE.

MACROSCOPIC 1-D CROSS SECTIONS FOR MIXTURE 1

	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
DIFF COEF → 1	2.55801E 00	1.99315E 00	2.10671E 00	1.60068E 00	1.17441E 00	1.21785E 00	8.74940E-01	7.21192E-01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.93129E-02	2.14203E-05	0.0	0.0	0.0	0.0	0.0	0.0
4	2.13685E-02	1.89162E-01	2.15033E-01	1.24422E-01	1.65849E-01	1.79962E-01	8.93313E-02	1.37922E-02
Σ_F → 5	2.24667E-02	1.35682E-02	1.31602E-02	9.19216E-03	1.85287E-03	9.15129E-04	9.96170E-04	1.47208E-03
6	2.73708E-02	1.55716E-02	1.40836E-02	1.08572E-02	4.35454E-03	3.62059E-03	4.11694E-03	7.3497E-02
7	7.95274E-02	4.01584E-02	3.53407E-02	2.37023E-02	4.70193E-03	2.28647E-03	2.44148E-03	3.56873E-03
8	2.04127E-01	2.80382E-01	2.31224E-01	2.60908E-01	3.42714E-01	3.55495E-01	4.06990E-01	4.76457E-01

	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	5.70010E-01	6.76109E-01	6.31303E-01	5.91500E-01	6.55663E-01	5.95300E-01	8.39517E-01	8.35195E-01
Σ_{UPSCAT} → 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.35966E-04
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.00153E-03	7.43954E-05	5.85302E-06	4.11166E-07	6.52894E-08	1.29386E-08	1.46222E-09	4.29355E-10
5	2.66287E-03	6.22629E-03	1.40726E-02	2.86946E-02	3.09926E-02	2.54490E-02	1.18193E-02	1.25722E-02
Σ_A → 6	2.17458E-02	3.37109E-02	6.23763E-02	1.18967E-01	1.28271E-01	1.87399E-01	2.95583E-02	2.68292E-02
7	6.44334E-03	1.50605E-02	3.40394E-02	6.94069E-02	7.49651E-02	6.15562E-02	2.85885E-02	3.04096E-02
8	5.92635E-01	5.00985E-01	5.36143E-01	5.71639E-01	5.16313E-01	5.67842E-01	4.04416E-01	4.06483E-01

	GRP. 17	GRP. 18	GRP. 19	GRP. 20	GRP. 21	GRP. 22	GRP. 23	GRP. 24
1	7.51804E-01	7.12428E-01	7.63441E-01	7.31935E-01	6.37721E-01	5.81427E-01	5.63295E-01	4.73444E-01
2	4.60523E-03	9.80138E-03	4.90039E-03	1.34303E-03	1.45443E-02	1.13651E-02	7.43655E-03	1.74019E-02
$\Sigma_{N,2N}$ → 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.38273E-10	9.89996E-11	1.39964E-10	2.27597E-10	3.33128E-11	3.86504E-11	3.69540E-11	1.00584E-11
5	4.35133E-02	8.81773E-02	4.41942E-02	5.75785E-02	1.06869E-01	1.41195E-01	1.55711E-01	2.44110E-01
6	6.52871E-02	9.33209E-02	6.13863E-02	7.84923E-02	1.44503E-01	1.94638E-01	2.12039E-01	3.22650E-01
$\nu\Sigma_F$ → 7	1.05250E-01	1.64907E-01	1.06897E-01	1.39271E-01	2.58457E-01	3.41523E-01	3.76622E-01	5.90357E-01
8	4.50764E-01	4.75275E-01	4.44021E-01	4.62829E-01	5.30117E-01	5.80726E-01	5.99218E-01	7.11711E-01

	GRP. 25	GRP. 26	GRP. 27
1	4.00229E-01	3.15391E-01	1.93880E-01
2	4.96875E-02	4.95665E-02	8.11715E-02
3	0.0	0.0	0.0
χ(SPEC) → 4	2.94445E-12	2.06466E-12	4.92020E-13
5	3.43653E-01	5.13274E-01	1.00544E 00
6	4.49811E-01	6.69398E-01	1.31030E 00
7	8.30837E-01	1.24139E 00	2.43196E 00
Σ_T → 8	8.40783E-01	1.06538E 00	1.72759E 00

MACROSCOPIC 1-D CROSS SECTIONS USED BY XSUNPM FOR MIXTURE NUMBER 1

MACROSCOPIC 1-D CROSS SECTIONS FOR MIXTURE 2

	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	3.[illegible]40056E 00	3.37598E 00	3.04441E 00	2.87718E 00	2.16775E 00	1.31607E 00	1.08063E 00	9.05749E-01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	2.739[illegible]3E-03	8.81040E-23	0.0	0.0	0.0	0.0	0.0	0.0
4	2.10846E-02	1.88333E-01	2.14896E-01	1.24528E-01	1.66143E-01	1.80449E-01	8.96379E-02	1.38446E-02
5	2.57392E-20	1.72296E-20	1.81223E-20	1.62481E-20	1.28034E-20	1.15785E-20	1.32202E-20	1.95493E-20
6	3.929[illegible]6E-04	1.88272E-04	3.95686E-04	4.80207E-04	4.67724E-04	5.11659E-04	5.64066E-04	6.33434E-04
7	9.14946E-20	5.09943E-20	4.89150E-20	4.23751E-20	3.28045E-20	2.89626E-20	3.24027E-20	4.73944E-20
8	1.76612E-01	1.62958E-01	1.90807[illegible]-01	2.21418E-01	2.67407E-01	3.81392E-01	3.87297E-01	3.85185E-01

	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	9.47241E-01	1.11584E 00	1.17552E 00	1.27607E 00	1.27207E 00	1.26971E 00	1.25882E 00	1.25903E 00
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.76790E-04
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.00543E-03	7.46863E-05	5.87592E-06	4.12775E-07	6.55448E-08	1.29893E-08	1.46794E-09	4.31035E-10
5	3.53850E-20	8.26732E-20	1.87048E-19	3.91492E-19	4.40242E-19	4.03790E-19	1.58896E-19	1.67108E-19
6	5.22625E-03	7.52207E-03	1.33437E-02	2.29680E-04	3.91846E-04	6.89144E-04	1.01754E-03	1.14316E-03
7	8.56218E-20	1.99983E-19	4.52438E-19	9.46944E-19	1.06486E-18	9.76688E-19	3.84337E-19	4.04202E-19
8	3.54786E-01	3.00890E-01	2.85567E-01	2.63155E-01	2.63982E-01	2.64471E-01	2.64797E-01	2.64754E-01

	GRP. 17	GRP. 18	GRP. 19	GRP. 20	GRP. 21	GRP. 22	GRP. 23	GRP. 24
1	1.25838E 00	1.25798E 00	1.25738E 00	1.25553E 00	1.25334E 00	1.25162E 00	1.24696E 00	1.23898E 00
2	5.21417E-03	9.16004E-03	5.31300E-03	1.56337E-03	1.26188E-02	8.23619E-03	4.21492E-03	9.12510E-03
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.38814E-10	9.93870E-11	1.40512E-10	2.28488E-10	3.34431E-11	3.88016E-11	3.70986E-11	1.00978E-11
5	5.78362E-19	5.06186E-19	5.87412E-19	7.65311E-19	1.42046E-18	1.87671E-18	2.06965E-18	3.24461E-18
6	1.27757E-03	1.36459E-03	1.48827E-03	1.88005E-03	2.34425E-03	2.70944E-03	3.71892E-03	5.40028E-03
7	1.39894E-[illegible]	2.19188E-18	1.42083E-18	1.85113E-18	3.43531E-18	4.53939E-18	5.00592E-18	7.84679E-18
8	2.64890E-01	2.64976E-01	2.65100E-01	2.65492E-01	2.65956E-01	2.66321E-01	2.67317E-01	2.69039E-01

	GRP. 25	GRP. 26	GRP. 27
1	1.23122E 00	1.21757E 00	1.17834E 00
2	2.60[illegible]0E-02	2.18495E-02	1.35753E-04
3	0.0	0.0	0.0
4	2.95557E-12	2.07274E-12	4.93946E-13
5	4.56770E-18	6.82223E-18	1.33639E-17
6	7.13057E-03	1.01869E-02	1.92709E-02
7	1.10432E-17	1.65000E-17	3.23247E-17
8	2.70734E-01	2.73770E-01	2.82883E-01

MACROSCOPIC 1-D CROSS SECTIONS FOR MIXTURE 3

	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	5.65736E 00	3.56615E 00	3.48054E 00	2.33386E 00	1.57238E 00	1.49577E 00	9.70514E-01	7.04698E-01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.78328E-20	8.81040E-23	0.0	0.0	0.0	0.0	0.0	0.0
4	2.10846E-02	1.88333E-01	2.14896E-01	1.24528E-01	1.66143E-01	1.80449E-01	8.96379E-02	1.38446E-02
5	2.57352E-20	1.72296E-20	1.81223E-20	1.62481E-20	1.28034E-20	1.15785E-20	1.32202E-20	1.95493E-20
6	3.46339E-03	1.19963E-03	2.32585E-06	2.29156E-06	2.30157E-06	2.45863E-06	4.26933E-06	1.36539E-05
7	9.14946E-20	5.09943E-20	4.89150E-20	4.23751E-20	3.28045E-20	2.89626E-20	3.24027E-20	4.73944E-20
8	1.17560E-01	1.98659E-01	2.19649E-01	2.90255E-01	3.95235E-01	4.90643E-01	7.49893E-01	1.17959E 00

	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	6.03370E-01	5.83975E-01	5.80576E-01	5.79286E-01	5.78949E-01	5.78281E-01	5.08422E-01	4.88886E-01
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.07960E-04
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.00543E-03	7.46863E-05	5.87592E-06	4.12775E-07	6.57448E-08	1.29893E-08	1.46794E-09	4.31035E-10
5	3.53850E-20	8.26732E-20	1.87048E-19	3.91492E-19	4.02042E-19	4.03790E-19	1.58896E-19	1.67108E-19
6	4.13551E-05	1.01193E-04	2.36618E-04	4.83338E-04	8.57443E-04	1.52184E-03	2.31841E-03	2.85901E-03
7	8.56218E-20	1.99983E-19	4.52438E-19	9.46944E-19	1.06486E-18	9.76688E-19	3.84337E-19	4.04202E-19
8	1.42207E 00	1.47768E 00	1.48751E 00	1.49075E 00	1.49113E 00	1.49179E 00	1.52195E 00	1.50795E 00

	GRP. 17	GRP. 18	GRP. 19	GRP. 20	GRP. 21	GRP. 22	GRP. 23	GRP. 24
1	4.73745E-01	4.58293E-01	4.42548E-01	3.92053E-01	3.37149E-01	3.02415E-01	2.33804E-01	1.69836E-01
2	4.61189E-03	1.05046E-02	6.43785E-03	2.34657E-03	3.51033E-02	3.72172E-02	3.48811E-02	1.89016E-01
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.38814E-10	9.93870E-11	1.40512E-10	2.28688E-10	3.34431E-11	3.88016E-11	3.70986E-11	1.00978E-11
5	5.78362E-19	9.06186E-19	5.87412E-19	7.65311E-19	1.42046E-18	1.87671E-18	2.06965E-18	3.24461E-18
6	3.19552E-03	3.41240E-03	3.72145E-03	4.70028E-03	5.86082E-03	6.77389E-03	9.29771E-03	1.35025E-02
7	1.39894E-18	2.19188E-18	1.42083E-18	1.85113E-18	3.43531E-18	4.53939E-18	5.00592E-18	7.84679E-18
8	1.51885E 00	1.53474E 00	1.54948E 00	1.62458E 00	1.76761E 00	1.88088E 00	2.17992E 00	2.67802E 00

	GRP. 25	GRP. 26	GRP. 27
1	1.29385E-01	9.37011E-02	6.47150E-02
2	6.67426E-01	8.52913E-01	2.12923E 00
3	0.0	0.0	0.0
4	2.95557E-12	2.07274E-12	4.93946E-13
5	4.56770E-18	6.82223E-18	1.33639E-17
6	1.78335E-02	2.54220E-02	4.81854E-02
7	1.10432E-17	1.65000E-17	3.23247E-17
8	3.23404E 00	4.09337E 00	5.47550E 00

ELAPSED TIME 0.04 MIN.

23797 LOCATIONS WILL BE USED

33Q ARRAY HAS 1512 ENTRIES.

35Q ARRAY HAS 29 ENTRIES.

36Q ARRAY HAS 28 ENTRIES.

38Q ARRAY HAS 28 ENTRIES.

39Q ARRAY HAS 4 ENTRIES.

40Q ARRAY HAS 4 ENTRIES.

47Q ARRAY HAS 27 ENTRIES.

51Q ARRAY HAS 27 ENTRIES.

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK - ROOM TEMP
NEUTRON GROUP PARAMETERS

GP	ENERGY BOUNDARIES	LETHARGY BOUNDARIES	MID PT VELOCITIES	BROAD GP NUMBERS	CALC TYPE	RIGHT ALBEDO	LEFT ALBEDO
1	2.00000E 07	-6.93147E-01	4.65843E 09	1	0	1.00000E 00	
2	6.43400E 06	4.40988E-01	2.89910E 09	2	0	1.00000E 00	
3	3.00000E 06	1.20397E 00	2.12293E 09	3	0	1.00000E 00	
4	1.85000E 06	1.68740E 00	1.75464E 09	4	0	1.00000E 00	
5	1.40000E 06	1.96611E 00	1.46540E 09	5	0	1.00000E 00	
6	9.00000E 05	2.40795E 00	1.07137E 09	6	0	1.00000E 00	
7	4.00000E 05	3.21888E 00	6.18554E 08	7	0	1.00000E 00	
8	1.00000E 05	4.60517E 00	2.80850E 08	8	0	1.00000E 00	
9	1.70000E 04	6.37713E 00	1.16805E 08	9	0	1.00000E 00	
10	3.00000E 03	8.11173E 00	4.95716E 07	10	0	1.00000E 00	
11	5.50000E 02	9.80818E 00	2.11814E 07	11	0	1.00000E 00	
12	1.00000E 02	1.15129E 01	1.02363E 07	12	0	1.00000E 00	
13	3.00000E 01	1.27169E 01	5.75629E 06	13	0	1.00000E 00	
14	1.00000E 01	1.38155E 01	3.25040E 06	14	0	1.00000E 00	
15	3.05000E 00	1.50030E 01	2.10829E 06	15	0	1.00000E 00	
16	1.77000E 00	1.55471E 01	1.70350E 06	16	0	1.00000E 00	
17	1.30000E 00	1.58557E 01	1.52271E 06	17	0	1.00000E 00	
18	1.13000E 00	1.59959E 01	1.42605E 06	18	0	1.00000E 00	
19	1.00000E 00	1.61181E 01	1.30809E 06	19	0	1.00000E 00	
20	8.00000E-01	1.63412E 01	1.04028E 06	20	0	1.00000E 00	
21	4.00000E-01	1.70344E 01	8.30519E 05	21	0	1.00000E 00	
22	3.25000E-01	1.72420E 01	7.19254E 05	22	0	1.00000E 00	
23	2.25000E-01	1.76097E 01	5.35688E 05	23	0	1.00000E 00	
24	9.99959E-02	1.84207E 01	3.67796E 05	24	0	1.00000E 00	
25	5.00000E-02	1.91138E 01	2.72199E 05	25	0	1.00000E 00	
26	3.00000E-02	1.96246E 01	1.82031E 05	26	0	1.00000E 00	
27	1.00000E-02	2.07233E 01	2.45959E 04	27	0	1.00000E 00	
28	1.00000E-05	2.76310E 01					

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP

	MIXTURE BY ZONE	ORDER P(L) BY ZONE
1	1	3
2		0
3	2	3
4	3	3
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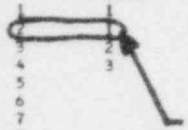


SEE NOTE ON NEXT PAGE

ACTIVITY TABLE

MATL NO.	REACTION

QUADRATURE CONSTANTS

WEIGHTS	DIRECTIONS	REFL DIREC	WT X COS
0	-2.79004E-01	3	0
5.06143E-02	-1.97286E-01	3	-9.98547E-03
5.06143E-02	1.97286E-01	2	9.98548E-03
0	-6.04419E-01	8	0
5.55952E-02	-5.58410E-01	8	-3.10449E-02
5.55952E-02	-2.31301E-01	7	-1.28592E-02
5.55952E-02	2.31301E-01	6	1.28593E-02
5.55952E-02	5.58411E-01	5	3.10450E-02
0	-8.50774E-01	15	0
5.22844E-02	-8.21784E-01	15	-4.29665E-02
5.22844E-02	-6.01587E-01	14	-3.14537E-02
5.22844E-02	-2.20195E-01	13	-1.15128E-02
5.22844E-02	2.20197E-01	12	1.15129E-02
5.22844E-02	6.01588E-01	11	3.14537E-02
5.22844E-02	8.21784E-01	10	4.29665E-02
0	-9.83032E-01	24	0
4.53355E-02	-9.64143E-01	24	-4.37099E-02
4.53355E-02	-8.17360E-01	23	-3.70554E-02
4.53355E-02	-5.46143E-01	22	-2.47596E-02
4.53355E-02	-1.91779E-01	21	-8.69440E-03
4.53355E-02	1.91781E-01	20	8.69447E-03
4.53355E-02	5.46143E-01	19	2.47597E-02
4.53355E-02	8.17361E-01	18	3.70555E-02
4.53355E-02	9.64143E-01	17	4.37099E-02

CONSTANTS FOR P(3) SCATTERING

ANGL	SET 1	SET 2	SET 3	SET 4	SET 5
1	-2.79004E-01	8.83234E-01	6.74143E-02	-6.16915E-01	-1.71701E-02
2	-1.97286E-01	8.83234E-01	0.0	-4.36226E-01	1.21412E-02
3	1.97286E-01	8.83234E-01	0.0	4.36227E-01	-1.21411E-02
4	-6.04419E-01	4.52015E-01	3.16378E-01	-8.04434E-01	-1.74564E-01
5	-5.58410E-01	4.52015E-01	2.23712E-01	-7.43199E-01	-6.68014E-02
6	-2.31301E-01	4.52015E-01	-2.23714E-01	-3.07843E-01	1.61276E-01
7	2.31302E-01	4.52015E-01	-2.23713E-01	3.07845E-01	-1.61276E-01
8	5.58411E-01	4.52015E-01	2.23713E-01	7.43200E-01	6.68026E-02
9	-8.50774E-01	-8.57236E-02	6.26843E-01	-1.98455E-01	-4.86835E-01
10	-8.21784E-01	-8.57236E-02	5.42860E-01	-1.91693E-01	-3.44242E-01
11	-6.01587E-01	-8.57236E-02	0.0	-1.40329E-01	3.44246E-01
12	-2.20195E-01	-8.57236E-02	-5.42863E-01	-5.13637E-02	3.44242E-01
13	2.20198E-01	-8.57236E-02	-5.42861E-01	5.13643E-02	-3.44246E-01
14	6.01588E-01	-8.57236E-02	0.0	1.40329E-01	-3.44244E-01
15	8.21784E-01	-8.57236E-02	5.42862E-01	1.91693E-01	3.44244E-01
16	-9.83032E-01	-4.49528E-01	8.36885E-01	5.00703E-01	-7.51005E-01
17	-9.64143E-01	-4.49528E-01	7.73179E-01	4.91082E-01	-6.24435E-01
18	-8.17360E-01	-4.49528E-01	3.20258E-01	4.16319E-01	1.46519E-01
19	-5.46142E-01	-4.49528E-01	-3.20264E-01	2.78175E-01	7.36575E-01
20	-1.91779E-01	-4.49528E-01	-7.73181E-01	9.76819E-02	4.17234E-01
21	1.91782E-01	-4.49528E-01	-7.73180E-01	-9.76831E-02	-4.17239E-01
22	5.46144E-01	-4.49528E-01	-3.20261E-01	-2.78176E-01	-7.36574E-01
23	8.17361E-01	-4.49528E-01	3.20262E-01	-4.16319E-01	-1.46513E-01
24	9.64143E-01	-4.49528E-01	7.73181E-01	-4.91082E-01	6.24437E-01

INT	RADII	MID PTS	ZONE NO.	AREAS	VOLUMES	DENS FACT	RADIUS MOD	SPEC(INT)	
1	0	1.58581E-02	1	0	3.16019E-03	1.00000E 00	0		
2	3.17162E-02	5.65972E-02	1	1.99279E-01	1.76959E-02	1.00000E 00	0		
3	8.14782E-02	1.43114E-01	1	5.11943E-01	1.10847E-01	1.00000E 00	0		FUEL (MIX. No. 1)
4	2.04750E-01	2.66386E-01	1	1.28648E 00	2.06326E-01	1.00000E 00	0		
5	3.28022E-01	3.52903E-01	1	2.06102E 00	1.10340E-01	1.00000E 00			
6	3.77784E-01	3.93642E-01	1	2.37368E 00	7.84445E-02	1.00000E 00			
7	4.09500E-01	4.10052E-01	2	2.57296E 00	2.84290E-03	0			
8	4.10603E-01	4.12177E-01	2	2.57990E 00	8.14867E-03	0			GAP (VOID)
9	4.13750E-01	4.15323E-01	2	2.59967E 00	8.2..14E-03	0			
10	4.16896E-01	4.17448E-01	2	2.61944E 00	2.89440E-03	0			
11	4.18000E-01	4.21700E-01	3	2.62637E 00	1.96061E-02	1.00000E 00			
12	4.25400E-01	4.35950E-01	3	2.67288E 00	5.77970E-02	1.00000E 00			CLAD (MIX. No. 2)
13	4.46500E-01	4.57050E-01	3	2.80544E 00	6.05946E-02	1.00000E 00			
14	4.67600E-01	4.71300E-01	3	2.93802E 00	2.19126E-02	1.00000E 00			
15	4.75000E-01	4.78524E-01	4	2.98451E 00	2.11935E-02	1.00000E 00			
16	4.82049E-01	4.86137E-01	4	3.02880E 00	2.49743E-02	1.00000E 00			
17	4.90225E-01	4.95092E-01	4	3.08017E 00	3.02806E-02	1.00000E 00			
18	4.99959E-01	5.05973E-01	4	3.14134E 00	3.82400E-02	1.00000E 00			
19	5.11588E-01	5.19862E-01	4	3.21691E 00	5.14441E-02	1.00000E 00			
20	5.27137E-01	5.39166E-01	4	3.31587E 00	7.74388E-02	1.00000E 00			
21	5.50596E-01	5.71767E-01	4	3.45950E 00	1.52117E-01	1.00000E 00			MODERATOR (MIX. No. 3)
22	5.92939E-01	6.14110E-01	4	3.72554E 00	1.63382E-01	1.00000E 00			
23	6.35282E-01	6.46711E-01	4	3.99159E 00	9.28855E-02	1.00000E 00			
24	6.58141E-01	6.66015E-01	4	4.13522E 00	6.59070E-02	1.00000E 00			
25	6.73890E-01	6.79904E-01	4	4.23418E 00	5.13854E-02	1.00000E 00			
26	6.85919E-01	6.90785E-01	4	4.30975E 00	4.22492E-02	1.00000E 00			
27	6.95653E-01	6.99741E-01	4	4.37091E 00	3.59483E-02	1.00000E 00			
28	7.03829E-01	7.07354E-01	4	4.42229E 00	3.13296E-02	1.00000E 00			
29	7.10878E-01			4.46658E 00					

ELAPSED TIME 0.04 MIN.

NOTE: IN THIS PARTICULAR CASE, ZONE 2 REPRESENTS THE GAP BETWEEN THE FUEL AND THE CLAD. WHILE THE USER ASSIGNED MIXTURE NO. 0 (A VOID) TO THIS ZONE, IT WAS NECESSARY FOR THE CONTROL MODULE TO ASSIGN MIXTURE NO. 1 TO THE ZONE AND APPLY A DENSITY FACTOR OF ZERO. THE NET EFFECT IS THE SAME AND THE USER NEED NOT BE CONCERNED.

OUTER ITER	INNER ITERS	1 - BALANCE	EIGENVALUE	1 - SOURCE RATIO	1 - SCATTER RATIO	1 - UPSCAT RATIO	TIME (MIN)
1	292	2.93683E-06	1.33353E 00	-3.76865E-01	1.00000E 00	-1.33017E-01	0.2680
2	471	2.79347E-06	1.38415E 00	-5.88613E-03	-6.79771E-02	-1.97658E-03	0.4085
3	552	2.78714E-06	1.38718E 00	-5.79177E-05	-4.69218E-03	5.66502E-03	0.4813
4	622	2.79325E-06	1.38523E 00	2.32049E-04	2.13150E-03	1.46042E-03	0.5477
5	679	2.79493E-06	1.38478E 00	-3.29485E-05	6.14472E-04	1.50386E-04	0.6035
6	722	2.79511E-06	1.38480E 00	-5.59770E-05	6.48527E-06	-2.77519E-06	0.6497

THESE NUMBERS SHOULD ALL BECOME SMALL AS THE PROBLEM CONVERGES

GROUP	INNER ITERS	MFD INT.	MAX. FLUX DIFFERENCE	MSF INT.	MAX. SCALE FACTOR	COARSE MESH
1	1	28	2.12960D-05	28	1.00002E 00	1
2	1	28	1.63281D-05	28	1.00002E 00	1
3	1	28	2.03211D-05	28	1.00001E 00	1
4	1	28	2.17725D-05	28	1.00001E 00	1
5	1	28	1.59935D-05	28	1.00002E 00	1
6	1	28	1.81003D-05	28	1.00003E 00	1
7	1	28	2.01351D-05	28	1.00004E 00	1
8	1	1	2.40850D-05	28	1.00004E 00	1
9	1	1	2.91380D-05	28	1.00005E 00	1
10	1	1	3.26640D-05	28	1.00005E 00	1
11	1	28	3.38717D-05	28	1.00005E 00	1
12	1	28	4.16392D-05	28	1.00005E 00	1
13	1	21	4.23628D-05	28	1.00004E 00	1
14	1	21	4.01087D-05	28	1.00004E 00	1
15	1	19	2.99303D-05	28	1.00002E 00	1
16	1	19	2.93357D-05	28	1.00001E 00	1
17	1	18	3.23050D-05	28	1.00001E 00	1
18	1	18	3.20926D-05	28	1.00001E 00	1
19	1	18	2.76658D-05	28	1.00001E 00	1
20	1	2	2.13383D-05	28	1.00002E 00	1
21	1	2	3.93059D-05	28	1.00002E 00	1
22	1	2	2.23302D-05	28	1.00001E 00	1
23	1	28	2.37204D-05	28	1.00003E 00	1
24	1	28	8.11158D-06	28	9.99995E-01	1
25	1	28	8.53565D-07	24	1.00000E 00	2
26	1	23	2.89230D-06	28	1.00000E 00	2
27	1	20	3.43663D-06	19	1.00000E 00	2
7	749	2.79512E-06	1.38483E 00	-2.41938E-05	-5.02829E-05	-4.12015E-06	0.6872

FINAL MONITOR

LAMBDA 1.38488E 00

ANGULAR FLUX ON 16

ELAPSED TIME 0.69 MIN.

K_{EFF} = 1.38488 FOR AN INFINITE LATTICE OF FUEL PINS LIKE THAT DESCRIBED ABOVE.

WHILE AN EDIT OF K_{EFF} IS PROVIDED AS A COURTESY, THE REAL PURPOSE OF THIS XSDRNPM CALCULATION WAS TO DETERMINE THE FLUX AT EACH POINT IN THE LATTICE CELL AND PRODUCE CELL-AVERAGED CROSS SECTION DATA THAT COULD BE USED IN KENO-IV. MUCH OF THAT DATA IS EDITED BELOW.

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP

INT.	ZONE NUMBER	RADIUS	INT. MIDPOINT	AREA	VOLUME	PROD DENSITY
1	1	0.0	1.58581E-02	0.0	3.16019E-03	7.86323D-03
2	1	3.17162E-02	5.65972E-02	1.99279E-01	1.76959E-02	4.40539D-02
3	1	8.14782E-02	1.43114E-01	5.11943E-01	1.10847E-01	2.79140D-01
4	1	2.04750E-01	2.66386E-01	1.28648E 00	2.06326E-01	5.37166D-01
5	1	3.28022E-01	3.52903E-01	2.06102E 00	1.10340E-01	2.98312D-01
6	1	3.77784E-01	3.9364[illegible]-01	2.37368E 00	7.84445E-02	2.18346D-01
7	2	4.09500E-01	4.10052E-01	2.57296E 00	2.84290E-03	0.0
8	2	4.10603E-01	4.12177E-01	2.57990E 00	8.14867E-03	0.0
9	2	4.13750E-01	4.15323E-01	2.59967E 00	8.21114E-03	0.0
10	2	4.16896E-01	4.17448E-01	2.61944E 00	2.89440E-03	0.0
11	3	4.18000E-01	4.21700E-01	2.62637E 00	1.96061E-02	7.10717D-19
12	3	4.25400E-01	4.35950E-01	2.67286E 00	5.77970E-02	2.11333D-18
13	3	4.46500E-01	4.57050E-01	2.80544E 00	6.05946E-02	2.23858D-18
14	3	4.67600E-01	4.71300E-01	2.93802E 00	2.19126E-02	8.14301D-19
15	4	4.75000E-01	4.78524E-01	2.98451E 00	2.11935E-02	7.91958D-19
16	4	4.82049E-01	4.86137E-01	3.02880E 00	2.49743E-02	9.40443D-19
17	4	4.90225E-01	4.95092E-01	3.08017E 00	3.02806E-02	1.15000D-18
18	4	4.99959E-01	5.05973E-01	3.14134E 00	3.82400E-02	1.46619D-18
19	4	5.11988E-01	5.19862E-01	3.21691E 00	5.14441E-02	1.99370D-18
20	4	5.27737E-01	5.39166E-01	3.31587E 00	7.74388E-02	3.03884D-18
21	4	5.50596E-01	5.71767E-01	3.45950E 00	1.52117E-01	6.06341D-18
22	4	5.92939E-01	6.14110E-01	3.72554E 00	1.63382E-01	6.60141D-18
23	4	6.35282E-01	6.46711E-01	3.99159E 00	9.28855E-02	3.77473D-18
24	4	6.58141E-01	6.66015E-01	4.13522E 00	6.59070E-02	2.68113D-18
25	4	6.73890E-01	6.79904E-01	4.23418E 00	5.13854E-02	2.08956D-18
26	4	6.85919E-01	6.90785E-01	4.30975E 00	4.22492E-02	1.71622D-18
27	4	6.95653E-01	6.99741E-01	4.37091E 00	3.59483E-02	1.45815D-18
28	4	7.03829E-01	7.07354E-01	4.42229E 00	3.13296E-02	1.26861D-18
29		7.10878E-01		4.46658E 00		

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP

TOTAL FLUX

INT.	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	1.80281E-01	1.32587E 00	1.64060E 00	9.98114E-01	1.47127E 00	2.61581E 00	2.45888E 00	1.75885E 00
2	1.80328E-01	1.32633E 00	1.64122E 00	9.98480E-01	1.47173E 00	2.61650E 00	2.45914E 00	1.75885E 00
3	1.79847E-01	1.32111E 00	1.63457E 00	9.94412E-01	1.46543E 00	2.60558E 00	2.45286E 00	1.75782E 00
4	1.78316E-01	1.30471E 00	1.61391E 00	9.81834E-01	1.44612E 00	2.57274E 00	2.43415E 00	1.75480E 00
5	1.76471E-01	1.28516E 00	1.58958E 00	9.67120E-01	1.42370E 00	2.53521E 00	2.41289E 00	1.75131E 00
6	1.74931E-01	1.26919E 00	1.57006E 00	9.55487E-01	1.40623E 00	2.50672E 00	2.39693E 00	1.74861E 00
7	1.74115E-01	1.26084E 00	1.55994E 00	9.49511E-01	1.39736E 00	2.49243E 00	2.38899E 00	1.74724E 00
8	1.73995E-01	1.25965E 00	1.55851E 00	9.48696E-01	1.39620E 00	2.49061E 00	2.38802E 00	1.74706E 00
9	1.73821E-01	1.25794E 00	1.55646E 00	9.47531E-01	1.39455E 00	2.48803E 00	2.38665E 00	1.74681E 00
10	1.73706E-01	1.25681E 00	1.55512E 00	9.46769E-01	1.39348E 00	2.48636E 00	2.38577E 00	1.74664E 00
11	1.73682E-01	1.25461E 00	1.55245E 00	9.45239E-01	1.39127E 00	2.48273E 00	2.38381E 00	1.74629E 00
12	1.72848E-01	1.24817E 00	1.54444E 00	9.40485E-01	1.38426E 00	2.47093E 00	2.37740E 00	1.74529E 00
13	1.72088E-01	1.24000E 00	1.53387E 00	9.33898E-01	1.37426E 00	2.45378E 00	2.36803E 00	1.74416E 00
14	1.71673E-01	1.23519E 00	1.52734E 00	9.29604E-01	1.36755E 00	2.44208E 00	2.36160E 00	1.74361E 00
15	1.71498E-01	1.23297E 00	1.52418E 00	9.27415E-01	1.36403E 00	2.43594E 00	2.35820E 00	1.74346E 00
16	1.71330E-01	1.23079E 00	1.52107E 00	9.25242E-01	1.36051E 00	2.42989E 00	2.35483E 00	1.74337E 00
17	1.71148E-01	1.22846E 00	1.51779E 00	9.22968E-01	1.35684E 00	2.42359E 00	2.35131E 00	1.74324E 00
18	1.70548E-01	1.22594E 00	1.51426E 00	9.20542E-01	1.35294E 00	2.41689E 00	2.34755E 00	1.74307E 00
19	1.70724E-01	1.22315E 00	1.51038E 00	9.17885E-01	1.34867E 00	2.40958E 00	2.34344E 00	1.74287E 00
20	1.70464E-01	1.21995E 00	1.50594E 00	9.14867E-01	1.34383E 00	2.40130E 00	2.33878E 00	1.74261E 00
21	1.70153E-01	1.21611E 00	1.50065E 00	9.11272E-01	1.33807E 00	2.39145E 00	2.33325E 00	1.74232E 00
22	1.69916E-01	1.21315E 00	1.49654E 00	9.08467E-01	1.33356E 00	2.38375E 00	2.32901E 00	1.74219E 00
23	1.69856E-01	1.21235E 00	1.49537E 00	9.07642E-01	1.33221E 00	2.38146E 00	2.32785E 00	1.74230E 00
24	1.69887E-01	1.21266E 00	1.49574E 00	9.07854E-01	1.33252E 00	2.38201E 00	2.32828E 00	1.74249E 00
25	1.69943E-01	1.21327E 00	1.49652E 00	9.08346E-01	1.33329E 00	2.38332E 00	2.32912E 00	1.74269E 00
26	1.70008E-01	1.21400E 00	1.49747E 00	9.08955E-01	1.33424E 00	2.38496E 00	2.33014E 00	1.74288E 00
27	1.70078E-01	1.21479E 00	1.49850E 00	9.09623E-01	1.33529E 00	2.38676E 00	2.33125E 00	1.74307E 00
28	1.70151E-01	1.21561E 00	1.49959E 00	9.10326E-01	1.33639E 00	2.38865E 00	2.33240E 00	1.74325E 00

INT.	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	1.34983E 00	1.24965E 00	1.16186E 00	7.34957E-01	6.38728E-01	6.00547E-01	3.18752E-01	1.84150E-01
2	1.34583E 00	1.24964E 00	1.16183E 00	7.34939E-01	6.38696E-01	6.00520E-01	3.18754E-01	1.84148E-01
3	1.35061E 00	1.25044E 00	1.16374E 00	7.37442E-01	6.40846E-01	6.03714E-01	3.19050E-01	1.84319E-01
4	1.35295E 00	1.25278E 00	1.16935E 00	7.44838E-01	6.47207E-01	6.13194E-01	3.19897E-01	1.84820E-01
5	1.35566E 00	1.25540E 00	1.17567E 00	7.53274E-01	6.54450E-01	6.24050E-01	3.20840E-01	1.85382E-01
6	1.35779E 00	1.25732E 00	1.18037E 00	7.59665E-01	6.59923E-01	6.32320E-01	3.21523E-01	1.85797E-01
7	1.35888E 00	1.25827E 00	1.18268E 00	7.62860E-01	6.62658E-01	6.36466E-01	3.21858E-01	1.86003E-01
8	1.35902E 00	1.25838E 00	1.18295E 00	7.63233E-01	6.62983E-01	6.36952E-01	3.21898E-01	1.86028E-01
9	1.35921E 00	1.25853E 00	1.18332E 00	7.63763E-01	6.63446E-01	6.37643E-01	3.21956E-01	1.86064E-01
10	1.35934E 00	1.25863E 00	1.18357E 00	7.64108E-01	6.63747E-01	6.38092E-01	3.21993E-01	1.86087E-01
11	1.35962E 00	1.25884E 00	1.18408E 00	7.64829E-01	6.64376E-01	6.39030E-01	3.22073E-01	1.86136E-01
12	1.36038E 00	1.25955E 00	1.18577E 00	7.67062E-01	6.66329E-01	6.41936E-01	3.22322E-01	1.86288E-01
13	1.36125E 00	1.26061E 00	1.18821E 00	7.70105E-01	6.68989E-01	6.45888E-01	3.22665E-01	1.86496E-01
14	1.36170E 00	1.26135E 00	1.18988E 00	7.72048E-01	6.70684E-01	6.48402E-01	3.22884E-01	1.86627E-01
15	1.36151E 00	1.26179E 00	1.19087E 00	7.73149E-01	6.71624E-01	6.49814E-01	3.22961E-01	1.86688E-01
16	1.36215E 00	1.26228E 00	1.19197E 00	7.74391E-01	6.72665E-01	6.51393E-01	3.23008E-01	1.86747E-01
17	1.36242E 00	1.26280E 00	1.19314E 00	7.75707E-01	6.73772E-01	6.53069E-01	3.23064E-01	1.86812E-01
18	1.36271E 00	1.26334E 00	1.19438E 00	7.77129E-01	6.74971E-01	6.54880E-01	3.23131E-01	1.86884E-01
19	1.36306E 00	1.26394E 00	1.19574E 00	7.78702E-01	6.76301E-01	6.56887E-01	3.23210E-01	1.86966E-01
20	1.36346E 00	1.26462E 00	1.19730E 00	7.80506E-01	6.77829E-01	6.59188E-01	3.23306E-01	1.87061E-01
21	1.36356E 00	1.26542E 00	1.19916E 00	7.82676E-01	6.79662E-01	6.61950E-01	3.23412E-01	1.87170E-01
22	1.36437E 00	1.26606E 00	1.20062E 00	7.84381E-01	6.81086E-01	6.64106E-01	3.23456E-01	1.87240E-01
23	1.36452E 00	1.26625E 00	1.20107E 00	7.84888E-01	6.81482E-01	6.64724E-01	3.23412E-01	1.87239E-01
24	1.36451E 00	1.26622E 00	1.20098E 00	7.84760E-01	6.81342E-01	6.64537E-01	3.23339E-01	1.87207E-01
25	1.36446E 00	1.26611E 00	1.20074E 00	7.84458E-01	6.81059E-01	6.64130E-01	3.23262E-01	1.87170E-01
26	1.36438E 00	1.26598E 00	1.20044E 00	7.84081E-01	6.80714E-01	6.63631E-01	3.23186E-01	1.87130E-01
27	1.36429E 00	1.26583E 00	1.20010E 00	7.83665E-01	6.80338E-01	6.63082E-01	3.23111E-01	1.87091E-01
28	1.36420E 00	1.26568E 00	1.19974E 00	7.83223E-01	6.79942E-01	6.62503E-01	3.23039E-01	1.87051E-01

INT.	GRP. 17	GRP. 18	GRP. 19	GRP. 20	GRP. 21	GRP. 22	GRP. 23	GRP. 24
1	8.18772E-02	7.03208E-02	1.32793E-01	4.35017E-01	1.26754E-01	2.30831E-01	7.24354E-01	8.78342E-01
2	8.18730E-02	7.03161E-02	1.32786E-01	4.34993E-01	1.26743E-01	2.30818E-01	7.24307E-01	8.78366E-01
3	8.20264E-02	7.04929E-02	1.33034E-01	4.35864E-01	1.27226E-01	2.31973E-01	7.28423E-01	8.86305E-01
4	8.24803E-02	7.10174E-02	1.33767E-01	4.38438E-01	1.28659E-01	2.35400E-01	7.40602E-01	9.09805E-01
5	8.29954E-02	7.16142E-02	1.34596E-01	4.41353E-01	1.30294E-01	2.39320E-01	7.54497E-01	9.36785E-01
6	8.33834E-02	7.20650E-02	1.35215E-01	4.43542E-01	1.31532E-01	2.42304E-01	7.65049E-01	9.57486E-01
7	8.35772E-02	7.22905E-02	1.35524E-01	4.44634E-01	1.32151E-01	2.43801E-01	7.70335E-01	9.67898E-01
8	8.36008E-02	7.23177E-02	1.35562E-01	4.44765E-01	1.32224E-01	2.43975E-01	7.70940E-01	9.69041E-01
9	8.36344E-02	7.23563E-02	1.35615E-01	4.44952E-01	1.32327E-01	2.44222E-01	7.71797E-01	9.70658E-01
10	8.36561E-02	7.23814E-02	1.35649E-01	4.45074E-01	1.32394E-01	2.44382E-01	7.72352E-01	9.71700E-01
11	8.37018E-02	7.24341E-02	1.35722E-01	4.45329E-01	1.32534E-01	2.44717E-01	7.73511E-01	9.73871E-01
12	8.38434E-02	7.25973E-02	1.35947E-01	4.46117E-01	1.32971E-01	2.45745E-01	7.77090E-01	9.80446E-01
13	8.40349E-02	7.28190E-02	1.36251E-01	4.47179E-01	1.33568E-01	2.47121E-01	7.81732E-01	9.89015E-01
14	8.41555E-02	7.29594E-02	1.36443E-01	4.47847E-01	1.33948E-01	2.47981E-01	7.84607E-01	9.94173E-01
15	8.42224E-02	7.30398E-02	1.36549E-01	4.48224E-01	1.34179E-01	2.48500E-01	7.86449E-01	9.97893E-01
16	8.42975E-02	7.31316E-02	1.36668E-01	4.48653E-01	1.34453E-01	2.49126E-01	7.88798E-01	1.00304E 00
17	8.43777E-02	7.32293E-02	1.36795E-01	4.49113E-01	1.34743E-01	2.49790E-01	7.91346E-01	1.00867E 00
18	8.44649E-02	7.33350E-02	1.36934E-01	4.49614E-01	1.35056E-01	2.50513E-01	7.94157E-01	1.01493E 00
19	8.45618E-02	7.34522E-02	1.37088E-01	4.50172E-01	1.35403E-01	2.51317E-01	7.97330E-01	1.02206E 00
20	8.46730E-02	7.35865E-02	1.37265E-01	4.50815E-01	1.35801E-01	2.52244E-01	8.01045E-01	1.03047E 00
21	8.48053E-02	7.37472E-02	1.37478E-01	4.51587E-01	1.36280E-01	2.53365E-01	8.05646E-01	1.04105E 00
22	8.49055E-02	7.38717E-02	1.37640E-01	4.52188E-01	1.36661E-01	2.54261E-01	8.09447E-01	1.05009E 00
23	8.49304E-02	7.39067E-02	1.37682E-01	4.52356E-01	1.36782E-01	2.54547E-01	8.10781E-01	1.05360E 00
24	8.49172E-02	7.38952E-02	1.37663E-01	4.52299E-01	1.36763E-01	2.54503E-01	8.10724E-01	1.05385E 00
25	8.48944E-02	7.38714E-02	1.37627E-01	4.52182E-01	1.36705E-01	2.54367E-01	8.10272E-01	1.05314E 00
26	8.48675E-02	7.38425E-02	1.37585E-01	4.52039E-01	1.36630E-01	2.54191E-01	8.09646E-01	1.05200E 00
27	8.48387E-02	7.38108E-02	1.37540E-01	4.51884E-01	1.36546E-01	2.53994E-01	8.08924E-01	1.05062E 00
28	8.48088E-02	7.37775E-02	1.37493E-01	4.51720E-01	1.36456E-01	2.53782E-01	8.08140E-01	1.04908E 00

INT.	GRP. 25	GRP. 26	GRP. 27
1	5.21932E-01	4.10475E-01	6.37536E-02
2	5.22068E-01	4.10851E-01	6.40270E-02
3	5.28546E-01	4.18798E-01	6.67299E-02
4	5.47699E-01	4.42311E-01	7.48478E-02
5	5.69831E-01	4.69835E-01	8.48206E-02
6	5.87016E-01	4.91948E-01	9.32284E-02
7	5.95702E-01	5.02814E-01	9.75668E-02
8	5.96619E-01	5.03962E-01	9.79643E-02
9	5.97915E-01	5.05520E-01	9.85068E-02
10	5.98750E-01	5.06480E-01	9.88434E-02
11	6.00477E-01	5.08714E-01	9.96006E-02
12	6.05635E-01	5.15088E-01	1.01722E-01
13	6.12157E-01	5.22069E-01	1.04212E-01
14	6.16023E-01	5.26307E-01	1.05384E-01
15	6.19106E-01	5.30354E-01	1.07235E-01
16	6.23675E-01	5.36814E-01	1.09416E-01
17	6.28705E-01	5.43934E-01	1.11963E-01
18	6.34320E-01	5.51881E-01	1.14974E-01
19	6.40730E-01	5.60968E-01	1.18363E-01
20	6.48330E-01	5.71701E-01	1.22330E-01
21	6.57589E-01	5.85466E-01	1.27369E-01
22	6.66416E-01	5.97749E-01	1.31907E-01
23	6.69901E-01	6.03179E-01	1.34005E-01
24	6.70380E-01	6.04297E-01	1.34546E-01
25	6.69962E-01	6.04097E-01	1.34605E-01
26	6.69128E-01	6.03272E-01	1.34432E-01
27	6.68056E-01	6.02082E-01	1.34117E-01
28	6.66826E-01	6.00642E-01	1.33704E-01

ELAPSED TIME 0.69 MIN.

FINE GROUP SUMMARY FOR ZONE 1 BY GROUP INCLUDING SUM FOR ALL GROUPS IN LINE 28

GRP.	FIX	SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0		2.13684E-02	0.0	1.00493E-02	8.34393E-03	2.56414E-03	1.22952E-02	9.99448E-01
2	0.0		1.89161E-01	1.84713E-03	1.29817E-01	5.15100E-02	1.06613E-02	1.28861E-01	9.99976E-01
3	0.0		2.15033E-01	2.03878E-02	1.22355E-01	6.15578E-02	1.19283E-02	1.61941E-01	9.99986E-01
4	0.0		1.24422E-01	2.97402E-02	7.82881E-02	5.05581E-02	5.59464E-03	9.80080E-02	1.00000E 00
5	0.0		1.65849E-01	5.13176E-02	1.87975E-01	6.88102E-02	3.30469E-03	1.45057E-01	9.99988E-01
6	0.0		1.79962E-01	9.98538E-02	4.38682E-01	3.65579E-02	4.88992E-03	2.38376E-01	9.99985E-01
7	0.0		8.93310E-02	6.95216E-02	4.91587E-01	2.39637E-02	5.26833E-03	1.29625E-01	9.99987E-01
8	0.0		1.37922E-02	2.84594E-02	4.16522E-01	1.41715E-02	9.56313E-03	1.35206E-02	9.99956E-01
9	0.0		1.00152E-03	1.43311E-02	3.93170E-01	1.39332E-02	1.55100E-02	-1.41192E-02	1.00028E 00
10	0.0		7.43952E-05	1.39480E-02	3.01372E-01	7.16872E-03	2.22594E-02	-1.54136E-02	1.00029E 00
11	0.0		5.85301E-06	7.16931E-03	2.86587E-01	5.63841E-03	3.84744E-02	-3.69457E-02	1.00056E 00
12	0.0		4.11165E-07	5.63864E-03	1.71367E-01	6.73949E-03	4.68086E-02	-4.79154E-02	1.00055E 00
13	0.0		6.52892E-08	6.73949E-03	1.28106E-01	4.55422E-03	4.38522E-02	-4.16713E-02	1.00032E 00
14	0.0		1.29386E-08	4.55423E-03	1.17545E-01	5.87926E-03	6.07963E-02	-6.21250E-02	1.00041E 00
15	0.0		1.46221E-09	5.94121E-03	5.72351E-02	5.98086E-03	4.98471E-03	-5.02523E-03	1.00007E 00
16	0.0		4.29353E-10	6.11404E-03	3.02327E-02	6.75888E-03	2.61410E-03	-3.25948E-03	1.00004E 00
17	0.0		1.38273E-10	5.57113E-03	1.09792E-02	5.62133E-03	3.01513E-03	-3.06551E-03	1.00002E 00
18	0.0		9.89993E-11	5.29240E-03	8.97380E-03	5.34495E-03	3.49843E-03	-3.55111E-03	1.00001E 00
19	0.0		1.39964E-10	6.70911E-03	1.97290E-02	7.27492E-03	4.33226E-03	-4.89834E-03	1.00002E 00
20	0.0		2.27596E-10	8.54779E-03	8.12554E-02	7.65699E-03	1.81584E-02	-1.72684E-02	1.00004E 00
21	0.0		3.33126E-11	7.42432E-03	1.89123E-02	7.30405E-03	9.82421E-03	-9.70440E-03	1.00003E 00
22	0.0		3.86502E-11	1.02150E-02	3.92712E-02	8.80079E-03	2.42345E-02	-2.28205E-02	1.00001E 00
23	0.0		3.69539E-11	1.62383E-02	1.36778E-01	1.49652E-02	8.31023E-02	-8.18295E-02	1.00001E 00
24	0.0		1.00584E-11	2.73651E-02	1.57505E-01	3.03156E-02	1.55761E-01	-1.58709E-01	9.99949E-01
25	0.0		2.94444E-12	3.07718E-02	8.58707E-02	2.80602E-02	1.31076E-01	-1.28363E-01	9.99970E-01
26	0.0		2.06466E-12	1.84653E-02	7.73596E-02	1.63634E-02	1.58435E-01	-1.56331E-01	9.99948E-01
27	0.0		4.92018E-13	4.98640E-03	1.37293E-02	3.31559E-03	5.35216E-02	-5.18503E-02	9.99960E-01
28	0.0		9.99999E-01	5.07149E-01	4.01[illegible]E 00	5.07148E-01	9.34033E-01	6.78173E-02	9.99991E-01

GRP.	RT BDY FLUX	RT LEAKAGE	LFT BDY FLUX	LFT LEAKAGE	N2N RATE	FISS RATE	FLUX*DB**2	TOTAL FLUX
1	1.74146E-01	1.22952E-02	1.80192E-01	0.0	1.80926E-03	2.10472E-03	0.0	9.36816E-02
2	1.28115E 00	1.28861E-01	1.32496E 00	0.0	1.46656E-05	9.28960E-03	0.0	6.84662E-01
3	1.58031E 00	1.61941E-01	1.63943E 00	0.0	0.0	1.11462E-02	0.0	8.46964E-01
4	9.49728E-01	9.80080E-02	9.97417E-01	0.0	0.0	4.73666E-03	0.0	5.15294E-01
5	1.39766E 00	1.45057E-01	1.47029E 00	0.0	0.0	1.40615E-03	0.0	7.58907E-01
6	2.49291E 00	2.38376E-01	2.61420E 00	0.0	0.0	1.23596E-03	0.0	1.35059E 00
7	2.38924E 00	1.29625E-01	2.45805E 00	0.0	0.0	1.27477E-03	0.0	1.27967E 00
8	1.74728E 00	1.85206E-02	1.75875E 00	0.0	0.0	1.36020E-03	0.0	9.24001E-01
9	1.35884E 00	-1.41192E-02	1.34991E 00	0.0	0.0	1.89891E-03	0.0	7.13108E-01
10	1.25824E 00	-1.54136E-02	1.24974E 00	0.0	0.0	4.11122E-03	0.0	6.60301E-01
11	1.18261E 00	-3.69457E-02	1.16207E 00	0.0	0.0	8.68017E-03	0.0	6.16812E-01
12	7.62760E-01	-4.79154E-02	7.35224E-01	0.0	0.0	1.12901E-02	0.0	3.93458E-01
13	6.62571E-01	-4.16713E-02	6.38969E-01	0.0	0.0	1.05955E-02	0.0	3.41872E-01
14	6.36336E-01	-6.21250E-02	6.00893E-01	0.0	0.0	8.25621E-03	0.0	3.24432E-01
15	3.21844E-01	-5.02523E-03	3.18777E-01	0.0	0.0	1.99320E-03	0.0	1.68640E-01
16	1.85994E-01	-3.25948E-03	1.84167E-01	0.0	0.0	1.22497E-03	0.0	9.74348E-02
17	8.35702E-02	-3.06551E-03	8.18949E-02	0.0	0.0	1.89354E-03	0.0	4.35165E-02
18	7.22826E-02	-3.55111E-03	7.03415E-02	0.0	0.0	2.55585E-03	0.0	3.74882E-02
19	1.35513E-01	-4.89834E-03	1.32821E-01	0.0	0.0	3.11895E-03	0.0	7.05737E-02
20	4.44594E-01	-1.72684E-02	4.35119E-01	0.0	0.0	1.33202E-02	0.0	2.31340E-01
21	1.32137E-01	-9.70440E-03	1.26809E-01	0.0	0.0	7.26563E-03	0.0	6.79862E-02
22	2.43752E-01	-2.28205E-02	2.30956E-01	0.0	0.0	1.75803E-02	0.0	1.24511E-01
23	7.70167E-01	-8.18295E-02	7.24900E-01	0.0	0.0	6.10263E-02	0.0	3.91920E-01
24	9.67583E-01	-1.58709E-01	8.79132E-01	0.0	0.0	1.17845E-01	0.0	4.82754E-01
25	5.95450E-01	-1.28363E-01	5.22504E-01	0.0	0.0	1.00142E-01	0.0	2.91404E-01
26	5.02489E-01	-1.56331E-01	4.11047E-01	0.0	0.0	1.21483E-01	0.0	2.36683E-01
27	9.74553E-02	-5.18503E-02	6.38618E-02	0.0	0.0	4.10690E-02	0.0	4.08467E-02
28	2.23841E 01	8.77964E-02	2.23598E 01	0.0	1.82393E-03	5.67904E-01	0.0	1.17888E 01

FINE GROUP EDITS BY ZONE AND FINE GROUP EDIT FOR SYSTEM (BELOW) SHOULD ALWAYS BE INSPECTED TO VERIFY THAT THE SOLUTION WAS ADEQUATELY CONVERGED.

FINE GROUP SUMMARY FOR ZONE 2 BY GROUP INCLUDING SUM FOR ALL GROUPS IN LINE 28

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0	0.0	0.0	0.0	0.0	0.0	7.45058E-09	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	1.19209E-07	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	-5.96046E-08	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	5.96046E-08	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	1.19209E-07	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	1.78814E-07	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	1.78814E-07	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	2.98023E-08	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	1.04308E-07	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	5.96046E-08	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	1.22935E-07	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	-4.09782E-08	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	1.30385E-07	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	1.00583E-07	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	-3.72529E-08	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	-4.88944E-09	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	2.32831E-10	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	-2.56114E-09	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00000E 00
20	0.0	0.0	0.0	0.0	0.0	0.0	7.45058E-08	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	1.86265E-08	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	-3.72529E-09	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	5.96046E-08	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00000E 00
25	0.0	0.0	0.0	0.0	0.0	0.0	-1.19209E-07	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	-1.78814E-07	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	-2.60770E-08	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	9.27597E-07	0.0

GRP.	RT BDY FLUX	RT LEAKAGE	LFT BDY FLUX	LFT LEAKAGE	N2N RATE	FISS RATE	FLUX*DB**2	TOTAL FLUX
1	1.73676E-01	1.22952E-02	1.74146E-01	1.22952E-02	0.0	0.0	0.0	3.84286E-03
2	1.25652E 00	1.28862E-01	1.26115E 00	1.28861E-01	0.0	0.0	0.0	2.78158E-02
3	1.55477E 00	1.61941E-01	1.56031E 00	1.61941E-01	0.0	0.0	0.0	3.44160E-02
4	9.46576E-01	9.80081E-02	9.49728E-01	9.80080E-02	0.0	0.0	0.0	2.09506E-02
5	1.39820E 00	1.45057E-01	1.39766E 00	1.45057E-01	0.0	0.0	0.0	3.08338E-02
6	2.48593E 00	2.38376E-01	2.49291E 00	2.38376E-01	0.0	0.0	0.0	5.50070E-02
7	2.38554E 00	1.29625E-01	2.38924E 00	1.29625E-01	0.0	0.0	0.0	5.27534E-02
8	1.74659E 00	1.85206E-02	1.74728E 00	1.85206E-02	0.0	0.0	0.0	3.86022E-02
9	1.35938E 00	-1.41191E-02	1.35884E 00	-1.41192E-02	0.0	0.0	0.0	3.00325E-02
10	1.25865E 00	-1.54136E-02	1.25824E 00	-1.54136E-02	0.0	0.0	0.0	2.78081E-02
11	1.18362E 00	-3.69456E-02	1.18261E 00	-3.69457E-02	0.0	0.0	0.0	2.61439E-02
12	7.64155E-01	-4.79154E-02	7.62760E-01	-4.79154E-02	0.0	0.0	0.0	1.68711E-02
13	6.63822E-01	-4.16711E-02	6.62571E-01	-4.16713E-02	0.0	0.0	0.0	1.46551E-02
14	6.38205E-01	-6.21249E-02	6.36336E-01	-6.21250E-02	0.0	0.0	0.0	1.40824E-02
15	3.22000E-01	-5.02527E-03	3.21844E-01	-5.02523E-03	0.0	0.0	0.0	7.11365E-03
16	1.86091E-01	-3.25948E-03	1.85994E-01	-3.25948E-03	0.0	0.0	0.0	4.11107E-03
17	8.36608E-02	-3.06551E-03	8.35702E-02	-3.06551E-03	0.0	0.0	0.0	1.84770E-03
18	7.23870E-02	-3.55111E-03	7.22826E-02	-3.55111E-03	0.0	0.0	0.0	1.59844E-03
19	1.35657E-01	-4.89834E-03	1.35513E-01	-4.89834E-03	0.0	0.0	0.0	2.99610E-03
20	4.45101E-01	-1.72683E-02	4.44594E-01	-1.72684E-02	0.0	0.0	0.0	9.83008E-03
21	1.32409E-01	-9.70438E-03	1.32130E-01	-9.70440E-03	0.0	0.0	0.0	2.92289E-03
22	2.44420E-01	-2.28205E-02	2.43752E-01	-2.28205E-02	0.0	0.0	0.0	5.39384E-03
23	7.72485E-01	-8.18295E-02	7.70167E-01	-8.18295E-02	0.0	0.0	0.0	1.70449E-02
24	9.71954E-01	-1.58709E-01	9.67583E-01	-1.58709E-01	0.0	0.0	0.0	2.14307E-02
25	5.98954E-01	-1.28363E-01	5.95450E-01	-1.28363E-01	0.0	0.0	0.0	1.31978E-02
26	5.06704E-01	-1.56331E-01	5.02489E-01	-1.56331E-01	0.0	0.0	0.0	1.11529E-02
27	9.89233E-02	-5.18504E-02	9.74553E-02	-5.18503E-02	0.0	0.0	0.0	2.17060E-03
28	2.23790E 01	6.77969E-02	2.23841E 01	6.77964E-02	0.0	0.0	0.0	4.94625E-01

FINE GROUP SUMMARY FOR ZONE 3 BY GROUP INCLUDING SUM FOR ALL GROUPS IN LINE 28

GRP.	FIX	SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0		8.94750E-20	0.0	2.82100E-03	2.11469E-03	1.08369E-05	-2.05014E-03	1.00110E 00
2	0.0		7.99214E-19	3.69326E-04	1.88531E-02	1.35281E-02	3.74551E-05	-1.31967E-02	1.00067E 00
3	0.0		9.11937E-19	1.93550E-03	3.56053E-02	1.12580E-02	9.73835E-05	-9.41962E-03	9.99929E-01
4	0.0		5.28451E-19	3.69601E-03	2.92995E-02	3.79478E-03	7.19584E-05	-1.84059E-04	1.00581E 00
5	0.0		7.05048E-19	7.93951E-03	5.53442E-02	3.50065E-03	1.03144E-04	4.31424E-03	1.00135E 00
6	0.0		7.65757E-19	1.30915E-02	1.47884E-01	2.02051E-03	2.01433E-04	1.08251E-02	1.00170E 00
7	0.0		3.80389E-19	8.46671E-03	1.45964E-01	7.33690E-04	2.13996E-04	7.49522E-03	1.00141E 00
8	0.0		5.87512E-20	1.42743E-03	1.02363E-01	4.92892E-03	1.76731E-04	-3.68028E-03	1.00072E 00
9	0.0		4.26665E-21	4.95252E-03	7.54372E-02	6.26851E-04	1.13726E-03	3.18465E-03	1.00018E 00
10	0.0		3.16940E-22	6.29685E-04	5.85343E-02	5.80761E-04	1.51573E-03	-1.46836E-03	1.00124E 00
11	0.0		2.49352E-23	5.80804E-04	5.10968E-02	5.77063E-04	2.53293E-03	-2.53085E-03	1.00144E 00
12	0.0		1.75166E-24	5.77067E-04	3.17261E-02	5.90256E-04	2.82301E-05	-4.27775E-05	1.00118E 00
13	0.0		2.78147E-25	5.90257E-04	2.75812E-02	5.62640E-04	4.18379E-05	-1.54153E-05	1.00101E 00
14	0.0		5.51215E-26	5.62640E-04	2.66408E-02	5.02426E-04	7.09655E-05	-1.17756E-05	1.00091E 00
15	0.0		6.22937E-27	5.31540E-04	1.30685E-02	5.34851E-04	5.24755E-05	-5.60619E-05	1.00026E 00
16	0.0		1.82915E-27	6.04841E-04	7.23087E-03	6.26421E-04	3.40736E-05	-5.58135E-05	1.00013E 00
17	0.0		5.89075E-28	7.03468E-04	2.83952E-03	6.98959E-04	1.71543E-05	-1.27256E-05	1.00006E 00
18	0.0		4.21761E-28	7.42202E-04	2.31694E-03	7.48128E-04	1.58664E-05	-2.18542E-05	1.00004E 00
19	0.0		5.98279E-28	7.56027E-04	4.99966E-03	7.37656E-04	3.23909E-05	-1.41263E-05	1.00007E 00
20	0.0		9.69614E-28	8.91010E-04	1.80608E-02	7.67830E-04	1.34284E-04	-1.12839E-05	1.00010E 00
21	0.0		1.41920E-28	9.80058E-04	4.53498E-03	1.08324E-03	4.99616E-05	-1.53299E-04	1.00008E 00
22	0.0		1.66659E-28	1.34028E-03	9.16402E-03	1.22474E-03	1.06777E-04	8.60170E-06	1.00006E 00
23	0.0		1.57433E-28	2.33713E-03	3.06073E-02	2.24708E-03	4.63520E-04	-3.74019E-04	1.00012E 00
24	0.0		4.28512E-29	4.26920E-03	3.65065E-02	5.00995E-03	8.50406E-04	-1.59091E-03	9.99970E-01
25	0.0		1.25440E-29	5.36379E-03	2.04133E-02	5.25410E-03	6.94312E-04	-5.84602E-04	9.99998E-01
26	0.0		8.79593E-30	2.72952E-03	1.93046E-02	2.55116E-03	8.42958E-04	-6.64413E-04	9.99967E-01
27	0.0		2.09612E-30	7.39710E-04	4.33574E-03	2.23393E-06	3.17120E-04	4.20380E-04	9.99984E-01
28	0.0		4.24363E-18	6.68076E-02	9.82552E-01	6.68076E-02	9.85115E-03	-9.89087E-03	1.00086E 00

GRP.	RT BDY FLUX	RT LEAKAGE	LFT BDY FLUX	LFT LEAKAGE	N2N RATE	FISS RATE	FLUX*D8**2	TOTAL FLUX
1	1.71579E-01	1.02451E-02	1.73676E-01	1.22952E-02	7.55557E-23	3.09906E-22	0.0	2.75808E-02
2	1.23403E 00	1.15665E-01	1.25652E 00	1.28862E-01	1.75275E-23	3.42768E-21	0.0	1.98941E-01
3	1.52569E 00	1.52521E-01	1.55477E 00	1.61941E-01	0.0	4.46014E-21	0.0	2.46113E-01
4	9.28481E-01	9.78240E-02	9.46576E-01	9.80081E-02	0.0	2.43476E-21	0.0	1.49849E-01
5	1.36576E 00	1.49371E-01	1.39320E 00	1.45057E-01	0.0	2.82343E-21	0.0	2.20522E-01
6	2.43852E 00	2.49201E-01	2.48593E 00	2.38376E-01	0.0	4.55830E-21	0.0	3.93687E-01
7	2.35986E 00	1.37120E-01	2.38554E 00	1.29625E-01	0.0	5.01550E-21	0.0	3.79382E-01
8	1.74349E 00	1.48404E-02	1.74659E 00	1.85206E-02	0.0	5.45433E-21	0.0	2.79004E-01
9	1.36179E 00	-1.09344E-02	1.35938E 00	-1.41191E-02	0.0	7.69995E-21	0.0	2.17605E-01
10	1.26155E 00	-1.68820E-02	1.25865E 00	-1.54136E-02	0.0	1.66590E-20	0.0	2.01504E-01
11	1.19032E 00	-3.94764E-02	1.18362E 00	-3.69456E-02	0.0	3.55057E-20	0.0	1.89821E-01
12	7.72543E-01	-4.79582E-02	7.64195E-01	-4.79154E-02	0.0	4.81186E-20	0.0	1.22911E-01
13	6.71117E-01	-4.16865E-02	6.63822E-01	-4.16711E-02	0.0	4.70052E-20	0.0	1.06771E-01
14	6.49045E-01	-6.21367E-02	6.38205E-01	-6.21249E-02	0.0	4.15807E-20	0.0	1.02976E-01
15	3.22936E-01	-5.08133E-03	3.22000E-01	-5.02527E-03	0.0	8.19437E-21	0.0	5.15708E-02
16	1.86658E-01	-3.31529E-03	1.86091E-01	-3.25948E-03	0.0	4.98090E-21	0.0	2.98064E-02
17	8.41852E-02	-3.07823E-03	8.36608E-02	-3.06551E-03	0.0	7.76339E-21	0.0	1.34231E-02
18	7.29945E-02	-3.57297E-03	7.23870E-02	-3.55111E-03	0.0	1.05364E-20	0.0	1.16272E-02
19	1.36450E-01	-4.91247E-03	1.35657E-01	-4.89834E-03	0.0	1.27846E-20	0.0	2.17642E-02
20	4.48011E-01	-1.72796E-02	4.45101E-01	-1.72683E-02	0.0	5.46627E-20	0.0	7.14255E-02
21	1.34044E-01	-9.85768E-03	1.32409E-01	-9.70438E-03	0.0	3.02736E-20	0.0	2.13124E-02
22	2.48195E-01	-2.28119E-02	2.44420E-01	-2.28205E-02	0.0	7.39600E-20	0.0	3.94093E-02
23	7.85312E-01	-8.22035E-02	7.72485E-01	-8.18295E-02	0.0	2.57957E-19	0.0	1.24638E-01
24	9.95419E-01	-1.60299E-01	9.71954E-01	-1.58709E-01	0.0	5.10944E-19	0.0	1.57474E-01
25	6.16920E-01	-1.28948E-01	5.98954E-01	-1.28363E-01	0.0	4.44763E-19	0.0	9.73712E-02
26	5.27269E-01	-1.56995E-01	5.06704E-01	-1.56331E-01	0.0	5.65643E-19	0.0	8.29117E-02
27	1.05554E-01	-5.14300E-02	9.89233E-02	-5.18504E-02	0.0	2.19916E-19	0.0	1.64559E-02
28	2.23358E 01	5.79057E-02	2.23790E 01	6.77969E-02	7.55557E-05	2.42783E-18	0.0	3.57585E 00

FINE GROUP SUMMARY FOR ZONE 4 BY GROUP INCLUDING SUM FOR ALL GROUPS IN LINE 28

GRP.	FIX	SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0		5.33391E-19	0.0	7.34522E-03	9.72312E-03	5.18103E-04	-1.02410E-02	4.29545E-12
2	0.0		4.76438E-18	5.57829E-03	9.12372E-02	1.19939E-01	1.28296E-03	-1.15643E-01	9.99990E-01
3	0.0		5.43636E-18	5.69362E-02	8.04580E-02	2.09422E-01	3.06954E-06	-1.52488E-01	9.99993E-01
4	0.0		3.15027E-18	8.23942E-02	5.24318E-02	1.80193E-01	1.83660E-06	-9.78018E-02	1.00000E 00
5	0.0		4.20303E-18	1.50394E-01	1.65408E-01	2.99737E-01	2.70870E-06	-1.49346E-01	1.00000E 00
6	0.0		4.56493E-18	3.11358E-01	4.71470E-01	5.60[illegible]4E-01	5.17131E-06	-2.49154E-01	9.99997E-01
7	0.0		2.26763E-18	5.86565E-01	8.14802E-01	7.[illegible]3637E-01	8.75876E-06	-1.37069E-01	9.99990E-01
8	0.0		3.50236E-19	7.59287E-01	1.03228E 00	7.74136E-01	2.09089E-05	-1.47913E-02	9.99951E-01
9	0.0		2.54349E-20	7.64243E-01	9.51157E-01	7.53317E-01	4.95715E-05	1.097[illegible]1E-02	9.99935E-01
10	0.0		1.88939E-21	7.49058E-01	9.10863E-01	7.32102E-01	1.12515E-04	1.69272E-02	9.99944E-01
11	0.0		1.48647E-27	7.35343E-01	8.71226E-01	6.95632E-01	2.49271E-04	3.95230E-02	9.99958E-01
12	0.0		1.04422E-2[illegible]	6.02133E-01	4.70621E-01	5.53820E-01	3.32254E-04	4.79967E-02	9.99987E-01
13	0.0		1.65[illegible]13E-24	5.42071E-01	3.89717E-01	4.99857E-01	5.11819E-04	4.17211E-02	9.99982E-01
14	0.0		3.28[illegible] 25	5.34539E-01	3.94642E-01	4.71494E-01	8.84482E-04	6.21691E-02	9.99991E-01
15	0.0		3.71354E-26	2.99605E-01	1.37886E-01	2.93854E-01	6.58682E-04	5.09514E-03	9.99995E-01
16	0.0		1.09041E-26	1.92033E-01	5.92395E-02	1.88241E-01	4.70108E-04	3.32314E-03	9.99997E-01
17	0.0		3.51167E-27	9.86218E-02	1.76053E-02	9.53009E-02	2.38080E-04	3.08202E-03	1.00000E 00
18	0.0		2.51426E-27	8.78034E-02	1.51858E-02	8.40061E-02	2.21043E-04	3.57623E-03	1.00000E 00
19	0.0		3.55462E-27	1.49719E-01	4.23221E-02	1.44352E-01	4.49428E-04	4.91778E-03	9.99998E-01
20	0.0		5.78018E-27	3.66098E-01	2.95653E-01	3.46946E-01	1.86459E-03	1.72926E-02	9.99992E-01
21	0.0		8.46032E-28	1.58686E-01	6.27332E-02	1.48122E-01	7.01459E-04	9.8[illegible]424E-03	9.99994E-01
22	0.0		9.81589E-28	2.70747E-01	1.70538E-01	2.44623E-01	1.50709E-03	2.28191E-02	9.99995E-01
23	0.0		9.38507E-28	6.63900E-01	9.60670E-01	5.75115E-01	6.57842E-03	8.22155E-02	9.99994E-01
24	0.0		2.55450E-28	9.94099E-01	1.61493E 00	8.21448E-01	1.23463E-02	1.60306E-01	9.99999E-01
25	0.0		7.47790E-29	9.17842E-01	1.08084E 00	7.79583E-01	1.03103E-02	1.28949E-01	1.00000E 00
26	0.0		5.24354E-29	8.13485E-01	1.45125E 00	6.43395E-01	1.30902E-02	1.56999E-01	1.00000E 00
27	0.0		1.24957E-29	2.95741E-01	3.70050E-01	2.38904E-01	5.40648E-03	5.14307E-02	1.00000E 00
28	0.0		2.52976E-17	1.11883E 01	1.29826E 01	1.11882E 01	5.78256E-02	-5.73544E-02	9.99982E-01

GRP.	RT BDY FLUX	RT LEAKAGE	LFT BDY FLUX	LFT LEAKAGE	N2N RATE	FISS RATE	FLUX*DB**2	TOTAL FLUX
1	1.70187E-01	4.11533E-06	1.71579E-01	1.02451E-02	2.66769E-21	3.85044E-21	0.0	1.49594E-01
2	1.21603E 00	2.17439E-05	1.23403E 00	1.15665E-01	9.42240E-23	1.84264E-20	0.0	1.06946E 00
3	1.50014E 00	3.34887E-05	1.52569E 00	1.52521E-01	0.0	2.39170E-20	0.0	1.31975E 00
4	9.10683E-01	2.21846E-05	9.28481E-01	9.78240E-02	0.0	1.30223E-20	0.0	8.01464E-01
5	1.33695E 00	2.44442E-05	1.36576E 00	1.49371E-01	0.0	1.50682E-20	0.0	1.17689E 00
6	2.38961E 00	4.67702E-05	2.43892E 00	2.49201E-01	0.0	2.43535E-20	0.0	2.10333E 00
7	2.33298E 00	5.13578E-05	2.35986E 00	1.37120E-01	0.0	2.71219E-20	0.0	2.05135E 00
8	1.74334E 00	4.40337E-05	1.74349E 00	1.48404E-02	0.0	2.99368E-20	0.0	1.53135E 00
9	1.38415E 00	4.13622E-05	1.36179E 00	-1.09344E-02	0.0	4.24112E-20	0.0	1.19856E 00
10	1.26560E 00	4.52606E-05	1.26155E 00	-1.68820E-02	0.0	9.1[illegible]728E-20	0.0	1.11188E 00
11	1.19956E 00	4.65311E-05	1.19032E 00	-3.94764E-02	0.0	1.97050E-19	0.0	1.05347E 00
12	7.82957E-01	3.84780E-05	7.72543E-01	-4.79582E-02	0.0	2.69118E-19	0.0	6.87417E-01
13	6.79739E-01	3.45950E-05	6.71117E-01	-4.16865E-02	0.0	2.62787E-19	0.0	5.96914E-01
14	6.62207E-01	3.23742E-05	6.49045E-01	-6.21367E-02	0.0	2.34679E-19	0.0	5.[illegible]1192E-01
15	3.23000E-01	1.38132E-05	3.22936E-01	-5.08133E-03	0.0	4.51438E-20	0.0	2.84109E-01
16	1.87030E-01	7.84771E-06	1.86658E-01	-3.31529E-03	0.0	2.74778E-20	0.0	1.64431E-01
17	8.47927E-02	3.78672E-06	8.41852E-02	-3.07823E-03	0.0	4.30850E-20	0.0	7.44948E-02
18	7.37557E-02	3.26544E-06	7.29945E-02	-3.57297E-03	0.0	5.86994E-20	0.0	6.47763E-02
19	1.37467E-01	5.31842E-06	1.36490E-01	-4.91247E-03	0.0	7.09398E-20	0.0	1.20767E-01
20	4.51633E-01	1.29871E-05	4.48011E-01	-1.72796E-02	0.0	3.03597E-19	0.0	3.96697E-01
21	1.36409E-01	6.56785E-06	1.34044E-01	-9.85768E-03	0.0	1.70010E-19	0.0	1.19686E-01
22	2.53670E-01	7.[illegible]7615E-06	2.48195E-01	-2.28119E-02	0.0	4.17542E-19	0.0	2.22485E-01
23	8.07729E-01	1.19866E-05	7.85312E-01	-8.22035E-02	0.0	1.46434E-18	0.0	7.07533E-01
24	1.04827E 00	7.[illegible]3470E-06	9.95419E-01	-1.60299E-01	0.0	2.96680E-18	0.0	9.14377E-01
25	6.66173E-01	1.49765E-06	6.16920E-01	-1.28948E-01	0.0	2.64077E-18	0.0	5.78140E-01
26	5.99864E-01	3.43766E-06	5.27269E-01	-1.56995E-01	0.0	3.51288E-18	0.0	5.14916E-01
27	1.33475E-01	7.37749E-07	1.05594E-01	-5.14300E-02	0.0	1.49946E-18	0.0	1.12202E-01
28	2.24551E 01	5.72048E-04	2.23358E 01	5.79057E-02	2.76191E-21	1.44744E-17	0.0	1.97073E 01

FINE GROUP SUMMARY FOR SYSTEM

GRP.	FIX SOURCE	FISS SOURCE	IN SCATTER	SLF SCATTER	OUT SCATTER	ABSORPTION	LEAKAGE	BALANCE
1	0.0	2.13684E-02	0.0	2.02155E-02	2.01817E-02	3.09308E-03	4.11533E-06	9.99448E-01
2	0.0	1.89161E-01	7.79475E-03	2.39907E-01	1.84977E-01	1.19816E-02	2.17439E-05	9.99975E-01
3	0.0	2.15033E-01	7.92595E-02	2.38419E-01	2.82237E-01	1.20287E-02	3.34887E-05	9.99987E-01
4	0.0	1.24422E-01	1.15830E-01	1.60019E-01	2.34546E-01	5.66844E-03	2.21846E-05	1.00003E 00
5	0.0	1.65849E-01	2.09651E-01	4.08727E-01	3.72048E-01	3.41054E-03	2.44442E-05	1.00017E 00
6	0.0	1.79962E-01	4.24303E-01	1.05804E 00	5.99087E-01	5.09652E-03	4.67702E-05	1.00003E 00
7	0.0	8.93310E-02	6.64554E-01	1.45235E 00	7.48334E-01	5.49109E-03	5.13578E-05	1.00000E 00
8	0.0	1.37922E-02	7.89174E-01	1.55116E 00	7.93237E-01	9.76077E-03	4.40337E-05	9.99953E-01
9	0.0	1.00152E-03	7.83526E-01	1.41976E 00	7.67879E-01	1.66968E-02	4.13622E-05	9.99943E-01
10	0.0	7.43952E-05	7.63636E-01	1.27077E 00	7.39851E-01	2.38876E-02	4.52606E-05	9.99952E-01
11	0.0	5.85301E-06	7.43093E-01	1.20891E 00	7.01847E-01	4.12566E-02	4.65311E-05	9.99965E-01
12	0.0	4.11165E-07	6.08348E-01	6.73715E-01	5.61149E-01	4.71691E-02	3.84780E-05	9.99983E-01
13	0.0	6.52892E-08	5.49400E-01	5.45404E-01	5.04974E-01	4.44079E-02	3.45950E-05	9.99987E-01
14	0.0	1.29386E-08	5.39655E-01	5.38847E-01	4.77876E-01	6.17[illegible]-02	3.23742E-05	9.99995E-01
15	0.0	1.46221E-09	3.06078E-01	2.08189E-01	3.00370E-01	5.69[illegible]-03	1.38132E-05	9.99997E-01
16	0.0	4.29353E-10	1.98752E-01	9.67030E-02	1.95626E-01	3.11[illegible]-03	7.84771E-06	9.99999E-01
17	0.0	1.38273E-10	1.04896E-01	3.14240E-02	1.01621E-01	3.2[illegible]-03	3.78672E-06	1.00000E 00
18	0.0	9.89993E-11	9.38379E-02	2.64766E-02	9.00991E-02	3.7[illegible]-03	3.26544E-06	1.00000E 00
19	0.0	1.39964E-10	1.57184E-01	6.70507E-02	1.52365E-01	4.[illegible]E-03	5.31842E-06	9.99999E-01
20	0.0	2.27596E-10	3.75536E-01	3.94970E-01	3.55371E-01	2.[illegible]E-02	1.29871E-05	9.99993E-01
21	0.0	3.33126E-11	1.67090E-01	8.61804E-02	1.56509E-01	1.[illegible]6E-02	6.56785E-06	9.99996E-01
22	0.0	3.86502E-11	2.82302E-01	2.18974E-01	2.56449E-01	2[illegible]84E-02	7.17615E-06	9.99996E-01
23	0.0	3.69539E-11	6.82475E-01	1.12806E 00	5.92327E-01	9.0[illegible]42E-02	1.19866E-05	9.99994E-01
24	0.0	1.00584E-11	1.02573E 00	1.80894E 00	8.56774E-01	1.68958E-01	7.08470E-06	9.99997E-01
25	0.0	2.94444E-12	9.53978E-01	1.18712E 00	8.11897E-01	1.42081E-01	1.49765E-[illegible]	9.99999E-01
26	0.0	2.06466E-12	8.34680E-01	1.54792E 00	6.62310E-01	1.72368E-01	3.43766E-06	9.99999E-01
27	0.0	4.92018E-13	3.01467E-01	3.88115E-01	2.42221E-01	5.92452E-02	7.37749E-07	9.99999E-01
28	0.0	9.99999E-01	1.17622E 01	1.79763E 01	1.17622E 01	1.00171E 00	5.72244E-04	9.99988E-01

GRP.	RT BDY FLUX	RT LEAKAGE	LFT BDY FLUX	LFT LEAKAGE	N2N RATE	FISS RATE	FLUX*D8**2	TOTAL FLUX
1	1.70187E-01	4.11533E-06	1.80192E-01	0.0	1.88482E-03	2.10472E-03	0.0	2.74700E-01
2	1.21603E 00	2.17439E-05	1.32496E 00	0.0	1.46656E-05	9.28960E-03	0.0	1.98088E 00
3	1.50014E 00	3.34887E-05	1.63943E 00	0.0	0.0	1.11462E-02	0.0	2.44724E 00
4	9.10683E-01	2.21846E-05	9.97417E-01	0.0	0.0	4.73666E-03	0.0	1.48756E 00
5	1.33695E 00	2.44442E-05	1.47029E 00	0.0	0.0	1.40615E-03	0.0	2.18716E 00
6	2.38961E 00	4.67702E-05	2.61420E 00	0.0	0.0	1.23596E-03	0.0	3.90261E 00
7	2.33258E 00	5.13578E-05	2.45805E 00	0.0	0.0	1.27477E-03	0.0	3.76335E 00
8	1.74334E 00	4.40337E-05	1.75875E 00	0.0	0.0	1.36020E-03	0.0	2.77296E 00
9	1.36415E 00	4.13622E-05	1.34991E 00	0.0	0.0	1.89891E-03	0.0	2.15931E 00
10	1.26560E 00	4.52606E-05	1.24974E 00	0.0	0.0	4.11122E-03	0.0	2.00150E 00
11	1.19556E 00	4.65311E-05	1.16207E 00	0.0	0.0	8.68017E-03	0.0	1.88625E 00
12	7.82957E-01	3.84780E-05	7.35224E-01	0.0	0.0	1.12066E-02	0.0	1.22066E 00
13	6.79739E-01	3.45950E-05	6.38969E-01	0.0	0.0	1.05955E-02	0.0	1.05021E 00
14	6.62207E-01	3.23742E-05	6.00893E-01	0.0	0.0	8.25621E-03	0.0	1.02267E 00
15	3.23000E-01	1.38132E-05	3.18777E-01	0.0	0.0	1.99320E-03	0.0	5.11434E-01
16	1.87030E-01	7.84771E-06	1.84167E-01	0.0	0.0	1.22497E-03	0.0	2.95783E-01
17	8.47927E-02	3.78672E-06	8.18949E-02	0.0	0.0	1.89354E-03	0.0	1.33282E-01
18	7.37597E-02	3.26544E-06	7.03415E-02	0.0	0.0	2.55585E-03	0.0	1.15490E-01
19	1.37467E-01	5.31842E-06	1.32821E-01	0.0	0.0	3.11895E-03	0.0	2.16101E-01
20	4.51633E-01	1.29871E-05	4.35119E-01	0.0	0.0	1.33202E-02	0.0	7.09292E-01
21	1.36409E-01	6.56785E-06	1.26809E-01	0.0	0.0	7.26563E-03	0.0	2.11908E-01
22	2.53670E-01	7.17615E-06	2.30956E-01	0.0	0.0	1.75803E-02	0.0	3.91799E-01
23	8.07729E-01	1.19866E-05	7.24800E-01	0.0	0.0	6.10263E-02	0.0	1.24114E 00
24	1.04827E 00	7.08470E-06	8.79132E-01	0.0	0.0	1.17845E-01	0.0	1.57604E 00
25	6.66173E-01	1.49765E-06	5.22504E-01	0.0	0.0	1.00142E-01	0.0	9.80113E-01
26	5.99864E-01	3.43766E-06	4.11047E-01	0.0	0.0	1.21483E-01	0.0	8.45663E-01
27	1.33475E-01	7.37749E-07	6.38618E-02	0.0	0.0	4.10690E-02	0.0	1.71675E-01
28	2.24551E 01	5.72048E-04	2.23598E 01	0.0	1.89948E-03	5.67904E-01	0.0	3.55665E 01

ELAPSED TIME 0.71 MIN.

DIRECT ACCESS UNIT 9 REQUIRES 133 BLOCKS OF LENGTH 1652 FOR CROSS SECTION WEIGHTING.
TRANSPORT CROSS SECTION WEIGHTING FUNCTION

ZONE	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	2.99812E-03	3.16382E-02	3.99459E-02	2.42234E-02	3.59960E-02	5.99319E-02	3.26845E-02	4.68278E-03
2	2.67937E-01	2.15759E 00	2.63897E 00	1.47763E 00	2.02054E 00	2.81828E 00	1.25000E 00	8.68918E-02
3	4.02779E-03	4.36541E-02	5.61079E-02	3.49180E-02	5.24793E-02	8.68919E-02	4.75310E-02	5.96585E-03
4	1.46856E-03	1.65612E-02	2.18313E-02	1.39950E-02	2.13600E-02	3.56539E-02	1.97462E-02	2.32540E-03
5	5.94275E-03	5.40931E-02	6.77214E-02	3.98683E-02	5.71767E-02	8.76009E-02	4.39614E-02	4.65131E-03

ZONE	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	3.59554E-03	2.59560E-03	9.36636E-03	1.21423E-02	1.05654E-02	1.56843E-03	1.29387E-03	8.30491E-04
2	1.57643E-01	1.46527E-01	2.83024E-01	3.23345E-01	2.74473E-01	4.00827E-01	6.30069E-02	3.43650E-02
3	4.48126E-03	5.75136E-03	1.36140E-02	1.70941E-02	1.48628E-02	2.21560E-02	1.80197E-03	1.17201E-03
4	1.50189E-03	2.38687E-03	5.59316E-03	6.80873E-03	5.97046E-03	8.85326E-03	8.27207E-04	5.04158E-04
5	4.67010E-03	5.24389E-03	1.15245E-02	1.40203E-02	1.21281E-02	1.79157E-02	1.94570E-03	1.15101E-03

ZONE	GRP. 17	GRP. 18	GRP. 19	GRP. 20	GRP. 21	GRP. 22	GRP. 23	GRP. 24
1	7.77100E-04	8.99466E-04	1.24710E-03	4.39093E-03	2.45342E-03	5.76207E-03	2.06633E-02	3.97987E-02
2	3.17420E-02	3.93976E-02	5.72868E-02	2.15162E-01	1.12866E-01	2.58946E-01	8.65188E-01	1.58173E 00
3	1.09533E-03	1.27009E-03	1.74925E-03	6.16001E-03	3.48713E-03	8.13644E-03	2.92459E-02	5.68719E-02
4	4.42453E-04	5.08412E-04	7.08013E-04	2.48001E-03	1.39013E-03	3.23095E-03	1.18854E-02	2.33015E-02
5	1.05491E-03	1.25618E-03	1.77928E-03	6.44502E-03	3.50576E-03	8.12414E-03	2.84237E-02	5.38482E-02

ZONE	GRP. 25	GRP. 26	GRP. 27	GRP. 28
1	3.19748E-02	3.83892E-02	1.21525E-02	4.48040E-01
2	1.32037E 00	1.51115E 00	3.55692E-01	2.07504E 01
3	4.58761E-02	5.58204E-02	1.83754E-02	6.40588E-01
4	1.86957E-02	2.24580E-02	6.91454E-03	2.57391E-01
5	4.39572E-02	5.18253E-02	1.46616E-02	6.44478E-01

WHILE NEITHER XSDRNPM OR KENO-IV USES THE TRANSPORT CROSS SECTION, IT IS INTERESTING TO NOTE THAT:

XSDRNPM GENERATES TRANSPORT CROSS SECTIONS THAT ARE BASED ON THE SOLUTION OF BOTH THE CONSISTENT AND THE ORDINARY P_ℓ SLOWING DOWN EQUATIONS. THESE WILL BE REFERRED TO HERE AS THE INSCATTER AND THE OUTSCATTER APPROXIMATIONS BECAUSE OF THE FORM OF THE EQUATIONS USED FOR THE WEIGHTING. THE CROSS SECTIONS GENERATED WILL BE LISTED BELOW AS MT 1001 AND MT 1000 RESPECTIVELY. MATHEMATICALLY THEY ARE DEFINED AS:

"CONSISTENT" "INSCATTER" "MT 1001"

$$\sigma^G_{tr} \equiv \left(\sum_{g\in G} J^g\right)^{-1} \sum_k N^k \sum_{g\in G} \left| J^g \sigma^g_T - \frac{1}{3}\sum_{g'} J^{g'} \sigma_{P1}(g'\to g) \right|$$

SHOULD BE USED FOR "TRANSPORT CORRECTED" DIFFUSION THEORY CALCULATIONS

"ORDINARY" "OUTSCATTER" "MT 1000"

$$\sigma^G_{tr} \equiv \left(\sum_{g\in G} J^g\right)^{-1} \sum_k N^k \sum_{g\in G} J^g \left| \sigma^g_T - \frac{1}{3}\sum_{g'} \sigma_{P1}(g\to g') \right|$$

SHOULD BE USED FOR "TRANSPORT CORRECTED" P_0 DISCRETE ORDINATE CALCULATIONS

IN THE PRESENT CASE WE ARE NOT COLLAPSING DATA FROM A FINE GROUP LIBRARY TO A BROAD GROUP LIBRARY, AND, AS A RESULT, MT 1000 IS INDEPENDENT OF THE CURRENT J^g. NOTE HOWEVER THAT MT 1001 WILL ALWAYS DEPEND ON THE CURRENT. WITH ITP=0, XSDRNPM APPROXIMATES THIS WEIGHTING FUNCTION AS:

$$\sigma^g_n \sim \left| \int_{\text{zone } n} \phi^g_1(\underline{r})\, d\underline{r} \right| \quad \text{WHERE } \phi^g_1(\underline{r}) \text{ IS THE FIRST MOMENT OF THE ANGULAR FLUX AT POINT } \underline{r} \text{ IN ZONE } n.$$

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP
H 1269 F, 1002 T 218 GP 032475(2)
CELL WEIGHTED CROSS SECTIONS FOR XSDRN MATERIAL 1001

THE WORKING CROSS SECTION LIBRARY PRODUCED BY XSDRNPM FOR KENO INCLUDES MICROSCOPIC DATA FOR NUCLIDE #1001. A PARTIAL EDIT FOLLOWS.

XSEC GRP. ID	MT #1	MT #2	MT #27	MT #101	MT #102	MT #1099	MT #1000	MT #1001
1	1.16075E 00	1.16071E 00	3.38030E-05	3.38030E-05	3.38030E-05	6.39395E-03	9.71838E-02	1.96134E-01
2	1.85509E 00	1.85905E 00	3.51730E-05	3.51730E-05	3.51730E-05	4.61073E-02	1.96512E-01	4.52554E-01
3	2.59832E 00	2.59828E 00	3.38944E-05	3.38944E-05	3.38944E-05	5.69623E-02	2.86578E-01	5.93547E-01
4	3.20813E 00	3.20810E 00	3.34002E-05	3.34002E-05	3.34002E-05	3.46246E-02	3.85654E-01	7.15597E-01
5	3.88635E 00	3.88631E 00	3.35015E-05	3.35015E-05	3.35015E-05	5.09086E-02	4.97828E-01	9.15137E-01
6	5.39309E 00	5.39304E 00	3.58415E-05	3.58415E-05	3.58415E-05	9.08377E-02	7.51441E-01	1.08595E 00
7	9.28363E 00	9.28358E 00	6.29499E-05	6.29499E-05	6.29499E-05	8.75964E-02	1.41157E 00	6.93445E-01
8	1.57979E 01	1.57977E 01	2.03976E-04	2.03976E-04	2.03976E-04	6.45437E-02	2.63864E 00	-8.38107E 00
9	1.94890E 01	1.94884E 01	6.21072E-04	6.21072E-04	6.21072E-04	5.02604E-02	2.08326E 00	9.66049E-01
10	2.03351E 01	2.03336E 01	1.52088E-03	1.52088E-03	1.52088E-03	4.65871E-02	3.07443E 00	3.91257E 00
11	2.05914E 01	2.05878E 01	3.57525E-03	3.57525E-03	3.57525E-03	4.39047E-02	3.30258E 00	4.69996E 00
12	2.08120E 01	2.08046E 01	7.36392E-03	7.36392E-03	7.36392E-03	2.84122E-02	3.31398E 00	4.68369E 00
13	2.08125E 01	2.07995E 01	1.30606E-02	1.30606E-02	1.30606E-02	2.46776E-02	3.36185E 00	3.47996E 00
14	2.10184E 01	2.09950E 01	2.33983E-02	2.33983E-02	2.33983E-02	2.38039E-02	3.37960E 00	4.24772E 00
15	2.09987E 01	2.09639E 01	3.48434E-02	3.48616E-02	3.48616E-02	1.19042E-02	3.41215E 00	-1.17758E 01
16	2.08027E 01	2.07593E 01	4.29990E-02	4.30889E-02	4.30889E-02	6.88469E-03	3.68702E 00	-4.10726E 00
17	2.10754E 01	2.10311E 01	4.83263E-02	4.84286E-02	4.84286E-02	3.10229E-03	3.66728E 00	2.60223E 00
18	2.13940E 01	2.13423E 01	5.17803E-02	5.18906E-02	5.18906E-02	2.68817E-03	3.68253E 00	3.74246E 00
19	2.15388E 01	2.14825E 01	5.62647E-02	5.63856E-02	5.63856E-02	5.02999E-03	3.77469E 00	2.39523E 00
20	2.26910E 01	2.26199E 01	7.11197E-02	7.12764E-02	7.12764E-02	1.65096E-02	4.20888E 00	3.11848E 00
21	2.50994E 01	2.50099E 01	8.95547E-02	8.97564E-02	8.97564E-02	4.93239E-03	5.15899E 00	5.43042E 00
22	2.65743E 01	2.68702E 01	1.04066E-01	1.04304E-01	1.04304E-01	9.11957E-03	5.85013E 00	5.76183E 00
23	3.16873E 01	3.15439E 01	1.43396E-01	1.43735E-01	1.43735E-01	2.86889E-02	8.17511E 00	7.70318E 00
24	4.00546E 01	3.98427E 01	2.11936E-01	2.12454E-01	2.12454E-01	3.66840E-02	1.19353E 01	1.19089E 01
25	4.95788E 01	4.92943E 01	2.84595E-01	2.85308E-01	2.85308E-01	2.28132E-02	1.96332E 01	1.57055E 01
26	6.52792E 01	6.48605E 01	4.18775E-01	4.19847E-01	4.19847E-01	1.96838E-02	2.22766E 01	2.23835E 01
27	9.42414E 01	9.33894E 01	8.52003E-01	8.54215E-01	8.54215E-01	3.99593E-03	3.53902E 01	3.47314E 01

MT #1 $\Longrightarrow \sigma_T$

MT #2 $\Longrightarrow \sigma_{el}$

MT #27 $\Longrightarrow \sigma_A$ (SEE NOTE BELOW)

MT #101 $\Longrightarrow \sigma_g$ (SEE NOTE BELOW)

MT #102 $\Longrightarrow \sigma_{n,\gamma}$

MT #1099 $\Longrightarrow \bar{\phi}^g$ IN THE CELL

MT #1000 $\Longrightarrow \sigma_{tr}$ (SEE NOTE ABOVE)

MT #1001 $\Longrightarrow \sigma_{tr}$ (SEE NOTE ABOVE)

EACH MT NO. REPRESENTS A DIFFERENT INTERACTION PROCESS. THE USER IS REFERRED TO "APPENDIX C: DEFINITION OF REACTION TYPES USED IN AMPX," PP. 557-565 OF THE PSR-63/AMPX-II MANUAL DATED 11-30-78; SEE ALSO: "SAMPLE PROBLEMS FOR THE NOVICE USER OF THE AMPX-II SYSTEM," PP. 183-191, ORNL/CSD/TM-72.

BECAUSE THE CELL-WEIGHTING PRESERVES THE OVERALL REACTION RATES IN THE UNIT CELL AND BECAUSE NUCLIDE #1001 WAS FOUND ONLY IN ZONE 3, THIS DATA SHOULD BE USED TO REPRESENT THE HYDROGEN ONLY IN AN HOMOGENIZED FUEL ASSEMBLY. IT SHOULD NOT, FOR EXAMPLE, BE USED IN A KENO CALCULATION WHERE EACH FUEL PIN IS MODELED EXPLICITLY. LIKEWISE, IT SHOULD NOT BE USED FOR THE H IN THE WATER BETWEEN FUEL ASSEMBLIES, OR ELSEWHERE IN THE CASK.

THE WORKING CROSS SECTION LIBRARY PRODUCED BY XSDRNPM FOR KENO INCLUDES MICROSCOPIC DATA FOR NUCLIDE #11. A PARTIAL EDIT FOLLOWS.

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP
H 1269 F, 1002 T 218 GP 032475121
CELL WEIGHTED CROSS SECTIONS FOR XSDRN MATERIAL

XSEC GRP.	ID MT #1	MT #2	MT #27	MT #101	MT #102	MT #1099	MT #1000	MT #1001
1	1.17982E 00	1.17979E 00	3.43586E-05	3.43586E-05	3.43586E-05	1.73029E-21	3.93271E-01	7.93691E-01
2	1.90603E 00	1.90600E 00	3.60612E-05	3.60612E-05	3.60612E-05	1.24773E-20	6.35329E-01	1.47238E 00
3	2.66656E 00	2.66692E 00	3.47898E-05	3.47898E-05	3.47898E-05	1.54148E-20	8.88981E-01	1.82190E 00
4	3.29595E 00	3.29591E 00	3.43144E-05	3.43144E-05	3.43144E-05	9.36989E-21	1.09864E 00	1.95134E 00
5	3.95781E 00	3.99777E 00	3.44623E-05	3.44623E-05	3.44623E-05	1.33766E-20	1.33261E 00	2.05455E 00
6	5.53888E 00	5.53884E 00	3.68105E-05	3.68105E-05	3.68105E-05	2.45820E-20	1.84630E 00	2.48825E 00
7	9.42647E 00	9.42641E 00	6.39184E-05	6.39184E-05	6.39184E-05	2.37048E-20	3.14219E 00	9.71304E-01
8	1.58346E 01	1.58344E 01	2.04449E-04	2.04449E-04	2.04449E-04	1.74664E-20	5.27795E 00	-2.03925E 01
9	1.94349E 01	1.94343E 01	6.19347E-04	6.19347E-04	6.19347E-04	1.36017E-20	6.47798E 00	5.63649E 00
10	2.02619E 01	2.02604E 01	1.51540E-03	1.51540E-03	1.51540E-03	1.26071E-20	6.75447E 00	7.50196E 00
11	2.04079E 01	2.04044E 01	3.54340E-03	3.54340E-03	3.54340E-03	1.18812E-20	6.80495E 00	9.51065E 00
12	2.04542E 01	2.04490E 01	7.23803E-03	7.23803E-03	7.23803E-03	7.68873E-21	6.82416E 00	9.63227E 00
13	2.04618E 01	2.04489E 01	1.28405E-02	1.28405E-02	1.28405E-02	6.67811E-21	6.82916E 00	9.97859E 00
14	2.04718E 01	2.04490E 01	2.27897E-02	2.27897E-02	2.27897E-02	6.44166E-21	6.83909E 00	8.56609E 00
15	2.09235E 01	2.08887E 01	3.47186E-02	3.47368E-02	3.47368E-02	3.22144E-21	8.02584E 00	-2.16451E 01
16	2.07128E 01	2.06700E 01	4.28140E-02	4.29036E-02	4.29036E-02	1.86309E-21	8.41765E 00	-7.16364E 00
17	2.08757E 01	2.08279E 01	4.78594E-02	4.79607E-02	4.79607E-02	8.39524E-22	8.74370E 00	7.47470E 00
18	2.11135E 01	2.10624E 01	5.11012E-02	5.12101E-02	5.12101E-02	7.27455E-22	9.09879E 00	1.03217E 01
19	2.13338E 01	2.12781E 01	5.57292E-02	5.58490E-02	5.58490E-02	1.36119E-21	9.48603E 00	7.26568E 00
20	2.24573E 01	2.23870E 01	7.03874E-02	7.05424E-02	7.05424E-02	4.46773E-21	1.09380E 01	8.87285E 00
21	2.45983E 01	2.45105E 01	8.77666E-02	8.79642E-02	8.79642E-02	1.33477E-21	1.30105E 01	1.37545E 01
22	2.62936E 01	2.61922E 01	1.01440E-01	1.01672E-01	1.01672E-01	2.46788E-21	1.47100E 01	1.45530E 01
23	3.07677E 01	3.06285E 01	1.39235E-01	1.39564E-01	1.39564E-01	7.81773E-21	1.95505E 01	1.83764E 01
24	3.82148E 01	3.80126E 01	2.02202E-01	2.02696E-01	2.02696E-01	9.92721E-21	2.75819E 01	2.74898E 01
25	4.65240E 01	4.62570E 01	2.67060E-01	2.67729E-01	2.67729E-01	6.17358E-21	3.67567E 01	3.69053E 01
26	5.93435E 01	5.89629E 01	3.80697E-01	3.81672E-01	3.81672E-01	5.32671E-21	5.14068E 01	5.15458E 01
27	7.98154E 01	7.90938E 01	7.21583E-01	7.23457E-01	7.23457E-01	1.08[illegible]E-21	7.50410E 01	7.40307E 01

1. σ_T
2. σ_{el}
4. σ_{inel} (total)
16. $\sigma_{n,2n}$ (direct)
17. $\sigma_{n,3n}$
18. σ_f
22. $\sigma_{n,n'a}$
27. σ_A
28. $\sigma_{n,n'p}$

51. $\sigma_{n,n'}$ (1st Excited State)
90. $\sigma_{n,n'}$ (40th Excited State)
91. $\sigma_{n,n'}$ (continuum)

101. σ_g
102. $\sigma_{n,\gamma}$
103. $\sigma_{n,p}$
104. $\sigma_{n,d}$
105. $\sigma_{n,t}$
106. $\sigma_{n,^3He}$
107. $\sigma_{n,a}$
113. $\sigma_{n,t2a}$

251. $\bar{\mu}_L^{el}$
252. ξ^{el}
253. $\overline{\xi^2}/2\bar{\xi}$
452. $\bar{\nu}$
1000. σ_{tr} (see previous remarks)
1001. σ_{tr} (see previous remarks)

$$\sigma_{MT=4} = \sum_{i=1}^{41} \sigma_{MT=(50+i)}$$

$$\sigma_{MT=101} = \sum_{i=2}^{14} \sigma_{MT=(100+i)}$$

$$\sigma_{MT=27} = \sigma_{MT=18} + \sigma_{MT=101}$$

1007. σ_a^g (for thermal groups only)
1008. χ^g
1021. $\sigma_{n,\gamma}$ (res. only)
1022. σ_p (res. only)
1023. σ_{el} (res. only)
1099. $\bar{\phi}^g$

BECAUSE NUCLIDE #11 WAS PRESENT IN EVERY ZONE OF THE UNIT CELL WITH THE SAME NEGLIGIBLE NUMBER DENSITY (1.0E-20), THE CROSS SECTION DATA FOR THIS NUCLIDE WAS UNCHANGED BY THE CELL WEIGHTING. BECAUSE IT WAS UNCHANGED, THIS DATA IS SUITABLE FOR THE H IN THE WATER BETWEEN FUEL ASSEMBLIES OR ELSEWHERE IN THE CASK. NOTE THAT THIS DATA IS SIGNIFICANTLY DIFFERENT FROM THAT LISTED FOR NUCLIDE #1001 ON THE PREVIOUS PAGE.

FOR BREVITY, THE NEXT 28 PAGES OF OUTPUT HAVE NOT BEEN INCLUDED HERE.

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP
U-238 1262 SIGP=5*4 NEWXLACS 218NGP P-3 293K(3)
CELL WEIGHTED CROSS SECTIONS FOR XSDRN MATERIAL 92238

THE WORKING CROSS SECTION LIBRARY PRODUCED BY [redacted] FOR KENO INCLUDES MICROSCOPIC DATA FOR NUCLIDE #92238. A PARTIAL EDIT FOLLOWS. SEE NOTE ON NEXT PAGE.

XSEC ID GRP.	MT #1	MT #2	MT #4	MT #16	MT #8	MT #1023	MT #17	MT #27
1	6.64057E 00	3.55355E 00	1.23564E 00	8.71466E-01	9.70634E-01	0.0	6.01457E-03	9.74303E-01
2	8.10916E 00	4.90964E 00	2.59628E 00	7.08496E-04	5.87801E-01	0.0	0.0	6.02535E-01
3	7.77550E 00	4.57144E 00	2.59707E 00	0.0	5.65791E-01	0.0	0.0	6.06991E-01
4	7.33247E 00	4.19071E 00	2.68430E 00	0.0	3.82595E-01	0.0	0.0	4.57467E-01
5	7.39087E 00	4.76716E 00	2.46828E 00	0.0	4.27765E-02	0.0	0.0	1.55426E-01
6	8.41479E 00	6.37345E 00	1.91914E 00	0.0	2.11104E-03	0.0	0.0	1.22205E-01
7	1.05645E 01	9.27438E 00	1.15721E 00	0.0	7.27254E-05	0.0	0.0	1.32867E-01
8	1.32250E 01	1.27539E 01	9.66251E-02	0.0	5.93014E-05	0.0	0.0	3.74453E-01
9	1.80201E 01	1.72179E 01	0.0	0.0	3.04370E-05	-1.50137E 00	0.0	8.02147E-01
10	1.36838E 01	1.25751E 01	0.0	0.0	2.88165E-04	9.48526E 00	0.0	1.10872E 00
11	1.45641E 01	1.27363E 01	0.0	0.0	1.48792E-08	2.98474E 01	0.0	1.82782E 00
12	1.48821E 01	1.16140E 01	0.0	0.0	1.26245E-08	5.08923E 01	0.0	3.26814E 00
13	1.20804E 01	8.87613E 00	0.0	0.0	2.01897E-08	1.78336E 01	0.0	3.20424E 00
14	1.45561E 01	8.43766E 00	0.0	0.0	3.41819E-08	5.89942E 00	0.0	6.11845E 00
15	8.98838E 00	8.48687E 00	0.0	0.0	5.36451E-08	-2.65096E-02	0.0	5.01499E-01
16	9.14579E 00	8.66483E 00	0.0	0.0	6.60509E-08	-3.98612E-02	0.0	4.80971E-01
17	9.14212E 00	8.64929E 00	0.0	0.0	7.31420E-08	-2.55938E-02	0.0	4.92826E-01
18	9.13153E 00	8.62705E 00	0.0	0.0	7.76207E-08	-9.32935E-03	0.0	5.04489E-01
19	9.23622E 00	8.70384E 00	0.0	0.0	0.0	0.0	0.0	5.32382E-01
20	9.36196E 00	8.73550E 00	0.0	0.0	0.0	0.0	0.0	6.26455E-01
21	9.36152E 00	8.62408E 00	0.0	0.0	0.0	0.0	0.0	7.37436E-01
22	9.38580E 00	8.55579E 00	0.0	0.0	0.0	0.0	0.0	8.30008E-01
23	9.62272E 00	8.51671E 00	0.0	0.0	0.0	0.0	0.0	1.10601E 00
24	9.81789E 00	8.28035E 00	0.0	0.0	0.0	0.0	0.0	1.53754E 00
25	1.00061E 01	8.04438E 00	0.0	0.0	0.0	0.0	0.0	1.96177E 00
26	1.02162E 01	7.58793E 00	0.0	0.0	0.0	0.0	0.0	2.62823E 00
27	1.07239E 01	6.48049E 00	0.0	0.0	0.0	0.0	0.0	4.24338E 00

XSEC ID GRP.	MT #101	MT #102	MT #452	MT #1021	MT #1022	MT #1099	MT #1018	MT #51
1	3.66936E-03	3.66936E-03	3.53838E 00	0.0	0.0	1.34432E-03	2.36997E-02	0.0
2	1.47340E-02	1.47340E-02	2.95976E 00	0.0	0.0	9.69399E-03	1.95967E-01	1.05993E-01
3	4.11996E-02	4.11996E-02	2.68384E 00	0.0	0.0	1.19762E-02	2.16161E-01	2.10737E-01
4	7.48721E-02	7.48721E-02	2.57402E 00	0.0	0.0	7.27977E-03	1.23552E-01	2.65953E-01
5	1.12649E-01	1.12649E-01	2.51110E 00	0.0	0.0	1.07035E-02	1.63440E-01	6.92227E-01
6	1.20094E-01	1.20094E-01	2.44155E 00	0.0	0.0	1.90985E-02	1.75968E-01	1.38637E 00
7	1.32794E-01	1.32794E-01	2.36456E 00	0.0	0.0	1.84170E-02	8.68143E-02	1.08013E 00
8	3.74394E-01	3.74394E-01	2.32571E 00	0.0	0.0	1.35702E-02	1.33625E-02	9.66220E-02
9	8.02118E-01	8.02118E-01	2.32146E 00	1.47179E-01	0.0	1.05672E-02	9.69530E-04	0.0
10	1.10843E 00	1.10843E 00	2.31964E 00	2.04914E 00	5.12787E-04	9.79487E-03	7.20083E-05	0.0
11	1.82782E 00	1.82782E 00	2.31955E 00	1.15281E 01	0.0	9.23089E-03	5.66511E-06	0.0
12	3.26814E 00	3.26814E 00	2.31951E 00	4.49996E 01	0.0	5.97362E-03	3.97963E-07	0.0
13	3.20424E 00	3.20424E 00	2.31950E 00	5.53191E 01	0.0	5.18844E-03	6.31928E-08	0.0
14	6.11845E 00	6.11845E 00	2.31950E 00	1.05794E 02	0.0	5.00473E-03	1.25231E-08	0.0
15	5.01499E-01	5.01499E-01	2.31950E 00	0.0	0.0	2.50284E-03	1.41526E-09	0.0
16	4.80971E-01	4.80971E-01	2.31950E 00	0.0	0.0	1.44750E-03	4.15569E-10	0.0
17	4.92826E-01	4.92826E-01	2.31950E 00	0.0	0.0	6.52253E-04	1.33833E-10	0.0
18	5.04489E-01	5.04489E-01	2.31950E 00	0.0	0.0	5.65183E-04	9.58195E-11	0.0
19	5.32382E-01	5.32382E-01	0.0	0.0	0.0	1.05755E-03	1.35470E-10	0.0
20	6.26455E-01	6.26455E-01	0.0	0.0	0.0	3.47112E-03	2.20289E-10	0.0
21	7.37436E-01	7.37436E-01	0.0	0.0	0.0	1.03703E-03	3.22428E-11	0.0
22	8.30008E-01	8.30008E-01	0.0	0.0	0.0	1.91738E-03	3.74090E-11	0.0
23	1.10601E 00	1.10601E 00	0.0	0.0	0.0	6.07384E-03	3.57671E-11	0.0
24	1.53754E 00	1.53754E 00	0.0	0.0	0.0	7.71276E-03	9.73547E-12	0.0
25	1.96177E 00	1.96177E 00	0.0	0.0	0.0	4.79645E-03	2.84990E-12	0.0
26	2.62823E 00	2.62823E 00	0.0	0.0	0.0	4.13848E-03	1.99836E-12	0.0
27	4.24338E 00	4.24338E 00	0.0	0.0	0.0	8.40138E-04	4.76216E-13	0.0

XSEC ID GRP.	MT #52	MT #53	MT #54	MT #55	MT #56	MT #57	MT #58	MT #59
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3.08962E-03	3.08962E-03	4.63442E-03	2.47169E-03	2.16273E-03	4.63442E-03	6.17922E-03	4.63442E-03
3	5.65003E-02	1.73841E-02	5.41618E-02	4.49427E-02	1.62390E-02	5.28701E-02	4.75650E-02	5.88640E-02
4	1.95834E-01	3.45222E-02	1.42901E-01	1.46206E-01	5.25147E-02	1.48039E-01	1.35372E-01	1.59619E-01
5	4.37988E-01	4.74941E-02	3.01034E-01	2.43017E-01	7.46344E-02	1.56752E-01	1.46029E-01	1.06824E-01
6	3.63467E-01	2.96891E-02	9.90817E-02	4.01201E-02	2.87706E-04	0.0	0.0	0.0
7	7.56776E-02	1.29882E-03	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRPS	9 THRU	27 ARE THE SAME AS ABOVE						

XSEC ID GRP.	MT #60	MT #61	MT #62	MT #63	MT #64	MT #65	MT #66	MT #67
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	6.17922E-03	9.26885E-03	7.03016E-03	7.72404E-03	7.03016E-03	6.17923E-03	7.72404E-03	4.63442E-03
3	5.97267E-02	9.46898E-02	6.80974E-02	7.86117E-02	6.73510E-02	5.97894E-02	7.69158E-02	4.68783E-02
4	1.48327E-01	2.27250E-01	1.60503E-01	1.80790E-01	1.45898E-01	1.04022E-01	9.98002E-02	6.58092E-02
5	7.56774E-02	1.01364E-01	4.34593E-02	4.13778E-02	2.63720E-02	7.01697E-03	3.62536E-03	6.30944E-04
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRPS	7 THRU	27 ARE THE SAME AS ABOVE						

XSEC ID GRP.	MT #68	MT #69	MT #70	MT #71	MT #72	MT #73	MT #74	MT #75
1	0.0	0.0	0.0	0.0	0.0	1.34710E-02	1.34701E-02	1.34654E-02
2	6.17923E-03	9.26885E-03	2.16273E-02	1.50368E-01	1.49523E-01	2.93075E-03	2.10652E-03	9.76278E-04
3	4.28771E-02	8.65020E-02	2.15953E-01	3.70411E-01	2.81852E-01	6.66788E-04	0.0	0.0
4	4.11528E-02	8.09860E-02	1.08448E-01	4.01176E-02	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRPS	6 THRU	27 ARE THE SAME AS ABOVE						

XSEC ID GRP.	MT # 76	MT # 91	MT # 1007	MT # 1000	MT #1001
1	1.32577E-02	1.18191E 00	0.0	8.44120E 00	8.45545E 00
2	4.10635E-04	2.06006E 00	0.0	8.98477E 00	8.98515E 00
3	0.0	4.87780E-01	0.0	9.89269E 00	9.88636E 00
4	0.0	0.0	0.0	9.97611E 00	9.96544E 00
5	0.0	0.0	0.0	9.82584E 00	9.80342E 00
6	0.0	0.0	0.0	1.13567E 01	1.13495E 01
7	0.0	0.0	0.0	1.56234E 01	1.56640E 01
8	0.0	0.0	0.0	2.17652E 01	2.19097E 01
9	0.0	0.0	0.0	3.78493E 01	3.78287E 01
10	0.0	0.0	0.0	2.53110E 01	2.53497E 01
11	0.0	0.0	0.0	2.61002E 01	2.61078E 01
12	0.0	0.0	0.0	2.68746E 01	2.68699E 01
13	0.0	0.0	0.0	2.16554E 01	2.16476E 01
14	0.0	0.0	0.0	2.64261E 01	2.64155E 01
15	0.0	0.0	8.46037E 00	1.75605E 01	1.77458E 01
16	0.0	0.0	8.62496E 00	1.74487E 01	1.74487E 01
17	0.0	0.0	8.62370E 00	1.78150E 01	1.78150E 01
18	0.0	0.0	8.61772E 00	1.81888E 01	1.81888E 01
19	0.0	0.0	8.70385E 00	1.84678E 01	1.84678E 01
20	0.0	0.0	8.73552E 00	1.90187E 01	1.90187E 01
21	0.0	0.0	8.62408E 00	1.90329E 01	1.90329E 01
22	0.0	0.0	8.55580E 00	1.92208E 01	1.92208E 01
23	0.0	0.0	8.51671E 00	1.94173E 01	1.94173E 01
24	0.0	0.0	8.28035E 00	2.00741E 01	2.00741E 01
25	0.0	0.0	8.04438E 00	2.12323E 01	2.12323E 01
26	0.0	0.0	7.58793E 00	2.27160E 01	2.27160E 01
27	0.0	0.0	6.48049E 00	2.62224E 01	2.62224E 01

BECAUSE THE CELL WEIGHTING PRESERVES THE OVERALL REACTION RATES IN THE UNIT CELL AND BECAUSE NUCLIDE #92238 WAS FOUND ONLY IN ZONE 1, THIS DATA SHOULD BE USED TO REPRESENT THE U^{238} ONLY IN AN HOMOGENIZED FUEL ASSEMBLY. IT SHOULD NOT, FOR EXAMPLE, BE USED IN A KENO CALCULATION WHERE EACH FUEL PIN IS MODELED EXPLICITLY. LIKEWISE, IT SHOULD NOT BE USED FOR THE U^{238} IN THE DEPLETED URANIUM SHIELD, OR ANYWHERE ELSE IN THE CASK.

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP
U-238 1262 SIGP=544 NEWXLACS 218NGP P-3 293K(3)
CELL WEIGHTED CROSS SECTIONS FOR XSDRN MATERIAL

(4) THE WORKING CROSS SECTION LIBRARY PRODUCED BY XSDRNPM FOR KENO INCLUDES MICROSCOPIC DATA FOR NUCLIDE #4. A PARTIAL EDIT FOLLOWS. SEE NOTE ON NEXT PAGE.

XSEC GRP. ID	MT #1	MT #2	MT #4	MT #16	MT #18	MT #1023	MT #17	MT #27
1	6.46752E 00	3.46074E 00	1.20336E 00	8.48704E-01	9.45282E-01	0.0	5.85748E-03	9.48856E-01
2	7.79516E 00	4.71953E 00	2.49574E 00	6.81062E-04	5.65040E-01	0.0	0.0	5.79204E-01
3	7.46455E 00	4.38862E 00	2.49321E 00	0.0	5.43165E-01	0.0	0.0	5.82717E
4	7.03272E 00	4.01939E 00	2.57456E 00	0.0	3.66954E-01	0.0	0.0	4.38765E
5	7.07706E 00	4.56475E 00	2.36348E 00	0.0	4.09603E-02	0.0	0.0	1.48827E-01
6	8.07794E 00	6.11832E 00	1.84231E 00	0.0	2.02653E-03	0.0	0.0	1.17313E-01
7	1.03167E 01	9.05689E 00	1.13007E 00	0.0	7.10200E-05	0.0	0.0	1.29751E-01
8	1.31720E 01	1.27028E 01	9.62382E-02	0.0	5.90639E-05	0.0	0.0	3.72954E-01
9	1.77569E 01	1.69872E 01	0.0	0.0	3.05778E-05	-1.50832E 00	0.0	7.69681E-01
10	1.13301E 01	1.05978E 01	0.0	0.0	2.38573E-04	9.53913E 00	0.0	7.32331E-01
11	1.20611E 01	1.10384E 01	0.0	0.0	1.50924E-08	3.02752E 01	0.0	1.02270E 00
12	1.24273E 01	1.09248E 01	0.0	0.0	1.29848E-08	5.23449E 01	0.0	1.50247E 00
13	1.16685E 01	9.69553E 00	0.0	0.0	1.07583E-08	1.83359E 01	0.0	1.97297E 00
14	1.41018E 01	1.04558E 01	0.0	0.0	3.57114E-08	6.16231E 00	0.0	3.64596E 00
15	9.04332E 00	8.53876E 00	0.0	0.0	5.39731E-08	-2.66717E-02	0.0	5.04565E-01
16	9.21072E 00	8.72634E 00	0.0	0.0	6.65198E-08	-4.01442E-02	0.0	4.84386E-01
17	9.28683E 00	8.78621E 00	0.0	0.0	7.42997E-08	-2.59990E-02	0.0	5.00627E-01
18	9.32872E 00	8.81334E 00	0.0	0.0	7.92969E-08	-9.53081E-03	0.0	5.15383E-01
19	9.38021E 00	8.83953E 00	0.0	0.0	0.0	0.0	0.0	5.40682E-01
20	9.51986E 00	8.88284E 00	0.0	0.0	0.0	0.0	0.0	6.37021E-01
21	9.67280E 00	8.91085E 00	0.0	0.0	0.0	0.0	0.0	7.61957E-01
22	9.78753E 00	8.92199E 00	0.0	0.0	0.0	0.0	0.0	8.65533E-01
23	1.00970E 01	8.93648E 00	0.0	0.0	0.0	0.0	0.0	1.16052E 00
24	1.06110E 01	8.94924E 00	0.0	0.0	0.0	0.0	0.0	1.66175E 00
25	1.11320E 01	8.94949E 00	0.0	0.0	0.0	0.0	0.0	2.18250E 00
26	1.20527E 01	8.95197E 00	0.0	0.0	0.0	0.0	0.0	3.10069E 00
27	1.47971E 01	8.94197E 00	0.0	0.0	0.0	0.0	0.0	5.85514E 00

XSEC GRP. ID	MT #101	MT #102	MT #452	MT #102.	MT #1022	MT #1099	MT #1018	MT #51
1	3.57352E-03	3.57352E-03	3.53838E 00	0.0	0.0	1.73029E-21	2.36997E-02	0.0
2	1.41635E-02	1.41635E-02	2.95976E 00	0.0	0.0	1.24773E-20	1.95967E-01	1.01889E-01
3	3.95520E-02	3.95520E-02	2.68384E 00	0.0	0.0	1.54148E-20	2.16161E-01	2.02310E-01
4	7.18113E-02	7.18113E-02	2.57402E 00	0.0	0.0	9.36989E-21	1.23552E-01	2.55081E-01
5	1.07866E-01	1.07866E-01	2.51110E 00	0.0	0.0	1.37766E-20	1.63440E-01	6.62836E-01
6	1.15286E-01	1.15286E-01	2.44159E 00	0.0	0.0	2.45820E-20	1.75968E-01	1.33087E 00
7	1.29680E-01	1.29680E-01	2.36456E 00	0.0	0.0	2.37048E-20	8.68143E-02	1.05480E 00
8	3.72895E-01	3.72895E-01	2.32571E 00	0.0	0.0	1.74664E-20	1.33625E-02	9.62351E-02
9	7.69651E-01	7.69651E-01	2.32146E 00	1.47860E-01	0.0	1.36012E-20	9.69530E-04	0.0
10	7.32092E-01	7.32092E-01	2.31964E 00	2.06078E 00	3.14563E-04	1.26071E-20	7.20083E-05	0.0
11	1.02270E 00	1.02270E 00	2.31955E 00	1.16933E 01	0.0	1.18812E-20	5.66511E-06	0.0
12	1.50247E 00	1.50247E 00	2.31951E 00	4.62839E 01	0.0	7.68873E-21	3.97963E-07	0.0
13	1.97297E 00	1.97297E 00	2.31950E 00	5.68771E 01	0.0	6.67811E-21	6.31928E-08	0.0
14	3.64596E 00	3.64596E 00	2.31950E 00	1.10508E 02	0.0	6.44166E-21	1.25231E-08	0.0
15	5.04565E-01	5.04565E-01	2.31950E 00	0.0	0.0	3.22144E-21	1.41526E-09	0.0
16	4.84386E-01	4.84386E-01	2.31950E 00	0.0	0.0	1.86392E-21	4.15569E-10	0.0
17	5.00627E-01	5.00627E-01	2.31950E 00	0.0	0.0	8.39524E-22	1.33833E-10	0.0
18	5.15383E-01	5.15383E-01	2.31950E 00	0.0	0.0	7.27455E-22	9.58195E-11	0.0
19	5.40682E-01	5.40682E-01	0.0	0.0	0.0	1.36119E-21	1.35470E-10	0.0
20	6.37021E-01	6.37021E-01	0.0	0.0	0.0	4.46773E-21	2.20289E-10	0.0
21	7.61957E-01	7.61957E-01	0.0	0.0	0.0	1.33477E-21	3.22428E-11	0.0
22	8.65533E-01	8.65533E-01	0.0	0.0	0.0	7.46708E-21	3.74090E-11	0.0
23	1.16052E 00	1.16052E 00	0.0	0.0	0.0	7.81773E-21	3.57671E-11	0.0
24	1.66175E 00	1.66175E 00	0.0	0.0	0.0	9.92721E-21	9.73547E-12	0.0
25	2.18250E 00	2.18250E 00	0.0	0.0	0.0	6.17358E-21	2.84990E-12	0.0
26	3.10069E 00	3.10069E 00	0.0	0.0	0.0	5.32671E-21	1.99836E-12	0.0
27	5.85514E 00	5.85514E 00	0.0	0.0	0.0	1.08135E-21	4.76216E-13	0.0

XSEC ID GRP.	MT #52	MT #53	MT #54	MT #55	MT #56	MT #57	MT #58	MT #59
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.96998E-03	2.96998E-03	4.45496E-03	2.37598E-03	2.07898E-03	4.45496E-03	5.93995E-03	4.45496E-03
3	5.42403E-02	1.66889E-02	5.19959E-02	4.31454E-02	1.55896E-02	5.07557E-02	4.56629E-02	5.65100E-02
4	1.87828E-01	3.31109E-02	1.37059E-01	1.40230E-01	5.03679E-02	1.41987E-01	1.29838E-01	1.53094E-01
5	4.19392E-01	4.54776E-02	2.88252E-01	2.32699E-01	3.58737E-02	1.50097E-01	1.39828E-01	1.02288E-01
6	3.48917E-01	2.85006E-02	9.51154E-02	3.85141E-02	2.76190E-04	0.0	0.0	0.0
7	7.39030E-02	1.26836E-03	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRPS	9 THRU	27 ARE THE SAME AS ABOVE						

XSEC ID GRP.	MT #60	MT #61	MT #62	MT #63	MT #64	MT #65	MT #66	MT #67
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	5.93995E-03	8.90994E-03	6.75793E-03	7.42495E-03	6.75793E-03	5.93996E-03	7.42495E-03	4.45496E-03
3	5.73381E-02	9.09031E-02	6.53741E-02	7.54679E-02	6.46576E-02	5.73983E-02	7.38399E-02	4.50036E-02
4	1.42264E-01	2.17960E-01	1.53941E-01	1.73399E-01	1.39934E-01	9.97698E-02	9.97202E-02	6.31190E-02
5	7.24042E-02	9.70598E-02	4.16141E-02	3.96210E-02	2.52523E-02	6.71904E-03	3.47143E-03	6.04155E-04
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRPS	7 THRU	27 ARE THE SAME AS ABOVE						

XSEC ID GRP.	MT #68	MT #69	MT #70	MT #71	MT #72	MT #73	MT #74	MT #75
1	0.0	0.0	0.0	0.0	0.0	1.31192E-02	1.31187E-02	7.11378E-02
2	5.93996E-03	8.90994E-03	2.07899E-02	1.44546E-01	1.43733E-01	2.81726E-03	2.02495E-03	1.38476E-04
3	4.11625E-02	8.30427E-02	2.07317E-01	3.55598E-01	2.70580E-01	6.40122E-04	0.0	0.0
4	3.94705E-02	7.76753E-02	1.04014E-01	3.84776E-02	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRPS	6 THRU	27 ARE THE SAME AS ABOVE						

XSEC ID GRP.	MT #76	MT #91	MT #1007	MT #1000	MT #1001
1	1.29114E-02	1.15104E 00	0.0	3.67137E 00	3.67756E 00
2	3.94734E-04	1.98029E 00	0.0	4.14617E 00	4.14637E 00
3	0.0	4.68273E-01	0.0	4.63399E 00	4.63105E 00
4	0.0	0.0	0.0	4.80744E 00	4.80229E 00
5	0.0	0.0	0.0	4.84795E 00	4.83696E 00
6	0.0	0.0	0.0	5.81883E 00	5.81489E 00
7	0.0	0.0	0.0	8.40785E 00	8.42769E 00
8	0.0	0.0	0.0	1.26671E 01	1.27404E 01
9	0.0	0.0	0.0	1.76963E 01	1.76909E 01
10	0.0	0.0	0.0	1.13002E 01	1.13186E 01
11	0.0	0.0	0.0	1.20299E 01	1.20333E 01
12	0.0	0.0	0.0	1.23964E 01	1.23939E 01
13	0.0	0.0	0.0	1.16411E 01	1.16358E 01
14	0.0	0.0	0.0	1.40722E 01	1.40643E 01
15	0.0	0.0	8.51208E 00	9.04333E 00	9.16955E 00
16	0.0	0.0	8.68619E 00	9.21072E 00	9.21072E 00
17	0.0	0.0	8.76021E 00	9.28683E 00	9.28683E 00
18	0.0	0.0	8.80381E 00	9.32871E 00	9.32871E 00
19	0.0	0.0	8.83954E 00	9.38022E 00	9.38022E 00
20	0.0	0.0	8.88285E 00	9.51986E 00	9.51986E 00
21	0.0	0.0	8.91085E 00	9.67280E 00	9.67280E 00
22	0.0	0.0	8.92199E 00	9.78753E 00	9.78753E 00
23	0.0	0.0	8.93648E 00	1.00970E 01	1.00970E 01
24	0.0	0.0	8.94925E 00	1.06110E 01	1.06110E 01
25	0.0	0.0	8.94949E 00	1.11320E 01	1.11320E 01
26	0.0	0.0	8.95197E 00	1.20527E 01	1.20527E 01
27	0.0	0.0	8.94197E 00	1.47971E 01	1.47971E 01

BECAUSE NUCLIDE #4 WAS PRESENT IN EVERY ZONE OF THE UNIT CELL WITH THE SAME NEGLIGIBLE NUMBER DENSITY (1.0E-20), THE CROSS SECTION DATA FOR THIS NUCLIDE WAS UNCHANGED BY THE CELL WEIGHTING. BECAUSE IT WAS UNCHANGED, THIS DATA IS SUITABLE FOR THE U^{238} IN THE DEPLETED URANIUM SHIELD OR ANYWHERE ELSE IN THE CASK. NOTE THAT THIS DATA IS SIGNIFICANTLY DIFFERENT FROM THAT LISTED FOR NUCLIDE #92238 ON THE PREVIOUS PAGE.

SEVEN PWR FUEL ASSEMBLIES IN A SHIPPING CASK AT ROOM TEMP

CELL AVERAGED FLUXES

ZONE	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	1.77827E-01	1.29963E 00	1.60771E 00	9.78132E-01	1.44756E 00	2.56369E 00	2.42908E 00	1.75394E 00
2	1.73908E-01	1.25880E 00	1.55749E 00	9.48115E-01	1.39538E 00	2.46933E 00	2.38734E 00	1.74693E 00
3	1.72477E-01	1.24408E 00	1.53907E 00	9.37081E-01	1.37904E 00	2.46192E 00	2.37247E 00	1.74476E 00
4	1.70230E-01	1.21699E 00	1.50180E 00	9.12023E-01	1.33924E 00	2.39348E 00	2.33455E 00	1.74259E 00
5	1.73029E-01	1.24772E 00	1.54148E 00	9.36987E-01	1.37765E 00	2.45819E 00	2.37047E 00	1.74684E 00

AVERAGE FLUX IN EACH OF THE 4 ZONES

AVERAGE FLUX IN THE UNIT CELL

ZONE	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	1.35363E 00	1.25339E 00	1.17083E 00	7.46864E-01	6.48942E-01	6.15819E-01	3.20113E-01	1.84951E-01
2	1.35911E 00	1.25845E 00	1.18313E 00	7.63496E-01	6.63213E-01	6.37295E-01	3.21927E-01	1.86046E-01
3	1.36080E 00	1.26011E 00	1.18705E 00	7.68624E-01	6.67694E-01	6.43963E-01	3.22498E-01	1.86395E-01
4	1.36390E 00	1.26526E 00	1.19880E 00	7.82244E-01	6.79256E-01	6.61366E-01	3.23301E-01	1.87113E-01
5	1.36011E 00	1.26071E 00	1.18812E 00	7.68870E-01	6.67810E-01	6.44165E-01	3.22144E-01	1.86309E-01

ZONE	GRP. 17	GRP. 18	GRP. 19	GRP. 20	GRP. 21	GRP. 22	GRP. 23	GRP. 24
1	8.26031E-02	7.11603E-02	1.33963E-01	4.39130E-01	1.29052E-01	2.36346E-01	7.43945E-01	9.16366E-01
2	8.36174E-02	7.23369E-02	1.35588E-01	4.44858E-01	1.32275E-01	2.44097E-01	7.71365E-01	9.69843E-01
3	8.39413E-02	7.27109E-02	1.36103E-01	4.46660E-01	1.33278E-01	2.46447E-01	7.79425E-01	9.84768E-01
4	8.47712E-02	7.37120E-02	1.37426E-01	4.51420E-01	1.36196E-01	2.53177E-01	8.05135E-01	1.04051E 00
5	8.39521E-02	7.27453E-02	1.36118E-01	4.46772E-01	1.33477E-01	2.46788E-01	7.81770E-01	9.92718E-01

ZONE	GRP. 25	GRP. 26	GRP. 27
1	5.53143E-01	4.49272E-01	7.75354E-02
2	5.97261E-01	5.04723E-01	9.82299E-02
3	6.08912E-01	5.18489E-01	1.02907E-01
4	6.57893E-01	5.85947E-01	1.27679E-01
5	6.17357E-01	5.32670E-01	1.08135E-01

FLUX DISADVANTAGE FACTORS (ZONE AVERAGE/CELL AVERAGE-FLUX)

ZONE	GRP. 1	GRP. 2	GRP. 3	GRP. 4	GRP. 5	GRP. 6	GRP. 7	GRP. 8
1	1.02773E 00	1.04160E 00	1.04297E 00	1.04391E 00	1.04566E 00	1.04292E 00	1.02472E 00	1.00418E 00
2	1.00508E 00	1.00887E 00	1.01039E 00	1.01188E 00	1.01287E 00	1.01267E 00	1.00712E 00	1.00017E 00
3	9.96809E-01	9.97081E-01	9.98440E-01	1.00010E 00	1.00101E 00	1.00152E 00	1.00084E 00	9.98922E-01
4	9.83827E-01	9.75370E-01	9.74263E-01	9.73357E-01	9.72120E-01	9.73675E-01	9.84847E-01	9.97685E-01
5	1.00050E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00

ZONE	GRP. 9	GRP. 10	GRP. 11	GRP. 12	GRP. 13	GRP. 14	GRP. 15	GRP. 16
1	9.95230E-01	9.94191E-01	9.85453E-01	9.71378E-01	9.71746E-01	9.55996E-01	9.93696E-01	9.92713E-01
2	9.99266E-01	9.98209E-01	9.95805E-01	9.93010E-01	9.93116E-01	9.89335E-01	9.99326E-01	9.98587E-01
3	1.00050E 00	9.99525E-01	9.99101E-01	9.99679E-01	9.99826E-01	9.99687E-01	1.00110E 00	1.00046E 00
4	1.00278E 00	1.00361E 00	1.00899E 00	1.01739E 00	1.01714E 00	1.02670E 00	1.00359E 00	1.00432E 00
5	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00

ZONE	GRP. 17	GRP. 18	GRP. 19	GRP. 20	GRP. 21	GRP. 22	GRP. 23	GRP. 24
1	9.83931E-01	9.78211E-01	9.84169E-01	9.82896E-01	9.66845E-01	9.57690E-01	9.51[illegible]E-01	9.23088E-01
2	9.96013E-01	9.94385E-01	9.96105E-01	9.95716E-01	9.90993E-01	9.89098E-01	9.86691E-01	9.76957E-01
3	9.99871E-01	9.99526E-01	9.99887E-01	9.99749E-01	9.98506E-01	9.98617E-01	9.97001E-01	9.91991E-01
4	1.00976E 00	1.01329E 00	1.00961E 00	1.01040E 00	1.02037E 00	1.02589E 00	1.02989E 00	1.03914E 00
5	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00	1.00000E 00

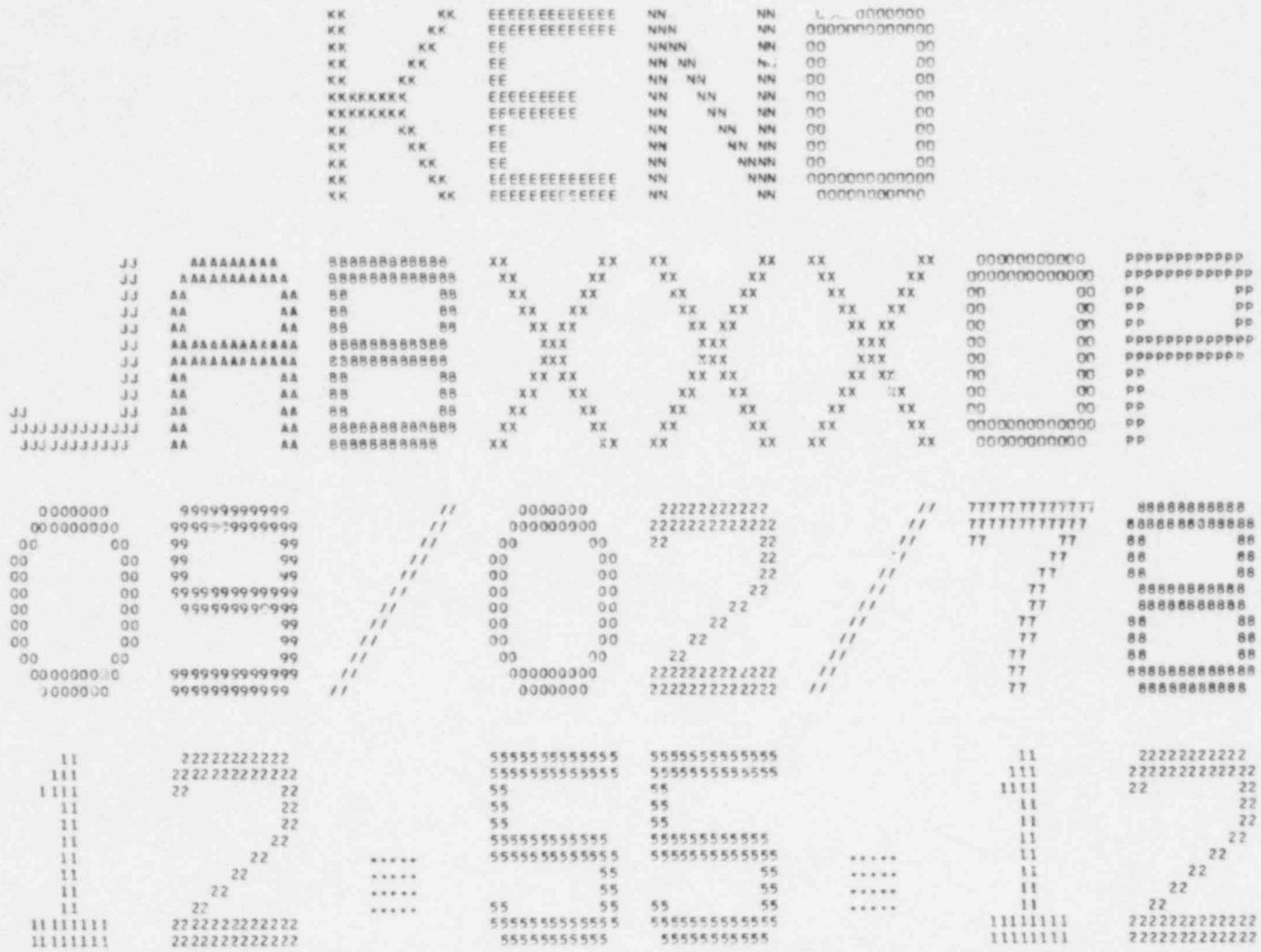
ZONE	GRP. 25	GRP. 26	GRP. 27
1	8.95986E-01	8.43434E-01	7.17023E-01
2	9.67448E-01	9.47533E-01	9.08399E-01
3	9.86320E-01	9.73377E-01	9.51653E-01
4	1.06566E 00	1.10002E 00	1.18074E 00
5	1.00000E 00	1.00000E 00	1.00000E 00

ZONE	VOLUME	VOL. FRACTION
1	5.26814E-01	3.31832E-01
2	2.20971E-02	1.39186E-02
3	1.59910E-01	1.00725E-01
4	8.78776E-01	5.53527E-01
5	1.58759E 00	1.00000E 00

VOLUME OF EACH OF THE 4 ZONES

VOLUME OF THE UNIT CELL

...SED TIME 0.) MIN.



INFINITE HOMOGENEOUS MEDIA

NUMBER OF GENERATIONS	100	START TYPE	1
NUMBER PER GENERATION	300	GENERATIONS BETWEEN CHECKPOINTS	0
NUMBER OF GENERATIONS TO BE SKIPPED	4	LIST INPUT X-SECTIONS READ FROM TAPE	NO
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIXTURE X SECTIONS	NO
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIXTURE X-SECTIONS	NO
NUMBER OF INPUT NUCLIDES	19	LIST FISS. AND ABS. BY REGION	NO
NUMBER OF MIXTURES	8	USE X-SECTIONS FROM PREVIOUS CASE	NO
NUMBER OF MIXING TABLE ENTRIES	25	USE GEOMETRY FROM PREVIOUS CASE	NO
NUMBER OF GEOMETRY CARDS	1	USE VELOCITIES FROM PREVIOUS CASE	NO
NUMBER OF BOX TYPES	1	COMPUTE MATRIX K-EFFECTIVE BY UNIT	NO
NUMBER OF UNITS IN X DIRECTION	1	COMPUTE MATRIX K-EFFECTIVE BY BOX TYPE	NO
NUMBER OF UNITS IN Y DIRECTION	1	LIST FISS PROB MATRIX BY UNIT	NO
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALCULATION	NO
NUMBER OF NUCLIDES READ FROM TAPE	-19	USE EXPONENTIAL TRANSFORM	NO
ALBEDO TYPE	1	CALCULATE FLUX	NO
SEARCH TYPE	0	CALCULATE FISSION DENSITIES	YES

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = 1.00000E 00 -X = 1.00000E 00 +Y = 1.00000E 00 -Y = 1.00000E 00 +Z = 1.00000E 00 -Z = 1.00000E 00

MAXIMUM TIME = 0.5000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 17886
REMAINING AVAILABLE LOCATIONS= 82978

A DETAILED EDIT OF THE INPUT DATA FOR THIS PARTICULAR KENO CASE WILL BE PRINTED NEXT.

FOLLOWING THAT, THE CODE WILL EDIT THE AVERAGE VALUE OF K_{EFF} FOR THE SYSTEM AS COMPUTED AT THE END OF EACH GENERATION.

FOR BREVITY, THE NEXT 8 PAGES OF OUTPUT HAVE NOT BEEN INCLUDED HERE

SINGLE BARE FUEL ASSEMBLY (HOMOGENIZED)

NUMBER OF GENERATIONS	100
NUMBER PER GENERATION	300
NUMBER OF GENERATIONS TO BE SKIPPED	4
NUMBER OF ENERGY GROUPS	27
MAX. NUMBER OF ENERGY TRANSFERS	27
NUMBER OF INPUT NUCLIDES	19
NUMBER OF MIXTURES	8
NUMBER OF MIXING TABLE ENTRIES	25
NUMBER OF GEOMETRY CARDS	1
NUMBER OF BOX TYPES	1
NUMBER OF UNITS IN X DIRECTION	1
NUMBER OF UNITS IN Y DIRECTION	1
NUMBER OF UNITS IN Z DIRECTION	1
NUMBER OF NUCLIDES READ FROM TAPE	-19
ALBEDO TYPE	0
SEARCH TYPE	0

MAXIMUM TIME = 0.5000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 17886
REMAINING AVAILABLE LOCATIONS= 82978

START TYPE	1
GENERATIONS BETWEEN CHECKPOINTS	0
LIST INPUT X-SECTIONS READ FROM TAPE	NO
LIST 1-D MIXTURE X SECTIONS	NO
LIST 2-D MIXTURE X-SECTIONS	NO
LIST FISS. AND ABS. BY REGION	NO
USE X-SECTIONS FROM PREVIOUS CASE	NO
USE GEOMETRY FROM PREVIOUS CASE	NO
USE VELOCITIES FROM PREVIOUS CASE	NO
COMPUTE MATRIX K-EFFECTIVE BY UNIT	NO
COMPUTE MATRIX K-EFFECTIVE BY BOX TYPE	NO
LIST FISS PROB MATRIX BY UNIT	NO
ADJOINT CALCULATION	NO
USE EXPONENTIAL TRANSFORM	NO
CALCULATE FLUX	NO
CALCULATE FISSION DENSITIES	YES

A DETAILED EDIT OF THE INPUT DATA FOR THIS PARTICULAR KENO CASE WILL BE PRINTED NEXT.

FOLLOWING THAT, THE CODE WILL EDIT THE AVERAGE VALUE OF K_{EFF} FOR THE SYSTEM AS COMPUTED AT THE END OF EACH GENERATION.

FOR BREVITY, THE NEXT 11 PAGES OF OUTPUT HAVE NOT BEEN INCLUDED HERE.

SINGLE FUEL ASSEMBLY REFLECTED BY WATER

NUMBER OF GENERATIONS	100
NUMBER PER GENERATION	300
NUMBER OF GENERATIONS TO BE SKIPPED	4
NUMBER OF ENERGY GROUPS	27
MAX. NUMBER OF ENERGY TRANSFERS	27
NUMBER OF INPUT NUCLIDES	19
NUMBER OF MIXTURES	8
NUMBER OF MIXING TABLE ENTRIES	25
NUMBER OF GEOMETRY CARDS	13
NUMBER OF BOX TYPES	1
NUMBER OF UNITS IN X DIRECTION	1
NUMBER OF UNITS IN Y DIRECTION	1
NUMBER OF UNITS IN Z DIRECTION	1
NUMBER OF NUCLIDES READ FROM TAPE	-19
ALBEDO TYPE	0
SEARCH TYPE	0

MAXIMUM TIME = 0.5000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 20322
REMAINING AVAILABLE LOCATIONS= 80542

START TYPE	1
GENERATIONS BETWEEN CHECKPOINTS	0
LIST INPUT X-SECTIONS READ FROM TAPE	NO
LIST 1-D MIXTURE X SECTIONS	NO
LIST 2-D MIXTURE X-SECTIONS	NO
LIST FISS. AND ABS. BY REGION	NO
USE X-SECTIONS FROM PREVIOUS CASE	NO
USE GEOMETRY FROM PREVIOUS CASE	NO
USE VELOCITIES FROM PREVIOUS CASE	NO
COMPUTE MATRIX K-EFFECTIVE BY UNIT	NO
COMPUTE MATRIX K-EFFECTIVE BY BOX TYPE	NO
LIST FISS PROB MATRIX BY UNIT	NO
ADJOINT CALCULATION	NO
USE EXPONENTIAL TRANSFORM	NO
CALCULATE FLUX	NO
CALCULATE FISSION DENSITIES	YES

A DETAILED EDIT OF THE INPUT DATA FOR THIS PARTICULAR KENO CASE WILL BE PRINTED NEXT.

FOLLOWING THAT, THE CODE WILL EDIT THE AVERAGE VALUE OF K_{EFF} FOR THE SYSTEM AS COMPUTED AT THE END OF EACH GENERATION.

FOR BREVITY, THE NEXT 16 PAGES OF OUTPUT HAVE NOT BEEN INCLUDED HERE.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

NUMBER OF GENERATIONS	100	START TYPE	1
NUMBER PER GENERATION	300	GENERATIONS BETWEEN CHECKPOINTS	0
NUMBER OF GENERATIONS TO BE SKIPPED	4	LIST INPUT X-SECTIONS READ FROM TAPE	NO
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIXTURE X SECTIONS	NO
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIXTURE X-SECTIONS	NO
NUMBER OF INPUT NUCLIDES	19	LIST FISS. AND ABS. BY REGION	NO
NUMBER OF MIXTURES	8	USE X-SECTIONS FROM PREVIOUS CASE	NO
NUMBER OF MIXING TABLE ENTRIES	25	USE GEOMETRY FROM PREVIOUS CASE	NO
NUMBER OF GEOMETRY CARDS	24	USE VELOCITIES FROM PREVIOUS CASE	NO
NUMBER OF BOX TYPES	19	COMPUTE MATRIX K-EFFECTIVE BY UNIT	NO
NUMBER OF UNITS IN X DIRECTION	19	COMPUTE MATRIX K-EFFECTIVE BY BOX TYPE	NO
NUMBER OF UNITS IN Y DIRECTION	11	LIST FISS PROB MATRIX BY UNIT	NO
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALCULATION	NO
NUMBER OF NUCLIDES READ FROM TAPE	-19	USE EXPONENTIAL TRANSFORM	NO
ALBEDO TYPE	0	CALCULATE FLUX	NO
SEARCH TYPE	0	CALCULATE FISSION DENSITIES	YES

MAXIMUM TIME = 10.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 22725
REMAINING AVAILABLE LOCATIONS= 78139

WHILE THE USER DEFINED 7 MIXTURES, MIXTURE NO. 500 IS THE 8TH. INDEED, THE CONTROL MODULE INTERNALLY SUBSTITUTES MIXTURE NO. 8 EVERYWHERE THE USER ENTERED MIXTURE NO. 500. THIS SUBSTITUTION WILL BE NOTED IN THE KENO MIXING TABLE (SHOWN BELOW) AND IN THE EDIT OF GEOMETRY DATA (ALSO SHOWN BELOW). HAD THE USER DEFINED N MIXTURES, MIXTURE NO. 500 WOULD BECOME NUMBER N+1.

INPUT DATA FOR THIS KENO CASE AS READ OFF THE BINARY INPUT TAPE PREPARED BY THE CONTROL MODULE.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

MIXTURE	NUCLIDE	DENSITY
1	-92235	7.52355E-04
8	-92235	2.49654E-04
7	-2	4.45568E-05
1	92238	2.24709E-02
8	92238	7.45655E-03
7	4	2.19490E-02
1	8016	4.64466E-02
8	8016	1.54124E-02
3	6	3.33797E-02
8	6	1.84765E-02
5	7	3.33797E-02
7	8	4.39871E-02
2	40302	4.25181E-02
8	40302	4.28262E-03
3	1001	6.67593E-02
8	1001	3.69530E-02
5	11	6.67593E-02
4	5010	3.22734E-04
4	5011	1.39394E-03
4	6012	4.29167E-04
4	13027	5.80432E-02
6	24304	1.74249E-02
6	25055	1.73644E-03
6	26304	5.93560E-02
6	28304	7.72081E-03

THE NEGATIVE NUCLIDE I.D. NUMBERS FLAG THE PRIMARY FISSILE ISOTOPE IN THE GIVEN MIXTURE. THE FISSION SPECTRUM FOR THAT PARTICULAR NUCLIDE WILL BE USED BY KENO IN EACH OF THE RESPECTIVE MIXTURES.

NUCLIDE NUMBER 8016, 6, 7, AND 8 ALL REPRESENT OXYGEN IN EACH OF SEVERAL DIFFERENT MIXTURES. LIKEWISE, NUCLIDE 1001 AND 11 BOTH REPRESENT HYDROGEN IN EACH OF TWO DIFFERENT MIXTURES. (IN THE CASE OF MIXTURE NO. 8, THE TOTAL OXYGEN CONTENT EQUALS THE NO. DENSITY FOR NUCLIDE #8016 PLUS THE NO. DENSITY FOR NUCLIDE #6).

AS NOTED PREVIOUSLY, MIXTURE NO. 8 NOW REPRESENTS THE HOMOGENIZED CELL-AVERAGED CROSS SECTION DATA FOR THE LATTICE CELL.

CROSS SECTIONS READ FROM TAPE

```
NUCLIDE =      1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =        11   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =      5010   B-10 1273 218NGP 042375 P-3 293K
NUCLIDE =      5011   B-11 1160 WT 1/EST 218NGP P-3 293K RE(042375)
NUCLIDE =      6012   C-12 1274F,1065T 218 GP 030476(7)
NUCLIDE =      8016   O-16 1276 218 GP 030476(7)
NUCLIDE =         6   O-16 1276 218 GP 030476(7)
NUCLIDE =         7   O-16 1276 218 GP 030476(7)
NUCLIDE =         8   O-16 1276 218 GP 030476(7)
NUCLIDE =     13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =     24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4,423751'
NUCLIDE =     25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(423751'
NUCLIDE =     28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(+23751'
NUCLIDE =     40302   ZR-2(1284) SIGP=5+4 NEWXLACS 293K 9-20-77 1/E WT.
NUCLIDE =     92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =         2   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =     92238   U-238 1262 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =         4   U-238 1262 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
```

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

GEOMETRY DESCRIPTION

THIS EDIT OF THE GEOMETRY DATA IS PRODUCED DIRECTLY BY THE KENO CODE. A SIMILAR EDIT WAS PRODUCED PREVIOUSLY BY THE CONTROL MODULE. USERS ARE ENCOURAGED TO CHECK THIS EDIT AND VERIFY THAT ALL DATA SHOWN HERE IS CORRECT.

BOX TYPE 1

REGION

1	CUBOID	5	+X = 4.9600E 00	-X = 0.0	+Y = 2.5000E-01	-Y = 0.0	+Z = 3.7084E 02	-Z = 0.0

BOX TYPE 2

REGION

1	CUBOID	4	+X = 2.5000E-01	-X = 0.0	+Y = 2.5000E-01	-Y = 0.0	+Z = 3.7084E 02	-Z = 0.0

BOX TYPE 3

REGION

1	CUBOID	4	+X = 7.9800E 00	-X = 0.0	+Y = 2.5000E-01	-Y = 0.0	+Z = 3.7084E 02	-Z = 0.0

BOX TYPE 4

REGION

1	CUBOID	4	+X = 4.9600E 00	-X = 0.0	+Y = 2.5000E-01	-Y = 0.0	+Z = 3.7084E 02	-Z = 0.0

BOX TYPE 5

REGION

1	CUBOID	5	+X = 1.3190E 01	-X = 0.0	+Y = 2.5000E-01	-Y = 0.0	+Z = 3.7084E 02	-Z = 0.0

BOX TYPE 6

REGION

1	CUBOID	5	+X = 2.5000E-01	-X = 0.0	+Y = 2.5000E-01	-Y = 0.0	+Z = 3.7084E 02	-Z = 0.0

BOX TYPE 7

REGION

1	CUBOID	5	+X = 4.9600E 00	-X = 0.0	+Y = 2.1420E 01	-Y = 0.0	+Z = 3.7084E 02	-Z = 0.0

BOX TYPE 8

REGION

1 CUBOID 4 +X = 2.5000E-01 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 9

REGION

1 CUBOID 8 +X = 7.9800E 00 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 10

REGION

1 CUBOID 8 +X = 2.5000E-01 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 11

REGION

1 CUBOID 8 +X = 4.9600E 00 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 12

REGION

1 CUBOID 5 +X = 1.3190E 01 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 13

REGION

1 CUBOID 5 +X = 2.5000E-01 -X = 0.0 +Y = 2.1420E 01 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 14

REGION

1 CUBOID 5 +X = 4.9600E 00 -X = 0.0 +Y = 4.9600E 00 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 15

REGION

1 CUBOID 5 +X = 2.5000E-01 -X = 0.0 +Y = 4.9600E 00 -Y = 0.0 +Z = 3.7084E 02 -Z = 0.0

BOX TYPE 16

REGION

```
  1 CUBOID      5      +X = 7.9800E 00   -X = 0.0          +Y = 4.9600E 00   -Y = 0.0          +Z = 3.7084E 02   -Z = 0.0

BOX TYPE  17
REGION
  1 CUBOID      5      +X = 1.3190E 01   -X = 0.0          +Y = 4.9600E 00   -Y = 0.0          +Z = 3.7084E 02   -Z = 0.0

BOX TYPE  18
REGION
  1 CUBOID      4      +X = 1.3190E 01   -X = 0.0          +Y = 2.5000E-01   -Y = 0.0          +Z = 3.7084E 02   -Z = 0.0

BOX TYPE  19
REGION
  1 CUBOID      8      +X = 1.3190E 01   -X = 0.0          +Y = 2.1420E 01   -Y = 0.0          +Z = 3.7084E 02   -Z = 0.0
```

MIXTURE NO. 8 NOW REPRESENTS THE HOMOGENIZED CELL-AVERAGED DATA FOR THE LATTICE CELL (PREVIOUSLY CALLED MIXTURE NO. 500)

```
REFLECTOR
REGION
  1 CORE        0      +X = 3.7840E 01   -X =-3.7840E 01   +Y = 3.7840E 01   -Y =-3.7840E 01   +Z = 1.8542E 02   -Z =-1.8542E 02
  2 CYLINDER    5  RADIUS = 5.4000E 01   +Z = 1.8550E 02   -Z =-1.8550E 02
  3 CYLINDER    6  RADIUS = 5.5500E 01   +Z = 1.8700E 02   -Z =-1.8700E 02
  4 CYLINDER    7  RADIUS = 6.5500E 01   +Z = 1.9700E 02   -Z =-1.9700E 02
  5 CYLINDER    6  RADIUS = 6.9500E 01   +Z = 2.0130E 02   -Z =-2.0100E 02
```

THE CORE REGION NOW CORRESPONDS TO THAT REGION INSIDE THE ARRAY BOUNDARY.

THESE GEOMETRY CARDS DESCRIBE THE REGION(S) OUTSIDE THE ARRAY BOUNDARY. BECAUSE THEY WERE DESCRIBED EXPLICITLY BY THE USER, THESE GEOMETRY CARDS SHOULD CORRESPOND TO THE USER'S INPUT. IN SOME OTHER PROBLEM WHERE ONE USES THE AUTOMATIC REFLECTOR CARD, THE CODE WILL AUTOMATICALLY GENERATE AND PRINT OUT A NUMBER OF CUBOID CARDS NOT FOUND IN THE USER'S DECK. THE CODE WILL ALSO SUPPLY THE APPROPRIATE MULTIGROUP WEIGHTS FOR THESE "EXTRA" GEOMETRY REGIONS.

BELOW, THESE ARE REFERRED TO AS GEOMETRY CARDS #20-24

BELOW, THIS IS REFERRED TO AS GEOMETRY CARD #19. NOTE THAT GEOMETRY CARD 19 DOESN'T ALWAYS HAVE TO BE IN BOX TYPE #19. THAT WAS THE CASE HERE ONLY BECAUSE WE HAD ONE REGION PER BOX.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

WEIGHTING FUNCTION

BOX TYPE 1

REGION 1 DEFINED BY GEOMETRY CARD 1

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

BOX TYPE 2

REGION 1 DEFINED BY GEOMETRY CARD 2

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

BOX TYPE 3

REGION 1 DEFINED BY GEOMETRY CARD 3

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

BOX TYPE 4

REGION 1 DEFINED BY GEOMETRY CARD 4

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

BOX TYPE 5

REGION 1 DEFINED BY GEOMETRY CARD 5

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

BOX TYPE 6

REGION 1 DEFINED BY GEOMETRY CARD 6

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

BOX TYPE 7

REGION 1 DEFINED BY GEOMETRY CARD 7

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

BOX TYPE 8

REGION 1 DEFINED BY GEOMETRY CARD 8

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

BOX TYPE 9

REGION 1 DEFINED BY GEOMETRY CARD 9

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

BOX TYPE 10

REGION 1 DEFINED BY GEOMETRY CARD 10

GROUP	WTLOW	WT AVG	WT HI
1	0.167	0.500	1.500
GROUPS 2 TO 27 SAME AS ABOVE			

KENO ALSO PRINTS THIS EDIT OF THE SPATIALLY DEPENDENT MULTIGROUP WEIGHTS FOR EACH REGION.

DATA LISTED UNDER WT AVG WAS SUPPLIED BY THE USER OR GENERATED INTERNALLY USING THE AUTOMATIC REFLECTOR CARD.

USERS ARE ENCOURAGED TO CHECK THIS EDIT AND VERIFY THAT ALL DATA IS CORRECT.

THERE MAY BE ONE OR MORE REGIONS INSIDE ANY GIVEN BOX. FOR MORE THAN ONE REGION, THE USER WOULD NEED MORE THAN ONE BASIC GEOMETRY DESCRIPTION CARD. FOR THIS PARTICULAR PROBLEM, A SIMPLE CUBOID ADEQUATELY DESCRIBED EACH BOX TYPE.

```
BOX TYPE  11                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  11
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  12                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  12
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  13                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  13
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  14                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  14
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  15                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  15
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  16                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  16
                                                     1     0.167     0.500      .500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  17                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  17
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  18                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  18
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

BOX TYPE  19                                        GROUP   WTLOW    WT AVG    WT HI

        REGION   1 DEFINED BY GEOMETRY CARD  19
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

REFLECTOR

        REGION   1 DEFINED BY GEOMETRY CARD  20
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

        REGION   2 DEFINED BY GEOMETRY CARD  21
                                                     1     0.167     0.500     1.500
                                                   GROUPS 2 TO   27 SAME AS ABOVE

        REGION   3 DEFINED BY GEOMETRY CARD  22
```

```
                                        1      0.167      0.500      1.500
                                   GROUPS 2 TO   27 SAME AS ABOVE

REGION   4 DEFINED BY GEOMETRY CARD  23
                                        1      0.167      0.500      1.500
                                   GROUPS 2 TO   27 SAME AS ABOVE

REGION   5 DEFINED BY GEOMETRY CARD  24
                                        1      0.167      0.500      1.500
                                   GROUPS 2 TO   27 SAME AS ABOVE
```

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

ARRAY DESCRIPTION

Z = 1

	I=1		I=3		I=5		I=7		I=9		I=11		I=13		I=15		I=17		I=19
J=11:	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6
J=10:	13	12	8	5	10	11	10	9	8	7	8	9	10	11	10	9	8	12	13
J=9:	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6
J=8:	15	17	15	16	15	14	15	16	15	14	15	16	15	14	15	16	15	17	15
J=7:	2	18	2	3	2	1	2	3	2	4	2	3	2	1	2	3	2	18	2
J=6:	8	19	10	9	8	7	8	9	10	11	10	9	8	7	8	9	10	19	8
J=5:	2	18	2	3	2	1	2	3	2	4	2	3	2	1	2	3	2	18	2
J=4:	15	17	15	16	15	14	15	16	15	14	15	16	15	14	15	16	15	17	15
J=3:	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6
J=2:	13	12	8	5	10	11	10	9	8	7	8	9	10	11	10	9	8	12	13
J=1:	6	5	2	3	2	4	2	3	2	1	2	3	2	4	2	3	2	5	6

THIS EDIT SHOWS THE "BOX TYPE" THAT WAS ULTIMATELY PRESCRIBED FOR EACH LOCATION (I, J, K) IN THE ARRAY.

THE USER IS STRONGLY ENCOURAGED TO CHECK THIS EDIT AND VERIFY THAT THE DATA WAS CORRECTLY ENTERED—ESPECIALLY IF HE DID NOT USE THE POINT-BY-POINT INPUT SCHEME FOR THE MIXED BOX ORIENTATION DATA.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

VOLUMES

ACTUAL VOLUME OF A GIVEN REGION INSIDE A PARTICULAR BOX TYPE

VOLUME OF A GIVEN REGION PLUS THAT OF ALL PREVIOUS REGIONS INSIDE THE PARTICULAR BOX

BOX TYPE 1	REGION DEFINED BY GEOMETRY CARD 1	VOLUME = 4.59841E 02 CM**3	CUMULATIVE VOLUME =	4.39841E 02 CM**3
BOX TYPE 2	REGION DEFINED BY GEOMETRY CARD 2	VOLUME = 2.31775E 01 CM**3	CUMULATIVE VOLUME =	2.31775E 01 CM**3
BOX TYPE 3	REGION DEFINED BY GEOMETRY CARD 3	VOLUME = 7.39825E 02 CM**3	CUMULATIVE VOLUME =	7.39825E 02 CM**3
BOX TYPE 4	REGION DEFINED BY GEOMETRY CARD 4	VOLUME = 4.59841E 02 CM**3	CUMULATIVE VOLUME =	4.59841E 02 CM**3
BOX TYPE 5	REGION DEFINED BY GEOMETRY CARD 5	VOLUME = 1.22284E 03 CM**3	CUMULATIVE VOLUME =	1.22284E 03 CM**3
BOX TYPE 6	REGION DEFINED BY GEOMETRY CARD 6	VOLUME = 2.31775E 01 CM**3	CUMULATIVE VOLUME =	2.31775E 01 CM**3
BOX TYPE 7	REGION DEFINED BY GEOMETRY CARD 7	VOLUME = 3.93992E 04 CM**3	CUMULATIVE VOLUME =	3.93992E 04 CM**3
BOX TYPE 8	REGION DEFINED BY GEOMETRY CARD 8	VOLUME = 1.98585E 03 CM**3	CUMULATIVE VOLUME =	1.98585E 03 CM**3
BOX TYPE 9	REGION DEFINED BY GEOMETRY CARD 9	VOLUME = 6.33882E 04 CM**3	CUMULATIVE VOLUME =	6.33882E 04 CM**3
BOX TYPE 10	REGION DEFINED BY GEOMETRY CARD 10	VOLUME = 1.98585E 03 CM**3	CUMULATIVE VOLUME =	1.98585E 03 CM**3
BOX TYPE 11	REGION DEFINED BY GEOMETRY CARD 11	VOLUME = 3.93992E 04 CM**3	CUMULATIVE VOLUME =	3.93992E 04 CM**3
BOX TYPE 12	REGION DEFINED BY GEOMETRY CARD 12	VOLUME = 1.04773E 05 CM**3	CUMULATIVE VOLUME =	1.04773E 05 CM**3
BOX TYPE 13	REGION DEFINED BY GEOMETRY CARD 13	VOLUME = 1.98585E 03 CM**3	CUMULATIVE VOLUME =	1.98585E 03 CM**3
BOX TYPE 14	REGION DEFINED BY GEOMETRY CARD 14	VOLUME = 9.12324E 03 CM**3	CUMULATIVE VOLUME =	9.12324E 03 CM**3
BOX TYPE 15	REGION DEFINED BY GEOMETRY CARD 15	VOLUME = 4.59841E 02 CM**3	CUMULATIVE VOLUME =	4.59841E 02 CM**3
BOX TYPE 16	REGION DEFINED BY GEOMETRY CARD 16	VOLUME = 1.46781E 04 CM**3	CUMULATIVE VOLUME =	1.46781E 04 CM**3
BOX TYPE 17	REGION DEFINED BY GEOMETRY CARD 17	VOLUME = 2.42612E 04 CM**3	CUMULATIVE VOLUME =	2.42612E 04 CM**3
BOX TYPE 18	REGION DEFINED BY GEOMETRY CARD 18	VOLUME = 1.22284E 03 CM**3	CUMULATIVE VOLUME =	1.22284E 03 CM**3
BOX TYPE 19	REGION DEFINED BY GEOMETRY CARD 19	VOLUME = 1.04773E 05 CM**3	CUMULATIVE VOLUME =	1.04773E 05 CM**3

REFLECTOR VOLUMES - GEOMETRY CARD 20 IS THE CORE BOUNDARY CARD

VOLUME OF ARRAY = (3.39869E+06)-(1.27472E+06)

REGION DEFINED BY GEOMETRY CARD 21 VOLUME = 1.27472E 06 CM**3 CUMULATIVE VOLUME = 3.39869E 06 CM**3

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          REGION DEFINED BY GEOMETRY CARD     22   VOLUME =     2.20469E 05 CM**3        CUMULATIVE VOLUME =     3.61916E 06 CM**3
          REGION DEFINED BY GEOMETRY CARD     23   VOLUME =     1.69126E 06 CM**3        CUMULATIVE VOLUME =     5.31042E 06 CM**3
          REGION DEFINED BY GEOMETRY CARD     24   VOLUME =     7.89802E 05 CM**3        CUMULATIVE VOLUME =     6.10022E 06 CM**3

 TOTAL VOLUMES
    1        3.67873E 03
    2        1.20523E 03
    3        1.77558E 04
    4        4.59841E 03
    5        5.78275E 03
    6        1.85420E 03
    7        1.57597E 05
    8        2.78018E 04
    9        7.60658E 05
   10        2.38301E 04
   11        1.96996E 05
   12        4.19093E 05
   13        7.94338E 03
   14        5.47395E 04
   15        5.19681E 03
   16        1.17425E 05
   17        9.70448E 04
   18        4.69138E 03
   19        2.09546E 05
                          ARRAY
 VOLUME FRACTION OF THE ARRAY CONTAINING FISSILE MATERIAL= 0.56076E 00

 START TYPE =     1

  THE NEUTRONS WERE STARTED IN THE ARRAY WITH A COSINE DISTRIBUTION.

    300 NEUTRONS WERE INITIALLY STARTED
 0.00183 MINUTES WERE REQUIRED FOR STARTING.
```

(TOTAL VOLUME OF REGION 7 INSIDE THE ARRAY) = (VOLUME OF REGION 7 INSIDE BOX TYPE M) X (NO. OF TIMES BOX TYPE M IS FOUND IN THE ARRAY)

NOTE: "REGION 7" IS ALWAYS "DEFINED BY GEOMETRY CARD 7". IN THIS PARTICULAR CASE IT IS FOUND IN BOX TYPE 7 BECAUSE WE HAD ONLY ONE REGION PER BOX. IN GENERAL, ONE MAY HAVE TWO OR MORE REGIONS IN A GIVEN BOX.

TO DETERMINE THE STARTING LOCATIONS FOR NEUTRONS IN THE FIRST GENERATION, THE CODE BEGINS BY RANDOMLY SELECTING A POINT (X, Y, Z) INSIDE THE ARRAY BOUNDARY. THE SELECTION IS MADE FROM A 3-D COSINE DISTRIBUTION FUNCTION SPANNING THE BOUNDARIES OF THE ARRAY. IF THE POINT (X, Y, Z) HAPPENS TO BE LOCATED IN A FISSILE MATERIAL, IT WILL BE SAVED AND LATER USED AS ONE OF THE STARTING POINTS. IF THE POINT (X, Y, Z) DOES NOT HAPPEN TO BE IN A FISSILE MATERIAL, IT WILL BE REJECTED AND ANOTHER POINT WILL BE RANDOMLY SELECTED, CHECKED, ETC. THE CODE MAY "TRY" UP TO 10,000 POINTS (FOR EXAMPLE). IF BY THAT TIME IT HAS NOT FOUND 300 ACCEPTABLE STARTING POINTS IT WILL "REUSE" SOME OF THE POINTS IT HAS FOUND (I.E. IF IT FOUND 290 ACCEPTABLE STARTING POINTS IT WILL START 1 NEUTRON AT 280 OF THESE AND 2 NEUTRONS AT 10 OF THEM).

NOTE: IF THE VOLUME FRACTION OF THE FISSILE MATERIAL IN THE ARRAY IS VERY SMALL, THE CODE MAY NOT ADEQUATELY SAMPLE THE FISSION SOURCE. THIS SITUATION MIGHT ARISE, FOR EXAMPLE, IF ONE HAD AN ARRAY WITH RELATIVELY SMALL CLUMPS OF FISSILE MATERIAL DISPERSED THROUGHOUT, OR IF THE BULK OF THE FISSILE MATERIAL WERE LOCATED CLOSE TO THE ARRAY BOUNDARY. DESPITE A LARGE NUMBER OF HISTORIES, GOOD STATISTICS, AND WHAT MIGHT APPEAR TO BE A SMALL "STANDARD DEVIATION," THE AVERAGE K-EFFECTIVE RENDERED BY SUCH A CALCULATION MAY BE IN SERIOUS ERROR. CHECK THE NUMBER OF "INDEPENDENT FISSIONS POINTS GENERATED" PRIOR TO THE FIRST GENERATION, AS LISTED ON THE FOLLOWING PAGE. IF FEWER THAN 100 OR 200 POINTS WERE GENERATED, ONE MIGHT HAVE CAUSE FOR CONCERN. IN STANDARD KENO-IV, THIS PROBLEM CAN BE OVERCOME BY OPTING FOR A DIFFERENT TYPE OF STARTING DISTRIBUTION (C.F. PARAMETER 20, NTYPST, ON THE PARAMETER CARD FOR THE "STAND-ALONE" KENO-IV MODULE). IN CSAS2 THE USER DOES NOT HAVE THIS OPTION AND THE CONTROL MODULE AUTOMATICALLY SETS NTYPST=1. ON THOSE RARE OCCASIONS WHEN THIS PROVES TO BE INADEQUATE, IT IS SUGGESTED THAT THE USER EXECUTE KENO-IV AS A STAND-ALONE MODULE IMMEDIATELY AFTER CSAS2. RUNNING BOTH MODULES BACK-TO-BACK IN A SINGLE SCALE RUN WILL ALLOW THE KENO MODULE TO TAKE ADVANTAGE OF THE CROSS SECTION LIBRARY PRODUCED BY CSAS2.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

GENERATION	K-EFFECTIVE	ELAPSED TIME(MIN)	AVG. K-EFF	DEVIATION	MATRIX K-EFF
			WARNING - ONLY 290 INDEPENDENT FISSION POINTS WERE GENERATED.		
1	8.94839E-01	1.00167E-01	1.00000E 00	0.0	0.0
			WARNING - ONLY 293 INDEPENDENT FISSION POINTS WERE GENERATED.		
2	8.53930E-01	2.16000E-01	1.00000E 00	0.0	0.0
3	9.37191E-01	3.20000E-01	9.37191E-01	0.0	0.0
4	9.41571E-01	4.18833E-01	9.39381E-01	2.35441E-03	0.0
5	9.22883E-01	5.31667E-01	9.33881E-01	5.67857E-03	0.0
6	9.02567E-01	6.50167E-01	9.26053E-01	8.80149E-03	0.0
7	8.40770E-01	7.69167E-01	9.08996E-01	1.83690E-02	0.0
8	7.87906E-01	9.01667E-01	8.88814E-01	2.51443E-02	0.0
9	8.88039E-01	1.01800E 00	8.88703E-01	2.12515E-02	0.0
10	8.83970E-01	1.12717E 00	8.88112E-01	1.84139E-02	0.0
11	9.35241E-01	1.24183E 00	8.93348E-01	1.70634E-02	0.0
12	8.96948E-01	1.36667E 00	8.93713E-01	1.52663E-02	0.0
13	8.87987E-01	1.48717E 00	8.93193E-01	1.38184E-02	0.0
14	8.59344E-01	1.60017E 00	8.90372E-01	1.29265E-02	0.0
15	8.82061E-01	1.71917E 00	8.89733E-01	1.19077E-02	0.0
16	8.73097E-01	1.83050E 00	8.88544E-01	1.10683E-02	0.0
17	8.59198E-01	1.95100E 00	8.86588E-01	1.05068E-02	0.0
18	9.17075E-01	2.06767E 00	8.88493E-01	1.00110E-02	0.0
			WARNING - ONLY 286 INDEPENDENT FISSION POINTS WERE GENERATED.		
19	7.88099E-01	2.18383E 00	8.82588E-01	1.11045E-02	0.0
20	8.74522E-01	2.29833E 00	8.82140E-01	1.04790E-02	0.0
21	8.17721E-01	2.42583E 00	8.78749E-01	1.04772E-02	0.0
22	9.08625E-01	2.54333E 00	8.80242E-01	1.00535E-02	0.0
23	8.84378E-01	2.65683E 00	8.80439E-01	9.56583E-03	0.0
24	8.49907E-01	2.77767E 00	8.79050E-01	9.22626E-03	0.0
25	8.58901E-01	2.89933E 00	8.78174E-01	8.86105E-03	0.0
26	8.62464E-01	3.01517E 00	8.77519E-01	8.50952E-03	0.0
27	8.96745E-01	3.12583E 00	8.78288E-01	8.19721E-03	0.0
28	8.80706E-01	3.24000E 00	8.78362E-01	7.87511E-03	0.0
29	9.00071E-01	3.35517E 00	8.79166E-01	7.61953E-03	0.0
30	9.37776E-01	3.46750E 00	8.81259E-01	7.63429E-03	0.0
31	8.44948E-01	3.59250E 00	8.80006E-01	7.47212E-03	0.0
32	9.31743E-01	3.70050E 00	8.81731E-01	7.42262E-03	0.0
33	8.86315E-01	3.81467E 00	8.81878E-01	7.18150E-03	0.0
34	9.36653E-01	3.93083E 00	8.83590E-01	7.16216E-03	0.0
35	8.78065E-01	4.05517E 00	8.83422E-01	6.94528E-03	0.0
36	8.53855E-01	4.17583E 00	8.82552E-01	6.79406E-03	0.0
37	9.01186E-01	4.27633E 00	8.83085E-01	6.61834E-03	0.0
38	8.79911E-01	4.39250E 00	8.82996E-01	6.43320E-03	0.0
39	8.69806E-01	4.50217E 00	8.82639E-01	6.26799E-03	0.0
40	8.76588E-01	4.62883E 00	8.82480E-01	6.10286E-03	0.0
41	8.52388E-01	4.74217E 00	8.81708E-01	5.99395E-03	0.0
42	8.27918E-01	4.87133E 00	8.80363E-01	5.99526E-03	0.0
43	8.51173E-01	4.99267E 00	8.79651E-01	5.89070E-03	0.0
44	8.60919E-01	5.10850E 00	8.79205E-01	5.76621E-03	0.0
45	9.20605E-01	5.22167E 00	8.80168E-01	5.71270E-03	0.0
46	9.38082E-01	5.32250E 00	8.81484E-01	5.73431E-03	0.0
47	9.36367E-01	5.43550E 00	8.82703E-01	5.73683E-03	0.0
48	8.52946E-01	5.55583E 00	8.82056E-01	5.64828E-03	0.0
49	8.90889E-01	5.67050E 00	8.82244E-01	5.52990E-03	0.0
50	8.16827E-01	5.79517E 00	8.80881E-01	5.58307E-03	0.0
51	8.92796E-01	5.90500E 00	8.81124E-01	5.47312E-03	0.0
52	8.48549E-01	6.02917E 00	8.80472E-01	5.40237E-03	0.0
53	9.07985E-01	6.14500E 00	8.81012E-01	5.32338E-03	0.0
54	8.76398E-01	6.25750E 00	8.80923E-01	5.22103E-03	0.0
55	8.71571E-01	6.38750E 00	8.80746E-01	5.12460E-03	0.0
56	8.62513E-01	6.49550E 00	8.80408E-01	5.04068E-03	0.0
57	8.90086E-01	6.59917E 00	8.80584E-01	4.95195E-03	0.0

K-EFF OF THE SYSTEM AS CALCULATED BY A DIFFERENT METHOD. IT IS NOT USED IN KENO-IV AS EMPLOYED BY CSAS2.

SEE NOTE ON PREVIOUS PAGE WHENEVER THIS MESSAGE IS PRINTED PRIOR TO THE FIRST GENERATION. IN THIS PARTICULAR CASE THERE'S NOTHING TO WORRY ABOUT.

AFTER THE FIRST 5 OR 6 NEUTRON GENERATIONS, THIS MESSAGE MAY STILL APPEAR FROM TIME TO TIME. UNLESS IT APPEARS CONSISTENTLY (WHICH IS VERY, VERY RARE), THERE IS NO CAUSE FOR CONCERN.

THE AVERAGE VALUE OF K-EFFECTIVE SHOWN HERE IS A RUNNING AVERAGE BASED ON GENERATIONS 1 THROUGH N. THIS GENERATION-BY-GENERATION EDIT OF THE AVERAGE VALUE OF K-EFFECTIVE IS ONE OF THE MORE POWERFUL TOOLS AVAILABLE FOR LOOKING AT THE FINAL RESULTS (SHOWN IN THE FOLLOWING EDIT) AND DECIDING WHICH ONES TO BELIEVE AND WHICH ONES TO IGNORE. THE RESULTS SHOWN IN THIS PARTICULAR EDIT ARE PROVIDED PRIMARILY FOR DIAGNOSTIC PURPOSES AS NOTED BELOW.

FROM THE VARIATION OF $\overline{K_{EFF}}(N)$ NOTED HERE, IT IS CLEAR THAT IT TOOK 7 OR 8 GENERATIONS FOR THE FISSION SOURCE DISTRIBUTION TO "SETTLE" INTO THE FUNDAMENTAL MODE FOR THIS PARTICULAR PROBLEM. THOSE VALUES OF K-EFF CALCULATED DURING THE FIRST 7 OR 8 GENERATIONS SHOULD THEREFORE BE EXCLUDED FROM THE FINAL DETERMINATION OF $\overline{K_{EFF}}$ FOR THE SYSTEM.

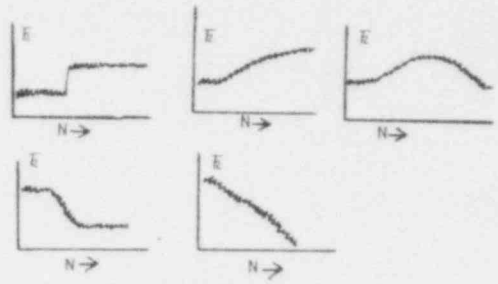
58	8.72405E-01	6.72833E 00	8.80438E-01	4.86514E-03	0.0
59	9.03791E-01	6.84583E 00	8.80847E-01	4.79726E-03	0.0
60	8.85499E-01	6.96333E 00	8.80928E-01	4.71436E-03	0.0
61	8.94168E-01	7.08800E 00	8.81152E-01	4.63912E-03	0.0
62	9.00933E-01	7.20467E 00	8.81481E-01	4.57342E-03	0.0
63	8.05349E-01	7.33350E 00	8.80233E-01	4.66771E-03	0.0
64	8.55104E-01	7.45133E 00	8.79828E-01	4.60961E-03	0.0
65	8.64740E-01	7.57017E 00	8.79588E-01	4.54265E-03	0.0
66	8.82078E-01	7.68600E 00	8.79627E-01	4.47179E-03	0.0
67	8.81691E-01	7.80217E 00	8.79659E-01	4.40289E-03	0.0
68	8.84469E-01	7.92633E 00	8.79731E-01	4.33635E-03	0.0
69	8.66700E-01	8.05683E 00	8.79537E-01	4.27526E-03	0.0
70	8.45451E-01	8.18050E 00	8.79035E-01	4.24187E-03	0.0
71	8.38947E-01	8.29050E 00	8.79904E-01	4.26948E-03	0.0
72	8.75854E-01	8.40833E 00	8.79845E-01	4.20908E-03	0.0
73	8.41512E-01	8.52633E 00	8.79306E-01	4.18410E-03	0.0
74	8.48449E-01	8.64350E 00	8.78877E-01	4.14857E-03	0.0
75	8.40655E-01	8.76717E 00	8.78353E-01	4.12468E-03	0.0
76	9.28731E-01	8.88250E 00	8.79034E-01	4.12503E-03	0.0
77	8.78526E-01	8.99750E 00	8.79027E-01	4.06965E-03	0.0
78	9.05017E-01	9.10517E 00	8.79369E-01	4.03012E-03	0.0
79	9.33709E-01	9.21017E 00	8.80075E-01	4.03989E-03	0.0
80	8.72650E-01	9.32433E 00	8.79979E-01	3.98910E-03	0.0
81	8.73910E-01	9.44433E 00	8.79902E-01	3.93936E-03	0.0
82	8.98884E-01	9.54550E 00	8.80140E-01	3.89697E-03	0.0
83	8.42303E-01	9.65750E 00	8.79672E-01	3.87696E-03	0.0
84	8.34437E-01	9.76800E 00	8.79121E-01	3.86906E-03	0.0
85	8.66411E-01	9.88050E 00	8.78967E-01	3.82492E-03	0.0
86	8.53014E-01	9.99550E 00	8.78658E-01	3.79179E-03	0.0
87	8.79444E-01	1.01052E 01	8.78668E-01	3.74677E-03	0.0

THE MATRIX K-EFF IS THE LARGEST EIGENVALUE OF THE MATRIX OF FISSION PROBABILITIES BY UNIT.
THERE ARE NBXMAX * NBYMAX * NBZMAX UNITS IN AN ARRAY.

EVALUATION OF KENO-IV RESULTS

THE ACTUAL K-EFFECTIVE FOR THE SYSTEM BEING ANALYZED SHOULD BE DETERMINED FROM THE EDIT ON THE FOLLOWING PAGE. THAT EDIT SHOWS THE AVERAGE VALUE OF K-EFFECTIVE BASED ON GENERATIONS M THRU 87. BY EXCLUDING THE FIRST FEW GENERATIONS FROM THE AVERAGING PROCESS ONE CAN (AND SHOULD) SCREEN OUT THE EARLY ESTIMATES OF K_{EFF} THAT WERE MADE PRIOR TO THE CONVERGENCE OF THE FISSION SOURCE DISTRIBUTION. THE FINAL "ANSWER" SHOULD ALSO EXHIBIT GOOD STATISTICS. FOR THAT REASON, RESULTS BASED ONLY ON THE LAST FEW GENERATIONS SHOULD ALSO BE EXCLUDED. (IN THIS PARTICULAR PROBLEM THE "BEST ANSWER" MIGHT BE THAT BASED ON GENERATIONS 14 THRU 87, K_{EFF} = 0.876±.004). HAVING SELECTED WHAT APPEARS TO BE A REASONABLE ANSWER, THE USER SHOULD STILL CHECK ONE OR TWO OTHER THINGS BEFORE BEING SATISFIED WITH "THE ANSWER". 1) IF THE VOLUME FRACTION OF THE FISSILE MATERIAL IN THE ARRAY IS VERY SMALL, HE SHOULD VERIFY THAT THE CODE GENERATED ENOUGH INDEPENDENT STARTING LOCATIONS TO ADEQUATELY SAMPLE THE FISSILE MATERIAL PRIOR TO STARTING THE FIRST BATCH OF NEUTRONS. (SEE PREVIOUS NOTE). 2) IF THE SYSTEM IS NEUTRONICALLY VERY LARGE, WEAKLY COUPLED, OR KNOWN TO HAVE HOT SPOTS, THE USER SHOULD ALSO CHECK THE EDIT OF "FISSION DENSITY BY REGION." IF THE USER HAS DIVIDED THE FISSILE MATERIAL INTO A NUMBER OF DIFFERENT BOXES OR REGIONS, HE CAN USE THIS EDIT (WHICH IS THE NEXT TO THE LAST THING PRINTED BY KENO) TO DETECT ANOMALIES THAT MIGHT OTHERWISE GO UNDETECTED. A MORE COMPLETE DESCRIPTION OF HOW THAT INFORMATION CAN BE USED AND WHEN IT MIGHT BE IMPORTANT IS PROVIDED BELOW.

THE AVERAGE VALUE OF K-EFFECTIVE, $\overline{K_{EFF}}(N)$, WILL TYPICALLY VARY FOR THE FIRST FEW GENERATIONS AND THEN TEND TO STABILIZE. DEPENDING ON THE SYSTEM BEING ANALYZED, HOWEVER, IT MAY VARY AS:



IT IS USUALLY ADVISABLE TO RUN AT LEAST 50-100 GENERATIONS IN ORDER TO VERIFY THAT THE PROBLEM HAS CONVERGED. PROLONGED DRIFT IN $\overline{K_{EFF}}$ (N) USUALLY INDICATES A POORLY CONVERGED FISSION SOURCE DISTRIBUTION. IN CSAS2, THE USER SHOULD TRY INCREASING THE NUMBER OF NEUTRONS STARTED PER GENERATION (NSTART). EVEN A SMALL CHANGE IN NSTART WILL FORCE A DIFFERENT RANDOM NUMBER SEQUENCE. FREQUENTLY THAT WILL SOLVE THE PROBLEM. A LARGE INCREASE IN NSTART WILL ENHANCE THE SAMPLING OF THE FISSION SOURCE. THAT IS FREQUENTLY HELPFUL WHEN ONE HAS A LARGE ARRAY. FOR PROBLEMS WITH KNOWN HOT SPOTS, THIS PROBLEM CAN USUALLY BE OVERCOME BY RUNNING STANDARD KENO-IV AS A STAND-ALONE MODULE AND OPTING FOR A DIFFERENT TYPE OF STARTING DISTRIBUTION, AS NOTED PREVIOUSLY.

"THE ANSWER SHEET"

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

*1 LIFETIME = 9.46204E-05 + OR - 9.04611E-07 *2 GENERATION TIME = 1.44532E-05 + OR - 4.12895E-07

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
4	0.87720	+ OR - 0.00368	0.87352 TO 0.88089	0.86984 TO 0.88457	0.86616 TO 0.88825	24900
5	0.87665	+ OR - 0.00368	0.87296 TO 0.88033	0.86928 TO 0.88402	0.86559 TO 0.88770	24600
6	0.87633	+ OR - 0.00372	0.87261 TO 0.88004	0.86890 TO 0.88376	0.86518 TO 0.88748	24300
7	0.87677	+ OR - 0.00374	0.87304 TO 0.88051	0.86930 TO 0.88424	0.86556 TO 0.88798	24000
8	0.87790	+ OR - 0.00361	0.87429 TO 0.88151	0.87068 TO 0.88511	0.86707 TO 0.88872	23700
9	0.87777	+ OR - 0.00365	0.87412 TO 0.88142	0.87046 TO 0.88507	0.86681 TO 0.88872	23400
10	0.87769	+ OR - 0.00370	0.87399 TO 0.88139	0.87029 TO 0.88509	0.86659 TO 0.88878	23100
11	0.87693	+ OR - 0.00367	0.87326 TO 0.88060	0.86959 TO 0.88427	0.86592 TO 0.88794	22800
12	0.87666	+ OR - 0.00371	0.87295 TO 0.88037	0.86925 TO 0.88408	0.86554 TO 0.88779	22500
13	0.87651	+ OR - 0.00376	0.87275 TO 0.88026	0.86900 TO 0.88402	0.86524 TO 0.88778	22200
18	0.87639	+ OR - 0.00397	0.87242 TO 0.88036	0.86845 TO 0.88433	0.86448 TO 0.88830	20700
23	0.87809	+ OR - 0.00390	0.87419 TO 0.88199	0.87029 TO 0.88589	0.86638 TO 0.88979	19200
28	0.87880	+ OR - 0.00417	0.87463 TO 0.88298	0.87046 TO 0.88715	0.86629 TO 0.89132	17700
33	0.87683	+ OR - 0.00424	0.87259 TO 0.88107	0.86835 TO 0.88531	0.86411 TO 0.88954	16200
38	0.87549	+ OR - 0.00445	0.87104 TO 0.87994	0.86658 TO 0.88440	0.86213 TO 0.88885	14700
43	0.87775	+ OR - 0.00477	0.87299 TO 0.88252	0.86822 TO 0.88729	0.86345 TO 0.89205	13200
48	0.87467	+ OR - 0.00471	0.86997 TO 0.87938	0.86526 TO 0.88408	0.86056 TO 0.88879	11700
53	0.87516	+ OR - 0.00491	0.87024 TO 0.88007	0.86533 TO 0.88498	0.86042 TO 0.88989	10200
58	0.87525	+ OR - 0.00573	0.86952 TO 0.88098	0.86379 TO 0.88672	0.85806 TO 0.89245	8700
63	0.87469	+ OR - 0.00599	0.86870 TO 0.88069	0.86270 TO 0.88668	0.85671 TO 0.89268	7200
68	0.87498	+ OR - 0.00748	0.86749 TO 0.88246	0.86001 TO 0.88995	0.85253 TO 0.89743	5700
73	0.87544	+ OR - 0.00845	0.86699 TO 0.88389	0.85854 TO 0.89234	0.85009 TO 0.90079	4200
78	0.87275	+ OR - 0.01005	0.86270 TO 0.88280	0.85265 TO 0.89285	0.84261 TO 0.90290	2700
83	0.85833	+ OR - 0.00962	0.84871 TO 0.86794	0.83909 TO 0.87756	0.82947 TO 0.88718	1200

These results should be discarded since the source dist. was not adequately converged. See note on previous page.

"Best" answer is probably somewhere in this range. See note on previous page.

Average value of K_{eff} based on generations 24 thru 87

Average value of K_{eff} based on generations 29 thru 87

These results should be discarded since the relatively few number of histories used yielded large standard deviations.

*1 NEUTRON LIFETIME - AVERAGE LIFESPAN OF A NEUTRON FROM THE TIME IT IS BORN UNTIL IT LEAKS FROM THE SYSTEM OR IS ABSORBED (GIVEN IN SECONDS)

*2 MEAN GENERATION TIME - AVERAGE TIME BETWEEN SUCCESSIVE NEUTRON GENERATIONS IN THIS PARTICULAR SYSTEM (GIVEN IN SECONDS). THIS IS THE PARAMETER THAT IS USEFUL IN KINETIC CALCULATIONS. OTHER AUTHORS HAVE REFERRED TO THIS AS THE "EFFECTIVE PROMPT NEUTRON LIFETIME" FOR THE FINITE SYSTEM (C.F. LAMARSH, PP. 432).

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

GROUP	REGION	LEAKAGE	ABSORPTIONS	FISSIONS	WITH 4 GENERATIONS SKIPPED
1		2.61612D-04	2.57684D-03	3.43712D-03	
2		4.03137D-04	9.25614D-03	1.98891D-02	
3		5.25762D-04	8.74850D-03	2.17242D-02	
4		2.77897D-04	4.03552D-03	8.67607D-03	
5		6.33454D-04	2.55884D-03	2.62500D-03	
6		1.57887D-03	3.74466D-03	2.08210D-03	
7		1.69652D-03	3.96237D-03	1.99850D-03	
8		8.61488D-04	6.95900D-03	2.05287D-03	
9		1.58349D-04	1.09682D-02	2.77820D-03	
10		1.16551D-04	1.48643D-02	5.83089D-03	
11		2.15907D-04	2.51542D-02	1.22248D-02	
12		2.30692D-05	2.88393D-02	1.59872D-02	
13		2.78008D-05	2.76380D-02	1.49234D-02	
14		1.44064D-05	3.91039D-02	1.16880D-02	
15		2.24453D-05	5.19351D-03	2.79417D-03	
16		2.57178D-05	3.05385D-03	1.67676D-03	
17		0.0	2.54454D-03	2.71960D-03	
18		1.11231D-05	2.75914D-03	3.54616D-03	
19		0.0	3.99602D-03	4.44446D-03	
20		1.59759D-05	1.65935D-02	1.87538D-02	
21		0.0	8.08733D-03	1.01094D-02	
22		2.84047D-05	1.94294D-02	2.45639D-02	
23		1.19683D-05	8.63153D-02	8.95900D-02	
24		0.0	1.95192D-01	1.81738D-01	
25		0.0	1.72032D-01	1.55730D-01	
26		0.0	2.14357D-01	1.90612D-01	
27		0.0	7.73748D-02	6.30156D-02	
TOTAL =		6.91046D-03	9.95338D-01	8.77210D-01	

ELAPSED TIME 10.10517MINUTES

THE SUM OF THE TOTAL LEAKAGE AND ABSORPTION PROBABILITIES SHOULD BE VERY CLOSE TO 1.0 IF ALBEDOS ARE NOT USED AND SEVERE WEIGHTING IS NOT IMPOSED. IN PRACTICE, THE SPATIALLY DEPENDENT MULTIGROUP WEIGHTS GENERATED BY THE AUTOMATIC REFLECTOR CARD MAY CAUSE THESE ESTIMATES TO BE OFF BY 4 OR 5 PERCENT. (THE RESULTS PRINTED HERE HAVE NOT BEEN NORMALIZED TO UNITY).

THE FISSION DENSITY BY ENERGY GROUP GIVES AN INDICATION OF WHERE THE FISSION ACTIVITY HAS OCCURRED. THE TOTAL FISSION DENSITY PRINTED SHOULD BE NUMERICALLY VERY CLOSE TO THE AVERAGE K-EFFECTIVE BASED ON ALL BUT THE FIRST FEW GENERATIONS.

REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

**** FISSION DENSITIES ****

	REGION	FISSION DENSITY	PERCENT DEVIATION	TOTAL FISSIONS
BOX TYPE 1	1	0.0	0.0	0.0
BOX TYPE 2	1	0.0	0.0	0.0
BOX TYPE 3	1	0.0	0.0	0.0
BOX TYPE 4	1	0.0	0.0	0.0
BOX TYPE 5	1	0.0	0.0	0.0
BOX TYPE 6	1	0.0	0.0	0.0
BOX TYPE 7	1	0.0	0.0	0.0
BOX TYPE 8	1	0.0	0.0	0.0
BOX TYPE 9	1	7.503E-07	0.69	5.707E-01
BOX TYPE 10	1	7.685E-07	2.05	1.831E-02
BOX TYPE 11	1	7.586E-07	1.52	1.494E-01
BOX TYPE 12	1	0.0	0.0	0.0
BOX TYPE 13	1	0.0	0.0	0.0
BOX TYPE 14	1	0.0	0.0	0.0
BOX TYPE 15	1	0.0	0.0	0.0
BOX TYPE 16	1	0.0	0.0	0.0
BOX TYPE 17	1	0.0	0.0	0.0
BOX TYPE 18	1	0.0	0.0	0.0
BOX TYPE 19				

IF ONE HAD A LARGE ARRAY OF BOXES WITH FISSILE MATERIAL THROUGHOUT AND NOTICED A SIGNIFICANTLY LARGER THAN AVERAGE FISSION DENSITY IN ONE OR TWO OF THE BOXES, ONE SHOULD INTERPRET THE PREVIOUS RESULTS WITH SOME CARE. WHILE THE SIGNIFICANTLY HIGHER THAN AVERAGE FISSION DENSITY IN A GIVEN REGION MAY BE THE RESULT OF A HIGHER THAN AVERAGE ENRICHMENT, OR JUSTIFIED ON SOME OTHER GROUNDS, IT RAISES THE QUESTION: "WAS THE SOURCE DISTRIBUTION CONVERGED TO THE FUNDAMENTAL MODE?" IF NOT, THE AVERAGE VALUE OF K-EFFECTIVE MAY BE IN SERIOUS ERROR DESPITE GOOD STATISTICS. IN SUCH SITUATIONS, THE USER SHOULD FLIP BACK 3 OR 4 PAGES AND CHECK THE GENERATION-BY-GENERATION EDIT OF THE AVERAGE VALUE OF K-EFFECTIVE. IN THIS PARTICULAR CASE, $\overline{K}_{EFF}$ BEGAN TO SETTLE-OUT AFTER 7 OR 8 GENERATIONS. IN PROBLEMS THAT HAVE "HOT SPOTS," $\overline{K}_{EFF}$ MAY NOT BEGIN TO SETTLE OUT FOR 30 OR 40 GENERATIONS. IN SUCH CASES ONE SHOULD DISCARD THOSE "AVERAGE VALUES OF K-EFFECTIVE" THAT INCLUDE THE FIRST 30 OR 40 GENERATIONS. (TO INSURE HIMSELF OF GOOD STATISTICS AFTER DISCARDING SO MANY HISTORIES, THE USER MAY ALSO WISH TO RESUBMIT THE PROBLEM AND LET IT RUN FOR AN ADDITIONAL 80 OR 90 GENERATIONS).

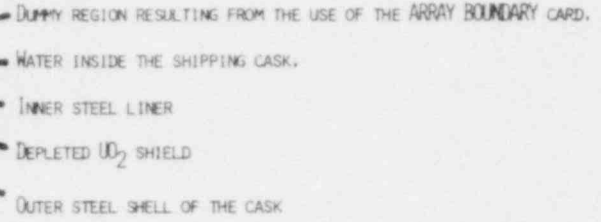
WHILE THE ABOVE PROCEDURE IS USUALLY ADEQUATE, IT IS STILL NO GUARANTEE THAT THE SOURCE DISTRIBUTION HAS CONVERGED TO THE FUNDAMENTAL MODE. PROBLEMS WITH HOT SPOTS ARE NOT ALONE IN THIS REGARD. IN LARGE REACTOR CORES WHERE THE SECOND LARGEST EIGENVALUE (λ_2) IS VERY CLOSE TO K_{EFF}, IT IS OFTEN POSSIBLE TO EXCITE THE SECONDARY MODE (IN BOTH AN OPERATING REACTOR AND ITS MONTE CARLO SIMULATION). WHILE THE SECONDARY MODE WILL DECAY, IT MAY DIE OUT SO SLOWLY THAT THE "AVERAGE VALUE OF K-EFFECTIVE" MAY APPEAR TO BE CONVERGED (ALBEIT TO THE WRONG VALUE). CHECKING THIS EDIT OF THE FISSION DENSITY BY REGION SHOULD AFFORD THE USER SOME PROTECTION PROVIDED HE TOOK THE PRECAUTION OF DIVIDING THE CORE INTO A NUMBER OF DIFFERENT REGIONS. OTHER WEAKLY COUPLED SYSTEMS, SUCH AS FUEL ASSEMBLIES SEPARATED BY A MODERATE AMOUNT OF WATER IN A FUEL STORAGE PIT, MAY PRESENT SIMILAR DIFFICULTIES. THE INTERSECTION OF TWO LONG PIPES CONTAINING A FISSILE SOLUTION IS ANOTHER GOOD EXAMPLE.

PROBLEMS WITH KNOWN "HOT SPOTS," SUCH AS A HIGHLY ENRICHED ASSEMBLY IN THE MIDST OF MANY LOW ENRICHED ASSEMBLIES, ARE OFTEN BEST SOLVED BY INTENTIONALLY DRIVING THE FUNDAMENTAL MODE. THIS APPROACH SHOULD ALSO BE USED FOR THE PIPE INTERSECTION PROBLEM. TO DRIVE THE FUNDAMENTAL MODE, ONE WOULD START ALL (OR MOST) OF THE NEUTRONS IN THE KNOWN HOT SPOTS AND LET THEM DIFFUSE OUTWARD. THE HOT ASSEMBLY OR THE ACTUAL PIPE INTERSECTION MIGHT BE DESCRIBED AS BOX TYPE NO. 1 WHILE THE REST OF THE SYSTEM IS DESCRIBED BY OTHER BOX TYPES. USING STANDARD KENO-IV AS A STAND-ALONE MODULE ONE COULD THEN USE MYRST (PARAMETER NO. 20) TO START ALL NEUTRONS IN BOX TYPE NO. 1. RUNNING CSAS2 AND THE STAND-ALONE KENO-IV MODULE BACK-TO-BACK IN A SINGLE SCALE RUN WILL ALLOW THE KENO MODULE TO TAKE ADVANTAGE OF THE CROSS SECTION LIBRARY PRODUCED BY CSAS2.

	1	6.341E-07	2.13	1.329E-01

REFLECTOR

1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0
4	3.371E-09	6.41	5.701E-03
5	0.0	0.0	0.0



REALISTIC MODEL OF A SPENT FUEL SHIPPING CASK (KENO-IV GEOMETRY)

FREQUENCY FOR GENERATIONS 5 TO 87*

```
0.7733 TO 0.7964     **
0.7964 TO 0.8195     ***
0.8195 TO 0.8426     ******
0.8426 TO 0.8657     ********************
0.8657 TO 0.8888     ****************************
0.8888 TO 0.9118     ****************
0.9118 TO 0.9349     ******
0.9349 TO 0.9580     ******
```

FREQUENCY FOR GENERATIONS 26 TO 87

```
0.7733 TO 0.7964
0.7964 TO 0.8195     **
0.8195 TO 0.8426     *****
0.8426 TO 0.8657     ***************
0.8657 TO 0.8888     ***********************
0.8888 TO 0.9118     ************
0.9118 TO 0.9349     ****
0.9349 TO 0.9580     *****
```

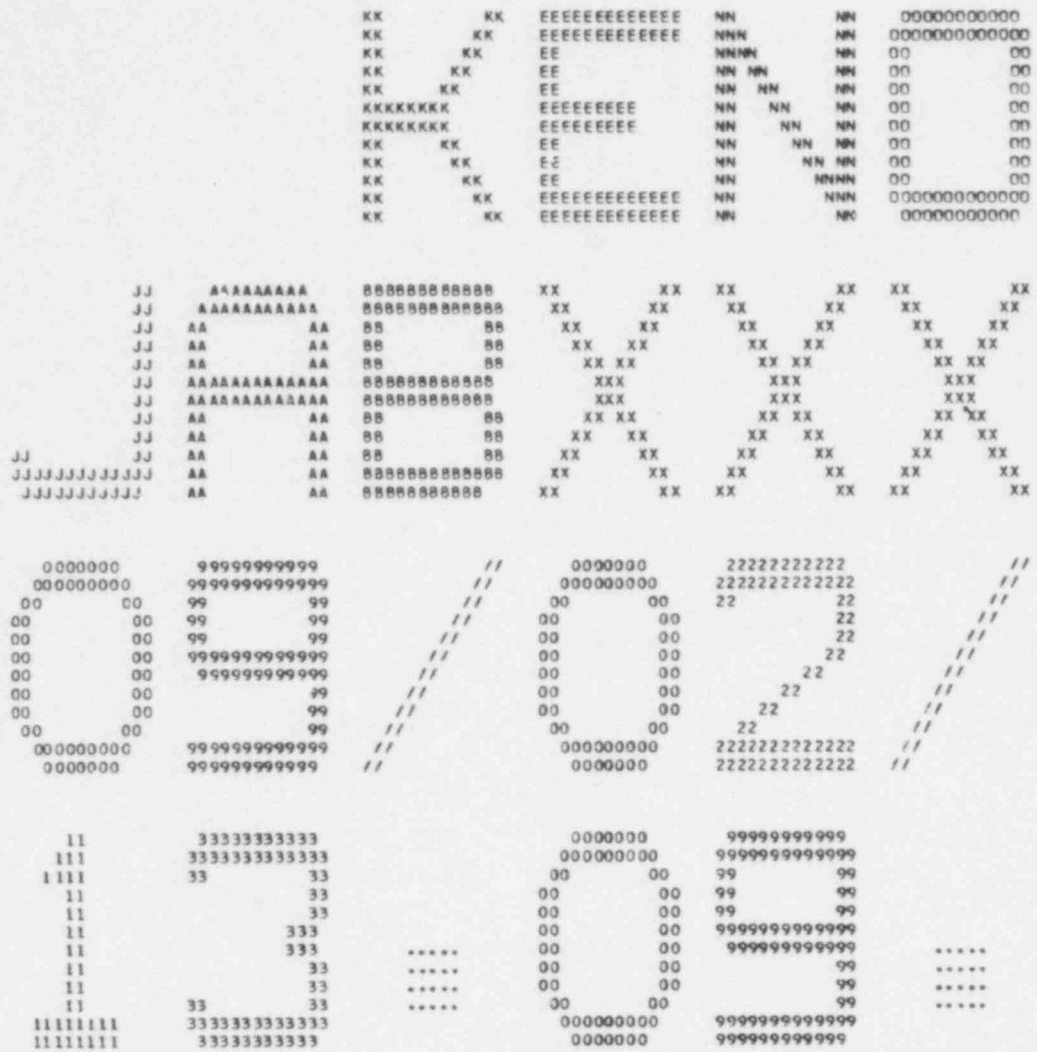
FREQUENCY FOR GENERATIONS 46 TO 87

```
0.7733 TO 0.7964
0.7964 TO 0.8195     **
0.8195 TO 0.8426     ****
0.8426 TO 0.8657     ********
0.8657 TO 0.8888     ***************
0.8888 TO 0.9118     *********
0.9118 TO 0.9349     **
0.9349 TO 0.9580     ***
```

FREQUENCY FOR GENERATIONS 67 TO 87

```
0.7733 TO 0.7964
0.7964 TO 0.8195
0.8195 TO 0.8426     ****
0.8426 TO 0.8657     ***
0.8657 TO 0.8888     *********
0.8888 TO 0.9118     **
0.9118 TO 0.9349     **
0.9349 TO 0.9580     *
```

THESE ARE PLOTS OF THE FREQUENCY WITH WHICH THE INDIVIDUAL GENERATION K-EFFECTIVE'S FALL WITHIN A CERTAIN RANGE. ONE ASTERISK IS PRINTED FOR EACH K-EFFECTIVE THAT IS CALCULATED. THESE PLOTS CAN BE USED TO ESTIMATE THE NORMALITY OF THE DISTRIBUTION OF THE K-EFFECTIVE'S, AND CAN SOMETIMES SHOW A TREND INDICATIVE OF SOURCE CONVERGENCE DIFFICULTIES.



C1.203

9. ERROR MESSAGES FOR CSAS1

The CSAS1/CSAS2 control modules are charged with the task of reading the input described in Section 6 and generating the binary input files for the various functional modules. The error messages described in this section may be generated by either control module.

While the code will try to read and check as much data as possible before terminating execution, there are some errors the user could make which would cause the input processor to get "out of phase" and stop execution before processing all of the data. For that reason, it is suggested that one use high-priority jobs requiring very little CPU time to debug his input, and then resubmit the problem with more CPU time only after the code successfully enters the first functional module (BONAMI).

The following error messages are generated by subroutine SETUPB

1. ***ERROR*** SYSTEM GEOMETRY NAME INCORRECT. INSTEAD OF (aaaaaaaaaaaa), THE USER SHOULD HAVE ENTERED LATTICECELL, MULTIREGION OR INFHOMMEDIUM AS THE FIFTH ITEM ON THE PARAMETER CARD. CHECK SPELLING.

2. ***ERROR*** THE USER ENTERED A VOLUME FRACTION (VF) OF 0.0 FOR ONE OF THE STANDARD COMPOSITIONS (aaaaaaaaaaaa). THIS INDICATES THAT HE INTENDS TO ENTER A NUMBER DENSITY FOR THE STANDARD COMPOSITION. THAT, HOWEVER, CAN ONLY BE DONE WHEN THE STANDARD COMPOSITION NAME REPRESENTS A SINGLE NUCLIDE (LIKE H, O, NA, PB, B-10, U-238, ETC.). CHECK THE STANDARD COMPOSITION LIBRARY.

3. ***ERROR*** CELL TYPE NAME INCORRECT. INSTEAD OF (aaaaaaaaaaaa). THE USER SHOULD HAVE ENTERED SQUAREPITCH, TRIANGPITCH, SPHSQUAREP, SPHTRIANGP, SYMMSLABCELL, OR ASYMSLABCELL AS THE FIRST ITEM ON THE GEOMETRY DESCRIPTION CARD. CHECK SPELLING.

4. ***ERROR*** THE NUMBER OF ZONES (IZM= nn) IS INCORRECT FOR ASYMSLABCELL GEOMETRY. FOR AN ASYMMETRIC LATTICECELL CALCULATION, ONE SHOULD HAVE IZM = 3, 5,OR 7 DEPENDING ON THE MATERIALS PRESENT.

5. **WARNING** NUMBER OF ENTRIES ON THE GEOMETRY DESCRIPTION CARD EXCEEDS THE NUMBER EXPECTED. CHECK THE VALUE OF IZM ON PARAMETER CARD. (THIS MESSAGE WILL ALSO BE GENERATED IF USER FORGOT TO ENTER THE END ON THE GEOMETRY DESCRIPTION CARD).

6. ***ERROR*** INSUFFICIENT DATA SUPPLIED ON THE GEOMETRY DESCRIPTION CARD. CHECK THE VALUE OF IZM ON THE PARAMETER CARD.

7. ***ERROR*** THE COORDINATE SYSTEM NAME (aaaaaaaaaaaa) IS INCORRECT. FOR THIS MULTIREGION CALCULATION, THE USER SHOULD HAVE ENTERED SLAB, CYLINDRICAL, SPHERICAL, BUCKLEDSLAB OR BUCKLEDCYL ON THE GEOMETRY DESCRIPTION CARD. CHECK SPELLING.

8. ***ERROR*** ALPHANUMERIC DESCRIPTION OF THE RIGHT-HAND BOUNDARY CONDITION (aaaaaaaaaaaa) IS INCORRECT. ONLY VACUUM, REFLECTED, PERIODIC AND WHITE BOUNDARY CONDITIONS ARE ALLOWED. CHECK SPELLING. CHECK INPUT DESCRIPTION FOR THE GEOMETRY DESCRIPTION CARD FOR ADDITIONAL INSTRUCTIONS.

9. ***ERROR*** ALPHANUMERIC DESCRIPTION OF THE LEFT-HAND BOUNDARY CONDITION (aaaaaaaaaaaa) IS INCORRECT. ONLY VACUUM, REFLECTED, PERIODIC AND WHITE BOUNDARY CONDITIONS ARE ALLOWED IN SLAB GEOMETRY. IN THE CASE OF CYLINDRICAL OR SPHERICAL GEOMETRY, ONLY THE REFLECTED BOUNDARY CONDITION IS ALLOWED ON THE LEFT. CHECK SPELLING. CHECK INPUT DESCRIPTION FOR THE GEOMETRY DESCRIPTION CARD FOR ADDITIONAL INSTRUCTIONS.

10. ***ERROR*** USER MADE AT LEAST nn DATA ERRORS. PROBLEM WILL NOT BE RUN. HOPEFULLY, EACH OF THESE ERRORS WILL HAVE GENERATED ITS OWN

SELF-EXPLANATORY ERROR MESSAGE. IF NOT, CHECK DATA CAREFULLY BEFORE RESUBMITTING.

11. ***ERROR*** ALL MIXTURE NUMBERS (MX) DEFINED BY THE USER SHOULD BE SUCH THAT ((MX.GE.1).AND. (MX.LE.MXX)). HERE, THE USER DEFINED MXX=iii ON THE PARAMETER CARD AND THEN TRIED TO USE MX=jjj ON ONE OF THE STANDARD COMPOSITION CARDS.

12. **WARNING** STANDARD COMPOSITION SPECIFICATION CARD NUMBER nn IMPLIES THAT MIXTURE NUMBER ii HAS A TEMPERATURE OF ttt.t DEGREES KELVIN WHEREAS STANDARD COMPOSITION SPECIFICATION CARD NUMBER mm IMPLIES THAT MIXTURE NUMBER ii HAS A TEMPERATURE OF sss.s DEGREES KELVIN. (ONE OF THESE MAY HAVE BEEN THE VALUE SPECIFIED BY DEFAULT). THE CODE WILL ASSUME THE HIGHER OF THE TWO AND PROCEED. IF THIS IS NOT SATISFACTORY, THE USER SHOULD ENTER THE CORRECT TEMPERATURE ON EACH OF THE STANDARD COMPOSITION SPECIFICATION CARDS INDICATED.

13. ***ERROR*** STANDARD COMPOSITION SPECIFICATION CARD(S) MISSING FOR MIXTURE NUMBER mm.

14. ***ERROR*** aaaaaaaaaaa NOT FOUND IN STANDARD COMPOSITION LIBRARY. MAKE SURE THAT COMPOSITION NAME USED IS IN THE STANDARD COMPOSITION LIBRARY. THE NUMBER OF COMPOSITION SPECIFICATIONS (MSC) MUST BE THE SAME AS THE NUMBER ACTUALLY ENTERED.

The following error messages are generated by subroutine EPSIG

1. ***ERROR*** FOR I=iii, MIXNO(I)=mmm IS OUT OF THE RANGE 1 TO MXX WHERE MXX=nnn. SEE SUBROUTINE EPSIG.

   By setting MXX=nnn on the Parameter Card, the user told the code he was going to define (and subsequently use) mixtures 1, 2, 3, ..., nnn. On the Geometry Description Card (see MFUEL,

MMOD, MMOD2, MCLAD, or MGAP) or on the Multiregion Zone Description Card (see MXZ_1, MXZ_2, MXZ_3, etc.) he has used some other mixture.

2. ***ERROR*** FOR I=iii, NXREF(I)=mmm IS OUT OF THE RANGE 1 TO NNUC WHERE NNUC=nnn. SEE SUBROUTINE EPSIG.

   If one uses the standard composition specification cards to define ten mixtures (MXX=10), three of which are used on the Geometry Description Card (see MFUEL, MMOD, MMOD2, MCLAD, or MGAP) or on the Multiregion Zone Description Card (see MXZ_1, MXZ_2, MXZ_3, etc.), then those three mixtures must be entered as mixtures 1, 2, and 3.

The following error messages are generated by subroutine NITXSD

1. ***ERROR*** THE MIX. NO. (MIXZ= mm) ASSIGNED TO ZONE IZ=ii WAS OUTSIDE THE RANGE 0 to MXX=nn.

2. **WARNING** A GIVEN MIXTURE (I.E. MIX.NO. mm) WAS ASSIGNED TO MORE THAN ONE ZONE (I.E. ZONE ii AND ZONE jj). IF THIS MIXTURE HAS NO RESONANCE NUCLIDES AND IF IT HAS THERMAL SCATTERING DATA AT ONLY ONE TEMPERATURE, THIS IS OK. NORMALLY, HOWEVER, ONE SHOULD DEFINE SEPARATE MIXTURE NUMBERS WITH IDENTICAL SPECIFICATIONS AND USE EACH OF THESE "SEPARATE MIXTURE NUMBERS" IN ONLY ONE ZONE. THIS WILL, FOR EXAMPLE, ALLOW NITAWL TO PRODUCE SEPARATE WORKING LIBRARIES BASED ON THE APPROPRIATE NUMBER OF EXTERNAL MODERATORS AND THE ACTUAL MEAN CHORD LENGTH FOR THAT ZONE AS WELL AS THE ACTUAL TEMPERATURE FOR THAT ZONE.

3. ***ERROR*** USER SPECIFIED MORE THAN ONE ZONE FOR THIS INFINITE-HOMOGENEOUS-MEDIA PROBLEM.

   Change value of IZM on the Parameter Card.

The following error message is generated by subroutine MIXTAB

1. ***ERROR*** SEARCH USING DO LOOP NO. nnn FAILED TO FIND MATCH.

   If the user has specified the isotope distribution for any of the materials, check the "ZA" nuclide I.D. numbers used in the corresponding specification statement(s). Likewise, if an Arbitrary Material has been specified anywhere in the input, each of the associated "ZA" nuclide I.D. numbers should also be checked. Only those I.D. numbers found in the Standard Composition Library are acceptable.

The following error messages are generated by subroutine NOFRAC

1. ***ERROR*** THE MATRIX (A) WAS SINGULAR – SEE SUBROUTINE NOFRAC. MAKE SURE THE SPECIFIED ISOTOPE DISTRIBUTION SUMS TO 100.0 PERCENT.

2. ***ERROR*** CALCULATED NO. FRACTIONS WILL NOT REPRODUCE WT. FRACTIONS – SEE SUBROUTINE NOFRAC.

   Usually generated in conjunction with other error messages. Make sure the specified isotope distribution sums to 100.0 percent.

The following error message is generated by subroutine STOCHK

1. ***ERROR*** ADDITIONAL STORAGE NEEDED FOR AT LEAST iiii MORE WORDS – INCREASE REGION SIZE BY jjjK. THIS MESSAGE GENERATED BY STATEMENT NO. nnn IN SUBROUTINE xxxxx.

   Since the control module determines the length of several mixing tables, the number of mesh intervals in any given zone, and other material, cross section and geometry dependent data, the amount of core required is very problem dependent and cannot easily be estimated by the user. The simplest thing the user can do is to increase the region size for the "go step" by the amount indicated and resubmit the job.

   Specification (by the control module) of too many mesh intervals in a given zone is the most frequent cause of failure. In multiregion calculations where one has a large zone containing a

strong absorber (such as a tank of uranyl fluoride solution), it may be necessary to reduce the number of mesh intervals by increasing the size factor (SZF) on the Optional Control Parameter Card. Making this factor large enough (SZF=10, 15, 20, 30, etc.), will generally allow any problem to run in the space allocated. Once the problem runs, one should check the number density of all strong absorbers to see if they are realistic. Occasionally a user will accidentally specify an unrealistic concentration of a strong absorber in one or more zones. Such a mistake dramatically increases the number of mesh intervals the code thinks it needs.

10. ERROR MESSAGES FOR CSAS2

The CSAS2 control module is charged with the task of reading the input described in Section 6 and generating the binary input files for the various functional modules. In addition to the error messages listed in this section, CSAS2 may also generate any of the error messages listed in Section 9.

While the code will try to read and check as much data as possible before terminating execution, there are some errors the user could make which would cause the input processor to get "out of phase" and stop execution before processing all of the data. For that reason it is suggested that one use high-priority jobs requiring very little CPU time to debug his input, and then resubmit the problem with more CPU time only after the code successfully enters the first functional module (BONAMI).

The following error messages are generated by subroutine KIP

1. ***ERROR*** NXX SHOULD BE ASSIGNED AN INTEGER VALUE OF 0 OR 1 ONLY.
2. ***ERROR*** NBXMAX, NBYMAX OR NBZMAX IS .LE. ZERO WHILE NBOX IS .GT. ONE.
3. ***ERROR*** BOUNDARY CONDITION SPECIFICATIONS (MLRX2, MLRX1, MLRY2, MLRY1, MLRZ2, MLRZ1) SHOULD BE ASSIGNED AN INTEGER VALUE OF 0 OR 1.
4. ***ERROR*** THIS KENO INFORMATION PROCESSOR CANNOT READ CROSS SECTIONS OFF CARDS.
5. ***ERROR*** UNACCEPTABLE GEOMETRY WORD (aaaaaaaaaaaa) FOUND IN INPUT STREAM.
6. ***ERROR*** THIS KENO INFORMATION PROCESSOR CANNOT HANDLE GENERALIZED GEOMETRY.
7. ***ERROR*** IDWT ON REFLECTOR CARD IS OUT OF RANGE. MUST BE GREATER THAN NINE. SEE TABLE OF POSSIBLE VALUES.
8. ***ERROR*** ON THE AUTOMATIC REFLECTOR CARD, THE USER ASSIGNED IDWT A VALUE OF iii (WHICH IS NOT ACCEPTABLE). CHECK LIST OF ACCEPTABLE VALUES IN TABLE A-5.

9. ***ERROR*** BECAUSE THE USER ASSIGNED MIX. NO. 500 TO ONE OR MORE OF THE KENO GEOMETRY REGIONS, AN XSDRNPM CALCULATION WILL BE PERFORMED TO CELL-AVERAGE THE CROSS SECTION DATA FOR THE MIXTURES SPECIFIED ON THE GEOMETRY DESCRIPTION CARD OR THE MULTIREGION ZONE DESCRIPTION CARD. (THESE CELL-AVERAGED CROSS SECTIONS WILL THEN BE HOMOGENIZED TO FORM MIX. NO. 500). BECAUSE OF THE CELL-AVERAGING, IT IS INCORRECT TO RE-ASSIGN ANY OF THOSE MIXTURES (EXCEPT MIX. NO 0) TO A KENO GEOMETRY REGION. CHECK MIX. NO. mm IN PARTICULAR. TO CORRECT THE SITUATION, THE USER SHOULD USE THE STANDARD COMPOSITION SPECIFICATION CARDS TO DEFINE A NEW MIXTURE IN A SIMILAR FASHION AND THEN USE THAT NEW MIX. NO. WHEREVER NEEDED IN THE KENO PORTION OF THE PROBLEM.

10. ***ERROR*** NBXMAX*NBYMAX*NBZMAX = mmmm ENTRIES REQUIRED IN THE MBD(I) ARRAY. ONLY nnnn WERE FOUND.

11. ***ERROR*** NBXMAX*NBYMAX*NBZMAX = mmmm ENTRIES REQUIRED IN THE MBD(I) ARRAY. IN THIS CASE, USER SPECIFIED MORE THAN mmmm ENTRIES AND/OR FORGOT TO FOLLOW THAT DATA WITH A ZERO (IENDD) AS REQUIRED.

12. ***ERROR*** USER ATTEMPTED TO STACK TOO MANY KENO CASES BACK-TO-BACK (NO. OF KENO TITLE CARDS + NO. OF "END CASE" CARDS + NO. OF "END KENO" CARDS) MUST BE .LE. 21.

The following error messages are generated by subroutine KENOG

1. ***ERROR*** NUMBER OF BOXES ON PARAMETER CARD DOES NOT AGREE WITH BOX DATA READ IN. NBOX = nnn ITP = iii.

   NBOX is the parameter stating how many box types are in the problem. ITP is the number of box types that were encountered

when reading geometry data. Either NBOX was incorrectly specified or the geometry data was incorrectly entered.

2. ***ERROR*** A SINGLE UNIT PROBLEM CANNOT HAVE A CORE BOUNDARY REGION.

   By setting NBOX=0 on the KENO Parameter Card, the user told the code that this particular problem did not contain an "array of boxes" and then, further down in the input, he supplied an ARRAY BOUNDARY card. One solution is to change NBOX from 0 to 1 and set NBXMAX = NBYMAX =NBZMAX = 1. Alternately, the user may simply delete the ARRAY BOUNDARY card and use the Basic Geometry Description cards to describe the surrounding regions. See Appendix C.

3. **WARNING** A CORE BOUNDARY CARD IS REQUIRED ONLY IF AN EXTERNAL REFLECTOR IS PRESENT.

   This is just a warning message and does not cause termination of the problem. It does, however, cause the problem to run less efficiently.

4. ***ERROR*** UNRECOGNIZABLE GEOMETRY WORD aaaaaaaaaa MATERIAL mmm

   This geometry word is not one of those specified in the input instructions. Either the card was mispunched or the data is out of order. Check to be sure the proper number of dimensions, the mixture number and the proper number of weights are on the preceding geometry card.

5. ***ERROR*** MIXTURE mm IS NOT SPECIFIED IN THE MIXING TABLE.

   This mixture number, which was found on the previous geometry card, was less than zero or greater than MXX, where MXX is the total number of mixtures defined using the Standard Composition Specification Cards (cf., Section 6). This message may also mean that the data was mispunched or out of order.

6. ***ERROR*** NEGATIVE WEIGHTS ARE NOT ALLOWED. THE PROBLEM WILL NOT BE RUN.

   One or more of the region/group dependent weights entered by the user was negative. This is not allowed. (A single entry of −0.5 will cause a weight of +0.5 to be assigned to all groups in the given region. That is not what the code is complaining about here.) Check data for those regions where the user entered the weight for each group separately. Check for mispunched data and/or data that is out of order.

7. ***ERROR*** AN ERROR WAS FOUND IN THE HEMISPHERE DESIGNATION.

   The alphanumeric geometry word did not correctly specify the direction in which the hemisphere exists. Check spelling.

8. ***ERROR*** NHCYL = iii

   The alphanumeric geometry word for one of the hemicylinders was incorrect. Check spelling.

9. ***ERROR*** END OF KENO FLAG READ IN GEOMETRY DATA.

   Code expected to find additional geometry data which wasn't there. Make sure geometry data was entered for each box type and that each box type ended with a CUBE or CUBOID. On each geometry card, make sure correct number of entries were included for the material, dimensions and weights. Make sure the END GEOMETRY card was included at the proper place. Check the Mixed Box Orientation Data (if any). Data may be incorrectly punched or improperly arranged.

The following error message is generated by subroutine MAKREF

1. ***ERROR*** A WEIGHTING ID OF iii WAS SPECIFIED USING gg ENERGY GROUPS BUT IT WAS NOT FOUND ON TAPE.

   The weighting ID, IDWT, specified on the automatic reflector card is not available in the library of reflector weights for the particular group structure specified by the user. See Table A-5.

The following error messages are generated by subroutine JOMCHK

1. ***ERROR*** REGION NUMBER kk INTERSECTS REGION NUMBER ℓℓ

   The surface defined by a given geometry card must fully enclose (or be tangent to) the surface defined by the previous geometry card. Check the dimensions on each geometry card and the order in which the data was entered.

2. ***ERROR*** BOX TYPE ii CONTAINS THE FOLLOWING GEOMETRY INCONSISTENCIES: REGION NUMBER kk INTERSECTS REGION NUMBER ℓℓ ; REGION NUMBER mm INTERSECTS REGION NUMBER nn; etc.

   The surface defined by a given geometry card must fully enclose (or be tangent to) the surface defined by the previous geometry card. Check the dimensions on each geometry card and the order in which the data was entered.

3. ***ERROR*** REFLECTOR GEOMETRY DIMENSIONS ARE INCONSISTENT: REGION NUMBER kk INTERSECTS REGION NUMBER ℓℓ ; REGION NUMBER mm INTERSECTS REGION NUMBER nn; etc.

   The surface defined by a given geometry card must fully enclose (or be tangent to) the surface defined by the previous geometry card. Check the dimensions on each geometry card and the order in which the data was entered.

4. ***ERROR*** INVALID NESTING OF GEOMETRY REGIONS INVOLVING GENERAL OR HEMISPHERE REGIONS.

   The surface defined by a given geometry card must fully enclose (or be tangent to) the surface defined by the previous geometry card. Since spheres and cylinders are both centered at the origin, a hemisphere can never fully enclose either of these bodies.

5. ***ERROR*** INVALID HEMICYLINDER TYPE. NHCYL = iii

   The alphanumeric geometry word for one of the hemicylinders was incorrect. Check spelling.

The following error messages are generated by subroutine VOLUME

1. ***ERROR*** REGION NUMBER nn CONTAINS AN ERROR IN THE DIMENSIONS.

   This message occurs if the X2, Y2, Z2 or S2 surface of a body is to the left, behind or below the X1, Y1, Z1 or S1 surface of a body. For bodies such as cubes, cuboids and cylinders (etc.), the user must specify the data such that X2 > X1, Y2 > Y1, Z2 > Z1 and S2 > S1. The data may be mispunched or out of order.

2. ***ERROR*** THE VOLUME SPECIFIED BY GEOMETRY CARD nn IS NEGATIVE.

   The volume of a region is calculated by taking the volume enclosed by the surface described by one geometry card and subtracting the volume enclosed by the surface described by the preceding geometry card. As noted in Appendix C, the tracking scheme used in KENO assumes that each geometry region fully encloses all previous ones. This, therefore, . . a serious error. Check the nesting of spatial regions within each box type and the nesting of any spatial regions outside an array.

3. ***ERROR*** A BOX VOLUME MUST BE GREATER THAN ZERO

   The last geometry card describing a given box type must be a CUBE or CUBOID. It must fully enclose (or be tangent to) all other regions within the box. Check the dimensions and the order in which the data was specified. This message will also be printed if the user included a BOX TYPE card and forgot to follow it with some sort of geometric description.

4. ***ERROR*** THE LAST GEOMETRY CARD IN THE UNIT MUST BE A CUBE OR CUBOID

   The last geometry card describing a given box type must be a CUBE or CUBOID. It must fully enclose (or be tangent to) all other regions within the box.

The following error message is generated by subroutine BOX

1. ***ERROR*** AN ERROR EXISTS IN THE ARRAY DESCRIPTION X INDEX = ii, Y INDEX = jj, Z INDEX = kk

   Some strange box type n (n $\leq$ 0 or n > NBOX) has been assigned to position (ii, jj, kk) of the KENO array. This error usually results from leaving some positions in the array undefined or from mispunching the Mixed Box Orientation Data. Check the printout of the Mixed Box Orientation Data at the position(s) indicated and correct the input.

The following error messages are generated by subroutine FILBOX

1. ***ERROR*** MIXED BOX ORIENTATION CARD nn CONTAINS mm ERROR(S).
   LTYPE = ℓ IX1 = i_1 IX2 = i_2 INCX = Δi IY1 = j_1
   IY2 = j_2 INCY = Δj IZ1 = k_1 IZ2 = k_2 INCZ = Δk

2. ***ERROR*** THE ABOVE MIXED BOX ORIENTATION CARD(S) CONTAIN(S) AT LEAST ONE OF THE FOLLOWING ERRORS: 1) IX1, IY1, IZ1, INCX, INCY, OR INCZ IS LESS THAN OR EQUAL TO ZERO; 2) IX2 IS LESS THAN IX1, IY2 IS LESS THAN IY1, OR IZ2 IS LESS THAN IZ1; 3) IX2 IS GREATER THAN NBXMAX, IY2 IS GREATER THAN NBYMAX, OR IZ2 IS GREATER THAN NBZMAX; 4) LTYPE IS LESS THAN 1 OR GREATER THAN NBOX.

The following error message is generated by subroutine CORSIZ

1. ***ERROR*** THE DIMENSIONS OF BOX TYPE mm AT (ii, jj, kk) DO NOT MATCH THOSE OF BOX TYPE nn AT (ii', jj', kk').

   FOR BOX TYPE mm $\begin{Bmatrix}+X\\+Y\\+Z\end{Bmatrix}$ = ppppp AND $\begin{Bmatrix}-X\\-Y\\-Z\end{Bmatrix}$ = qqqqq

   WHILE FOR BOX TYPE nn $\begin{Bmatrix}+X\\+Y\\+Z\end{Bmatrix}$ = rrrrr AND $\begin{Bmatrix}-X\\-Y\\-Z\end{Bmatrix}$ =sssss.

   This message appears because the common faces of adjacent boxes are not the same size. One or more of the dimensions of one of the box types specified in the message may be incorrect or the mixed box orientation data may be incorrect.

APPENDIX A.1
The Standard Composition Library

The Standard Composition Library describes the various compounds, alloys, elements and isotopes one may use in defining the material mixtures for a given problem.* Typically, one will use the alphanumeric description of one or more of these materials to define a material mixture as noted in Section 6 (c.f., the Standard Composition Specification Card).

Often when formulating such a mixture, it is necessary to know the density (gms/cc) of the various constituent materials. For convenience, the reference values used by the code have been listed in Table A-1. (Note that the reference values given represent the actual theoretical density, except in the case of some individual nuclides where a default value of 1.0 gm/cc was used.)

While the user is never required to enter the temperature of a given material, he is always allowed to enter it (c.f., item 5 of the Standard Composition Specification Card). Indeed, the temperature probably should be entered if resonance data or Bondarenko data is available for the material, or if thermal scattering data is available at more than one temperature. YES/NO flags for both conditions are given in Table A-1. [Note: The list of nuclides having resonance data differs from one master cross-section library to another. Table A-7 lists those nuclides having resonance data on each of the master cross-section libraries. The list of nuclides having thermal scattering cross-section data at more than one temperature also differs from one library to another. Table A-8 lists those nuclides (and the associated temperatures) for each of the master cross-section libraries. Table A-7 and A-8 have been included for the sake of completeness. While the user may find this information interesting and/or helpful, he should have no direct need of it.]

Unfortunately, all nuclides are not presently available on all master cross-section libraries. Column 5 of Table A-1 is designed to give a quick indication of whether or not all the nuclides in a given material are available on a given cross-section library. Thus, for example one should not use ORCONCRETE or CA in conjunction with the 123GROUPGMTH library. Column 5 does indicate, however, that both materials are available on the HANSEN-ROACH, the 27GROUPNDF4 and the 218GROUPNDF4 libraries.

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*In addition to the various materials listed here, one is also free to use any of the solutions found in the Table of Available Solutions (Table A-2).

To more fully document the composition of each material and/or to document the assumptions used in producing the associated cross-section data, a brief description of each material in Table A-1 is included here:

1.	BORON	Boron; natural isotope distribution obtained by default
2.	B4C	Boron carbide: B_4C; natural isotope distribution obtained by default
3.	H2O	Water; cross-sections developed using 1/E weighting everywhere
4.	H2O-X(E)-HR	Water; cross-sections developed using fission spectrum weighting at high energies and 1/E at lower energies
5.	D2O	Heavy water: D_2O
6.	ZIRCALLOY	Zircalloy-2 as tabulated in ENDF/B-IV (~97.91 wt % zirconium, 1.59 wt % tin, 0.5 wt % iron); Note. the thermal capture cross section and the resonance capture integrals of zirc-2 and zirc-4 are equal within the experimental measurement uncertainties and the variance on the contents of the alloying agents used in zirc-2 and zirc-4.
7.	SS304	Stainless Steel - 304: 69.5 wt % iron, 19 wt % chromium, 9.5 wt % nickel, 2 wt % manganese
8.	SS316	Stainless Steel - 316: 65.42 wt % iron, 17 wt % chromium, 12 wt % nickel, 2.5 wt % molybdenum, 2 wt % manganese, 1 wt % silicon, 0.08 wt % carbon
9.	INCONEL	Inconel: 73 wt % nickel, 15 wt % chromium, 7 wt % iron, 2.5 wt % titanium, 2.5 wt % silicon
10.	CARBONSTEEL	Carbon steel: 99 wt % iron, 1 wt % carbon; cross-sections developed using 1/E weighting
11.	ORCONCRETE	Oak Ridge Concrete: 41.02 wt % oxygen, 32.13 wt % calcium, 17.52 wt % carbon, 3.448 wt % silicon, 3.261 wt % magnesium, 1.083 wt % aluminum, 0.7784 wt % iron, 0.6187 wt % hydrogen, 0.1138 wt % potassium, 0.0271 wt % silicon
12.	RFCONCRETE	Rocky Flats Concrete: 48.49 wt % oxygen, 23 wt % calcium, 15.5 wt % silicon, 5.52 wt % carbon, 2.17 wt % aluminum, 1.37 wt % potassium, 1.25 wt % magnesium, 1.01 wt % iron, 0.75 wt % hydrogen, 0.63 wt % sodium, 0.19 wt % sulfur, 0.1 wt % titanium, 0.02 wt % nitrogen

13.	MGCONCRETE	Magnuson's Concrete: 45.84 wt % oxygen, 20.77 wt % calcium, 9.674 wt % carbon, 8.666 wt % potassium, 8.644 wt % magnesium, 3.863 wt % silicon, 0.721 wt % aluminum, 0.5134 wt % iron, 0.4146 wt % zinc, 0.3046 wt % hydrogen, 0.2285 wt % sulfur, 0.1366 wt % titanium, 0.1294 wt % sodium, 0.048 wt % chlorine, 0.0469 wt % manganese
14.	PLEXIGLASS	Plexiglass: $C_5H_8O_2$, 1.18 gm/cc
15.	POLYETHYLENE	Polyethylene: C_2H_4, 0.92 gm/cc
16.	PARAFFIN	Paraffin: $C_{25}H_{52}$, 0.93 gm/cc
17.	HNO3	Nitric acid: HNO_3
18.	HFACID	Hydrafluoric acid: HF
19.	UO2	Uranium oxide: UO_2
20.	U3O8	Uranium oxide: U_3O_8
21.	UC	Uranium carbide: UC
22.	UN	Uranium nitride: UN
23.	UF4	Uranium tetrafluoride: UF_4
24.	UF6	Uranium hexafluoride UF_6
25.	UO2F2	Uranyl fluoride: UO_2F_2
26.	UO2(NO3)2	Uranyl nitrate: $UO_2(NO_3)_2$
27.	URANIUM	Uranium metal (19.05 gm/cc) having a variable isotope distribution – i.e., the user may specify the actual isotope distribution or use the natural isotope distribution supplied by default
28.	U(.27)METAL	Depleted uranium metal (19.05 gm/cc) having a fixed isotope distribution: 0.27 wt % ^{235}U, 99.73 wt % ^{238}U; to specify a different distribution, the user should use URANIUM instead of U(.27)METAL
29.	PUO2	Plutonium oxide: PuO_2
30.	PUC	Plutonium carbide: PuC
31.	PUN	Plutonium nitride: PuN
32.	PUF4	Plutonium tetrafluoride: PuF_4

33.	PU(NO3)4	Plutonium nitrate: $Pu(NO_3)_4$
34.	PLUTONIUMALP	Plutonium metal – α phase; has density of 19.84 gm/cc but is otherwise the same as the Δ phase
35.	PLUTONIUMDLT	Plutonium metal – Δ phase; has density of 15.92 gm/cc but is otherwise the same as the α phase
36.	1/VABSORBER	Fictitious material having a 1/v absorption cross section normalized to 1.0 at 0.0253 eV.
37.	H	Hydrogen, cross-sections developed using 1/E weighting everywhere
38.	H-X(E)-HR	Hydrogen, cross-sections developed using fission spectrum weighting at high energies and 1/E weighting at lower energies
39.	D	Deuterium
40.	HE	Helium
41.	LI-6	Lithium-6
42.	LI-7	Lithium-7
43.	BE	Beryllium, cross-sections developed assuming a free atom
44.	BEBOUND	Beryllium, cross-sections developed assuming Be atom bound in a crystalline lattice
45.	B-10	Boron-10
46.	B-11	Boron-11
47.	C	Carbon
48.	N	Nitrogen
49.	O	Oxygen
50.	F	Fluorine
51.	NA	Sodium: Na
52.	MG	Magnesium: Mg
53.	AL	Aluminum: Al
54.	SI	Silicon: Si
55.	P	Phosphorous

56.	S	Sulfur
57.	CL	Chlorine: Cl
58.	K	Potassium
59.	CA	Calcium: Ca
60.	TI	Titanium: Ti
61.	V	Vanadium
62.	CR	Chromium, cross-sections developed using 1/E weighting
63.	CRSS	Chromium, cross-sections developed using $[E\sigma_T(E)]^{-1}$ weighting where $\sigma_T(E)$ is that of SS-304
64.	CRINCONEL	Chromium, cross-sections developed using $[E\sigma_T(E)]^{-1}$ weighting where $\sigma_T(E)$ is that of inconel
65.	MN	Manganese, cross-sections developed using 1/E weighting
66.	MNSS	Manganese, cross-sections developed using $[E\sigma_T(E)]^{-1}$ weighting where $\sigma_T(E)$ is that of SS-304
67.	FE	Iron, cross-sections developed using 1/E weighting
68.	FESS	Iron, cross-sections developed using $[E\sigma_T(E)]^{-1}$ weighting where $\sigma_T(E)$ is that of SS-304
69.	FEINCONEL	Iron, cross-sections developed using $[E\sigma_T(E)]^{-1}$ weighting where $\sigma_T(E)$ is that of inconel
70.	CO	Cobalt-59
71.	NI	Nickel, cross-sections developed using 1/E weighting
72.	NISS	Nickel, cross-sections developed using $[E\sigma_T(E)]^{-1}$ weighting where $\sigma_T(E)$ is that of SS-304
73.	NIINCONEL	Nickel, cross-sections developed using $[E\sigma_T(E)]^{-1}$ weighting where $\sigma_T(E)$ is that of inconel
74.	CU	Copper: Cu
75.	ZN	Zinc: Zn
76.	BR-79	Bromine-79
77.	BR-81	Bromine-81

78.	KR-82	Krypton-82
79.	KR-83	Krypton-83
80.	ZR	Zirconium: Zr
81.	NB	Niobium: Nb
82.	MO	Molybdeum: Mo
83.	RH-103	Rhodium-103
84.	RH-105	Rhodium-105
85.	AG-107	Silver-107
86.	AG-109	Silver-109
87.	CD	Cadmium (natural)
88.	CD-113	Cadmium-113
89.	IN-113	Indium-113
90.	IN-115	Indium-115
91.	SN	Tin: Sn
92.	XE-131	Xenon-131
93.	XE-133	Xenon-133
94.	XE-135	Xenon-135
95.	CS-133	Cesium-133
96.	CS-134	Cesium-134
97.	CS-135	Cesium-135
98.	BA-138	Barium-138
99.	ND-143	Neodymium-143
100.	ND-145	Neodymium-145
101.	PM-147	Promethium-147
102.	PM-148	Promethium-148
103.	PM-148M	Promethium-148 (metastable)
104.	SM-149	Samarium-149

105.	SM-150	Samarium-150
106.	SM-151	Samarium-151
107.	SM-152	Samarium-152
108.	EU-153	Europium-153
109.	EU-154	Europium-154
110.	EU-155	Europium-155
111.	GD	Gadolinium: Gd
112.	DY-164	Dysprosium-164
113.	LU-175	Lutetium-175
114.	LU-176	Lutetium-176
115.	HF	Hafnium: Hf
116.	TA-181	Tantalum-181
117.	W-182	Tungsten-182
118.	W-183	Tungsten-183
119.	W-184	Tungsten-184
120.	W-186	Tungsten-186
121.	RE-185	Rhenium-185
122.	RE-187	Rhenium-187
123.	AU	Gold: Au
124.	PB	Lead: Pb
125.	TH-232	Thorium-232
126.	PA-233	Protactinium-233
127.	U-233	Uranium-233
128.	U-234	Uranium-234
129.	U-235	Uranium-235
130.	U-236	Uranium-236
131.	U-238	Uranium-238

132.	NP-237	Neptunium-237
133.	PU-238	Plutonium-238
134.	PU-239	Plutonium-239
135.	PU-240	Plutonium-240
136.	PU-241	Plutonium-241
137.	PU-242	Plutonium-242
138.	AM-241	Americium-241
139.	AM-243	Americium-243
140.	CM-244	Curium-244

Table A-1: The Standard Composition Library

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
BORON	2.5350	NO	YES	16 27 123 218	{5010 5011}
B4C	2.5200	NO	YES	16 27 123 218	{5010 5011} 6012
H2O	0.9982	NO	YES	16 27 123 218	1001 8016
H2O-X(E)-HR	0.9982	NO	YES	16 -- --- ---	1301 8016
D2O	1.1053	NO	YES	16 27 123 218	1002 8016
ZIRCALLOY	6.4400	YES	NO	16 27 --- 218	40302
SS304	7.9200	YES	NO	16 27 --- 218	24304 25055 26304 28304
SS316	7.7500	YES	YES	16 27 --- 218	6012 14028 24304 25055 26304 28304 42000
INCONEL	8.3000	NO	NO	16 27 --- 218	14028 22000 24404 26404 28404
CARBONSTEEL	7.8212	YES	YES	16 27 123 218	6012 26000

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
ORCONCRETE	2.2994	YES	YES	16 27 --- 218	1001 6012 8016 11023 12000 13027 14028 19039 20040 26000
RFCONCRETE	2.3210	YES	YES	16 27 --- 218	1001 6012 7014 8016 11023 12000 13027 14028 16032 19039 20040 22000 26000
MGCONCRETE	2.3298	YES	YES	16 -- --- ---	1001 6012 8016 11023 12000 13027 14028 16032 17000 19039 20040 22000 25055 26000 30000
PLEXIGLASS	1.1800	NO	YES	16 27 123 218	1001 6012 8016
POLYETHYLENE	0.9200	NO	YES	16 27 123 218	1001 6012
PARAFFIN	0.9300	NO	YES	16 27 123 218	1001 6012
HNO3	1.0000	NO	YES	16 27 123 218	1001 7014 8016
HFACID	1.0000	NO	YES	16 27 123 218	1001 9019

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
UO2	10.9600	YES	YES	16 27 123 218	{92233 92234 92235 92236 92238} 8015
U3O8	8.3000	YES	YES	16 27 123 218	{92233 92234 92235 92236 92238} 8016
UC	13.6300	YES	YES	16 27 123 218	{92233 92234 92235 92236 92238} 6012
UN	14.3100	YES	NO	16 27 123 218	{92233 92234 92235 92236 92238} 7014
UF4	6.7000	YES	YES	16 27 123 218	{92233 92234 92235 92236 92238} 9019
UF6	4.8500	YES	YES	16 27 123 218	{92233 92234 92235 92236 92238} 9019
UO2F2	6.3700	YES	YES	16 27 123 218	{92233 92234 92235 92236 92238} 8016 9019
UO2(NO3)2	2.2030	YES	YES	16 27 123 218	{92233 92234 92235 92236 92238} 7014 8016

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
URANIUM	19.0500	YES	NO	16 27 123 218	{92233 92234 92235 92236 92238}
U(.27)METAL	19.0500	YES	NO	16 27 123 218	92235 92238
PUO2	11.4600	YES	YES	16 27 123 218	{94238 94239 94240 94241 94242} 8016
PUC	13.6000	YES	YES	16 27 123 218	{94238 94239 94240 94241 94242} 6012
PUN	14.2500	YES	NO	16 27 123 218	{94238 94239 94240 94241 94242} 7014
PUF4	7.0000	YES	YES	16 27 123 218	{94238 94239 94240 94241 94242} 9019
PU(NO3)4	2.4470	YES	YES	16 27 123 218	{94238 94239 94240 94241 94242} 7014 8016
PLUTONIUMALP	19.8400	YES	NO	16 27 123 218	{94238 94239 94240 94241 94242}
PLUTONIUMDLT	15.9200	YES	NO	16 27 123 218	{94238 94239 94240 94241 94242}

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
1/VABSORBER	1.0000	NO	NO	16 27 --- 218	999
H	1.0000	NO	YES	16 27 123 218	1001
H-X(E)-HR	1.0000	NO	NO	16 -- --- ---	1301
D	1.0000	NO	YES	16 27 123 218	1002
HE	1.0000	NO	NO	16 27 --- 218	2004
LI-6	1.0000	NO	YES	16 27 123 218	3006
LI-7	1.0000	NO	YES	16 27 123 218	3007
BE	1.8480	NO	YES	16 27 123 218	4009
BEBOUND	1.8480	NO	NO	-- -- --- ---	4309
B-10	2.1950	NO	YES	16 27 123 218	5010
B-11	2.4130	NO	YES	16 27 123 218	5011

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
C	2.3000	NO	YES	16 27 123 218	6012
N	1.0000	NO	NO	16 27 123 218	7014
O	1.0000	NO	YES	16 27 123 218	8016
F	1.0000	NO	YES	16 27 123 218	9019
NA	1.0000	YES	YES	16 27 123 218	11023
MG	1.0000	NO	NO	16 27 123 218	12000
AL	2.6589	NO	YES	16 27 123 218	13027
SI	1.0000	NO	NO	16 27 123 218	14028
P	1.0000	NO	NO	16 27 --- 218	15031
S	1.0000	NO	NO	16 27 123 218	16032
CL	1.0000	NO	NO	16 27 --- 218	17000

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
K	1.0000	NO	NO	16 27 123 218	19039
CA	1.0000	NO	NO	16 27 --- 218	20040
TI	4.5400	NO	NO	16 27 --- 218	22000
V	6.1100	NO	NO	16 27 --- 218	23051
CR	7.1900	NO	YES	16 27 123 218	24000
CRSS	7.1900	NO	NO	16 27 --- 218	24304
CR INCONEL	7.1900	NO	NO	16 27 --- 218	24404
MN	7.4400	YES	NO	16 27 123 218	25055
MNSS	7.4400	NO	NO	-- -- --- ---	25304
FE	7.8740	YES	YES	16 27 123 218	26000
FESS	7.8740	NO	NO	16 27 --- 218	26304

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
FEINCONEL	7.8740	NO	NO	16 27 --- 218	26404
CO	8.9000	YES	NO	16 27 --- 218	27059
NI	8.9020	NO	YES	16 27 123 218	28000
NISS	8.9020	NO	NO	16 27 --- 218	28304
NIINCONEL	8.9020	NO	NO	16 27 --- 218	28404
CU	8.9600	YES	YES	16 27 123 218	29000
ZN	7.1330	NO	NO	16 -- --- ---	30000
BR-79	1.0000	YES	NO	-- 27 --- 218	35790
BR-81	1.0000	YES	NO	-- 27 --- 218	35810
KR-82	1.0000	NO	NO	-- -- 123 ---	36082
KR-83	1.0000	NO	NO	-- -- 123 ---	36083

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
ZR	6.4400	NO	NO	16 27 123 218	40000
NB	1.0000	YES	NO	16 27 123 218	41093
MO	10.2200	YES	NO	16 27 123 218	42000
RH-103	12.5000	NO	NO	-- -- 123 ---	45103
RH-105	12.5000	NO	NO	-- -- 123 ---	45105
AG-107	10.4060	YES	NO	16 27 --- 218	47107
AG-109	10.6010	YES	NO	16 27 123 218	47109
CD	8.6500	NO	NO	16 27 --- 218	48000
CD-113	8.6500	NO	NO	-- -- 123 ---	48113
IN-113	1.0000	YES	NO	16 27 --- 218	49113
IN-115	1.0000	YES	NO	16 27 123 218	49115

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
SN	7.3100	NO	NO	16 27 123 218	50000
XE-131	1.0000	NO	NO	-- -- 123 ---	54131
XE-133	1.0000	NO	NO	-- -- 123 ---	54133
XE-135	1.0000	NO	NO	-- 27 123 218	54135
CS-133	1.8730	NO	NO	-- -- 123 ---	55133
CS-134	1.8730	NO	NO	-- -- 123 ---	55134
CS-135	1.8730	NO	NO	-- -- 123 ---	55135
BA-138	1.0000	NO	NO	16 27 --- 218	56138
ND-143	6.9600	NO	NO	-- -- 123 ---	60143
ND-145	6.9600	NO	NO	-- -- 123 ---	60145
PM-147	1.0000	NO	NO	-- -- 123 ---	61147

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
PM-148	1.0000	NO	NO	-- -- 123 ---	61148
PM-148M	1.0000	NO	NO	-- -- --- ---	61601
SM-149	7.7000	NO	NO	-- -- 123 ---	62149
SM-150	7.7000	NO	NO	-- -- 123 ---	62150
SM-151	7.7000	NO	NO	-- -- 123 ---	62151
SM-152	7.7000	NO	NO	-- -- 123 ---	62152
EU-153	5.2400	NO	NO	-- -- 123 ---	63153
EU-154	5.2400	NO	NO	-- -- 123 ---	63154
EU-155	5.2400	NO	NO	-- -- 123 ---	63155
GD	1.0000	YES	NO	16 27 --- 218	64000
DY-164	1.0000	YES	NO	16 27 --- 218	66164

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
LU-175	1.0000	YES	NO	16 27 --- 218	71175
LU-176	1.0000	YES	NO	16 27 --- 218	71176
HF	1.0000	NO	NO	16 27 --- 218	72000
TA-181	1.0000	YES	NO	16 27 --- 218	73181
W-182	1.0000	YES	NO	16 27 --- 218	74182
W-183	1.0000	YES	NO	16 27 --- 218	74183
W-184	1.0000	YES	NO	16 27 --- 218	74184
W-186	1.0000	YES	NO	16 27 --- 218	74186
RE-185	1.0000	YES	NO	16 27 --- 218	75185
RE-187	1.0000	YES	NO	16 27 123 218	75187
AU	1.0000	YES	NO	16 27 123 218	79197

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
PB	11.3500	NO	NO	16 27 123 218	82000
TH-232	1.0000	YES	NO	16 27 123 218	90232
PA-233	1.0000	YES	NO	16 27 123 218	91233
U-233	1.0000	YES	NO	16 27 123 218	92233
U-234	1.0000	YES	NO	16 27 123 218	92234
U-235	1.0000	YES	NO	16 27 123 218	92235
U-236	1.0000	YES	NO	16 27 123 218	92236
U-238	1.0000	YES	NO	16 27 123 218	92238
NP-237	1.0000	YES	NO	16 27 123 218	93237
PU-238	1.0000	YES	NO	16 27 123 218	94238
PU-239	1.0000	YES	NO	16 27 123 218	94239

Table A-1: (continued)

ALPHANUMERIC DESCRIPTION OF THE STANDARD COMPOSITION	THEORETICAL DENSITY ρ_{th} IN GRAMS/CC	RESONANCE DATA OR BONDARENKO DATA AVAILABLE?	SCATTERING X-SECT DATA AVAILABLE AT MULTIPLE TEMPERATURES?	X-SECT LIBRARIES FOR WHICH THIS STD. COMPOSITION IS AVAILABLE	LIST OF NUCLIDES IN THIS STD. COMPOSITION (WITH ISOTOPES THE USER MAY SPECIFY SHOWN IN BRACKETS)
PU-240	1.0000	YES	NO	16 27 123 218	94240
PU-241	1.0000	YES	NO	16 27 123 218	94241
PU-242	1.0000	YES	NO	16 27 123 218	94242
AM-241	1.0000	YES	NO	16 27 --- 218	95241
AM-243	1.0000	YES	NO	16 27 --- 218	95243
CM-244	1.0000	YES	NO	16 27 --- 218	96244

APPENDIX A.2
Table of Available Solutions

The Standard Composition Library (Table A-1) describes the various compounds, alloys, elements and isotopes one may use in defining the material mixtures for a given problem. In addition to the various materials listed there, one is also free to use any of the fissile solutions listed in Table A-2. Indeed, the user is encouraged to treat the solutions listed in Table A-2 as he would any other standard composition. Using empirical fits to experimental data, the code will then automatically calculate the volume fraction corresponding to the heavy metal, acid, and water components of the solution (c.f., Section 3.1).

TABLE A-2: TABLE OF AVAILABLE SOLUTIONS

Alphanumeric Description of the Solution	Resonance Data or Bondarenko Data Available?	Scattering Cross-Section Data Available at Multiple Temperatures?	Cross-Section Libraries For Which This Solution is Available	List of Nuclides in This Fissile Solution (With Isotopes the User May Specify Shown in Brackets)
SOLNUO2F2	YES	YES	16 27 123 218	(92233 92234 92235 92236 92238) 1001 8016 9019
SOLNUO2(NO3)2	YES	YES	16 27 123 218	(92233 92234 92235 92236 92238) 1001 7014 8016
SOLNPU(NO3)4	YES	YES	16 27 123 218	(94238 94239 94240 94241 94242) 1001 7014 8016

APPENDIX A.3
Isotope Distribution Table

Those materials in the Standard Composition Library containing multiple isotopes of a single element are denoted in Table A-1. For materials containing boron, uranium, or plutonium, the user is free to specify the isotopic distribution using items 6a and 6b of the Standard Composition Specification Card. Alternately, the user may elect not to enter this data, thereby telling the code to assume the default values shown in Table A-3. In the case of boron and uranium, Table A-3 lists the naturally occurring abundance of each isotope.

TABLE A-3

ISOTOPE DISTRIBUTION TABLE

Boron		Uranium		Plutonium	
I.D.	wt%	I.D.	wt%	I.D.	wt%
5010	17.2859	92233	0.0000	94238	0.0
5011	82.7141	92234	0.0056	94239	100.0
		92235	0.7050	94240	0.0
		92236	0.0000	94241	0.0
		92238	99.2894	94242	0.0

APPENDIX A.4
Available Cross Section Libraries

At present, four cross-section libraries have been assembled for use in the SCALE system. These include a 16-group cross-section set based on earlier Hansen-Roach data, a 123-group cross-section set based on earlier GAM-THERMOS data, and a 218-group cross-section set based on ENDF/B-IV data. A 27-group cross-section set collapsed from the 218-group data is also available. The user may select the library he desires by specifying the appropriate alphanumeric name (HANSEN-ROACH, 27GROUPNDF4, 123GROUPGMTH, 218GROUPNDF4) on the Parameter Card.

The data for almost all of the nuclides in the HANSEN-ROACH library is based on the original Los Alamos report by Hansen and Roach.[22] While this data has been used widely with good results, it was developed primarily for the analysis of fast systems. Data for a few nuclides missing in the original library was generated by collapsing the 218GROUPNDF4 data to 16 groups. This was done for the sake of completeness and to extend the utility of the present library. Resonance data is available for 31 of the nuclides in this library. Seven of these have Bondarenko factors in lieu of resonance parameters and must be self-shielded using the BONAMI module (c.f., Table A-7).

The data for the 27GROUPNDF4 library was collapsed from the 218GROUPNDF4 data. This broad group library was developed especially for criticality analysis of a wide variety of thermal systems and has undergone extensive evaluation.[23] Of the 27 groups, 13 groups are thermal ($E \leq 3.05$eV). Additional information may be found in Tables A-7 and A-8.

The 123GROUPGMTH library is based on earlier data produced by the GAM-II and THERMOS codes.[24,25] It has 93 fast and 30 thermal groups. The fast group boundaries were based on equal lethargy widths. As noted in Table A-7, resonance data is available for only six nuclides. On the other hand, thermal scattering data for many nuclides is available over a wide range of temperatures (c.f., Table A-8).

The 218GROUPNDF4 library is based on ENDF/B-IV data[26] and has not been "adjusted" to give better results (as has the data in the HANSEN-ROACH and 123GROUPGMTH libraries). It has 72 thermal groups and is suitable for the analysis of thermal systems. The group structure was chosen to fit the cross-section variation and reaction thresholds of light and intermediate nuclides, to bracket the major resonance levels of intermediate and heavy nuclides, and to "march over" the thermal resonances in fuel nuclides.[26] Additional information may be found in Tables A-7 and A-8.

The 16, 27 and 123 group libraries are available on a permanently mounted disk such that the user may select the library he desires by simply specifying the appropriate alphanumeric name on the Parameter Card. Because of its length, the 218-group library resides on a tape which must be mounted each time it is requested. Thus, the user must specify the appropriate alphanumeric name on the Parameter Card (218GROUPNDF4) and include an FT84 card in his JCL. At K-25 it would have the following form:

```
//GO.FT84F001 DD UNIT=TAPE9,VOL=SER=A13603,
//  LABEL=(1,SL),DSN=ODGRN.X218,DISP=(OLD,KEEP),
//  DCB=(RECFM=VBS,LRECL=X,BLKSIZE=4000,BUFL=4088)
```

At X-10, it would have the following form:

```
//GO.FT84F001 DD UNIT=TAPE9,VOL=SER=X17694,
//  LABEL=(1,SL),DSN=ODGRN.X218,DISP=(OLD,KEEP),
//  DCB=(RECFM=VBS,LRECL=X,BLKSIZE=4000,BUFL=4088)
```

Lastly, it should be pointed out that none of the four libraries described above have gamma or n-γ cross-section data. They are included here for use in CSAS1 and CSAS2 only.

TABLE A-4.

AVAILABLE CROSS SECTION LIBRARIES

ALPHANUMERIC NAME OF CROSS-SECTION SET	ANALYTIC SEQUENCE WITH WHICH THIS CROSS-SECTION SET MAY BE USED								
	CSAS1	CSAS2		SAS1	SAS2	SAS3			
HANSEN-ROACH	✓	✓							
27GROUPNDF4	✓	✓							
123GROUPGMTH	✓	✓							
218GROUPNDF4	✓	✓							

APPENDIX A.5
I.D. Numbers to be Used on the Automatic Reflector Card

Various sets of spatially dependent multigroup reflector weights have been calculated and stored on an on-line disk for use in KENO-IV. Table A-5 gives the I.D. No. corresponding to the set of pre-calculated weights for each of the four materials in the library. This I.D. No. (IDWT) should be entered as the eighth parameter on the automatic reflector card (c.f., Appendix C). The code will then "break-up" the reflector into a number of smaller regions and supply each with the appropriate set of multigroup weights taken from the library. An edit of the multigroup weights associated with each spatial region will be printed by KENO-IV during execution. (Indeed, one could set up a number of "dummy" KENO cases using the automatic reflector card and the 27GROUPNDF4 cross-section set to obtain edits of those reflector weights not reported in ORNL/TM-4660.)

The 16, 27, and 123 group weights are available for concrete, paraffin, water and graphite. A new 218-group set is also available for water. It should also be noted that reflector weights for one material can often be used for other similar materials. If in reality one had a plexiglass reflector, he might use the reflector weights corresponding to paraffin or water. The key requirement is that the two materials be neutronically similar – that is: the absorption cross section (Σ_A) must be similar and the slowing down power ($\xi\Sigma_s$) must be similar. This point is discussed further in Appendix C.

TABLE A-5

I.D. NUMBERS TO BE USED ON THE AUTOMATIC REFLECTOR CARD

IDWT*	Refl. Matl.	X-Sect. Set Used
301	Concrete	HANSEN-ROACH
301	Concrete	27GROUPNDF4
301	Concrete	123GROUPGMTH
400	Paraffin	HANSEN-ROACH
400	Paraffin	27GROUPNDF4
400	Paraffin	123GROUPGMTH
500	Water	HANSEN-ROACH
500	Water	27GROUPNDF4
500	Water	123GROUPGMTH
500	Water	218GROUPNDF4
6100	Graphite	HANSEN-ROACH
6100	Graphite	27GROUPNDF4
6100	Graphite	123GROUPGMTH

*IDWT is the I.D. No. corresponding to the set of pre-calculated weights for the reflector material.

APPENDIX A.6

Density of Subcooled Water at Various Temperatures and Pressures

For systems under pressure, the density of water may be substantially different from that given in the Standard Composition Library. This is especially true for PWR's at operating temperature and pressure. To account for this, the user must enter the appropriate density factor (VF) on the Standard Composition Specification Card.

The density of subcooled water at various temperatures and pressures is given in Table A-6. This table was produced using a Fortran routine borrowed from the Leopard-II code.[20] The values listed in Table A-6 agree well with those in the Steam Tables published by Keenan and Keys.[21]

```
      FUNCTION DENH20(PP,TT)
C
C     THIS FUNCTION WAS 'BORROWED' FROM LEOPARD-II WHERE IT
C     HAD SLIGHTLY DIFFERENT UNITS AND WAS KNOWN AS THE VCL
C     FUNCTION -- J.A.BUCHOLZ (5-15-78)
C
C     DENH20 = DENSITY IN GMS/CC
C     PP = PRESSURE IN PSI
C     TT = TEMPERATURE IN DEG.F
C
      REAL*8 P,T,X,X3,PSL,E1,E3,E4,E2,E5,E6,E7,E8,DEXP,DLOG,VCL
      REAL*8 A(10)/
     A7.46908269,-7.50675994D-3,-.46203229D-8,-.12154701 11D-2,0.0,
     B7.70517043,-5.29739118D-2,-2.96725673D-9,-.766360055D-2,
     C1.4396/0206D-11/
      T = TT
      P = PP
      IF ((T.LT.50.0).OR.(T.GT.705.4))  GO TO 4
      X = T-705.398
      X3 = X**3
      I = 0
      IF (T.GE.200.0)  I=5
      PSL=DEXP (X*(A(I+1)+A(I+2)*X+A(I+3)*X3+A(I+5)*X3*X)/((1.+A(I+4)*X)
     1*(T+459.688))+8.0728362)
      IF (P.LE.PSL)  GO TO 4
      E1 = DLOG(P-PSL)-2.68756849
      E3=E1*2.
      E4=E1/2.
      E2=-T*.55555555+391.88778
      E5 = E2**(1.0/6.0)
      E6=E5*E5
      E7=E6*E5
      E5=E7/(-8.21761572)*E5
      E5=DEXP((E7*1.05467592D-3-.0160537197)*E2+
     1E5-3.7166732+E1+4.13401091)+62.4278183
      E8=DEXP(((E7*1.355998750-3-.0297916028)*E7-.22389889)
     1*E7-2.97626224+E1)
      E8=DEXP(E2*(-6.850781560-2)-11.4147912+E3)-E8
      E8=DEXP(E7*(-.92085142)-.9504583+E4)+E8
      E7 = 1.0+0.1342489*E6-0.003946263*E2
      E4 = E2*(E2**3/1.33527748D12-1.203374D-3)
      VCL=((E6*(-.3151548)+E4+3.1975)/E7-E8)/E5
      DENH20 = (1.0/VCL)/62.428
      RETURN
    4 DENH20 = 1.0
        (6,45) TT,PP
     AT (' ***ERROR***   AT  T=',E10.3,' DEG.F,  P=',E11.4,
      PSI,  H20 IS NOT SUBCOOLED',/,15X,'AND THE ALGORITHM',
     2  ' IN THE ''DENH20'' FUNCTION BREAKS DOWN.  A DENSITY',/,
     3  15X, 'OF  1.0 GM/CC  WAS RETURNED.')
      RETURN
      END
```

Table A-6: Density of Subcooled Water (in grams/cc) at Various Temperatures and Pressures

	3000 PSI	2500 PSI	2000 PSI	1500 PSI	1000 PSI	800 PSI	600 PSI	400 PSI	200 PSI
50 DEG.F	1.0084	1.0069	1.0055	1.0040	1.0025	1.0019	1.0013	1.0007	1.0000
100 DEG.F	1.0018	1.0004	0.9989	0.9975	0.9960	0.9954	0.9948	0.9942	0.9936
150 DEG.F	0.9893	0.9878	0.9864	0.9849	0.9834	0.9828	0.9822	0.9815	0.9809
200 DEG.F	0.9725	0.9709	0.9694	0.9679	0.9663	0.9656	0.9650	0.9644	0.9637
250 DEG.F	0.9522	0.9505	0.9489	0.9472	0.9455	0.9449	0.9442	0.9435	0.9428
300 DEG.F	0.9289	0.9271	0.9252	0.9234	0.9215	0.9208	0.9200	0.9192	0.9185
350 DEG.F	0.9026	0.9006	0.8985	0.8964	0.8943	0.8934	0.8925	0.8916	
400 DEG.F	0.8733	0.8709	0.8685	0.8660	0.8634	0.8624	0.8613	0.8603	
450 DEG.F	0.8405	0.8375	0.8345	0.8314	0.8281	0.8268	0.8255		
500 DEG.F	0.8029	0.7992	0.7952	0.7911	0.7869	0.7851			
510 DEG.F	0.7947	0.7907	0.7866	0.7822	0.7776				
520 DEG.F	0.7862	0.7820	0.7776	0.7729	0.7680				
530 DEG.F	0.7775	0.7729	0.7682	0.7632	0.7579				
540 DEG.F	0.7683	0.7635	0.7584	0.7530	0.7472				
550 DEG.F	0.7589	0.7537	0.7482	0.7423					
560 DEG.F	0.7490	0.7434	0.7374	0.7310					
570 DEG.F	0.7386	0.7326	0.7261	0.7190					
580 DEG.F	0.7278	0.7212	0.7141	0.7062					
590 DEG.F	0.7164	0.7092	0.7012	0.6923					
600 DEG.F	0.7043	0.6963	0.6874						
610 DEG.F	0.6915	0.6825	0.6724						
620 DEG.F	0.6777	0.6676	0.6558						
630 DEG.F	0.6629	0.6512	0.6370						
640 DEG.F	0.6467	0.6329							
650 DEG.F	0.6288	0.6119							
660 DEG.F	0.6086	0.5866							
670 DEG.F	0.5850								
680 DEG.F	0.5559								

APPENDIX A.7

Nuclides Having Resonance Data

The list of nuclides having resonance data differs from one master cross-section library to another as shown in Table A-7. The temperature of all materials containing any of these nuclides should be specified by the user. NITAWL will then use the resonance parameters to properly account for the Doppler broadening of the cross section data.

The six nuclides denoted by an (*) in the HANSEN-ROACH library have Bondarenko data in lieu of resonance parameters. Regretably, the Bondarenko factors for these nuclides are only available at a single temperature. Thus, for example, the HANSEN-ROACH library should not be used to determine the Doppler coefficient of reactivity.

TABLE A-7

NUCLIDES HAVING RESONANCE DATA

Resonance nuclides found on the HANSEN-ROACH library:
25055, 47107, 47109, 49113, 49115, 66164, 71175, 71176, 74182, 74183, 74184, 74186, 75185, 75187, 79197, 90232*, 91233, 92233*, 92234, 92235*, 92236, 92238*, 93237, 94338*, 94239*, 94240*, 94241, 94242, 95241, 95243, 96244
Resonance nuclides found on the 27GROUPNDF4 and 218GROUPNDF4 libraries:
11023, 25055, 26000, 27059, 29000, 35790, 35810, 40302, 41093, 42000, 47107, 47109, 49113, 49115, 64000, 66164, 71175, 71176, 73181, 74182, 74183, 74184, 74186, 75185, 75187, 79197, 90232, 91233, 92233, 92234, 92235, 92236, 92238, 93237, 94238, 94239, 94240, 94241, 94242, 95241, 95243, 96244
Resonance nuclides found on the 123GROUPGMTH library:
90232, 92234, 92236, 92238, 94240, 94242

*denotes nuclides having Bondarenko data in lieu of resonance parameters

APPENDIX A.8

Nuclides With Multiple Sets of Thermal Scattering Data

The list of nuclides having thermal scattering cross-section data at more than one temperature differs from one cross-section library to another as shown in Table A-8. Likewise, the temperatures at which thermal scattering data is available for a given nuclide may also differ from one library to the next as shown in Table A-8.

Since scattering matrices for nuclides in media at elevated temperatures are generally fuller than those at lower temperatures, the user should enter a rough estimate of the temperature of all materials containing any of these nuclides. From the various sets of thermal scattering data available on the master cross-section library, NITAWL will produce a working library containing the data for the temperature closest to that specified by the user.

Lastly, it should be noted that those nuclides found in the Standard Composition Library but not listed in Table A-8 all have thermal scattering data at room temperature (293° K).

TABLE A-8. NUCLIDES WITH MULTIPLE SETS OF THERMAL SCATTERING DATA

Cross-Section Library Specified by User	Nuclide I.D. No.	Temperatures (°K) for Which Different Sets of Thermal Scattering X-Section Data is Available
HANSEN-ROACH	5010	293, 550
	5011	293, 550
27GROUPNDF4 and 218GROUPNDF4	1001	293, 550
	1002	293, 550
	4009	296, 900, 1000, 1200
	5010	293, 550
	5011	293, 550
	6012	293, 900, 1000, 1200
123GROUPGMTH	1001	295, 345
	1002	294, 345, 361
	3006	294, 800, 900, 1000
	3007	294, 800, 850, 900, 950, 1000
	4009	294, 800, 850, 900, 950, 1000
	5011	300, 600, 900, 1200
	6012	589, 627, 675, 800, 850, 900, 950, 1000
	8016	294, 345, 361, 900, 1165
	9019	294, 800, 850, 900, 950, 1000
	11023	294, 900
	13027	627, 900
	24000	295, 627, 900
	26000	295, 627, 900
	28000	295, 627, 900
	29000	295, 900

APPENDIX B

How to Describe a Special Mixture

An attempt has been made to include in the Standard Composition Library most of the materials commonly encountered in fuel reprocessing, shipping cask design, reactor analysis and shielding. Yet, future users will undoubtedly have need of additional materials from time to time. To illustrate how the user might "create" compounds, mixtures or alloys not found in the Standard Composition Library, we will assume that the user needs to represent a mixture of Boral having 35 wt % B_4C, 65 wt % Al and an overall density of 2.64 gm/cc. Since B_4C and Al are both in the Standard Composition Library, this mixture could be "created" using just two Standard Composition Specification Cards. If, on the other hand, B_4C were not in the Standard Composition Library, the special Boral mixture could still be "created" using the elements and isotopes that are found in the library. This Appendix describes two approaches that could be taken. The first uses a separate Standard Composition Specification Card to describe each element (or isotope) in the mixture. The emphasis here is on how one would determine the value of VF to be entered on each card. The second approach (which is considerably more straightforward) does not require the user to calculate anything. It illustrates how one may describe two or more "Arbitrary Materials" and combine them to "create" the special Boral mixture.

Using the first approach, the aluminum component of the Boral may be specified quite easily. From the Standard Composition Library, $\rho(\text{Al}) = 2.6989$ gm/cc. The first component of the mixture would therefore be

$$\text{Al with VF} = (.65)(2.64)/(2.6989) = (.63581)$$

The BORON and C components of B_4C are more difficult since B_4C is a compound and BORON has two isotopes. We'll assume a natural isotope distribution of B-10 and B-11, that is:

B-10:	17.2859 wt %,	10.0129 a.m.u.
B-11:	82.7141 wt %,	11.0930 a.m.u.

First, it is necessary to obtain the naturally occurring atom percents from the weight percents:

$$w_{B\text{-}10} = \frac{n_{B\text{-}10} M_{B\text{-}10}}{n_{B\text{-}10} M_{B\text{-}10} + n_{B\text{-}11} M_{B\text{-}11}} = \frac{n_{B\text{-}10}(10.0129)}{n_{B\text{-}10}(10.0129) + (1-n_{B\text{-}10})(11.093)} = .172859$$

$$\therefore \quad n_{B\text{-}10}\left[\left(\frac{10.0129}{.172859}\right) - 10.0129 + 11.093\right] = 11.093$$

$$\therefore \quad n_{B\text{-}10} = 0.188$$

A similar equation may be used for n_{B-11}. Alternately,

$$n_{B-11} = 1 - n_{B-10} = 0.812$$

Thus, naturally occurring $B_4C = B^{10}_{.752}\ B^{11}_{3.248}\ C$

and the total mass of the average molecule is

$$TM = (.752)(10.0129) + (3.248)(11.093) + (12.011) = 55.5708 \text{ a.m.u.}$$

The total mass of the naturally occurring BORON is 43.5598 a.m.u.

From the Standard Composition Library, we note that ρ(BORON) = 2.535 gm/cc and ρ(C) = 2.30 gm/cc. Hence, the second component of the Boral mixture would be

$$\text{BORON with VF} = \left(\frac{43.5598}{55.5708}\right)\left[\frac{(.35)(2.64)}{2.535}\right] = (.28572)$$

and the third component of the Boral mixture would be

$$\text{C with VF} = \left(\frac{12.011}{55.5708}\right)\left[\frac{(.35)(2.64)}{2.30}\right] = (.08683)$$

The resulting Standard Composition Specifications for Boral (mixture 1) would then look like:

```
AL      1  0.63581  END
BORON   1  0.28572  END
C       1  0.08683  END
```

Alternately, the user could delete the BORON specification card and replace it with separate specifications for B-10 and B-11. From the Standard Composition Library, we note that ρ(B-10) = 2.195 gm/cc and ρ(B-11) = 2.413 gm/cc. Hence, we would have:

$$\text{B-10 with VF} = \left[\frac{(.752)(10.0129)}{55.5708}\right]\left[\frac{(.35)(2.64)}{2.195}\right] = (.05704)$$

$$\text{B-11 with VF} = \left[\frac{(3.248)(11.093)}{55.5708}\right]\left[\frac{(.35)(2.64)}{2.413}\right] = (.24828)$$

The resulting Standard Composition Specifications for Boral (mixture 1) would then look like:

```
AL    1  0.63581  END
B-10  1  0.05704  END
B-11  1  0.24828  END
C     1  0.08683  END
```

Note that the two sets of specifications shown above are interchangeable and will yield the same number density for each of the nuclides in the Boral mixture.

The above approach assumes that the user is intent upon describing the Boral mixture using the alphanumeric description of the various isotopes and elements along with their associated volume fractions.* That approach is perfectly correct and rigorous. For this particular example, however, an alternate approach is available which does not require the user to calculate anything. The user could, for example, define both B_4C and Al as "Arbitrary Materials," each with a density of 2.64 gm/cc and with respective volume fractions of 0.35 and 0.65. The resulting Standard Composition Specifications for Boral (mixture 1) would then look like:

```
ARBMTL-B4C  2.64  2  1  1  0   5000  4  6012  1  1  0.35  END

ARBMTL-AL   2.64  1  0  0  0   13027  100.0  1  0.65  END
```

The various data items shown here are described in Section 6. Note that this set of specifications for mixture 1 is interchangeable with the previous two.

---

*VF is referred to only loosely as the "volume fraction" of a material in the mixture. To be more correct, it should be called a "reduction factor" or a "density factor" whose usage is consistent with the various examples in Section 6. The sum of the VF's for each constituent material in a mixture may be less than 1.0 or greater than 1.0 depending on how that particular mixture has been described.

APPENDIX C

The Rudiments of KENO-IV Geometry

KENO geometry is three-dimensional and allows for the simultaneous use of cuboids, spheres, hemispheres, cylinders, hemicylinders and an imbedded array of such bodies. The rules of grammar detailing what data should be entered on what card (and how) are presented in Section 6 (c.f., the Multidimensional Geometry Specification Data and the Mixed Box Orientation Data). This section deals with the overall philosophy behind the KENO geometry package and attempts to answer the question: "How do I use all that good stuff in Section 6 to actually set up this or that particular problem?"

The most basic geometry input for KENO consists of certain alphanumeric keywords representing simple types of three-dimensional surfaces (CUBOID, CYLINDER, SPHERE, etc.*[1]). For each surface, the user must supply the necessary dimensions and an associated material number (which will be explained momentarily). One "geometry card" is needed to describe each surface. A single geometry card defines a single region containing the specified material. One can, however, enter additional geometry cards describing two or more such surfaces. It is important, however, that the first surface be completely enclosed by the second, that the second surface be completely enclosed by the third, etc.*[2] Thus, if material 1 describes the homogeneous cross section data for a reactor core and material 2 describes the cross section data for the reflector,

CUBOID 1 plus dimensions

may fully describe a bare homogeneous core and

CUBOID 1 plus dimensions
CYLINDER 2 plus bigger dimensions

may fully describe a homogeneous core surrounded by a reflector.

While the basic geometry input described above is adequate to handle many simple situations, it is severely limited. Using only the basic geometry input, one could not, for example, describe the experimental configuration shown in Fig. C-1. Indeed, this represents a problem of "intermediate complexity." To describe such problems, the user must mentally subdivide the assembly into a number of "boxes" as shown in Fig. C-2. When trying to decide "how" to subdivide the assembly into boxes, there are two rules that should be followed: 1) Each box should represent a sufficiently small part of the assembly that all of the geometry within each individual box can be described using the basic geometry input described above, and 2) Each box is formed by mentally passing a set of

---

*A more complete list would include: CUBOID, CYLINDER, SPHERE, CUBE, XCYLINDER, YCYLINDER, XHEMICYL+Y, XHEMICYL-Y, XHEMICYL+Z, XHEMICYL-Z, YHEMICYL+X, YHEMICYL-X, YHEMICYL+Z, YHEMICYL-Z, ZHEMICYL+X, ZHEMICYL-X, ZHEMICYL+Y, ZHEMICYL-Y, HEMISPHERE, HEMISPHE+Z, HEMISPHE-Z, HEMISPHE+X, HEMISPHE-X, HEMISPHE+Y, HEMISPHE-Y. See Section 6 for a detailed description of each.

*Consecutive surfaces may have common surfaces and common points of tangency, but they may not otherwise intersect, i.e., is OK, is OK, is not OK.

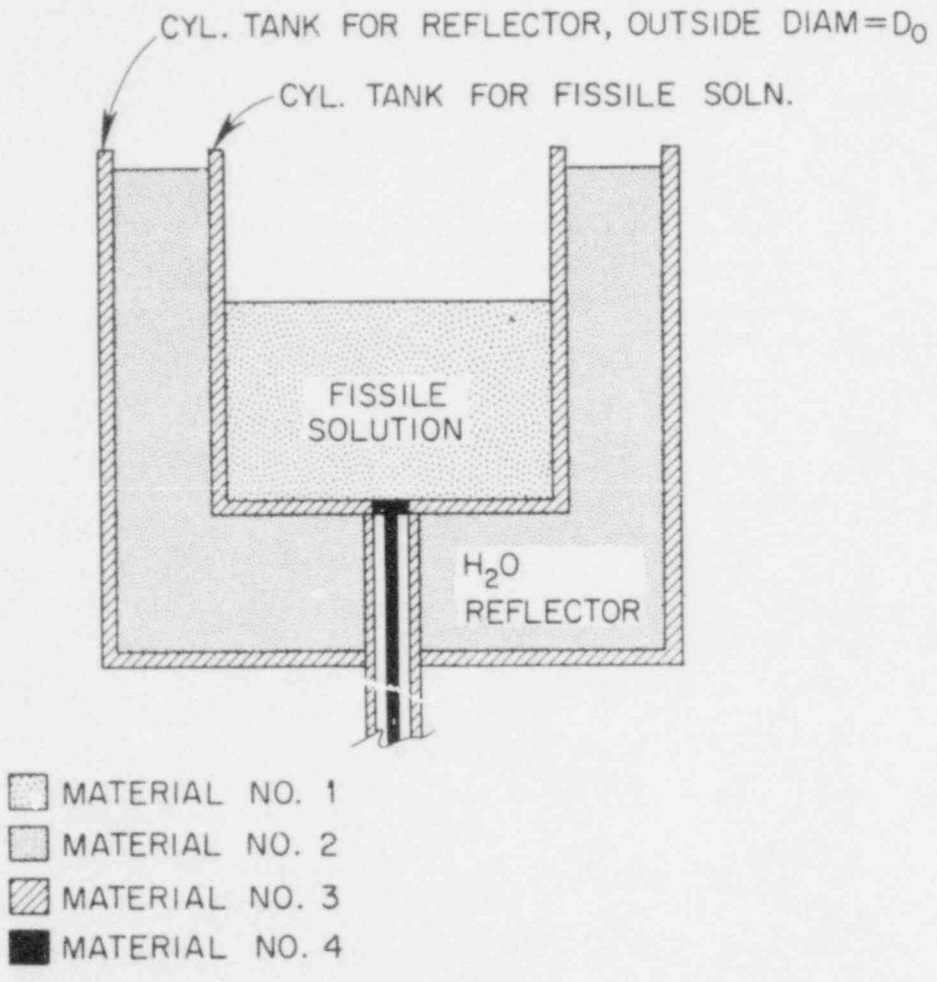


Fig. C.1. Configuration Used in a Series of Criticality Experiments.

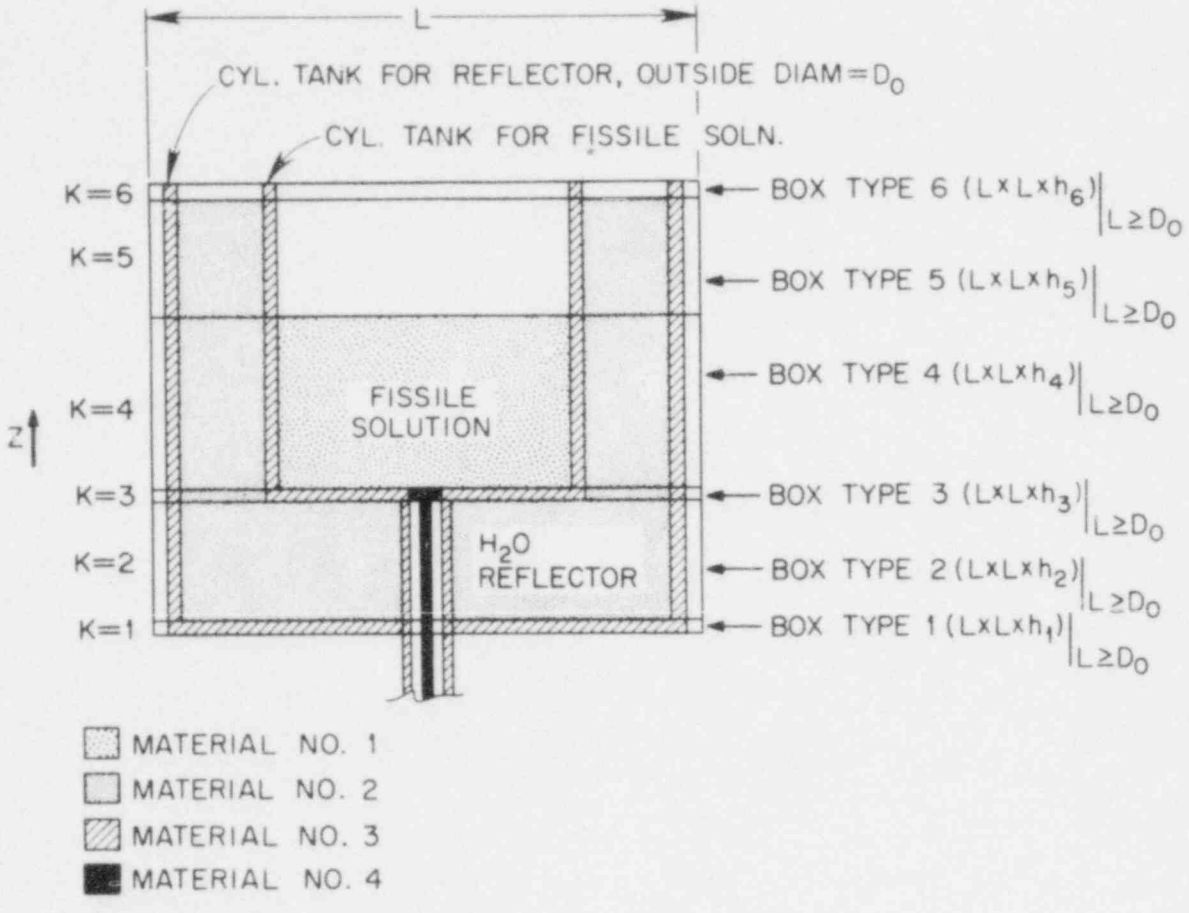
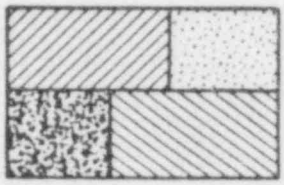


Fig. C.2. Subdivision of the Experimental Configuration into "Boxes" Which can be Described Using KENO Geometry.

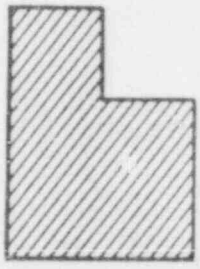
infinite planes through the assembly parallel to each axis. Each of these "mental planes" cut clear through the assembly, resulting in the formation of additional boxes.* Care must be taken to insure that one can (and does) describe the contents of each of these additional boxes using the basic geometry input described above. To describe the configuration in Sketch 1a, for example, requires six boxes as shown in Sketch 1b.



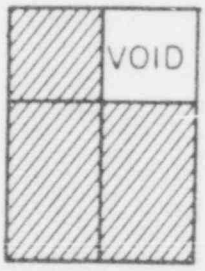
(1a)

(1b)

Likewise, the configuration in Sketch 2a would require four boxes as shown in Sketch 2b.



(2a)



(2b)

In this second case, note that the user would have to define only three "types" of boxes:

box type 1 = small box of material no. 1

box type 2 = small box containing a void

box type 3 = big box of material no. 1

Configuration (2) could then be described as an "array of boxes" where

box (1,1) = box type 3

box (2,1) = box type 3

box (1,2) = box type 1

box (2,2) = box type 2

The assigning of "box types" to individual boxes of the array will be discussed later. That, you see, is the purpose of the Mixed Box Orientation Data (c.f., Section 6). The purpose of the Multidimensional Geometry Specification Data, on the other hand, is to define each "box type" in terms of its size and shape, and the geometric information contained therein. To describe how that is done, it might be well to list the Multidimensional Geometry Specification Data for the experimental configuration shown in Fig. C-2. For that configuraton, the user would enter:

---

*Rule (2) stated another way requires that: Adjacent faces of adjacent boxes must be the same size; the number of boxes in the x direction and their respective widths (Δx_i) must be independent of y and z; the number of boxes in the y direction and their respective heights (Δy_j) must be independent of x and z; and the number of boxes in the z direction and their respective depths (Δz_k) must be independent of x and y.

BOX TYPE	1	
CYLINDER	4	dimensions, including radius of connecting rod
CYLINDER	0	dimensions, including inside radius of housing
CYLINDER	3	dimensions, including outside radius of housing
CYLINDER	3	dimensions, including outside radius of reflector tank ($D = D_0$)
CUBOID	0	dimensions, including width = L and depth = L (where $L \geq D_0$)

BOX TYPE	2	
CYLINDER	4	dimensions, including radius of connecting rod
CYLINDER	0	dimensions, including inside radius of housing
CYLINDER	3	dimensions, including outside radius of housing
CYLINDER	2	dimensions, including inside radius of reflector tank
CYLINDER	3	dimensions, including outside radius of reflector tank ($D = D_0$)
CUBOID	0	dimensions, including width = L and depth = L (where $L \geq D_0$)

BOX TYPE	3	
CYLINDER	4	dimensions, including radius of "plug"
CYLINDER	3	dimensions, including outside radius of core tank
CYLINDER	2	dimensions, including inside radius of reflector tank
CYLINDER	3	dimensions, including outside radius of reflector tank ($D = D_0$)
CUBOID	0	dimensions, including width = L and depth = L (where $L \geq D_0$)

BOX TYPE	4	
CYLINDER	1	dimensions, including inside radius of core tank
CYLINDER	3	dimensions, including outside radius of core tank
CYLINDER	2	dimensions, including inside radius of reflector tank
CYLINDER	3	dimensions, including outside radius of reflector tank ($D = D_0$)
CUBOID	0	dimensions, including width = L and depth = L (where $L \geq D_0$)

BOX TYPE	5	
CYLINDER	0	dimensions, including inside radius of core tank
CYLINDER	3	dimensions, including outside radius of core tank
CYLINDER	2	dimensions, including inside radius of reflector tank
CYLINDER	3	dimensions, including outside radius of reflector tank ($D = D_0$)
CUBOID	0	dimensions, including width = L and depth = L (where $L \geq D_0$)

BOX TYPE	6	
CYLINDER	0	dimensions, including inside radius of core tank
CYLINDER	3	dimensions, including outside radius of core tank
CYLINDER	0	dimensions, including inside radius of reflector tank
CYLINDER	3	dimensions, including outside radius of reflector tank ($D = D_0$)
CUBOID	0	dimensions, including width = L and depth = L (where $L \geq D_0$)

In this example, box type 4 contains materials 1, 2, and 3, while box type 3 contains materials 2, 3, and 4. As always, material 0 denotes a void. Note that the final geometry card describing a particular "box type" must always be a CUBOID or a CUBE. Note, however, that the material

associated with that final geometry card need not be a void. The following Multidimensional Geometry Specification Data would, for example, adequately describe the configuration shown in Sketch (2b):

```
BOX TYPE   1
CUBOID     1      dimensions for small box containing material no. 1

BOX TYPE   2
CUBOID     0      dimensions for small box containing a void

BOX TYPE   3
CUBOID     1      dimensions for big box containing material no. 1
```

The experimental configuration shown in Fig. C-1 was referred to as a problem of "intermediate complexity" which required that the user subdivide the assembly into a number of "boxes." Another frequently encountered problem that fits into this category is that of a dry fuel assembly. (The problem of a single fuel assembly immersed in a pool of water represents a further degree of complexity and will be discussed later.) Consider the BWR fuel assembly shown in Fig. C-3. After dividing it into 49 boxes (see Fig. C-4), the user would have to define a "box type" for each type of fuel pin. The Multidimensional Geometry Specification Data would look like:

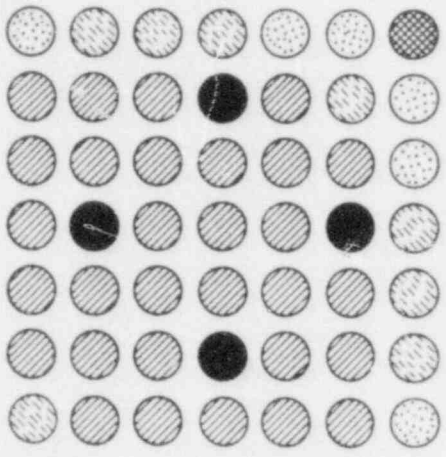
```
BOX TYPE   1
CYLINDER   1   dimensions, including radius of fuel pellet
CYLINDER   0   dimensions, including inside radius of clad (optional)
CYLINDER   6   dimensions, including outside radius of clad (optional)
CUBOID     0      dimensions, including width = pitch, depth = pitch

   .
   .
   .
   .
   .

BOX TYPE   5
CYLINDER   5   dimensions, including radius of fuel pellet
CYLINDER   0   dimensions, including inside radius of clad (optional)
CYLINDER   6   dimensions, including outside radius of clad (optional)
CUBOID     0      dimensions, including width = pitch, depth = pitch
```

Having defined each of the five "box types," one can describe the entire fuel assembly as an "array of boxes" having an overall height, width, and depth. The mechanics of "how the user tells the code which 'box type' is to be assigned to each and every box in the array" is presented in Section 6. That is, in fact, the purpose of the Mixed Box Orientation Data. That information, however, is not part of the Multidimensional Geometry Specification Data, and it need not be discussed here.

The experimental configuration shown in Fig. C-2 and the (dry) BWR fuel assembly shown in Fig. C-4 could both be described as an array of boxes where the "contents" of each box were



MATERIAL NO. 1 (FUEL, HIGH ENRICHMENT)

MATERIAL NO. 2 (FUEL, MEDIUM ENRICHMENT)

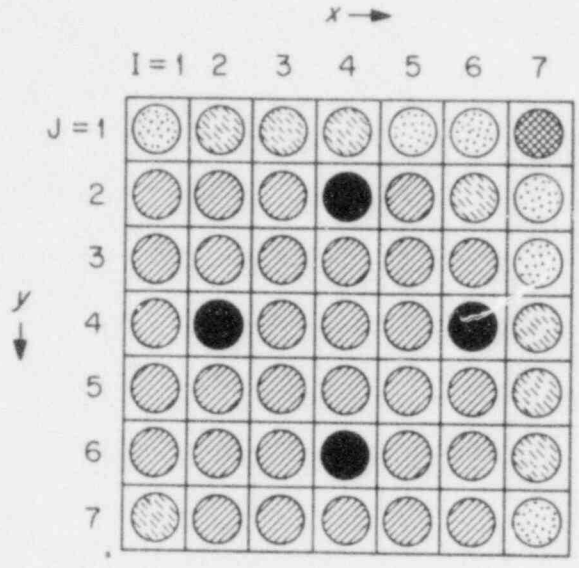
MATERIAL NO. 3 (FUEL, MEDIUM ENRICHMENT)

MATERIAL NO. 4 (FUEL, LOW ENRICHMENT)

MATERIAL NO. 5 (POISON PIN)

NOT SHOWN: MATERIAL NO. 6 (CLAD)

Fig. C.3. A Typical BWR Fuel Assembly.



MATERIAL NO. 1 (FUEL, HIGH ENRICHMENT)

MATERIAL NO. 2 (FUEL, MEDIUM ENRICHMENT)

MATERIAL NO. 3 (FUEL, MEDIUM ENRICHMENT)

MATERIAL NO. 4 (FUEL, LOW ENRICHMENT)

MATERIAL NO. 5 (POISON PIN)

NOT SHOWN: MATERIAL NO. 6 (CLAD)

Fig. C.4. Subdivision of a Typical BWR Fuel Assembly into "Boxes" Which can be Described Using KENO Geometry.

described using the basic geometry input associated with each BOX TYPE card. Before moving on, it should be noted that one can have an array of boxes where every box is identical. Such might be the case, for example, if all the fuel pins in the fuel assembly were identical. In that event, the Multidimensional Geometry Specification Data might look like:

```
CYLINDER  1   dimensions, including radius of fuel pellet
CYLINDER  0   dimensions, including inside radius of clad (optional)
CYLINDER  6   dimensions, including outside radius of clad (optional)
CUBOID    0   dimensions, including width = pitch, depth = pitch
```

Note that while the BOX TYPE 1 card is optional, it is no longer necessary.

While the geometry input described above is adequate to handle problems of "intermediate complexity," it is still somewhat limited. One could not, for example, use it to describe a fuel assembly submerged in a tank of water as shown in Fig. C-5. Indeed, this represents a more advanced configuration. To model such situations, the user must be able to describe regions outside the array*[1] and to position the array within the innermost region.

The first step in describing this type of "advanced configuration" is to fix the location of the array with respect to the origin of a more "global" coordinate system. By its nature, the array is a rectangular parallelepiped with known overall dimensions (ΔX_A, ΔY_A, ΔZ_A). After all the previously described Multidimensional Geometry Specification Data has been entered, the user may (and indeed should) enter a special geometry card known as the "array boundary card." It has the following form:*[2]

ARRAY BOUNDARY m, X_2, X_1, Y_2, Y_1, Z_2, Z_1, w

where X_2, X_1, . . . , Z_1 locate the array with respect to the origin of the "global" coordinate system, and m and w are simple constants (m = 0 and w = –0.5). Note that the array is assumed to extend from X_1 to X_2, such that $\Delta X_A = X_2 - X_1$. Likewise, $\Delta Y_A = Y_2 - Y_1$ and $\Delta Z_A = Z_2 - Z_1$. Having established the surface of the array, one can enter additional geometry cards describing the regions beyond the array. As before, the surface corresponding to each succeeding region must fully enclose (or be tangent to) the surface of the previous region. Thus, the Multidimensional Geometry Specification Data for the submerged BWR fuel assembly shown in Fig. C-5 would look like:

---

*[1]Frequently these are called "reflector" regions. There is, however, no reason why one or more of these regions could not contain fissile material or be a void.

*[2]Seasoned KENO users will recognize this as the "core boundary card." It may also have any of the following forms:

```
CORE  m, X2, X1, etc.
CORE BDY  m, X2, X1, etc.
CORE BOUND  m, X2, X1, etc.
ARRAY  m, X2, X1, etc.
ARRAY BDY  m, X2, X1, etc.
ARRAY BOUND  m, X2, X1, etc.
```

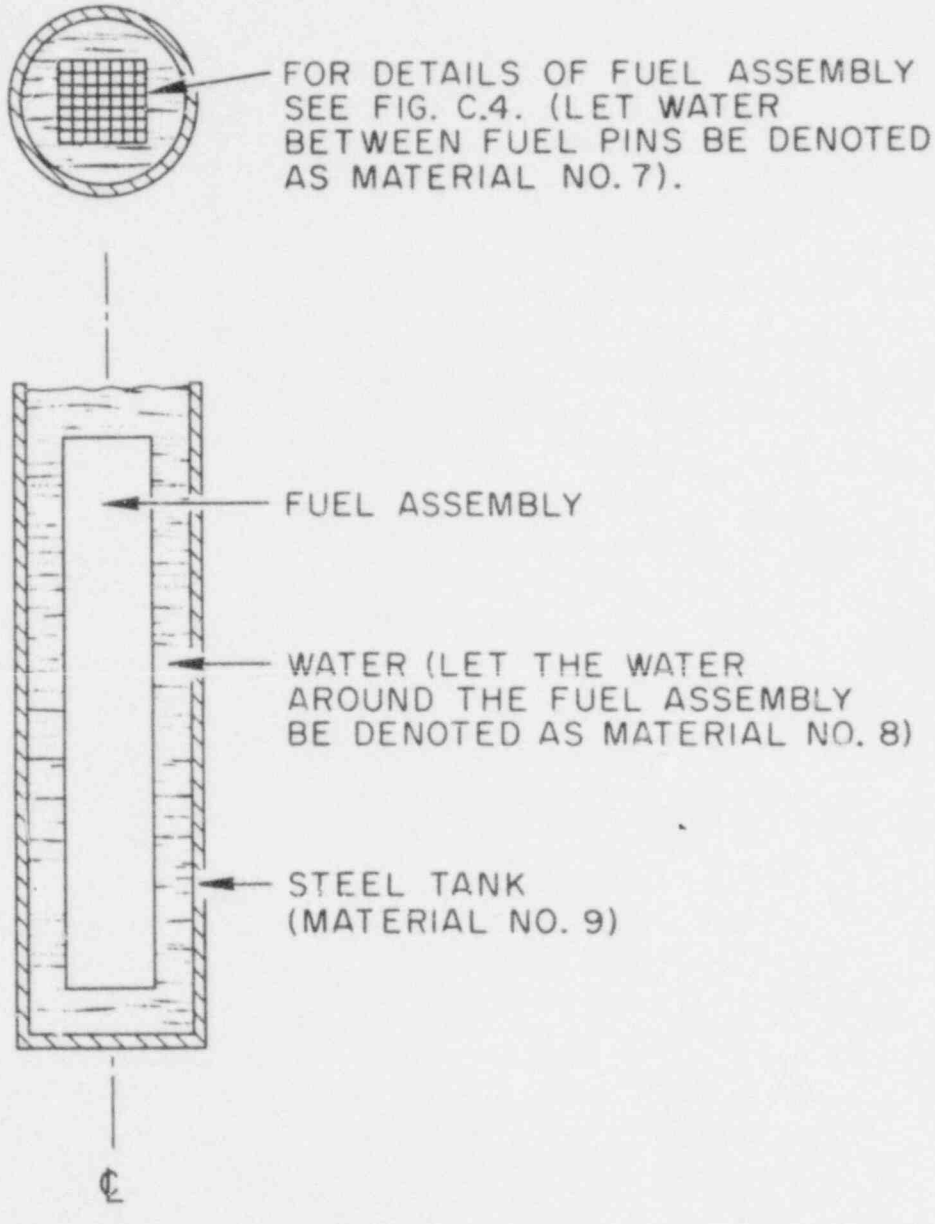


Fig. C.5. A BWR Fuel Assembly Submerged in a Tank of Water.

```
BOX TYPE   1
CYLINDER   1   dimensions, including radius of fuel pellet
CYLINDER   0   dimensions, including inside radius of clad (optional)
CYLINDER   6   dimensions, including outside radius of clad (optional)
CUBOID     7   dimensions, including width = pitch, depth = pitch

.
.
.
.
.

BOX TYPE   5
CYLINDER   5   dimensions, including radius of fuel pellet
CYLINDER   0   dimensions, including inside radius of clad (optional)
CYLINDER   6   dimensions, including outside radius of clad (optional)
CUBOID     7   dimensions, including width = pitch, depth = pitch
ARRAY BOUNDARY   0, X2, X1, Y2, Y1, Z2, Z1, -0.5
CYLINDER   8   inside dimensions of tank
CYLINDER   9   outside dimensions of tank
```

If $X_2 = \Delta X_A/2$, $X_1 = -X_2$, $Y_2 = \Delta Y_A/2$, $Y_1 = -Y_2$, etc., the fuel assembly would be centered in the tank. To shift it off-center, for example, one could enter $X_2 = \epsilon + \Delta X_A/2$, $X_1 = X_2 - \Delta X_A$.

Up to this point we have effectively described the entire KENO geometry package without having to consider the physics of the problem. KENO-IV, being a Monte Carlo code, calculates the effective multiplication factor (k_{eff}) in a statistical fashion by tracking particles as they travel throughout the system and experience collisions. The amount of calculational work required (i.e., the amount of CPU time required) to develop a reliable value for k_{eff} is directly proportional to the amount of tracking that is done. In systems having a relatively small core and a relatively large reflector, for example, one could waste a great deal of time tracking many particles in the reflector which never re-enter the core or induce another fission. Because particles in these regions are "worth" less, it is computationally more efficient to track fewer of them and assign the ones we do track a greater "weight" so that they will statistically represent all the others, thus maintaining some semblance of a fair game. Obviously these "weights" should be both space and energy dependent. (Precisely "how" these weights are used in the tracking scheme is explained in the KENO-IV manual.[7] A separate report, ORNL-TM-4660,[19] details how these weights might be pre-calculated.) The point to be made here is that the user is required to enter the appropriate set of multigroup weights for every spatial region. This data is usually entered as the last string of data items on each geometry card (c.f., Section 6). As a matter of convenience, the user may punch a single entry of -0.5 as a flag to tell the code that (in the given region) a weight of 0.5 is to be used for all energy groups. Indeed, a weight of 0.5 should be used for all energy groups in any region containing a large amount of fissile material, in the clad and moderator surrounding a fuel pin in a fuel assembly, or whenever "something better" is not available. In other surrounding regions, however, it is computationally more efficient to use pre-calculated space-energy weights whenever possible. This is especially true whenever the surrounding material is a good reflector (such as: water, graphite, concrete, paraffin, plexiglas, etc.) having a Σ_S/Σ_T ratio close to 1.0.

As a first example, consider a near-critical uranyl-floride solution (material 1) contained in a 6-inch I.D. stainless steel canister (material 2) submerged in a large pool of water (material 3). Very few particles penetrating deep into the water will ever return to the fuel or induce another fission. For criticality calculations, it is safe to ignore all neutrons penetrating more than 25 or 30 centimeters into the reflector. Thus, instead of an "infinite" pool of water, the calculational model will assume a finite pool ~30 cm thick. The most simplistic form of the Multidimensional Geometry Specification Data may look like:

```
CYLINDER  1   7.62   59.2   -59.2   -0.5
CYLINDER  2   7.77   59.35  -59.35  -0.5
CYLINDER  3  37.77   89.35  -89.35  -0.5
```

Given enough computer time, the calculation would eventually converge. Because of the large amount of water surrounding the fuel, however, it is computationally much more efficient to "break-up" the region containing the water into a number of smaller regions, each with its own set of multigroup weights. Libraries of spatially dependent multigroup weights for water do exist for many group structures and can be easily generated for others.[19] How one "breaks-up" a reflector is usually dependent on how the library of spatially dependent weights presents the data or how one originally calculated the weights. For water, for example, the library lists one set of multigroup weights for that portion of the reflector 0 – 3 cm from the source, another set for that portion 3 – 6 cm from the source, another for 6 – 9 cm from the source, etc., in 3 cm increments. Our calculational model, therefore, "breaks-up" the reflector into 10 regions as shown in Fig. C-6. The Multidimensional Geometry Specification Data for this problem (including a set of 27 group weights) is listed in Table C-1. Note that the group 1 weights for the innermost reflector zone is 0.60221 while the group 1 weight for the outermost reflector zone is 9.2387; for group 27, the respective weights are 0.85637 and 1299.1.

At this point, two very important points should be made: 1) The use of an appropriate set of spatially dependent multigroup weights does not change the ultimate answer (k_{eff}), it only accelerates the rate at which the calculation converges to that answer, and 2) Because one will ultimately arrive at the true value of k_{eff} regardless of the weights,* those weights found in a library or pre-calculated for a particular source-reflector configuration may be used with a great deal of flexibility. For example, the immersed stainless steel canister containing the near-critical uranyl-floride solution might just as well be modeled as shown in Fig. C-7, with the eighth (i.e., the outermost) region of the reflector in this "square" geometry using the same set of multigroup weights as the eighth region of

*One will arrive at the true value of k_{eff} if an appropriate set of spatially dependent multigroup weights is used, if a flat weight of 0.5 is used everywhere, or if any set of spatially dependent multigroup weights bracketed by these two extremes is used. Using a set of spatially dependent multigroup weights substantially larger than what might be appropriate would over-bias the solution and cause the calculation to converge to some other value of k_{eff}. Thus, for example, it would be incorrect to use arbitrarily large reflector weights merely to accelerate the calculation. For that same reason, it would be incorrect to use water weights for a graphite reflector. The statement that one will arrive at the true value of k_{eff} "regardless of the weights" was made to indicate that existing sets of pre-calculated weights may be used with a great deal of flexibility as noted in the text that follows. It should not be taken literally out of context.

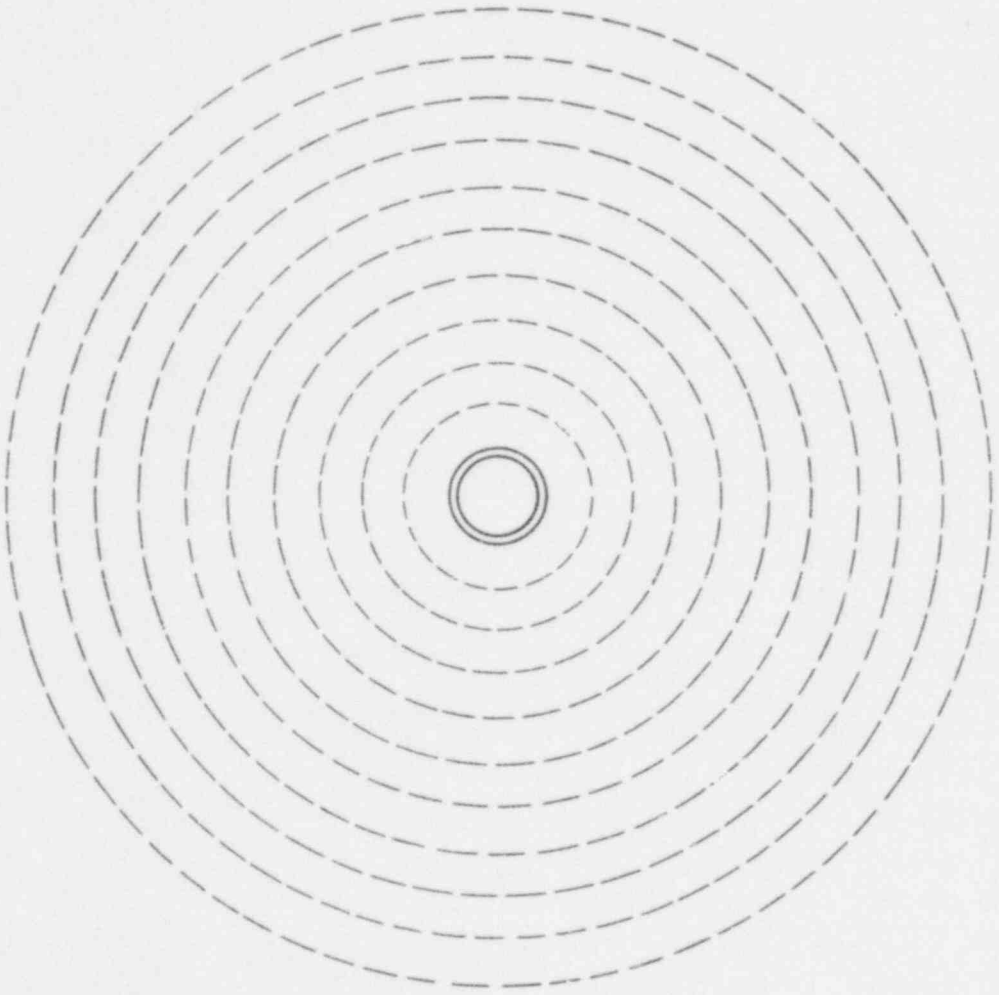


Fig. C.6. One Model of a Canister of Uranyl-Floride Solution Submerged in a Large Pool of Water

Table C.1. Multidimensional Geometry Specification Data for a Canister of Uranyl-Floride Solution Submerged in a Large Pool of Water as Modeled in Fig. C.6

```
CYLINDER     1        7.62 59.2 -59.2       -0.5
CYLINDER     2      7.77 59.35 -59.35       -0.5
CYLINDER     3       10.77 62.35 -62.35
60221-5 57675-5 57152-5 56957-5 56464-5 55463-5 56072-5 58526-5 61529-5 64108-5
64338-5 64532-5 64573-5 65111-5 66838-5 71246-5 70992-5 73565-5 75532-5 76281-5
75814-5 75676-5 77947-5 80251-5 81681-5 8338-4 85637-5
CYLINDER     3       13.77 65.35 -65.35
8147-4 76401-5 77149-5 78619-5 79653-5 80899-5 90214-5 10528-4 12004-4 13231-4
13847-4 14541-4 15173-4 16096-4 17409-4 19261-4 19339-4 20364-4 2119-3 2164-3
21687-4 21783-4 22874-4 2393-3 24533-4 25197-4 2599-3
CYLINDER     3       16.77 68.35 -68.35
10808-4 10635-4 11424-4 12423-4 13403-4 14708-4 18797-4 24435-4 29597-4 33965-4
36858-4 39981-4 42623-4 46015-4 50375-4 55946-4 56264-4 59305-4 61768-4 63168-4
63405-4 63714-4 66919-4 69978-4 71695-4 73596-4 75863-4
CYLINDER     3       19.77 71.35 -71.35
14467-4 15598-4 18331-4 21898-4 25682-4 30901-4 45333-4 6415-3 80515-4 94137-4
1035-2 11321-3 12108-3 13085-3 1432-2 15896-3 15979-3 16838-3 17531-3 17913-3
17955-3 18029-3 18912-3 19745-3 20202-3 20716-3 21328-3
CYLINDER     3       22.77 74.35 -74.35
1952-3 23724-4 31039-4 41517-4 53448-4 70613-4 11658-3 17317-3 21942-3 25668-3
2814-2 30663-2 32596-3 35028-3 38144-3 42249-3 42414-3 44659-3 46452-3 47357-3
47316-3 47431-3 49623-3 51638-3 52683-3 53901-3 55355-3
CYLINDER     3       25.77 77.35 -77.35
2648-3 36914-4 54306-4 82303-4 11648-3 16721-3 29827-3 44505-3 55654-3 64274-3
69499-3 74595-3 78517-3 83464-3 90055-3 99366-3 9952-2 10464-2 10866-2 11035-2
10965-2 1096-1 11416-2 11814-2 11996-2 12228-2 12506-2
CYLINDER     3       28.77 80.35 -80.35
3604-3 58237-4 9676-3 167-1 25788-3 39269-3 71203-3 10226-2 12424-2 1405-1
1489-1 15682-2 16278-2 17074-2 18222-2 20016-2 19993-2 20989-2 21752-2 21993-2
21718-2 21641-2 2243-1 23072-2 2331-1 23667-2 241
CYLINDER     3       31.77 83.35 -83.35
49161-4 92675-4 17397-3 34142-3 56546-3 88092-3 1523-1 20591-2 24244-2 26862-2
27953-2 28965-2 29723-2 30848-2 32644-2 35737-2 35623-2 37353-2 38655-2 3896-1
383 38078-2 39331-2 40288-2 40565-2 41078-2 4171-1
CYLINDER     3       34.77 86.35 -86.35
67226-4 14851-3 31436-3 69747-3 12111-2 18621-2 29715-2 38116-2 43906-2 48006-2
49398-2 50693-2 51679-2 5332-1 56166-2 61377-2 61114-2 64043-2 66226-2 66636-2
65355-2 64903-2 66923-2 68409-2 68765-2 69546-2 7052-1
CYLINDER     3       37.77 89.35 -89.35
92387-4 24039-3 57211-3 14322-2 25708-2 38507-2 57782-2 7227-1 82587-2 89929-2
92242-2 94429-2 96104-2 98998-2 10415-1 11375-1 11322-1 11862-1 12263-1 12332-1
12085-1 11997-1 12361-1 12625-1 12682-1 12819-1 12991-1
END GEOMETRY
```

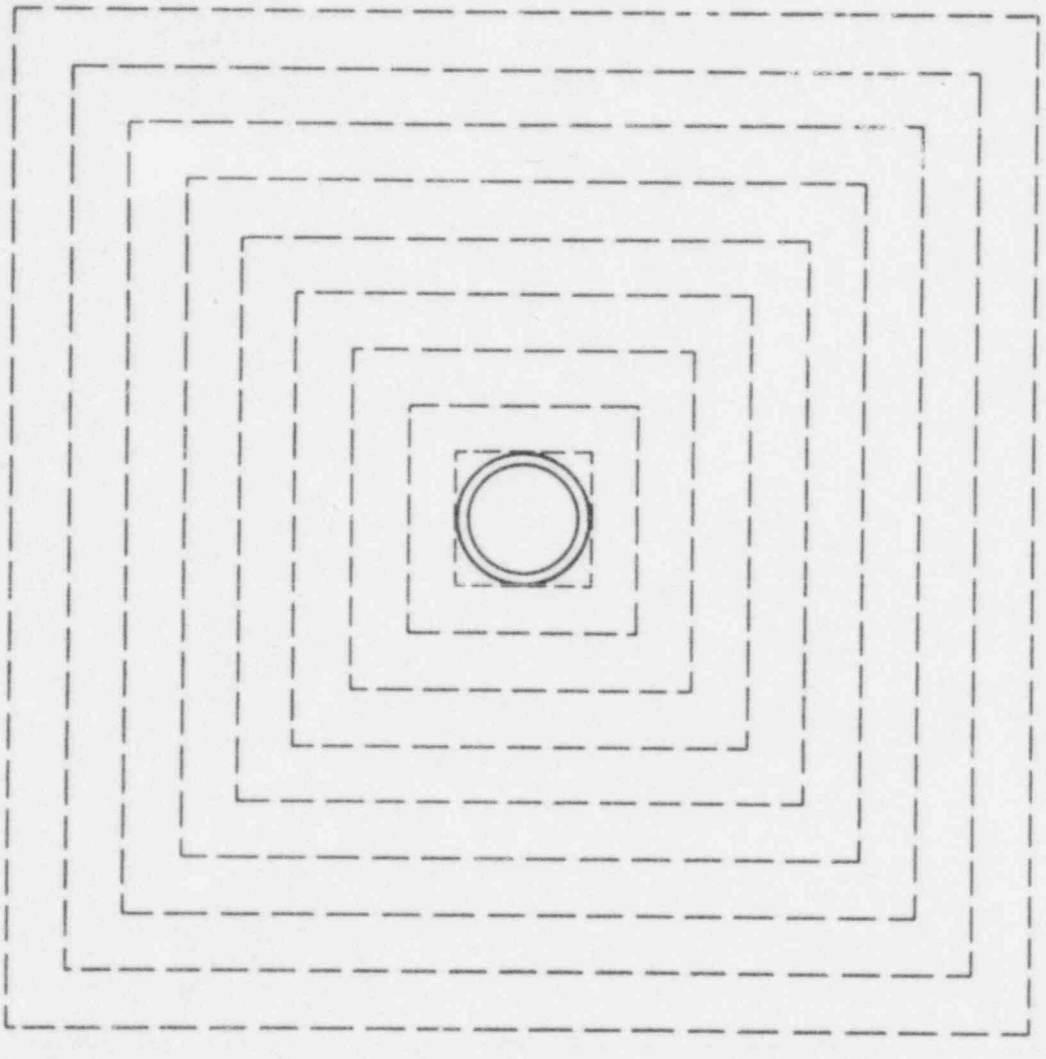


Fig. C.7. An Alternate Model of a Canister of Uranyl-Floride Solution Submerged in a Large Pool of Water.

Table C.2. Multidimensional Geometry Specification Data for a Cartesian of Uranyl-Floride Solution Submerged in a Large Pool of Water as Modeled in Fig. C.7

```
CYL INDER    1  7.62   59.2   -59.2   -0.5
CYL INDER    2  7.77   59.35  -59.35  -0.5
CUBOID    3   8.0   -8.0   8.0   -8.0   60.0   -60.0   -0.5
CUBOID    3   11.0   -11.0   11.0   -11.0   63.0   -63.0
60221-5 57675-5 57152-5 56957-5 56464-5 55463-5 56072-5 58526-5 61529-5 64108-5
64338-5 64532-5 64573-5 65111-5 66838-5 71246-5 70992-5 73565-5 75532-5 76281-5
75814-5 75676-5 77947-5 80251-5 81681-5 8338-4 85637-5
CUBOID    3   14.0   -14.0   14.0   -14.0   66.0   -66.0
8147-4 76401-5 77149-5 78619-5 79653-5 80899-5 90214-5 10528-4 12004-4 13231-4
13847-4 14541-4 15173-4 16096-4 17409-4 19261-4 19339-4 20364-4 2119-3 2164-3
21687-4 21783-4 22874-4 2393-3 24533-4 25197-4 2599-3
CUBOID    3   17.0   -17.0   17.0   -17.0   69.0   -69.0
10808-4 10635-4 11424-4 12423-4 13403-4 14708-4 18797-4 24435-4 29597-4 33965-4
36858-4 39981-4 42623-4 46015-4 50375-4 55946-4 56264-4 59305-4 61768-4 63168-4
63405-4 63714-4 66919-4 69978-4 71695-4 73596-4 75863-4
CUBOID    3   20.0   -20.0   20.0   -20.0   72.0   -72.0
14467-4 15598-4 18331-4 21898-4 25682-4 30901-4 45333-4 6415-3 80515-4 94137-4
1035-2 11321-3 12108-3 13085-3 1432-2 15896-3 15979-3 16838-3 17531-3 17913-3
17955-3 18029-3 18912-3 19745-3 20202-3 20716-3 21328-3
CUBOID    3   23.0   -23.0   23.0   -23.0   75.0   -75.0
1952-3 23724-4 31039-4 41517-4 53448-4 70613-4 11658-3 17317-3 21942-3 25668-3
2814-2 3063-2 32596-3 35028-3 38144-3 42249-3 42414-3 44659-3 46452-3 47357-3
47316-3 47431-3 49623-3 51638-3 52683-3 53901-3 55355-3
CUBOID    3   26.0   -26.0   26.0   -26.0   78.0   -78.0
2648-3 36914-4 54306-4 82303-4 11648-3 16721-3 29827-3 44505-3 55654-3 64274-3
69499-3 74595-3 78517-3 83464-3 90055-3 99366-3 9952-2 10464-2 10866-2 11035-2
10965-2 1096-1 11416-2 11814-2 11996-2 12228-2 12506-2
CUBOID    3   29.0   -29.0   29.0   -29.0   81.0   -81.0
3604-3 58237-4 9676-3 167-1 25788-3 39269-3 71203-3 10226-2 12424-2 1405-1
1489-1 15682-2 16278-2 17074-2 18222-2 20016-2 19993-2 20989-2 21752-2 21993-2
21718-2 21641-2 2243-1 23072-2 2331-1 23667-2 241
CUBOID    3   32.0   -32.0   32.0   -32.0   84.0   -84.0
49161-4 52675-4 17397-3 34142-3 56586-3 88092-3 1523-1 20591-2 24244-2 26862-2
27953-2 28965-2 29723-2 30848-2 32644-2 35737-2 35623-2 37353-2 38655-2 3896-1
383 38078-2 39331-2 40288-2 40565-2 41078-2 4171-1
END GEOMETRY
```

the reflector in the "circular" geometry of Fig. C-6. The Multidimensional Geometry Specification Data for this problem, as modeled in Fig. C-7, is listed in Table C-2. We will come back to this model later to illustrate another input option that is frequently very convenient. Before moving on, however, it might also be noted that reflector weights for one material can often be used for other similar materials. For example, the predominant moderator in water, plexiglass and paraffin is hydrogen. If multigroup weights are available for water but not plexiglass or paraffin, it would be to one's advantage to use the water weights for the other two reflectors. The k_{eff} to which the solution will converge will be essentially the same as it would have been had the "correct" set of weights been available. The key requirement is that the two materials be neutronically similar – that is: the absorption cross sections (Σ_A) must be similar, and the slowing down power ($\xi\Sigma_S$) must be similar. Because of the very low absorption cross section in graphite, the actual reflector weights for graphite are relatively constant over the first 60 cm, whereas the weights for water change by several orders of magnitude over the first 30 cm (c.f., Fig. C-8). Use of the water weights in graphite would over-bias the solution and perhaps cause the calculation to converge to something other than the true value of k_{eff}. Because of the relatively low hydrogen content in concrete, its slowing down power is not as great as pure water, and the multigroup weights for the two materials should not be considered "interchangeable" (c.f., Fig. C-8). Indeed, use of the water weights in concrete would again over-bias the solution and perhaps cause the calculation to converge to something other than the true value of k_{eff}. Within these guidelines, however, existing tables of spatially dependent multigroup reflector weights may be used with a great deal of flexibility.

The experimental configuration shown in Fig. C-1 represents a somewhat unusual, but still fairly common, type of problem in which the reflecting material surrounding the fissile solution lies within the "array of boxes" required to describe the spatial configuration (c.f., Fig. C-2). Because of the large amount of water surrounding the fuel, it would again be computationally more efficient to "break-up" the region containing the water into a number of smaller regions, each with its own set of multigroup weights. This may be done by using two or more cylindrical annuli to represent the water in the uppermost boxes and/or by slicing the region below the fissile material into additional "boxes," each of which may be subdivided into two or more cylindrical annuli. Assuming a 6 cm water-filled gap between the stainless steel tanks in the radial direction and a 9 cm offset in the axial direction, and assuming that pre-calculated multigroup reflector weights for water are available in 3 cm increments, a more efficient calculational model might divide the experimental configuration into eight "box types" as shown in Fig. C-9. The letters B, C, D, etc., denote the particular set of multigroup weights that should be used for each of the subregions in order to realize maximum computational efficiency. For the fissile solution, the tank containing it, and the plug at the bottom, set "A" should be used. For the water reflector, set "B," "C," "D," or "E" should be used. For the connecting rod and tubular housing, set "B," "C," or "D" should be used, depending on the set used in the surrounding water. For the outermost tank, set "C," "D," or "E" should be used, depending on the set used in water adjacent to it. For those regions containing a void (i.e., material "zero") it doesn't matter what set of weights is used since no neutron will ever experience a collision in such a region. For voids, set "A" is recommended simply because it is the easiest to enter, requiring only a single entry of -0.5. Without presenting all the minute details, the Multidimensional Geometry Specification Data for box type 3 might look like:

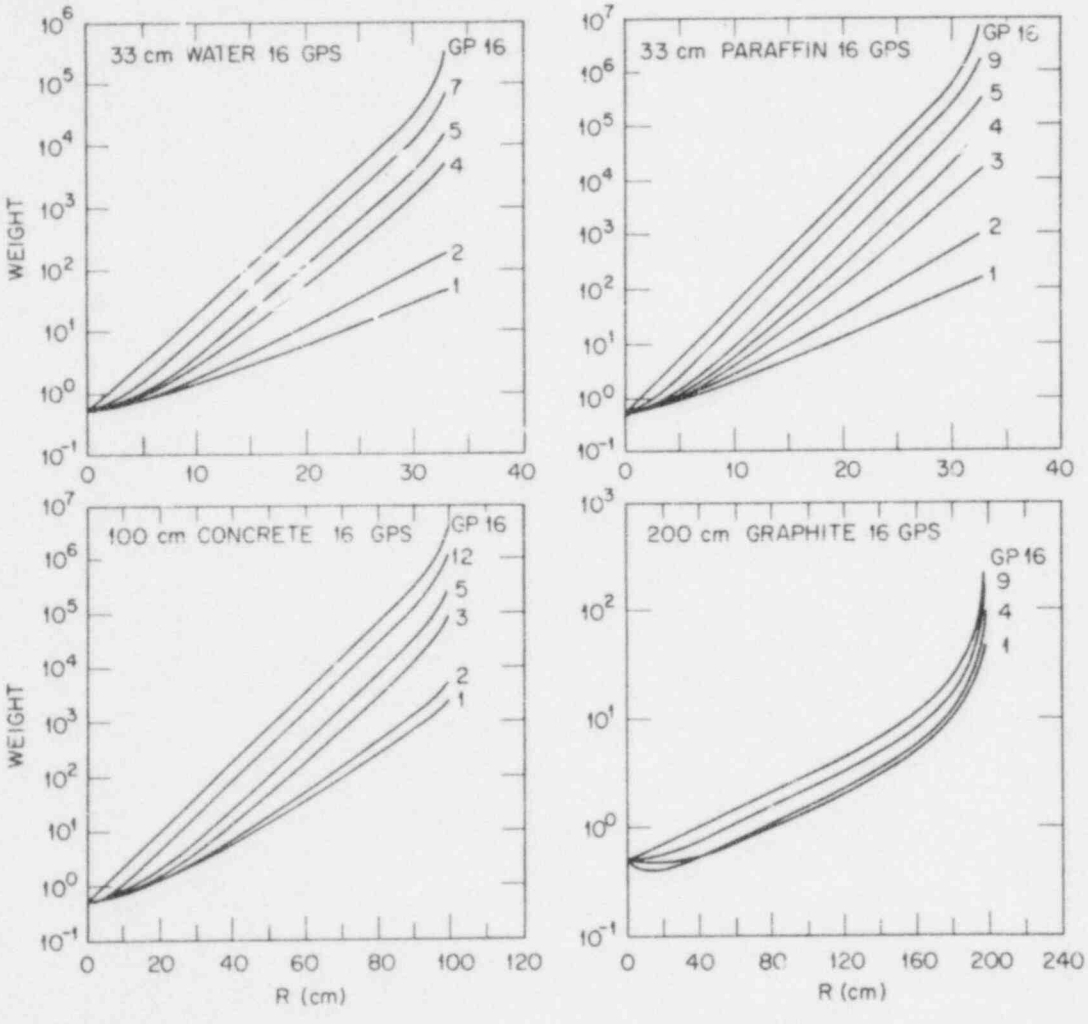


Fig. C.8. Sixteen Group Reflector Weights for Water, Paraffin, Concrete and Graphite.

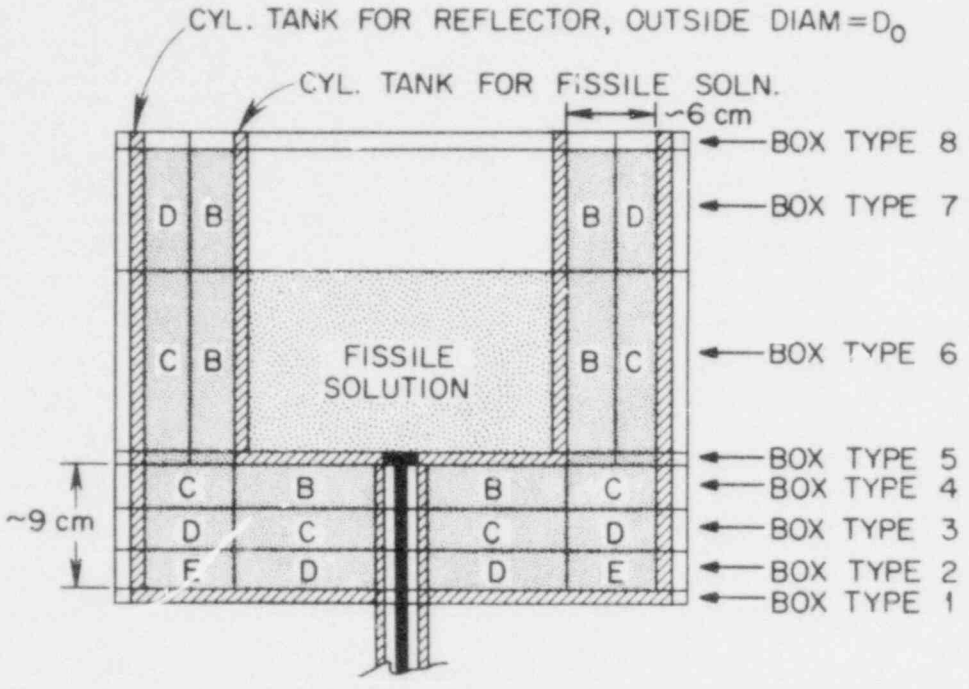


Fig. C.9. Subdivision of the Experimental Configuration into "Boxes" which can be Described Using KENO Geometry and which Adequately Subdivide the Reflector into Separate Regions where Space-Dependent Multigroup Weights can be Used Effectively.

A denotes a weight of 0.5 for each energy group (used but not shown).

B denotes pre-calculated multigroup reflector weights for water (0 - 3 cm).

C denotes pre-calculated multigroup reflector weights for water (3 - 6 cm).

D denotes pre-calculated multigroup reflector weights for water (6 - 9 cm).

E denotes pre-calculated multigroup reflector weights for water (9 - 12 cm).

```
BOX TYPE  3
CYLINDER  4  dimensions, including radius of connecting rod; weights (set "C")
CYLINDER  0  dimensions, including inside radius of housing; weights (set "A")
CYLINDER  3  dimensions, including outside radius of housing; weights (set "C")
CYLINDER  2  dimensions, including outside radius of core tank; weights (set "C")
CYLINDER  2  dimensions, including inside radius of reflector tank; weights (set "D")
CYLINDER  3  dimensions, including outside radius of reflector tank; weights (set "D")
CUBOID    0  dimensions, including width = L, depth = L; weights (set "A")
```

Likewise, the Multidimensional Geometry Specification Data for box type 6 might look like:

```
BOX TYPE  6
CYLINDER  1  dimensions, including inside radius of core tank; weights (set "A")
CYLINDER  3  dimensions, including outside radius of core tank; weights (set "A")
CYLINDER  2  dimensions, including outside radius of core tank plus 3 cm; weights (set "B")
CYLINDER  2  dimensions, including inside radius of reflector tank; weights (set "C")
CYLINDER  3  dimensions, including outside radius of reflector tank; weights (set "C")
CUBOID    0  dimensions, including width = L and depth = L; weights (set "A")
```

(note that the ARRAY BOUNDARY may be used but is not needed since nothing outside the array is being included in the calculational model.

The previous example represented a somewhat unusual situation in which the reflecting material surrounding the fissile solution had to be included within the "array of boxes" in order to describe the spatial configuration. A much more common situation is that where an "array of boxes" (representing a fuel assembly, reactor core, or a cluster of uranyl-floride canisters) is surrounded by a thick reflector. Even then, a fair amount of variation is possible. At least three such examples will be considered: 1) an array surrounded by a reflector which is surrounded by something else; 2) an array surrounded by a reflector only; and 3) an array surrounded by a reflector with "something else" between the array and the reflector. The second and third examples will be used to introduce the REFLECTOR card – the last of the nice KENO options.

As the first example of an array surrounded by a thick reflector, let us again consider the BWR fuel assembly submerged in a tank of water as shown in Fig. C-5. We will assume here that the tank is big enough that it is computationally desirable to "break-up" the reflector into smaller regions, each with its own set of multigroup weights. Again using B, C, D, etc., to denote the pre-calculated multigroup reflector weights, the resulting Multidimensional Geometry Specification Data for that configuration might look like:

```
BOX TYPE  1
CYLINDER  1  dimensions, including radius of fuel pellet; weights (set "A")
CYLINDER  0  dimensions, including inside radius of clad; weights (set "A")
CYLINDER  6  dimensions, including outside radius of clad; weights (set "A")
CUBOID    7  dimensions, including width = pitch, depth = pitch; weights (set "A")
```

```
.
.
.
.
.
```

BOX TYPE 5
CYLINDER 5 dimensions, including radius of fuel pellet; weights (set "A")
CYLINDER 0 dimensions, including inside radius of clad; weights (set "A")
CYLINDER 6 dimensions, including outside radius of clad; weights (set "A")
CUBOID 7 dimensions, including width = pitch, depth = pitch; weights (set "A")

ARRAY BOUNDARY 0, X_2, X_1, Y_2, Y_1, Z_2, Z_1, −0.5
CYLINDER 8 $R = R_0 = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2}$, $Z_{max} = Z_2$, $Z_{min} = Z_1$; weights (set "A")
CYLINDER 8 $R = R_0 + 3$ cm, $Z_{max} = Z_2 + 3$ cm, $Z_{min} = Z_1 - 3$ cm; weights (set "B")
CYLINDER 8 $R = R_0 + 6$ cm, $Z_{max} = Z_2 + 6$ cm, $Z_{min} = Z_1 - 6$ cm; weights (set "C")
CYLINDER 8 $R = R_0 + 9$ cm, $Z_{max} = Z_2 + 9$ cm, $Z_{min} = Z_1 - 9$ cm; weights (set "D")
CYLINDER 8 $R = R_0 + 12$ cm, $Z_{max} = Z_2 + 12$ cm, $Z_{min} = Z_1 - 12$ cm; weights (set "E")
CYLINDER 9 outside dimensions of tank; weights (set "E")

Note that the multigroup weights used for the tank should be the same as those used for the outermost portion of the reflector.

As a second example of an array surrounded by a thick reflector, consider a rack containing nine PWR assemblies in the middle of a large, water-filled spent fuel storage area as shown in Fig. C-10. For simplicity, we will ignore the rack itself in this discussion. As before, we will neglect all neutrons penetrating more than 25–30 cm into the reflector. Thus, instead of an "infinite" pool of water, the calculational model will assume a finite pool ~25–30 cm thick.* Typically each fuel assembly contains 264 identical fuel pins and 25 water holes (normally occupied by control pins) arranged in a 17 × 17 matrix. For this problem, we will assume that the spacing (s) between adjacent fuel assemblies is 5.0 cm. [Other dimensions characteristic of such a fuel assembly are: $D_{incl} = 0.824$ cm, $t_{gap} = 0.005$ cm, $t_{clad} = 0.058$ cm, $D_{pin} = 0.950$ cm, $p = 1.260$ cm (pitch), $L = 365.76$ cm (length)]. To model the nine fuel assemblies as arranged in Fig. C-10, the user will need an "array of boxes" measuring 53 × 53 × 1, and he will have to define five "box types": one for a typical fuel pin, one for a typical water hole, and three for the water-filled regions between fuel assemblies (i.e., one s × p, one p × s, and one s × s). Outside of the array, it will be computationally advantageous to "break-up" the reflector into eight smaller regions, each 3 cm thick, and each having its own set of multigroup weights (c.f., Fig. C-10 and Table C-3). The Multidimensional Geometry Specification Data for this particular problem is listed in Table C-3. Note that the 27 group reflector weights for water are entered explicitly for each segment of the reflector.

To increase the spacing (s) between fuel assemblies, one would obviously change the dimensions used to describe box types 3, 4, and 5. Unfortunately, the array boundary would also expand, and each of the surfaces describing the various reflector regions should also be moved outward. This can become tiresome, especially if one is interested in a parametric study of k_{eff} versus s. For that reason, a library of pre-calculated reflector weights has been stored on disc, and the procedure for

*An alternate example not having this "approximation" might be an array of uranium metal fuel rods clustered in the middle of a large block of graphite having "definite" dimensions.

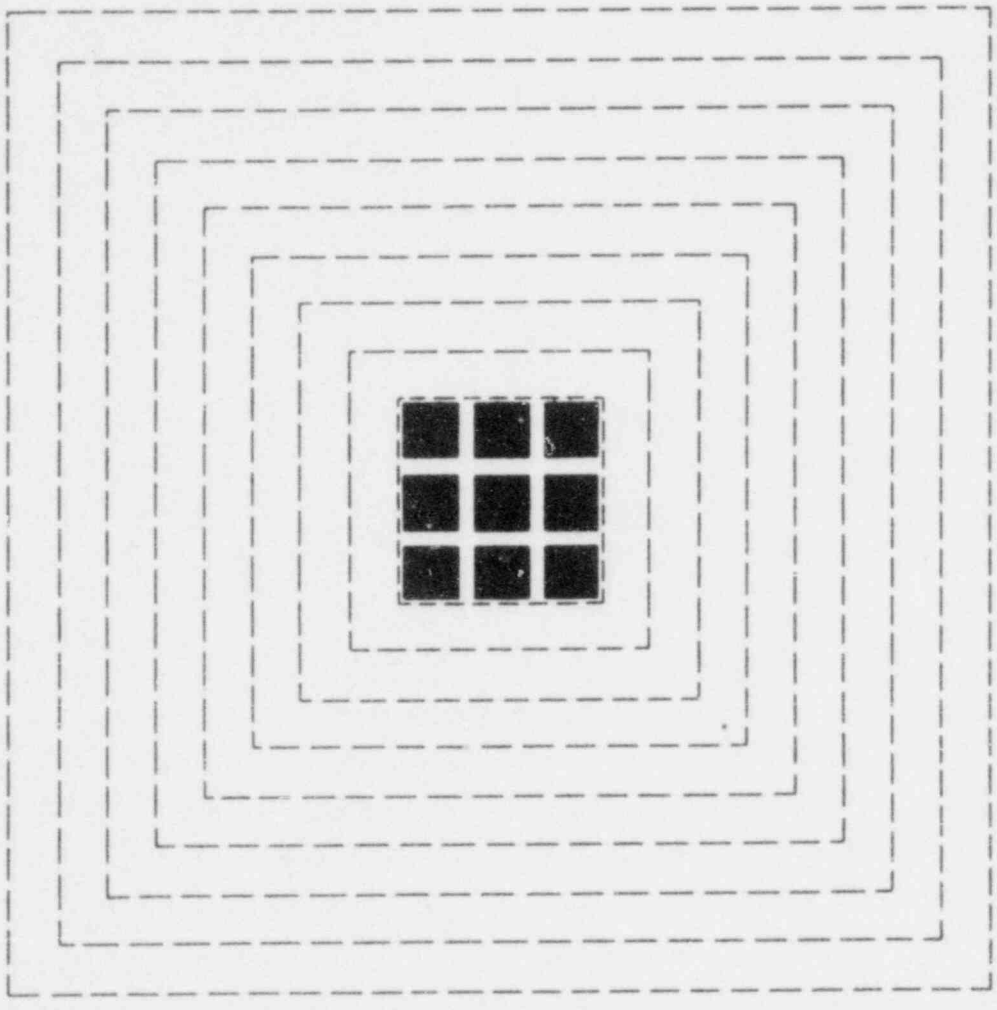


Fig. C.10. Rack of Nine PWR Assemblies in the Middle of a Large Water-Filled Spent Fuel Storage Area.

Material #0 Void

Material #1 Fuel

Material #2 Clad

Material #3 Water

Table C.3. Multidimensional Geometry Specification Data for the Rack of PWR Fuel Assemblies in a Large Water-Filled Storage Area as Modeled in Fig. C.10

```
BOX TYPE   1
CYLINDER   1 0.412 365.76 0.0 -0.5
CYLINDER   0 0.417 365.76 0.0 -0.5
CYLINDER   2 0.475 365.76 0.0 -0.5
CUBOID   3 0.63 -0.63 0.63 -0.63 365.76 0.0 -0.5
BOX TYPE   2
CUBOID   3 1.26 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE   3
CUBOID   3 5.0 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE   4
CUBOID   3 1.26 0.0 5.0 0.0 365.76 0.0 -0.5
BOX TYPE   5
CUBOID   3 5.0 0.0 5.0 0.0 365.76 0.0 -0.5
ARRAY BOUNDARY   0 37.13 -37.13 37.13 -37.13 182.88 -182.88 -0.5
CUBOID   3 40.13 -40.13 40.13 -40.13 185.88 -185.88
60221-5 57675-5 57152-5 56957-5 56464-5 55463-5 56072-5 58526-5 61529-5 64108-5
64338-5 64532-5 64573-5 65111-5 66838-5 71246-5 70992-5 73565-5 75532-5 76281-5
75814-5 75676-5 77947-5 80251-5 81681-5 8338-4 85637-5
CUBOID   3 43.13 -43.13 43.13 -43.13 188.88 -188.88
8147-4 76401-5 77149-5 78619-5 79653-5 80899-5 90214-5 10528-4 12004-4 13231-4
13847-4 14541-4 15173-4 16096-4 17409-4 19261-4 19339-4 20364-4 2119-3 2164-3
21687-4 21783-4 22874-4 2393-3 24533-4 25197-4 2599-3
CUBOID   3 46.13 -46.13 46.13 -46.13 191.88 -191.88
10808-4 10635-4 11424-4 12423-4 13403-4 14708-4 18797-4 24435-4 29597-4 33965-4
36858-4 39981-4 42623-4 46015-4 50375-4 55946-4 56264-4 59305-4 61768-4 63168-4
63405-4 63714-4 66919-4 69978-4 71695-4 73596-4 75863-4
CUBOID   3 49.13 -49.13 49.13 -49.13 194.88 -194.88
14467-4 15598-4 18331-4 21898-4 25682-4 30901-4 45333-4 6415-3 80515-4 94137-4
1035-2 11321-3 12108-3 13085-3 1432-2 15896-3 15979-3 16838-3 17531-3 17913-3
17955-3 18029-3 18912-3 19745-3 20202-3 20716-3 21328-3
CUBOID   3 52.13 -52.13 52.13 -52.13 197.88 -197.88
1952-3 23724-4 31039-4 41517-4 53448-4 70613-4 11658-3 17317-3 21942-3 25668-3
2814-2 3063-2 32596-3 35028-3 38134-3 42249-3 42414-3 44659-3 46452-3 47357-3
47316-3 47431-3 49623-3 51638-3 52683-3 53901-3 55355-3
CUBOID   3 55.13 -55.13 55.13 -55.13 200.88 -200.88
2648-3 36914-4 54306-4 82303-4 11648-3 16721-3 29827-3 44505-3 55654-3 64274-3
69499-3 74595-3 78517-3 83464-3 90055-3 99366-3 9952-2 10464-2 10866-2 11035-2
10965-2 1096-1 11416-2 11814-2 11996-2 12228-2 12506-2
CUBOID   3 58.13 -58.13 58.13 -58.13 203.88 -203.88
3604-3 58237-4 9676-3 167-1 25788-3 39269-3 71203-3 10226-2 12424-2 1405-1
1489-1 15682-2 16278-2 17074-2 18222-2 20016-2 19993-2 20989-2 21752-2 21993-2
21718-2 21641-2 2243-1 23072-2 2331-1 23667-2 241
CUBOID   3 61.13 -61.13 61.13 -61.13 206.88 -206.88
49161-4 92675-4 17397-3 34142-3 56546-3 88092-3 1523-1 20591-2 24244-2 26862-2
27953-2 28965-2 29723-2 30848-2 32644-2 35737-2 35623-2 37353-2 38655-2 3896-1
383 38078-2 39331-2 40288-2 40565-2 41078-2 4171-1
END GEOMETRY
```

*The "Mixed Box Orientation Data" is used to further describe the array of boxes. While that data is necessary to complete the geometry description, it is entered as a separate block of data. See Sec. 6 for details.

"breaking-up" a reflector into smaller regions has been automated. To use the pre-calculated weights from the library and take advantage of the automated procedure, the user should enter a special geometry card known as the "automatic reflector card." It has the following form:

REFLECTOR MAT, TX2, TX1, TY2, TY1, TZ2, TZ1, IDWT

where TX2, TX1, . . . , TZ1 denote the total thickness of the reflector on the respective faces of the array (X_2, X_1, . . . , Z_1), MAT is the mixture number the user has established for the reflector material, and IDWT is the I.D. number corresponding to the set of pre-calculated weights for the reflector material (see Appendix A-5). When the automatic reflector card is used, the code will automatically "break-up" the reflector into smaller regions and supply the appropriate set of weights for each. This greatly simplifies the input and eliminates the need for the user to enter a lot of the data listed in Table C-3. Indeed, the Multidimensional Geometry Specification Data for that particular example may be re-written as shown in Table C-4.

Before elucidating further on the possible uses of the automatic reflector card, it would be beneficial to make several remarks concerning the data on the card and lay down at least two rules for its use. Remarks concerning the data on the automatic reflector card: 1) While MAT is the mixture number the user has established for the actual reflector material, IDWT may denote the weights for a different (but similar) material. Thus, for example, the weights for water may be used for a plexiglass reflector since no special weights are available for plexiglass. 2) As with the rest of the input, a convenient repeat option is available such that entering 6*24.0 or 6R24 is equivalent to entering 24.0 six times. 3) While the thicknesses TX2, TX1, . . . , TZ1 must all be greater than or equal to zero, they need not be the same. Thus, an array reflected only on four sides would have six entries, two of which would be zero. 4) The ARRAY BOUNDARY card is optional whenever the REFLECTOR card is used and the reflector material (MAT) extends all the way in to the array boundary. Thus, the Multidimensional Geometry Specification Data for the current problem is most conveniently written as shown in Table C-5. (Contrast, for example, the simplicity of Table C-5 with the complexity of Table C-3.)

Obviously it is desirable to use the automatic reflector card whenever possible. The question is: "When is that?" Basically, there are two rules: 1) The automatic reflector card cannot be used whenever there is anything beyond the reflector which the user intends (and/or needs) to model. Thus, the REFLECTOR card cannot be used to describe the BWR fuel assembly submerged in a tank of water (c.f., Fig. C-5) unless the inside diameter of the tank is so large that the tank itself can be ignored. 2) The automatic reflector card can be used only when one has an "array of boxes" (i.e., only when the fifth item on the KENO Parameter Card, NBOX, is greater than or equal to one). Thus, the REFLECTOR card cannot be used to describe the canister of uranyl-floride solution submerged in a pool of water as modeled in Fig. C-6. Fortunately, this very same physical situation may also be modeled as shown in Fig. C-7. This model may, for example, be viewed as an "array of boxes" surrounded by a reflector. The array, of course, would only measure 1 × 1 × 1, and the single "box" would be a water-filled cuboid containing the canister of uranyl-floride in the center. Adopting this approach, the necessary Multidimensional Geometry Specification Data may be

Table C.4. A Shorter Set of Multidimensional Geometry Specification Data for the Rack of PWR Fuel Assemblies in a Large Water-Filled Storage Area as Shown in Fig. C.10

```
BOX TYPE    1
CYLINDER    1 0.412 365.76 0.0 -0.5
CYLINDER    0 0.417 365.76 0.0 -0.5
CYLINDER    2 0.475 365.76 0.0 -0.5
CUBOID    3 0.63 -0.63 0.63 -0.63 365.76 0.0 -0.5
BOX TYPE    2
CUBOID    3 1.26 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE    3
CUBOID    3 5.0 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE    4
CUBOID    3 1.26 0.0 5.0 0.0 365.76 0.0 -0.5
BOX TYPE    5
CUBOID    3 5.0 0.0 5.0 0.0 365.76 0.0 -0.5
ARRAY BOUNDARY   0 37.13 -37.13 37.13 -37.13 182.88 -182.88 -0.5
REFLECTOR   3 24.0 24.0 24.0 24.0 24.0 24.0 500
END GEOMETRY
```

*The "Mixed Box Orientation Data" is used to further describe the array of boxes. While that data is necessary to complete the geometry description, it is entered as a separate block of data. See Sec. 6 for details.

Table C.5. A Still Shorter Set of Multidimensional Geometry Specification Data for the Rack of PWR Fuel Assemblies in a Large Water-Filled Storage Area as Shown in Fig. C.10

```
BOX TYPE    1
CYLINDER    1 0.412 365.76 0.0 -0.5
CYLINDER    0 0.417 365.76 0.0 -0.5
CYLINDER    2 0.475 365.76 0.0 -0.5
CUBOID    3 0.63 -0.63 0.63 -0.63 365.76 0.0 -0.5
BOX TYPE    2
CUBOID    3 1.26 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE    3
CUBOID    3 5.0 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE    4
CUBOID    3 1.26 0.0 5.0 0.0 365.76 0.0 -0.5
BOX TYPE    5
CUBOID    3 5.0 0.0 5.0 0.0 365.76 0.0 -0.5
REFLECTOR   3 6*24.0 500
END GEOMETRY
```

*The "Mixed Box Orientation Data" is used to further describe the array of boxes. While that data is necessary to complete the geometry description, it is entered as a separate block of data. See Sec. 6 for details.

Table C.6. A Shorter Set of Multidimensional Geometry Specification Data for a Canister of Uranyl-Floride Solution Submerged in a Large Pool of Water as Modeled in Fig. C.7

```
BOX TYPE     1
CYLINDER     1   7.62   59.2   -59.2   -0.5
CYLINDER     2   7.77   59.35  -59.35  -0.5
CUBOID     3   8.0   -8.0   8.0   -8.0   60.0   -60.0   -0.5
ARRAY BOUNDARY     0   8.0   -8.0   8.0   -8.0   60.0   -60.0   -0.5
REFLECTOR     3   6*24.0   500
END GEOMETRY
```

Table C.7. A Still Shorter Set of Multidimensional Geometry Specification Data for a Canister of Uranyl-Floride Solution Submerged in a Large Pool of Water as Modeled in Fig. C.7

```
CYLINDER     1   7.62   59.2   -59.2   -0.5
CYLINDER     2   7.77   59.35  -59.35  -0.5
CUBOID     3   8.0   -8.0   8.0   -8.0   60.0   -60.0   -0.5
REFLECTOR     3   6*24.0   500
END GEOMETRY
```

written as shown in Table C-6. Since the reflector material extends all the way in to the array boundary, the ARRAY BOUNDARY card may again be eliminated. Likewise, since there is only one type of box (NBOX = 1), the BOX TYPE card is also optional. Thus, the Multidimensional Geometry Specification Data may be written quite simply as shown in Table C-7. It should be noted that this ultra-simple input is exactly equivalent to that shown in Table C-2 and neutronically equivalent to that shown in Table C-1.

As a third example of an array surrounded by a thick reflector, consider a rack of PWR fuel assemblies enclosed in a concrete vault as shown in Fig. C-11. This type of configuration typifies a class of problems in which one has an array surrounded by a reflector, with "something else" between the two. In such situations, the ARRAY BOUNDARY card must be entered by the user.

Figure C-11 shows the nine PWR fuel assemblies previously described sitting in the middle of a concrete vault. In this case, the "something else" between the array boundary and the concrete reflector is a void. The Multidimensional Geometry Specification Data for this configuration is listed in Table C-8. Note that while this example places the array in the center of the vault, the parameters on the ARRAY BOUNDARY card (X_2, X_1, . . . , Z_1) could have been used to shift it off-center or move it to one of the corners. Also note that the automatic reflector card can be used just as before, provided the region adjacent to the reflector is a CUBE or CUBOID.*

Figure C-12 shows a slight variation of this problem in which the concrete vault is assumed to have a cylindrical cavity. A steel jacket representing a main structural component of the fuel storage rack has also been included. The Multidimensional Geometry Specification Data for this configuration is listed in Table C-9. Note that one may have more than one region between the array boundary and the reflector. In this example we have a steel jacket, a void region, and a portion of the concrete we chose to describe separately. Note that not all of these regions must be cuboids. Indeed, a CYLINDER card has been used to describe the void. Lastly, note that the innermost portion of the concrete was described using a CUBOID card so that the automatic reflector card could be used to describe the rest. Because the steel jacket is relatively thin, not a particularly good reflector, and immediately adjacent to the fuel assemblies, a weight of 0.5 was used for all energy groups in that region. A weight of 0.5 was also used for all energy groups in the innermost region of the concrete.

Figure C-13 represents another variation of this problem in which the original concrete vault containing the fuel assemblies is filled with water. This is a particularly devilish situation because both the water and the concrete are potentially good reflectors for which spatially dependent multigroup weights can/should be supplied. Unfortunately, the KENO code does not allow the automatic reflector card to be used more than once in the description of a single problem. Thus, the user cannot use the automatic reflector card for the water and again for the concrete. (The reason for this will become apparent near the end of this discussion). The best way to proceed in this situation would be for the user to perform a preliminary calculation to determine the spatially

*A second requirement which is necessary if one is going to use the automatic reflector card is that a weight of 0.5 must be assigned for all energy groups in those regions between the array boundary and the reflector. This point will be amplified later.

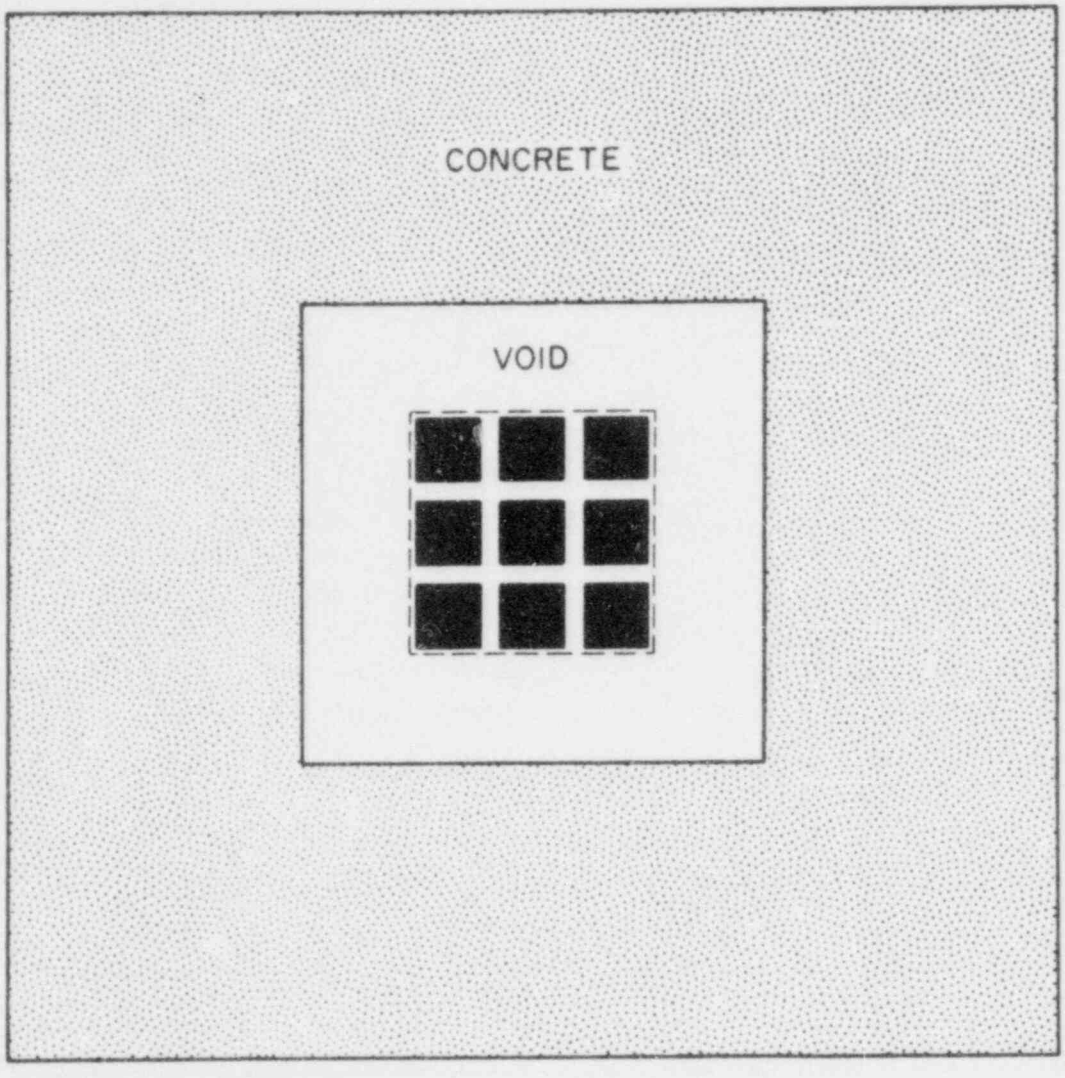


Fig. C.11. Rack of Nine PWR Fuel Assemblies in the Middle of a Large Concrete Vault.

Material #0 Void

Material #1 Fuel

Material #2 Clad

Material #3 Concrete

Table C.8. Multidimensional Geometry Specification Data for a Rack of Nine PWR Fuel Assemblies in the Middle of a Large Concrete Vault as Shown in Fig. C.11

```
BOX TYPE   1
CYLINDER   1 0.412 365.76 0.0 -0.5
CYLINDER   0 0.417 365.76 0.0 -0.5
CYLINDER   2 0.475 365.76 0.0 -0.5
CUBOID   0 0.63 -0.63 0.63 -0.63 365.76 0.0 -0.5
BOX TYPE   2
CUBOID   0 1.26 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE   3
CUBOID   0 5.0 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE   4
CUBOID   0 1.26 0.0 5.0 0.0 365.76 0.0 -0.5
BOX TYPE   5
CUBOID   0 5.0 0.0 5.0 0.0 365.76 0.0 -0.5
ARRAY BOUNDARY   0 37.13 -37.13 37.13 -37.13 182.88 -182.88 -0.5
CUBOID   0 74.0 -74.0 74.0 -74.0 182.88 -182.88 -0.5
REFLECTOR   3 6*100.0 301
END GEOMETRY
```

*The "Mixed Box Orientation Data" is used to further describe the array of boxes. While that data is necessary to complete the geometry description, it is entered as a separate block of data. See Sec. 6 for details.

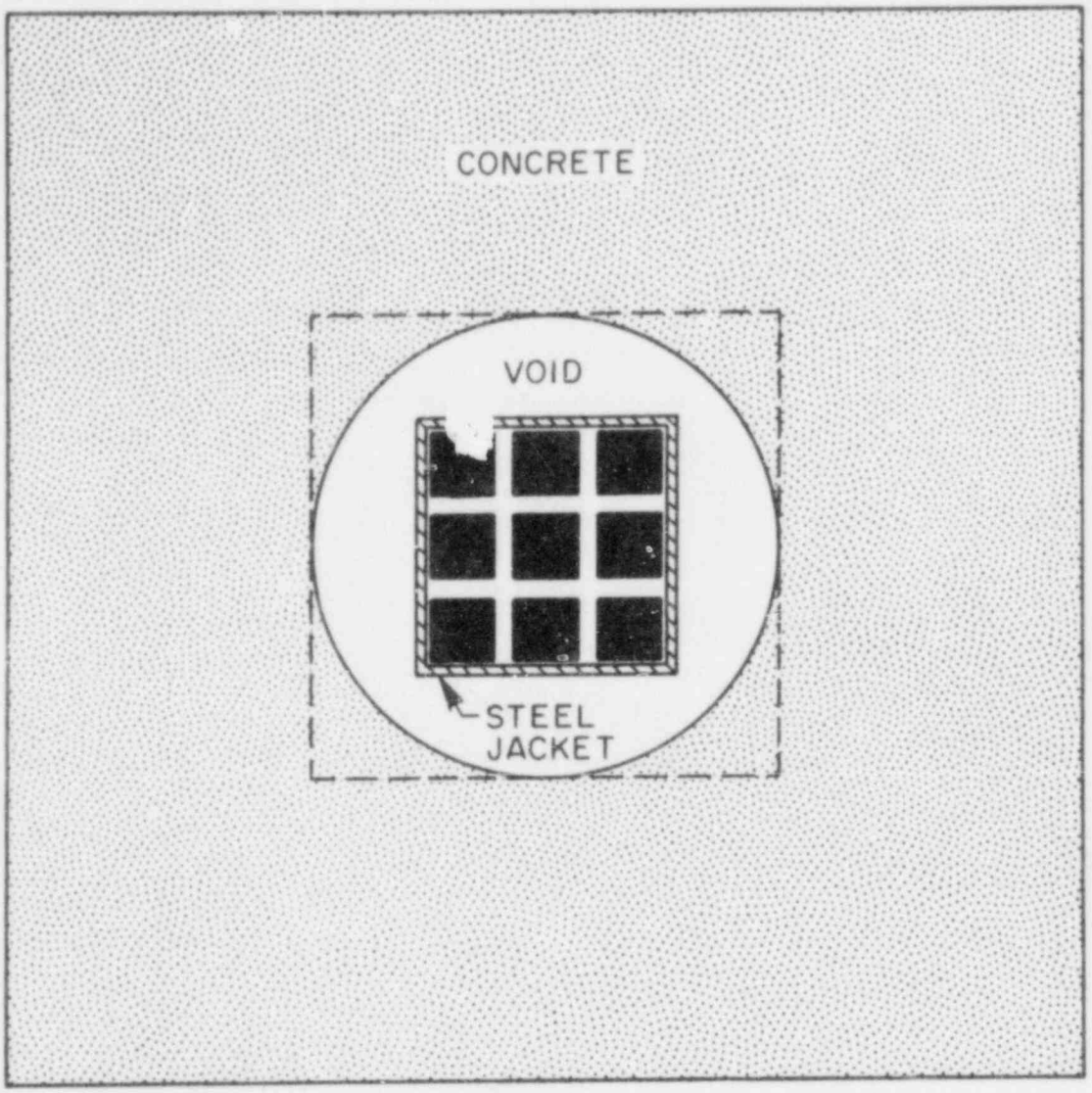


Fig. C.12. Rack of Nine PWR Fuel Assemblies in the Middle of a Large, Cylindrical Concrete Vault.

Material #0 Void

Material #1 Fuel

Material #2 Clad

Material #3 Concrete

Material #4 Steel

Table C.9. Multidimensional Geometry Specification Data for a Rack of Nine PWR Fuel Assemblies in the Middle of a Large, Cylindrical Concrete Vault as Shown in Fig. C.12

```
BOX TYPE    1
CYLINDER    1  0.412  365.76  0.0  -0.5
CYLINDER    0  0.417  365.76  0.0  -0.5
CYLINDER    2  0.475  365.76  0.0  -0.5
CUBOID   0  0.63  -0.63  0.63  -0.63  365.76  0.0  -0.5
BOX TYPE    2
CUBOID   0  1.26  0.0  1.26  0.0  365.76  0.0  -0.5
BOX TYPE    3
CUBOID   0  5.0  0.0  1.26  0.0  365.76  0.0  -0.5
BOX TYPE    4
CUBOID   0  1.26  0.0  5.0  0.0  365.76  0.0  -0.5
BOX TYPE    5
CUBOID   0  5.0  0.0  5.0  0.0  365.76  0.0  -0.5
ARRAY BOUNDARY   0  37.13  -37.13  37.13  -37.13  182.88  -182.88  -0.5
CUBOID   4  38.4  -38.4  38.4  -38.4  182.88  -182.88  -0.5
CYLINDER    0  74.0  182.88  -182.88  -0.5
CUBOID   3  74.0  -74.0  74.0  -74.0  182.88  -182.88  -0.5
REFLECTOR   3  6*100.0  301
END GEOMETRY
```

*The "Mixed Box Orientation Data" is used to further describe the array of boxes. While that data is necessary to complete the geometry description, it is entered as a separate block of data. See Sec. 6 for details.

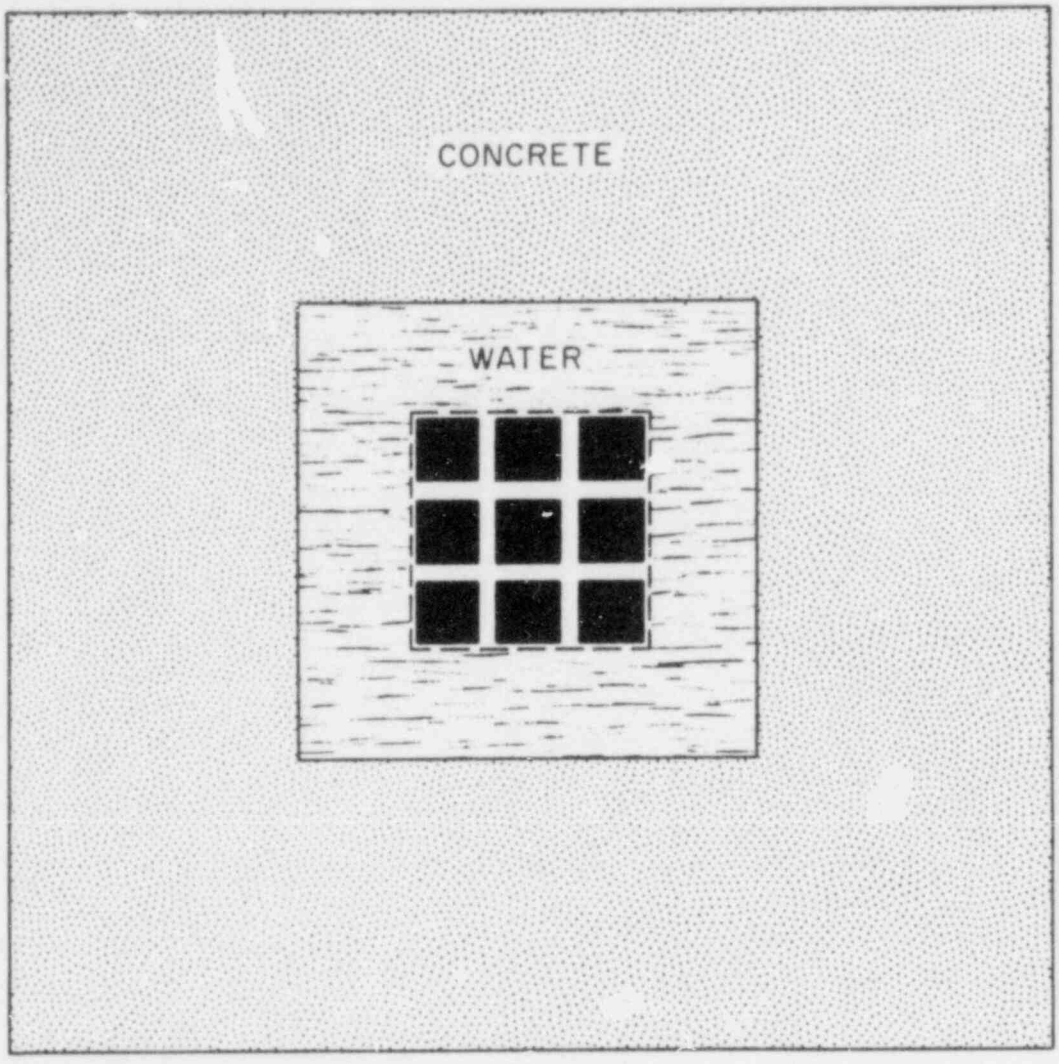


Fig. C.13. Rack of Nine PWR Fuel Assemblies in the Middle of a Large Water-Filled Concrete Vault.

Material #0 Void

Material #1 Fuel

Material #2 Clad

Material #3 Concrete

Material #4 Water

dependent multigroup weights for this particular configuration. Both the water and the concrete could then be "broken-up" into smaller regions as required. (To calculate the necessary weights, the user would start by using a code such as XSDRNPM to perform a one-dimensional multigroup adjoint calculation for a similar configuration. The space and energy dependent adjoint flux could then be used to calculate the necessary weights as shown in ORNL-TM-4660.) The purpose of the present problem, however, is to explain alternate ways the user might proceed, and to point out other ways that are clearly wrong.

The simplest and most straightforward way to proceed is to assign a weight of 0.5 to all energy groups in the water and to use the automatic reflector card to represent the concrete. The Multidimensional Geometry Specification Data would then be essentially the same as that in Table C-8, except that material no. 0 (representing a void) would now become material no. 4 (representing water). This simple changeover would have to be made on each of the six CUBOID cards. As long as the distance from the array boundary to the concrete reflector is reasonably small ($\leq$ 3 or 4 mean free paths), the neutron spectrum at the surface of the array should be approximately the same as that impingent on the inner surface of the concrete, and the reflector weights the code takes from the data library for concrete should be reasonably correct. Indeed, as long as the distance from the array boundary to the concrete reflector is reasonably small, the code should not spend an excessive amount of time tracking unimportant particles through the water, and the calculation should converge in short order. If, on the other hand, the distance from the array boundary to the concrete reflector is quite large ($\geq$ 25 or 30 cm), the concrete reflector could probably be ignored completely. In this case, the array boundary card would be followed by the automatic reflector card representing the water, and the automatic reflector card would be followed by the END GEOMETRY card.

A particularly devilish situation arises when the distance from the array boundary to the concrete reflector is between the two extremes noted above. Using a constant weight of 0.5 throughout a moderately thick water region may cause the code to waste a great deal of time tracking many particles which will never re-enter the fuel or induce another fission. In such cases, it is computationally more efficient to describe the water using a number of smaller spatial regions and to enter an appropriate set of multigroup weights for each. Assuming the water region is 6 cm thick, the user should break it up into two sub-regions: one 0 – 3 cm from the source and one 3 – 6 cm from the source. Multigroup weights for these regions are given in Table C-10 as "Set A_1" and "Set B_1." (These particular weights, like those given below for concrete, were taken from ORNL-TM-4660.) Knowing how to describe the water, we must now consider the concrete. With only a "moderately" thick water region separating it from the fissile array, the concrete reflector cannot be ignored. For reasons that will be made clear shortly, it would be incorrect to use the automatic reflector card to represent the concrete once a set of spatially biased multigroup weights has been used for the water. Let us therefore assume that the automatic reflector card does not exist and that the user will have to manually "break-up" the concrete into smaller regions and enter the appropriate set of multigroup weights for each. Assuming the concrete is 20 cm thick, the user should break it up into four sub-regions: one 0 – 5 cm from the water, one 5 – 10 cm from the water, one 10 – 15 cm from the water, and one 15 – 20 cm from the water. Table C-11 lists the

Table C.10. 16 Group Reflector Weights for Water

Group	Set A_1 0.- 3. cm	Set B_1 3.- 6. cm	Set C_1 6.- 9. cm	Set D_1 9.- 12. cm
1	5.815E-01	7.688E-01	1.054E 00	1.519E 00
2	5.713E-01	7.678E-01	1.137E 00	1.838E 00
3	5.666E-01	7.873E-01	1.291E 00	2.419E 00
4	5.581E-01	8.077E-01	1.439E 00	2.974E 00
5	5.684E-01	9.016E-01	1.806E 00	4.224E 00
6	6.035E-01	1.088E 00	2.484E 00	6.561E 00
7	6.296E-01	1.212E 00	2.937E 00	8.109E 00
8	6.408E-01	1.284E 00	3.245E 00	9.199E 00
9	6.422E-01	1.329E 00	3.498E 00	1.012E 01
10	6.274E-01	1.340E 00	3.664E 00	1.076E 01
11	6.003E-01	1.326E 00	3.724E 00	1.103E 01
12	5.773E-01	1.348E 00	3.877E 00	1.156E 01
13	7.006E-01	1.836E 00	5.381E 00	1.610E 01
14	7.448E-01	2.053E 00	6.079E 00	1.823E 01
15	7.499E-01	2.107E 00	6.271E 00	1.882E 01
16	8.083E-01	2.434E 00	7.315E 00	2.198E 01

Group	Set E_1 12.- 15. cm	Set F_1 15.- 18. cm	Set G_1 18.- 21. cm	Set H_1 21.- 24. cm
1	2.274E 00	3.496E 00	5.467E 00	8.643E 00
2	3.162E 00	5.662E 00	1.040E 01	1.936E 01
3	4.981E 00	1.098E 01	2.539E 01	6.092E 01
4	6.798E 00	1.663E 01	4.267E 01	1.132E 02
5	1.088E 01	2.973E 01	8.414E 01	2.434E 02
6	1.868E 01	5.500E 01	1.641E 02	4.922E 02
7	2.367E 01	7.053E 01	2.114E 02	6.352E 02
8	2.717E 01	8.129E 01	2.440E 02	7.334E 02
9	3.011E 01	9.027E 01	2.712E 02	8.150E 02
10	3.218E 01	9.662E 01	2.903E 02	8.726E 02
11	3.306E 01	9.930E 01	2.984E 02	8.970E 02
12	3.467E 01	1.042E 02	3.131E 02	9.411E 02
13	4.835E 01	1.453E 02	4.366E 02	1.312E 03
14	5.476E 01	1.645E 02	4.945E 02	1.486E 03
15	5.654E 01	1.699E 02	5.106E 02	1.535E 03
16	6.606E 01	1.985E 02	5.966E 02	1.793E 03

These weights are taken from ORNL-TM-4660, p. 13.

Table C.11. 16 Group Reflector Weights for Concrete

Group	Set A_2 0.- 5. cm	Set B_2 5.- 10. cm	Set C_2 10.- 15. cm	Set D_2 15.- 20. cm
1	5.806E-01	7.309E-01	9.155E-01	1.190E 00
2	5.549E-01	6.678E-01	8.370E-01	1.113E 00
3	5.421E-01	6.453E-01	8.457E-01	1.212E 00
4	5.332E-01	6.423E-01	8.704E-01	1.295E 00
5	5.397E-01	6.870E-01	9.849E-01	1.546E 00
6	5.625E-01	7.785E-01	1.194E 00	1.991E 00
7	5.814E-01	8.474E-01	1.353E 00	2.349E 00
8	5.907E-01	8.849E-01	1.454E 00	2.600E 00
9	5.935E-01	9.005E-01	1.521E 00	2.800E 00
10	5.823E-01	8.825E-01	1.538E 00	2.918E 00
11	5.530E-01	8.350E-01	1.501E 00	2.914E 00
12	5.222E-01	8.126E-01	1.520E 00	3.018E 00
13	6.204E-01	1.120E 00	2.191E 00	4.436E 00
14	6.589E-01	1.267E 00	2.535E 00	5.185E 00
15	6.525E-01	1.253E 00	2.520E 00	5.170E 00
16	6.957E-01	1.455E 00	3.025E 00	6.292E 00

Group	Set E_2 20.- 25. cm	Set F_2 25.- 30. cm	Set G_2 30.- 35. cm	Set H_2 35.- 40. cm
1	1.610E 00	2.256E 00	3.259E 00	4.829E 00
2	1.560E 00	2.284E 00	3.464E 00	5.408E 00
3	1.867E 00	3.045E 00	5.204E 00	9.239E 00
4	2.072E 00	3.508E 00	6.214E 00	1.141E 01
5	2.602E 00	4.622E 00	8.560E 00	1.636E 01
6	3.549E 00	6.643E 00	1.288E 01	2.561E 01
7	4.341E 00	8.382E 00	1.667E 01	3.375E 01
8	4.934E 00	9.726E 00	1.962E 01	4.014E 01
9	5.440E 00	1.090E 01	2.224E 01	4.580E 01
10	5.793E 00	1.177E 01	2.421E 01	5.009E 01
11	5.868E 00	1.202E 01	2.482E 01	5.146E 01
12	6.147E 00	1.266E 01	2.623E 01	5.445E 01
13	9.114E 00	1.885E 01	3.912E 01	8.128E 01
14	1.071E 01	2.220E 01	4.611E 01	9.584E 01
15	1.069E 01	2.219E 01	4.610E 01	9.583E 01
16	1.308E 01	2.721E 01	5.659E 01	1.177E 02

These weights are taken from ORNL-TM-4660, p. 39.

corresponding multigroup weights for concrete at various distances "from a fissile source." Because the "fissile source" is not adjacent to the concrete, set C_2 (not set A_2) should be used for the region 0 – 5 cm from the water, and set D_2 (not set B_2) should be used for the region 5 – 10 cm from the water, etc., etc. To understand the reason for this "offset," one must again consider the physics of the problem. As one gets further and further from the array, a smaller and smaller fraction of the neutron population will ever re-enter the fuel or induce another fission. Because particles in these regions are "worth" less, it is computationally more efficient to track fewer of them and assign the ones we do track a greater "weight" so that they statistically represent all the others, thus maintaining some semblance of a fair game. The thing to be noted here is the direct bearing the physics of the problem should have on the calculational model: "the further from the fuel – the smaller the fraction – the greater the weight." Certainly, those particles which have made it out to the concrete stand a smaller chance of returning to the fuel than those which are still in the water. Thus the weights for the innermost concrete region should be greater than the weights for the outermost water region. It was for that reason that set C_2 was used for the innermost region of the concrete. To have used set A_2 or set B_2 would have misrepresented the physics of the problem and led to erroneous results. The Multidimensional Geometry Specification Data for this example is listed in Table C-12. Note that the weights corresponding to sets A_1 and B_1 were used for the water, while those corresponding to sets C_2, D_2, E_2, and F_2 were used for the concrete. (Had the automatic reflector card been used for the concrete, the code would have automatically picked up the weights corresponding to sets A_2, B_2, C_2 and D_2. As noted above, that would have upset the physics of the problem and led to erroneous results. For that reason, the user should never use the automatic reflector card when there is "something else" between the array boundary and the reflector for which he has supplied a spatially biased set of multigroup weights. It is for that same reason that a user is never allowed to enter more than one automatic reflector card in the description of a single problem.)

Table C.12. Multidimensional Geometry Specification Data for a Rack of Nine PWR Fuel Assemblies in the Middle of a Large, Water-Filled Concrete Vault

```
BOX TYPE    1
CYLINDER    1 0.412 365.76 0.0 -0.5
CYLINDER    0 0.417 365.76 0.0 -0.5
CYLINDER    2 0.475 365.76 0.0 -0.5
CUBOID    4 0.63 -0.63 0.63 -0.63 365.76 0.0 -0.5
BOX TYPE    2
CUBOID    4 1.26 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE    3
CUBOID    4 5.0 0.0 1.26 0.0 365.76 0.0 -0.5
BOX TYPE    4
CUBOID    4 1.26 0.0 5.0 0.0 365.76 0.0 -0.5
BOX TYPE    5
CUBOID    4 5.0 0.0 5.0 0.0 365.76 0.0 -0.5
ARRAY BOUNDARY   0 37.13 -37.13 37.13 -37.13 182.88 -182.88 -0.5
CUBOID    4 40.13 -40.13 40.13 -40.13 182.88 -182.88
          .5815 .5713 .5666 .5581 .5684 .6035 .6296 .6408
          .6422 .6274 .6003 .5773 .7006 .7448 .7499 .8083
CUBOID    4 43.13 -43.13 43.13 -43.13 182.88 -182.88
          .7688 .7678 .7873 .8077 .9016 1.088 1.212 1.284
          1.329 1.340 1.326 1.348 1.836 2.053 2.107 2.434
CUBOID    3 48.13 -48.13 48.13 -48.13 187.88 -187.88
          .9155 .8370 .8457 .8704 .9849 1.194 1.353 1.454
          1.521 1.538 1.501 1.520 2.191 2.535 2.520 3.025
CUBOID    3 53.13 -53.13 53.13 -53.13 192.88 -192.88
          1.190 1.113 1.212 1.295 1.546 1.991 2.349 2.600
          2.800 2.918 2.914 3.018 4.435 5.185 5.170 6.292
CUBOID    3 58.13 -58.13 58.13 -58.13 197.88 -197.88
          1.610 1.560 1.867 2.072 2.602 3.549 4.341 4.934
          5.440 5.793 5.868 6.147 9.114 10.71 10.69 13.08
CUBOID    3 63.13 -63.13 63.13 -63.13 202.88 -202.88
          2.256 2.284 3.045 3.508 4.622 6.643 8.382 9.726
          10.90 11.77 12.02 12.66 18.85 22.20 22.19 27.21
END GEOMETRY
```

*The "Mixed Box Orientation Data" is used to further describe the array of boxes. While that data is necessary to complete the geometry description, it is entered as a separate block of data. See Sec. 6 for details.

APPENDIX D

(to be issued later)

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This document describes the CSAS1 and CSAS2 control modules which shield the group-averaged cross-section data for the given situation and perform a one-dimensional discrete ordinates or multidimensional Monte Carlo calculation to obtain the effective neutron multiplication factor (k-eff) for the configuration described by the user.

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