SCALE

A Modular Code System for Performing
Standardized Computer Analyses for Licensing Evaluation

Functional Modules, Part 3

Oak Ridge National Laboratory

Prepared for
U.S. Nuclear Regulatory Commission

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

Functional Modules
F16–F17

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*Obsolete with SCALE-4.0 release.

**Not included in SCALE-4.3 release.

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*Obsolete with SCALE-4.0 release.

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*Obsolete with SCALE-4.0 release.

PREFACE

Background

This Manual represents Revision 5 of the user documentation for the modular code system referred to as SCALE. The history of the SCALE code system dates back to 1969 when the current Computational Physics and Engineering Division at Oak Ridge National Laboratory (ORNL) began providing the transportation package certification staff at the U.S. Atomic Energy Commission with computational support in the use of the new KENO code for performing criticality safety assessments with the statistical Monte Carlo method. From 1969 to 1976 the certification staff relied on the ORNL staff to assist them in the correct use of codes and data for criticality, shielding, and heat transfer analyses of transportation packages. However, the certification staff learned that, with only occasional use of the codes, it was difficult to become proficient in performing the calculations often needed for an independent safety review. Thus, shortly after the move of the certification staff to the U.S. Nuclear Regulatory Commission (NRC), the NRC staff proposed the development of an easy-to-use analysis system that provided the technical capabilities of the individual modules with which they were familiar. With this proposal, the concept of the Standardized Computer Analyses for Licensing Evaluation (SCALE) code system was born.

The NRC staff provided ORNL with some general development criteria for SCALE: (1) focus on applications related to nuclear fuel facilities and package designs, (2) use well-established computer codes and data libraries, (3) design an input format for the occasional or novice user, (4) prepare "standard" analysis sequences (control modules) that will automate the use of multiple codes (functional modules) and data to perform a system analysis, and (5) provide complete documentation and public availability. With these criteria the ORNL staff laid out the framework for the SCALE system and began development efforts. The initial version (Version 0) of the SCALE Manual was published in July 1980. Then, as now, the Manual is divided into three volumes – Volume 1 for the control module documentation (Sections C4, C6, S1– S4, and H1), Volume 2 for the functional module documentation (Sections F1– F17), and Volume 3 for the documentation of the data libraries and subroutine libraries (Sections M1–M16).

System Overview

The original concept of SCALE was to provide "standardized" sequences where the user had very few analysis options in addition to the geometry model and materials. Input for the control modules has been designed to be free-form with extensive use of keywords and engineering-type input requirements. The more flexible functional modules have a more difficult input logic and require the user to interface the data sets necessary to run the modules in a stand-alone fashion. As the system has grown in popularity over the years and additional options have been requested, the control modules have been improved to allow sophisticated users additional access to the numerous capabilities within the functional modules. However, the most important feature of the SCALE system remains the capability to simplify the user knowledge and effort required to prepare material mixtures and to perform adequate problem-dependent cross-section processing.

The modules available in Version 0 of SCALE were for criticality safety analysis sequences (CSAS) that provided automated material and cross-section processing prior to a one-dimensional (1-D) or multidimensional criticality analysis. Since that time the capabilities of the system have been

significantly expanded to provide additional CSAS capabilities, new shielding analysis sequences (SAS) that also include depletion/decay capabilities for spent fuel characterization, and a heat transfer analysis sequence (HTAS). At the center of the CSAS and SAS sequences is the library of subroutines referred to as the Material Information Processor or MIPLIB (see Section M7). The purpose of MIPLIB is to allow users to specify problem materials using easily remembered and easily recognizable keywords that are associated with mixtures, elements, and nuclides provided in the Standard Composition Library (see Section M8). MIPLIB also uses other keywords and simple geometry input specifications to prepare input for the modules that perform the problem-dependent cross-section processing: BONAMI, NITAWL-II, and XSDRNPM. A keyword supplied by the user selects the cross-section library from a standard set provided in SCALE (see Section M4) or designates the reference to a user-supplied library. Several utility modules from AMPX¹ have been included to provide users with the capability to edit the cross-section data and reformat user-supplied libraries for use in SCALE.

Over the history of the project several modules have been removed from the system because they are no longer supported by the development staff at ORNL. Tables 1 and 2 provide a summary of the major applications of each of the control modules and functional modules currently in the SCALE code system. The control modules were designed to provide the system analysis capability originally requested by the NRC staff. The CSAS module (sometimes denoted as the CSAS4 module and documented in Section C4) is the primary control module designed for the calculation of the neutron multiplication factor of a system. Eight sequences enable general analysis of a 1-D system model or a multidimensional system model, capabilities to search on geometry spacing, and problem-dependent cross-section processing for use in executing stand-alone functional modules. CSAS6 is a new criticality control module to provide automated problem-dependent cross-section processing and criticality calculations via the new KENO-VI functional module. The SAS1 and SAS3 modules (see Sections S1 and S3, respectively) provide general 1-D deterministic and 3-D Monte Carlo analysis capabilities. The SAS2 module (see Section S2) was originally developed to perform a depletion/decay calculation to obtain spent fuel radiation source terms that were subsequently input automatically to a 1-D, radial shielding analysis in a cylindrical geometry. Over time the depletion/decay portion of the SAS2 module has been significantly enhanced and interfacing to the other shielding modules has been provided. The SAS4 module (see Section S4) enables automated particle biasing for a Monte Carlo analysis of a transportation package-type geometry. The HTAS1 module (see Section H1) is the only heat transfer control module and uses the various capabilities of the HEATING code to perform different sequences of steady-state and transient analysis that enable the normal and accident conditions of a transportation package to be evaluated. Like SAS4, the HTAS1 module is limited to a package-type geometry.

The capability to perform a point-kernel shielding analysis within the SCALE system has been developed in the QADS control module which has been added in this release of the software package.

A 238-energy-group neutron cross-section library based on ENDF/B-V has recently been prepared for the SCALE system.⁵ All the nuclides that are available in ENDF/B-V are in the library. A 44-group library has been collapsed from this 238-group library and validated against numerous critical measurements.⁶ These libraries are available in this version of SCALE or as a separate data package from the software distribution centers.

Major Enhancements in SCALE-4.3

New ENDF/B-V libraries

SCALE-4.3 includes 238GROUPNDF5, a 238-group, AMPX master-format neutron cross-section library that contains data for all the nuclides available in ENDF/B-V. The library has Bondarenko shielding factors included for nuclides with unresolved resonances, nuclides with Adler-Adler resonance data (U-233 and Pu-241), and the nonresonance nuclides Li-7, F-19, Al-27, and Si-14. Bondarenko factors are used for the latter nuclides because they exhibit resonance structure in the point data. The initial development of this library included only s-wave resonance data in the resonance parameters that are passed to the Nordheim treatment in NITAWL. Although demonstrated sufficient for thermal systems, it was found that p-wave and perhaps d-wave resonances can have a significant effect on the results for shielding applications and for unmoderated, intermediate energy problems. Thus, p-wave and d-wave data were added to the library. Users, however, will not be able to readily access the p- and d-wave resonance data until SCALE-4.3 has been made available to RSIC in 1995.

Several spectra suitable for collapsing this fine-group library to a broad-group structure are included as part of the library. A 44-group derivative of the 238-group library, 44GROUPNDF5, collapsed using a spectrum for a pressurized-water-reactor fuel pin lattice, is also included in the package. This broad-group library has a similar group structure as that provided in the SCALE 27-group ENDF/B-IV library, except that additional groups were added to ensure more accurate treatment of the 0.3-eV resonance of ²³⁹Pu. Based on an analysis of a set of 93 thermal and fast critical experiments, the ENDF/B-V 44-group library has demonstrated markedly improved performance over similar analyses performed with the ENDF/B-IV 27-group library ("Validation of SCALE-4 Criticality Sequences Using ENDF/B-V Data," *Proceedings of the Topical Meeting on Physics and Methods in Criticality Safety*, September 19-23, 1993). In addition, by comparing SAS2H/ORIGEN-S results with measured isotopic data, the library has demonstrated improved results in the prediction of spent fuel isotopics (*Validation of the SCALE System for PWR Spent Fuel Isotopic Composition Analyses*, ORNL/TM-12667, March 1995).

KENO-VI

KENO-VI is a new version of the KENO Monte Carlo Criticality Safety Code developed at Oak Ridge National Laboratory. It constructs and processes geometry data as sets of quadratic equations. A lengthy set of simple, easy-to-use geometric functions, similar to those provided in KENO-V.a, and the ability to build more complex geometric shapes (represented by sets of quadratic equations) are the heart of the geometry package in KENO-VI. The code's flexibility is increased by allowing the following features: intersecting geometry regions; hexagonal as well as cuboidal arrays; regions, holes, arrays, and units rotated to any angle and truncated to any position; and the use of an array boundary that intersects the array.

KENO-VI maintains all the flexibility and options of KENO-V.a plus a variety of new options. In KENO-VI, units can be constructed using both the simple geometric shapes provided and the tailored geometric shapes constructed using quadratic equations. It includes the new 2-D color plotting capability that has been added to KENO-V.a (see "Improvements to KENO-V.a Include 2-D

Color Plot Capability"). A new SCALE Criticality Safety Analysis Sequence, CSAS6, has been added for running KENO-VI.

Users should be aware that the added geometry features in KENO-VI can result in significantly longer run times than KENO-V.a. A KENO-VI problem that can also be modeled with KENO-V.a will typically run twice as long as the same problem using KENO-V.a. Thus, the new version VI is not a replacement for the existing version V.a, but an additional version for complex geometries that could not be modeled previously.

New criticality search on material concentrations

A new search feature has been added to the criticality search sequences in SCALE. Searches may now be done on the concentration of standard compositions in one or more mixtures in the problem. During a concentration search, if the search convergence criteria have not been met, the atom densities of the specified standard compositions are updated, problem-dependent resonance processing is performed using BONAMI, NITAWL, and applicable sections of the material information processor, and a new k_{eff} is calculated using KENO-V.a. Concentration searches cannot be performed on materials contained in cell-weighted mixtures.

In all search sequences (both geometry and concentration), problem-dependent resonance processing of the cross sections is now performed for each iteration prior to the execution of KENO. Heterogeneous effects, Dancoff factors, and self-shielding are now accounted for between iterations. Prior to the addition of concentration searches, a search sequence would update only the specified geometry, but not the cross sections, prior to calculating a new k_{eff} using KENO-V.a. Previously, to ensure that the converged result was acceptable, the problem needed to be rerun with the converged geometry data. The recent changes to the search sequences eliminate the need to rerun a converged problem to account for changes in cross sections.

Enhanced graphical capabilities

The graphical display of KENO-V.a and KENO-VI geometry models has been dramatically improved by the new capability to produce high-resolution 2-D color plot files that can be viewed on-screen using appropriate viewer software or printed on a color printer. This new option is activated by using the parameter `scr=yes` in the KENO plot data. A plot file using up to 256 colors is generated. The plot data parameter `"clr="` can be used to override the default color assignments. These plots can be generated only on UNIX workstations and MS-DOS-based personal computers (PC).

In addition to the 2-D color plots, fractional values are now valid for the `lpi=` parameter in the plot data, which will make it easier to print circles on laser printers.

KENO-V.a enhancements

Enhancements to KENO-V.a fall into one of three categories: removed limitations, editing changes, or added capabilities.

Two independent limitations to KENO-V.a were removed. The first limitation involved HOLE boundaries touching other HOLE or adjacent geometry region boundaries. Significant errors

in k_{eff} (as much as 1%) occurred when HOLE boundaries touched with no indication of a problem. HOLE boundaries may now touch other HOLE or adjacent geometry region boundaries.

The second limitation involved the number of scattering angles allowed. Although the parameter `sct=` (number of scattering angles) was limited to 13, no check was made to avoid oversteering data. Any number of scattering angles are now allowed.

The mixing table edit has been changed to sort mixture data by mixture number. The mixture number and density make up the first line of the data for each mixture. The following lines, which represent the nuclides in the mixture, are sorted by nuclide number. Each line contains a nuclide number, atom density, weight fraction, ZA number, atomic weight, and nuclide title. This provides the user a concise table of the components that make up the mixtures used in the problem.

Three new capabilities were also added to KENO-V.a which provide the user with useful information for analyzing and checking the problem.

The energy corresponding to the average lethargy causing fission is now calculated and the printing of this information (i.e., `NUB=YES`) is now a default parameter. This is useful for determining trends in k_{eff} as a function of neutron energy to look for problem-type biases.

System total fissions and absorptions by region are now calculated. A parameter to suppress printing fissions and absorptions by region for each group has been added. Set `GAS=NO` to print only the system totals by group. These values have several uses, such as helping to verify proper problem sampling and determining region importance.

Finally, the total mass of each mixture in the problem is now calculated and printed. These values can be used to help verify the geometry and material masses of the problem.

New cross-section processing features

The cross-section processing portion of the SCALE system has been upgraded to add major improvements to the NITAWL-II code. NITAWL-II has been modified to perform the resonance calculation in double precision. The mesh generation for a resonance has been modified to better span higher energy resonances and to reduce excessive numbers of mesh points.

In addition, this new version of NITAWL-II is able to interpolate the available thermal-scattering matrices to obtain data for the temperature requested by user input (via direct input to NITAWL-II or via the SCALE Standard Composition data). Previously, NITAWL-II had no such capability and selected the thermal-scattering data that was closest to the requested temperature. Thermal-scattering data for moderator materials, such as hydrogen and graphite, are available at many more temperatures in the new ENDF/B-V SCALE libraries than in the older ENDF/B-IV SCALE libraries. However, even with the new ENDF/B-V libraries, the interpolation should better determine the effect that a change in moderator temperature will have on the system multiplication factor.

The CSAS and SAS1-SAS4 modules also have been modified via MIPLIB to provide two new parameters in the optional MORE DATA input:

`MLV=` maximum L value for which resonance calculation will be done ($L = 0$ is s-wave, $L = 1$ includes p-wave, $L = 2$ includes d-wave). The default value is $L = 2$.

`MSH=` maximum number of mesh points per resonance. The default value is 2001.

Note that if NITAWL-II is run stand-alone, the default values for `MLV` and `MSH` are 0 and 501, respectively.

New KENO-V.a sample problems

The KENO-V.a sample problems have been updated to improve the range of functionality testing and provide more flexibility in using other cross-section libraries. The SCALE-4.2 sample problems used the 27-group ENDF/B-IV cross-section library. The cross sections were processed by NITAWL-II prior to the execution of KENO-V.a. The new sample problems use BONAMI, which is not necessary for the 27-group library, as well as NITAWL-II for resonance processing of cross sections so that the sample problems can easily be run with other cross-section libraries that require the use of BONAMI. The NITAWL-II input data were updated to specify 2001 mesh points per resonance and the highest resonance L-value of 2. The previous input data used the default values of 501 mesh points and an L-value of 0.

Eight new problems were added to the existing 25 sample problems. Sample problems 26 through 28 are variations of sample problem 1, modeled as hemicylinders with chords and origins, and are extensions of sample problems 23 through 25, which are modeled using chords without origins. Sample problem 29 is a bare critical sphere, and sample problems 30 through 32 are the same critical system modeled using hemispheres with origins. Sample problem 33 is a critical triangular pitched array of partially flooded cylindrical annuli of low-enriched-uranium metal.

Standard Composition Library updated for ENDF/B-VI compatibility

The Standard Composition Library has been expanded for compatibility with ENDF/B-VI cross-section libraries. In addition, the Material Information Processor Library (MIPLIB) has also been updated so that all the control modules can use ENDF/B-VI cross-section libraries via the new expanded Standard Composition Library. The changes were necessary because the cross sections for the natural-element identifiers such as FE for iron are no longer available in the ENDF/B-VI data. Most problems set up to use other cross-section libraries should now run without any changes using ENDF/B-VI libraries.

The changes to the Standard Composition Library were very extensive and fall into several categories. Additions were made so that nearly all the elements are given by both their full name and by their chemical symbol. The full-name elements are all given as naturally occurring abundance nuclides, while a few of the chemical symbol nuclides are given as the principal isotope. For instance, **HYDROGEN** would include trace amounts of deuterium, while **H** would be 100% ¹H.

The isotopic distribution table was changed to include most of the elements. Arbitrary materials may now contain more than one multiple-isotope nuclide. In addition, the specially weighted elements in stainless steel and in Inconel were added, specifying the natural abundance of each.

Atomic masses for isotopes were taken from ENDF/B-VI, if available. Atomic masses for naturally occurring elements were taken from ENDF/B-V, if available. Remaining atomic masses were taken from *GE Chart of the Nuclides* or the *CRC Handbook of Chemistry and Physics*.

QAD-CGGP and QADS

The 3-D point-kernel shielding code, QAD-CGGP, and its associated SCALE control module have been added. QADS performs multidimensional point-kernel estimation of gamma transport through practically any type of shielding materials using a simplified input scheme that follows the

general input philosophy of the SCALE shielding sequences. QADS was designed to capture the flexibility and power of the QAD technique for problems amenable to point-kernel solution while allowing for an easy-to-use input interface. The QADS module is called via the SCALE driver and preprocesses the actual input for the QAD-CGGP code. The driver then calls and executes QAD-CGGP automatically. The SCALE standard composition library is used to allow simplified input of materials. The problem geometry is coded using the well-known MORSE combinatorial geometry package. Finally, the dose portion of the input follows the XSDOSE input data format in SAS1. The combined use of the SCALE standard compositions and free-form input with the multidimensional geometry capabilities and generally short running time of point-kernel techniques produces a very powerful procedure for shielding analysis of a wide variety of problems.

SCALE-4.3 minor modifications

In addition to the major enhancements noted above, SCALE-4.3 contains many minor modifications, including corrections to errors in SCALE-4.2 and changes to improve portability to other computing platforms.

SCALE driver: The driver was modified to improve portability to other types of workstations. Modifications to accept upper or lower case input files were also added.

KENO-V.a: (1) Corrected error that sometimes occurred when the boundary of a HOLE touched another HOLE or adjacent geometry region. The error can produce erroneous results, either conservative or nonconservative, without triggering warning or error messages. The effect on k_{eff} can be very significant in some cases ($\sim 1\%$). (2) Fixed to allow more than 13 scattering angles. Although the parameter "sct=" was limited to 13, no check was made to avoid oversteering data. (3) Corrected error causing core dump on some workstations when a global unit wasn't explicitly defined. (4) Corrected error that permitted a case with a negative radius to run. (5) Added calculation of the energy corresponding to the average lethargy causing fission and made the printing of this information (i.e., NUB=YES) a default parameter. (6) Corrected errors in the starting points edit obtained when PSP=YES. (7) Corrected an error that occurred when a history encountered an edge where differential albedos were used. Other minor fixes were made for (8) printing densities of mixtures that have other mixtures added in and (9) printing plot coordinates for problems ending in a bare array. (10) Output was enhanced to print information on start and plot input parameters that were previously omitted.

NITAWL: (1) Corrected the grayness correction to self-shielding in annular regions. (2) Corrected an error passing a variable of the wrong type that resulted in incorrect self-shielding of thermal groups below 0.5 eV.

All Control Modules (MIPLIB): (1) Added checks to avoid the use of negative number densities when solutions with physically unrealistic parameters are entered. (2) Corrected an error that caused CSAS to loop if the collapse option was specified and an input nuclide ID was not found in the cross-section library. (3) Modified MIPLIB to check for resonance data on the cross-section library used to determine whether to perform resonance corrections for a nuclide. Previously, a flag in the Standard Composition Library was used to make this determination. (4) Corrected calculated thickness ("lbar") of cylindrical and spherical annuli for input to BONAMI. (5) Modified reading of Dancoff factor keywords in MORE DATA to detect and prevent erroneous keyword input. (6) Changed the label "lbar" printed by CSAS in PARM=CHECK output to "abar." (7) Replaced the 123GROUP and 218GROUP cross-section-library keywords with 44GROUP and

238GROUP. The former libraries, which were the least used of the standard SCALE libraries, were removed as defaults so the new ENDF/B-V libraries, which give more accurate results, could be accessed directly via keyword input.

CSAS/MODIFY: Added an option in the CSAS4 and CSAS4X sequences to perform a criticality search on nuclide concentration. Modified the search sequences to update unit cell data or number densities (depending on the type of search) and execute BONAMI and NITAWL prior to every KENO-V.a calculation.

SAS2: (1) Modified for compatibility with recent MIPLIB changes. (2) Corrected the soluble boron concentration to change linearly when $NLIB/CYC > 1$. (3) Modified to allow use of the SYMMSLABCELL geometry in MIPLIB and more than one fuel zone. (4) Automated model setup when burnable poison rods occupy some but not all guide tubes in a fuel assembly. (5) Added THERM, RES, FAST, and the two energy boundaries for converting cross sections to the total flux normalization. (6) Modified the AMPX cross-section library defaults to match MIPLIB, including the use of unit 70 for unrecognized libraries. (7) Corrected an error that occurred if light element nuclides are in both the ORIGEN-S light element and fission product libraries and are input as individual nuclides in the MIPLIB input.

ORIGEN-S : (1) Replaced call to INQOPN with call to OPNFIL for standard input (unit 5) to improve portability to other computers. (2) Initialize arrays only within the array boundaries for better portability. (3) Added EXTERNAL statements for BLOCK DATA files to improve portability. (4) Improved coding for the integral option using the actinide library. (5) Program was corrected to execute a continuation subcase when using the integral option. (6) Corrected call to subroutine STOP.

ORIGEN-S Libraries: (1) Corrected Cf-249 data in lowest energy group in Master Photon Library. It was high by factor of 100. (2) Corrected the half-life of Se-79. It was low by factor of 10. (3) Corrected Br-86m decay data that was erroneously changed in ENDF/B-VI update.

COUPLE: (1) Added check for correct ordering of fission product nuclides by atomic weight in input library. (2) Added EXTERNAL statement for BLOCK DATA files to improve portability to other computers. (3) Modified output format for THERM, RES, and FAST from floating point (F) to exponential (E). (4) Corrected an error that occurred when only fission product yield data were being updated. Note that this error did not occur when using COUPLE in the SAS2 sequence.

Standard Composition Library: (1) Revised the resonance energy scattering and/or total cross sections for 197 materials based on the 44-group ENDF/B-V cross-section library. Consistent values were specified for both the natural element and individual isotopes B, Zr, Eu, Hf, and W. (2) Added new composition ZIRC2 for Zircaloy-2 when using ENDF/B-V cross-section libraries. (3) Replaced σ_s and σ_t values in Nuclide Information Table with average values calculated from ENDF/B-V or ENDF/B-VI libraries. (4) Density for ZIRCALLOY and ZIRC2 was corrected from 6.506 to 6.56 g/cc.

All Cross-Section Libraries: The atomic masses of nuclides were modified to all be in terms of neutron mass for consistency.

XSDRNPM: (1) Modified to scale the weighting flux so that minimum value is $1E-20$. This modification was made to reduce the likelihood that an underflow would occur when creating a weighted cross-section library for problems where there are large variations in the flux (many orders of magnitude). (2) Corrected an error that caused broad-group-flux edits to print bad values. (3) Corrected an error that would occur when creating a gamma-only broad-group library.

XSDRNPM/SAS4: Adjoint calculation in XSDRNPM for SAS4 was corrected. Only affects fixed-source calculations with upscatter on machines whose single- and double-precision formats are different (includes IBM workstations). Any such calculations should be rerun to determine impact of correction.

SAS4: (1) Increased the number of mesh intervals for both neutrons and gammas in the XSDRN adjoint calculation to improve the likelihood of convergence. Made additional minor changes to improve portability. (2) Updated for consistency with new nuclide ID numbering scheme in MIPLIB.

MORSE: Corrected a problem caused by the use of an incorrect normalization factor on standard deviations at the end of each batch. This occurred when NMOST was equal to NSTRT.

BONAMI: (1) Restored Bondarenko factor printout that was inadvertently deleted in July 1990 modification. Results were not impacted. (2) Corrected so that calculations with more than one nuclide specified with a zero number density will run.

SAS1: (1) Modified to force the pointer for the double-precision flux array to start on a double word boundary. This change improves performance significantly on some workstations other than IBM. (2) Corrected setting of termination flag so that SCALE driver can run other modules when cases are stacked in an input file.

AIM: Corrected error that created a bad magic word in a binary library if a magic word position occurred as the last position of a transfer array in the BCD data.

HEATING: A coding flaw was found and corrected in HEATING that prevented the proper application of the unit system conversion factors for the material properties database. This option allows the user to select a material from the database and convert the property values to the user's unit system. Due to the flaw, the material property values were not converted and values were used in the calculations that were not correct for the unit system. This flaw would affect only HEATING or HTAS1 problems that specify unit conversion factors for the material properties database.

HTAS1: A coding flaw was found and corrected in HTAS1 that prevented the building and the use of enclosure radiation connectors for models that replace the material in the neutron shield with a void (no material). A normal (and the default) analysis would replace the material in the neutron shield with air. Any other material or a void can be placed in the neutron shield volume. As long as any type of material (not a void) is in the neutron shield then the thermal radiation connectors are built in OCULAR and the analysis procedures correctly. However, if a void volume is modeled in HTAS1 then the flaw prevented the building and use of the connectors. Thus, no heat would be transferred across the neutron shield, which could significantly and potentially nonconservatively alter the thermal history of the shipping cask.

All modules (UNIXLIB): Modified subroutine DATIM to read the date and time from the file "datetime.std" if it exists. This option will be useful for comparing sample problem output files.

KENO-V.a, SAS2 (SUBLIB): Modified subroutine YREAD to correctly read an array of numbers separated by commas.

Portability

Version 4.3 of the SCALE system has been developed to ensure portability among various computing platforms. The system is maintained and enhanced at ORNL under quality assurance and configuration management plans. The system has been routinely tested on IBM and DEC

workstations. In addition, the system has been applied by ORNL on SUN and HP workstations. Information needed to install SCALE on each of these systems is included with the software package distributed by the code centers. A separate SCALE software package, designated SCALE-PC, is available for the execution of the SCALE system, except heat transfer modules, on a MS-DOS personal computer.

Related developments

The definition of "easy-to-use" has changed considerably since the late 1970s. As funding has allowed, the ORNL development staff has sought to develop user interfaces that provide a distinct aid to novice or occasional users of the system. These full-screen input processors were developed to work on a MS-DOS personal computer and provide interactive help to the user in preparing accurate input for a SCALE module. Currently, input processors are available only for the criticality control sequences² and the ORIGEN-S functional module. ³The SCALE-PC version includes an updated version of the ORIGEN-S processor coupled with the ARP code, which interpolates on standard LWR ORIGEN-S binary libraries, in the ORIGEN-ARP system (Section F7.A).

Availability

The SCALE code system and the other software designated under Related Developments have been packaged by the Radiation Shielding Information Center (RSIC). The SCALE system and the related software may be obtained by contacting

Radiation Shielding Information Center
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6362
Telephone: (615) 574-6176
FAX: (615) 574-6182
E-mail: pdcc@ornl.gov

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The SCALE system is maintained at ORNL and enhanced to keep pace with normal technical advancements in the analysis areas of interest. Although the NRC continues its role as the controlling sponsor of the SCALE system, the U.S. Department of Energy (DOE) began assisting in the maintenance of the SCALE system in 1987. Over the years numerous individuals within these sponsoring organizations have played key roles in ensuring that the SCALE system remained a readily available, reliable system for the analysis of nuclear fuel facilities and packages. The individuals who have worked with the ORNL staff to coordinate maintenance and development activities include R. H. Odegaarden (NRC, ret.), G. H. Bidinger (NRC, ret.), C. Mauck (DOE, ret.), E. P. Easton (NRC), W. H. Lake (NRC and DOE), M. E. Wangler (DOE), and M. G. Bailey (NRC).

As demonstrated by this Manual, there are also numerous individuals from the ORNL staff who have contributed significantly to the development and enhancement of the SCALE system. Most

are credited by their authorship of the sections in this Manual that correspond to their work. A few individuals have been essential to the development and maintenance of SCALE but are not credited by authorship. These individuals include: S. K. Martin, who is responsible for implementing and controlling software system changes; C. H. Shappert, who provided the editorial review of this Manual; and L. F. Norris, who prepared the entire manuscript. Special acknowledgement is also due to R. M. Westfall and G. E. Whitesides who, together with R. H. Odegarden of the NRC, developed the concept and long-range goals of the SCALE system in the late 1970s. Finally, this Project Leader will always be grateful to C. V. Parks, who has served as the SCALE Project Leader for the past 15 years, and L. M. Petrie, who for nearly 20 years has consistently provided consultation and advice on the technical direction that should be taken in development of nearly every module and cross-section library that are in the present system.

Stephen M. Bowman
SCALE Project Leader
January 1997

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Table 1 Analysis capabilities summary of the SCALE control modules

Control module	Analysis function(s)	Functional modules executed	Section reference
CSAS	1-D deterministic calculation of neutron multiplication 3-D Monte Carlo calculation of neutron multiplication Problem-dependent cross-section processing Multiplication search or spacing	BONAMI NITAWL-II XSDRNPM KENO V.a ICE	C4
CSAS6	3-D Monte Carlo calculation of neutron multiplication	BONAMI NITAWL-II XSDRNPM KENO-VI	C6
SAS1	1-D deterministic calculation of radiation transport through shield and dose evaluation at a point Calculation of dose at detector based on leakage from critical volume	BONAMI NITAWL-II XSDRNPM XSDOSE	S1
SAS2	Point depletion/decay of nuclear fuel 1-D radial shielding analysis in cylindrical geometry	BONAMI NITAWL-II XSDRNPM COUPLE ORIGEN-S XSDOSE	S2
SAS3	Dose evaluation using MORSE Monte Carlo code	BONAMI NITAWL-II XSDRNPM MORSE-SGC	S3
SAS4	Calculation of dose outside of transportation package using MORSE code and automated biasing techniques	BONAMI NITAWL-II XSDRNPM MORSE-SGC	S4
QADS	3-D point-kernel gamma-ray shielding analysis	QAD-CGGP	S5
HTAS1	R-Z steady-state and transient analyses of a transportation package	OCULAR HEATING	H1

Table 2 Analysis capabilities summary of the SCALE functional modules

Module	Function	Section reference
BONAMI	Resonance self-shielding of cross sections with Bondarenko factors	F1
NITAWL-II	Resonance self-shielding of cross sections with resolved resonance data	F2
XSDRNPM	General 1-D, discrete-ordinates code for: <ul style="list-style-type: none"> • zone-weighting of cross sections • eigenvalue calculations for neutron multiplication • fixed-source calculation for shielding analysis • adjoint calculation for determining importance functions 	F3
XSDOSE	Module for calculation of dose at a point based on the 1-D leakage flux from a finite shield	F4
COUPLE	Interface module for preparation of cross-section and spectral data for ORIGEN-S	F6
ORIGEN-S	General-purpose point-depletion and decay code to calculate isotopic, decay heat, radiation source terms, and curie levels	F7
ICE	Cross-section utility module for mixing cross sections	F8
MORSE-SGC	Monte Carlo code with combinatorial and array geometry features used to perform radiation shielding analysis	F9
HEATING7.2	Finite-volume, multidimensional code for conduction and radiation heat transfer	F10
KENO V.a	Monte Carlo code for calculation of neutron multiplication factors	F11
OCULAR	Calculation of radiation exchange factors	F16
KENO-VI	Monte Carlo code for calculation of neutron multiplication factors for complex geometries	F17

Computational Physics and Engineering Division

OCULAR: A RADIATION EXCHANGE FACTOR COMPUTER PROGRAM

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ABSTRACT

OCULAR is a radiation exchange factor computer code compatible with the axisymmetric r-z geometry of HEATING. The code may be used to generate graybody exchange factors, as well as geometric configuration factors, which describe the radiative exchange in the cylindrical or annular enclosures that are characteristic of an axisymmetric geometry.

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F16.1 INTRODUCTION

The radiative exchange factor computer program OCULAR was developed for the U.S. Nuclear Regulatory Commission (NRC) as part of their efforts to develop standardized methods for performing safety analyses of nuclear fuel shipping containers. The program is a functional module within the SCALE system.

Frequently, nuclear fuel shipping containers are modeled as an assembly of right circular cylinders. Historically, standardized thermal analyses of these containers have been performed using the axisymmetric geometry (type R-Z) capability of HEATING (see Sect. F10).

Version 6.0 of the HEATING code provided the analyst with the capability of modeling one-dimensional (1-D) radiant heat transfer. Radiation is present in the cylindrical and annular enclosures characteristic of the axisymmetric geometry. The HEATING program was enhanced with the release of version 6.1 to provide the capability of modeling multidimensional radiant heat transfer. Exchange factors defining the radiative interaction between enclosure surfaces must be supplied to HEATING as input.

OCULAR is designed to calculate graybody exchange factors for the cylindrical and annular enclosures characteristic of an axisymmetric geometry. The geometric configuration factor (view factor) is the fraction of energy leaving blackbody surface i , which arrives at blackbody surface j directly. For any blackbody surface i in the enclosure, conservation of energy requires that the sum of the configuration factors from surface i to itself and the remaining enclosure surfaces equal 1.0. The exchange factor is the fraction of the energy emitted by graybody surface i that is absorbed by graybody surface j directly and by all reflections. Similarly, for any graybody surface i in the enclosure, conservation of energy requires that the sum of the exchange factors from surface i to itself and the remaining enclosure surfaces equal the emissivity of surface i . OCULAR calculates the configuration factor between the two surfaces analytically. The exchange factors are calculated using Hottel's Matrix Method (Ref. 1).

The input data have been designed to be compatible with that of the other functional modules within SCALE. OCULAR uses SCALE's free-form reading subroutines (see Sect. M3). The input data are subdivided into data blocks that are identifiable by keywords.

The OCULAR input data have been developed with the intention that OCULAR can read and process the HEATING input data. OCULAR is geometrically compatible with the axisymmetric geometry of HEATING, and its output may be directly input to HEATING. The OCULAR input data contain additional data blocks required to describe the enclosure of interest. Thus, a user may develop the HEATING input data to model a heat transfer problem, include the additional data blocks required to perform the exchange-factor calculations, execute OCULAR, and then use the data set coupled with the exchange factors for the HEATING thermal analysis.

Essentially every array whose size is a function of the input data is variably dimensioned. The default values used to compute these variable dimensions may be overridden using input data, and thus the code does not have to be recompiled each time a change in array size is specified. OCULAR uses the SCALE computer memory allocation feature (see Sect. M2).

OCULAR will read the input for a case until it encounters an end-of-case indicator. The program checks the input data for errors and inconsistencies and issues messages identifying any data problems that may have been encountered. Input processing is continued but the problem is not executed. This procedure results in the code identifying all or most of the input data errors with one execution. If no input data errors are encountered, OCULAR will proceed with the specific calculations for the case.

OCULAR solves for the graybody exchange factors (or blackbody configuration factors) for the nodal mesh employed by HEATING. The emissivity of the enclosure surfaces may be positionally dependent. The positional dependence may be specified through the use of analytical functions, tabular

functions, or a user-supplied subroutine. Multiple surfaces and materials may be used to define an enclosure. The surface definitions must be consistent with the axisymmetric geometry. Calculations may be performed for multiple enclosures. Nodal spacing need not be equal.

OCULAR output includes the node numbers i and j , the exchange (or configuration) factor between i and j , and the sum of the factors for each emitting node i . This output is provided for verification purposes. Additional binary output is generated which will serve as unformatted input to HEATING through the CONNECTOR data block.

OCULAR has been developed for the axisymmetric geometry. In the course of the development, efforts have been made to make the code easily adaptable to the other HEATING geometry types.

F16.2 NUMERICAL TECHNIQUE

F16.2.1. Statement of the Problem

The HEATING program offers twelve possible geometries and currently OCULAR is designed to analytically calculate graybody exchange factors for the annular and cylindrical enclosures characteristic of an r - z axisymmetric geometry. The code has been developed with a general format to facilitate future inclusion of the other two-dimensional (2-D) and three-dimensional (3-D) geometries.

As stated previously, OCULAR is geometrically compatible with the r - z axisymmetric geometry of HEATING. The nodal mesh developed by OCULAR is identical to that of HEATING. Thus, OCULAR solves for the radiative exchange factors for nodes that lie on enclosure surfaces using HEATING's node-numbering convention.

HEATING employs a finite-difference mesh generation technique to develop an approximation to the physical problem. In order to define the nodal mesh, a system of orthogonal curvilinear coordinate surfaces is superimposed on the problem. The surfaces may be unevenly spaced, but must extend to the outer boundaries of the problem. A typical node is defined at the intersection of any three surfaces. For an r - z axisymmetric geometry, a node may lie at the intersection of four different materials. The axisymmetric geometry of interest is illustrated in Fig. F16.2.1.

Figure F16.2.1 OCULAR axisymmetric geometry

The enclosure within the finite-difference mesh may be characterized for an axisymmetric geometry as a series of finite-length cylindrical surfaces or annular rings. Each node has an associated area in the radial and axial directions. With reference to Fig. F16.2.2, these nodal areas are defined by:

$$A_r(i,k) = \pi \left[\left(\frac{r(i+1) + r(i)}{2} \right)^2 - \left(\frac{r(i) + r(i-1)}{2} \right)^2 \right] , \quad (\text{F16.1})$$

$$A_z(i,k) = \pi r(i)(z(k+1) - z(k-1)) . \quad (\text{F16.2})$$

OCULAR calculates exchange factors between areas associated with nodes that lie on defined enclosure surfaces.

Figure F16.2.2 Nodal description for axisymmetric geometry

F16.2.2. Enclosure Definition

An enclosure is defined as a closed set of surfaces that lie within the model boundaries. OCULAR has been developed to model enclosures characteristic of the r-z axisymmetric geometry, with the capability of extension to other geometries based on this enclosure definition. A general OCULAR model is illustrated in Fig. F16.2.1.

The following conventions are incorporated into the program:

1. multiple enclosures may be present in a model,

2. each enclosure is defined by surfaces that must be parallel to the coordinates axes,
3. each enclosure may be composed of multiple surfaces,
4. the nodal areas on parallel surfaces need not be equal,
5. surface boundaries must correspond to fine gridline locations,
6. the emissivity of a surface may vary with position,
7. the emissivity of a nodal area must be constant across the area,
8. the emissivity of a nodal area composed of different enclosure surfaces is an area-weighted emissivity, and
9. the enclosure may be bounded by multiple materials.

The annular and cylindrical enclosures modeled by OCULAR are illustrated in Figs. F16.2.3 and F16.2.4. The components of these enclosures may be described as a cylinder, lower ring, upper ring, and shell. Each component may be subdivided into smaller components through the use of the variable spacing capabilities of the mesh generator.

Figure F16.2.3 Annular axisymmetric enclosure

Figure F16.2.4 Cylindrical axisymmetric enclosure

Direct radiant exchange in the annulus is described by interaction between the following:

1. the cylinder and the lower ring,
2. the cylinder and the upper ring,
3. the cylinder and the shell,

4. the lower ring and the shell,
5. the upper ring and the shell,
6. the lower ring and the upper ring, and
7. the shell and itself.

The analytic expressions for the geometric configuration factors for this enclosure are described in Sect. F16.2.3. Note that these expressions account for the shading effects in the enclosure which result from the presence of the cylinder.

Direct radiant exchange in the cylindrical enclosure may be described by interaction between:

1. the lower ring and the shell,
2. the upper ring and the shell,
3. the lower ring and the upper ring, and
4. the shell and itself.

The analytic expressions for the geometric configuration factors for this enclosure are described in Sect. F16.2.4.

F16.2.3. Annular Geometric Configuration Factors

The annular enclosure may be described as consisting of a cylindrical surface, two ring surfaces, and a shell surface, as illustrated in Fig. F16.2.3. The analytic expressions for the configuration factor between nodal areas that lie on these major surfaces are described in the following sections. The view factor algebra necessary to calculate reciprocal factors is not presented.

F16.2.3.1. Cylinder-to-ring factors

The configuration factor from cylindrical area 1 to ring area 2, F_{1-2} , illustrated in Fig. F16.2.5, is a function of the cylinder-to-disk configuration factor $F_{(a-b)}$, illustrated in Fig. F16.2.6 (Ref. 2). The factor F_{1-2} may be expressed as:

$$F_{1-2} = \frac{A_1 + A_4}{A_1} \left(F_{((1+4)-(2+3))} - F_{((1+4)-(3))} \right) - \frac{A_4}{A_1} \left(F_{(4)-(2+3)} - F_{(4)-(3)} \right), \quad (\text{F16.3})$$

where

$$\begin{aligned}
 F_{(a-b)} = \frac{1}{2\pi} \left\{ \cos^{-1} \left(\frac{h^2 - r_d^2 + r_c^2}{h^2 + r_d^2 - r_c^2} \right) - \left(\frac{r_c}{2h} \right) \left[\frac{(h^2 + r_d^2 + r_c^2)^2}{r_c^4} - 4 \left(\frac{r_d}{r_c} \right)^2 \right]^{1/2} \right. \\
 \cdot \cos^{-1} \frac{r_c(h^2 - r_d^2 + r_c^2)}{r_d(h^2 + r_d^2 - r_c^2)} + \left[\frac{h^2 - r_d^2 + r_c^2}{r_c^2} \right] \sin^{-1} \left(\frac{r_c}{r_d} \right) \\
 \left. - \left(\frac{\pi}{2} \right) \left[\frac{h^2 + r_d^2 - r_c^2}{r_c^2} \right] \right\}.
 \end{aligned} \tag{F16.4}$$

Figure F16.2.5 Cylinder-to-ring model

Figure F16.2.6 Cylinder-to-disk model

F16.2.3.2. Cylinder-to-shell factors

The configuration factor from cylindrical area 1 to shell area 2, F_{1-2} , is a function of the cylinder-to-disk configuration factor, defined in Sect. F16.2.3.1, and the relative position of area 2 with respect to area 1 (Ref. 2). The four configurations are illustrated in Fig. F16.2.7 and will be referred to as I, II, III, and IV. In each case, the radius of the cylinder is r_c , and the shell is r_o . A shorthand notation is used

where $F_{(h_1-h_2)}$ represents the cylinder-to-disk factor $F_{(a-b)}$, with $h = h_1 - h_2$. The factors for each configuration are as follows:

(a) Configuration I

$$F_{1-2} = \frac{1}{h_1} [h_3 + h_2 F_{(h_2)} + h_4 F_{(h_4)} - (h_2 + h_3) F_{(h_2+h_3)} - (h_3 + h_4) F_{(h_3+h_4)}], \quad (\text{F16.5})$$

(b) Configuration II

$$F_{1-2} = \frac{1}{h_1} [h_2 F_{(h_2)} + h_4 (1 - F_{(h_4)}) + (h_3 - h_4) F_{(h_3-h_4)} - (h_2 + h_3) F_{(h_2+h_3)}], \quad (\text{F16.6})$$

(c) Configuration III

$$F_{1-2} = \frac{1}{h_3} [h_3 + h_2 F_{(h_2)} + h_4 F_{(h_4)} - (h_2 + h_3) F_{(h_2+h_3)} - (h_3 + h_4) F_{(h_3+h_4)}], \quad (\text{F16.7})$$

(d) Configuration IV

$$F_{1-2} = \frac{1}{h_1} [(h_1 + h_2) F_{(h_1+h_2)} + (h_2 + h_3) F_{(h_2+h_3)} - h_2 F_{(h_2)} - (h_1 + h_2 + h_3) F_{(h_1+h_2+h_3)}]. \quad (\text{F16.8})$$

Figure F16.2.7 Cylinder-to-shell configurations

F16.2.3.3. Ring-to-shell factors

The configuration factor from ring area 1 to shell area 2, F_{1-2} , illustrated in Fig. F16.2.8 may be expressed as (Ref. 3):

$$F_{1-2} = \frac{2}{\rho_o^2 - \rho_i^2} \int_{\rho_i}^{\rho_o} r F_{dA_1-A_2} dr, \quad (\text{F16.9})$$

where

$$F_{dA_1-A_2} = \frac{1}{\pi} \tan^{-1} \left[\frac{r_s + r}{r_s - r} \tan \left(\frac{\omega}{2} \right) \right] - \frac{(r_s^2 - r^2 - h^2)}{\pi \sqrt{(r_s^2 + r^2 + h^2)^2 - (4r^2 r_s^2)}} \quad (\text{F16.10})$$

$$\tan^{-1} \left[\frac{\sqrt{(r_s^2 + r^2 + h^2)^2 - 4(r^2 r_s^2)}}{r_s^2 + r^2 + h^2 - 2r r_s} \tan \left(\frac{\omega}{2} \right) \right],$$

for

$$\omega = \cos^{-1} \left(\frac{r_c}{r} \right) + \cos^{-1} \left(\frac{r_c}{r_s} \right). \quad (\text{F16.11})$$

Figure F16.2.8 Annular ring-to-shell model

F16.2.3.4. Ring-to-ring factors

The configuration factor from ring 1 to ring 2 separated by a solid coaxial cylinder (Ref. 4), as shown in Fig. F16.2.9, may be expressed as

$$F_{1-2} = \frac{2}{(\rho_o^2 - \rho_i^2)} \int_{\rho_i}^{\rho_o} \rho F_{dA_1-A_2} d\rho, \quad (\text{F16.12})$$

where

$$F_{dA_1-A_1} = \frac{\omega - \phi}{2\pi} + \frac{r_o^2 - \rho^2 - h^2}{\pi \sqrt{(r_o^2 + \rho^2 + h^2)^2 - 4\rho^2 r_o^2}} \tan^{-1} \left(\frac{\sqrt{r_o^2 + \rho^2 + h^2 + 2\rho r_o} \tan \frac{\omega}{2}}{\sqrt{r_o^2 + \rho^2 + h^2 - 2\rho r_o}} \right) \\ - \frac{(r_i^2 - \rho^2 - h^2)}{\pi \sqrt{(r_i^2 + \rho^2 + h^2)^2 - 4\rho^2 r_i^2}} \tan^{-1} \left(\frac{\sqrt{r_i^2 + \rho^2 + h^2 + 2\rho r_i} \tan \frac{\phi}{2}}{\sqrt{r_i^2 + \rho^2 + h^2 - 2\rho r_i}} \right), \quad (\text{F16.13})$$

for

$$\omega = \cos^{-1} \left(\frac{r_o}{\rho} \right) + \cos^{-1} \left(\frac{r_c}{r_o} \right), \quad (\text{F16.14})$$

$$\phi = \cos^{-1} \left(\frac{r_c}{\rho} \right) + \cos^{-1} \left(\frac{r_c}{r_i} \right). \quad (\text{F16.15})$$

Figure F16.2.9 Annular ring-to-ring model

F16.2.3.5. Shell-to-shell factors

The configuration factor from the interior of a shell to itself for an annular enclosure (Ref. 5), as illustrated in Fig. F16.2.10, may be expressed as

$$F_{1-1} = 1 - \frac{1}{R} + \frac{2}{\pi R} \tan^{-1} \frac{2\sqrt{R^2 - 1}}{L} - \frac{L}{2\pi R} \left[\frac{\sqrt{4R^2 + L^2}}{L} \sin^{-1} \frac{4(R^2 - 1) + \left(\frac{L^2}{R^2}\right)(R^2 - 2)}{L^2 + 4(R^2 - 1)} \right] - \sin^{-1} \frac{(R^2 - 2)}{R^2} + \frac{\pi}{2} \left(\frac{\sqrt{4R^2 + L^2}}{L} - 1 \right), \quad (\text{F16.16})$$

where

$$R = \frac{r_s}{r_c}, \quad (\text{F16.17})$$

$$L = \frac{h}{r_c}. \quad (\text{F16.18})$$

Figure F16.2.10 Annular shell-to-shell model

F16.2.4. Cylindrical Geometric Configuration Factors

The cylindrical enclosure consists of two ring surfaces and a shell surface, as illustrated in Fig. F16.2.4. In the model generation process, the program treats the centerline of the enclosure as a window. Thus, the centerline is a pseudosurface that must be included in the input to completely define the enclosure. Although this surface is used to define the enclosure, it is not included in the solution technique. The analytic expressions for the configuration factor between nodal areas that lie on these major surfaces are described in the following sections. The view factor algebra necessary to calculate reciprocal factors is not presented.

F16.2.4.1. Shell-to-ring factors

The configuration factor from the interior of shell area 1 to ring area 2, F_{1-2} , as illustrated in Fig. F16.2.11, may be expressed as (Ref. 6):

$$F_{1-2} = \frac{1}{4(L_2 - L_1)} \left[\sqrt{L_2^4 + 2L_2^2(1 + R_2^2) + (1 - R_2^2)^2} - \sqrt{L_2^4 + 2L_2^2(1 + R_1^2) + (1 - R_1^2)^2} \right. \\ \left. + \sqrt{L_1^4 + 2L_1^2(1 + R_1^2) + (1 - R_1^2)^2} - \sqrt{L_1^4 + 2L_1^2(1 + R_2^2) + (1 - R_2^2)^2} \right], \quad (\text{F16.19})$$

where

$$L_1 = \frac{h_1}{r_s}, \quad (\text{F16.20})$$

$$L_2 = \frac{h_2}{r_s}, \quad (\text{F16.21})$$

$$R_1 = \frac{r_i}{r_s}, \quad (\text{F16.22})$$

$$R_2 = \frac{r_o}{r_s}. \quad (\text{F16.23})$$

Figure F16.2.11 Cylindrical shell-to-ring model

F16.2.4.2. Ring-to-ring factors

For two coaxial rings, the configuration factor from ring 1 to ring 2, F_{1-2} , is a function of the configuration factor between two coaxial disks, $F_{(a-b)}$ (Ref. 5). The ring-to-ring configuration is illustrated in Fig. F16.2.12, the disk-to-disk configuration in Fig. F16.2.13.

$$F_{1-2} = \frac{A_1 + A_4}{A_1} \left(F_{((1+4)-(2+3))} - F_{((1+4)-3)} \right) - \frac{A_4}{A_1} \left(F_{(4-(2+3))} - F_{(4-3)} \right), \quad (\text{F16.24})$$

where

$$F_{(a-b)} = \frac{1}{2} \left[1 + \frac{1+R_b^2}{R_a^2} - \left(\left(1 + \left(\frac{1+R_b^2}{R_a^2} \right) \right)^2 - 4 \left(\frac{R_b}{R_a} \right)^2 \right)^{1/2} \right], \quad (\text{F16.25})$$

$$R_a = \frac{a}{h}, \quad (\text{F16.26})$$

$$R_b = \frac{b}{h}. \quad (\text{F16.27})$$

Figure F16.2.12 Cylindrical ring-to-ring model

Figure F16.2.13 Disk-to-disk model

F16.2.4.3. Shell-to-shell factors

The configuration factor from the interior of a shell to itself, F_{1-1} , as illustrated in Fig. F16.2.14, may be expressed as (Ref. 6):

$$F_{1-1} = \left(1 + \frac{h}{2r_s}\right) - \left(1 + \left(\frac{h}{2r_s}\right)^2\right)^{1/2} \quad (\text{F16.28})$$

F16.2.5. Exchange Factors

The exchange factor is defined as the fraction of energy emitted by surface i (if it is assumed to be a black surface) absorbed by surface j (Ref. 1). The exchange factor depends on the geometric arrangement of all surfaces in the enclosure and their emittances. OCULAR solves for the exchange factors using Hottel's Matrix Method. This portion of the code is modeled upon an earlier computer program, HOTTEL (Ref. 7). OCULAR outputs the factor between two nodal areas and the sum of the factors for each emitting node. This sum should equal the emittance of the emitting nodal area. Since OCULAR employs exact solutions for configuration factor computations, any differences that do exist are a result of numerical integration over a finite surface area. The magnitude of the configuration factor asymptotically approaches the exact solution for the annular ring-to-ring and ring-to-shell factors as the finite surface area approaches zero. These solutions are presented as Eqs. (F16.9) and (F16.12). Experience has shown that the configuration factor for the innermost ring contains this error. Thus, care should be exercised when defining the mesh spacing for the annular enclosure in this region. If the difference due to discretization error is unacceptable, the mesh should be refined in this region and the problem repeated.

Figure F16.2.14 Shell-to-shell model

The exchange factors are calculated assuming that the following restrictions in the heat transfer analysis will be met:

1. the temperature is uniform across a nodal area,
2. the directional spectral emissivity and the directional spectral absorptivity are equal and independent of either angle or wavelength,
3. all energy is emitted and reflected diffusely, and
4. the incident and reflected energy flux is uniform over each nodal area.

F16.3 PROGRAM LOGIC FLOW AND SUBROUTINE DESCRIPTION

OCULAR reads input data for one case per computer run. Execution is halted after the input data are read and the exchange factors are generated. The calling sequence of routines is depicted in Fig. F16.3.1.

F16.3.1. Description of Subroutines Used by OCULAR

Descriptions of subroutines and entry points that comprise OCULAR are presented in Table F16.3.1.

Figure F16.3.1 Calling sequence of routines

Table F16.3.1 Summary of subroutines and entries

BLOCK DATA	Initializes data in labeled commons /ARYLNG/ and /IUNIT/
MAIN OCULRA	Directs ALOCAT to call subroutine ALCROR and opens buffers.
ALCROR	Serves as an interface between the OCULAR main routine and subroutines. Determines the maximum dimension of the array that holds all variably dimensioned arrays.
ANALFN	Reads card images for one analytical function from the analytical function data block for each call. Checks the data to determine if they are compatible and writes error messages if they are not. Called from READER. Calls ERRMSG, NEXTCD, REORAF, and REORTF. Calls SCALE free-form reading routines DREAD and IREAD.
ANALYT	Entry in PREANA. Evaluates the referenced analytical function or calls the specified user-supplied subroutine. Called from FUNCTN. Calls EMSSVY.
BLDENC	Builds the general-enclosure mesh that overlays the problem mesh. Called from OCULST.
CFDTOD	Calculates the view factor from one radial disk to another coaxial radial disk. Called from VFRTOR.
CFSTOS	Calculates the view factor from the interior of a right circular cylinder to itself for an annular or cylindrical enclosure. Called from VFSTOS.
CHKATF	Checks the external reference number (input data) to an analytical or tabular function to determine whether or not it has been defined. Calculates internal reference numbers to defined functions. Writes error messages for undefined functions. Called from ERRCK.
CONFAC	Serves as a driver for the calculation of the analytic geometric view factors and exchange factors. Called from OCULST. Calls EXCHNG, FUNCTN, VFCTOR, VFCTOS, VFRTOR, VFRTOS, and VFSTOS.
DECOMP	Decomposes a real matrix by Gaussian elimination and estimates the condition of the matrix. Called from EXCHNG. Calls SOLVE (Ref. 8).
DIFFER	Calculates the fine lattice lines that bound a region and a surface. Called from WRITER. Calls REGION.
ECHO	Reads remaining standard input data card images from unit IECHO, lists input data card images on unit IO, blanks out columns 73 through 80 except for title cards, comments, and end of data indicators, and writes the resulting input data images on unit IN. Assumes card image with "@" in column 1 is a continuation of the previous card image. Replaces "@" in column 1 with a blank. Called from MAIN.

Table F16.3.1 (continued)

EMISSY	Reads card images for one emissivity function from the emissivity function data block for each call. Checks the data to determine if they are compatible and writes error messages if they are not. Called from READER. Calls ERRMSG and REOREM. Calls SCALE free-form reading routines DREAD and IREAD.
EMSSVY	Evaluates the user-supplied function defining the emissivity for the portion of the node whose properties are being evaluated. Writes an error message and stops when called unless the user-supplied algorithm has been added. Called from ANALYT.
ENCLSE	Reads card images for one enclosure function from the enclosure function data block for each call. Checks the data to determine if it is compatible and writes error messages if it is not. Called from READER. Calls ERRMSG and REOREN. Calls SCALE free-form reading routine IREAD.
ENREGN	Entry in REGION. Writes error message if the fine grid matching a surface boundary cannot be located. Called from DIFFER.
ERRCK	Checks references by the region, material, enclosure, surface, and emissivity input data to determine whether or not the referenced parameters have been defined. Called from INPUT. Calls CHKATF.
ERRMSG	Called when the number of parameters defined by the input data exceeds the maximum allowed by the code. Writes error message and sets flag indicating number of errors encountered. Called from ANALFN, EMISSY, ENCLSE, GRIDS, MATERL, REGONS, and SURFCE. Calls SCALE free-form reading routine AREAD.
EXCHNG	Uses Hottel's matrix solution to calculate the exchange factor terms. Called by CONFAC. Calls DECOMP and SOLVE.
F1RTOR	Function representing an integrand of the function in the $F_{dA_1-A_2}$ ring-to-ring configuration factor calculations. Accessed by VFRTOR through SIMPSN.
F2RTOR	Function representing an integrand of the function in the $F_{dA_1-A_2}$ ring-to-ring configuration factor calculations. Accessed by VFRTOR through SIMPSN.
F3RTOR	Function representing an integrand of the $F_{dA_1-A_2}$ function in the ring-to-ring configuration factor calculations. Accessed by VFRTOR through SIMPSN.
F4RTOS	Function representing an integrand of the $F_{dA_1-A_2}$ function in the ring to dA, shell configuration factor calculations. Accessed by VFRTOS through SIMPSN.
F5RTOS	Function representing an integrand of the $F_{dA_1-A_2}$ function in the ring-to-shell configuration factor calculations. Accessed by VFRTOS through SIMPSN.

Table F16.3.1 (continued)

FGRID	Calculates the fine gridlines along each axis based on the respective set of gross gridlines and their related divisions. Called from GRIDS.
FUNCTN	Computes the value of an emissivity which can be positional-dependent. Value of the emissivity is a function of the independent variables X (or R), Y (or θ), and Z (or ϕ). Called from CONFAC. Calls entries ANALYT and TABLE.
GRIDS	Reads the card images from the XGRID, YGRID, and ZGRID data blocks. Called from READER. Calls ERRMSG, FGRID, and NEXTCD.
INITIL	Initializes variables and arrays to zero. Called from INPUT.
INPUT	Reads the first four input cards and calls routines to read and write the remaining input data. Job information and parameters are output. Called from OCULST. Calls ERRCK, INITIL, NEXTCD, OUTPUT, PREANA, PRETAB, READER, SETTYP, and WRITER. Calls SCALE free-form reading routines AREAD, DREAD, IREAD, and SCANON.
MATERL	Reads card images for one material from the material data block for each call. Checks the data to determine if they are compatible and writes error messages if they are not. Called from READER. Calls ERRMSG, NEXTCD, and REORMT. Calls SCALE free-form reading routines CREAD, DREAD, and IREAD.
NEXTCD	Reads the first word of the next card image. Writes message to include last card image successfully read if "end-of-file" or "end-of-data" is encountered and sets appropriate flag. Writes out entire card image if it is a comment and looks at next card image. Otherwise, resets flag so that the next read is from first word of this card image and returns to the calling subroutine. Called from ANALFN, ENCLSE, GRIDS, INPUT, MATERL, READER, REGONS, SURFCE, and TABLFN. Calls SCALE routine AREAD.
OCULST	Sets the size of the variably dimensioned arrays and initializes the parameters for the run. Called from ALCROR. Calls entries INPUT, NEXTCD, PLANES, POINTS, BLDENC, CONFAC, and PRINTR. Calls SCALE routine IONUMS.
OPTION	Reads the OPTION data block and writes out the values of the parameters that can be reset with this data block. Called from MAIN.
OUTPUT	Writes out the parameters from Card 2, checks the parameters for errors, and writes error messages if errors are encountered. Called from INPUT.
PLANES	Performs error checking to determine whether the surface data are properly defined and whether enclosures are defined by prescribed surfaces. Called from OCULST.
POINTR	Sets the size of the variably dimensioned arrays. Called from MAIN.

Table F16.3.1 (continued)

POINTS	Generates the nodal configuration and the arrays defining the fine lattice lines passing through each node. Called from OCULST.
PREANA	Serves as initial entry for passing variably dimensioned arrays for later use by entry ANALYT. Called from INPUT.
PRETAB	Serves as initial entry for passing variably dimensioned arrays for later use by entry TABLE. Checks tabular data for consistency and writes messages if errors are detected. Called from INPUT.
PRINTR	Writes out the exchange factor data and the HEATING CONNECTOR input data. Called from OCULST.
READER	Reads each card image in the standard input data beginning with the data immediately following the title card and card 2. Checks for keywords defining a data block and branches to associated subroutine where related input data from the block are read. Assumes card image belongs to currently open data block if a keyword is not found. Writes error message and continues with next card image if keyword is not found on first card image. Returns to INPUT upon encountering an "end-of-file" or an "end-of-data." Called from INPUT. Calls MATERL, NEXTCD, REGONS, GRIDS, ANALFN, ENCLSE, SURFCE, and EMISSY. Calls entry TABLFN.
REGION	Checks input data to ensure that the boundary of each region corresponds to a fine gridline. Called from DIFFER.
REGONS	Reads card images for one region from the region data block for each call. Checks the data to determine if they are compatible and writes error messages if they are not. Called from READER. Calls ERRMSG, NEXTCD, and REORDR. Calls SCALE free-form reading routines DREAD and IREAD.
REORDR	Reorders arrays containing the input data associated with the region data block when a region is deleted by the input data. Entries REORMT, REORAF, REORTF, REOREN, REORSR, and REOREM are independent sections of coding and perform similar tasks on other input data items. Called from REGONS.
REORAF	Reorders arrays containing the input data associated with the analytical function data block when an analytical function is deleted by the input data. Called from ANALFN.
REOREM	Reorders arrays containing the input data associated with the emissivity function data block when an emissivity function is deleted by the input data. Called from EMISSY.
REOREN	Reorders arrays containing the input data associated with the enclosure function data block when an enclosure function is deleted by the input data. Called from ENCLSE.
REORMT	Reorders arrays containing the input data associated with the material function data block when a material function is deleted by the input data. Called from MATERL.

Table F16.3.1 (continued)

REORSR	Reorders arrays containing the input data associated with the surface function data block when a surface function is deleted by the input data. Called from SURFCE.
REORTF	Reorders arrays containing the input data associated with the tabular function data block when a tabular function is deleted by the input data. Called from entry TABLFN.
SETTYP	Initializes flags and parameters that are a function of the geometry type. Called from INPUT.
SIMPSN	Integrates a specified function using Simpson's Rule. Called by VFRTOR and VFRTOS. Accesses functions F1RTOR, F2RTOR, F3RTOR, F4RTOS, and F5RTOS.
SOLVE	Solves the linear system $AA * X = CK$. Called from EXCHNG. Calls DECOMP (Ref. 8).
SURFCE	Reads card images for one surface from the surface data block for each call. Checks the data to determine if they are compatible and writes error messages if they are not. Called from READER. Calls ERRMSG, NEXTCD, and REORSR. Calls SCALE free-form reading routines DREAD and IREAD.
TABLE	Entry in PRETAB. Performs checking to ensure tabular function values bound the argument values. Writes warning message. Called from FUNCTN.
TABLFN	Entry in ANALFN. Reads card images for one tabular function from the tabular function data block for each call. Checks the data to determine if they are compatible and writes error messages if they are not. Called from READER. Calls ERRMSG, NEXTCD, and REORTF. Calls SCALE free-form reading routines DREAD and IREAD.
VFCTOD	Computes the configuration factor from the outside surface of a cylinder to a disk. Called from VFCTOR and VFCTOS.
VFCTOR	Calculates the configuration factor from the outer surface of a cylinder to a ring at the base of the cylinder for an annular enclosure. Called from CONFAC. Calls VFCTOD.
VFCTOS	Calculates the configuration factor from the exterior of an inner-right circular cylinder of finite length to the interior of an outer-right circular cylinder (shell) using cylinder-to-disk configuration factors and view factor algebra for an annular enclosure. Called from CONFAC. Calls VFCTOD.
VFRTOR	Calculates the configuration factor between coaxial rings. Called from CONFAC. Calls CFDTOD, SIMPSN, and VFCTOD. Accesses functions F1RTOR, F2RTOR, and F3RTOR.

Table F16.3.1 (continued)

VFRTOS	Calculates the configuration factor between a ring in the enclosure and the inner surface of the outer shell. Calls SIMPSN. Accesses F4RTOS and F5RTOS.
VFSTOS	Calculates the configuration factor from the interior of a right circular cylindrical shell of finite length to itself and from the interior of a right circular cylindrical shell to the interior of a coaxial shell. Called from CONFAC, calls CFSTOS.
WRITER	Writes out the input data values, except for the title card, card 2 and comment cards. Checks for errors and outputs messages if errors are detected. Called from INPUT. Calls DIFFER.

F16.4 INPUT DESCRIPTION FOR OCULAR

F16.4.1. General

A detailed discussion of the input data cards is presented, followed by a brief outline of the input data for the benefit of the user who is familiar with the data preparation. In preparing the input data, any consistent set of units may be used in the OCULAR program. The units associated with the algorithms which appear in the user-supplied subroutine EMSSVY must be consistent with those of the input data.

The input data set for OCULAR is derived from the HEATING input data set with the intention that OCULAR can read and process the HEATING input data. Thus, a user may develop a HEATING input deck to model a heat transfer problem, include the additional enclosure, surface, and emissivity information required by OCULAR, and use the same data set that will be used for the thermal analysis to produce the necessary exchange factors. OCULAR will read only the data needed from the HEATING input deck. By necessity, OCULAR data assume the same format as HEATING data. If a user chooses not to use a HEATING input data set, zeros should be supplied in appropriate HEATING data entries. The input description assumes that a HEATING data set is not being used.

Formatted input data are read from logical unit No. 4 and unformatted input data are read from logical unit No. 95. Formatted output is written to logical unit No. 6 and unformatted node-to-node connector data are written to logical unit No. 12.

The input data for OCULAR are read using the SCALE free-form reading routines (see Sect. M2). When OCULAR is executed within the SCALE system, =OCULAR or #OCULAR must be the first record in the data set. An input data set is terminated with a percent (%) sign. When executed within the SCALE system, an END card must be supplied as the last card of the data deck to signify the end of the input data to the SCALE driver.

Data are entered in an unformatted manner by separating each data item by one or more blanks or by a comma. With a few exceptions noted, the data items may be entered anywhere in columns 1 through 72. If the data that are to appear on a card will not fit on one card, an "@" must appear in column 1 of each continuation card. Otherwise, the code will read the remaining data for that card image as either zero or blank. There is no limit to the number of continuation cards. However, a continuation card may not immediately follow a title card, an end-of-data card, a comment card, or a keyword indicator card. Columns 73 through 80 of each card are reserved for identification to aid the user in the preparation and handling of data. Decimal data may be entered as FORTRAN input. For example, 1.733×10^{-4} may be entered as 1.733-4, 1.733E-4, 1.733D-4, or 0.0001733. Note that imbedded blanks are not allowed within a given number representation. SCALE free-form reading routines have provisions for multiple entries of the same data value. This step 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. No blanks should be inserted between the multiplier and the repeat flag, but each multiple entry must be separated from the rest of the data by one or more blanks or by a comma. Because blanks are ignored, an embedded zero must be specified in the input data either as 0 followed by one or more blanks, as 0 followed by a comma, or as one or more blanks followed by a comma. However trailing blanks may be omitted. Multiple zeros may be specified as NZ, where N is the number of zeros to be repeated. Again, there must 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 or by a comma. All literal data fields, such as material names, must be delineated by a blank, they must not be delineated by a comma.

The input data for an execution of OCULAR consist of data defining the size of the variably dimensioned arrays and the options that will be in effect during the computer run. Case parameters that dictate the required size of the variably dimensioned arrays are input with the OPTIONS data block. This data block contains variables whose default values may be modified and it is placed at the beginning of an OCULAR data set.

This data block is followed by case data. A case consists of a title card, one parameter card, and the data blocks necessary to define the problem being modeled. The user may wish to add comment cards to the input data for documentation purposes. Any number of comment cards may appear anywhere in the input data following the title card, except a comment card may not precede a continuation card. The comment cards are identified by an asterisk (*) in column 1. The comments will be written on the standard output unit as they are encountered.

Ten different data blocks may be used in describing the model to the computer code. A data block consists of a block indicator card containing the keyword followed by the data for that block. No embedded blanks can be present in the first four characters of the keyword. The keyword for each data block is contained in Table F16.4.1.

Table F16.4.1 Data block keywords

REGIONS
MATERIALS
XGRID
YGRID
ZGRID
ANALYTICAL FUNCTIONS
TABULAR FUNCTIONS
ENCLOSURES
SURFACES
EMISSIVITIES

The data reference number blocks may appear in any order within the block and may have any positive integer value accepted by the machine. If a data reference number appears more than once within a data block, the last data read with that reference number are used.

The final data card in a data deck for a case is an end-of-data card and must contain a percent % in column 1 and a blank in column 2. This card signifies the end of data for a problem. As OCULAR reads the input data, it sets a flag when an error is encountered and continues to read additional data unless the error was fatal. When the end of data indicator (%) is encountered, OCULAR terminates reading and commences processing the input data. After processing is completed, the code performs the specified calculations unless an error was encountered.

In the sections that follow, the characters (A), (I), or (R) may appear after the heading for the entries to indicate that the entry is alphanumeric, integer, or real, respectively. Suggested data card labels follow each data block section heading. These labels may be entered in columns 73 through 80 of the related data cards to aid in identifying the data.

F16.4.2. OPTION Data Block

The variables labeled in commons /ARYLNG/ and /IOUNIT/ are initialized in a BLOCK DATA subprogram. In general, it is advantageous to tailor OCULAR to a specific problem by overriding the default values specified in the BLOCK DATA with values appropriate for the problem. This adaptation is accomplished through the use of the OPTION data block input feature described below. Each of the variables in the two common blocks whose default value can be modified appears in this data block.

The first record read by OCULAR contains data for the OPTION data block. This feature allows the user to change the default value of any or all variables in the data block by including the variable name and its desired value. The variables are input beginning with OPTION and ending with END. These parameters apply to OCULAR for the entire run. Table F16.4.2 contains each variable name and its default value.

Table F16.4.2 List of OCULAR variables whose default value may be modified through the OPTION data block

MAXANA	5	Maximum number of analytical functions
MAXCON	1	Maximum number of connectors
MAXEMS	5	Maximum number of emissivity functions
MAXENC	5	Maximum number of enclosures
MAXGGL	10	Maximum number of gross gridlines along any axis
MAXMAT	5	Maximum number of materials
MAXNEA	8	Maximum number of nodal areas in an enclosure
MAXPRS	10	Maximum number of pairs in each tabular function
MAXPTS	50	Maximum number of lattice points (nodes)
MAXREG	5	Maximum number of regions
MAXRFG	50	Maximum number of X (or R) fine gridlines
MAXSRF	5	Maximum number of enclosure surfaces
MAXTBL	5	Maximum number of tabular functions
MAXTFG	50	Maximum number of Y (or 0) fine gridlines
MAXZFG	50	Maximum number of Z (or 0) fine gridlines

F16.4.3. Problem Control Parameters

F16.4.3.1. Card 1

This card, which can contain alphanumeric characters in the first 72 columns, contains a descriptive title for the problem and must be the first card in the data deck. The card itself cannot be omitted, although it may be left blank. This title serves to identify the output associated with a problem, and it appears at the top of a number of the tables generated by the program. It is also included in messages output by the code.

F16.4.3.2. Card 2

F16.4.3.2.1. Entry 1

The first entry on card 2 is not processed by OCULAR. The entry itself cannot be omitted and should be set to zero if the user is not using a HEATING input data deck.

F16.4.3.2.2. Entry 2 - geometry type

The HEATING program offers twelve possible geometries (seven and eight are functionally the same) which are members of either the cylindrical, Cartesian, or the spherical coordinate system. The geometry types are listed in Table F16.4.3 below.

Table F16.4.3 HEATING geometry types

Cylindrical	Rectangular	Spherical
1 R- θ -Z	6 X-Y-Z	10 R
2 R- θ	7 X-Y	11 R- θ
3 R-Z	8 X-Z	12 R- θ - ϕ
4 R	9 X	
5 Z		

Currently OCULAR is designed to model enclosures for the R-Z geometry type. Thus, entry 2 on card 2 should be 3.

F16.4.4. Region Data Block (Cards R1 and R2)

Each region is described by two cards that must appear in pairs. The cards are repeated for each region. There must be at least one region specified. The maximum number of regions is MAXREG.

F16.4.4.1. Block indicator card

REGIONS

F16.4.4.2. Card R1

a. Region Number (I)

This entry contains the number of the region to be described. The region numbering system does not require that a region occupy any particular zone in the overall configuration.

b. Region Material Number (I)

The second entry of this card defines the material which occupies the region. The integer entry is the function number of the material listed in the material data block.

c. Region Dimensions (R)

Dimensions of the region boundaries are entered as floating-point numbers and are arranged in the following order:

1. smaller dimension of X or R region boundary,
2. larger dimension of X or R region boundary,
3. smaller dimension of Y or θ region boundary,
4. larger dimension of Y or θ region boundary,
5. smaller dimension of Z or ϕ region boundary, and
6. larger dimension of Z or ϕ region boundary.

These dimensions constitute the third through eighth entries, respectively. If the problem is 1- or 2-D, then the region boundary dimensions for the remaining unnecessary coordinate should be zero. For the R-Z geometry type, the fifth and sixth entries should be zero. The region volume must be nonnegative. Although it is usually more convenient to place the overall configuration at the origin, it is not necessary to do so; however, all region boundary dimensions are entered as their distance from the origin. For the axisymmetric geometry, the minimum inner radial dimension is zero. The axial region boundary dimensions need not be positive, but must extend in the positive Z direction.

F16.4.4.3. Card R2

This card must be included with the appropriate R1 card even if it is blank for an OCULAR run. The HEATING data contained on this card are not utilized.

F16.4.5. Material Data Block (Cards M and PC)

A group of cards, consisting of an M card and possibly a PC card, is required to describe each material for a HEATING model. A subset of the HEATING data is processed and used by OCULAR, and only this subset is described below.

F16.4.5.1. Block indicator card

MATERIALS

F16.4.5.2. Card M

a. Material Number (I)

The first entry, an integer, contains the number of the material which is to be described. This entry corresponds to the material specified as entry 2 on card R1. Each different material has a unique number.

b. Material Name (A)

The second entry contains the name of the material. The name, which may consist of up to eight alphanumeric characters, is used to aid in identification of output data. It cannot contain any embedded-blanks and must be terminated by one or more blanks. Note that OCULAR does not access the material properties library of SCALE. However, an asterisk is acceptable as the first character of the material name.

c. HEATING Data

Entries 3, 4, 5, 6, 7, and 8 are HEATING data that are not processed for use by OCULAR. If OCULAR is being used in a stand-alone fashion, these entries should be blank.

d. Phase Change Flag (I)

When employing a HEATING input deck, the ninth entry on the M card is a positive integer indicating that a material can undergo a change-of-phase. OCULAR uses this entry as a flag to indicate that a PC card immediately follows the M card. The entry should be blank for a stand-alone OCULAR run and for materials that do not undergo a phase change.

F16.4.5.3. Card PC

Information on this card is not processed for use by OCULAR. This card must be present if the ninth entry on card M is nonzero.

F16.4.6. X (or R) Grid Data Block (Cards L1 and N1)

Gross lattice data for the X (or R) axis are entered on two sets of cards: the first set specifies the lattice dimensions, and the second indicates the mesh divisions between gross lattice lines. All numbers on the first set (L1 cards) are of the floating-point type and are entered by specifying all of the gross lattice dimensions along the X (or R) axis sequentially on one or more cards. The second set (N1 cards) specify the number (an integer greater than or equal to 1) of equal increments which are between the gross lattice lines whose dimensions are given on the first set of cards. In particular, an entry on an N1 card specifies the number of equal increments between the gross lattice line in the corresponding entry on the

L1 card and the gross lattice line immediately following it. Any L1 or N1 card that is a continuation card must contain an "@" in column 1.

F16.4.6.1. Block indicator card

XGRID

F16.4.6.2. Card L1

The L1 cards correspond to the X (or R) coordinate. The total number of entries must not exceed MAXGGL.

F16.4.6.3. Card N1

The N1 cards correspond to the X (or R) coordinate and have one less entry than the L1 cards. The total number of fine lattice lines along the X (or R) axis or the sum of the entries on the N1 card plus 1 must not exceed MAXRFG.

F16.4.7. Z (or ϕ) Grid Data Block (Cards L3 and N3)

The gross lattice data for the Z (or ϕ) axis are formed in the same manner as for the data along the X (or R) axis. Any L3 or N3 card that is a continuation card must contain an "@" in column 1.

F16.4.7.1. Block indicator card

ZGRID

F16.4.7.2. Card L3

The L3 cards correspond to the Z (or ϕ) coordinate. The total number of entries must not exceed MAXGGL.

F16.4.7.3. Card N3

The N3 cards correspond to the Z (or ϕ) coordinate and have one less entry than the L3 card. The total number of fine lattice lines along the Z (or ϕ) axis or the sum of the entries on the N3 card plus 1 must not exceed MAXZFG.

F16.4.8. Enclosure Data Block (Cards EN1 and EN2)

Each enclosure is described by two cards that must appear in pairs. The cards are repeated for each enclosure. There must be at least one enclosure for each problem. Each different enclosure is assigned a unique positive integer. Enclosures may be defined to exist in voided regions or in regions containing nonparticipating materials such as air. The surfaces that comprise the enclosure must be defined such that a complete enclosure is formed. For input purposes, the program treats the centerline of a cylindrical enclosure as a window. Thus, the centerline is a pseudosurface that must be input. This

surface is used to define the enclosure, but it is not included in the solution technique. The maximum number of enclosures is MAXENC.

F16.4.8.1. Block indicator card

ENCLOSURES

F16.4.8.2. Card EN1

- a. Enclosure Number (I)

The first entry on card EN1 is an integer that contains the number of the enclosure to be defined.

- b. Boundary Number (I)

The second entry on the EN1 card contains the boundary number defining the HEATING boundary condition number which will be used to model the radiant heat transfer within the enclosure.

- c. Number of Surfaces (I)

The third entry contains the number of surfaces that comprise the enclosure.

F16.4.8.3. Card EN2

The entries on the EN2 card define the surfaces that comprise the enclosure. The total number of entries must correspond to the number specified by the third entry on card EN1. The surface numbers must correspond to surfaces defined in the Surface Data Block.

F16.4.9. Surface Data Block (Card SU)

Surface data are described in a manner similar to regions. The location of the surface is defined by specifying where its endpoints lie in the model. A 2-D surface may be visualized as a line; a 3-D surface as an area. The surface dimension will always be one dimension less than the model's dimension. The input data have been generalized to provide for future implementation HEATING geometries. The number of surfaces cannot exceed MAXSRF.

F16.4.9.1. Block indicator card

SURFACES

F16.4.9.2. Card SU

- a. Surface Number (I)

This entry contains the number of the surface to be described.

b. Emissivity of Surface (I)

The second entry of this card indicates the emissivity function number that describes the hemispherical total emissivity of the surface.

c. Surface Dimensions (R)

Dimensions of the surface boundaries are entered as floating-point numbers and are arranged in the following order:

1. smaller dimension of X (or R) surface boundary,
2. larger dimension of X (or R) surface boundary,
3. smaller dimension of Y (or θ) surface boundary,
4. larger dimension of Y (or θ) surface boundary,
5. smaller dimension of Z (or ϕ) surface boundary, and
6. larger dimension of Z (or ϕ) surface boundary.

For the axisymmetric geometry, the Y (or θ) boundary is set to zero by OCULAR. The two X (or R) boundaries must be equal or the two Z (or ϕ) entries must be equal. For a 3-D model, either the X, the Y, or the Z surface boundary dimensions must be equal.

F16.4.10. Emissivity Data Block (Card EM)

Total hemispherical emissive property data are entered on the EM cards. At least one emissivity function must be defined for each problem. The total number of emissivity functions cannot exceed MAXEMS. An area-weighted average emissivity is used for nodal areas comprised of two different enclosure surfaces.

F16.4.10.1. Block indicator card

EMISSIVITIES

F16.4.10.2. Card EM

Each different emissivity function is assigned a unique positive integer. The emissivity function may be expressed as:

$$\epsilon(x,y,z) = \epsilon_c F_i(x) F_j(y) F_k(z) , \quad (\text{F16.29})$$

where $\epsilon(x,y,z)$ is a total hemispherical emissivity at a location (x, y, z) in the model. Since the emissivity associated with a surface may be a function of position, the data card consists of five entries. All of them

are integers except the second, which is a floating-point number. The first entry contains the emissivity function number. The second entry contains the constant factor describing the emissivity function. This term corresponds to ϵ_∞ in Eq. (F16.29). The remaining entries, which identify analytical or tabular functions $F(x)$, $F(y)$, $F(z)$, contain the x - (or r -), y - (or θ -), and z - (or ϕ -) dependent function parameters corresponding to the i , j , and k , respectively, in Eq. F16.29. If the emissivity does not vary along a particular axis of the surface, then the position-dependent function parameter associated with the coordinate must be zero, and the corresponding function value will be set to 1.0 by the code. The emissivity function value may not be set to zero. To model a surface with an emissivity of zero, a small value, such as 1.0×10^{-6} is suggested. A value of 1.0 is recommended to model black surfaces such as holes in the enclosure.

F16.4.11. Analytical Function Data Block (Cards A1 and A2)

Each analytical function, defined as

$$F(v) = A_1 + A_2 v + A_3 v^2 + A_4 \cos(A_5 v) + A_6 e^{A_7 v} + A_8 \sin(A_9 v) + A_{10} \ln(A_{11} v) \quad (\text{F16.30})$$

is described by an A1 card and one or more A2 cards. The total number of analytical functions must not exceed MAXANA.

F16.4.11.1. Block indicator card

ANALYTICAL FUNCTIONS

F16.4.11.2. Card A1

The first entry on Card A1 is a unique analytical function number, an integer. The second entry, also an integer, is the number of coefficients, A_i , which are on the A2 cards. If the second entry is blank or zero, then the code assumes that a user-supplied subroutine will be supplied for the emissivity. The second entry cannot exceed MAXPAR which is currently 11.

F16.4.11.3. Card A2

The A2 cards contain up to MAXPAR (currently set to 11) ordered pairs, where each ordered pair is defined as follows: the first element of an ordered pair consists of an integer i ; the second element consists of the value of the coefficient A_i . The integer i must not exceed MAXPAR. The A2 cards will be continued until each coefficient in the analytical function is defined. If the second entry on Card A1 is blank or zero, then the related A2 card is omitted. A continuation card must contain an "@" in column 1.

As an example, the cards which are necessary to describe

$$f(x) = 100.0 \sin(5x) + e^{-3x} \quad (\text{F16.31})$$

are presented in Table F16.4.4.

Table F16.4.4 A1 and A2 cards necessary to describe
the function $100.0 \sin(5x) + e^{-3x}$

Entry	1	2	3	4	5	6	7	8	Card
	1	4							A1
	8	100.0	9	5.0	6	1.0	7	-3.0	A2

F16.4.11.4. User-supplied subroutine EMSSVY

The dummy FORTRAN subroutine, EMSSVY, incorporated in OCULAR to model the emissivity of an enclosure surface is presented in Fig. F16.4.1. The user must overwrite this dummy routine with FORTRAN coding designed to describe the emissivity behavior.

F16.4.12. Tabular Function Data Block (Cards T1 and T2)

The tabular function is assumed to be a set of linearly connected points. The function is described by specifying a set of ordered pairs v and $F(v)$. Each ordered pair contains an independent variable and its functional value. A maximum of MAXPRS points is allowed, and linear interpolation is performed between the points. The function is evaluated according to

$$F(v) = \begin{cases} F(v_1) & v < v_i \\ F(v_n) & v > v_n \end{cases} \quad (\text{F16.32})$$

for points outside the defined domain. The total number of tabular functions must not exceed MAXTBL.

F16.4.12.1. Block indicator card

TABULAR FUNCTIONS

F16.4.12.2. Card T1

The first entry on the T1 card (an integer) is a unique tabular function number. The number of points (an integer) is the second entry.

```

SUBROUTINE EMSSVY(RVALUE,R,TH,Z,VALUE,NUMBER)
C*****
C
C   WHEN IT IS REFERENCED, THIS SUBROUTINE MUST BE SUPPLIED BY THE USER TO
C   EVALUATE THE USER-SUPPLIED FUNCTION DEFINING THE EMISSIVITY.
C   THIS PARAMETER MAY BE POSITIONAL-DEPENDENT
C   THE VARIABLES IN THE ARGUMENT LIST ARE DEFINED IN THE FOLLOWING TABLE.
C   (Y) INDICATES THAT THE VARIABLE HAS BEEN DEFINED WHEN THE ROUTINE
C   IS CALLED. (N) INDICATES THAT IT HAS NOT BEEN DEFINED.
C
C   VARIABLE      TYPE DEFINITION
C   RVALUE  REAL  VALUE OF THE USER-SUPPLIED FUNCTION
C               EVALUATING THE EMISSIVITY PROPERTY
C               THIS VALUE MUST BE COMPUTED BY THE
C               ROUTINE (N)
C   R        REAL  X OR R COORDINATE OF THE ENCLOSURE NODELY)
C   TH       REAL  Y OR THETA COORDINATE OF THE ENCLOSURE NODELY)
C   Z        REAL  Z OR PHI COORDINATE OF THE ENCLOSURE NODELY)
C   VALUE    REAL  CONSTANT VALUE OF THE PARAMETER
C               WHICH APPEARS ON ITS RESPECTIVE INPUT
C               CARD (1) IF IT IS NONZERO
C               IF = ZERO, VALUE=1.0 (Y)
C   NUMBER   INTEGER INDEX OF PARAMETER BEING EVALUATED (Y)
C               NAME IN CALLING SEQUENCE - NEMVYT
C*****
      DOUBLE PRECISION RVALUE,R,TH,Z,VALUE
      COMMON /IOUNIT/ IBIN,IECHO,IN,IO,IRECLG,IBOUT
C
C INSERT ALGORITHM TO COMPUTE THE VALUE OF THE EMISSIVITY FUNCTION
C 'NUMBER' ASSOCIATED WITH NODE 'N' HERE
C
      WRITE(IO,9000)
9000  FORMAT('*** ERROR *** YOU HAVE CALLED SUBROUTINE EMSSVY',
* ' WHICH IS A USER-SUPPLIED SUBROUTINE',/
* ' *** ERROR *** THIS SUBROUTINE HAS NOT BEEN SUPPLIED.',
* ' EITHER SUPPLY SUBROUTINE EMSSVY',/
* ' *** ERROR *** OR CORRECT THE INPUT DATA TO',
* ' NOT REFERENCE THIS SUBROUTINE.')
```

Figure F16.4.1 User-supplied subroutine EMSSVY

F16.4.12.3. Card T2

The T2 cards contain the ordered pairs, all floating-point numbers. The first member of the pair is the independent variable; the second, the function value. A continuation card must contain an "@" in column 1.

An example of an acceptable tabular function is presented in Fig. F16.4.2. The input for this example is presented in Table F16.4.5.

Figure F16.4.2 Tabular function example

Table F16.4.5 T1 and T2 cards necessary to describe the tabular function depicted in Fig. F16.4.2

Entry	1	2	3	4	5	6	7	8	Card
	1	8							T1
	0.0	25.0	1.0	30.0	2.0	30.0	2.5	35.0	T2
	@3.5	35.0	4.0	30.0	4.5	30.0	5.5	20.0	T2

F16.4.13. Data Block Termination Card

Each problem (or case) must be terminated with a data block termination card. This card consists of a percent sign (%) in column 1, followed by a blank in column 2.

F16.4.14. Summary and Format of Input

A summary of the format and information needed to prepare the input data deck is presented in Table F16.4.6. Columns 73 through 80 of each card are reserved for identification. This input format assumes that an OCULAR input data deck is not being enhanced for use as a HEATING input data deck.

Thus all HEATING dependent input data are reflected as blank entries. The user should supply zeros in these entries when OCULAR is used in a stand-alone fashion. The table provides proposed identification names for the cards, and parenthetically, the section of the report where more information can be found. The first line in each format box includes the variable name actually used in the program, and in the parentheses, the variable type. The rest of the box includes a short explanation of the input in that box.

Table F16.4.6 Summary of OCULAR input data

Entry 1	Entry 2	Entry 3	Entry 4	Entry 5	Entry 6	Entry 7	Entry 8	Entry 9	Card
JOBDES - Job Description - Up to 72 Alphanumeric Characters									Card 1 (F16.4.3.1)
	NGEOM (I) Geometry Type Cylindrical Cartesian 1 r- θ -z 6 x-y-z 2 r- θ 7 x-y 3 r-z 8 x-z 4 r 9 x 5 z Spherical 10 r 11 r- ϕ 12 r- θ - ϕ								Card 2 (F16.4.3.2)
REGIONS									
NOREG(I) Region number	MATL(I) Region material number. (Card M) Enter zero for gap region	RRIN(R) Smaller X or R region dimension	RROT(R) Larger X or R region dimension	THLT(R) Smaller Y or θ region dimension	THRT(R) Larger Y or θ region dimension	ZZBK(R) Smaller Z or ϕ region dimension	ZZFR(R) Larger Z or θ region dimension		Card R1 (F16.4.4.2) Maximum MAXREG
NOTE: Although not used, this card cannot be omitted.									Card R2 (F16.4.4.3)
MATERIALS									
MAT(I) Material number	MATNAM(A) Material name							MCP(I) Phase change flag. Zero implies no phase changes	Card M (F16.4.5.2) Maximum MAXMAT
NOTE: This card is only present for materials with change of phase capabilities. There can only be MAXCP such materials.									Card PC (F16.4.5.3)

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Table F16.4.6 (continued)

Entry 1	Entry 2	Entry 3	Entry 4	Entry 5	Entry 6	Entry 7	Entry 8	Entry 9	Card
XGRID									
RG(R) Smallest X or R gross lattice line dimension	RG(R) Next X or R gross lattice line dimension	RG(R) Next X or R gross lattice line dimension	NOTE: Maximum of MAXGGL.						Card L1
NDRG(I) Number of divisions between corre- sponding X or R gross line and the following line	NDRG(I)	NDRG(I)	NOTE: Must have one less entry than in L1 cards. Maximum of MAXRFG.						Card N1 (F16.4.6.3)
ZGRID									
ZG(R)	NOTE: Same as L1 cards except for Z or ϕ direction. Maximum of MAXGGL.								Card L3 (F16.4.7.2)
NDZG(I)	NOTE: Same as N1 cards except for Z or ϕ direction. Maximum of MAXZFG.								Card N3 (F16.4.7.3)
ENCLOSURES									
NENCLT(I) Enclosure number	NENBCT(I) Boundary condition number describing heat transfer. Mech- anism in enclosure	NSRF(I) Number of surfaces defining enclosure							Card EN1 (F16.4.8.2) Maximum MAXENC
NSURFT(I) Surface number comprising enclosure.	NSURFT(I) Next surface number.	NSURFT(I) Next surface number.							Card EN2 (F16.4.8.3)
SURFACES									
NENSRT(I) Surface number	NEMST(I) Surface emissivity function number	ENRRIN(R) Smaller X or R surface dimension	ENRROT(R) Larger X or R surface dimension	ENTHLT(R) Smaller Y or θ surface dimension	ENTHRT(R) Larger Y or θ surface dimension	ENZBKB(R) Smaller Z or ϕ surface dimension	ENZZFK(R) Larger Z or θ surface dimension		Card SU (F16.4.9.2) Maximum MAXSRF
EMISSIONITIES									
NEMVYT(I) Emissivity number	EMIS(R) Emissivity if constant	NEMR(I) X- or R-dependent function number	NEMTH(I) Y- or θ -dependent function number	NEMZ(I) Z- or ϕ -dependent function number					Card EM (F16.4.10.2) Maximum MAXEM

Table F16.4.6 (continued)

Entry 1	Entry 2	Entry 3	Entry 4	Entry 5	Entry 6	Entry 7	Entry 8	Entry 9	Card
ANALYTICAL FUNCTIONS									
NANALT(I) Analytical function number	NPARM(I) Number of coefficients on A2 cards. Maximum MAXPAR	NOTE: A1 and A2 establish the mth analytical function in the form $F_m(V) = A_{m,1} + A_{m,2}V + A_{m,3}V^2 + A_{m,4}\cos(A_{m,5}V) + A_{m,6}\exp(A_{m,7}V) + A_{m,8}\sin(A_{m,9}V) + A_{m,10}\ln(A_{m,11}V).$							Card A1 (F16.4.11.2) Maximum MAXANA
NPRM(I) Coefficient index I	A(NPRM)(R) Coefficient $A_{m,I}$	NPRM(I) Coefficient index i	A(NPRM)(R) Coefficient $A_{m,I}$	NOTE: To indicate a user-supplied function, the second entry on Card A1 is zero and Card A2 is omitted.					Card A2 (F16.4.11.3)
TABULAR FUNCTIONS									
NTABL(I) Tabular function number	NTBPRS(I) Number of pairs in table. Maximum MAXPRS	NOTE: The code uses linear interpolation to obtain the value of this function.							Card T1 (F16.4.12.2) Maximum MAXTBL
ARG(1)(R) Independent variable	VAL(1)(R) Corresponding function value	ARG(2)(R) Independent variable	VAL(2)(R) Corresponding function value	NOTE: Maximum of MAXPRS pairs.					Card T2 (F16.4.12.3)
% Data Block Termination Card									(F16.4.13)

F16.4.17

F16.5 OUTPUT DESCRIPTION FOR OCULAR

F16.5.1. General

The output generated by the OCULAR program is best illustrated by an example, thus the reader is referred to Appendix F16.A for an example of the actual output. The code automatically lists the input data card images, tabulates the input data with descriptive headings, and lists model information generated by the code from the input data. If the problem runs to completion, the code prints the emitting node number, the absorbing node number, the exchange (configuration) factor between the emitting and the absorbing node and the sum of the factors for each emitting node. The sum of the factors should equal the emissivity of the emitting node. If the difference due to discretization error is unacceptable, the mesh should be refined and the problem rerun.

In addition to the exchange factor results, the code writes the data necessary for input to HEATING. These data consist of an emitting (base) node number, the number of exchange factor connections made to this node, the boundary condition number describing the heat transfer mechanism present in the enclosure, a reciprocity flag, the absorbing node numbers, and the connector value. The connector is defined as the product of the emitting node's area and the exchange factor between the two nodes. In addition to including this information as standard output, the code writes a binary data set to unit No. 12 to be read as input by HEATING. Any errors encountered in the input data which cause problem termination are included as program output.

F16.5.2. Input Return

If the input data are read in card image form, OCULAR automatically lists the card images with the card columns indicated every tenth card and with each card image numbered. Since this capability serves to document the input data exactly as these data were supplied to the code, this feature assists the user in the location of input data errors identified by the program.

The standard output contains a summary of the capabilities of the current version of OCULAR, along with a heading identifying the version of the code, the date and time of the run, and the computer on which the job was executed. This summary is followed by tables indicating the maximum number of parameters that may be utilized during the run. These values are obtained from the BLOCK DATA subprogram and any data entered through the OPTION data block. The values of parameters from the first three data cards are then tabulated along with the input/output logical unit numbers available for the program. The code then tabulates data it generates from the input data. These data include the fine lattice lines along each axis, the orientation of the enclosure surfaces, the total number of nodes in the problem, and the enclosure nodes. Additionally, the code writes a summary of the dimensional characteristics of the enclosure nodes.

F16.5.3. Exchange Factors

The user-oriented output from OCULAR lists the emitting node, the absorbing node, and the exchange factor between the two nodes. Additionally, the code prints the sum of the exchange factors from each emitting node to all absorbing nodes. This sum should equal the emissivity of the emitting node. If the difference due to discretization error is unacceptable, the mesh should be refined and the problem should be rerun. OCULAR reports the total number of connectors produced. This value may be used as the value for MAXCON in the HEATING data set.

F16.5.4. HEATING Input

OCULAR output data are written on a binary data set to unit 12 for input into HEATING as unformatted input through the CONNECTOR data block. This data set contains the emitting node number, the number of absorbing nodes to which the emitting node has connections, the boundary condition number describing the heat transfer mechanism present, a reciprocity flag, the absorbing node numbers, and the connector value. The connector is defined as the product of the exchange factor and the emitting node's area.

F16.6 REFERENCES

1. J. A. Wiebelt, *Engineering Radiation Heat Transfer*, Holt, Rinehart, and Winston, New York, 1966.
2. S. N. Rea, "Rapid Method for Determining Concentric Cylinder Radiation View Factors," *AIAA Journal* 13(8), 1122 (August 1975).
3. C. P. Minning, "Radiation Shape Factors between End Wall and Outer Wall of Concentric Tubular Enclosures," *AIAA Journal* 17(12), 1407 (December 1979).
4. C. P. Minning, "Shape Factors between Coaxial Annular Disks Separated by a Solid Cylinder," *AIAA Journal* 17(3), 318 (March 1979).
5. R. Siegel and J. R. Howell, *Thermal Radiation Heat Transfer*, McGraw-Hill, New York, 1981.
6. J. R. Howell, *A Catalog of Radiation Configuration Factors*, McGraw-Hill, New York, 1982.
7. P. T. Williams, "Sample Problems for RADFAC/HOTTEL/ TRUMP Radiation Calculations," Union Carbide Corp. Letter Report, Union Carbide Corp., Nucl. Div., Oak Ridge Gaseous Diffusion Plant, January 10, 1983.
8. G. E. Forsythe, M. A. Malcolm, and C. B. Moler, *Computer Methods for Mathematical Computations*, Prentice-Hall, Inc., 1977.

F16.A SAMPLE PROBLEM

The use of the OCULAR program is best illustrated by example. This sample problem is presented for instructive purposes. It is not intended to represent an actual engineering problem, but rather to introduce the novice user to the capabilities of the program. Graybody radiation exchange factors are computed for both an annular and cylindrical axisymmetric enclosure.

The problem of interest is illustrated in Fig. F16.A.1. The OCULAR input data set is presented in Fig. F16.A.2. The user-supplied routine EMSSVY employed in this model is presented in Fig. F16.A.3.

The model consists of three materials — iron, air, and stainless steel. The air is assumed not to participate in the radiant exchange. The surfaces of the steel and the iron are assumed to be treated to exhibit emissive characteristics dependent upon surface orientation. The emissivity for horizontally oriented surfaces present in the enclosure is referred to as the radial emissivity of a material. The emissivity for vertically oriented surfaces is referred to as the axial emissivity of a material. The emissivity data for iron are assumed constant. The emissivity of stainless steel varies as a function of axial position on the enclosure surface. These data are presented in Table F16.A.1 below.

Table F16.A.1 Hemispherical total emissive property data

Material	Iron	Stainless steel
Radial emissivity	0.3	—
Axial emissivity	0.8	$0.1 + 0.01 z$

Illustrated in Fig. F16.A.1 are the locations of regions, enclosures, and surfaces contained in the OCULAR input. Region numbers are contained in circles, enclosure numbers in squares, and surface numbers in triangles. Regions 1, 4, 5, and 7 contain material 1, defined to be iron. Regions 2 and 6 contain material 2, defined to be air. Regions 3 and 8 contain material 3, defined to be stainless steel.

Multidimensional radiant exchange is present in regions 2 and 6. These regions are defined to be enclosures 1 and 2, respectively.

Enclosure 1 is a cylindrical enclosure composed of four surfaces. Note that one of these surfaces describes the centerline. In the calculation of exchange factors, it is necessary for a complete enclosure to be input to OCULAR. The centerline surface is actually a pseudosurface that must be input in order to describe a complete enclosure, but which is eliminated from the problem solution by the program. The emissivity of the upper- and lower-ring surfaces is constant. The emissivity of the shell surface varies as a function of axial position on the shell. This positional-dependent emissivity is input using the user-supplied routine capability of OCULAR.

Enclosure 2 is an annular enclosure composed of six surfaces. The enclosure consists of a cylinder, lower ring, upper ring, and shell. The cylinder is comprised of three enclosure surfaces which exhibit the different emissive properties of the iron and steel composing the surface. The positional-dependent emissivity present on a portion of the cylinder is input using the analytical

Figure F16.A.1 Sample problem model geometry

function capability of OCULAR. The emissivity of the lower and upper rings is constant. The emissivity of the shell is positional-dependent and is input using the tabular function capability.

In developing an input data set to produce exchange factors that will later be input to HEATING, it is necessary to define the boundary condition number that will be used by HEATING to describe the heat transfer mechanism which is present between nodes input in the CONNECTOR data block. In this sample problem, it is assumed that boundary condition 1, input as the second entry on the EN1 card, will be used to describe the radiation heat transfer mechanism present between nodes. As a side note, the Stefan-Boltzmann constant would generally be entered as the coefficient for radiation in the HEATING input data set for boundary condition 1.

The output for this sample problem is presented in Table F16.A.2. The printed output contains an echo of the input, summary tables of the input data, descriptions of each enclosure, and the surfaces composing it. Additional output is provided describing the location and emissivity of each enclosure surface nodal area. This output is provided for the purpose of validation of the model. It is recommended that the user run HEATING to receive a nodal map of the problem. Note that corner nodes appear twice in the enclosure node summary. The area associated with a corner node is composed of a vertical and horizontal area. Exchange factors for these areas are computed and reported separately. Reciprocity is used to reduce the number of connectors input to HEATING.

```

OPTION
MAXRFG=53,MAXTFG=5,MAXZFG=53,MAXPBT=50,MAXSRF=10,
@MAXNEA=38,MAXREG=8,MAXEMS=6,MAXPTS=200
OCULAR SAMPLE PROBLEM
500 3 .30000000D+02 0 1 0 0
REGION
1 1 0.0 2.0 0.0 0.0 0.0 7.0
0
2 2 0.0 1.0 0.0 0.0 7.0 9.0
0
3 3 1.0 2.0 0.0 0.0 7.0 9.0
0
4 1 0.0 2.0 0.0 0.0 9.0 13.0
0
5 1 2.0 4.0 0.0 0.0 0.0 3.0
0
6 2 2.0 4.0 0.0 0.0 3.0 11.0
0
7 1 2.0 4.0 0.0 0.0 11.0 13.0
0
8 3 4.0 5.0 0.0 0.0 0.0 13.0
0
MATERIALS
1 IRON
2 AIR
3 STAINLSS
XGRID
0.0 1.0 2.0 4.0 5.0
4 1 6 1
ZGRID
0.0 3.0 7.0 9.0 11.0 13.0
1 3 5 3 1
ANALYTICAL FUNCTIONS
1 0
2 2
1 0.1 2 0.01
TABULAR FUNCTIONS
1 2
3.0 0.13 11.0 0.21
ENCLOSURES
1 1 4
1 2 3 4
2 1 6
5 6 7 8 9 10
SURFACES
1 6 0.0 0.0 0.0 0.0 7.0 9.0
2 1 0.0 1.0 0.0 0.0 7.0 7.0
3 2 1.0 1.0 0.0 0.0 7.0 9.0
4 1 0.0 1.0 0.0 0.0 9.0 9.0
5 1 2.0 4.0 0.0 0.0 3.0 3.0
6 3 2.0 2.0 0.0 0.0 3.0 7.0
7 4 2.0 2.0 0.0 0.0 7.0 9.0
8 3 2.0 2.0 0.0 0.0 9.0 11.0
9 1 2.0 4.0 0.0 0.0 11.0 11.0
10 5 4.0 4.0 0.0 0.0 3.0 11.0
EMISSIVITY
1 0.3
2 1.0 0 0 1
3 0.8
4 1.0 0 0 2
5 1.0 0 0 -1
6 1.0
%
```

Figure F16.A.2 Sample problem OCULAR input

```

      SUBROUTINE EMSSVY(RVALUE,R,TH,Z,VALUE,NUMBER)
C*****
C
C WHEN IT IS REFERENCED, THIS SUBROUTINE MUST BE SUPPLIED BY THE USER TO
C EVALUATE THE USER-SUPPLIED FUNCTION DEFINING THE EMISSIVITY
C THIS PARAMETER MAY BE POSITIONAL-DEPENDENT
C THE VARIABLES IN THE ARGUMENT LIST ARE DEFINED IN THE FOLLOWING TABLE
C (Y) INDICATES THAT THE VARIABLE HAS BEEN DEFINED WHEN THE ROUTINE
C IS CALLED. (N) INDICATES THAT IT HAS NOT BEEN DEFINED
C
C   VARIABLE      TYPE      DEFINITION
C   RVALUE        REAL      VALUE OF THE USER-SUPPLIED FUNCTION
C                               EVALUATING THE EMISSIVITY PROPERTY
C                               THIS VALUE MUST BE COMPUTED BY THE
C                               ROUTINE (N)
C   R              REAL      X OR R COORDINATE OF THE ENCLOSURE NODE(Y)
C   TH             REAL      Y OR TH COORDINATE OF THE ENCLOSURE NODE(Y)
C   Z              REAL      Z OR P COORDINATE OF THE ENCLOSURE NODE(Y)
C   VALUE          REAL      CONSTANT VALUE OF THE PARAMETER
C                               WHICH APPEARS ON ITS RESPECTIVE INPUT
C                               CARD (I) IF IT IS NONZERO
C                               IF = ZERO, VALUE=1.0 (Y)
C                               NAME IN CALLING SEQUENCE - EMIS(NEMVYT)
C   NUMBER         INTEGER    INDEX OF PARAMETER BEING EVALUATED (Y)
C                               NAME IN CALLING SEQUENCE - NEMVYT
C*****
C
      DOUBLE PRECISION RVALUE,R,TH,Z,VALUE
      RVALUE=VALUE*(0.10D0+Z/100.0D0)
      RETURN
      END

```

Figure F16.A.3 User-supplied routine EMSSVY

Table F16.A.2 OCULAR sample problem output

written by: c.b. bryan
contact:

g.e. giles
computing applications division
oak ridge national laboratory
building k-1007, mail stop number 7039
martin marietta energy systems, inc.
post office box 2003
oak ridge, tennessee 37831-7039

phone - 615-574-8667

definition of input/output units

name	no	unit number definitions
ibin	95	binary input data set (optional)
iecho	5	initial input data set
in	13	standard input data set
io	6	standard output data set
ireclg	80	record length in single word for binary data set on unit ibin (maximum of 80)
ibout	12	unformatted connector data set

print input card images with card columns indicated every 10th card--

card

no./col. 1.....10.....20.....30.....40.....50.....60.....70.....80

1	option
2	maxrfg=53,maxtfg=5,maxzfg=53,maxpbt=50,maxsrf=10,
3	amaxnea=38,maxreg=8,maxems=6,maxpts=200
4	ocular sample problem
5	500 3 .30000000D+02 0 1 0 0
6	region
7	1 1 0.0 2.0 0.0 0.0 0.0 7.0
8	2 2 0.0 1.0 0.0 0.0 7.0 9.0
9	0

no./col. 1.....10.....20.....30.....40.....50.....60.....70.....80

10	3 3 1.0 2.0 0.0 0.0 7.0 9.0
11	0
12	4 1 0.0 2.0 0.0 0.0 9.0 13.0
13	0
14	5 1 2.0 4.0 0.0 0.0 0.0 3.0
15	0
16	6 2 2.0 4.0 0.0 0.0 3.0 11.0
17	0
18	7 1 2.0 4.0 0.0 0.0 11.0 13.0
19	0

no./col. 1.....10.....20.....30.....40.....50.....60.....70.....80

20	8 3 4.0 5.0 0.0 0.0 0.0 13.0
21	0

22	materials
23	1 iron
24	2 air
25	3 stainless
26	xgrid
27	0.0 1.0 2.0 4.0 5.0
28	4 1 6 1
29	zgrid
no./col.	1.....10.....20.....30.....40.....50.....60.....70.....80
30	0.0 3.0 7.0 9.0 11.0 13.0
31	1 3 5 3 1
32	analytical functions
33	1 0
34	2 2
35	1 0.1 2 0.01
36	tabular functions
37	1 2
38	3.0 0.13 11.0 0.21
39	enclosures
no./col.	1.....10.....20.....30.....40.....50.....60.....70.....80
40	1 1 4
41	1 2 3 4
42	2 1 6
43	5 6 7 8 9 10
44	surfaces
45	1 6 0.0 0.0 0.0 0.0 7.0 9.0
46	2 1 0.0 1.0 0.0 0.0 7.0 7.0
47	3 2 1.0 1.0 0.0 0.0 7.0 9.0
48	4 1 0.0 1.0 0.0 0.0 9.0 9.0
49	5 1 2.0 4.0 0.0 0.0 3.0 3.0
no./col.	1.....10.....20.....30.....40.....50.....60.....70.....80
50	6 3 2.0 2.0 0.0 0.0 3.0 7.0
51	7 4 2.0 2.0 0.0 0.0 7.0 9.0
52	8 3 2.0 2.0 0.0 0.0 9.0 11.0
53	9 1 2.0 4.0 0.0 0.0 11.0 11.0
54	10 5 4.0 4.0 0.0 0.0 3.0 11.0
55	emissivity
56	1 0.3
57	2 1.0 0 0 1
58	3 0.8
59	4 1.0 0 0 2
no./col.	1.....10.....20.....30.....40.....50.....60.....70.....80
60	5 1.0 0 0 -1
61	6 1.0
62	%
63	%
64	end

Table F16.A.2 (continued)

the variably dimensioned arrays require 82814 single words or 324k bytes of core.

release date: 05/12/93

fortran 77 - first edition

code: ocular 05/12/93
date: 06/14/93
time: 14:53:53
jobnam: geg
computer: unix

job description -- ocular sample problem
geometry type number
definition of input/output units
iecho 5 initial input data set
in 13 standard input data set
io 6 standard output data set
ibout 12 unformatted connector data set

3 (or rz)

number of parameters specified by the input data

number of regions	8
number of materials	3
number of analytical functions	2
number of tabular functions	1
number of points in gross x or r lattice	5
number of points in gross y of t lattice	1
number of points in gross z or p lattice	6
number of enclosures in the model	2
number of surfaces	10
number of emissivities	6

summary of region data

***** dimensions *****

region number	left-x or inner-r	right-x or outer-r	lower-y or left-theta	upper-y or right-theta	rear-z or upper phi	front-z or lower phi
1	.0000	2.0000	.0000	.0000	.0000	7.0000
2	.0000	1.0000	.0000	.0000	7.0000	9.0000
3	1.0000	2.0000	.0000	.0000	7.0000	9.0000
4	.0000	2.0000	.0000	.0000	9.0000	13.0000
5	2.0000	4.0000	.0000	.0000	.0000	3.0000
6	2.0000	4.0000	.0000	.0000	3.0000	11.0000
7	2.0000	4.0000	.0000	.0000	11.0000	13.0000
8	4.0000	5.0000	.0000	.0000	.0000	13.0000

Table F16.A.2 (continued)

region number	material number	initial temp	heat generation	-----boundary numbers-----											
				lf-x in-r	rt-x ot-r	lo-y lf-t	up-y rt-t	rr-z sm-p	ft-z lg-p						
1	1	0	0	0	0	0	0	0	0	0	0	0	0		
2	2	0	0	0	0	0	0	0	0	0	0	0	0		
3	3	0	0	0	0	0	0	0	0	0	0	0	0		
4	1	0	0	0	0	0	0	0	0	0	0	0	0		
5	1	0	0	0	0	0	0	0	0	0	0	0	0		
6	2	0	0	0	0	0	0	0	0	0	0	0	0		
7	1	0	0	0	0	0	0	0	0	0	0	0	0		
8	3	0	0	0	0	0	0	0	0	0	0	0	0		
gross lattices and number of increments															
r or x				.000000	1.000000	2.000000	4.000000	5.000000							
				4	1	6	1								
phi or z				.000000	3.000000	7.000000	9.000000	11.000000	13.000000						
				1	3	5	3		1						
summary of material data															
material number	material name														
1	iron														
2	air														
3	stainlss														

Table F16.A.2 (continued)

summary of analytic functions

$$f(v) = a(1) + a(2)*v + a(3)*v**2 + a(4)*\cos(a(5)*v) + a(6)*\exp(a(7)*v) + a(8)*\sin(a(9)*v) + a(10)*\log(a(11)*v)$$

no.	a(1)	a(2)	a(3)	a(4)	a(5)	a(6)	a(7)	a(8)	a(9)	a(10)	a(11)
2	1.000D-01	1.000D-02	0.000D+00	0.000D+00	0.000D+00	0.000D+00	0.000D+00	0.000D+00	0.000D+00	0.000D+00	0.000D+00

analytic function no. 1 is user supplied

summary of tabular functions

table number - argument	1	number of pairs - value	2
3.00000000D+00		1.30000000D-01	
1.10000000D+01		2.10000000D-01	

Table F16.A.2 (continued)

summary of enclosure data

enclosure number	boundary condition describing the heat transfer mechanism in the enclosure	surface numbers comprising the ***** enclosure *****							
1	1	1	2	3	4				
2	1	5	6	7	8	9	10		

summary of surface data

***** dimensions *****							
surface number	emissivity number	left-x or inner-r	right-x or outer-r	lower-y or left-theta	upper-y or right-theta	rear-z or lower phi	front-z or upper phi
1	6	.0000	.0000	.0000	.0000	7.0000	9.0000
2	1	.0000	1.0000	.0000	.0000	7.0000	7.0000
3	2	1.0000	1.0000	.0000	.0000	7.0000	9.0000
4	1	.0000	1.0000	.0000	.0000	9.0000	9.0000
5	1	2.0000	4.0000	.0000	.0000	3.0000	3.0000
6	3	2.0000	2.0000	.0000	.0000	3.0000	7.0000
7	4	2.0000	2.0000	.0000	.0000	7.0000	9.0000
8	3	2.0000	2.0000	.0000	.0000	9.0000	11.0000
9	1	2.0000	4.0000	.0000	.0000	11.0000	11.0000
10	5	4.0000	4.0000	.0000	.0000	3.0000	11.0000

summary of emissivity data

number	emissivity	position-dependent function numbers		
		x or r	y or th	z or p
1	3.00000D-01	0	0	0
2	1.00000D+00	0	0	1
3	8.00000D-01	0	0	0
4	1.00000D+00	0	0	2
5	1.00000D+00	0	0	-1
6	1.00000D+00	0	0	0

summary of fine lattice lines
x or r fine lattice lines

1	.000000	2	.250000	3	.500000	4	.750000	5	1.000000
6	2.000000	7	2.333333	8	2.666667	9	3.000000	10	3.333333
11	3.666667	12	4.000000	13	5.000000				

F16.A.11

Table F16.A.2 (continued)

z or phi fine lattice lines

1	.000000	2	3.000000	3	4.333333	4	5.666667	5	7.000000
6	7.400000	7	7.800000	8	8.200000	9	8.600000	10	9.000000
11	9.666667	12	10.333333	13	11.000000	14	13.000000		

***** job description *****ocular sample problem

***** the input data for this case have been read and processed

***** number of errors encountered in the input data for this case was -- 0

***** number of warnings encountered in the input data for this case was -- 0

summary of surface orientations

surface number 1 is a z (or phi) surface
 surface number 2 is an x (or r) surface
 surface number 3 is a z (or phi) surface
 surface number 4 is an x (or r) surface
 surface number 5 is an x (or r) surface
 surface number 6 is a z (or phi) surface
 surface number 7 is a z (or phi) surface
 surface number 8 is a z (or phi) surface
 surface number 9 is an x (or r) surface
 surface number 10 is a z (or phi) surface

summary of enclosure surface connections

enclosure number 1

surface connected to surface

1	2
1	4
2	1
2	3
3	2
3	4
4	1
4	3

enclosure number 2

surface connected to surface

5	6
5	10
6	5
6	7
7	6
7	8

Table F16.A.2 (continued)

8	7
8	9
9	8
9	10
10	5
10	9

this model contains 182 nodes.

summary of enclosure nodes
enclosure number 1

base surface nodes

node number	nodal area	radial location	axial location	area boundaries		emissivity
				minimum r	maximum r	
53	.049087	.000000	7.000000	.000000	.125000	.300000
54	.392699	.250000	7.000000	.125000	.375000	.300000
55	.785398	.500000	7.000000	.375000	.625000	.300000
56	1.178097	.750000	7.000000	.625000	.875000	.300000
57	.736311	1.000000	7.000000	.875000	1.000000	.300000

upper surface nodes

node number	nodal area	radial location	axial location	area boundaries		emissivity
				minimum r	maximum r	
118	.049087	.000000	9.000000	.000000	.125000	.300000
119	.392699	.250000	9.000000	.125000	.375000	.300000
120	.785398	.500000	9.000000	.375000	.625000	.300000
121	1.178097	.750000	9.000000	.625000	.875000	.300000
122	.736311	1.000000	9.000000	.875000	1.000000	.300000

shell surface nodes

node number	nodal area	radial location	axial location	area boundaries		emissivity
				minimum z	maximum z	
57	1.256637	1.000000	7.000000	7.000000	7.200000	.170000
70	2.513274	1.000000	7.400000	7.200000	7.600000	.174000
83	2.513274	1.000000	7.800000	7.600000	8.000000	.178000
96	2.513274	1.000000	8.200000	8.000000	8.400000	.182000
109	2.513274	1.000000	8.600000	8.400000	8.800000	.186000
122	1.256637	1.000000	9.000000	8.800000	9.000000	.190000

F16.A.13

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Table F16.A.2 (continued)

ocular	05/12/93	ocular sample problem										14:53:53	06/14/93
geg		***** summary of exchange factor data*****											
enclosure number		1											

heat transfer mechanism specified by boundary condition		1.											

node / exchange		exchange factors from node i to node j											
i / factor sum	/	node j factor	node j factor	node j factor	node j factor	node j factor	node j factor	node j factor	node j factor	node j factor	node j factor	node j factor	node j factor
53	3.00000D-01	53 9.23053D-04	54 7.39448D-03	55 1.48043D-02	56 2.18573D-02	57 1.28627D-02	57 1.33311D-02						
		70 3.64666D-02	83 3.85296D-02	96 3.53164D-02	109 3.21274D-02	118 1.20961D-03	119 9.56428D-03						
		120 1.85481D-02	121 2.63995D-02	122 1.55690D-02	122 1.50966D-02								
54	3.00000D-01	53 9.24310D-04	54 7.41038D-03	55 1.48703D-02	56 2.20481D-02	57 1.30308D-02	57 1.37262D-02						
		70 3.74176D-02	83 3.83694D-02	96 3.48563D-02	109 3.17331D-02	118 1.19609D-03	119 9.46269D-03						
		120 1.83733D-02	121 2.61863D-02	122 1.54590D-02	122 1.49361D-02								
55	3.00000D-01	53 9.25272D-04	54 7.43515D-03	55 1.50234D-02	56 2.25959D-02	57 1.36075D-02	57 1.52132D-02						
		70 3.99174D-02	83 3.75008D-02	96 3.35553D-02	109 3.06825D-02	118 1.16139D-03	119 9.19931D-03						
		120 1.79094D-02	121 2.56077D-02	122 1.51578D-02	122 1.45080D-02								
56	3.00000D-01	53 9.10720D-04	54 7.34937D-03	55 1.50639D-02	56 2.36185D-02	57 1.54437D-02	57 2.08592D-02						
		70 4.18863D-02	83 3.47391D-02	96 3.12242D-02	109 2.89106D-02	118 1.10532D-03	119 8.76705D-03						
		120 1.71228D-02	121 2.45951D-02	122 1.46240D-02	122 1.37802D-02								
57	3.00000D-01	53 8.57513D-04	54 6.94975D-03	55 1.45146D-02	56 2.47099D-02	57 1.93835D-02	57 3.43904D-02						
		70 3.61126D-02	83 3.10345D-02	96 2.87806D-02	109 2.70657D-02	118 1.04752D-03	119 8.31693D-03						
		120 1.62865D-02	121 2.34985D-02	122 1.40415D-02	122 1.30099D-02								
57	1.70000D-01	53 5.20744D-04	54 4.28943D-03	55 9.50825D-03	56 1.95555D-02	57 2.01506D-02	57 1.15187D-02						
		70 1.95657D-02	83 1.72759D-02	96 1.55350D-02	109 1.41830D-02	118 5.30528D-04	119 4.19713D-03						
		120 8.14231D-03	121 1.15655D-02	122 6.79416D-03	122 6.66747D-03								
70	1.74000D-01	53 7.12237D-04	54 5.84650D-03	55 1.24742D-02	56 1.96342D-02	57 1.05799D-02	57 9.78287D-03						
		70 2.06916D-02	83 1.93472D-02	96 1.74429D-02	109 1.58448D-02	118 5.88848D-04	119 4.65083D-03						
		120 8.98113D-03	121 1.26548D-02	122 7.37094D-03	122 7.39715D-03								
83	1.78000D-01	53 7.52531D-04	54 5.99522D-03	55 1.17190D-02	56 1.62839D-02	57 9.09214D-03	57 8.63794D-03						
		70 1.93472D-02	83 2.09892D-02	96 1.99087D-02	109 1.81812D-02	118 6.74683D-04	119 5.32467D-03						
		120 1.02374D-02	121 1.42442D-02	122 8.16696D-03	122 8.44497D-03								
96	1.82000D-01	53 6.89774D-04	54 5.44630D-03	55 1.04860D-02	56 1.46363D-02	57 8.43181D-03	57 7.76749D-03						
		70 1.74429D-02	83 1.99087D-02	96 2.18772D-02	109 2.10227D-02	118 7.67291D-04	119 6.11008D-03						
		120 1.19272D-02	121 1.65200D-02	122 9.17595D-03	122 9.79021D-03								
109	1.86000D-01	53 6.27488D-04	54 4.95830D-03	55 9.58827D-03	56 1.35519D-02	57 7.92939D-03	57 7.09151D-03						
		70 1.58448D-02	83 1.81812D-02	96 2.10227D-02	109 2.34588D-02	118 7.57301D-04	119 6.21441D-03						
		120 1.32471D-02	121 2.08043D-02	122 1.11484D-02	122 1.15742D-02								
118	3.00000D-01	53 1.20961D-03	54 9.56869D-03	55 1.85823D-02	56 2.65277D-02	57 1.57128D-02	57 1.35815D-02						
		70 3.01490D-02	83 3.45438D-02	96 3.92853D-02	109 3.87738D-02	118 9.19318D-04	119 7.36004D-03						
		120 1.47094D-02	121 2.16398D-02	122 1.26710D-02	122 1.47660D-02								

Table F16.A.2 (continued)

119	3.00000D-01	53	1.19554D-03	54	9.46269D-03	55	1.83986D-02	56	2.63011D-02	57	1.55942D-02	57	1.34308D-02
		70	2.97653D-02	83	3.40779D-02	96	3.91045D-02	109	3.97722D-02	118	9.20004D-04	119	7.37130D-03
		120	1.47656D-02	121	2.18145D-02	122	1.28276D-02	122	1.51980D-02				
120	3.00000D-01	53	1.15926D-03	54	9.18663D-03	55	1.79094D-02	56	2.56842D-02	57	1.52686D-02	57	1.30277D-02
		70	2.87396D-02	83	3.27597D-02	96	3.81671D-02	109	4.23908D-02	118	9.19337D-04	119	7.38281D-03
		120	1.48907D-02	121	2.23146D-02	122	1.33684D-02	122	1.68312D-02				
121	3.00000D-01	53	1.09998D-03	54	8.72878D-03	55	1.70718D-02	56	2.45951D-02	57	1.46866D-02	57	1.23365D-02
		70	2.69968D-02	83	3.03877D-02	96	3.52428D-02	109	4.43825D-02	118	9.01658D-04	119	7.27150D-03
		120	1.48764D-02	121	2.32343D-02	122	1.51114D-02	122	2.30761D-02				
122	3.00000D-01	53	1.03793D-03	54	8.24481D-03	55	1.61683D-02	56	2.33983D-02	57	1.40415D-02	57	1.15954D-02
		70	2.51595D-02	83	2.78766D-02	96	3.13206D-02	109	3.80533D-02	118	8.44730D-04	119	6.84139D-03
		120	1.42597D-02	121	2.41782D-02	122	1.88814D-02	122	3.80984D-02				
122	1.90000D-01	53	5.89713D-04	54	4.66753D-03	55	9.06752D-03	56	1.29189D-02	57	7.62297D-03	57	6.66747D-03
		70	1.47943D-02	83	1.68899D-02	96	1.95804D-02	109	2.31484D-02	118	5.76796D-04	119	4.74938D-03
		120	1.05195D-02	121	2.16339D-02	122	2.23233D-02	122	1.42500D-02				

***** summary of heating6 input data*****

connectors

53 16 1 1

53 4.531026D-05 54 3.629756D-04 55 7.267068D-04

a 56 1.072917D-03 57 6.313958D-04 57 6.543868D-04

a 70 1.790048D-03 83 1.891318D-03 96 1.733591D-03

a 109 1.577049D-03 118 5.937658D-05 119 4.694857D-04

a 120 9.104778D-04 121 1.295882D-03 122 7.642423D-04

a 122 7.410549D-04

54 15 1 1

54 2.910049D-03 55 5.839551D-03 56 8.658273D-03

a 57 5.117173D-03 57 5.390261D-03 70 1.469387D-02

a 83 1.506764D-02 96 1.368804D-02 109 1.246157D-02

a 118 4.697019D-04 119 3.715988D-03 120 7.215159D-03

a 121 1.028335D-02 122 6.070740D-03 122 5.865385D-03

55 14 1 1

55 1.179933D-02 56 1.774677D-02 57 1.068729D-02

a 57 1.194842D-02 70 3.135108D-02 83 2.945307D-02

a 96 2.635427D-02 109 2.409794D-02 118 9.121566D-04

a 119 7.225123D-03 120 1.406601D-02 121 2.011225D-02

a 122 1.190488D-02 122 1.139458D-02

56 13 1 1

56 2.782484D-02 57 1.819420D-02 57 2.457412D-02

a 70 4.934619D-02 83 4.092598D-02 96 3.678509D-02

a 109 3.405955D-02 118 1.302174D-03 119 1.032843D-02

a 120 2.017231D-02 121 2.897546D-02 122 1.722845D-02

a 122 1.623442D-02

57 12 1 1

57 1.427229D-02 57 2.532205D-02 70 2.659006D-02

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Table F16.A.2 (continued)

83	2.285104D-02	96	2.119146D-02	109	1.992874D-02
118	7.713006D-04	119	6.123844D-03	120	1.199194D-02
121	1.730223D-02	122	1.033893D-02	122	9.579306D-03
57	11 1 1				
57	1.447486D-02	70	2.458703D-02	83	2.170950D-02
96	1.952184D-02	109	1.782290D-02	118	6.666817D-04
119	5.274271D-03	120	1.023193D-02	121	1.453365D-02
122	8.537797D-03	122	8.378592D-03		
70	10 1 1				
70	5.200361D-02	83	4.862491D-02	96	4.383877D-02
109	3.982222D-02	118	1.479938D-03	119	1.168880D-02
120	2.257205D-02	121	3.180486D-02	122	1.852519D-02
122	1.859107D-02				
83	9 1 1				
83	5.275164D-02	96	5.003600D-02	109	4.569421D-02
118	1.695663D-03	119	1.338235D-02	120	2.572941D-02
121	3.579969D-02	122	2.052582D-02	122	2.122453D-02
96	8 1 1				
96	5.498346D-02	109	5.283571D-02	118	1.928413D-03
119	1.535631D-02	120	2.997639D-02	121	4.151940D-02
122	2.306167D-02	122	2.460547D-02		
109	7 1 1				
109	5.895851D-02	118	1.903305D-03	119	1.561851D-02
120	3.329362D-02	121	5.228694D-02	122	2.801909D-02
122	2.908912D-02				
118	6 1 1				
118	4.512690D-05	119	3.612849D-04	120	7.220458D-04
121	1.062240D-03	122	6.219841D-04	122	7.248237D-04
119	5 1 1				
119	2.894704D-03	120	5.798449D-03	121	8.566536D-03
122	5.037392D-03	122	5.968242D-03		
120	4 1 1				
120	1.169515D-02	121	1.752582D-02	122	1.049954D-02
122	1.321916D-02				
121	3 1 1				
121	2.737229D-02	122	1.780265D-02	122	2.718592D-02
122	2 1 1				
122	1.390261D-02	122	2.805226D-02		
122	1 1 1				
122	1.790710D-02				

Table F16.A.2 (continued)

summary of enclosure nodes						
enclosure number 2						
cylinder surface nodes						
node number	nodal area	radial location	axial location	area boundaries		emissivity
				minimum z	maximum z	
19	8.377580	2.000000	3.000000	3.000000	3.666667	.800000
32	16.755161	2.000000	4.333333	3.666667	5.000000	.800000
45	16.755161	2.000000	5.666667	5.000000	6.333333	.800000
58	10.890855	2.000000	7.000000	6.333333	7.200000	.655077
71	5.026548	2.000000	7.400000	7.200000	7.600000	.174000
84	5.026548	2.000000	7.800000	7.600000	8.000000	.178000
97	5.026548	2.000000	8.200000	8.000000	8.400000	.182000
110	5.026548	2.000000	8.600000	8.400000	8.800000	.186000
123	6.702064	2.000000	9.000000	8.800000	9.333333	.570500
136	8.377580	2.000000	9.666667	9.333333	10.000000	.800000
149	8.377580	2.000000	10.333333	10.000000	10.666667	.800000
162	4.188790	2.000000	11.000000	10.666667	11.000000	.800000
base surface nodes						
node number	nodal area	radial location	axial location	area boundaries		emissivity
				minimum r	maximum r	
19	2.181662	2.000000	3.000000	2.000000	2.166667	.300000
20	4.886922	2.333333	3.000000	2.166667	2.500000	.300000
21	5.585054	2.666667	3.000000	2.500000	2.833333	.300000
22	6.283185	3.000000	3.000000	2.833333	3.166667	.300000
23	6.981317	3.333333	3.000000	3.166667	3.500000	.300000
24	7.679449	3.666667	3.000000	3.500000	3.833333	.300000
25	4.101524	4.000000	3.000000	3.833333	4.000000	.300000
upper surface nodes						
node number	nodal area	radial location	axial location	area boundaries		emissivity
				minimum r	maximum r	
162	2.181662	2.000000	11.000000	2.000000	2.166667	.300000
163	4.886922	2.333333	11.000000	2.166667	2.500000	.300000
164	5.585054	2.666667	11.000000	2.500000	2.833333	.300000
165	6.283185	3.000000	11.000000	2.833333	3.166667	.300000
166	6.981317	3.333333	11.000000	3.166667	3.500000	.300000
167	7.679449	3.666667	11.000000	3.500000	3.833333	.300000
168	4.101524	4.000000	11.000000	3.833333	4.000000	.300000
shell surface nodes						
node number	nodal area	radial location	axial location	area boundaries		emissivity
				minimum z	maximum z	
25	16.755161	4.000000	3.000000	3.000000	3.666667	.130000
38	33.510322	4.000000	4.333333	3.666667	5.000000	.143333

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Table F16.A.2 (continued)

51	33.510322	4.000000	5.666667	5.000000	6.333333	.156667
64	21.781709	4.000000	7.000000	6.333333	7.200000	.165333
77	10.053096	4.000000	7.400000	7.200000	7.600000	.174000
90	10.053096	4.000000	7.800000	7.600000	8.000000	.178000
103	10.053096	4.000000	8.200000	8.000000	8.400000	.182000
116	10.053096	4.000000	8.600000	8.400000	8.800000	.186000
129	13.404129	4.000000	9.000000	8.800000	9.333333	.191333
142	16.755161	4.000000	9.666667	9.333333	10.000000	.196667
155	16.755161	4.000000	10.333333	10.000000	10.666667	.203333
168	8.377580	4.000000	11.000000	10.666667	11.000000	.210000

Table F16.A.2 (continued)

ocular geg	05/12/93	ocular sample problem										14:53:53	06/14/93		
***** summary of exchange factor data*****															
enclosure number		2													

heat transfer mechanism specified by boundary condition				1.											

node /		exchange		exchange factors from node i to node j											
i /		factor sum		/ node j factor		/ node j factor		/ node j factor		/ node j factor		/ node j factor		/ node j factor	
19		8.00000D-01		19	8.70522D-02	19	2.78361D-02	20	3.98851D-02	21	2.73511D-02	22	2.21879D-02	23	2.10817D-02
				24	2.24168D-02	25	1.22969D-02	25	3.26076D-02	32	1.18061D-01	38	5.78237D-02	45	8.68303D-02
				51	3.60056D-02	58	3.44527D-02	64	1.72022D-02	71	3.57946D-03	77	7.23448D-03	84	3.32275D-03
				90	6.83011D-03	97	3.10136D-03	103	6.44277D-03	110	2.91356D-03	116	6.05997D-03	123	1.09198D-02
				129	7.54867D-03	136	1.74604D-02	142	8.71161D-03	149	1.61760D-02	155	8.38124D-03	162	7.51869D-03
				162	1.68490D-03	163	4.34955D-03	164	5.38748D-03	165	6.28354D-03	166	7.05037D-03	167	7.67711D-03
				168	4.02458D-03	168	4.25056D-03								
19		2.99999D-01		19	1.06891D-01	19	1.55742D-03	20	3.01703D-03	21	3.08172D-03	22	3.34040D-03	23	3.67553D-03
				24	3.96680D-03	25	2.05108D-03	25	4.77560D-03	32	3.10090D-02	38	1.45713D-02	45	2.55864D-02
				51	1.27131D-02	58	1.16327D-02	64	6.78746D-03	71	1.28217D-03	77	2.92737D-03	84	1.22578D-03
				90	2.79107D-03	97	1.17330D-03	103	2.65507D-03	110	1.12652D-03	116	2.51769D-03	123	4.31618D-03
				129	3.16669D-03	136	7.07235D-03	142	3.70209D-03	149	6.69157D-03	155	3.61477D-03	162	3.11367D-03
				162	6.96418D-04	163	1.87926D-03	164	2.37196D-03	165	2.78767D-03	166	3.14056D-03	167	3.43117D-03
				168	1.80469D-03	168	1.85509D-03								
20		3.00000D-01		19	6.83745D-02	19	1.34689D-03	20	2.87684D-03	21	3.19491D-03	22	3.60494D-03	23	4.03826D-03
				24	4.39435D-03	25	2.27967D-03	25	5.33106D-03	32	4.90653D-02	38	1.63003D-02	45	3.04631D-02
				51	1.39042D-02	58	1.32711D-02	64	7.47968D-03	71	1.45281D-03	77	3.24795D-03	84	1.38686D-03
				90	3.10849D-03	97	1.32697D-03	103	2.96693D-03	110	1.27450D-03	116	2.82175D-03	123	4.88786D-03
				129	3.56014D-03	136	8.02470D-03	142	4.17683D-03	149	7.62381D-03	155	4.08954D-03	162	3.58317D-03
				162	8.34328D-04	163	2.19161D-03	164	2.72816D-03	165	3.18338D-03	166	3.57101D-03	167	3.89118D-03
				168	2.04401D-03	168	2.09889D-03								
21		3.00000D-01		19	4.10266D-02	19	1.20380D-03	20	2.79555D-03	21	3.30818D-03	22	3.85236D-03	23	4.40064D-03
				24	4.88005D-03	25	2.57571D-03	25	6.29246D-03	32	6.03600D-02	38	1.80326D-02	45	3.54693D-02
				51	1.43439D-02	58	1.46144D-02	64	7.73607D-03	71	1.57748D-03	77	3.38235D-03	84	1.49859D-03
				90	3.24980D-03	97	1.42950D-03	103	3.11222D-03	110	1.37047D-03	116	2.96835D-03	123	5.25048D-03
				129	3.75572D-03	136	8.61860D-03	142	4.42068D-03	149	8.20018D-03	155	4.34180D-03	162	3.87381D-03
				162	9.17361D-04	163	2.37625D-03	164	2.93732D-03	165	3.41599D-03	166	3.82547D-03	167	4.16572D-03
				168	2.18834D-03	168	2.23186D-03								
22		3.00000D-01		19	2.95839D-02	19	1.15986D-03	20	2.80384D-03	21	3.42432D-03	22	4.07490D-03	23	4.76297D-03
				24	5.46525D-03	25	2.99040D-03	25	7.91875D-03	32	6.13902D-02	38	1.93342D-02	45	3.88166D-02
				51	1.40591D-02	58	1.54287D-02	64	7.64927D-03	71	1.64553D-03	77	3.37330D-03	84	1.55653D-03
				90	3.25576D-03	97	1.48067D-03	103	3.12962D-03	110	1.41717D-03	116	2.99416D-03	123	5.42425D-03
				129	3.79985D-03	136	8.90221D-03	142	4.48828D-03	149	8.47814D-03	155	4.42442D-03	162	4.01658D-03
				162	9.57240D-04	163	2.46143D-03	164	3.03233D-03	165	3.52197D-03	166	3.94315D-03	167	4.29598D-03
				168	2.25873D-03	168	2.28030D-03								

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Table F16.A.2 (continued)

23	3.00000D-01	19	2.52980D-02	19	1.14860D-03	20	2.82678D-03	21	3.52051D-03	22	4.28668D-03	23	5.19333D-03
		24	6.33814D-03	25	3.69679D-03	25	1.09675D-02	32	5.92289D-02	38	1.95613D-02	45	4.03240D-02
		51	1.31993D-02	58	1.57431D-02	64	7.34022D-03	71	1.66697D-03	77	3.27383D-03	84	1.57306D-03
		90	3.17720D-03	97	1.49444D-03	103	3.06780D-03	110	1.42960D-03	116	2.94587D-03	123	5.47224D-03
		129	3.75219D-03	136	8.98829D-03	142	4.45086D-03	149	8.57357D-03	155	4.40786D-03	162	4.07105D-03
		162	9.72890D-04	163	2.49065D-03	164	3.06301D-03	165	3.55667D-03	166	3.98416D-03	167	4.34604D-03
		168	2.28842D-03	168	2.28005D-03								
24	3.00000D-01	19	2.44547D-02	19	1.12693D-03	20	2.79640D-03	21	3.54913D-03	22	4.47157D-03	23	5.76194D-03
		24	7.79804D-03	25	5.00029D-03	25	1.68746D-02	32	5.66883D-02	38	1.71876D-02	45	3.99044D-02
		51	1.18715D-02	58	1.55191D-02	64	6.86558D-03	71	1.64206D-03	77	3.10627D-03	84	1.55041D-03
		90	3.03470D-03	97	1.47440D-03	103	2.94615D-03	110	1.41227D-03	116	2.84189D-03	123	5.41552D-03
		129	3.63631D-03	136	8.91765D-03	142	4.33688D-03	149	8.53078D-03	155	4.32079D-03	162	4.06048D-03
		162	9.72080D-04	163	2.48185D-03	164	3.05011D-03	165	3.54339D-03	166	3.97416D-03	167	4.34369D-03
		168	2.29205D-03	168	2.24599D-03								
25	3.00000D-01	19	2.51170D-02	19	1.09100D-03	20	2.71620D-03	21	3.50735D-03	22	4.58105D-03	23	6.29242D-03
		24	9.36225D-03	25	6.46097D-03	25	2.36165D-02	32	5.49686D-02	38	1.31219D-02	45	3.84578D-02
		51	1.06874D-02	58	1.50249D-02	64	6.43700D-03	71	1.59639D-03	77	2.94910D-03	84	1.51117D-03
		90	2.89772D-03	97	1.44063D-03	103	2.82644D-03	110	1.38316D-03	116	2.73735D-03	123	5.31768D-03
		129	3.51698D-03	136	8.78445D-03	142	4.21537D-03	149	8.43021D-03	155	4.22284D-03	162	4.02096D-03
		162	9.63990D-04	163	2.45808D-03	164	3.02085D-03	165	3.51204D-03	166	3.94416D-03	167	4.31920D-03
		168	2.28369D-03	168	2.20507D-03								
25	1.30000D-01	19	1.63038D-02	19	6.21823D-04	20	1.55489D-03	21	2.09749D-03	22	2.96953D-03	23	4.56981D-03
		24	7.73421D-03	25	5.78112D-03	25	3.65743D-03	32	2.70671D-02	38	5.26631D-03	45	1.53540D-02
		51	4.19050D-03	58	5.46195D-03	64	2.37528D-03	71	5.60316D-04	77	1.05454D-03	84	5.20707D-04
		90	1.01807D-03	97	4.87947D-04	103	9.76820D-04	110	4.60843D-04	116	9.31217D-04	123	1.73898D-03
		129	1.17484D-03	136	2.80606D-03	142	1.37432D-03	149	2.63167D-03	155	1.33650D-03	162	1.24195D-03
		162	2.90380D-04	163	7.40117D-04	164	9.03325D-04	165	1.03893D-03	166	1.15023D-03	167	1.23648D-03
		168	6.42125D-04	168	6.78380D-04								
32	8.00000D-01	19	5.90305D-02	19	4.03763D-03	20	1.43107D-02	21	2.01200D-02	22	2.30213D-02	23	2.46787D-02
		24	2.59821D-02	25	1.34559D-02	25	2.70671D-02	32	1.23643D-01	38	6.53800D-02	45	1.03892D-01
		51	5.09373D-02	58	4.27310D-02	64	2.24513D-02	71	4.41326D-03	77	8.94369D-03	84	4.05726D-03
		90	8.24459D-03	97	3.74277D-03	103	7.63463D-03	110	3.47215D-03	116	7.07494D-03	123	1.28232D-02
		129	8.68581D-03	136	2.01357D-02	142	9.86154D-03	149	1.83285D-02	155	9.33496D-03	162	8.44981D-03
		162	1.84935D-03	163	4.73154D-03	164	5.84059D-03	165	6.79889D-03	166	7.60906D-03	167	8.24939D-03
		168	4.30198D-03	168	4.67816D-03								
38	1.43333D-01	19	1.44559D-02	19	9.48652D-04	20	2.37712D-03	21	3.00544D-03	22	3.62517D-03	23	4.07527D-03
		24	3.93882D-03	25	1.60607D-03	25	2.63315D-03	32	3.26900D-02	38	5.68122D-03	45	2.32129D-02
		51	5.07007D-03	58	7.63678D-03	64	2.91186D-03	71	7.39998D-04	77	1.29037D-03	84	6.69402D-04
		90	1.24098D-03	97	6.13723D-04	103	1.18438D-03	110	5.69265D-04	116	1.12178D-03	123	2.11057D-03
		129	1.40297D-03	136	3.34058D-03	142	1.62070D-03	149	3.07924D-03	155	1.55183D-03	162	1.44202D-03
		162	3.30724D-04	163	8.40496D-04	164	1.02133D-03	165	1.16784D-03	166	1.28313D-03	167	1.36542D-03
		168	7.01933D-04	168	7.76221D-04								
45	8.00000D-01	19	4.34152D-02	19	3.33157D-03	20	8.88508D-03	21	1.18231D-02	22	1.45562D-02	23	1.68017D-02
		24	1.82895D-02	25	9.41414D-03	25	1.53540D-02	32	1.03892D-01	38	4.64258D-02	45	1.12355D-01
		51	6.72965D-02	58	5.45964D-02	64	3.79485D-02	71	5.93951D-03	77	1.44539D-02	84	5.53380D-03

Table F16.A.2 (continued)

51	1.56667D-01	90	1.26674D-02	97	5.11651D-03	103	1.11846D-02	110	4.71824D-03	116	9.95367D-03	123	1.71848D-02
		129	1.17632D-02	136	2.63579D-02	142	1.28424D-02	149	2.33249D-02	155	1.17443D-02	162	1.05492D-02
		162	2.17808D-03	163	5.56396D-03	164	6.89841D-03	165	8.06106D-03	166	9.02793D-03	167	9.74708D-03
		168	5.04430D-03	168	5.76034D-03								
		19	9.00140D-03	19	8.27677D-04	20	2.02769D-03	21	2.39066D-03	22	2.63609D-03	23	2.74986D-03
		24	2.72056D-03	25	1.30809D-03	25	2.09525D-03	32	2.54687D-02	38	5.07007D-03	45	3.36482D-02
		51	6.17384D-03	58	1.43838D-02	64	4.03645D-03	71	1.34717D-03	77	1.83737D-03	84	1.16219D-03
		90	1.78075D-03	97	1.01626D-03	103	1.70239D-03	110	9.04139D-04	116	1.60713D-03	123	3.22126D-03
		129	1.99319D-03	136	4.89760D-03	142	2.26827D-03	149	4.36874D-03	155	2.12954D-03	162	2.01791D-03
		162	4.48587D-04	163	1.13061D-03	164	1.36394D-03	165	1.54688D-03	166	1.68160D-03	167	1.76390D-03
		168	8.93637D-04	168	1.04524D-03								
		19	2.65021D-02	19	2.33028D-03	20	5.95496D-03	21	7.49454D-03	22	8.90119D-03	23	1.00918D-02
		24	1.09429D-02	25	5.65843D-03	25	8.40299D-03	32	6.57400D-02	38	2.34978D-02	45	8.39944D-02
		51	4.42580D-02	58	4.90929D-02	64	4.02780D-02	71	5.88105D-03	77	1.83510D-02	84	5.73145D-03
		90	1.65169D-02	97	5.47039D-03	103	1.43749D-02	110	5.14176D-03	116	1.23661D-02	123	1.88832D-02
		129	1.39762D-02	136	2.88232D-02	142	1.44956D-02	149	2.50569D-02	155	1.26887D-02	162	1.11249D-02
		162	2.14812D-03	163	5.51182D-03	164	6.91812D-03	165	8.16924D-03	166	9.20141D-03	167	9.92496D-03
		168	5.10281D-03	168	6.07806D-03								
		19	6.61621D-03	19	6.79834D-04	20	1.67813D-03	21	1.98361D-03	22	2.20652D-03	23	2.35264D-03
		24	2.42056D-03	25	1.21210D-03	25	1.82714D-03	32	1.72702D-02	38	4.47979D-03	45	2.91911D-02
		51	6.20992D-03	58	2.01390D-02	64	5.17830D-03	71	2.28407D-03	77	2.53480D-03	84	2.04052D-03
		90	2.50377D-03	97	1.76911D-03	103	2.42263D-03	110	1.52560D-03	116	2.29945D-03	123	5.20145D-03
		129	2.84962D-03	136	7.51342D-03	142	3.21639D-03	149	6.42336D-03	155	2.97694D-03	162	2.91117D-03
		162	6.24126D-04	163	1.56171D-03	164	1.87441D-03	165	2.11229D-03	166	2.27472D-03	167	2.35380D-03
		168	1.17572D-03	168	1.43913D-03								
71	1.74000D-01	19	5.96577D-03	19	5.56499D-04	20	1.41246D-03	21	1.75275D-03	22	2.05692D-03	23	2.31523D-03
		24	2.50871D-03	25	1.30261D-03	25	1.86772D-03	32	1.47109D-02	38	4.93332D-03	45	1.97984D-02
		51	8.98110D-03	58	1.27423D-02	64	9.89764D-03	71	1.63214D-03	77	5.47119D-03	84	1.65488D-03
		90	5.41563D-03	97	1.63392D-03	103	4.96610D-03	110	1.57672D-03	116	4.33311D-03	123	5.90833D-03
		129	4.83374D-03	136	9.12194D-03	142	4.85083D-03	149	7.91324D-03	155	4.09965D-03	162	3.47685D-03
		162	6.37732D-04	163	1.64940D-03	164	2.10006D-03	165	2.50849D-03	166	2.84440D-03	167	3.07068D-03
		168	1.57205D-03	168	1.92666D-03								
		19	6.02873D-03	19	6.35280D-04	20	1.57887D-03	21	1.87908D-03	22	2.10831D-03	23	2.27350D-03
		24	2.37285D-03	25	1.20319D-03	25	1.75756D-03	32	1.49062D-02	38	4.30122D-03	45	2.40898D-02
		51	6.12458D-03	58	1.98802D-02	64	5.49207D-03	71	2.73560D-03	77	2.99420D-03	84	2.69491D-03
		90	3.04060D-03	97	2.46900D-03	103	2.97935D-03	110	2.16352D-03	116	2.85374D-03	123	7.28454D-03
		129	3.55707D-03	136	1.01818D-02	142	4.02018D-03	149	8.41239D-03	155	3.70582D-03	162	3.74995D-03
		162	7.81361D-04	163	1.94694D-03	164	2.33040D-03	165	2.61507D-03	166	2.79644D-03	167	2.86325D-03
		168	1.41476D-03	168	1.77775D-03								
		19	5.53792D-03	19	5.32025D-04	20	1.34833D-03	21	1.66510D-03	22	1.94566D-03	23	2.18480D-03
		24	2.36868D-03	25	1.23307D-03	25	1.73569D-03	32	1.35242D-02	38	4.46268D-03	45	1.84460D-02
		51	7.74794D-03	58	1.24181D-02	64	8.84227D-03	71	1.65488D-03	77	5.38983D-03	84	1.72477D-03
		90	5.79833D-03	97	1.74842D-03	103	5.70989D-03	110	1.72682D-03	116	5.20925D-03	123	6.60787D-03
		129	5.91005D-03	136	1.03716D-02	142	5.86767D-03	149	9.04484D-03	155	4.83747D-03	162	3.95197D-03
		162	6.96180D-04	163	1.81831D-03	164	2.34913D-03	165	2.83621D-03	166	3.23522D-03	167	3.49644D-03
84	1.78000D-01	19	5.53792D-03	19	5.32025D-04	20	1.34833D-03	21	1.66510D-03	22	1.94566D-03	23	2.18480D-03
		24	2.36868D-03	25	1.23307D-03	25	1.73569D-03	32	1.35242D-02	38	4.46268D-03	45	1.84460D-02
		51	7.74794D-03	58	1.24181D-02	64	8.84227D-03	71	1.65488D-03	77	5.38983D-03	84	1.72477D-03
		90	5.79833D-03	97	1.74842D-03	103	5.70989D-03	110	1.72682D-03	116	5.20925D-03	123	6.60787D-03
		129	5.91005D-03	136	1.03716D-02	142	5.86767D-03	149	9.04484D-03	155	4.83747D-03	162	3.95197D-03
		162	6.96180D-04	163	1.81831D-03	164	2.34913D-03	165	2.83621D-03	166	3.23522D-03	167	3.49644D-03

Table F16.A.2 (continued)

[illegible]

Table F16.A.2 (continued)

F16.A.23	NUREG/CR-0200, Vol. 2, Rev. 5	136	8.00000D-01	51	4.98298D-03	58	1.13557D-02	64	4.63064D-03	71	1.81265D-03	77	2.66780D-03	84	2.21627D-03
				90	2.98173D-03	97	2.67075D-03	103	3.26087D-03	110	3.08994D-03	116	3.49011D-03	123	1.33780D-02
				129	4.87019D-03	136	2.17161D-02	142	5.87722D-03	149	1.76818D-02	155	5.60884D-03	162	7.40225D-03
				162	1.27034D-03	163	3.16412D-03	164	3.83534D-03	165	4.32069D-03	166	4.52089D-03	167	4.34444D-03
				168	1.98041D-03	168	2.67488D-03								
				19	1.74604D-02	19	1.84176D-03	20	4.68108D-03	21	5.74573D-03	22	6.67666D-03	23	7.49024D-03
				24	8.17451D-03	25	4.30072D-03	25	5.61212D-03	32	4.02714D-02	38	1.33623D-02	45	5.27158D-02
				51	1.95904D-02	58	3.74701D-02	64	1.95349D-02	71	5.47316D-03	77	1.22181D-02	84	6.22294D-03
				90	1.48274D-02	97	6.99916D-03	103	1.80087D-02	110	7.75335D-03	116	2.16870D-02	123	3.40045D-02
				129	3.47457D-02	136	6.24705D-02	142	4.87128D-02	149	6.17292D-02	155	4.69294D-02	162	2.74062D-02
				162	3.86654D-03	163	1.32472D-02	164	1.94856D-02	165	2.32109D-02	166	2.52382D-02	167	2.63463D-02
				168	1.32618D-02	168	2.12273D-02								
		142	1.96667D-01	19	4.35581D-03	19	4.82043D-04	20	1.21824D-03	21	1.47356D-03	22	1.68310D-03	23	1.85452D-03
				24	1.98774D-03	25	1.03189D-03	25	1.37432D-03	32	9.86154D-03	38	3.24140D-03	45	1.28424D-02
				51	4.53653D-03	58	9.42214D-03	64	4.18130D-03	71	1.45525D-03	77	2.41211D-03	84	1.76030D-03
				90	2.71088D-03	97	2.14794D-03	103	2.99335D-03	110	2.61071D-03	116	3.24784D-03	123	1.26154D-02
				129	4.70178D-03	136	2.43564D-02	142	6.29878D-03	149	2.26392D-02	155	6.35860D-03	162	9.67000D-03
				162	1.38526D-03	163	3.50840D-03	164	4.44087D-03	165	5.28410D-03	166	5.76602D-03	167	5.43093D-03
				168	2.25561D-03	168	3.07036D-03								
				19	1.61760D-02	19	1.74260D-03	20	4.44722D-03	21	5.46679D-03	22	6.35860D-03	23	7.14464D-03
				24	7.81988D-03	25	4.12729D-03	25	5.26333D-03	32	3.66569D-02	38	1.23169D-02	45	4.66498D-02
				51	1.74750D-02	58	3.25740D-02	64	1.67007D-02	71	4.74794D-03	77	1.00949D-02	84	5.42691D-03
				90	1.19480D-02	97	6.17725D-03	103	1.42090D-02	110	6.97867D-03	116	1.70177D-02	123	3.16492D-02
				129	2.82909D-02	136	6.17292D-02	142	4.52785D-02	149	6.78329D-02	155	5.25606D-02	162	3.38592D-02
				162	6.51985D-03	163	2.75520D-02	164	2.94492D-02	165	2.69784D-02	166	2.57011D-02	167	2.59114D-02
				168	1.33102D-02	168	2.58570D-02								
				19	4.19062D-03	19	4.70673D-04	20	1.19278D-03	21	1.44727D-03	22	1.65916D-03	23	1.83661D-03
				24	1.98036D-03	25	1.03372D-03	25	1.33650D-03	32	9.33496D-03	38	3.10366D-03	45	1.17443D-02
				51	4.25908D-03	58	8.24763D-03	64	3.87003D-03	71	1.22989D-03	77	2.22349D-03	84	1.45124D-03
				90	2.50195D-03	97	1.73681D-03	103	2.77711D-03	110	2.10642D-03	116	3.04332D-03	123	1.06103D-02
				129	4.48707D-03	136	2.34647D-02	142	6.35860D-03	149	2.62803D-02	155	7.43970D-03	162	1.21888D-02
				162	1.25224D-03	163	3.22313D-03	164	4.37601D-03	165	5.96030D-03	166	8.05991D-03	167	9.45539D-03
				168	3.43319D-03	168	3.96602D-03								
				19	1.50374D-02	19	1.62170D-03	20	4.18036D-03	21	5.16508D-03	22	6.02487D-03	23	6.78508D-03
				24	7.44422D-03	25	3.93719D-03	25	4.96780D-03	32	3.37992D-02	38	1.15361D-02	45	4.21967D-02
				51	1.61432D-02	58	2.89247D-02	64	1.51381D-02	71	4.17222D-03	77	8.99988D-03	84	4.74236D-03
				90	1.05000D-02	97	5.37745D-03	103	1.22748D-02	110	6.06742D-03	116	1.44402D-02	123	2.76039D-02
				129	2.36872D-02	136	5.48125D-02	142	3.86800D-02	149	6.77185D-02	155	4.87553D-02	162	6.24002D-02
				162	4.74300D-02	163	4.49637D-02	164	2.27465D-02	165	1.79189D-02	166	1.77019D-02	167	1.94014D-02
				168	1.07333D-02	168	2.59705D-02								
		162	2.99999D-01	19	6.47002D-03	19	6.96418D-04	20	1.86889D-03	21	2.34844D-03	22	2.75685D-03	23	3.11325D-03
				24	3.42172D-03	25	1.81230D-03	25	2.23012D-03	32	1.42030D-02	38	5.07992D-03	45	1.67276D-02
				51	6.89029D-03	58	1.07234D-02	64	6.23127D-03	71	1.46933D-03	77	3.60051D-03	84	1.60400D-03
				90	4.09784D-03	97	1.73622D-03	103	4.63181D-03	110	1.85943D-03	116	5.19132D-03	123	7.92948D-03
				129	7.80498D-03	136	1.48475D-02	142	1.06388D-02	149	2.50362D-02	155	9.61723D-03	162	9.10656D-02
				162	2.01504D-03	163	3.15066D-03	164	3.02635D-03	165	3.31753D-03	166	3.68030D-03	167	3.91771D-03
				168	1.89569D-03	168	3.29234D-03								

Table F16.A.2 (continued)

163	3.00000D-01	19	7.45638D-03	19	8.38955D-04	20	2.19161D-03	21	2.71571D-03	22	3.16470D-03	23	3.55807D-03
		24	3.90005D-03	25	2.06303D-03	25	2.53754D-03	32	1.62224D-02	38	5.76340D-03	45	1.90764D-02
		51	7.75274D-03	58	1.22835D-02	64	6.96074D-03	71	1.69653D-03	77	4.00514D-03	84	1.87026D-03
		90	4.54648D-03	97	2.05716D-03	103	5.12865D-03	110	2.26291D-03	116	5.74656D-03	123	1.02319D-02
		129	8.67872D-03	136	2.27095D-02	142	1.20288D-02	149	4.72321D-02	155	1.10507D-02	162	3.85403D-02
		162	1.40654D-03	163	2.92671D-03	164	3.27796D-03	165	3.72698D-03	166	4.17496D-03	167	4.44929D-03
		168	2.13877D-03	168	3.62778D-03								
164	3.00000D-01	19	8.08122D-03	19	9.26548D-04	20	2.38714D-03	21	2.93732D-03	22	3.41137D-03	23	3.82876D-03
		24	4.19390D-03	25	2.21844D-03	25	2.70998D-03	32	1.75218D-02	38	6.12798D-03	45	2.06952D-02
		51	8.18364D-03	58	1.34903D-02	64	7.31021D-03	71	1.89005D-03	77	4.19472D-03	84	2.11422D-03
		90	4.75415D-03	97	2.37358D-03	103	5.35981D-03	110	2.68533D-03	116	6.02025D-03	123	1.26782D-02
		129	9.20482D-03	136	2.92283D-02	142	1.33226D-02	149	4.41737D-02	155	1.31280D-02	162	1.70599D-02
		162	1.18217D-03	163	2.86822D-03	164	3.46439D-03	165	4.05466D-03	166	4.62289D-03	167	4.99189D-03
		168	2.40870D-03	168	4.19552D-03								
165	3.00000D-01	19	8.37805D-03	19	9.67941D-04	20	2.47596D-03	21	3.03643D-03	22	3.52197D-03	23	3.95185D-03
		24	4.33081D-03	25	2.29258D-03	25	2.77048D-03	32	1.81304D-02	38	6.22847D-03	45	2.14962D-02
		51	8.25001D-03	58	1.41600D-02	64	7.32259D-03	71	2.00680D-03	77	4.18412D-03	84	2.26896D-03
		90	4.72715D-03	97	2.58097D-03	103	5.31454D-03	110	2.96087D-03	116	5.96772D-03	123	1.41014D-02
		129	9.21748D-03	136	3.09478D-02	142	1.40909D-02	149	3.59712D-02	155	1.58941D-02	162	1.19459D-02
		162	1.15192D-03	163	2.89876D-03	164	3.60415D-03	165	4.31343D-03	166	5.02935D-03	167	5.57094D-03
		168	2.74583D-03	168	5.19188D-03								
166	3.00000D-01	19	8.46044D-03	19	9.81424D-04	20	2.49971D-03	21	3.06038D-03	22	3.54883D-03	23	3.98416D-03
		24	4.37157D-03	25	2.31719D-03	25	2.76056D-03	32	1.82617D-02	38	6.15902D-03	45	2.16670D-02
		51	8.07166D-03	58	1.43542D-02	64	7.09714D-03	71	2.04797D-03	77	4.02688D-03	84	2.32936D-03
		90	4.52232D-03	97	2.66673D-03	103	5.04849D-03	110	3.07316D-03	116	5.62992D-03	123	1.45565D-02
		129	8.68011D-03	136	3.02859D-02	142	1.38385D-02	149	3.08413D-02	155	1.93438D-02	162	1.06211D-02
		162	1.15009D-03	163	2.92247D-03	164	3.69832D-03	165	4.52641D-03	166	5.44414D-03	167	6.34049D-03
		168	3.34406D-03	168	7.46694D-03								
167	3.00000D-01	19	8.37503D-03	19	9.74765D-04	20	2.47621D-03	21	3.02961D-03	22	3.51489D-03	23	3.95095D-03
		24	4.34369D-03	25	2.30685D-03	25	2.69777D-03	32	1.79987D-02	38	5.95819D-03	45	2.12664D-02
		51	7.69702D-03	58	1.40754D-02	64	6.67622D-03	71	2.00990D-03	77	3.74826D-03	84	2.28858D-03
		90	4.16966D-03	97	2.62261D-03	103	4.59635D-03	110	3.02078D-03	116	5.04087D-03	123	1.42123D-02
		129	7.58301D-03	136	2.87414D-02	142	1.18493D-02	149	2.82670D-02	155	2.06299D-02	162	1.05826D-02
		162	1.11299D-03	163	2.83136D-03	164	3.63046D-03	165	4.55804D-03	166	5.76408D-03	167	7.60746D-03
		168	4.95112D-03	168	1.48404D-02								
168	3.00000D-01	19	8.22042D-03	19	9.59942D-04	20	2.43542D-03	21	2.97987D-03	22	3.46018D-03	23	3.89519D-03
		24	4.29150D-03	25	2.28369D-03	25	2.62315D-03	32	1.75740D-02	38	5.73495D-03	45	2.06065D-02
		51	7.30121D-03	58	1.35496D-02	64	6.24385D-03	71	1.92660D-03	77	3.46766D-03	84	2.18702D-03
		90	3.82011D-03	97	2.49792D-03	103	4.15451D-03	110	2.86699D-03	116	4.46714D-03	123	1.34323D-02
		129	6.47216D-03	136	2.70878D-02	142	9.21439D-03	149	2.71868D-02	155	1.40250D-02	162	1.09617D-02
		162	1.00835D-03	163	2.54832D-03	164	3.27993D-03	165	4.20638D-03	166	5.69202D-03	167	9.27018D-03
		168	8.02297D-03	168	3.00443D-02								
168	2.10000D-01	19	4.25056D-03	19	4.83097D-04	20	1.22435D-03	21	1.48791D-03	22	1.71022D-03	23	1.90004D-03
		24	2.05883D-03	25	1.07957D-03	25	1.35676D-03	32	9.35631D-03	38	3.10489D-03	45	1.15207D-02
		51	4.18094D-03	58	7.90147D-03	64	3.74173D-03	71	1.15600D-03	77	2.13330D-03	84	1.34269D-03
		90	2.39113D-03	97	1.57847D-03	103	2.64700D-03	110	1.88141D-03	116	2.89765D-03	123	9.37321D-03
		129	4.27980D-03	136	2.12273D-02	142	6.14073D-03	149	2.58570D-02	155	7.93204D-03	162	1.29852D-02
		162	8.57380D-04	163	2.11620D-03	164	2.79701D-03	165	3.89391D-03	166	6.22245D-03	167	1.36037D-02
		168	1.47092D-02	168	6.61985D-03								

Table F16.A.2 (continued)

***** summary of heating6 input data*****											
connectors											
19	38	1	1								
19	7.292871D-01	19	2.331993D-01	20	3.341410D-01						
21	2.291357D-01	22	1.858808D-01	23	1.766134D-01						
24	1.877988D-01	25	1.030181D-01	25	2.731725D-01						
32	9.890657D-01	38	4.844228D-01	45	7.274280D-01						
51	3.016397D-01	58	2.886303D-01	64	1.441124D-01						
71	2.998723D-02	77	6.060741D-02	84	2.783664D-02						
90	5.721976D-02	97	2.598190D-02	103	5.397485D-02						
110	2.440855D-02	116	5.076790D-02	123	9.148128D-02						
129	6.323963D-02	136	1.462755D-01	142	7.298222D-02						
149	1.355160D-01	155	7.021454D-02	162	6.298846D-02						
162	1.411540D-02	163	3.643874D-02	164	4.513402D-02						
165	5.264083D-02	166	5.906502D-02	167	6.431559D-02						
168	3.371623D-02	168	3.560943D-02								
19	37	1	1								
19	3.397760D-03	20	6.582134D-03	21	6.723272D-03						
22	7.287625D-03	23	8.018761D-03	24	8.654208D-03						
25	4.474753D-03	25	1.041875D-02	32	6.765113D-02						
38	3.178962D-02	45	5.582092D-02	51	2.773573D-02						
58	2.537872D-02	64	1.480794D-02	71	2.797271D-03						
77	6.386529D-03	84	2.674247D-03	90	6.089159D-03						
97	2.559735D-03	103	5.792466D-03	110	2.457689D-03						
116	5.492750D-03	123	9.416446D-03	129	6.908654D-03						
136	1.542948D-02	142	8.076702D-03	149	1.459874D-02						
155	7.886201D-03	162	6.792971D-03	162	1.519348D-03						
163	4.099907D-03	164	5.174822D-03	165	6.081755D-03						
166	6.851631D-03	167	7.485661D-03	168	3.937225D-03						
168	4.047182D-03										
20	36	1	1								
20	1.405890D-02	21	1.561329D-02	22	1.761708D-02						
23	1.973465D-02	24	2.147484D-02	25	1.114057D-02						
25	2.605245D-02	32	2.397782D-01	38	7.965817D-02						
45	1.488710D-01	51	6.794863D-02	58	6.485464D-02						
64	3.655262D-02	71	7.099785D-03	77	1.587249D-02						
84	6.777462D-03	90	1.519095D-02	97	6.484782D-03						
103	1.449915D-02	110	6.228367D-03	116	1.378969D-02						
123	2.388661D-02	129	1.739811D-02	136	3.921611D-02						
142	2.041183D-02	149	3.725697D-02	155	1.998528D-02						
162	1.751067D-02	162	4.077296D-03	163	1.071023D-02						
164	1.333232D-02	165	1.555692D-02	166	1.745127D-02						
167	1.901590D-02	168	9.988916D-03	168	1.025711D-02						
21	35	1	1								
21	1.847638D-02	22	2.151565D-02	23	2.457779D-02						
24	2.725537D-02	25	1.438547D-02	25	3.514373D-02						
32	3.371137D-01	38	1.007132D-01	45	1.980981D-01						
51	8.011169D-02	58	8.162195D-02	64	4.320634D-02						
71	8.810294D-03	77	1.889062D-02	84	8.369725D-03						

Table F16.A.2 (continued)

a	90	1.815031D-02	97	7.983822D-03	103	1.738192D-02
a	110	7.654164D-03	116	1.657839D-02	123	2.932424D-02
a	129	2.097591D-02	136	4.813535D-02	142	2.468973D-02
a	149	4.579845D-02	155	2.424918D-02	162	2.163545D-02
a	162	5.123508D-03	163	1.327146D-02	164	1.640510D-02
a	165	1.907847D-02	166	2.136546D-02	167	2.326577D-02
a	168	1.222199D-02	168	1.246506D-02		
	22	34	1	1		
	22	2.560335D-02	23	2.992665D-02	24	3.433918D-02
a	25	1.878927D-02	25	4.975500D-02	32	3.857261D-01
a	38	1.214806D-01	45	2.438920D-01	51	8.833614D-02
a	58	9.694153D-02	64	4.806180D-02	71	1.033919D-02
a	77	2.119505D-02	84	9.779971D-03	90	2.045657D-02
a	97	9.303300D-03	103	1.966395D-02	110	8.904358D-03
a	116	1.881288D-02	123	3.408155D-02	129	2.387517D-02
a	136	5.593424D-02	142	2.820067D-02	149	5.326971D-02
a	155	2.779944D-02	162	2.523693D-02	162	6.014519D-03
a	163	1.546564D-02	164	1.905271D-02	165	2.212918D-02
a	166	2.477554D-02	167	2.699244D-02	168	1.419201D-02
a	168	1.432753D-02				
	23	33	1	1		
	23	3.625631D-02	24	4.424854D-02	25	2.580849D-02
a	25	7.656788D-02	32	4.134954D-01	38	1.365637D-01
a	45	2.815148D-01	51	9.214864D-02	58	1.099079D-01
a	64	5.124442D-02	71	1.163763D-02	77	2.285567D-02
a	84	1.098203D-02	90	2.218101D-02	97	1.043318D-02
a	103	2.141731D-02	110	9.980512D-03	116	2.056606D-02
a	123	3.820345D-02	129	2.619522D-02	136	6.275011D-02
a	142	3.107283D-02	149	5.985481D-02	155	3.077266D-02
a	162	2.842127D-02	162	6.792056D-03	163	1.738799D-02
a	164	2.138382D-02	165	2.483021D-02	166	2.781470D-02
a	167	3.034110D-02	168	1.597620D-02	168	1.591776D-02
	24	32	1	1		
	24	5.988464D-02	25	3.839950D-02	25	1.295880D-01
a	32	4.353347D-01	38	1.319911D-01	45	3.064436D-01
a	51	9.116679D-02	58	1.191779D-01	64	5.272390D-02
a	71	1.261014D-02	77	2.385447D-02	84	1.190628D-02
a	90	2.330485D-02	97	1.132260D-02	103	2.262478D-02
a	110	1.084549D-02	116	2.182417D-02	123	4.158818D-02
a	129	2.792488D-02	136	6.848260D-02	142	3.330484D-02
a	149	6.551167D-02	155	3.318126D-02	162	3.118228D-02
a	162	7.465036D-03	163	1.905923D-02	164	2.342314D-02
a	165	2.721129D-02	166	3.051935D-02	167	3.335711D-02
a	168	1.760168D-02	168	1.724799D-02		
	25	31	1	1		
	25	2.649982D-02	25	9.686361D-02	32	2.254552D-01
a	38	5.381991D-02	45	1.577354D-01	51	4.383465D-02
a	58	6.162519D-02	64	2.640151D-02	71	6.547618D-03
a	77	1.209582D-02	84	6.198083D-03	90	1.188507D-02

Table F16.A.2 (continued)

116	1.122732D-02	123	2.181059D-02	129	1.442497D-02
136	3.602963D-02	142	1.728945D-02	149	3.457669D-02
155	1.732009D-02	162	1.649207D-02	162	3.953829D-03
163	1.008186D-02	164	1.239011D-02	165	1.440473D-02
166	1.617707D-02	167	1.771530D-02	168	9.366616D-03
168	9.044160D-03				
25	30 1 1				
25	6.128076D-02	32	4.535144D-01	38	8.823786D-02
45	2.572586D-01	51	7.021248D-02	58	9.151577D-02
64	3.979814D-02	71	9.388185D-03	77	1.766892D-02
84	8.724527D-03	90	1.705791D-02	97	8.175628D-03
103	1.636678D-02	110	7.721502D-03	116	1.560268D-02
123	2.913693D-02	129	1.968462D-02	136	4.701600D-02
142	2.302693D-02	149	4.409399D-02	155	2.239319D-02
162	2.080907D-02	162	4.865363D-03	163	1.240078D-02
164	1.513536D-02	165	1.740746D-02	166	1.927233D-02
167	2.071738D-02	168	1.075891D-02	168	1.136637D-02
32	29 1 1				
32	2.071651D+00	38	1.095452D+00	45	1.740726D+00
51	8.534634D-01	58	7.159644D-01	64	3.761753D-01
71	7.394494D-02	77	1.498530D-01	84	6.798009D-02
90	1.381394D-01	97	6.271065D-02	103	1.279194D-01
110	5.817651D-02	116	1.185417D-01	123	2.148555D-01
129	1.455322D-01	136	3.373772D-01	142	1.652317D-01
149	3.070965D-01	155	1.564087D-01	162	1.415780D-01
162	3.098615D-02	163	7.927775D-02	164	9.786005D-02
165	1.139166D-01	166	1.274910D-01	167	1.382198D-01
168	7.208035D-02	168	7.838328D-02		
38	28 1 1				
38	1.903796D-01	45	7.778710D-01	51	1.698998D-01
58	2.559109D-01	64	9.757750D-02	71	2.479757D-02
77	4.324061D-02	84	2.243188D-02	90	4.158548D-02
97	2.056605D-02	103	3.968908D-02	110	1.907625D-02
116	3.759122D-02	123	7.072591D-02	129	4.701387D-02
136	1.119438D-01	142	5.431014D-02	149	1.031862D-01
155	5.200237D-02	162	4.832251D-02	162	1.108267D-02
163	2.816530D-02	164	3.422507D-02	165	3.913462D-02
166	4.299804D-02	167	4.575565D-02	168	2.352202D-02
168	2.601143D-02				
45	27 1 1				
45	1.882528D+00	51	1.127563D+00	58	9.147707D-01
64	6.358326D-01	71	9.951744D-02	77	2.421768D-01
84	9.271966D-02	90	2.122445D-01	97	8.572787D-02
103	1.873990D-01	110	7.905489D-02	116	1.667753D-01
123	2.879345D-01	129	1.970940D-01	136	4.416308D-01
142	2.151758D-01	149	3.908125D-01	155	1.967778D-01
162	1.767531D-01	162	3.649402D-02	163	9.322505D-02
164	1.155839D-01	165	1.350644D-01	166	1.512644D-01

Table F16.A.2 (continued)

a	167	1.633139D-01	168	8.451808D-02	168	9.651543D-02
	51	26 1 1				
	51	2.068874D-01	58	4.820071D-01	64	1.352626D-01
a	71	4.514394D-02	77	6.157099D-02	84	3.894538D-02
a	90	5.967357D-02	97	3.405511D-02	103	5.704755D-02
a	110	3.029800D-02	116	5.385540D-02	123	1.079454D-01
a	129	6.679255D-02	136	1.641200D-01	142	7.601030D-02
a	149	1.463979D-01	155	7.136152D-02	162	6.762065D-02
a	162	1.503228D-02	163	3.788702D-02	164	4.570605D-02
a	165	5.183633D-02	166	5.635082D-02	167	5.910891D-02
a	168	2.994608D-02	168	3.502619D-02		
	58	25 1 1				
	58	5.346641D-01	64	4.386615D-01	71	6.404962D-02
a	77	1.998577D-01	84	6.242035D-02	90	1.798829D-01
a	97	5.957724D-02	103	1.565555D-01	110	5.599814D-02
a	116	1.346772D-01	123	2.056537D-01	129	1.522131D-01
a	136	3.139089D-01	142	1.578694D-01	149	2.728915D-01
a	155	1.381904D-01	162	1.211593D-01	162	2.339486D-02
a	163	6.002846D-02	164	7.534423D-02	165	8.896997D-02
a	166	1.002112D-01	167	1.080912D-01	168	5.557392D-02
a	168	6.619522D-02				
	64	24 1 1				
	64	1.127922D-01	71	4.975097D-02	77	5.521230D-02
a	84	4.444608D-02	90	5.453639D-02	97	3.853432D-02
a	103	5.276898D-02	110	3.323025D-02	116	5.008604D-02
a	123	1.132964D-01	129	6.206965D-02	136	1.636552D-01
a	142	7.005843D-02	149	1.399118D-01	155	6.484294D-02
a	162	6.341021D-02	162	1.359452D-02	163	3.401661D-02
a	164	4.082794D-02	165	4.600921D-02	166	4.954736D-02
a	167	5.126968D-02	168	2.560930D-02	168	3.134661D-02
	71	23 1 1				
	71	8.204047D-03	77	2.750122D-02	84	8.318352D-03
a	90	2.722195D-02	97	8.212966D-03	103	2.496236D-02
a	110	7.925461D-03	116	2.178057D-02	123	2.969849D-02
a	129	2.429701D-02	136	4.585187D-02	142	2.438295D-02
a	149	3.977626D-02	155	2.060708D-02	162	1.747655D-02
a	162	3.205588D-03	163	8.290797D-03	164	1.055605D-02
a	165	1.260906D-02	166	1.429751D-02	167	1.543491D-02
a	168	7.901983D-03	168	9.684449D-03		
	77	22 1 1				
	77	3.010094D-02	84	2.709222D-02	90	3.056745D-02
a	97	2.482106D-02	103	2.995172D-02	110	2.175012D-02
a	116	2.868892D-02	123	7.323215D-02	129	3.575952D-02
a	136	1.023582D-01	142	4.041528D-02	149	8.457056D-02
a	155	3.725497D-02	162	3.769859D-02	162	7.855094D-03
a	163	1.957280D-02	164	2.342773D-02	165	2.628959D-02
a	166	2.811293D-02	167	2.878453D-02	168	1.422268D-02

Table F16.A.2 (continued)

168	1.787189D-02				
84	21	1	1		
84	8.669642D-03	90	2.914559D-02	97	8.788530D-03
103	2.870106D-02	110	8.679924D-03	116	2.618456D-02
123	3.321477D-02	129	2.970716D-02	136	5.213318D-02
142	2.949411D-02	149	4.546433D-02	155	2.431578D-02
162	1.986474D-02	162	3.499380D-03	163	9.139816D-03
164	1.180802D-02	165	1.425632D-02	166	1.626197D-02
167	1.757501D-02	168	8.970101D-03	168	1.124852D-02
90	20	1	1		
90	3.290328D-02	97	2.869107D-02	103	3.294351D-02
110	2.629127D-02	116	3.182478D-02	123	8.995531D-02
129	3.996746D-02	136	1.242174D-01	142	4.542115D-02
149	1.000956D-01	155	4.192054D-02	162	4.398213D-02
162	8.940096D-03	163	2.221828D-02	164	2.655216D-02
165	2.970155D-02	166	3.157173D-02	167	3.202067D-02
168	1.566825D-02	168	2.003186D-02		
97	19	1	1		
97	9.156483D-03	103	3.068129D-02	110	9.283716D-03
116	3.005922D-02	123	3.647121D-02	129	3.579906D-02
136	5.863606D-02	142	3.598915D-02	149	5.175045D-02
155	2.910056D-02	162	2.252503D-02	162	3.787851D-03
163	1.005320D-02	164	1.325656D-02	165	1.621672D-02
166	1.861731D-02	167	2.014023D-02	168	1.024529D-02
168	1.322373D-02				
103	18	1	1		
103	3.490752D-02	110	3.018021D-02	116	3.445451D-02
123	1.082173D-01	129	4.370911D-02	136	1.508693D-01
142	5.015398D-02	149	1.190374D-01	155	4.653099D-02
162	5.141640D-02	162	1.010505D-02	163	2.506331D-02
164	2.993484D-02	165	3.339226D-02	166	3.524512D-02
167	3.529745D-02	168	1.703984D-02	168	2.217543D-02
110	17	1	1		
110	9.673415D-03	116	3.210428D-02	123	3.916365D-02
129	4.141799D-02	136	6.495432D-02	142	4.374279D-02
149	5.846439D-02	155	3.529343D-02	162	2.541513D-02
162	4.056642D-03	163	1.105867D-02	164	1.499770D-02
165	1.860369D-02	166	2.145470D-02	167	2.319795D-02
168	1.175904D-02	168	1.576163D-02		
116	16	1	1		
116	3.600482D-02	123	1.245145D-01	129	4.678183D-02
136	1.816844D-01	142	5.441804D-02	149	1.425673D-01
155	5.099127D-02	162	6.048693D-02	162	1.132569D-02
163	2.808299D-02	164	3.362342D-02	165	3.749628D-02
166	3.930424D-02	167	3.871107D-02	168	1.832208D-02
168	2.427527D-02				
123	15	1	1		
123	1.645047D-01	129	1.793211D-01	136	2.848752D-01
142	2.113734D-01	149	2.651439D-01	155	1.777780D-01

Table F16.A.2 (continued)

162	1.156270D-01	162	1.729945D-02	163	5.000241D-02
164	7.080845D-02	165	8.860184D-02	166	1.016236D-01
167	1.091423D-01	168	5.509297D-02	168	7.852486D-02
129	14 1 1				
129	6.528069D-02	136	2.910852D-01	142	7.877903D-02
149	2.370096D-01	155	7.518166D-02	162	9.922065D-02
162	1.702782D-02	163	4.241225D-02	164	5.140942D-02
165	5.791514D-02	166	6.059861D-02	167	5.823337D-02
168	2.654571D-02	168	3.585437D-02		
136	13 1 1				
136	5.233514D-01	142	4.080957D-01	149	5.171416D-01
155	3.931546D-01	162	2.295979D-01	162	3.239225D-02
163	1.109796D-01	164	1.632419D-01	165	1.944509D-01
166	2.114351D-01	167	2.207179D-01	168	1.111014D-01
168	1.778333D-01				
142	12 1 1				
142	1.055371D-01	149	3.793242D-01	155	1.065393D-01
162	1.620225D-01	162	2.321022D-02	163	5.878382D-02
164	7.440743D-02	165	8.853594D-02	166	9.661063D-02
167	9.099610D-02	168	3.779304D-02	168	5.144445D-02
149	11 1 1				
149	5.682755D-01	155	4.403305D-01	162	2.836586D-01
162	5.462061D-02	163	2.308194D-01	164	2.467127D-01
165	2.260134D-01	166	2.153132D-01	167	2.170747D-01
168	1.115071D-01	168	2.166188D-01		
155	10 1 1				
155	1.246534D-01	162	2.042258D-01	162	2.098153D-02
163	5.400412D-02	164	7.332073D-02	165	9.986582D-02
166	1.350450D-01	167	1.584266D-01	168	5.752371D-02
168	6.645129D-02				
162	9 1 1				
162	2.613815D-01	162	1.986744D-01	163	1.883434D-01
164	9.528020D-02	165	7.505848D-02	166	7.414936D-02
167	8.126859D-02	168	4.495952D-02	168	1.087849D-01
162	8 1 1				
162	4.396136D-03	163	6.873671D-03	164	6.602473D-03
165	7.237721D-03	166	8.029173D-03	167	8.547120D-03
168	4.135764D-03	168	7.182774D-03		
163	7 1 1				
163	1.430260D-02	164	1.601915D-02	165	1.821347D-02
166	2.040270D-02	167	2.174331D-02	168	1.045201D-02
168	1.772867D-02				
164	6 1 1				
164	1.934882D-02	165	2.264552D-02	166	2.581911D-02
167	2.787995D-02	168	1.345270D-02	168	2.343221D-02
165	5 1 1				
165	2.710209D-02	166	3.160033D-02	167	3.500326D-02

Table F16.A.2 (continued)

Q	168	1.725256D-02	168	3.262152D-02	
	166	4 1 1			
	166	3.800727D-02	167	4.426495D-02	168 2.334595D-02
Q	168	5.212906D-02			
	167	3 1 1			
	167	5.842108D-02	168	3.802185D-02	168 1.139661D-01
	168	2 1 1			
	168	3.290641D-02	168	1.232275D-01	
	168	1 1 1			
	168	5.545834D-02			

***** job description ***** ocular sample problem
 ***** the calculations for this case have been completed.
 ***** number of connectors generated for this case was -- 1700
 ***** number of warnings issued for this case was -- 0
 ***** number of errors issued for this case was -- 0

Computational Physics and Engineering Division

KENO-VI: A GENERAL QUADRATIC VERSION OF THE KENO PROGRAM

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ABSTRACT

KENO-VI is an extension of the KENO Monte Carlo criticality program. It was developed for use in the SCALE system. KENO-VI contains all the features currently in KENO-V.a plus a more flexible geometry package. The geometry package in KENO-VI is capable of modeling any volume that can be constructed using quadratic equations. In addition, such features as geometry intersections, body rotation, hexagonal arrays, and array boundaries have been included to make the code more flexible.

A set of predefined geometry volumes have been incorporated into KENO-VI. Additional volumes can be constructed using the QUADRATIC geometry card that allows the user to specify any volume that can be modeled using quadratic equations. The ability to intersect the volumes makes it possible to exactly model such things as pipe intersections, which was previously impossible in KENO-V.a The ability to rotate bodies means volumes no longer must be positioned parallel to a major axis. Hexagonal arrays were added to simplify the construction of arrays. The use of array boundaries makes it possible to fill a noncuboidal volume with an array, specifying the boundary where a particle leaves and enters the array.

The primary purpose of KENO-VI is to determine k-effective. Other calculated quantities include lifetime, generation time, energy-dependent leakages, energy- and region-dependent absorptions, fissions, fluxed, and fission densities.

KENO-VI retains the KENO-V.a features such as flexible data input, the capability of supergrouping energy-dependent data, a P_n scattering model in the cross sections, a procedure for matching lethargy boundaries between albedos and cross sections to extend the usefulness of the albedo feature, and restart capabilities.

This advanced user-oriented program features a more complex geometry package, simplified data input, and efficient use of computer storage. These features allow the user to readily solve large geometrically complex problems whose computer storage requirements and geometric complexity preclude solution by previous versions of KENO.

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F17.1 INTRODUCTION

KENO-VI, a functional module in the SCALE system, is a multigroup Monte Carlo criticality program used to calculate the k_{eff} of a three-dimensional (3-D) system. Special features include simplified data input, supergrouping of energy-dependent data, the use of quadratic equations to represent geometry input, a P_n scattering treatment, extended use of differential albedo reflection, and an improved restart capability.

The KENO-VI data input features flexibility in the order of input. The single restriction is that the title must be entered first and the parameter data, if any, must immediately follow. A large portion of the data has been assigned default values that have been found to be adequate for many problems. This feature enables the user to run a problem with a minimum of input data.

Blocks of input data are entered in the form:

READ XXXX input data END XXXX

where XXXX is the keyword for the type of data being entered. The types of data entered include parameters, geometry region data, array definition data, biasing or weighting data, albedo boundary conditions, starting distribution information, the cross-section mixing table, extra one-dimensional (1-D) (reaction rate) cross-section IDs for special applications, and printer plot information.

A block of data can be omitted unless it is needed or desired for the problem. Within the blocks of data, most of the input is activated by using keywords to override the default values.

KENO-VI contains a more flexible geometry package than the one in KENO-V.a. In KENO-VI, geometry regions are constructed and processed as sets of quadratic equations. A set of geometric shapes that include all those used in KENO-V.a plus others and the ability to build more complex geometric shapes using sets of quadratic equations is available in KENO-VI. Unlike KENO-V.a, KENO-VI allows intersections between geometry regions within a unit and the ability to specify an array boundary that intersects the array.

The primary difference between the KENO-V.a and KENO-VI geometry input is the methodology used to represent the geometry/material regions in a unit. KENO-VI uses two geometry records to describe a region. The first record, called the GEOMETRY record, contains the geometry keyword, region boundary definitions, and any geometry modification data. The second record, called the MEDIA record, contains the media keyword, the material, hole, or array ID number, the bias ID number, and the region definition vector. Using geometry modification data, regions can be rotated and translated to any angle and position within a unit. KENO-VI requires that a global unit be specified in a problem, including single unit problems.

All the options in KENO-V.a pertaining to arrays are present in KENO-VI, plus additional flexibility. In addition to cuboidal arrays, hexagonal arrays can be directly constructed in KENO-VI. Also, the ability to specify an array boundary that intersects the array makes it possible to construct a lattice in a cylinder using one array in KENO-VI instead of multiple arrays and holes that would be required in KENO-VI.

An important feature of KENO-VI is the capability of supergrouping the energy-dependent information such as cross sections and fluxes. This automatic feature is activated when the computer storage is insufficient to hold the entire problem at once. The energy-dependent data are then broken into supergroups that are written on a direct-access device and moved in and out of memory as necessary. Thus larger problems can be run on smaller computers.

Anisotropic scattering is treated by using discrete scattering angles. The angles and associated probabilities are generated in a manner that preserves the moments of the angular scattering distribution for the selected group-to-group transfer. These moments can be derived from the coefficients of a P_n Legendre polynomial expansion. All moments through the $2n-1$ moment are preserved for n discrete scattering angles. A one-to-one correspondence exists such that n Legendre coefficients yield n moments. The cases of zero and one scattering angle are treated in a special manner. KENO-VI can recognize that the distribution is isotropic

even if the user specifies multiple scattering angles, and therefore selects from a continuous isotropic distribution. If the user specifies one scattering angle, the code performs semicontinuous scattering by picking scattering angle cosines uniformly over some range between -1 and +1. The probability is zero over the rest of the range.

Differential albedos are available to simulate tracking in a reflector. These albedos were generated using the Hansen-Roach 16-energy-group structure. KENO-VI can extend the use of these albedos to include other energy group structures by matching lethargy boundaries between the albedos and cross sections so the appropriate energy transfers can be made. Lethargy boundary tables are created for both the albedo and cross-section energy group structures, and the lethargy interval corresponding to the desired transfer is determined based on a uniform distribution over the lethargy interval. Approximations must be made when the energy group boundaries of the albedos and cross sections are different. Therefore, the user should scrutinize the results to evaluate the effects of the approximations until an adequate information base is established.

The KENO-VI restart option is easy to activate. Certain changes can be made when a problem is restarted, including the use of a different random sequence and turning off certain print options, such as fluxes or the fissions and absorptions, by region.

F17.2 THEORY AND TECHNIQUES

F17.2.1. THE TRANSPORT EQUATION

The equation KENO-VI solves may be derived in the following manner, starting with the Boltzmann neutron transport equation which may be written as¹

$$\frac{1}{v} \frac{\partial \Phi}{\partial t}(X, E, \Omega, t) + \Omega \cdot \nabla \Phi(X, E, \Omega, t) + \Sigma_t(X, E, \Omega, t) \Phi(X, E, \Omega, t) = S(X, E, \Omega, t) + \int_{E'} \int_{\Omega'} \Sigma_s(X, E' \rightarrow E, \Omega' \rightarrow \Omega, t) \Phi(X, E', \Omega', t) d\Omega' dE' , \quad (F17.2.1)$$

where

$\Phi(X, E, \Omega, t)$	=	neutron flux (neutrons/cm ² /s) per unit energy at energy E per steradian about direction Ω at position X at time t moving at speed v corresponding to E,
$\Sigma_t(X, E, \Omega, t)$	=	macroscopic total cross section of the media (cm ⁻¹) at position X, energy E, direction Ω and time t,
$\Sigma_s(X, E' \rightarrow E, \Omega' \rightarrow \Omega, t)$	=	macroscopic differential cross section of the media (cm ⁻¹) per unit energy at energy E' per steradian about direction Ω' at position X, and time t, for scattering to energy E and direction Ω ,
$S(X, E, \Omega, t)$	=	neutrons/cm ³ /s born at position X and time t per unit energy at energy E per steradian about direction Ω (excludes scatter source).

Defining $q(X, E, \Omega, t)$ as the total source resulting from the external source, scattering, fission and all other contributions, the following relationship can be written:

$$q(X, E, \Omega, t) = S(X, E, \Omega, t) + \int_{E'} \int_{\Omega'} \Sigma_s(X, E' \rightarrow E, \Omega' \rightarrow \Omega, t) \Phi(X, E', \Omega', t) d\Omega' dE' . \quad (F17.2.2)$$

Combining Eqs. (F17.2.1) and (F17.2.2), assuming the media to be isotropic, ignoring the time dependence of the cross sections and converting the equation to multigroup form, yields

$$\frac{1}{v_g} \frac{\partial \Phi_g}{\partial t}(X, \Omega, t) + \Omega \cdot \nabla \Phi_g(X, \Omega, t) + \Sigma_t(X) \Phi_g(X, \Omega, t) = q_g(X, \Omega, t) , \quad (F17.2.3)$$

where

g	is the energy group of interest,
v_g	is the average velocity of the neutrons in group g,

$\Phi_g(X, \Omega, t)$ is the angular flux of neutrons having their energies in group g , at position X and time t ,

$\Sigma_{tg}(X)$ is the macroscopic total cross section of the media at position X for group g , corresponding to

$$\Sigma_{tg}(X) = \frac{\int_{\Delta E_g} \Sigma_t(X, E) \Phi(X, E, \Omega, t) dE}{\int_{\Delta E_g} \Phi(X, E, \Omega, t) dE} ,$$

where

ΔE_g defines group g ,

$q_g(X, \Omega, t)$ is the total source contributing to energy group g at position X , and time t in direction Ω .

Utilizing the relationship $X' = X - R\Omega$, defining the problem to be time-independent, using an integrating factor² on both sides of Eq. (F17.2.3), and defining

$$T(R) = \int_0^R \Sigma_{tg}(X - R'\Omega) dR' ,$$

the following equation can be written:

$$\Phi_g(X, \Omega) = \int_0^\infty q_g(X - R\Omega, \Omega) e^{-T(R)} dR . \quad (F17.2.4)$$

At this point, the problem becomes an eigenvalue problem. If there is no external source, the source may be defined as

$$q_g(X, \Omega) = \sum_{g'} \int d\Omega' \Phi_{g'}(X, \Omega') \Sigma_s(X, g' \rightarrow g, \Omega' \cdot \Omega) + \frac{1}{k} Q'_g(X, \Omega) , \quad (F17.2.5)$$

where

k is the largest eigenvalue of the integral equation,

$Q'_g(X, \Omega)$ is the fission source at position X for energy group g and direction Ω (all fission contributions to group g from all energy groups in the previous generation),

$\Sigma_s(X, g' \rightarrow g, \Omega' \cdot \Omega)$ is the scattering cross section for scattering at position X from group g' and direction Ω' to group g and direction Ω .

In terms of energy, the scatter can be defined as

$$\Sigma_s(X, g' \rightarrow g, \Omega', \Omega) = \frac{\int_{\Delta E_g} \int_{\Delta E_{g'}} \Sigma_s(X, E' \rightarrow E, \Omega' \cdot \Omega) \Phi(X, E', \Omega') dE' d\Omega'}{\int_{\Delta E_{g'}} \Phi(X, E', \Omega') dE'} , \quad (F17.2.6)$$

where

ΔE_g is the energy range defining energy group g

$\Delta E_{g'}$ is the energy range defining energy group g' .

Assuming the fission neutrons to be isotropic, the fission source $Q_g(X, \Omega)$ can be written as

$$Q'_g(X, \Omega) = \frac{1}{4\pi} \sum_{g'} \int_{\Omega'} d\Omega' \Phi_{g'}(X, \Omega') \chi(X, g' \rightarrow g) \nu_{g'}(X) \Sigma_{fg'}(X) , \quad (F17.2.7)$$

where

$\chi(X, g' \rightarrow g)$ is the fraction of neutrons born in energy group g from fission in energy group g' in the media at position X ,

$\nu_{g'}(X)$ is the number of neutrons resulting from a fission in group g' at position X ,

$\Sigma_{fg'}(X)$ is the macroscopic fission cross section of the material at position X for a neutron in energy group g' .

Substituting Eq. (F17.2.5) into Eq. (F17.2.4) yields the following equation:

$$\Phi_g(X, \Omega) = \int_0^\infty dR e^{-T(R)} \left\{ \frac{1}{k} Q'_g(X - R\Omega, \Omega) + \sum_{g'} \left[\int_{\Omega'} d\Omega' \Phi_{g'}(X - R\Omega, \Omega') \Sigma_s(X - R\Omega, g' \rightarrow g, \Omega' \cdot \Omega) \right] \right\} . \quad (F17.2.8)$$

The definition of k may be given as the ratio of the number of neutrons in the $(n + 1)$ th generation to the number of neutrons in the n th generation or the largest eigenvalue of the integral equation. Using Eq. (F17.2.7), Eq. (F17.2.8) can be written as

$$\Phi_g(X, \Omega) = \int_0^\infty dR e^{-T(R)} \left\{ \sum_{g'} \frac{1}{k} \int_{\Omega'} v_{g'}(X - R\Omega) \Sigma_{fg'}(X - R\Omega) \chi(X - R\Omega, g' \rightarrow g) \Phi_{g'}(X - R\Omega, \Omega') \frac{d\Omega'}{4\pi} \right. \\ \left. + \sum_{g'} \int_{\Omega'} d\Omega' \Sigma_{tg'}(X - R\Omega, \Omega') \frac{\Sigma_s(X - R\Omega, g' \rightarrow g, \Omega' \rightarrow \Omega)}{\Sigma_{tg'}(X - R\Omega)} \right\}. \quad (F17.2.9)$$

Writing Eq. (F17.2.9) in "generation notation," multiplying and dividing certain terms by $\Sigma_t(X)$ and multiplying both sides of the equation by $v_g(X) \Sigma_{fg}(X)$, yield the following equation, which is solved by KENO-VI.

$$\frac{v_g(X) \Sigma_{fg}(X)}{\Sigma_{tg}(X)} \Sigma_{tg}(X) \Phi_{g,n}(X, \Omega) = \frac{v_g(X) \Sigma_{fg}(X)}{\Sigma_{tg}(X)} \Sigma_{tg}(X) \int_0^\infty dR e^{-T(R)} \\ \left\{ \frac{1}{k} \sum_{g'} \int_{\Omega'} \frac{v_{g'}(X - R\Omega) \Sigma_{fg'}(X - R\Omega)}{\Sigma_{tg'}(X - R\Omega)} \chi(X - R\Omega, g' \rightarrow g) \Sigma_{tg}(X - R\Omega) \Phi_{g',n-1}(X - R\Omega, \Omega') \frac{d\Omega'}{4\pi} \right. \\ \left. + \sum_{g'} \int_{\Omega'} \frac{\Sigma_s(X - R\Omega, g' \rightarrow g, \Omega' \rightarrow \Omega)}{\Sigma_{tg'}(X - R\Omega)} \Sigma_{tg'}(X - R\Omega) \Phi_{g',n}(X - R\Omega, \Omega') d\Omega' \right\}. \quad (F17.2.10)$$

where n indicates the n th generation and $n - 1$ is the $(n - 1)$ th generation. Note that the left-hand side of the equation, $v_g(X) \Sigma_{fg}(X) \Phi_{g,n}(X, \Omega)$ is the fission production for the n th generation.

The solution strategy utilized by KENO-VI solves Eq. (F17.2.10) by using an iterative procedure. The fission production at point X in energy group g due to neutrons in the $(n - 1)$ th generation, normalized to the system multiplication, is

$$\frac{1}{k} \sum_{g'} \int_{\Omega'} \frac{v_{g'}(X) \Sigma_{fg'}(X)}{\Sigma_{tg'}(X)} \chi(X, g' \rightarrow g) \Sigma_{tg'}(X) \Phi_{g',n-1}(X, \Omega') \frac{d\Omega'}{4\pi}.$$

The collision points used in KENO-VI are chosen by selecting path lengths from the distribution

$$e^{-T(R)n},$$

which is the probability of transport from any position $X - R\Omega$ to position X .

The first collision density of neutrons in group g per unit solid angle about Ω resulting from the fission source produced by the $(n - 1)$ generation, normalized to the system multiplication, is

$$\Sigma_{tg}(X) \int_0^\infty dR e^{-T(R)} \frac{1}{k} \int_{\Omega'} \sum_g \frac{v_g(X-R\Omega) \Sigma_{fg}(X-R\Omega)}{\Sigma_{tg}(X-R\Omega)}$$

$$\chi(X-R\Omega, g' \rightarrow g) \Sigma_{tg'}(X-R\Omega) \Phi_{g',n-1}(X-R\Omega, \Omega') \frac{d\Omega'}{4\pi}.$$

The scattering source at position X emerging in group g and direction Ω resulting from previous collisions in the same generation, is

$$\sum_{g'} \int_{\Omega'} \frac{\Sigma_s(X, g' \rightarrow g, \Omega' \cdot \Omega)}{\Sigma_{tg'}(X)} \Sigma_{tg'}(X) \Phi_{g',n}(X, \Omega') d\Omega'.$$

The collision density in group g, per solid angle about Ω is

$$\Sigma_{tg} \int_0^\infty dR e^{-T(R)} \sum_{g'} \int_{\Omega'} \frac{\Sigma_s(X-R\Omega, g' \rightarrow g, \Omega' \cdot \Omega)}{\Sigma_{tg'}(X-R\Omega)} \Sigma_{tg'}(X-R\Omega) \Phi_{g',n}(X-R\Omega, \Omega') d\Omega'.$$

The total collision density times $\frac{v_g(X) \Sigma_{fg}(X)}{\Sigma_{tg}(X)}$ is the relationship from which KENO-VI picks the source points for the next generation.

F17.2.2 COLLISION TREATMENT

A collision occurs in a geometrical region when a history exhausts its mean free path length within the boundaries of the region. For each collision, the absorbed weight and the fission weight are tabulated, then the weight is modified by the nonabsorption probability. This new weight is checked for splitting and Russian roulette; if it survives, the history is scattered. A new energy group is selected from the cumulative transfer probability distribution. This group-to-group transfer determines an angular scattering distribution, usually expressed as a Legendre expansion of the cross-section transfer array. A set of discrete angles and probabilities are generated by a generalized Gaussian quadrature procedure,³ preserving the moments of the Legendre expansion of the angular scattering distribution. KENO-VI treats P_0 and P_1 Legendre expansions as special cases. If the scattering distribution is isotropic, a flag is set to randomly select new direction cosines from an isotropic distribution, instead of using discrete scattering angles. If the distribution is a P_1 expansion, KENO-VI randomly selects the cosine of the scattering angle according to

$$(1) \quad |\bar{\mu}| < \frac{10^{-10}}{3}: \text{ scattering distribution is isotropic,}$$

$$(2) \quad |\bar{\mu}| \leq 1/3: \quad \mu = (\sqrt{1 + 6\zeta\bar{\mu} + (3\bar{\mu})^2} - 1)/3\bar{\mu},$$

or

$$(3) \quad |\bar{\mu}| > 1/3: \quad \mu = \zeta(1 - |\bar{\mu}|) + \bar{\mu},$$

where ζ is a uniform random variable between -1 and $+1$, and $\bar{\mu}$ is the mean cosine of the scattering angle. Otherwise, KENO-VI randomly selects one of the discrete scattering angles (μ). New direction cosines are then calculated according to the following relationships where u , v , and w are the initial direction cosines and u' , v' , and w' are the direction cosines after the collision.

$$u' = u \cos \psi - \sqrt{v^2 + w^2} \sin \psi \cos \eta$$

$$v' = v \cos \psi + \frac{uv}{\sqrt{v^2 + w^2}} \cos \eta \sin \psi - \frac{w}{\sqrt{v^2 + w^2}} \sin \psi \sin \eta ,$$

$$w' = w \cos \psi + \frac{uw}{\sqrt{v^2 + w^2}} \cos \eta \sin \psi + \frac{v}{\sqrt{v^2 + w^2}} \sin \psi \sin \eta ,$$

where

$$\sin \psi = \sqrt{1 - \mu^2},$$

$$\cos \psi = \mu = \text{cosine of the scattering angle,}$$

$$\eta = \text{a random azimuthal angle between } 0 \text{ and } 2\pi.$$

F17.2.3 BIASING OR WEIGHTING

In order to minimize the statistical deviation of k_{eff} per unit computer time, KENO-VI utilizes weighted tracking rather than analog tracking. Weighted tracking accounts for absorption by reducing the neutron weight, rather than allowing the neutron history to be terminated by absorption. To prevent expending excessive computer time tracking low-weight neutrons, Russian roulette is played when the weight of the neutron drops below a preset weight, WTLOW. Neutrons that survive Russian roulette are assigned a weight, WTAVG. The value of WTLOW and WTAVG can be assigned as a function of position and energy. The following values are used by KENO-VI:

DWTAV = 0.5 is the default value of WTAVG,
 WTAVG = DWTAV is the weight given a neutron that survives Russian roulette, and
 WTLOW = WTAVG/3.0 is the value of weight at which Russian roulette is played.

A study⁴ by Hoffman shows these default values to be reasonable for bare critical assemblies. Figure F17.2.1, from this study, shows the analytic relationship between the variance and WTLOW when WTAVG is 0.5. Note that the default value of 0.167 for WTLOW is very close to the minimum point on the curve. Experimental results of actual Monte Carlo calculations⁵ provide further assurance that 0.167 is an optimum choice for WTLOW when WTAVG is 0.5.

Figure F17.2.2, also from the Hoffman study, shows the analytic relationship between the variance and the value chosen for WTAVG for a value of WTLOW = 0.167. Although the KENO-VI default value for WTAVG is not the optimum, a close examination of the data shows the variance to be changing relatively slow as a function of WTAVG. Even though this study shows a value near 0.26 to be optimum for this system, further

studies of other systems are needed before changing the default value of WTAVG from the 0.5 that has been used in previous versions of KENO.

Inside a fissile core, the importance of a neutron is a slowly varying function in terms of energy and position. Hence for many systems, the standard defaults for WTLOW and WTAVG are good values to use. For reflectors, however, the worth of a neutron varies both as a function of distance from the fissile material and as a function of energy. As a neutron in the reflector becomes less important relative to a neutron in the fissile region, it becomes desirable to spend less time tracking it. Therefore a space- and energy-dependent weighting or biasing function is used in KENO-VI to allow the user to minimize the variance in k_{eff} per unit tracking time. When a biasing function is used in a reflector, it becomes possible for a neutron to move from one importance region into another whose WTLOW is greater than the weight of the neutron. When this occurs, Russian roulette is played to reduce the number of neutrons tracked. When the reverse occurs, that is, when the neutron moves to a region of higher importance, its weight may be much higher than WTAVG for that region. When the weight of the neutron is greater than a preset value, WTHI, the neutron is split into two neutrons, each having a weight equal to one-half the weight of the original neutron. This procedure is repeated until the weight of the split neutron is less than WTHI. The default value for WTHI is WTAVG*3.0. WTHI is the weight at which splitting occurs.

The weighting or biasing function for a given core material and reflector material can be obtained by using the adjoint solution from S_n type programs for a similar (usually simplified) problem. This adjoint flux gives the relative contribution of a neutron at a given energy and position to the total fissions in the system. The weighting function for KENO-VI is thus proportional to the reciprocal of the adjoint flux. Although such a function can be difficult to obtain, the savings gained makes the effort worthwhile for many of the materials that are frequently used as reflectors. Biasing functions⁶ have been prepared for several reflector materials commonly used in KENO-VI calculations. The use of biasing to minimize the variance in k_{eff} per unit computer time will usually increase the variance in other parameters such as leakage or absorption in the reflector.

F17.2.4 DIFFERENTIAL ALBEDOS

Arrays reflected by thick layers of material having a small absorption to scattering ratio may require large amounts of computer time to determine k_{eff} because of the relatively long time a history may spend in the reflector. A differential albedo technique⁷ was developed for use with the KENO codes to eliminate tracking in the reflector. This technique involves returning a history at the point it impinges on the reflector and selecting an emergent energy and polar angle from a joint density function dependent upon the incident energy and polar angle. The weight of the history is adjusted by the functional return from the reflector, which is also based on the incident energy and angle.

The characteristics of a differential albedo emulate the attributes of the reflector material and are independent of the material or materials adjacent to the reflector. Thus a differential albedo that is generated for a given reflector material can be used with any array, regardless of the type of fuel or fissile material contained within the array.

For many calculations involving reflected arrays of fissile material, the differential albedo treatment is a powerful tool that can significantly reduce the computing time required to determine k_{eff} . The savings will vary, depending on the importance of the reflector to the system. A substantial effort is required to generate a differential albedo, but the savings gained are well worth the effort for commonly used reflector materials.

To generate the differential albedo information for a material, a fixed source calculation must be made for each incident energy and angle. The data presently available for use with KENO-VI were generated by 1-D discrete-ordinates calculations for slab geometry, representing infinite slabs. Consequently, for a finite reflector, these data will not correctly treat histories that enter the reflector near an edge. Past experience with differential albedo reflectors indicates that k_{eff} appears to be conservative for small faces and will tend toward the correct

Figure F17.2.1. Analytic estimate of the relationship between WTLOW and the variance, σ_k^2 , when WTAVG is 0.5

Figure F17.2.2. Analytic estimate of the relationship between WTAVG and the variance, σ_k^2 , when WTLOW is 1/6

result as the face becomes large relative to the area near the corners. Therefore, care must be taken to ensure that any surface to which a differential albedo is applied is large enough that the errors at the edges can be ignored.

Because differential albedos are expensive and time-consuming to generate, those corresponding to the Hansen-Roach 16-energy-group structure are the only differential albedos currently available for use with KENO-VI. In the past, their use was limited to problems utilizing cross sections having the Hansen-Roach 16-energy-group structure. KENO-VI extends the use of differential albedos to other energy group structures by allowing appropriate energy transfers. Lethargy boundary tables are created for the albedo group structure and the cross-section group structure and determining the lethargy interval corresponding to the desired transfer (cross section group structure to albedo group structure or vice versa), as based on a uniform lethargy distribution over the interval. When the energy group boundaries of the cross sections and albedos are different, the results should be scrutinized by the user to evaluate the effects of the approximations.

F17.2.5 SUPERGROUPING

An important feature of KENO-VI is the capability of supergrouping energy-dependent information—cross sections, albedos, pointer arrays, weights, leakages, absorptions, fissions, and fluxes. If the available computer memory is too small to hold all the problem data at once, KENO-VI determines the number of supergroups necessary to allow execution of the problem. A problem cannot be supergrouped if the energy-dependent data associated with any individual energy group are too large to fit in the available memory. If enough memory is available to accommodate all the energy-dependent data at once, only one supergroup is created. Once the number of supergroups has been determined, the energy-dependent data are arranged in supergroups and are written on the direct-access supergroup file. During execution of a problem, the supergrouped data are moved in and out of memory as necessary.

The advantage of supergrouping is that larger problems can be run on smaller computers. This capability is gained at the expense of running time and increased I/Os. The more supergroups, the more I/Os are used, and the slower the problem will run because of the banking, sorting, and use of direct-access devices in the solution of the problem.

In order to reduce the amount of data movement between memory and the direct-access supergroup file, KENO-VI maintains a bank of histories (the neutron bank) and follows all those histories that fall within the current supergroup before going to the next supergroup. Histories that are scattered out of the current supergroup are placed back in the bank. When all the histories in the current supergroup have been processed, the bank is sorted, placing the histories for the most populous supergroup at the top of the bank. All other histories are placed at the bottom of the bank. The data for the most populous supergroup are then brought into memory and tracking proceeds.

F17.2.6 RESTART

KENO-VI incorporates a versatile and convenient restart capability. The decision to write a restart file requires the user to specify only the number of generations between writing restart data and the unit number where the restart file is to be written. A file definition must be included in the job control language for the restart data file. The input data are the first data written on the restart data file. The group-dependent input data are written a group at a time. This includes the cross sections, albedos, pointer arrays, and weights. The number of records of input data is automatically determined by the code and written on the restart data file. After the input data have been written on the restart data file, the calculated data are written at the end of each specified generation. These data include the generation number, random number, number of histories per generation,

number of energy groups, bank lengths, common information, the k_{eff} values by generation, the neutron bank, the fission densities, matrix arrays, and the calculated group-dependent data. These group-dependent data are written a group at a time and include leakages, absorptions, fissions and fluxes.

The KENO-VI restart capability allows a problem to be restarted at the first generation with different input because all data input supersedes data from the restart data file.

If a problem is to be restarted at a generation greater than 1, the only data that can be changed are certain parameter data. Changes in the parameter data that are not allowed include (1) requesting fissions and absorptions by region if they were not requested by the parent case, (2) requesting fission densities and fluxes if they were not requested by the parent case, (3) requesting matrix information that was not requested in the parent case, and (4) changing the configuration of the neutron bank to be different from that of the parent case.

Because restart data are written a group at a time, a problem may be restarted with an entirely different supergroup structure.

If a problem is to be restarted following a generation for which restart data were not written, the code will write a message and restart with the next available generation for which restart data exist. If no such generation is found, the problem is terminated.

F17.2.7 GEOMETRY

KENO-VI geometry can model any geometric shape that can be described using quadratic equations. These geometric shapes are stacked together forming regions. The set of regions is then used to build units. A set of predefined shapes that include cones, cuboids (rectangular parallelepipeds), cylinders, dodecahedrons, eucylinders (elliptical cylinders), ellipsoids, hexprisms, hoppers, parallelepipeds, planes, rhombohedrons, spheres, and wedges is used to construct regions. In addition, the keyword quadratic is provided which allows additional shapes to be constructed by specifying the quadratic equations that describe the shape. These shapes can be rotated and translated to any orientation and position within their respective unit. Hemispheres and hemicylinders can be constructed using spheres and cylinders with a chord. Regions are rotated by providing the nonzero angles associated with the Euler X-convention.

A major improvement in KENO-VI is the ability to intersect regions. Region volumes are no longer calculated due to the complexity involved with intersecting regions. Each set of multiple geometry regions is called a unit. KENO-VI allows multiple sets of geometry regions (i.e., units), with each set having an independent coordinate system. A global unit must be specified for every problem, including single-unit problems. Units having cuboidal outer boundaries where the adjoining faces have the same dimensions can be stacked together in a 3-D rectangular parallelepiped called an array or lattice, just as children's blocks can be stacked. Unlike KENO-V.a, units having hexagonal outer boundaries where the adjoining faces have the same dimensions can also be stacked together in an array. An array boundary must be specified that either coexists with the outermost edge of the array or that is entirely within the array. The array boundary can be any shape that is definable using quadratic equations. An array can be treated as a building block and be used as a unit within another array.

The use of holes in KENO-VI allows a unit to be emplaced within another unit. This feature allows the addition of a complex structure, previously defined as a unit, to be directly placed within another unit. However, a hole is not allowed to intersect other holes and must be completely contained within a specified region. In KENO-VI, the use of holes to place complex structures within a unit may actually reduce the CPU time needed for the problem.

Multiple arrays can be described in KENO-VI. A global array must be specified if one is desired. In KENO-VI the outermost boundary is always specified as the global-unit boundary. If the outermost boundary is to be the array boundary, a global unit must still be specified with the global-unit boundary coinciding with the array boundary. Unlike past versions of KENO, KENO-VI cannot run a single unit problem without specifying a global unit.

F17.2.8 REFERENCES

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F17.3 LOGICAL PROGRAM FLOW

The general flow of the KENO-VI program during the solution of a problem is given in this section. A formal flowchart is not included because of the voluminous nature of the program. The logical program flow is broken up into small sections. The format of each section includes an abbreviated flowchart, a brief explanation of the purpose of that section of the program, and a brief description of each subroutine involved. The abbreviated flowcharts are drawn with KENO-VI subroutine names contained in boxes and library routines as bare names. An arrow in the flowchart indicates that the subroutine associated with the arrow will be treated in detail later in the section.

F17.3.1 PROGRAM INITIATION

Figure F17.3.1. Flowchart of program initiation

The function of this portion of the program is to initialize information, print a header page, call the parameter reading subroutine PARAM, access subroutine MASTER with the storage space allocated by subroutine ALOCAT, and close out the direct-access files when the problem is completed or terminated (Figure F17.3.1).

KENOVI - These main programs set flags to specify the proper mode of data reading for the stand-alone
000019 - KENO-VI program. INITAL is called to perform some initialization. MASTER is then called from ALOCAT with the requested storage allocation. The direct-access files are closed out by CLOSDA when a problem is completed or terminated.

OPNFIL - This library routine is called to initialize the input and output logical units.

- INITAL - This subroutine calls library routines to perform initialization and print a header page. It then reads the problem's title card and parameter read flag and calls subroutine PARAM to do the actual reading of the parameter data.

- JSTIME - This call to the library routine JSTIME is for the purpose of storing the initial time in COMMON/FINAL/ for timing purposes.

- IOLEFT - This call to the library routine IOLEFT is for the purpose of storing the initial I/O count in COMMON/FINAL/ for future calculations that indicate the number of I/Os used in certain parts of the program.

- SCANON - This library routine is called to activate the feature that allows scanning for the word END when reading data.

- MESSAGE - This library routine is called with two arguments, an eight-character hollerith argument and an output unit. Additional library routines are called from MESSAGE to print a header page in block letters. The header page includes the eight-character hollerith argument (KENO-VI), the date, the time execution was begun, and the job name. The library routine LISTQA is called to provide a program verification page for quality assurance purposes.

- AREAD - This library routine is used to read alphanumeric data. It is used here to read the title and the parameter reading flag.

- PARAM - This subroutine is called to set default values for the parameter input data and to read parameter data. See Sect. F17.3.2 for a more detailed description of PARAM.

- PARTBL - This subroutine prints out a table containing the values of all input parameters.

- ALOCAT - This subroutine is called with three arguments. The first argument is a subroutine name, and the second argument is the maximum number of words of storage to be allocated. ALOCAT calls subroutine MASTER with two arguments, an array name, and the length of the array. The third argument is prefixed by an asterisk and specifies the statement number to return to if there is not enough storage to run the problem.

- MASTER - This subroutine is called by subroutine ALOCAT. It is the controlling subroutine for the bulk of the KENO-VI program flow. See Sect. F17.3.3 for a more-detailed description of subroutine MASTER.

- CLOSDA - This library routine is called to close out each direct-access file at the normal completion or normal termination of a problem.

- STOP - This library routine is called to write a message and terminate execution when there is insufficient storage to run the problem.

F17.3.2 PARAMETER DATA

The function of this section of the program is to set default values for the parameters and to read the parameter input data (Figure F17.3.2).

Figure F17.3.2. Flowchart of parameter reading

- PARAM -** This subroutine is responsible for reading the parameter input data and setting default values for the parameters. The library routine **CLEAR** is used to zero parameters that are defaulted to zero. The parameter data block is read using **AREAD**, **IREAD**, **FREAD** and **ZREAD**. Each entry in the parameter data block uses a keyword so the code can store the parameter data in the correct location. If the problem is a restart problem, restart information including the title of the original case, parameter data and some common information is read from the restart data file. The defaulted and input parameter tables are printed by **PARAM**. Some preliminary data checking is done, and appropriate warning and error messages may be printed.
- CLEAR -** This library routine is called to zero the parameters that are defaulted to zero.
- AREAD -** This library routine can be called many times from subroutine **PARAM**. It is used to read parameter names and alphanumeric parameter data.
- IREAD -** This library routine can be called many times from subroutine **PARAM**. It is used to read integer parameter data.
- FREAD -** This library routine can be called many times from subroutine **PARAM**. It is used to read floating-point data.
- ZREAD -** This library routine can be called from subroutine **PARAM** to read a hexadecimal random number that will be used as a kernel for the random number package.
- RNDIN -** This library routine is called from subroutine **PARAM** to transfer the random number read by **ZREAD** to the random number package. It is called only if a random number was entered as parameter data.

- RNDOUT - This library routine is called from subroutine PARAM to preserve the current random number so it can be written on the restart data set and printed in the parameter data.
- TIMFAC - This library routine is called from subroutine PARAM to provide the proper adjustment factor by which the allotted time is multiplied. This factor adjusts the execution time for execution on different computers.
- OPNFIL - This library routine is called to initialize the logical unit for the restart data file.
- BIRITE - This subroutine writes information to a buffer in CSAS format which could later be used for a restart problem.
- LIBEQL - This subroutine reads the library number from ICE type input which contains the cross-section data to be used by the problem.

F17.3.3 OVERALL PROGRAM FLOW

Figure F17.3.3. Flowchart of overall program flow

The purpose of this section of the program is to direct the primary flow of KENO-VI (Figure F17.3.3). This flowchart covers the complete scope of the program from data reading to editing and printing the results.

MASTER - This subroutine controls the primary flow of KENO-VI. It initializes the direct access files and calls subroutines to read, check and print the input data, calls the tracking routines and prints the calculated results. The number of I/Os used during various operations is calculated and printed. The following subroutines are called from MASTER as indicated:

<u>Subroutine</u>	<u>Function</u>	<u>Condition</u>
OPENDA	Initializes direct access	Always
BOOK2	Controls Inputting of Data	Always
BOOK3	Controls Data Mixing and Organization	Always
BOOK4	Controls Geometry Processing and biasing data	Always
BOOK5	Controls Tracking and Plots	Always
BOOK1	Controls Output	Always
IOSDUN	Initializes I/Os	Always
DATAIN	Reads input data	Always
MIXER	Mixes cross sections	If mixing table is read
ICEMIX	Reads ICE mixed library	If cross sections are not to be used from the restart data file
WRTRST	Writes restart information	If a unit is defined for writing restart information
CORRE	Generates albedo-cross-section information	If differential albedo data are used
NSUPG	Creates supergrouped data	Always
POINT	Calculates pointers	Always
JOMITY	Primarily controls geometry processing	Always
PRTPLT	Prints specified plots	If a plot data block is entered and the plot option is not turned off
CLEAR	Initializes arrays where calculated data are stored	Always
LODWTS	Loads biasing data from direct access into memory	Always
GUIDE	Controls tracking	Always
KEDIT	Edits calculated results	Always
FITFLX	Loads fluxes for printing	If fluxes are calculated
FREAK	Prints frequency distribution	Always
JSTIME	Timing	Always

OPENDA - This library routine initializes the direct-access files.

BOOK2 - This subroutine is called once to call the subroutines needed to read the input data.

BOOK3 - This subroutine is called once to call the subroutines that read, mix, or generate the required cross-section data, write restart information, create supergroup data if required, and calculate pointers.

- BOOK4 - This subroutine is called once to call the subroutines that controls geometry data processing and reads required biasing data.
- BOOK5 - This subroutine is called once to call the subroutines that print plots and control particle tracking.
- BOOK1 - This subroutine is called once to call the subroutines that calculate results and print output.
- IOSDUN - This subroutine is called several times to indicate the number of I/Os used for various operations.
- DATAIN - This subroutine controls the reading of all input data except the title and parameters. It is explained in more detail in Sect. F17.3.4.
- MIXER - This subroutine is called only if mixing table information is to be entered as data. It controls the mixing of cross-section information and writes a Monte Carlo formatted mixed cross-section library for use later in the program. More details are contained in Sect. F17.3.5.
- ICEMIX - This subroutine reads the Monte Carlo formatted mixed cross-section library and manipulates the cross sections to obtain the cross-section information used by KENO-VI. This information is then written on the direct-access data file. See Sect. F17.3.6 for additional information.
- WRTRST - This subroutine is called if a unit has been defined on which to write restart information. The function of WRTRST is to write restart information as explained in Sect. F17.3.7.
- CORRE - This subroutine is called only if the albedo data block specifies differential albedo data. It creates lethargy boundary tables and generates albedo cross-section energy group correspondence information. See Sect. F17.3.8 for additional details.
- NSUPG - The purpose of this subroutine is to create supergrouped information and write it on the direct-access file as described in Sect. F17.3.9.
- POINT - This subroutine calculates pointers to access data in memory.
- JOMITY - This subroutine is primarily responsible for generating additional geometry data, checking the geometry data, writing appropriate geometry error messages, and printing the geometry that is used in the problem. Section F17.3.10 contains additional details.
- LODWTS - This subroutine reads biasing information data from the direct-access data file, loads it into memory and prints it as described in Sect. F17.3.11.
- PRTPLT - This subroutine is called to generate and print 2-D printer plots representing slices through the geometrical representation of the physical problem. See Sect. F17.3.12 for additional details.
- CLEAR - This library routine initializes arrays where the calculated data are stored.
- GUIDE - This subroutine guides the flow of the program through the actual tracking of each history. See Sect. F17.3.13 for a more detailed explanation.

- KEDIT** - This subroutine is responsible for editing the k_{eff} values and printing the various information calculated by KENO-VI. Section F17.3.14 contains additional details.
- FITFLX** - This subroutine is called only if fluxes are calculated. Its purpose is to determine the maximum number of regions for which fluxes can be contained in memory and to print the fluxes. A more-detailed description is contained in Sect. F17.3.15.
- FREAK** - This subroutine is called to generate and print the frequency distribution of the k_{eff} calculated for each generation. The library routines SQRT and EXP are utilized in these calculations.
- JSTIME** - This library routine is called at the completion of a problem to compute the total amount of time used.

F17.3.4 PROBLEM DESCRIPTION

Figure F17.3.4. Flowchart of input data reading

This section of the program controls the reading of the input data (Figure F17.3.4), excluding the title card and parameter data. After the data have been read, they are written on the direct-access data file.

DATAIN - This subroutine controls all the data reading with the exception of the title and parameter data. It initializes COMMON/STDATA/, the common that contains the start data, and initializes the MT array that contains the IDs of the 1-D cross sections that are to be utilized in the problem. The data

reading is accomplished by reading blocks of data, as described in Sect. F17.4. A keyword precedes the data, indicating the type of data to be read. After reading the keyword, the appropriate subroutine is called to read the accompanying data block. After the data block has been read, it is written on the direct-access data file. IOWRT is called several times to generate a table that lists the unit numbers used by KENO-VI, their names, data set names and the volume containing the data set. This table can be valuable for quality assurance applications. The library routine STOP is called to write error messages. Subroutine FLDATA is then called to supply information that was not entered as data.

- CLEAR - This library routine is called to initialize COMMON /STDATA/. If biasing data are entered, it is called to clear the space that will contain the biasing data. CLEAR is called with two arguments, a beginning location and a length. It initializes all included locations to zero.
- AREAD - This library routine is used to read the READ flag, the keyword for the type of data to be read, the END flag and the keyword for the type of data just completed. It can be called many times from DATAIN.
- RT - This subroutine is called to write data on the direct-access data file. It passes information between DATAIN and RITE. INQUIR is called to return the value of the next direct-access record after the geometry data and/or the extra 1-D cross sections are written on a direct-access device.
- RITE - This library routine is called from RT to write an array of data on the direct-access data file.
- ARRAYIN - This subroutine is called to read data defining the array size. It also reads the unit orientation data if any are entered as data. ARRAYIN is always called if array data are specified. See Sect. F17.3.4.1 for additional information. Data input for the array data block is described in detail in Sect. F17.4.5.
- RTARA - This subroutine is called only if ARRAYIN is called. CLEAR is called to zero the array before RTARA reads the array data from the scratch unit and writes them on the direct-access device. INQUIR is called to return the value of the next direct-access record after the array data are written on the direct-access device.
- EXTRA - This dummy subroutine is provided to allow the user to input extra data that are not typically processed by KENO-VI. The user must provide the programming to read and utilize the data.
- GEOMIN - This subroutine is called to read the geometry region data. See Sect. F17.3.4.2 for additional information. The geometry region data block is described in detail in Sect. F17.4.4.
- IDX1D - This subroutine is called if the number of extra 1-D cross sections is greater than zero and an extra 1-D data block is entered. It reads the extra 1-D IDs and loads them into the MT array. The data reading is accomplished using the library routine IREAD. Section F17.4.9 describes the data input for defining extra 1-D data.
- MIXIT - This subroutine is called to read the mixing table data block that defines the mixtures that are to be created. Section F17.3.4.3 explains the mixing procedure in more detail.

- RDREF** - This subroutine is called to read the boundary conditions (or albedo options) that are to be applied at the outer boundaries of the system described by the geometry data and the unit orientation data. The boundary condition data block is read using the library routine AREAD. The library routine, CREAD, is used to read the albedo names. Some preliminary data checks are made to detect invalid face code names and incompatible boundary conditions. Section F17.4.6 describes the data input for defining the boundary conditions.
- RDSTRT** - This subroutine is called to read the start data block that is used to define the spatial distribution of the initial generation. The library routine, CLEAR, is called to zero the array that will contain the start data. The library routine AREAD is used to read the keywords associated with the start data. IREAD and FREAD are used to read the integer and floating-point start data, respectively. The library routine IO is used to write the start data associated with start type 6 on the scratch data file. The library routine, INQUIR, returns the value of the next direct-access record after writing the start data on the direct-access device. Data input for defining the initial source distribution is described in Sect. F17.4.8.
- SAVST6** - This subroutine is called to save the data associated with start type 6. SAVST6 is called only if start type 6 was specified in the start type data. See Sect. F17.4.8 for start type information. The library routine CLEAR is called to initialize the array that will contain the start data arrays. The library routine IO is used to read the start data array from the scratch data file and load it into memory. The library routine MOVE is used to move the start data array into the neutron bank. The library routine RITE is called to write the neutron bank data on the direct-access data file. The library routine, INQUIR, returns the value of the next direct-access record after writing the start type 6 data on the direct-access device.
- RDPLLOT** - This subroutine is called to read the plot data block that is used to generate printer plots. Section F17.3.4.4 explains the processing of the plot data in more detail. Section F17.4.11 describes the plot input data in detail.
- WRTPLT** - This subroutine reads the plot data block from the scratch data file and loads it on direct access. IO reads the data from the scratch data file and loads them in memory. RITE writes the data on the direct-access data file. INQUIR returns the value of the next direct-access record.
- RDBIAS** - This subroutine is called to read the biasing or weighting data to be used in the problem. See Sect. F17.3.4.5 for more information. The biasing input data block is described in detail in Sect. F17.4.7.
- IOWRT** - This library routine is called with five arguments. They are, in order, (1) the output unit, (2) a four-character hollerith name representing a unit name, (3) the unit number represented by the second argument, (4) the number of words of hollerith information contained in the fifth argument, and (5) hollerith information to be printed. IOWRT is called several times to generate a table of the unit numbers, their names, the data set names, and the volumes on which each resides.
- DTASET** - This library routine is called from IOWRT to provide the data set name of the requested I/O unit and the volume on which it resides.
- RDRST** - After the data reading is complete, this subroutine is called if a unit containing data for restarting the problem has been defined. It loads data from the restart data file as described in Sect. F17.3.4.6.

FLDATA - This subroutine is called to supply default data for arrays that were not entered as input. Section F17.3.4.7 contains a more-detailed account of the exact procedure.

F17.3.4.1 Array Data

Figure F17.3.5. Flowchart for reading array data

This section explains the procedure involved in reading the array data used in the problem (Figure F17.3.5).

ARAYIN - This subroutine is called from DATAIN when the words READ ARRA are encountered. It is responsible for reading the data parameters that define the size of each unit orientation array. The unit orientation array data block for each array is read by YREAD for the FILL option and by RDBOX for the LOOP option. BOX then writes the array data on the scratch data file. CLEAR is called to zero the unit orientation array and the data reading is done using the library routines AREAD, IREAD, and YREAD. Section F17.4.5 describes the data read by this subroutine.

AREAD - This library routine is used to read the keywords associated with the array data.

IREAD - This library routine is used to read the integer data associated with the array data.

STOP - This library routine is called to write an error message and stop if insufficient memory is available to accommodate the unit orientation array.

CLEAR - This library routine is called to zero the unit orientation array before it is loaded.

YREAD - This library routine is called to read the unit orientation data for the FILL option.

BOX - This subroutine is called to write the array data on the scratch data file.

- RDBOX** - This subroutine is called only if the LOOP option is used for entering the unit orientation data. It uses the library routine IREAD to read the unit orientation data. Some data consistency checks are made and appropriate error messages are written if errors are encountered. If the input geometry is to be printed, RDBOX prints the unit orientation for each array.
- RCHRS** - This subroutine is used to read the comment associated with an array. The intrinsic function LEN determines the length of the comment. GETPTR is used to return the current pointer in the input buffer. RSTPTR resets the pointer. AREAD is used to read the input data and RCRDLN sets the length of the input buffer. STOP is called to write an error message and stop if the array comment is too long (i.e., the ending delimiter is missing).

F17.3.4.2 Geometry Data

Figure F17.3.6. Flowchart for reading geometry and media keyword data

This section of the program reads the geometry data (Figure F17.3.6).

- GEOMIN** - This subroutine controls the reading of the geometry data. KENOG is called to read each geometry region specification and write it on the scratch data unit. Pointers for the data arrays are then calculated, and CLEAR is called to initialize the data arrays. READGM is called to read the data from the scratch data unit and load them into the appropriate data arrays. STOP is called to write an error message if more storage is needed. The data block read in this portion of the program is described in Sect. F17.4.4.
- KENOG** - This subroutine uses AREAD to read the geometry word and IREAD to read the unit number. KENOG then calls the appropriate subroutine, based on the geometry word previously read, to read in the associated geometry data. The necessary geometry data block is written on the scratch data unit. If the input geometry data block is to be printed, KENOG does this as the data are read.

READGM - This subroutine reads the geometry data from the scratch data unit created in KENOG and loads them into the proper arrays.

KLANGA - This subroutine creates a geometry word sector array that defines how the geometry/material regions relate to the geometric shapes in each unit.

ROTHOL - This subroutine creates a rotation matrix for the holes if required.

PRTSEC - This subroutine writes the sector array to the file.

This section of the program contains the subroutines that read the geometry data for each geometric input shape, as well as holes and arrays, and writes the data to a scratch file.

ROTRNS - This subroutine translates and rotates the location and orientation of a geometric body based on the geometric keyword read in and the data relating to the body read from the subroutines ORIGIN and ROTATE.

SPHERE - This subroutine reads the radius of a sphere using DREAD and generates the coefficients of the quadratic equation that represents the surface of the sphere.

CYLNDR - This subroutine reads the radius and top and bottom surfaces of a cylinder using DREAD and generates the set of quadratic equations that represent the surface of the cylinder.

ECYL - This subroutine reads the x-radius, y-radius, and top and bottom surfaces of an elliptical cylinder using DREAD and generates the set of quadratic equations that represent the surface of the cylinder.

ELLIPS - This subroutine reads the x-radius, y-radius, and z-radius of an ellipse using DREAD and generates the quadratic equation that represents the surface of the ellipse.

CONE - This subroutine reads the top radius, bottom radius, top surface, and bottom surface using DREAD and generates the set of quadratic equations that represent the surface of the cone section.

CUBOID - This subroutine reads the +X, -X, +Y, -Y, +Z, and -Z faces of the cuboid using DREAD and generates the set of quadratic equations that represent the surface of the cuboid.

HXPISM - This subroutine reads the inscribed radius, the top surface, and the bottom surface of a hexprism using DREAD and generates the set of quadratic equations that represent the surface of the hexprism.

WEDGE - This subroutine reads the x-coordinate of the triangular base, the x and y coordinates of the intersection of the other two sides, and the height of the wedge using DREAD and generates the set of quadratic equations that represent the surface of the wedge.

RHOMB - This subroutine reads the length of a side and the angle between the y-face and the y-axis of the rhomboid using DREAD and generates the set of quadratic equations that represent the surface of the rhomboid.

CRSPRD - This subroutine generates and returns a unit vector from the cross product of two input vectors.

PPIPED - This subroutine reads the x-distance, y-distance, z-distance, the angle between the y-distance and the y-axis, the angle between the z-distance and the z-axis, and the angle between the projection of the z-distance on the x-y plane and the x-axis using DREAD and generates the set of quadratic equations that represent the surface of the parallelepiped.

Figure F17.3.7. Flowchart for reading geometry boundary and media data

HOPPER - This subroutine reads the x half-length, y half-length and z surface for the top and the x half-length, y half-length, and z surface for the bottom using DREAD and generates the set of quadratic equations that represent the surface of the hopper.

PLANE - This subroutine reads the keywords and associated dimensions that represent a plane using AREAD and DREAD, respectively, and generates the quadratic equation that represents the planar surface.

QUAD - This subroutine reads the keywords and associated coefficients of a quadratic using AREAD and DREAD respectively.

- VEXCAV - This function determines if the quadratic equation specified using QUAD is convex or concave.
- DEDUCE - This subroutine reads the inscribed radius of the dodecahedron using DREAD and generates the quadratic equation that represents the surface of the dodecahedron.
- ARRAY - This subroutine reads the array number and definition vector of the region containing the array using IREAD, the keyword for placing the array in the unit using AREAD, and the origin of the unit at the specified array position relative to the origin of the unit containing the array using IREAD and DREAD.
- MEDIA - This subroutine reads the media number, the importance region, and the definition vector for the sector using IREAD.
- BNDRY - This subroutine reads the definition vector that describes the boundary of a unit.
- HOLEIN - This subroutine reads the unit number inserted in the hole and the definition vector of the region containing the hole using IREAD.
- CHORD - This subroutine reads the chord orientation keyword using AREAD and the plane location using DREAD, then generates the quadratic equation that represents the surface of the plane and adds it to the set of equations that represents the geometric shape being developed.
- ORIGIN - This subroutine reads the set of translation keywords using AREAD and the values associated with each keyword using DREAD. These values are then stored in common block /RTRN/.
- ROTATE - This subroutine reads the set of rotation keywords using AREAD and the values associated with each keyword using DREAD. These values are then stored in common block /RTRN/.

F17.3.4.3 *Mixing Table Data*

Figure F17.3.8. Flowchart for reading mixing table data

This section deals with reading the mixing table data (Figure F17.3.8).

- MIXIT - This subroutine uses AREAD to read the mixture keywords and the scattering keyword. IREAD is used to read the mixture numbers and the number of scattering angles as well as the nuclide IDs. LREAD is used to determine if the next digit is a numeric digit. FREAD reads the number

densities. The necessary data arrays are written on the scratch data file. Pointers are calculated for the necessary storage arrays and RDMIXT is called to load the data from the scratch file into the storage arrays. RITE is called to write the mixing table information on the direct-access device and INQUIR is called to return the value of the next direct-access record.

- LREAD - This library routine returns a value of "true" if the next character is a numeric digit. Otherwise, a value of "false" is returned.
- STOP - This library routine is called from MIXIT if the storage space is insufficient to hold the mixing table arrays.
- RDMIXT - This subroutine reads the mixing table data arrays from the scratch data file and loads them into the storage arrays.

F17.3.4.4 Plot Data

Figure F17.3.9. Flowchart for reading plot data

This section of the program reads the plot or picture data used to generate printer plot maps of the mixtures, units and/or bias IDs used in the problem (Figure F17.3.9). The plot input data block is described in Sect. F17.4.11.

- RDPLLOT - This subroutine uses CLEAR to initialize the data arrays. RCHRS is used to read the plot title and the character string of symbols to be used in the plot. AREAD, IREAD and FREAD are used to read the plot or picture input data. SQRT is used to determine the normalization factor for the direction cosines, and IO is called to load the plot data on the scratch data file.
- RCHRS - This subroutine is used to read the plot title and the character string that defines the symbols to be used in the plot. The intrinsic function LEN is used to determine the length of a character variable. GETPTR is used to return the current pointer in the input buffer. RSTPTR resets the pointer. AREAD is used to read the input data, and RCRDLN sets the length of the input buffer. STOP is called to write an error message if the plot title is too long and terminate the problem.

CLRNIT - This subroutine initializes the color tables for screen plots.

RCOLOR - This subroutine is used to redefine the red, green, and blue components of the screen plot color tables. AREAD is used to read the color table position and the new red, green, and blue values of that position.

F17.3.4.5 Biasing Data

Figure F17.3.10. Flowchart for reading biasing data

This section of the program reads the biasing data used in the problem (Figure F17.3.10). The biasing input data block is described in Sect. F17.4.7.

RDBIAS - This subroutine is responsible for reading the biasing data block and writing it on the scratch data file. AREAD is used to read the keywords used in the biasing data and a title for the biasing material if the energy and space dependent values of the biasing function are entered by the user. IREAD and FREAD are used to read the numerical data. Pointers for the storage arrays needed to process the biasing data are determined, and WAITIN is called to load the data from the scratch data file into the storage arrays and write them on the direct-access data file.

WAITIN - This subroutine reads the biasing data block from the scratch data file and loads it into the storage arrays. IO is used to load the energy- and space-dependent biasing function (*wtavg*) into the storage arrays. RITE is used to write the biasing data on the direct-access data file. INQUIR is then called to return the value of the next direct-access record.

Figure F17.3.11. Flowchart for reading restart data

This section of the program reads restart information from the restart data file (Figure F17.3.11).

- RDRST -** This subroutine is called only if the problem is to use data from the restart data file. The program recognizes that restart data will be read if the restart unit is defined as a number greater than zero. IO is used to load the array that contains the 1-D IDs from the restart data file. Each type of data is loaded from the restart data file using IO and is written on the direct-access data file by RITE. All restart data, except the mixed cross-section data, the differential albedo data, the array data, and the biasing data, are processed directly in RDRST. RDICE is called to load the cross-section data on the direct-access data file, RDALB is called to load the differential albedo data on the direct-access data file, RDARA is called to load the array data on the direct-access data file, and RDWTS is called to load the biasing data on the direct-access data file. The library routine INQUIR is called to return the value of the next direct-access record.
- RDALB -** This subroutine is called from RDRST to read the albedo data block from the restart data file and write it on the direct-access data file. IO is used to load the albedo pointer and length arrays into memory from the restart data file. CLEAR is called to zero the albedo pointer and length arrays and RITE writes them on the direct-access data file. Each record of albedo data is read from the restart data file, loaded into memory using IO, and written on the direct-access data file using RITE. When all the records of albedo data have been processed, the updated pointer and length arrays are rewritten over the initial ones using RITE. INQUIR returns the value of the next direct-access record.
- RDICE -** This subroutine is called from RDRST to read the cross-section data block from the restart data file and write it on the direct-access data file. CLEAR is called to zero the pointer and length arrays. The length array is then read from the restart data file. RITE is used to write the pointer array and the length array on the direct-access data file. Then IO and RITE are used to load the cross-section data from the restart data file and write them on the direct-access data file. This procedure is repeated for every record of each mixture. The updated pointer and length arrays are then rewritten over the initial ones using RITE. INQUIR returns the value of the next direct-access record.

- RDARA** - This subroutine is called from RDRST to read the array data block from the restart data file and write it on the direct-access data file. IO is used to load the data from the restart data file, and RITE is used to write them on the direct-access data file. INQUIR returns the value of the next direct-access record.
- RDWTS** - This subroutine is called from RDRST to read the biasing data block from the restart data file and write it on the direct-access data file. IO is used to load the data from the restart data file and RITE is used to write them on the direct-access data file. INQUIR returns the value of the next direct-access record.

F17.3.4.7 Generate Remaining Data

Figure F17.3.12. Flowchart for generating remaining data

This section of the program is responsible for generating data blocks that are required to solve a problem but are not entered directly as data (Figure F17.3.12).

- FLDATA** - The library routine REED is used to load data arrays from the beginning of the mixtures used in the geometry through the geometry data. The library routine, STOP, may be called to print an error message. SORTA is called to determine which arrays and holes are used as well as the array and hole nesting levels. RITE is called to write the geometry data on the direct-access data file. RGUSED is called to determine which geometry regions are used in the problem. SORTR is called to generate the mixture correspondence array. It is called again to generate the bias region correspondence array. These correspondence arrays are used to avoid storing mixture cross sections and biasing data that were entered as data but are not actually used in the problem. If boundary conditions specify differential albedo data and they are not available from the restart data file, DIFALB is called to read the albedo data block and load the requested data on the direct-access file.

If the requested biasing data were unavailable from the restart data file, WATES is called to load the energy and position biasing function (*wtavg* array) on the direct-access data file.

- SORTA - This subroutine checks to see that the global array is properly defined. It determines the array correspondence array and the nesting levels for holes and arrays. SORTA uses CLEAR to initialize arrays. REED is used to load the array data and STOP is used to write an error message and terminate if more computer storage is needed for the problem.
- ARSCAN - This function, which is called from sorta, is used to determine if array data have been entered if an array was specified.
- HOLE - This subroutine is called from SORTA to determine what holes occur at the next nesting level and to adjust the array nesting level for arrays that occur in holes. It also checks to be sure holes are not recursively nested.
- LOCBOX - This function subprogram is called from SORTA to determine the unit at a given position in the unit orientation array.
- RGUSED - This subroutine determines which geometry regions are used in the problem. The library routine CLEAR is called to zero the space for the region correspondence array. LSCAN determines if a particular unit has been used in the unit orientation array and if it has, LODRGC is called to load the region number into the region correspondence array.
- LSCAN - This is a logical function that returns a value of true if the specified unit is used in the unit orientation array. A value of false is returned if the unit was not used in the unit orientation array.
- LODRGC - This subroutine loads the region number in the region correspondence array.
- SORTR - This subroutine is called twice from FLDATA to create a mixture correspondence array and a biasing correspondence array. These correspondence arrays are used to avoid storing mixture cross sections and biasing information that were defined in the input data but were not referenced in the geometry data utilized in the problem. They are also used throughout the code for accessing the proper mixture cross sections and biasing information.
- DIFALB - This subroutine is called if differential albedos are specified as a boundary condition but are not available from the restart data file. It rewinds the albedo data file, reads the header record and calculates pointers. ALBRD is called to load the albedo data.
- ALBRD - This subroutine searches through the albedo data file to locate the requested albedo name or boundary condition. If it is not found, an error message is written. If it is found, the number of different differential albedos that were requested are tabulated and ALBUSE is called.
- ALBUSE - This subroutine writes the pointer array on the direct-access data file. IO is used to load data from the albedo data file and RITE is used to write the data on the direct-access data file. Then the pointer and length arrays are rewritten on the direct-access data file. The library routine INQUIR is called after each call to RITE to return the value of the next direct-access record.

If the requested biasing data were unavailable from the restart data file, WATES is called to load the energy and position biasing function (*wtavg* array) on the direct-access data file.

- SORTA -** This subroutine checks to see that the global array is properly defined. It determines the array correspondence array and the nesting levels for holes and arrays. SORTA uses CLEAR to initialize arrays. REED is used to load the array data and STOP is used to write an error message and terminate if more computer storage is needed for the problem.
- ARSCAN -** This function, which is called from sorta, is used to determine if array data have been entered if an array was specified.
- HOLE -** This subroutine is called from SORTA to determine what holes occur at the next nesting level and to adjust the array nesting level for arrays that occur in holes. It also checks to be sure holes are not recursively nested.
- LOCBOX -** This function subprogram is called from SORTA to determine the unit at a given position in the unit orientation array.
- RGUSED -** This subroutine determines which geometry regions are used in the problem. The library routine CLEAR is called to zero the space for the region correspondence array. LSCAN determines if a particular unit has been used in the unit orientation array and if it has, LODRGC is called to load the region number into the region correspondence array.
- LSCAN -** This is a logical function that returns a value of true if the specified unit is used in the unit orientation array. A value of false is returned if the unit was not used in the unit orientation array.
- LODRGC -** This subroutine loads the region number in the region correspondence array.
- SORTR -** This subroutine is called twice from FLDATA to create a mixture correspondence array and a biasing correspondence array. These correspondence arrays are used to avoid storing mixture cross sections and biasing information that were defined in the input data but were not referenced in the geometry data utilized in the problem. They are also used throughout the code for accessing the proper mixture cross sections and biasing information.
- DIFALB -** This subroutine is called if differential albedos are specified as a boundary condition but are not available from the restart data file. It rewinds the albedo data file, reads the header record and calculates pointers. ALBRD is called to load the albedo data.
- ALBRD -** This subroutine searches through the albedo data file to locate the requested albedo name or boundary condition. If it is not found, an error message is written. If it is found, the number of different differential albedos that were requested are tabulated and ALBUSE is called.
- ALBUSE -** This subroutine writes the pointer array on the direct-access data file. IO is used to load data from the albedo data file and RITE is used to write the data on the direct-access data file. Then the pointer and length arrays are rewritten on the direct-access data file. The library routine INQUIR is called after each call to RITE to return the value of the next direct-access record.

WATES - This subroutine reads the biasing input data block from the direct-access data file and reads the KENO-VI weights library. STOP is called if the computer storage space is too small to contain the energy- and position-dependent biasing function (*wtavg*). IO is used to load the biasing function into a temporary storage array. If a specific biasing function is to be used, MOVE is called to load it into the *wtavg* array. If biasing or weighting data are entered, REED is used to load the data into a temporary storage array. If a specific biasing function that was loaded from cards is to be used in the problem, MOVE is called to load it into the *wtavg* array. When all the data have been processed, RITE is called to load the biasing input data on the direct-access data file. RITE is called again to load the *wtavg* array on the direct-access data file. INQUIR returns the value of the next direct-access record after each call to RITE.

F17.3.5 CREATE A MIXED CROSS-SECTION DATA FILE

Figure F17.3.13. Flowchart for mixing cross sections

The function of this portion of the program is to utilize the mixing table data and AMPX working format library from the cross-section data file to create a Monte-Carlo-formatted mixed cross-section data file (Figure F17.3.13). This data file has the same format as an ICE mixed cross-section MORSE/KENO-VI library.¹

MIXER - This subroutine controls the mixing of cross sections and the generation of the angles and probabilities to create a Monte-Carlo-formatted mixed cross-section library. First the mixing table is read from the direct-access data file, MIXCRS is called to generate the mixture correspondence array, and JLL2 is called to generate the array that points to the beginning of each group in the triangularized mixture array. XLNTHS is called to calculate the number of direct-access blocks required for the mixtures and MIXMIX is called to do the mixing. MAKANG is called to generate the angles and probabilities from the mixed cross sections, and MAKTAP is called to write the Monte-Carlo-formatted mixture tape. Calls to STOP are made to print error messages if more space is needed to mix the cross sections or to process the angles.

- MIXCRS - The mixture correspondence array is generated by this subroutine. This array relates the mixture number in the mixing table to the mixture index.
- JLL2 - This routine generates an array of pointers that point to the beginning location of each energy group in a triangularized mixture transfer array.
- XLNTHS - This routine computes the number of direct-access blocks necessary to hold the mixtures.
- MIXMIX - This subroutine controls the actual mixing of the cross sections. See Sect. F17.3.5.1 for a more detailed description of subroutine MIXMIX.
- MAKANG - This subroutine controls the generation of angles and probabilities. See Sect. F17.3.5.2 for a more detailed description of subroutine MAKANG.
- MAKTAP - Subroutine MAKTAP is used to write a mixed cross-section library in a format similar to the ICE Monte Carlo library format. MAKTAP calls SCOOT to compress out zero 1-D cross sections.
- SCOOT - This subroutine eliminates 1-D cross sections that are zero in all groups.

F17.3.5.1 Cross-Section Mixing

Figure F17.3.14. Flowchart of mixing operations

This section of the program produces mixed cross sections (Figure F17.3.14).

- MIXMIX - This subroutine controls the actual mixing of the cross sections. It calls PRTMIX to print the mixing table and calls NNITL to initialize the mixtures. It then reads the input AMPX working library, calls MIX1D to mix the 1-D cross sections, and calls MIX2D to mix the 2-D arrays. After all the nuclides selected from the working library have been mixed, the already mixed cross sections may be used as input for further mixing operations using MIX1D to mix the 1-D cross sections and MIX2M to mix the 2-D cross sections. NORM1D is then called to normalize the fission spectrum

and to prepare the adjoint production cross sections if necessary. CMPRS is called to generate the magic word array and to compress the 2-D arrays. SUMSCT is called to sum the transfer array by group and NORM2D is called to convert the transfer array to a probability density function.

- PRTMIX - This subroutine prints the requested number of scattering angles and the mixing table.
- NNITL - This subroutine initializes the mixture cross sections to zero on the direct-access storage. CLEAR is called to zero the array, RITE writes the array on the direct-access device, and INQUIR returns the value of the next direct-access record.
- MIX1D - This subroutine mixes the 1-D cross sections. It mixes most 1-D cross sections using number densities, but the fission spectrum is mixed based on $\nu\Sigma_f\phi dE$ for the nuclide being mixed. The flux is the flux used to generate the multigroup cross sections, if it is available. Otherwise a flat flux is used. If the problem is an adjoint case, MIX1D prepares the cross sections in adjoint form as they are mixed.
- MIX2D - This subroutine mixes the 2-D cross sections from a working library. The mixture cross sections are stored in a triangularized array. The library routine, MGCWRD, is called to create the magic word for accessing the mixture cross sections. If the problem is an adjoint case, MIX2D prepares the cross sections in adjoint form as they are mixed.
- MIX2M - This subroutine mixes previously mixed 2-D cross sections into new mixtures using new number densities or volume fractions.
- NORM1D - This subroutine is used to normalize the fission spectrum vector. If the problem is an adjoint problem, it also interchanges $\nu\Sigma_f$ and the fission spectrum.
- CMPRS - This subroutine compresses out zeros in the 2-D mixture arrays and generates the pointer array used to access data in these arrays.
- SUMSCT - This subroutine is used to sum the transfers for each group.
- NORM2D - This subroutine normalizes the transfer arrays and divides the P_i arrays by $(2_i + 1)$.

F17.3.5.2 Generate Angles and Probabilities

Figure F17.3.15. Flowchart of angle and probability generation

This portion of the program produces the angles and probabilities for each mixture.

MAKANG - This subroutine controls the generation of angles and probabilities. If the available storage is insufficient to generate all the angles and probabilities for one mixture at a time, MAKANG supergroups the data. Subroutine PRANG is called to actually generate the angles and probabilities for a supergroup.

PRANG - This subroutine reads the mixture data for a supergroup and loops through each transfer in the supergroup. It calls LEGEND to convert the Legendre expansion to moments. GETMUS is called to generate the orthogonal polynomials and ANGLES is called to generate the angles and probabilities. If there is an error, BADMOM is called to print the data input and the data corresponding to the angles and probabilities actually used.

LEGEND - This subroutine determines the moments of a function from a Legendre expansion of the function.

GETMUS - This subroutine calculates the μ_i 's and σ_i 's that determine the orthogonal polynomials, the Q_i 's.²

ANGLES - This subroutine determines the angles and probabilities from the Q_i polynomials.² It calls FIND to determine the roots of Q_i , and calls the function Q to evaluate Q_i .

FIND - This subroutine finds the roots of a polynomial Q_i by using an interval-halving technique.

Q - This function evaluates a polynomial Q_i by using the recursion formulas.

$$Q_{i+1}(x) = (x - \mu_{i+1})Q_i(x) - \sigma_i^2 Q_{i-1}(x),$$

$$Q_0(x) = 1.0, \text{ and}$$

$$Q_1(x) = x - \mu_1.$$

BADMOM - This routine is called when an error is detected in generating the angles and probabilities. BADMOM prints the Legendre coefficients that were input to the calculation and the moments corresponding to these coefficients. It then computes the moments corresponding to the angles and probabilities actually generated and the Legendre coefficients corresponding to these moments. BADMOM then prints these moments and coefficients so they may be compared with the original moments and coefficients.

F17.3.6 WRITE CROSS SECTIONS ON DIRECT-ACCESS FILE

Figure F17.3.16. Flowchart of mixed cross-section processing

This section of the program is responsible for reading the Monte Carlo mixed cross-section library, selecting the desired information, and writing it on the direct-access data file (Figure F17.3.16).

ICEMIX - This subroutine reads information from the Monte Carlo mixed cross-section library, performs preliminary checks for data consistency, calculates pointers for the desired data arrays and calls RDTAPE to actually read the library and write the desired information on the direct-access data file.

RDTAPE - This subroutine reads the Monte Carlo formatted mixed cross-section library, sorts out the data needed by KENO-VI, and writes the data on the direct-access data file. The library routine SQRT is used in calculating the inverse velocities used by KENO-VI. The library routine IO is used repeatedly to read and load data from the Monte Carlo formatted mixed cross-section library. RITE is used to write data required by KENO-VI on the direct-access data file. INQUIR returns the value of the next direct-access record after each call to RITE. XTENDA is a library routine that is called to extend the number of blocks for a direct-access device if too few blocks were initialized. XSEC1D is called to process the 1-D cross sections. RDTAPE manipulates the pointer array and

writes it on the direct-access data file. The P_0 cross sections, angles and probabilities are also processed by RDTAPE.

XSEC1D - This subroutine sorts the 1-D cross sections and loads them in the following order: total cross section, scattering cross section, production cross section, absorption cross section, extra cross sections for special purposes, and the fission spectrum. The extra cross sections require the user to provide programming to utilize them. If one of the required cross sections is not found, it is padded with zeros. The cross sections are normalized by the total cross section and the fission spectrum is summed and normalized to 1.0. The data are transferred back to RDTAPE where they are written on the direct-access data file.

F17.3.7 WRITE INPUT DATA ON RESTART FILE

Figure F17.3.17. Flowchart for writing data on the restart data file

This section of the program is responsible for writing all data except the calculated results on the restart data file (Figure F17.3.17). This section of the program is omitted if a unit number has not been assigned for the restart data file. This information is entered as parameter data, WRS=, as described in Sect. F17.4.3. The calculated results are written on the restart data file later in the program. The restart data file is used for restarting a problem.

WRTRST - This subroutine writes the input data on the restart data file. RNDOUT is called to return the seed of the next random number. The problem title and parameter data are in the first record written on the restart data file. The array containing the IDs of the 1-D cross sections is then written. The geometry region data, mixing table data, extra 1-D data, biasing data, start data, plot data, and energy and inverse velocities are written. The unit orientation header record is written and WRTARA is called to write the unit orientation data. The albedo header record is written, and WRTALB is called to write the albedo data. The cross-section header record is written and WRTICE is called to write the cross sections. The header record for user-supplied weighting data is written, and WRTWTS is called to write the user-supplied weighting or biasing data on the restart data file.

- WRTARA** - This subroutine is called from **WRTRST** to write the array number, array size and corresponding unit orientation array on the restart data file for each array that is entered in the problem. The library routine **REED** is called to load the direct-access pointers for the albedo data blocks. **INQUIR** is called to return the value of the next direct-access record. **REED** is used to read the data from the direct-access data file, and **IO** is used to write the data on the restart data file.
- WRTALB** - This subroutine is called from **WRTRST** to write the albedo data on the restart data file. The library routine **REED** is used to read the albedo data from the direct-access data file, and **IO** is used to write the data on the restart data file.
- WRTICE** - This subroutine is called from **WRTRST** to write the cross-section data block on the restart data file. **REED** is called to load the direct-access pointers for the cross-section data blocks. **INQUIR** is called to return the value of the next direct-access record. The library routine **REED** is used to read the rest of the cross-section information from the direct-access data file, and **IO** is used to write it on the restart data file.
- WRTWTS** - This subroutine is called from **WRTRST** to write the biasing input data block on the restart data file. The library routine **REED** is used to read the data block from the direct-access data file, and **IO** is used to write it on the restart data file.

F17.3.8 GENERATE ALBEDO CROSS-SECTION CORRESPONDENCE TABLES

Figure F17.3.18. Flowchart for generating correspondence arrays

This section of the program generates the correspondence tables that are necessary to correlate the energy group structures of the cross sections and albedos (Figure F17.3.18). It is invoked only if differential albedos are used in the problem.

- CORRE** - This subroutine is called only if differential albedos are used. The library routine **REED** is called to read arrays. The library routine **INQUIR** is called to return the value of the next direct-access record. The library routine **CLEAR** is used to initialize arrays. **CORRE** reads the energy bounds for the albedos and the cross sections and converts them to lethargies by using the library routine **ALOG**. **RATIO** is called to create a probability array relating the cross-section energy bounds to those of the albedos. A second call is made to **RATIO** to create and print the probability array relating the albedo energy bounds to those of the cross sections. **RITE** is used to write the correspondence tables on the direct-access data file.

includes the supergroup and corresponding energy groups, the length of the cross section and albedo data for the supergroups and the total length of each supergroup. FILLSG is then called to construct the supergroups as described in Sect. F17.3.9.2. After the supergrouped data have been written on the direct-access device, the library routine FREECR is called to release the space that is not needed for the problem.

- PRTXS - This subroutine prints the cross-section information as described in Sect. F17.3.9.1.
- POINT - This subroutine determines the storage requirements of the nonsupergrouped data and creates pointers to access data within the nonsupergrouped storage array.
- PRATBL - This subroutine prints the additional information table to the computer output.
- RTADJ - This subroutine right adjusts the albedo boundary condition names which are read in as left-adjusted data. RTADJ utilizes the FORTRAN-supplied intrinsic function INDEX to locate the first blank character.
- IXALB - This function determines the amount of space necessary to contain the albedo data corresponding to a cross-section energy group.
- LIMLN - This subroutine is called to calculate and print the supergroup number, the energy groups contained in the supergroup, the length of the cross section and albedo data in the supergroup, and the total length of the supergroup. IXALB is utilized to obtain the amount of space required to contain the albedo data corresponding to a cross-section energy group.
- FILLSG - This subroutine constructs supergroups as described in Sect. F17.3.9.2.

F17.3.9.1 *Print Macroscopic Cross Sections*

Figure F17.3.20. Flowchart for printing macroscopic cross sections

This portion of the program prints the macroscopic cross-section data for materials used in the problem description (Figure F17.3.20).

PRTXS - If macroscopic cross sections are not to be printed, a return is executed. PRTXS loops over the number of mixtures that are used in the problem. REED is used to load the data, then pointers into the data arrays are calculated. If the space is insufficient to contain the data, a message is printed. If 1-D mixture cross sections are to be printed, PRT1DS is called to print them. If the extra 1-D cross sections are to be printed, REED is used to load the data and the library routine PRT1DS is called to print them. If the transfer arrays are to be printed, REED is called to load the data and PRT2DS is called to print them. If the number of scattering angles is greater than zero and the mixture probabilities and angles are to be printed, REED is used to load probability data and PRT2DS prints them. Then REED loads angle data and PRT2DS prints them.

PRT1DS - This subroutine prints the macroscopic 1-D cross sections, one energy group at a time.

PRT2DS - This subroutine prints a 2-D variable length array in a compact manner.

F17.3.9.2 Write Supergroup Data File

Figure F17.3.21. Flowchart for loading supergrouped data

This portion of the program collects the group-dependent data by supergroup and writes them on the direct-access supergroup data file (Figure F17.3.21).

FILLSG - This subroutine is responsible for filling the supergroups and writing them on the direct-access supergroup data file. For each supergroup, CLEAR is called to initialize the working space. Pointers are calculated for the data arrays and space is allotted for the calculated data such as fluxes that will be supergrouped. The library routines REED and RD are used to load data from the direct-access data file into the proper arrays as follows: For each mixture the inverse velocities are loaded, followed by the pointer array and all the 1-D cross-section arrays. RD and REED are used to load the 2-D arrays from the direct-access data file. FILL2D is called to load them into the supergroup. Pointers are calculated for the albedo data, and SGALB is called to load the albedo data into the

supergroup. SGWT loads the average weight array (biasing data) into the supergroup. FILLSG then calls RT to write the calculated data for the supergroup on the direct-access supergroup data file. RITE writes the group-dependent data on the direct-access supergroup data file. INQUIR is called as necessary to return the value of the next direct-access record.

- FIL2D - This subroutine loops over the number of mixtures. It uses RD to load the 2-D cross-section data for the supergroup from the direct-access data file; first the P_0 data, then for each scattering angle, the angles and probabilities. The pointer array is redefined so the supergrouped data can be accessed.
- SGALB - This subroutine uses REED and RD to load the albedo data for the supergroup from the direct-access data file. INQUIR is used to provide the value of the next direct-access record. It loops over the number of differential albedos used in the problem. Then the pointer array is redefined so the supergrouped data can be accessed.
- SGWT - This subroutine loops over the number of biasing regions used in the problem. RD is used to load the average weight array from the direct-access data file. If any average weight entry remains undefined or zero, it is set to the default value of weight average.
- RT - This subroutine is called to write the calculated data (fluxes, etc.) on the direct-access supergroup data file using the library routine, RITE. INQUIR is used to return the value of the next direct-access record, after the call to RITE.
- RITE - This library routine is used to write the group-dependent data for the supergroup on the direct-access supergroup data file.

F17.3.10. PROCESS GEOMETRY

Figure F17.3.22. Flowchart for processing geometry

This portion of the program is primarily responsible for loading the geometry data, generating additional geometry data, checking the geometry for consistency, writing error messages related to the geometry, and printing the geometry that is used in the problem (Figure F17.3.22).

- JOMITY - This subroutine is responsible for generating additional geometry data, checking the geometry data, writing geometry error messages, and printing the geometry.
- LOADIT - This subroutine loads the geometry data and the nonsupergrouped portion of the albedo data. Section F17.3.10.1 contains a more detailed description of the procedure.
- IOSDUN - This subroutine returns the number of IOs used. The library routine IOLEFT returns the number of input/output requests left before the system cancels the job.
- CORSIZ - This subroutine sends the appropriate lattice or array information to ARASIZ for each lattice that is used in the problem. Using this information, it calculates the overall positive dimensions of the global array. The library routine, SQRT, is utilized to calculate the maximum chord length of an unreflected array, a reflected array or a single unit problem.
- ARASIZ - This subroutine uses the array unit orientation data to calculate the positive dimensions of the core boundary for that array or lattice. The function LSCAN is called to determine if a specified unit has been used in the array. ARASIZ also checks to ensure that the faces of adjacent units are the same size and shape. Several error messages are written if errors are encountered.
- LSCAN - This is a logical function that returns a value of true if the specified unit is used in the unit orientation array. A value of false is returned if the unit was not used in the unit orientation array.
- PRTJOM - This subroutine prints the geometry data used in the problem.
- ARALBA - This subroutine calls PRTLBA for each array that is used in the problem.
- PRTLBA - This subroutine is called to print the unit orientation data for each lattice or array that is used in the problem. It may print a warning message associated with one or more lattices.
- VOLUME - This subroutine is responsible for calculating the volume of each geometry region and the cumulative volumes for each unit that is used in the problem. See Sect. F17.3.10.2 for additional details.

F17.3.10.1 Load Data From the Direct-Access File

Figure F17.3.23. Flowchart for loading data from direct access

This portion of the program loads data from the direct-access data file into permanent memory (Figure F17.3.23).

LOADIT - This subroutine calls the library routine REED to load the geometry data. If the problem is an array problem (lattice geometry), LODARA is called to load the lattices that are used in the problem and recompute and readjust the array nesting level array and hole nesting level array. If multiple units are used in the problem, PRTARA is called to print the unit orientation array for each lattice used in the problem. BOXC is called to load the unit correspondence array, and LODALB is called to load the nonsupergrouped portion of the albedo data.

LODARA - This subroutine is responsible for loading the lattices (unit orientation arrays) that are used in the problem, computing the hole nesting level array, and computing and adjusting the array nesting level array. CLEAR is used to initialize the arrays and REED is used to load the unit orientation arrays. HOLE and LOCBOX are both called by LODARA.

HOLE - This subroutine is called from LODARA to determine which holes occur at the next nesting level and to adjust the array nesting level for arrays that occur in holes. It also checks to ensure that holes are not recursively nested. CLEAR is used for initialization purposes and STOP is called if holes are recursively nested.

LOCBOX - This function is called from LODARA to return the unit at a given position in the unit orientation array.

PRTARA - This subroutine prints a table of the arrays used in the problem. The array number, the number of units in the x, y, and z directions, and the nesting level is printed for each array.

BOXC - This subroutine uses the number of units and the geometry region number corresponding to the first and last geometry region of each unit to generate the unit correspondence array which contains the

unit number for each geometry region. This information is loaded in the appropriate position as it is generated.

LODALB - This subroutine calls the library routine REED to load the pointer and length arrays for the albedo data from the direct-access data file. REED is used to load the nonsupergrouped albedo data, for each albedo that is used, into a temporary array. A loop over the number of angles is then used to load these data into the appropriate arrays. When all of the albedos used in the problem have been processed, REED is called to load the pointer arrays for the cross sections and albedos as well as the arrays defining the albedo to cross-section energy group correlation.

F17.3.10.2 Calculate Volumes

Figure F17.3.24. Flowchart for calculating volumes

This portion of the program is responsible for calculating the volume of each region used in the problem, the cumulative volumes for each unit used in the problem, the number of times each unit was used in the problem, and the total volume of each region summed over all occurrences (Figure F17.3.24).

VOLUME - This subroutine attempts to calculate the volume of each region for every unit that is used in the problem. It then attempts to calculate the cumulative volumes for each unit. CLEAR is used to initialize arrays. If an external reflector is present, HUNTER is called to determine the number of times each array and/or hole is used in the reflector. GOCURS is used to determine the number of times each unit, array and hole is used in the problem. GTVOLS is called to calculate and print the number of occurrences for each unit and the corresponding total volumes for the entire system. CLEAR is called to initialize the array for the total volume of each mixture used in the problem prior to calculating and printing those totals.

HUNTER - This subroutine determines the number of times each unit, array and hole is used. CLEAR is used to initialize storage arrays for the present hole level and the next hole level. MOVE is used to move the storage arrays.

GOCURS - This subroutine loops over the array size and calls HUNTER to determine the number of times each unit, lattice or array, and hole is used in the problem.

GTVOLS - This subroutine calculates the total volume of each region for the entire problem by multiplying the volume of the region by the number of times the region is used in the problem.

F17.3.11 LOAD BIASING OR WEIGHTING DATA

Figure F17.3.25. Flowchart for loading biasing data

This portion of the program is executed only if the input parameter data contain PWT=YES, as described in Sect. F17.4.3. If biasing data are to be printed, the program loads and prints the average weight array (Figure F17.3.25).

LODWTS - This subroutine is responsible for printing the bias IDs vs the material IDs used in the problem and for loading and printing the biasing or weighting data. The library routine REED is called to load the bias IDs used in the problem from the direct-access device. The number of sets of data that will fit in the available memory is calculated. Then the library routine CLEAR is used to initialize that space. RD is used to load the data that will fit, and PRTWTS is called to print them. Then the entire process is repeated until all the biasing or weighting data used in the problem have been loaded and printed.

PRTWTS - This subroutine prints the group-dependent weight-averaged array for each biasing region in a compact fashion.

F17.3.12 GENERATE PRINTER PLOT

Figure F17.3.26. Flowchart for pictures or plots

This portion of the program generates printer plots of a 2-D slice through the geometry (Figure F17.3.26). As many plots as are desired can be printed.

- PRTPLT** - This subroutine controls the generation of the printer plots. The library routine **CLEAR** is called to zero the necessary space. Subroutine **UNTCRS** is called to generate a unit correspondence array. **REED** is used to load the picture data from direct access. **INQUIR** is called to return the value of the next direct-access record. The picture title is printed, and subroutine **RELATE** is called to print a heading for the symbol map and print the symbol map. The picture coordinates, direction cosines and number of symbols across and down the page as well as the step intervals, are printed. Then subroutine **PRINT** is called to generate the actual picture.
- UNTCRS** - This subroutine calls **CLEAR** to zero the unit correspondence array. It then loads the appropriate unit number in the appropriate position of the array.
- RELATE** - This subroutine calls **CLEAR** to zero the reverse correspondence array. It then prints the plot header telling whether a mixture, unit, or bias ID map is to be printed. It loads the array that correlates the symbols to be used in the printer plot with the mixture numbers, bias ID numbers, or unit numbers that were used in the problem. The array is then printed to facilitate user interpretation of the printer plot.

- PRINT - This subroutine determines the number of pages that will be needed to print the printer plot picture. Subroutine MESH is called to load the appropriate mixture numbers, unit numbers or bias ID numbers for each line of print for the picture. Then PRINT prints the line of symbols corresponding to them.
- MESH - This subroutine loads an array that contains the appropriate mixture number, unit number or bias ID number for each character in a line. CLEAR is called to initialize arrays if nested holes or nested arrays are present in the problem. LOCATE is called to determine the geometry region and unit that contains each mesh point. MESH then loads the mixture number, unit number, or bias ID number.
- LOCATE - This subroutine is responsible for determining the geometry region for each mesh point in the picture. Subroutine POSIT is called to determine the region that contains the specified mesh point. If array data are used, MOVE is called to load the current array data into the array stack. If the mesh point is located within a hole, HROTRN is called to determine the position within the unit contained in the hole that contains the mesh point. If the mesh point is within an array, FINDBX is called to determine the position within the lattice or array that contains the mesh point. LOCBOX is then called to determine the unit that contains the mesh point. POSIT is used to determine the geometry region that contains the mesh point. If the mesh point is in a region that contains a hole, the coordinates of the mesh point are translated to the hole and POSIT is called again.
- HROTRN - This subroutine rotates and translates the coordinates to locate the position of a specific point in a hole.
- FINDBX - This subroutine locates the position in an array that contains a specified point.
- LOCBOX - This function returns the unit at a given position in an array.
- POSIT - This subroutine determines the region within a unit that contains a specified point.

F17.3.13 PROCESS HISTORIES BY SUPERGROUP

Figure F17.3.27. Flowchart of tracking routines

This section of the program is where the tracking of the individual histories is done, one supergroup at a time (Figure F17.3.27).

GUIDE - This subroutine controls the tracking procedure. It loads the calculated data for a restarted problem, calls subroutine **START** to obtain the initial source distribution, calls **CHKSTR** to load the initial starting distribution in **COMMON /NUTRON/** and prints the starting points as requested by the data. The library routine **CLEAR** is called several times to initialize arrays. **IOLEFT** and **JSTIME** are called to initialize the I/Os and time for the tracking procedure. **INQUIRE** is used to return the value of the next direct-access record. **SQRT** is used in estimating the lower limit of the 99% confidence interval of the sample distribution of k_{eff} .

The heart of subroutine **GUIDE** is a loop over generations, from the starting generation to the number of generations requested. Subroutine **RESET** is called to accumulate the fission source and the source vectors for matrix k_{eff} . It also counts the number of histories in each supergroup and determines the supergroup with the largest number of histories. Then subroutine **BANKER** is called to sort the histories by supergroup, loading the largest supergroup at the top of the bank. **GUIDE** calculates pointers for the supergrouped data and loads the supergrouped data using the library routine **REED**. **TRACK** is called to do the actual tracking. The library routine **RITE** writes the calculated supergrouped data on the direct-access supergroup data file. When all the supergroups have been processed, **NSTART** is called to provide the fission source for the next generation. Then **FISFLX** is called to calculate matrix information and statistics for the calculated data. **GUIDE** then checks to be sure sufficient time and I/Os remain to ensure that another generation can be processed. If another generation cannot be processed and restart data are to be

written, WRTCAL is called to write the calculated data on the restart data file. A message is printed by GUIDE stating the reason for terminating the calculation.

GUIDE is a very important subroutine in KENO-VI. The following table is provided to assist in understanding the functions performed by the subroutines called by GUIDE:

<u>Subroutine</u>	<u>Function</u>	<u>Condition</u>
INQUIR	Set direct-access pointer	Always
JSTIME	Monitor time usage	Always
RDCALC	Load calculated data for restarting a problem	If the problem is restarted
REED	Load data from direct-access supergroup data file	Always
RD	Load data from direct access	Always
START	Provide initial source	If the problem is started with the first generation
CHKSTR	Print starting points	Always
INDX	Locate cross-section index	Always
RESET	Count histories/supergroup	Always
BANKER	Sort the neutron bank	Always
TRACK	Track individual histories	Always
RITE	Write data on direct access	Always
NSTART	Provide fission source for the next generation	Always
FISFLX	Calculate statistics	Always
IOLEFT	Monitor I/O usage	Always
PULL	Terminate problem	If excessive time is used
WRTCAL	Write data on restart file	If a restart data file is to be created

INQUIR - This library routine returns the value of the next direct-access record. It is called to obtain the pointer for the cross-section data.

JSTIME - This library routine is called several times from GUIDE for timing purposes.

RDCALC - This subroutine is called only if the problem is being restarted at a generation greater than 1. Its purpose is to read data from the restart data file and write the supergrouped data on the direct-access data file. See Sect. F17.3.13.1 for additional information.

REED - This library routine is called early in GUIDE if a problem is not being restarted in order to load data that are needed to create the initial source distribution. REED is called to load supergrouped data for the supergroup being processed from the direct-access supergroup file.

- RD - This library routine is called to load the fission spectrum for use in creating the initial source distribution.
- START - This subroutine is responsible for creating the initial source distribution. See Sect. F17.3.13.2 for additional details.
- CHKSTR - This subroutine calls the library routine MOVE to load the initial source distribution into COMMON /NUTRON/. If the starting points are to be printed, TRKWRT is called to print them using the debug tracking format.
- TRKWRT - This subroutine is called from CHKSTR to print information about the current status of the current neutron in the debug tracking format. When TRKWRT is called from CHKSTR, the information of interest is the position at which the neutron was started. RNDOUT is called from TRKWRT to make the current random number available for printing.
- CLEAR - This library routine is called to initialize the fission density array and the arrays that hold the matrix k_{eff} and associated statistics.
- INDX - This subroutine is called only if the average number of neutrons per fission and the average energy at which fission occurs are to be calculated. (See Sect. F17.4.3, NUB=.) INDX determines the position of the fission cross section in the extra 1-D cross-section array. The fission cross section is required for calculating the average energy at which fission occurs.
- RESET - This subroutine is called to accumulate the fission source and the source vectors for the matrix k_{eff} and to count the number of histories in a supergroup.
- BANKER - This subroutine is responsible for sorting all the particles in the current supergroup into the top of the neutron bank and all other particles into the bottom of the bank.
- TRACK - This subroutine is responsible for the actual tracking of each individual history. See Sect. F17.3.13.3 for a detailed description.
- RITE - When the program returns from TRACK, RITE is called to write the calculated supergrouped data on the direct-access supergroup data file.
- PULL - This library routine is called from GUIDE to set a time interval that results in a nonstandard return if that time interval is exceeded. This step is for the purpose of preventing the program from looping indefinitely. PULL is called later in GUIDE to reset the time interval as appropriate.
- NSTART - This subroutine is called from GUIDE to provide the fission source for the next generation. See Sect. F17.3.13.4 for specific details.
- FISFLX - This subroutine calculates statistics for k_{eff} , the matrix k_{eff} fissions, absorptions, leakages, and fluxes. Section F17.3.13.5 contains additional details.
- IOLEFT - This library routine is called to determine if sufficient I/Os remain to allow processing another generation.

- WRTCAL - If a restart data file is to be created, this subroutine writes the calculated information on the restart data file with a frequency specified by the parameter data (Sect. F17.4.3, RES=). RNDOUT is called to preserve the random number. Then the generation number, random number, number of histories per generation, number of energy groups, banked information, some common information and all the k_{eff} values calculated to this point are written on the restart data file. The neutron bank and, if requested, the fission densities are written. If matrix k_{eff} information is requested, IO is used to write it on the restart data file. Then WRTCAL loops over the number of supergroups, calculating pointers, using REED to load data from the direct-access supergroup file and calling WRTGRP to write the group-dependent calculated information on the restart data file. When all the data have been written, a message is printed.
- WRTGRP - This subroutine writes calculated data (leakages, absorptions, fissions, and if requested, fluxes) for each energy group on the restart data file.

F17.3.13.1 Load Calculated Restart Data

Figure F17.3.28. Flowchart for loading calculated restart data

This section of the program loads the calculated data such as k_{eff} values and fluxes from the restart data file if the starting generation number is greater than 1 (Figure F17.3.28).

- RDCALC - This subroutine is called from GUIDE if the starting generation number is greater than 1. This indicates that a calculation is to be restarted using the starting generation number as the first generation to be processed. Thus all the results that were calculated in a previous run must be loaded from the restart data file to continue the calculation. RDCALC reads the previously calculated data from the restart data file and checks for consistency against parameters that were entered as input data. Appropriate messages are printed if inconsistencies are encountered. RNDIN may be called to load a new random number. STOP is called if more storage is needed to hold the neutron bank. IO is used to load data from the restart data file and SHUFL is called to sort and store the neutron bank. Pointers are calculated for the supergrouped restart data, and RDGRP is called to read the group-dependent data from the restart data file. RITE is used to write the restart data on the supergroup data file.
- RNDIN - This library routine is called to load a new random number for use with the restarted problem if a random number was entered in the parameter input data.

- STOP - This library routine is called to write an error message and stop if the available storage is not large enough to hold the neutron bank.
- IO - This library routine is used to load matrix k_{eff} information if it is to be calculated.
- SHUFL - This subroutine is called to sort and store the neutron bank.
- RDGRP - This subroutine is used to load the supergrouped data from the restart data file. This includes leakages, fissions, absorptions and fluxes.
- RITE - This library routine is used to write previously calculated results on the direct-access supergroup data file so the problem can be restarted properly.

F17.3.13.2 Generate Initial Source Distribution

Figure F17.3.29. Flowchart for providing initial source distribution

This portion of the program is responsible for generating the initial source distribution (Figure F17.3.29) in accordance with information specified in the start data (see Sect. F17.4.8).

- START - This subroutine is responsible for generating the initial source distribution. If fissile material is not used in the problem, STOP is called to write a message and terminate the problem. Appropriate messages are printed if the specified start type is incompatible with the geometry

configuration. Subroutine VOLFIS is called to calculate the volume fraction of fissile material. STOP is called to print error messages if the start data are geometrically invalid or the fraction started as a spike is invalid. LSCAN is used to determine if the specified unit is in the global array. Then START0, STRTSU, START1, START2, START3, START4, START5, or START6 is called to generate starting points having the characteristics specified in the start data (see Sect. F17.4.8). Subroutine LOCBOX is called after both START2 and START3 to determine the unit number at the specified position in the array. Subroutine LOCATE then determines the geometry region that contains the specified point by utilizing POSIT, FINDBX and LOCBOX. FINDBX is called to locate the position within the array that contains the starting point. LOCBOX is called to determine the unit number located at that position in the array. The starting point is translated to the coordinate system of the unit and POSIT is called to determine which region within the unit contains the starting point. A check is then made to be sure the region contains fissile material. If it does not, the point is discarded. If the region contains fissile material, DGTISO is called to provide the initial direction cosines. START uses FLTRN to set the initial energy group and MOVE is called to load the initial data for the history into the neutron bank. JSTIME is called to be sure the allowed time is not exceeded. If it is, or if the required number of source neutrons have been generated, the starting is terminated. If too few initial source neutrons exist, FLTRN and MOVE are used to fill the remaining starting positions from those that were generated. A message to that effect is then printed.

- STOP - This library routine is called from START to write error messages.

- VOLFIS - This subroutine determines the volume fraction of fissile material in an unreflected array or an array whose reflector material is not fissile. It determines the volume fraction of fissile material in the system for single unit problems and reflected problems having fissile reflector material. If the volume fraction of fissile material is found to be zero, an error message is written and execution is terminated.

- LSCAN - This logical function returns a value of true if the specified unit is used in the problem.

- START0 - This subroutine is called from START to generate a uniform initial source distribution in a cuboidal volume. The source distribution is generated by choosing points uniformly throughout the volume using the library routine FLTRN, and discarding points that do not occur in fissile material. See Sect. F17.4.8 and Table F17.4.6 for assistance in modifying the default boundaries over which the starting points are chosen.

- STRTSU - This subroutine is called to generate a uniform initial source distribution for a single unit problem or a reflected problem for which the user has specified that the reflector be included in the starting distribution. FLTRN is used to choose points uniformly throughout a cuboidal volume. DAZIRN, DGTISO, and FLTRN are used to choose points uniformly throughout a noncuboidal volume.

- DAZIRN - This library routine provides the sine and cosine of a random azimuthal angle.

- DGTISO - This library routine provides the direction cosines of an isotopically distributed random direction. It is used to generate an isotropic source distribution.

- START1 -** This subroutine is used to provide starting points chosen from a cosine distribution. The library routines DARSIN and FLTRN are used to provide the cosine distribution. See Table F17.4.6 for details of the various initial starting distributions.
- START2 -** This subroutine starts a specified fraction of the initial source distribution uniformly in fissile material in the unit located at a specified position in the global array. The remainder of the initial source is chosen from a cosine distribution as described in Table F17.4.6. START5 is called to determine the source points located in the unit at the specified location, and START1 is called to choose points from a cosine distribution.
- LOCBOX -** This function is called to return the unit at a given position in a given array.
- START3 -** This subroutine starts all the initial source neutrons at a specified point within the unit located at a specified position in the global array.
- START4 -** In this subroutine, a unit type is specified for starting the initial source distribution. A uniform sampling is made over the global unit orientation array to locate units of the specified type, and start the initial source neutrons at a specified positions within these units. CHOOSE is called to determine the positions within the global array that are occupied by the specified unit type.
- CHOOSE -** This subroutine locates the positions of a specified unit within the global unit orientation array by randomly choosing positions in the array and discarding them if the specified unit was not at that position. The library routine FLTRN is used to randomly choose positions in the unit orientation array.
- START5 -** This subroutine starts the initial source neutrons uniformly in fissile material within a specified unit type. A uniform sampling is made over the global unit orientation array to locate units of this type by utilizing subroutine CHOOSE.
- START6 -** This subroutine starts the initial source neutrons at points specified by the user. These points must be specified relative to the origin of the global array. REED is called to load the start type 6 data from the direct-access device. MOVE is called to move the start data into common. FLTRN is used to randomly supply additional starting points from existing ones. ICOMPA is used to determine if the starting point is identical to the previous one. See Table F17.4.6 for start data specifications.
- LOCATE -** This subroutine determines the geometry region that contains the specified starting point. HROTRN is used to determine the points location in a unit that is contained within a hole. FINDBX is used to determine the point's location in an array and the unit number at that location.
- HROTRN -** This subroutine locates the position of a specific point in a unit that is contained within a hole.
- POSIT -** This subroutine determines the region within the unit that contains the specified position.
- FINDBX -** This subroutine locates the position in an array that contains a specified point.
- LOCBOX -** This function returns the unit for a specified position in an array.

- MOVE - This library routine is called from START to load data from COMMON /NUTRON/ into the neutron bank. It is also used to pad the neutron bank to provide enough starting positions if too few were initially created.
- FLTRN - This library routine is called from various subroutines during creation of the initial source distribution, to return a random number between zero and 1. START calls FLTRN to aid in choosing the initial source neutrons. It is also called if too few starting positions were generated. It is used to randomly choose from the initially created starting positions to pad the neutron bank until sufficient starting points exist.
- JSTIME - This library routine is used for timing purposes.

F17.3.13.3 Track Individual Histories

Figure F17.3.30. Flowchart for tracking individual histories

This section of the program does the actual tracking of the individual histories (Figure F17.3.30).

- TRACK - This subroutine is called by GUIDE to accomplish the actual tracking of the individual histories. Each history is tracked, and its contributions to the various calculated results are tabulated, until it escapes from the system or is killed via Russian roulette. If a history changes supergroups as a result of a collision or an albedo reflection, it is stored in the neutron bank. In the course of tracking a history, an initialization call is made to subroutine ALBIN if differential albedo boundary conditions are utilized in the problem. LDWRT may be called to print debug information and, if history tracks are to be printed, TRKWRT is called from strategic locations throughout TRACK to provide pertinent information about the history as it moves through the tracking process. The library routine MOVE is utilized throughout the tracking procedure to move data in and out of storage arrays and commons. FLTRN is used to provide random numbers used in playing Russian roulette, processing downscatters, picking fission points, picking

scattering angles and determining the fission energy group. EXPRN provides a random number, selected from an exponential distribution, to be used as the number of mean free paths a history can traverse. CROSS is called to determine if a boundary crossing has occurred. TKARRY is used to track a particle inside an array. FINDBX is used to locate the position of a particle in an array. HROTRN is called to transfer the coordinates of a particle from its current unit to the unit within the hole it is entering or vice versa. LOCBOX is called to determine the unit at a specified location in an array. ALBEDO is called to process differential albedo boundary conditions. The library routine DGTISO is used to provide direction cosines from an isotropic distribution. SFLRA provides a random number between -1.0 and 1.0 for use in processing an isotropic scattering. DAZIRN provides the sine and cosine of a random azimuthal angle for use in the anisotropic scattering treatment of a collision.

- DOTPRD - This function returns the dot product of two direction vectors.
- PERIOD - This subroutine processes periodic albedos on paired planes. Given a position and direct vector on one plane, it calculates the new position and direct vector on the paired plane.
- NORMAL - This subroutine returns the normal to a surface at a given point on the surface.
- LDWRT - This subroutine prints debug information that is useful only for a programmer. It is called if BUG=YES is specified in the parameter data (see Sect. F17.4.3). In normal operation, this subroutine should never be called.
- MOVE - This library routine is utilized frequently in TRACK to move data in and out of storage arrays and commons.
- TRKWRT - This subroutine is called from various locations in TRACK to print information about the current neutron as it is being processed. RNDOUT is called from TRKWRT to make the current random number available for printing.
- FLTRN - This library routine provides a random number between zero and 1. TRACK utilizes these random numbers for playing Russian roulette, processing downscatters, picking fission points, determining scattering angles and determining the fission energy group.
- CROSS - This important subroutine is responsible for processing crossings (i.e., it determines when a history has moved out of one geometry region into another). It determines if a crossing has actually occurred, and if it has, the coordinates of the crossing are upgraded to give the crossing point. The fraction of the path length used is also determined.
- TKARRY - This subroutine is used to track a particle inside an array. It determines if a particle changes position within an array or crosses of the array.
- FINDBX - This subroutine locates the position in an array that contains a specified point.
- HROTRN - This subroutine is used to transfer the coordinate system of a particle when it enters or leaves a hole. Upon entering a hole the particle location is transferred to the coordinate system of the unit within the hole. Upon exiting a hole the particle location is transferred to the coordinate system of the unit surrounding the hole.

- LOCBOX - This function returns the unit for a specified position in an array.
- ALBEDO - This subroutine is responsible for processing a differential albedo reflection. The direction cosines for the face where the albedo reflection occurs are loaded, and the incident angle and the albedo energy group corresponding to the incident energy group are determined. The position of the albedo energy group within the supergroup, and the first cross-section energy group and the number of cross-section energy groups corresponding to it are determined. This is used to calculate the new cross-section energy group of the history. Then the returning angle and direction cosines are calculated. The history's weight is then corrected for the weight lost in the albedo portion of the problem. The weight lost in the albedo reflection is summed.
- FLTRN - This library routine is called from ALBEDO to return a random number between zero and 1 that is used to select (1) the albedo energy group corresponding to the input energy group, (2) the returning albedo energy group, (3) the returning energy group corresponding to the returning albedo energy group, and (4) the returning angle.
- EXPRN - This library routine is called from TRACK to provide the number of mean free paths to the next collision. This random number is picked from an exponential distribution.
- DGTISO - This library routine is called from TRACK to provide direction cosines from an isotropic distribution. These direction cosines are utilized in processing isotropic scattering.
- SFLRA - This library routine is called from TRACK to provide a random number between -1.0 and 1.0 for use in processing anisotropic scattering.
- DAZIRN - This library routine is called from ALBEDO to return the sine and cosine of a random azimuthal angle which are used in determining the direction cosines of the returning history.

The remainder of this section is devoted to the logical flow of subroutine TRACK as illustrated by Fig. F17.3.31. The portions of TRACK performing specialized functions are denoted in the text by a descriptive name enclosed in quotes to distinguish them from subroutine names and in the figure by all capital letters. These descriptive names correspond to the functions depicted in the flowchart.

A brief discussion of the logical program flow through subroutine TRACK follows. If differential albedos are used, an initialization call is made to ALBIN. If debug print was specified in the parameter data, LDWRT is called. The library routine MOVE is used to load data from the neutron bank into COMMON /NUTRON/ and various flags are set. Then the fission source portion of TRACK, denoted "FSTART," initializes and sets information necessary for processing the history. The "PATH" portion of TRACK sets the path length. The "CROSSING" portion of TRACK calculates the distance required for the neutron to cross each region boundary in the unit it is currently in. If the neutron is in a unit that is part of an array the "ARRAY TRACKING" portion of TRACK calculates the distance required for the neutron to exit the array boundary. The "POSITION" section of TRACK determines which region in the unit the neutron is in. If the neutron is outside its current unit three possibilities exist: (1) it could be changing to a new array position, (2) it could be exiting a hole, or (3) it could be exiting the global unit. If the neutron is changing array positions it calls subroutine TKARRY which transforms the coordinates of the neutron to those of the unit in the array position containing the neutron. If the neutron is exiting a hole or changing array position, the unit number is updated and it returns to "CROSSING." If the neutron is exiting the global unit it can enter an albedo boundary or leak from the system. If it leaks from the system, the history is terminated. If it enters an albedo boundary it enters the "ALBEDO" portion of TRACK which reflects the neutron back into the global unit.

If the "POSITION" section of TRACK determines the neutron is inside the current unit, the contents of the region containing the neutron is checked. If the region contains a hole, the unit number and coordinate system of the neutron are updated and the code returns to the "CROSSING." If the region contains an array, the subroutine FINDBX is called, which determines the neutron's position relative to the unit it is entering. The neutron then returns to the "CROSSING" section of TRACK.

If the region the neutron is in contains a material, "POSIT" determines if the neutron traverses the region or has a collision in the region. If the neutron traverses the region, it is returned to the "NEUTRON POSITION" section of TRACK; otherwise it enters the "COLLISION" section of TRACK which updates its weights, position, direction, and energy group. If the collision occurs in a region containing fissile material, it enters the "FISSION" section of TRACK. After a collision, the particle can die, move to a new supergroup, in which case it is banked for later, or return to the "PATH" section of TRACK and continue.

"FSTART" - This portion of TRACK calls the library routine MOVE to load information pertaining to the history to be tracked. Then logical flags are set to indicate if the history is in an array and whether or not the history is a split neutron. Variables are initialized and if the history tracks are to be printed, TRKWRT is called to print information about the history. If the history is the result of an albedo reflection that resulted in the history moving to a new supergroup, and the weight is large enough, the history proceeds to the "PATH" portion of TRACK. Otherwise Russian roulette is played. If it survives, the weight is set to the average weight and the history proceeds to the "PATH" portion of TRACK. If the history is a split neutron, variables are initialized and the history proceeds to the "COLLISION" portion of TRACK to undergo the collision process.

"PATH" - This portion of TRACK determines the path length. If all the path length has been exhausted, the library routine EXPRN is used to define a new number of mean-free paths from an exponential distribution. If the region contains a void, the distance traveled is set to the maximum chord length of the system. Otherwise the distance traveled is equal to the remaining path length, divided by the macroscopic total cross section of the mixture contained in the region. The end point of the path is determined from the starting coordinates, the distance traveled and the direction cosines. If the starting and ending coordinates are identical in any given direction, the end point is changed by a very small amount in the proper direction.

"CROSSING"- This portion of TRACK initializes all the pointers and variables for the unit currently containing the neutron and determines which quadratic equations in the QC array need to be processed. It then checks to see if the current unit is in an array, and, if so, goes to the "ARRAY TRACKING" section of TRACK. Subroutine CROSS is then called to calculate the CA array which contains crossing distances from the current neutron position to the boundary of each region in the unit.

"ARRAY TRACKING"- This portion of TRACK initializes all the pointers and variables for the unit currently containing the array and determines which quadratic equations in the QC array need to be processed. Subroutine CROSS is then called to calculate the CA array which contains crossing distances from the current neutron position to the boundary of each region in the unit. The distance from the current neutron position needed to cross the array boundary is determined.

"POSITION"- This portion of TRACK determines which region, if any, in the current unit contains the neutron. This section first determines which region in the unit contains the neutron, if any, and sets a flag to .true. if the neutron is inside the unit and .false. if it is outside the unit. Error

messages are printed if the neutron is found to be in more than one region. These error messages may be caused by incorrectly specified regions (i.e., specifying the same volume in more than one region) or by not explicitly specifying which region contains the boundary between regions.

If the neutron is found to be inside the unit under consideration, the contents of the region are examined. The contents of the region containing the neutron will fall into one of three categories: (1) material, (2) hole, (3) or array. If the neutron is in a region containing material, it transfers to the "POSIT" section of the code. If the neutron is in a region containing a hole, a flag is set indicating an inward crossing into a hole and subroutine HOLROT is called, which translates and rotates the coordinates of the neutron to those of the unit in the hole. The neutron is then transferred to the "CROSSING" section of TRACK.

If the neutron is in a region containing an array, the array number is determined and the appropriate pointers and variables are initialized. If the neutron is already in an array, subroutine MOVE is used to store the current array location in the array stack. Subroutine FINDBX is then called to determine the array position of the neutron and transform the coordinates of the neutron into those of the unit in the array position it is crossing into. The neutron is then transferred to the "CROSSING" section of TRACK.

If the neutron is found not to be in the unit, there are four possibilities: (1) it has undergone an albedo reflection and roundoff error has put it outside the unit, (2) it has crossed out of the global unit, (3) it has crossed out of a hole, or (4) it has changed positions in an array. If the neutron crossed out of the global unit, it is transferred to the "ALBEDO" section of TRACK which determines if it leaks from the system or is reflected back into the system.

If the neutron has crossed out of a hole, a flag is set indicating an outward crossing out of a hole and subroutine HOLROT is called, which translates and rotates the coordinates of the neutron to those of the unit surrounding the hole. The neutron is then transferred to the "CROSSING" section of TRACK. If tracking information was asked for, subroutine TRKWRT is called to print pertinent information. The neutron is then transferred to the "CROSSING" section of TRACK.

If the neutron has changed position in an array, subroutine TKARRY is called to translate the neutron to the coordinate system of the unit in the new array position. If tracking information was asked for, subroutine TRKWRT is called to print pertinent information. The neutron is then transferred to the "CROSSING" section of TRACK.

"POSIT" -

This portion of TRACK determines the material in the region, determines the distance the neutron needs to travel to exit the unit, and computes the amount of mean free paths needed to travel to exit the region. If tracking data were asked for, subroutine TRKWRT is called to print pertinent data. If the number of mean free paths needed to exit the region is greater than the number of mean-free paths assigned in "PATH," the neutron is transferred to the "COLLISION" section of TRACK. Otherwise the distance the neutron has traveled is updated, and the amount of mean-free paths already traveled is computed to exit the region. If tracking data were asked for, subroutine TRKWRT is called to print pertinent data. If the neutron is in an array, the neutron is checked to see if it crosses the array boundary. If it does not, the neutron is transferred to the "POSITION" section of TRACK. If the array boundary is crossed, the region

number, position, unit number, and distance traveled are updated. If the array was nested, subroutine MOVE is called to restore the unit location in the surrounding array. If tracking information was indicated, subroutine TRKWRT is called to print pertinent information. The neutron is then transferred to the "CROSSING" section of TRACK.

"COLLISION" - When a history has a collision, the processing is done in this portion of TRACK. The number of mean-free paths used, distance traveled, and neutron position are updated. If fluxes are to be calculated, the new contribution is summed in. The age of the history is summed, the remaining path length is set to zero, the absorption weight, fission weight, and the contribution to the average number of neutrons produced per fission and the self-multiplication of the unit are calculated, based on the macroscopic cross-section data and the weight of the history. The weight of the history is then redefined to be the weight times the macroscopic nonabsorption probability. If the history tracks are to be printed, TRKWRT is called to print information pertinent to the collision process. If matrix k_{eff} values are to be calculated, the fission weight is summed into the proper arrays. If the weight of the history exceeds the weight at which splitting occurs, a check is made to ensure that the neutron bank has adequate space for another history. If it is full, a message is written and a counter incremented. If the counter reaches 50, the program is terminated and an error message is printed. If the bank can hold another history, the weight of the history is halved and the neutron counter is incremented. If the history tracks are to be printed, TRKWRT is called to print information pertinent to the split neutron. The library routine MOVE is used to store the split neutron in the neutron bank. The history cycles through the checking and splitting process until its weight is less than the weight at which splitting occurs. Then the weight is checked to see if Russian roulette should be played. If it is played and the history survives, the weight is set to the average weight. If Russian roulette is not played, the weight remains unchanged. In both cases, the new energy group is computed and a check is made to determine if the history undergoes anisotropic scattering. If it does, the azimuthal angle is chosen using DAZIRN, and the sine and cosine of that angle are returned to be used for calculating new direction cosines. If the history does not undergo anisotropic scattering, the new direction cosines are chosen from an isotropic distribution using DGTISO. This completes the "COLLISION" portion of TRACK.

"FISSION" - This portion of TRACK is responsible for generating and storing the fission source resulting from a collision. In the "COLLISION" portion of TRACK, the fission weight is defined as the weight of a history times the macroscopic production probability. If the fission weight of a history is greater than zero, the "FISSION" portion of TRACK is executed. To ensure generating enough fission source points to maintain an adequate representation of the true distribution, a minimum production factor is defined at the beginning of each generation to be

$$\frac{3.0\bar{k}}{\sqrt{FG}}$$

where $\bar{k}$ is the running average value of the k_{eff} through the current generation and FG is the number of histories per generation. This represents an estimate of the lower limit of the 99% confidence interval for the distribution of the generation k_{eff} . Experience indicates that using this factor to generate fission source points leads to enough new fission points to fill the neutron bank for most generations.

When the "FISSION" portion of TRACK is entered, the library routine FLTRN is used to provide a random number that is saved. A pseudo fission weight is defined as the fission weight divided by the random number. If the result is less than the production factor, the history proceeds to "PATH" or is stored in the neutron bank, depending on whether or not it remains in the same supergroup. If the history remained in the "FISSION" section, and its fission weight is greater than the production factor, the pseudo fission weight is redefined to be the production factor divided by the random number. If the fission bank is not full, the fission energy group is determined using FLTRN, the fission point is stored in the bank, and the number of fission points is incremented. The library routine MOVE is used to load information pertaining to the fission point from COMMON /NUTRON/ into the fission bank, and the pseudo fission weight is loaded directly into the fission bank. If the fission bank is full when a new fission source point is generated, the bank is searched for the smallest pseudo fission weight. This is compared with the pseudo fission weight of the new fission point, and the point having the larger pseudo fission weight is stored in the bank.

After the fission point has been banked, the fission weight of the history is decremented by the production factor. If the remaining fission weight is greater than zero, the history returns to the beginning of "FISSION" to continue processing.

"ALBEDO" - If an albedo boundary condition is specified on any face of the problem, this portion of TRACK is utilized to provide the proper treatment. Each face is checked in sequence to determine if the history (1) leaks from the system, (2) undergoes specular or mirror image reflection, (3) undergoes periodic reflection, or (4) proceeds through the differential albedo treatment.

If the history undergoes specular or mirror image reflection, it is returned at the point it exited the face with its energy unchanged and the sign of its direction cosines reversed. If a periodic reflection occurs, the history is moved to the opposing face with its energy and direction cosines unchanged. If the history enters a differential albedo reflector, subroutine ALBEDO is called to determine the new weight of the history and its returning angle and energy. If the history enters a new supergroup, TRKWRT may be called to print the history track information and MOVE is called to bank the history in the neutron bank. When a history remains in the same supergroup, it is returned at the point it exited, and Russian roulette is played if the returning weight is low enough to warrant that action. If the weight is sufficiently high to avoid playing Russian roulette, or if the history survives Russian roulette, the history proceeds to the beginning of "PATH" and tracking continues.

F17.3.13.4 Provide the Next-Generation Source

Figure F17.3.32. Flowchart for providing the next-generation source

This section of the program is responsible for providing the source for the next generation from the fission source generated during the tracking procedure (Figure F17.3.32).

NSTART - This subroutine calls CLEAR to initialize the neutron bank and writes an error message if no fission points were generated. Subroutine SORTBK is called to move information from the fission bank containing the fission source generated by the last generation into the neutron bank to be used as the source for the next generation. NSTART then checks to be sure enough source points exist to start the next generation. If too few starting points exist, the library routines MOVE and FLTRN are used to fill the required number of starting positions from the existing fission points.

SORTBK - This subroutine sorts the fission bank so the fission points are loaded in the order of their probability of being picked in a random selection process. For each source history, the library routine MOVE is used to move the fission source generated by the last generation into the neutron bank, and the library routine DGTISO is used to provide direction cosines from an isotropic distribution. Then the neutron number, weight and age are initialized.

F17.3.13.5 End-of-Generation Processing

Figure F17.3.33. Flowchart for end of generation processing

This portion of the program is responsible for processing data at the end of each generation.

- FISFLX -** This subroutine is called at the end of each generation to process data collected for that generation. The generation k_{eff} , the running average value of k_{eff} and its deviation, and the matrix k_{eff} and its deviation are processed and printed. MATK is called to process the matrix $k_{eff}(s)$ and associated information. LOOPER is called and, in turn, calls STATIS to collect and process the contribution and statistics for the flux, fissions, and absorptions, as well as the contribution to the leakage.
- MATK -** This subroutine is called to calculate the matrix k_{eff} by solving for the principal eigenvalue and eigenvector of a matrix using an iterative technique. The library routine CLEAR is used to initialize arrays and SQRT is used in calculating the deviation of the eigenvalue. MATK may be called to calculate the matrix k_{eff} by array position, unit type, array number, and/or hole number.
- LOOPER -** This subroutine is called from FISFLX to load arrays in preparation for calling STATIS. A loop is made over the number of supergroups, within which pointers are calculated, REED is called to load the leakage, absorption, fission and flux arrays from the direct-access supergroup file, STATIS is called to process the data and RITE writes the processed data on the direct-access supergroup file. This procedure is repeated until all supergroups have been processed.
- STATIS -** This subroutine collects the sum of the contributions and the sum of the square of the contributions for the fluxes, fissions, absorptions and leakages to be used at the end of the problem in calculating their deviations.

F17.3.14 END OF PROBLEM PROCESSING

Figure F17.3.34. Flowchart for end-of-problem processing

This portion of the program is responsible for processing data and printing all the results except the fluxes at the completion or termination of a problem.

- KEDIT -** This subroutine controls the processing and printing of results at the end of a problem. The life time and generation time are printed and, if the average number of neutrons per fission was calculated, it and the average fission group are printed. KEDIT then calculates and prints the average k_{eff} and its associated deviation for the 67, 95, and 99% confidence intervals and the number of histories involved. This is done repeatedly, skipping more generations each time. PLTKEF is called to print a plot of the average value of k_{eff} as a function of the number of generations. It also prints a plot of the average value of k_{eff} as a function of the number of generations skipped. LOOPER is called to prepare data for EDITOR which in turn calculates and prints the group-dependent fissions, absorptions and leakages and their deviations. If requested, the fissions and absorptions may also be printed by region. KEDIT then prints the total fissions, absorptions and leakages for the system, and their associated deviations. RNDOUT is called to provide the current random number to be printed. If matrix k_{eff} data were requested, MATRIX is called to calculate and print matrix information. KEDIT then processes and prints the fission densities.
- PLTKEF -** This subroutine is called from KEDIT to print a plot of the average value of k_{eff} vs generation and a plot of the average value of k_{eff} vs generations skipped. The library routines MIN, MAX, and SQRT are used to generate the k_{eff} axis of the plots. The MOD function is used in labeling the generation axis.
- LOOPER -** This subroutine is called from KEDIT to load arrays in preparation for calling EDITOR. A loop is made over the number of supergroups. Within the loop, pointers are calculated, REED is called to load the leakage, absorption, fission and flux arrays from the direct-access supergroup file and EDITOR is called to process the data. RITE then writes the processed data for the supergroup on the direct-access supergroup file.
- FSABED -** This subroutine is called from KEDIT to calculate and print the total fissions and absorptions by region of the problem after all generations have been completed.
- EDITOR -** This subroutine is called from LOOPER to calculate and print the energy-dependent fissions, absorptions and leakages and their deviations. The fissions and absorptions may be region-dependent as well as energy-dependent.
- MATRIX -** This subroutine is called from KEDIT to calculate and print various information related to the matrix k_{eff} . It is called if one or more matrix options were specified in the parameter data (see Sect. F17.4.3). If matrix information was collected, MATK is called to calculate cofactor k_{eff} values. MATRIX then prints them as they are calculated. MATRIX also prints the fission production matrix if that was specified in the parameter data (see Sect. F17.4.3). The library routine LABL is called to print the source vector. MATRIX then prints the average self-multiplication calculated on the basis of collected data. This procedure is repeated for each type of matrix information specified in the parameter data. JSTIME is called to determine the amount of time used in the problem, which is then printed in MATRIX.
- MATK -** This subroutine calculates the principal eigenvalue and eigenvector of a matrix using an iterative technique. It also calculates the deviation associated with the eigenvalue, using CLEAR to initialize arrays and SQRT in calculating the deviation. MATK may be called from MATRIX to calculate cofactor k_{eff} values.

F17.3.15 PRINT FLUXES

Figure F17.3.35. Flowchart for printing fluxes

This portion of the program is responsible for printing the fluxes at the completion of a problem (Figure F17.3.35).

FITFLX - This subroutine determines the maximum number of regions for which flux data will fit in memory and loads and prints them as they will fit. The library routine IOLEFT is called to determine the number of input/output requests remaining before the system cancels the job. Pointers are calculated and the library routine RD is used to load the fluxes for those regions from the direct-access supergroup file. PRTFLX is called to calculate the deviations and print the region- and energy-dependent fluxes and their associated deviations. If more fluxes remain to be printed, the process is repeated until all have been printed.

PRTFLX - This subroutine normalizes the fluxes, calculates their deviations and prints them, one supergroup at a time. The library routine SQRT is used when calculating the deviations.

F17.3.16 REFERENCES

1. S. K. Fraley, *Users Guide for ICE-II*, ORNL/CSD/TM-9/R1, Union Carbide Corp., Nucl. Div., Oak Ridge Natl. Lab., July 1977. Also see "ICE-S: Module to Mix Multigroup Cross Sections," Sect. F8 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 4 (ORNL/NUREG/CSD-2/R4), Vols. I, II, and III, February 1995). Available from Radiation Shielding Information Center, Oak Ridge National Laboratory as CCC-545.
2. "Appendix B, Generalized Gaussian Quadrature," *The MORSE Code - A Multigroup Neutron and Gamma-Ray Monte Carlo Transport Code*, ORNL-4585, Union Carbide Corp., Nucl. Div., Oak Ridge Natl. Lab., 1970. Also see "MORSE-SGC/S for the SCALE System," Sect. F9 of *SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation*, NUREG/CR-0200, Rev. 4 (ORNL/NUREG/CSD-2/R4), Vols. I, II, and III, February 1995). Available from Radiation Shielding Information Center, Oak Ridge National Laboratory as CCC-545.

F17.4 KENO-VI DATA GUIDE

KENO-VI may be run "stand alone" or as a part of a SCALE criticality safety sequence. If KENO-VI is run "stand alone," cross-section data can be utilized from an AMPX¹ working-format library or from an ICE (Sect. F8) mixed cross-section MORSE/KENO-V.a format library, also called a Monte Carlo format cross-section library. If KENO-VI uses an AMPX working-format library, a mixing table data block must be entered. If an ICE mixed cross-section MORSE/KENO-V.a library is used, a mixing table data block is not entered, and the mixtures specified in the KENO-VI geometry description must be consistent with the mixtures created in ICE. These are the entries in the 11\$[MUD] array in the ICE input data.

If KENO-VI is run as part of a SCALE criticality safety sequence, the mixtures are defined in the CSAS data (Sect. C6.4) and a mixing table data block cannot be entered in KENO-VI. Furthermore, the mixture numbers used in the KENO-VI geometry description must correspond to those defined in the standard composition data of the CSAS input. A mixture number of 500 must be used in the KENO-VI geometry description in order to use a cell-weighted mixture. A cell-weighted mixture is available only in SCALE sequences that use XSDRN to perform a cell-weighting calculation.

F17.4.1 KENO-VI INPUT OUTLINE

The data input for KENO-VI is outlined below. Defaulted data for KENO-VI have been found to be adequate for many problems. These values should be carefully considered when entering data. The information in **BOLD TYPE** is entered as data.

Blocks of input data are entered in the form:

READ XXXX input data **END XXXX**

where **XXXX** is the keyword for the type of data being entered. The keywords that can be used are listed in Table F17.4.1. A minimum of four characters are required for a keyword. However, the keywords can be up to twelve characters long, the first four of which must be input exactly as listed in the table. Data input is activated by entering the words **READ XXXX** followed by one or more blanks. All input data pertinent to **XXXX** are then entered. Data for **XXXX** are terminated by entering **END XXXX** followed by two or more blanks.

Table F17.4.1 Types of input data

Type of data	First four characters
Parameters	PARA or PARM
Geometry	GEOM
Biasing	BIAS
Boundary conditions	BOUN or BNDS
Start	STAR or STRT
Array (unit orientation)	ARRA
Extra 1-D cross sections	XIDS
Cross-section mixing table ^a	MIXT or MIX
Plot or picture ^a	PLOT or PLT or PICT

^aMIX and PLT must include a trailing blank that is considered part of the keyword.

Two data records **must** be entered for every problem. The first is the problem title. The second is the **END DATA** to terminate the problem.

(1) **problem title**

Enter a problem title (limit 80 characters including blanks). A title **must be entered** if running "stand alone."

See Sect. F17.4.3.

When used in a CSAS sequence, this title is omitted.

(2) **READ PARA parameter data END PARA**

Enter parameter input as needed to describe a problem. Default values are assigned to all parameters. A problem **can** be run without entering any parameter data if the default values are acceptable.

Parameter data must begin with the words **READ PARA**. Parameter data may be entered in any order. If a parameter is entered more than once, the last value is used. The words **END PARA** terminate the parameter data. See Sect. F17.4.3.

(n₁)...(n₉) The following data may be entered in any order. Data not needed to describe the problem may be omitted.

(n₁) **READ GEOM all geometry region data END GEOM**

Geometry region data **must be entered** for every problem that is not a restart problem. Geometry data must begin with the words **READ GEOM**. The words **END GEOM** terminate the geometry region data. See Sect. F17.4.4.

(n₂) **READ ARRA array definition data END ARRA**

Enter array definition data as needed to describe the problem. Array definition data define the array size and position units (defined in the geometry data) in a three-dimensional (3-D) lattice that represents the physical problem being analyzed. Array data must begin with the words **READ ARRA**. The words **END ARRA** terminate the array data. See Sect. F17.4.5.

(n₃) **READ BIAS biasing information END BIAS**

Biasing information is used to define the weight that is given a neutron surviving Russian roulette. Enter biasing information as needed to describe the problem. Biasing data must begin with the words **READ BIAS**. The words **END BIAS** terminate the biasing data. See Sect. F17.4.7.

(n₄) READ BOUN albedo boundary conditions END BOUN

Enter albedo boundary conditions as needed to describe the problem. Albedo data must begin with the words **READ BOUN** and terminate with the words **END BOUN**. See Sect. F17.4.6.

(n₅) READ STAR starting distribution information END STAR

Enter starting information data for starting the initial source neutrons only if a uniform starting distribution is undesirable. Start data must begin with the words **READ STAR** and terminate with the words **END STAR**. See Sect. F17.4.8.

(n₆) READ MIXT cross-section mixing table END MIXT

Enter a mixing table to define all the mixtures to be used in the problem. The mixing table must begin with the words **READ MIXT** and end with the words **END MIXT**. Do not enter mixing table data if KENO-VI is run as a part of a SCALE criticality safety sequence. See Sect. F17.4.10.

(n₇) READ X1DS extra 1-D cross-section IDs END X1DS

Enter the IDs of any extra one-dimensional (1-D) cross sections that are to be used in the problem. These must be available on the mixture cross-section library. Extra 1-D cross-section data must begin with the words **READ X1DS** and terminate with the words **END X1DS**. See Sect. F17.4.9.

(n₈) READ PLOT plot data END PLOT

Enter the data needed to provide a two-dimensional (2-D) printer plot of a slice through a specified portion of the 3-D geometrical representation of the problem. Plot or picture data must begin with the words **READ PLOT** and terminate with the words **END PLOT**. See Sect. F17.4.11.

(n₉) END DATA must be entered

Terminate the data for the problem.

F17.4.2 PROCEDURE FOR DATA INPUT

This section is a brief list of the input data for KENO-VI. Additional information concerning KENO-VI data input may be found in Sect. F17.5. The first data record of "stand alone" KENO VI must be the title. The next block of data must be the parameters if they are to be entered. A problem can be run without entering the parameters. The remaining blocks of data can be entered in any order.

BOLD TYPE specifies keywords. A keyword is used to identify the data that follow it. When a keyword is used, it must be entered exactly as shown in the data guide. All keywords, except those ending with an equal sign, must be followed by at least one blank.

small italics correlate data with a program variable name. The actual values are entered in place of the program variable name and are terminated by a blank or a comma.

CAPITAL ITALICS identify general data items. General data items are general classes of data including

- (1) geometry data such as *UNIT INITIALIZATION* and *UNIT NUMBER DEFINITION*, *GEOMETRY REGION DEFINITION VECTOR*, *GEOMETRY WORD*, *MIXTURE NUMBER*, *BIAS ID*, and *REGION DIMENSIONS*,
- (2) albedo data such as *FACE CODES* and *ALBEDO NAMES*, and
- (3) weighting data such as *BIAS ID NUMBERS*, etc.

F17.4.3 TITLE AND PARAMETER DATA

TITLE . . . A title must be entered if KENO VI is being run “stand alone” (i.e., not part of a CSAS sequence).

title length is 80 characters, including blanks.

PARAMETER DATA . . . Enter only those parameters whose values you wish to change. The commonly changed parameters are *TME*, *GEN*, and *NPG*. Seldom changed parameters are *NBK*, *NFB*, *XNB*, *XFB*, *WTH*, *WTL*, *TBA*, *BUG*, *TRK*, and *LNG*.

READ PARAM

Floating-point parameters

RND = <i>rndnum</i>	input hexadecimal random number; a default value is provided. If a random number is specified, it should be chosen from a previous run.
TME = <i>tmax</i>	execution time (in minutes) for the problem, default = 30 minutes.
TBA = <i>tbtc</i>	time allotted for each generation (in minutes), default = 0.5 minutes. If <i>tbtc</i> is exceeded in any generation, the problem is terminated and final edits are performed.
WTA = <i>dwtav</i>	the default average weight given a neutron that survives Russian roulette, <i>dwtav</i> default = 0.5.
WTH = <i>wthigh</i>	the default value of <i>wthigh</i> is 3.0 and should be changed only if the user has a valid reason to do so. The weight at which splitting occurs is defined to be <i>wthigh</i> x <i>wtavg</i> , where <i>wtavg</i> is the weight given to a neutron that survives Russian roulette.
WTL = <i>wtlow</i>	Russian roulette is played when the weight of a neutron is less than <i>wtlow</i> x <i>wtavg</i> . The <i>wtlow</i> default = 1.0/ <i>wthigh</i> .

SIG = *sigma* This is used to terminate a problem when a standard deviation of *sigma* has been reached. The problem will still terminate when the specified number of generations have been run, even if the standard deviation is still greater than *sigma*.

NOTE: The default values of *wthigh* and *wtlow* have been determined to minimize the deviation per unit running time for many problems.

Integer parameters

GEN = <i>nba</i>	number of generations to be run, default = 103
NPG = <i>npb</i>	number of neutrons per generation, default = 300
NSK = <i>nskip</i>	number of generations (1 through <i>nskip</i>) to be omitted when collecting results, default = 3
RES = <i>nrstr</i>	number of generations between writing restart data, default = 0. If RES is zero, restart data are not written. When restarting a problem, RES is defaulted to the value that was used when the restart data block was written. Thus, it must be entered as zero to terminate writing restart data for a restarted problem. (WRS is the logical unit number for writing restart data. See logical unit numbers in the parameter data.)
NBK = <i>nbank</i>	number of positions in the neutron bank, default = <i>npb</i> + 25
XNB = <i>nxnbk</i>	number of extra entries in the neutron bank, default = 0
NFB = <i>nfbnk</i>	number of positions in the fission bank, default = <i>npb</i>
XFB = <i>nxfbk</i>	number of extra entries in the fission bank, default = 0
X1D = <i>numxld</i>	number of extra 1-D cross sections, default = 0
LNG = <i>lng</i>	number of words of storage to be requested by subroutine <i>ALOCAT</i> , default = 1000000. (This value is reduced to fit in the space allotted to the job when the problem is run.)
BEG = <i>nbas</i>	beginning generation number, default = 1. If BEG is greater than 1, restart data must be available. BEG must be 1 greater than the number of generations retrieved from the restart file.
NB8 = <i>nb8</i>	number of blocks allocated for the first direct-access unit, default = 200
NL8 = <i>nl8</i>	length of blocks allocated for the first direct-access unit, default = 789

Alphanumeric parameter data ... enter *YES* or *NO*

RUN = *lrn* key for determining if the problem is to be executed when data checking is complete, default = YES

Note: The value of *RUN* set here will be overridden by a value entered in the *PLOT* data. However, if the problem is restarted, the default value or the value entered here is the value that will be used unless the *PLOT* data block from the restart unit is overridden by new *PLOT* data. See Sect. F17.4.11.

FLX = *nflx* key for collecting and printing fluxes, default = NO

FDN = *nfdn* key for collecting and printing fission densities, default = NO

ADJ = *nadj* key for running adjoint calculation, default = NO. Adjoint cross sections must be available to run an adjoint problem. If *LIB*= is specified, the cross sections will be adjointed by the code. If *XSC*= is specified, the cross sections must already be in adjoint order.

AMX = *amx* key for printing all mixture cross-section data. This is the same as activating *XAP*, *XS1*, *XS2*, *PKI*, and *uPID*. If any of these are entered in addition to *AMX*, that portion of *AMX* will be overridden, default = NO.

XAP = *prtap* key for printing discrete scattering angles and probabilities for the mixture cross sections, default = NO

XS1 = *prtp0* key for printing mixture 1-D cross sections, default = NO

XS2 = *prt1* key for printing mixture 2-D cross sections, default = NO

PKI = *prtchi* print input fission spectrum, default = NO

PID = *prtex* print extra 1-D cross sections, default = NO

FAR = *lfa* key for printing fissions and absorptions by region, default = NO

MKP = *larpos* calculate and print matrix k-effective by unit location, default = NO.
Unit location may also be referred to as array position or position index.

CKP = *lckp* calculate and print cofactor k-effective by unit location, default is the value of *MKP*. Unit location may also be referred to as array position or position index.

FMP = *pmapos* print fission production matrix by array position, default = NO

MKU = *lunit* calculate and print matrix k-effective by unit type, default = NO

CKU = *lcku* calculate and print cofactor k-effective by unit type, default is the value of *MKU*

FMU = *pmunit* print fission production matrix by unit type, default = NO

MKH = *lmhole* calculate and print matrix k-effective by hole number, default = NO

CKH = *lckh* calculate and print cofactor k-effective by hole number, default is the value of MKH

FMH = *pmhole* print fission production matrix by hole number, default = NO

HHL = *lhgh* collect matrix information by hole number at the highest hole nesting level, default = NO

MKA = *lmarray* calculate and print matrix k-effective by array number, default = NO
A global array must be specified if array matrix data are collected.

CKA = *lcka* calculate and print cofactor k-effective by array number, default is the value of MKA

FMA = *pmarray* print fission production matrix by array number, default = NO

HAL = *langh* collect matrix information by array number at the highest array nesting level, default = NO

PLT = *lplot* key for drawing specified pictures of the problem geometry, default = YES

Note: To draw a plot, appropriate plot data must be entered. The value of *PLT* set here will be overridden by a value entered in the *PLOT* data. However, if the problem is restarted, the default value or the value entered here is the value that will be used unless the *PLOT* data block from the restart unit is overridden by new *PLOT* data. See Sect. F17.4.11. The value of *lplot* set here is written on the restart unit, and the value of *lplot* set in the *PLOT* data is not.

BUG = *ldebug* print debug information, default = NO
Enter *YES* for code debug purposes only.

TRK = *ltrk* print tracking information, default = NO
Enter *YES* for code debug purposes only.

PWT = *lpwt* print weight average array, default = NO

PGM = *lgeom* print unprocessed geometry as it is read, default = NO

SMU = *lmult* calculate the average self-multiplication of a unit, default = NO

NUB = *newbar* calculate the average number of neutrons per fission and the average energy group at which fission occurred, default = NO

PAX = *lcorssp* print the arrays defining the correspondence between the cross-section energy group structure and the albedo energy group structure, default = NO

Logical Unit Numbers

XSC = <i>xsecs</i>	logical unit number for a MORSE/KENO-VI format mixed cross-section library, default = 14
ALB = <i>albedo</i>	logical unit number for albedo data, default = 79
WTS = <i>wts</i>	logical unit number for weights, default = 80
LIB = <i>lib</i>	logical unit number for <i>AMPX</i> working format cross-section library, default = 0
SKT = <i>skrt</i>	logical unit number for scratch space, default = 16
RST = <i>rstrt</i>	logical unit number for reading restart data, default = 0 Enter a logical unit number to restart if <i>BEG</i> > 1
WRS = <i>wstrt</i>	logical unit number for writing restart data, default = 0 A nonzero value must be entered if <i>RES</i> > 0.

EXAMPLE: READ PARAM NPG=203 FLX=YES END PARAM

F17.4.4 GEOMETRY DATA

GEOMETRY REGION DATA . . . geometric arrangements in KENO-VI are achieved in a manner similar to using a child's building blocks. Each building block is called a UNIT. An array or lattice is constructed by stacking these units. Once an array or lattice has been constructed, it can be placed in a unit by using the ARRAY specification.

Each UNIT has its own coordinate system. All geometry data used in a problem are correlated to the absolute coordinate system by specifying a global unit. A global unit that encloses the entire system must be specified for every problem including a single unit problem. Units are constructed of combinations from over a dozen predefined shapes plus any other shapes that can be defined using quadratic equations. These geometric shapes are allowed to intersect each other, producing regions that are then described by specifying them as internal or external to the geometric shapes. The geometric shapes can be translated anywhere within the system and rotated to any orientation. Figure 17.4.1 shows some acceptable geometric configurations.

Special options are provided to enhance the basic geometry package. These fall under the heading EXTENDED GEOMETRY DESCRIPTIONS and include ARRAY and HOLE descriptions. The HOLE option allows placing a unit within a geometry/material region (see Fig. F17.4.2). Where a hole record is used, the region boundary must coincide exactly with the boundary of the unit placed in the region. The hole option allows complex units to be constructed separately and then placed in a region on another unit. Since a particle must check every region to determine its location within a unit, using holes to contain complex sections of a problem may decrease the CPU time needed for the problem. An arbitrary number of HOLES can be placed in a unit.

Figure F17.4.1 Examples of geometric configurations allowed in KENO-VI

Figure F17.4.2 Example demonstrating HOLE capability in KENO-VI

Lattices or arrays are created by stacking UNITS. Units that have a rectangular parallelepiped outer region can be used to construct a rectangular array. Units that have a hexprism outer region can be used to construct a triangular-pitched matrix. In either case, the adjacent faces of adjacent units stacked together must match exactly. See Sect. F17.5.6.4 for additional clarification and Figs. F17.4.3 and 17.4.4 for typical examples.

Figure F17.4.3 Example of rectangular-pitched array construction

Figure F17.4.4 Example of triangular-pitched array construction

The ARRAY option is provided to allow placing an array or lattice within a unit. An array is placed in a unit by placing it directly into a geometry/material region. The region boundary containing the array must coincide with or be contained within the array boundary. The region boundary becomes the array boundary. A particle enters or leaves the array when the region boundary is crossed. Multiple array may be placed directly in a UNIT by placing them in separate regions. Arrays can also be placed within a unit using HOLES. When an array is placed in a unit via a HOLE, the unit that contains the array, rather than the array itself, is placed in the unit. Arrays of dissimilar arrays can be created by stacking units that contain arrays. See Fig. F17.4.5 for an example of an array composed of units containing holes and arrays.

Figure F17.4.5 Example of an array composed of units containing arrays and holes

The method of entering GEOMETRY REGION DATA follows:

READ GEOM GEOMETRY REGION DATA END GEOM

GEOMETRY REGION DATA must be entered unless the problem is being restarted. A description of all units the user wishes to define must be entered. See Sect. F17.5.6 for detailed examples.

The description of a unit includes all geometry data following a UNIT INITIALIZATION. A unit is terminated by encountering another UNIT INITIALIZATION or an END GEOM.

A GEOMETRY REGION DATA description consists of the following:

- (a) UNIT INITIALIZATION
 - (b) GEOMETRY REGION DESCRIPTION
 - (c) OPTIONAL GEOMETRY COMMENTS
- (a) *UNIT INITIALIZATION* . . . This data sequence signals the beginning of a new geometric coordinate system and assigns the unit number to the geometry regions comprising the unit.

A UNIT INITIALIZATION is invoked when one or more of the following data items are encountered:

(a1) GLOBAL SPECIFICATION

fgeom

GLOBAL

The word GLOBAL, when entered, must be followed by one or more blanks, the word UNIT, and a UNIT ID NUMBER. Enter the geometry word GLOBAL immediately prior to the UNIT that defines the overall geometric boundaries of the problem. A global unit must be entered for each problem.

(a2) UNIT NUMBER DEFINITION

KEYWORD UNIT ID NUMBER

fgeom

nbox

UNIT

enter unit ID number (greater than zero)

The UNIT NUMBER definition assigns the specified unit number to the geometry data that define the unit.

- (b) *GEOMETRY REGION DESCRIPTION* . . . This type of geometry data consists of geometry records, media records, a boundary record and their associated data. Free-form input is used to enter the data. Options R, *, \$, and P from Table F17.4.2 can be used. The first record, called the GEOMETRY RECORD, is entered in the form:

GEOMETRY KEYWORD

fgeom

GEOMETRY RECORD LABEL (integer)

lbl

APPROPRIATE REGION DIMENSIONS (cm)

xx

GEOMETRY MODIFICATION KEYWORD

moddat

APPROPRIATE MODIFICATION INFORMATION

modinf

The second record, called the *MEDIA RECORD*, is entered in the form:

MEDIA KEYWORD

fmed

MIXTURE, HOLE, OR ARRAY ID

mat

BIAS ID, if appropriate
imp

REGION DEFINITION VECTOR
i1 i2 i3 i4

The third record, called the BOUNDARY RECORD, is entered in the form:

BOUNDARY KEYWORD
bndry

REGION DEFINITION VECTOR
i1 i2 i3 i4

The geometry records contain information describing the dimensions and location of each geometric shape. The media records contain information describing the contents of each region and how the region boundaries relate to the geometric shapes. The geometry and media records can be combined in any order within a unit. The region definition vector in the media and boundary records refer to the geometry record labels. In the region definition vector, a positive label means the media is inside the specified geometric shape and a negative label means the media is outside the specified geometric shape. Each unit must contain one BOUNDARY record which describes the unit boundary. Only that section of the unit geometry contained within the volume specified by the boundary record is considered part of the unit.

The *GEOMETRY KEYWORD fgeom* is followed by one or more blanks and must be one of the keywords below. A label and the *APPROPRIATE REGIONAL DIMENSIONS* follow the keywords as described below.

CONE, CUBOID, CYLINDER, DODECAHEDRON, ECYLINDER, ELLIPSOID, HEXPRISM, HOPPER, PARALLELEPIPED, PPIPED, PLANE, QUADRATIC, RHOMBOID, SPHERE, WEDGE

Note: *fgeom* may be no more than 12 characters long.

- CONE** specifies a body consisting of one nappe of a right circular cone. It is defined by specifying the top radius of the cone, R_t , the Z coordinate of the top face, Z_t , the bottom radius of the cone, R_b , and the Z coordinate of the bottom face, Z_b . Figure 17.4.6 shows the correct input sequence for a cone.
- CUBOID** specifies a rectangular parallelepiped. It is defined by specifying the +X dimension, -X dimension, +Y dimension, -Y dimension, +Z dimension, -Z dimension. It is perpendicular to the X, Y, and Z axes unless otherwise specified by the option geometry modification data. Figure 17.4.7 shows the correct input sequence for a cuboid.
- CYLINDER** specifies a right circular cylinder. It is defined by specifying the radius of the cylinder, R , the Z coordinate of the top face, Z_t , and the Z coordinate of the bottom face, Z_b . Its centerline must lie on the Z axis, unless otherwise specified by the optional geometry modification data. Figure 17.4.8 shows the correct input sequence for a cylinder.

Figure F17.4.6 Example of cone construction

Figure F17.4.7 Example of cuboid construction

Figure F17.4.8 Example of cylinder construction

DODECAHEDRON specifies a body whose surface consists of 12 rhombuses of the same size and shape. It is defined by specifying the radius of the inscribed sphere, R . It is centered on the origin in a fixed orientation unless otherwise specified by the optional geometry modification data. Figure 17.4.9 shows the correct input sequence for a dodecahedron.

ECYLINDER specifies a right cylinder with an elliptical cross-section. It is defined by specifying the semiradius along the x-axis, R_x , the semiradius along the y-axis, R_y , the Z coordinate of the top face, Z_t , and the Z coordinate of the bottom face, Z_b . Its centerline must lie on the Z axis, unless otherwise specified by the optional geometry modification data. Figure 17.4.10 shows the correct input sequence for an elliptical cylinder.

ELLIPSOID specifies a body whose cross-section slices parallel to each of the coordinate axes are ellipses. It is defined by specifying the semiradius along the x-axis, R_x , the semiradius along the y-axis, R_y , and the semiradius along the z-axis, R_z . It is centered about the origin, unless otherwise specified by the optional geometry modification data. Figure 17.4.11 shows the correct input sequence for an ellipsoid.

HEXPRIISM specifies a body whose top and bottom faces are hexagons that have the same orientation and are perpendicular to the Z axis. It is defined by specifying the inscribed radius, R , the Z coordinate of the top face, Z_t , and the Z coordinate of the bottom face, Z_b . Figure 17.4.12 is an example input for a hexprism. See Fig. F17.4.4 for the default orientation used to stack hexprisms in an array.

DODECAHEDRON LBL R
(R is the Inscribed Radius)

Figure F17.4.9 Example of dodecahedron construction

Figure F17.4.10 Example of elliptical cylinder construction

Figure F17.4.11 Example of ellipsoid construction

HEXPRISM LBL R Z_t Z_b
 (R is the Inscribed Radius)

Figure F17.4.12 Example of hexprism construction

HOPPER specifies a body whose top and bottom faces are rectangular parallelograms centered about the z-axis and parallel to the x and y axes. It is defined by specifying the half-length of the top face along the x-axis, Lxt, the half-length of the top face along the y-axis, Lyt, the Z coordinate of the top face, Zt, the half-length of the bottom face along the x-axis, Lxb, the half-length of the bottom face along the y-axis, Lyb, and the Z coordinate of the bottom face, Zb. Its centerline must lie on the Z axis unless otherwise specified by the optional geometry modification data. Figure 17.4.13 shows the correct input sequence for a hopper.

PARALLELEPIPED is a body with six faces composed of parallelograms, whose opposing faces are parallel. It is defined by specifying the length of the faces in the x direction, XDIST, the length of the faces in the y direction, YDIST, the length of the faces in the z direction, ZDIST, the angle between the x-face and the y-axis, PSI, the angle between the y-face and the z-axis, THETA, and the angle between the projection of the top corner nearest the z-axis onto the x-y plane and the x-axis, PHI. The bottom face must lie on the x-y plane at $Z = 0$ with a corner at the origin unless otherwise specified by the optional geometry modification data. Figure 17.4.14 shows the correct input sequence for a parallelepiped. The angles psi, theta, and phi must be in the range 0 to 90° .

PLANE is a surface where any two points can be connected by a straight line entirely contained within plane that divides all space into two regions. The positive side of the plane is the side the normal points to or where the equation $aX + bY + cZ + d > 0$. It is defined by specifying the coefficients of the equation $aX + bY + cZ + d = 0$ using the keywords XPL=a, YPL=b, ZPL=c, and CON=d. Only the nonzero coefficients of the equation need to be specified. Figure 17.4.15 shows the correct input sequence for a plane.

QUADRATIC specifies a surface using a quadratic equation of the form:
$$aX^2 + bY^2 + cZ^2 + dXY + eXZ + fYZ + gX + hY + iZ + j = 0.$$
It is defined by specifying the coefficients of the above equation using the keywords AQU=a, BQU=b, CQU=c, DQU=d, EQU=e, FQU=f, GQU=g, HQU=h, IQU=i, and JQU=j. Only the nonzero coefficients of the equation need to be specified.

RHOMBOID is a body composed of six identical faces, each one a rhombus. It is defined by specifying the length of the edge of the base along the x-axis, DX, and the angle between y edge of the base and the y-axis, psi. Its base is in the xy plane at $Z = 0$, with a corner at the origin unless otherwise specified by the optional geometry modification data. Figure 17.4.16 shows the correct input sequence for a rhomboid.

SPHERE specifies a sphere. It is defined by specifying the radius, R. It is centered about the origin, unless otherwise specified by the optional geometry modification data. Figure 17.4.17 shows the correct input sequence for a sphere.

WEDGE is a right-triangular prism having five faces. The two ends are triangles, and the three sides are rectangles. It is defined by specifying the length of the base along the x-axis, XBASE, the x and y coordinate where the other two sides meet, XPT and YPT, and the length along the z-axis, ZLNG. One side is in the XZ plane at $Y = 0$, and the bottom face is in the XY plane at $Z = 0$,

Figure F17.4.13 Example of hopper construction

Figure F17.4.14 Example of parallelepiped construction

Figure F17.4.15 Example of plane construction

Figure F17.4.16 Example of rhomboid construction

Figure F17.4.17 Example of sphere construction

Figure F17.4.18 Example of wedge construction

with a corner at the origin unless otherwise specified by the optional geometry modification data. Figure 17.4.18 shows the correct input sequence for a wedge.

The *GEOMETRY MODIFICATION KEYWORD*, *moddat*, is followed by one or more blanks and must be one of the keywords below. The geometry modification data follow the appropriate region dimensions on the

geometry record. The modification data can be used in any order or combination with respect to a geometry record. The *APPROPRIATE MODIFICATION INFORMATION*, *modinf*, follows the keyword as described below.

CHORD, ORIGIN, ROTATE

- CHORD** is used to provide a place that truncates a geometry shape. It is used by following the keyword with a subordinate keyword, +X=, -X=, +Y=, -Y=, +Z=, or -Z=, which defines the direction of the chord and the intercept of the plane on the axis. A plus in the keyword indicates the positive side of the chord is the inside direction. A minus in the keyword indicates the negative side of the chord is the inside direction. Figure F17.4.19 provides two examples of the use of the CHORD option.
- ORIGIN** is used to translate the origin of the geometric shape to a specified location. It is used by following the keyword with the subordinate keywords, X=, Y=, and Z=, followed respectively by the translated coordinates. Only the nonzero coordinates and their respective keywords need to be specified. Figure F17.4.20 provides an example of the use of the ORIGIN option.
- ROTATE** is used to rotate the geometric shape with respect to the origin of the coordinate system of the unit. It is used by following the keyword with the subordinate keywords A1=, A2=, and A3=. The subordinate keywords are the three angles in degrees of the rotation associated with the Euler X-convention. Only the nonzero angles and their respective keywords need to be specified. Figure F17.4.21 provides an explanation of the ROTATION option.

The *MEDIA KEYWORD*, *fmed*, is followed by one or more blanks and must be one of the keywords below.
MEDIA, HOLE, ARRAY

- MEDIA** is used to define the location of a mixture relative to the geometric shapes in the unit. The keyword, MEDIA, is followed by one or more blanks and the *MIXTURE ID mat*, the *BIAS ID imp*, and the *REGION DEFINITION VECTOR* (i1, i2, ... in). Figure F17.4.22 shows the input for a set of three intersecting spheres in a cuboid.
- HOLE** is used to position a unit within a region in another unit relative to the geometric shapes in the other unit. The keyword, HOLE, is followed by one or more blanks and the *HOLE ID mat*, and the *REGION DEFINITION VECTOR*, i1 i2 ... in. The unit being placed in the hole can be rotated and translated using the *APPROPRIATE MODIFICATION INFORMATION*. The boundary dimensions of the unit being placed using HOLE must precisely match the boundary of the region containing the HOLE. If the unit boundary record crosses the volume of the region containing a hole, the unit boundary must be included as part of the boundary of the unit placed in the hole. The unit being placed in the hole is aligned in the region using ROTATE and ORIGIN.
- ARRAY** is used to position an array within a region in a surrounding unit relative to the geometric shapes in the surrounding unit. The keyword is followed by one or more blanks and the *ARRAY ID mat* and the *REGION DEFINITION VECTOR*, i1 i2 ... in. The *REGION DEFINITION VECTOR* defines the boundary of the array. The subordinate keyword PLACE is then entered, followed

Figure F17.4.19 Examples of the CHORD option

Figure F17.4.20 Example of the ORIGIN option

CYLINDER LBL R Zt Zb ROTATE A1= α A2= β A3= γ

Figure F17.4.21 Explanation of the ROTATE option

```
sphere 10 3 origin y=2
sphere 20 3 origin x=-2 y=-2
sphere 30 3 origin x=2 y=-2
cuboid 40 6 -6 6 -6 6 -6
media 1 1 10 -20 -30
media 2 1 20 -10 -30
media 3 1 30 -10 -20
media 4 1 10 20 -30
media 5 1 20 30 -10
media 6 1 30 10 -20
media 7 1 10 20 30
media 8 1 40 -10 -20 -30
boundary 40
```

Figure F17.4.22 Example of the MEDIA record

by six numbers that precisely locate the array within the surrounding unit. The first three numbers consist of the location in the array of the unit selected to position the array. The next three numbers consist of the position in the surrounding unit that contains the origin of the selected unit.

The *MIXTURE*, *HOLE*, or *ARRAY ID mat* specifies the mixture, hole, or array that is to occupy the volume defined by the region if the keyword is *MEDIA*. This information is followed by one or more blanks. If the region contains a mixture, *mat* specifies the mixture that is to occupy the volume defined by the region. The mixture ID number is followed by one or more blanks. [A *MIXTURE* ID of zero indicates a void region (i.e., no material is present in the volume defined by the region).]

The *BIAS ID imp* specifies the weights that are to be used in the volume defined by each media record. This is used only if the *MEDIA* keyword is specified. Default weights are used for every *imp* not specified in the *BIASING INFORMATION* data. For clarification of how to use *imp* to specify nondefault weights, see Sect. F17.4.7. The *BIAS ID* number is followed by one or more blanks.

REGION DEFINITION VECTOR i1 i2 ... is a series of geometry record numbers used to define the location of a region that contains a material mixture, hole, or array. A positive value indicates the region is located inside the space defined by the geometry record. A negative value indicates the region is located outside the space defined by the geometry record. As many geometry record numbers as are required to define the volume occupied by the region must be entered. Each media card represents a distinct region of the unit. Each region can only be represented by one media card. Care must be taken when regions share boundaries to specify which region contains the boundary.

The *BOUNDARY KEYWORD*, **BOUNDARY** is followed by one or more blanks and the region definition vector that defines the boundary of the unit. Each unit must have one and only one boundary record. The boundary record describes the volume contained within the unit. Only that section of the geometry contained within the volume specified by the unit boundary record is part of the unit.

- (c) *OPTIONAL GEOMETRY COMMENTS . . .* these data allow the user to enter a comment for any unit. Data are entered in the form:

COM = *delim coment delim*

The keyword **COM=** signals that a comment is to be read. The first nonblank character following the keyword is the beginning delimiter, *delim*. The comment can be as long as 132 characters, including imbedded blanks. It must be terminated with the same delimiter that signaled the beginning of the comment. The optional geometry comment must follow the *UNIT INITIALIZATION* for a unit but can precede or follow any *GEOMETRY REGION DESCRIPTION* within the unit. In the event that more than one comment is entered within a unit, the last one is used. Existing comments are printed at the beginning of each unit description in the computer printout.

Additional **EXAMPLES** of geometry input are given below:

1. Initiate input data for unit No. 6.

UNIT 6

2. Initiate input data for the global unit which is unit No. 4.

GLOBAL UNIT 4

3. Create a hemisphere labeled 10 with a radius of 5.0 cm which contains only material in the sphere with $z > 2.0$ with the sphere centered at the origin, and its origin translated to $x=1.0$, $y=1.5$, and $z=3.0$.

SPHERE 10 5.0 CHORD +Z=2.0 ORIGIN x=1.0 y=1.5 z=3.0

4. Create a hemicylinder labeled 10 having a radius of 5.0 cm and a length extending from $z=2.0$ cm to $z=7.0$ cm. The hemicylinder has been truncated parallel to the z axis at $x=-3$ such that no material exists between $x=-3$ and $x=-5$. Position the origin of the truncated hemicylinder at $x=10$ cm and $y=15$ cm with respect to the origin of the unit and rotate it so it is in the YZ plane centered at $x=10$ and at a 45° angle with the y plane.

CYLINDER 10 5.0 7.0 2.0 CHORD +x=-3.0 ORIGIN x=10.0 y=15.0 ROTATE A2=-45

5. Position array 6 so that the origin of the unit in position 1, 2, 3 is located at position $x=2$, $y=3$, $z=4$ relative to the origin of the surrounding unit. Specifying the array boundary to be the region that is inside the geometry records labeled 1 and 2 and outside the geometry record labeled 3 used to describe the surrounding unit.

ARRAY 6 1 2 -3 PLACE 1 2 3 2.0 3.0 4.0

6. Place unit 2 in the surrounding unit such that the origin of unit 2 is at $x=3$, $y=3.5$, $z=4$ relative to the origin of the surrounding unit and the region containing the hole is inside geometry records labeled 1 and 3 and outside geometry record labeled 2 used to describe the surrounding unit.

HOLE 2 1 -2 3 ORIGIN x=3.0 y=3.5 z=4.0

F17.4.5 ARRAY DATA

ARRAY DEFINITION data . . . The array definition data block is used to define the size and type of an array and to position units (defined in the geometry data) in a 3-D lattice that represents the array being described. As many arrays as are necessary can be described in a problem, subject to computer storage limitations. Any number of arrays can be placed in any unit either directly in regions or indirectly using holes. There is no default global array. If a global array is desired it must be explicitly defined.

An array definition data block consists of *ARRAY PARAMETERS* followed by a *UNIT ORIENTATION DESCRIPTION*. The sequence *ARRAY PARAMETERS*, *UNIT ORIENTATION DESCRIPTION* must be repeated for each array that is to be used in the problem. *ARRAY PARAMETERS* must be entered for all array problems and consist of parameter input defining (1) an array identification number for the lattice, (2) the array type, (3) the number of units in each direction of the 3-D lattice, (4) the global array number, and (5) a comment to be printed at the beginning of the array in the printout. The array identification number (1), the number of units in

each direction, (3), and the associated *UNIT ORIENTATION DESCRIPTION* must be entered for each array that is used in the problem. The array type (2) is entered to specify if the array is cuboidal or hexagonal. If not entered the array is assumed to be cuboidal. The global array number, (4), should be entered only if desired. A global array number is required to accumulate certain neutron physics information such as certain matrix information. If the global array number is entered more than once, the last value is used. The optional array comment is available for the user's convenience, but is not necessary for the problem. The *UNIT ORIENTATION DESCRIPTION* consists of a *KEYWORD*, *UNIT ORIENTATION DATA* and a *DELIMITER* which must be entered in order. The *KEYWORD* is used to indicate the method of entering the unit orientation data. The *UNIT ORIENTATION DATA* sequence is used to position units in a 3-D lattice and the *DELIMITER* is used to terminate the unit orientation data for the array. *The adjacent faces of units in contact with each other within an array must be the same size and shape.* Multiple arrays are defined by entering the sequence.

Arrays need to be properly placed in a unit for the problem to run correctly. The following is a set of rules used for placing arrays in a region of a unit.

Array Rules

1. Arrays may be nested as low as desired.
2. The array boundary (i.e., the region containing the array) must be completely contained within the volume defined by the units making up the array.
3. If a unit contained within an outer array contains a hole or another array (either directly or nested) the boundary of the outer array cannot cross the volume defined by the array or hole in the unit.

ARRAY PARAMETERS, UNIT ORIENTATION DESCRIPTION for each array that is to be described in the problem.

Enter **ARRAY DEFINITION DATA** in the form:

READ ARRAY ARRAY PARAMETERS UNIT ORIENTATION DESCRIPTION END ARRAY

ARRAY PARAMETERS define the array number and the array size. They utilize the following keywords. Enter only those whose value you wish to change.

ARRAY PARAMETERS

ARA = <i>numa</i>	array number for the array being input, no default
TYP = <i>atyp</i>	type of array (square or hexagonal). For an array composed of cuboids, <i>atyp</i> may be specified as SQUARE or CUBOIDAL. For an array composed of HEXPRISMS, <i>atyp</i> may be specified as TRIANGULAR or HEXAGONAL. Default = square
NUX = <i>nbxmax</i>	number of units in the X direction of the array, no default
NUY = <i>nbymax</i>	number of units in the Y direction of the array, no default

NUZ = *nbzmax* number of units in the Z direction of the array, no default

GBL = *globl* array number for the global array (if entered more than once the last value entered becomes the global array). Unit used only for collecting array matrix data. No default.

COM = *delim coment delim* allows entering a comment that will be printed with the unit orientation data. Maximum comment length is 132 characters.

The *UNIT ORIENTATION DESCRIPTION* is composed of a *KEYWORD*, *ORIENTATION DATA* and a *DELIMITER* as described below:

KEYWORD

type enter the word **LOOP** or **FILL**, followed by one or more blanks.

LOOP enters unit orientation data in a manner resembling *FORTRAN DO* loops. The first field contains the unit number, followed by three fields that are treated like *FORTRAN DO* loops. The arrangement of units may be considered as consisting of a 3-D matrix of unit numbers, with the unit position increasing in the positive X, Y, and Z directions, respectively. Each set of mixed unit orientation data for the **LOOP** option consists of the following parameters, separated by one or more blanks.

ORIENTATION DATA for LOOP

ltype The unit number, *ltype* must be greater than zero.

ix1 The starting position in the X direction, *ix1* must be at least 1 and less than or equal to *nbxmax* (parameter *NUX* =, see ARRAY PARAMETERS).

ix2 The ending position in the X direction, *ix2* must be at least 1 and less than or equal to *nbxmax*.

incx The number of units by which increments are made in the positive X direction. *incx* must be greater than zero and less than or equal to *nbxmax*.

iy1 The starting position in the Y direction. *iy1* must be at least 1 and less than or equal to *nbymax* (parameter *NUY* =, see ARRAY PARAMETERS).

iy2 The ending position in the Y direction, *iy2* must be at least 1 and less than or equal to *nbymax*.

incy The number of units by which increments are made in the positive Y direction, *incy* must be greater than zero and less than or equal to *nbymax*.

iz1 The starting position in the Z direction, *iz1* must be at least 1 and less than or equal to *nbzmax* (parameter *NUZ* =, see ARRAY PARAMETERS).

- iz2* The ending position in the Z direction, *iz2* must be at least 1 and less than or equal to *nbzmax*.
- incz* The number of units by which increments are made in the positive Z direction. *incz* must be greater than zero and less than or equal to *nbzmax*.

The sequence *ltype* through *incz* is repeated until the entire array is described. If any portion of an array is defined in a conflicting manner, the last entry to define that portion will determine the array's configuration. To utilize this feature, fill the entire array with the most relevant unit number and superimpose the other unit numbers in their proper places. An example showing the use of the LOOP option is given below. This $5 \times 4 \times 3$ array of units is a matrix of units that has 5 units stacked in the X direction, 4 units in the Y direction, and 3 units in the Z direction. X increases from left to right, and Y increases from bottom to top. Each Z layer is shown separately.

Given:

1 2 1 2 1	2 1 2 1 2	1 1 1 1 1
1 1 1 1 1	2 2 2 2 2	1 3 3 3 1
1 1 1 1 1	2 2 2 2 2	1 3 3 3 1
1 2 1 2 1	2 1 2 1 2	1 1 1 1 1
Z Layer 1	Z Layer 2	Z Layer 3

The data for this array could be entered using the following entries.

- (1) 1 1 5 1 1 4 1 1 3 1 This fills the entire array with 1's.
- (2) 2 2 5 2 1 4 3 1 1 1 This loads the four 2's in the first Z layer.
- (3) 2 1 5 1 2 3 1 2 2 1 This loads the second and third rows of 2's in the second Z layer.
- (4) 2 1 5 2 1 4 3 2 2 1 This loads the desired 2's in the first and fourth rows of the second Z layer.
- (5) 3 2 4 1 2 3 1 3 3 1 This loads the 3's in the third Z layer and completes the array data input.

The second layer could have been defined by substituting the following data for entries (3) and (4):

- (3) 2 1 5 1 1 4 1 2 2 1 This completely fills the second layer with 2's.
- (4) 1 2 4 2 1 4 3 2 2 1 This loads the four 1's in the second layer.

When using the **LOOP** option, there is no single correct method of entering the data. If a unit is improperly positioned in the array or if some positions in the array are left undefined, it is often easier to add additional data to correctly define it than to try to correct the existing data.

FILL enters data by stringing in unit numbers starting at X=1, Y=1, Z=1, and varying X, then Y, and then Z to fill the array. *nbxmax* x *nbymax* x *nbzmax* entries are required. FIDO-like input options are also available for filling the array.

ORIENTATION DATA for FILL

The **FILL** option consists of entering a unit number for every position in the array by using the FIDO-like input options specified in Table F17.4.2. The orientation data for the **FILL** option may be terminated with a T.

DELIMITER

Enter the word **END** followed by a blank and the previously entered *KEYWORD* (i.e., enter **END FILL** or **END LOOP**). The delimiter need not be entered if only one set of *ARRAY DEFINITION DATA* is to be read.

To illustrate the use of the options available in Table F17.4.2, consider the following examples. The positions in an array are numbered sequentially from left to right, bottom to top. A $3 \times 3 \times 1$ array has 9 positions and is numbered as shown below. X increases from left to right and Y increases from bottom to top.

7	8	9
4	5	6
1	2	3

EXAMPLE 1. Consider a $3 \times 3 \times 1$ array filled with 8 Unit 1's and a Unit 2 as shown below.

1	1	1
1	2	1
1	1	1

The input data to describe this array could be entered as follows:

- (1) 1 1 1 1 2 1 1 1 1 T This fills the array, one position at a time, starting at the lower left corner. The T terminates the data.
- (2) F1 A5 2 T The F1 fills the entire array with 1's, the A5 locates the fifth position in the array, and the 2 loads a 2 in that position. The T terminates the data.
- (3) F1 A1 4S 2 T The F1 fills the entire array with 1's, the A1 locates the first position in the array (lower left corner), the 4S skips over the next four positions in the array, and the 2 loads a 2 in the next (fifth) position. The T terminates the data.
- (4) 4R1 2 4R1 T The first 4R1 loads 1's in the first four positions of the array, a 2 is loaded in the next (fifth) position of the array, and the last 4R1 loads 1's in the next four positions of the array. The T terminates the data.
- (5) 4*1 2 4\$1 T The 4*1 loads 1's in the first four positions of the array. A 2 is loaded in the next position of the array, and the 4\$1 loads 1's in the next four positions of the array. The T terminates the data.

Table F17.4.2 FIDO-like input for mixed box orientation fill option

Count field	Option field	Operand field	Function
		j	Stores j at the current position in the array
i	R	j	Stores j in the next i positions in the array
i	*	j	Stores j in the next i positions in the array
i	\$	j	Stores j in the next i positions in the array
i	P	j	Alternately stores j and $-j$ in the next i positions of the array
	F	j	Fills the remainder of the array with unit number j , starting with the current position in the array
	A	j	Sets the current position in the array to j
i	S		Increments the current position in the array by i (This allows skipping i positions. i may be positive or negative.)
i	Q	j	Repeats the previous j entries i times. The default value of i is 1
i	N	j	Repeats the previous j entries i times, inverting the sequence each time. The default value of i is 1
i	B	j	Back i entries. From that position, repeat the previous j entries in reverse order. See Example 4. The default value of i is 1
i	I	$j k$	Provides the end points, j and k , with i entries linearly interpolated between them (i.e., a total of $i+2$ points). At least one blank must separate j and k . When used for an integer array, the I option should only be used to generate integer steps [i.e., $(k-j)/(i+1)$ should be a whole number]
i	L	$j k$	Provides the end points, j and k , with i entries logarithmically interpolated between them (i.e., a total of $i+2$ points). At least one blank must separate j and k
	T		Terminates the data reading for the array

Note: When entering data utilizing the options in this table, the *count field* and *option field* must be adjacent with no imbedded blanks. The operand field may be separated from the option field by one or more blanks.

EXAMPLE 2. Consider a $4 \times 3 \times 1$ array filled as shown below.

1	2	2	1
1	2	2	1
1	2	2	1

The input data to describe this array could be entered as follows.

- (1) 1 2 2 1 1 2 2 1 1 2 2 1 T This fills the array, one position at a time, starting at the lower left corner. The T terminates the data.

- (2) 1 2R2 2R1 Q4 2R2 1 T A 1 is loaded in the first position of the array. The 2R2 loads 2's in the next two positions of the array (positions two and three). The 2R1 loads 1's in the next two positions of the array (positions four and five). The Q4 loads the 2 2 1 1 from positions two through five in positions six through nine. The last 2R2 loads 2's in positions ten and eleven of the array. The last 1 loads a 1 in the next position (position twelve). The T terminates the data.

- (3) 1 2 5N2 T The 1 is entered in the first position of the array and the 2 is entered in the second position. The 5N2 causes the previous two entries to be repeated five times reversing their order each time. The T terminates the data.

- (4) 1 2R2 1 2Q4 T The first 1 is loaded in the first position of the array. The 2's are loaded in positions two and three of the array. Then a 1 is loaded in the fourth position of the array. This describes the entire bottom row of the array. The 2Q4 then repeats the previous four entries (those loaded in positions one through four of the array) two times. Thus the first row is repeated twice, filling the remainder of the array. The T terminates the data.

EXAMPLE 3. Consider a $6 \times 3 \times 1$ array as shown below.

1	2	2	1	1	2
1	2	2	1	1	2
1	2	2	1	1	2

A simple input description for this array is the following:

- (1) 1 2 2N2 2Q6 T The first position of the array is filled with a 1. The second position of the array is filled with a 2. The 2N2 causes the previous two entries to be repeated two times, reversing their order each time. This completes loading the bottom row of the array. The 2Q6 repeats the previous six entries twice, completing the second and third rows of the array. The T terminates the data.

EXAMPLE 4. Consider a $7 \times 3 \times 1$ array as shown below.

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

The input data to describe this array could be entered as follows:

- (1) 1 2 3 4 1B3 2 3 4 5 1B3 1 2 3 4 1B3 T The 1 2 3 and 4 are loaded in the first four positions of the array. The 1B3 steps back over the 4 and repeats the 1 2 3 sequence in reverse order (i.e., 3 2 1). This yields the 1 2 3 4 3 2 1 in the first row of the array. The same procedure applies to the next two rows.
- (2) 1 2 3 4 1B3 2 3 4 5 1B10 T The 1 2 3 4 1B3 yields the first row as explained above. The 2 3 4 5 enters the 2 3 4 5 at the left of the second row. The 1B10 enters the 4 3 2 at the right of the second row and the entire third row.

F17.4.6 ALBEDO DATA

ALBEDO DATA . . . Albedo boundary conditions are entered using a *FACE CODE* to define where albedo conditions are to be used, and an *ALBEDO NAME* to indicate which albedo condition is to be used on that face. The default value for each face is vacuum. The default values are overridden only on faces for which other albedo names are specified. Albedo boundary conditions are applied only to the outermost region of a problem. Different albedo options are allowed for different global boundaries. If the global unit boundary record definition vector contains a single geometry record label that references a cuboid, any available albedo option is allowed on any surface. However, if a periodic boundary condition is to be used, it must be specified on opposing faces simultaneously. If the global unit boundary record definition vector contains a single geometry record label that references a geometry shape composed of paired planes, i.e. hexprism, dodecahedron, parallelepiped, rhomboid, etc., any albedo type is allowed but the same type must be on all surfaces. If the global unit boundary record definition vector contains a single geometry record label that references any geometry shape, the void, mirror, or white albedo condition is allowed and the same condition must be on all surfaces. If the global unit boundary record definition vector contains more than one geometry record label the void albedo condition is allowed. If no albedo is specified a void albedo is assumed. The white albedo returns an outgoing particle at its point of departure with a random angle.

Enter **ALBEDO DATA** in the form:

READ BOUNDS

FACE CODE
face

ALBEDO NAME
aname

END BOUNDS

The sequence *FACE CODE*, *ALBEDO NAME* is entered as many times as necessary to define the appropriate albedo boundary conditions. If multiple entries are made for a face, the *ALBEDO NAME* associated with the last *FACE CODE* specifying that face is used.

The *FACE CODES* are described in Table F17.4.3, and the *ALBEDO NAMES* are given in Table F17.4.4.

Example: Use a 24-in. concrete albedo boundary condition on the -Z face of a problem with a cuboidal boundary and use mirror image reflection on the +X and -X faces of the cuboid to represent an infinite linear array on a 2-ft-thick concrete pad.

READ BOUNDS -ZB=CON24 XFC=MIRROR END BOUNDS

F17.4.7 BIASING OR WEIGHTING DATA

BIASING INFORMATION . . . The average weight of a neutron that survives Russian roulette, *wtavg*, is defaulted to *dwtav* (WTA= in the parameter data, Sect. F17.4.3) for all *BIAS IDs* and can be overridden by entering biasing information.

The biasing information is used to relate a *BIAS ID* to the desired energy-dependent values of *wtavg*. This concept is similar to the way the *MIXTURE ID*, *mat*, is related to the macroscopic cross-section data.

The weighting functions used in KENO-VI are energy-dependent values of *wtavg* that are applicable over a given thickness interval of a material. For example, the weighting function for water² is composed of sets of energy-dependent values of *wtavg* for 11 intervals, each interval being 3-cm thick. The first set of *wtavg*'s is for the 0- to 3-cm interval of water, the second set of *wtavg*'s is for the 3- to 6-cm interval of water, etc. The eleventh set of *wtavg*'s is for the 30- to 33-cm interval of water.

To input biasing information, a *BIAS ID* must be assigned to correspond to a set of *wtavg*. Biasing data can specify a *MATERIAL ID* from the existing KENO V.a weighting library or from the *AUXILIARY DATA* input. The materials available from the KENO V.a weighting library are listed in Table F17.4.5.

BIASING INFORMATION is entered in the following form:

READ BIAS KEYWORD CORRELATION DATA AUXILIARY DATA END BIAS

KEYWORD

enter **ID=**, **WT=**, or **WTS=**

ID= specifies that *CORRELATION DATA* will be entered next.

WT= or **WTS=** specifies that *AUXILIARY DATA* will be entered next.

CORRELATION DATA are used to correlate a set of *wtavg* to a *BIAS ID*, *imp*, as specified in the geometry data. This causes the specified *wtavg* to be used as the weighting function in the volume defined by that geometry region.

CORRELATION DATA must be entered in the order shown.

Table F17.4.3 Face codes for entering boundary (albedo) conditions

Face code	Faces defined by face codes
+XB=	Positive X face
&XB=	Positive X face
-XB=	Negative X face
+YB=	Positive Y face
&YB=	Positive Y face
-YB=	Negative Y face
+ZB=	Positive Z face
&ZB=	Positive Z face
-ZB=	Negative Z face
ALL=	All 6 faces
XFC=	Both positive and negative X faces
YFC=	Both positive and negative Y faces
ZFC=	Both positive and negative Z faces
+FC=	Positive X, Y, and Z faces
&FC=	Positive X, Y, and Z faces
-FC=	Negative X, Y, and Z faces
XYF=	Positive and negative X and Y faces
XZF=	Positive and negative X and Z faces
YZF=	Positive and negative Y and Z faces
+XY=	Positive X and Y faces
+YX=	Positive X and Y faces
&XY=	Positive X and Y faces
&YX=	Positive X and Y faces
+XZ=	Positive X and Z faces
+ZX=	Positive X and Z faces
&XZ=	Positive X and Z faces
&ZX=	Positive X and Z faces
+YZ=	Positive Y and Z faces
+ZY=	Positive Y and Z faces
&YZ=	Positive Y and Z faces
&ZY=	Positive Y and Z faces
-XY=	Negative X and Y faces
-XZ=	Negative X and Z faces
-YZ=	Negative Y and Z faces
YXF=	Positive and negative X and Y faces
ZXF=	Positive and negative X and Z faces
ZYF=	Positive and negative Y and Z faces
-YX=	Negative X and Y faces
-ZX=	Negative X and Z faces
-ZY=	Negative Y and Z faces

Table F17.4.4 Albedo names available on the KENO-VI
albedo library for use with the face codes

DP0H2O DPOH2O DP0 DPO	30.48-cm (12 in.) double P ₀ water differential albedo with 4 incident angles
H2O WATER	30.48-cm (12 in.) water differential albedo with 4 incident angles
PARAFFIN PARA WAX	30.48-cm (12 in.) paraffin differential albedo with 4 incident angles
CARBON GRAPHITE C	200.00-cm (78.74-in.) carbon differential albedo with 4 incident angles
ETHYLENE POLY CH2	30.48-cm (12-in.) polyethylene differential albedo with 4 incident angles
CONC-4 CON4 CONC4	10.16-cm (4-in.) concrete differential albedo with 4 incident angles
CONC-8 CON8 CONC8	20.32-cm (8-in.) concrete differential albedo with 4 incident angles
CONC-12 CON12 CONC12	30.48-cm (12-in.) concrete differential albedo with 4 incident angles
CONC-16 CON16 CONC16	40.64-cm (16-in.) concrete differential albedo with 4 incident angles
CONC-24 CON24 CONC24	60.96-cm (24-in.) concrete differential albedo with 4 incident angles
VACUUM VOID VACU VAC	Vacuum condition
SPECULAR MIRROR MIRR SPEC SPE MIR REFL REFLECT	Mirror image reflection
PERIODIC PERI PER	Periodic boundary condition
WHITE	White boundary condition

id enter the identification (MATERIAL ID) for the material whose weighting function is to be used. A material ID can be chosen from the existing KENO V.a weighting library (Table F17.4.5) or from the *AUXILIARY DATA* as described later. If a material ID appears in both the KENO V.a weighting library and the *AUXILIARY DATA*, the *wtavg* from the auxiliary data will be used.

ibgn is the BIAS ID of the weighting function for the first interval of material *id*. The geometry card having *imp* = *ibgn* will use the group-dependent *wtavg*'s from the first interval of material *id*.

iend is the BIAS ID of the group-dependent *wtavg*'s from the (*iend* - *ibgn* + 1)th interval of material *id*.

GENERIC EXAMPLE: READ BIAS ID=*mm* *ibgn* *iend* END BIAS where *mm* is a material ID from Table F17.4.5, *ibgn* is the bias ID associated with the 1st interval of material *mm*, and *iend* is the bias ID associated with the (*iend* - *ibgn* + 1) interval of material *mm*.

SPECIFIC EXAMPLE: Use CORRELATION DATA to utilize the water biasing factors in BIAS IDs 2 through 11.

READ BIAS ID=500 2 11 END BIAS

AUXILIARY DATA are used to enter user-supplied biasing or weighting information. It can be used to supply biasing information for materials not found in the KENO V.a weighting library or to override the *wtavgs* from that library. When *AUXILIARY DATA* are entered, *CORRELATION DATA* must also be entered in order to use the data. *AUXILIARY DATA* must be entered in the order shown.

wttitl enter an arbitrary title name (12 characters maximum), such as CONCRETE, WATER, SPECIALH2O, etc., to identify the material for which you are entering data. Embedded blanks are not allowed.

id enter an identification number (MATERIAL ID). The value is arbitrary. However, if the data are to be utilized in the problem, this ID must also be used at least once in the *CORRELATION DATA*.

nsets enter the number of sets of group structures for which *wtavg* will be read for this ID.

The sequence *thkinc*, *numinc*, *ngpwt*, *wtavg*, described below, is repeated *nsets* times.

thkinc enter the thickness of each increment for which *wtavg* will be read for this ID.

numinc enter the number of increments for which *wtavg* will be read for this ID.

ngpwt enter the number of energy groups for this set of *wtavg*.

Table F17.4.5 IDs, group structure and incremental thicknesses
for weighting data available on the KENO V.a weighting library

Material	Material ID	Group structure for which weights are available	Increment ^a thickness (cm)	Total number of increments available
Concrete	301	16	5	20
		27	5	20
		123	5	20
Paraffin	400	16	3	10
		27	3	11
		123	3	10
Water	500	16	3	10
		27	3	11
		123	3	10
		218	3	11
Graphite	6100	16	20	6
		27	20	10
		123	20	6

^aGroup-dependent weight averages are supplied for each increment of the specified incremental thickness [i.e., for any given material, the first *ngp* (number of energy groups) weights apply to the first increment of the thickness specified in Table F17.4.4, the next *ngp* weights apply to the next increment of that thickness, etc.]. CAUTION--If bias IDs defined in the weighting information data are used in the geometry, the region thickness should be consistent with the incremental thickness of the weighting data in order to avoid overbiasing or underbiasing.

wtavg enter *numinc* x *ngpwt* values of *wtavg*. For each value of *numinc*, *ngpwt* values of *wtavg* must be supplied.

GENERIC EXAMPLE of AUXILIARY DATA: READ BIAS WT=wttitl id nsets
thkinc numinc ngpwt wtavg END BIAS

SPECIFIC EXAMPLE: Enter AUXILIARY DATA to specify biasing factors for SPECIALWATER to be used in BIAS IDs 6 and 7. The SPECIALWATER biasing factors have a value of 0.69 for BIAS ID 6 and 0.86 for BIAS ID 7 in each energy group. Sixteen-group cross sections are being used. Each weighting region is 3.048 cm thick. The MATERIAL ID is arbitrarily chosen to be 510. Note that CORRELATION DATA must be entered to allow the AUXILIARY DATA to be used for BIAS IDs 6 and 7.

READ BIAS WT=SPECIALWATER 510 1 3.048 2 16 16*0.69
16*0.86 ID=510 6 7 END BIAS

WARNING: The user should thoroughly understand weighted tracking before attempting to generate and use auxiliary data for biasing. Incorrect weighting can cause the code to produce incorrect results without obvious symptoms.

CAUTIONS:

1. Each set of auxiliary or correlation data must be completely described in conjunction with its keyword. Complete sets of these data can be interspersed in an arbitrary order but data within each set must be entered in the specified order.
2. Auxiliary data: If the same *id* is specified in more than one set of data, the last set having the group structure used in the problem is the set that will be utilized. When auxiliary data are entered, correlation data must also be entered in order to use the auxiliary data.
3. Correlation data: If biasing data define the same bias ID (*imp*, from the geometry data) more than once, the value that is entered last supersedes previous entries. *Be well aware that multiple definitions for the same bias ID can cause erroneous answers due to overbiasing.* Error messages K5-125 and K5-128 may be printed.

An example of multiple definitions for the same bias ID follows:

READ BIAS ID=400 2 7 ID=500 5 7 END BIAS .

The data for paraffin (ID=400) will be used for bias IDs 2, 3, and 4, and the data for water (ID=500) will be used for bias IDs 5, 6, and 7. The paraffin data for bias IDs 5, 6, and 7 have been overwritten by water data.

Multiple definitions for the same bias ID are not necessarily incorrect. However, the user should be cautious about doing it and ensure that the desired biasing or weighting functions are utilized in the desired geometry regions.

An example of how the *BIAS ID* relates to the energy-dependent values of *wtavg* is given below.

Assume that a paraffin reflector is to be used, and it is desirable to use the weighting function from the KENO V.a weighting library to minimize the running time for the problem. Also assume that these weighting functions are to be used in the volumes defined in the geometry cards having *imp*= 6, 7, 8, and 9. *CORRELATION DATA* are then entered, and *AUXILIARY DATA* will not be entered.

KEYWORD is ID=

id is 400, the ID for paraffin

ibgn is 6, the first *imp* that uses the weighting function

iend is 9, the last *imp* that uses the weighting function

The biasing data would be: READ BIAS ID=400 6 9 END BIAS.

The results of these data are the following:

- (1) The group-dependent *wtavg* for the 0- to 3-cm interval of paraffin will be used in the volume defined by the geometry region having *imp*= 6.

- (2) The group-dependent *wtavg* for the 3- to 6-cm interval of paraffin will be used in the volume defined by the geometry region having *imp* = 7.
- (3) The group-dependent *wtavg* for the 6- to 9-cm interval of paraffin will be used in the volume defined by the geometry region having *imp* = 8.
- (4) The group-dependent *wtavg* for the 9- to 12-cm interval of paraffin will be used in the volume defined by the geometry region having *imp* = 9.

F17.4.8 START DATA

START DATA . . . Special start options are available for controlling the initial neutron distribution. The default starting distribution is flat over the volume specified by the unrotated, untranslated geometry record specified in the first position of the global unit boundary record in fissile material only. See Table F17.4.6 for the starting distributions available in KENO-VI.

READ START

The starting information that can be entered is given below. Enter only the data necessary to describe the desired starting distribution.

NST = <i>ntypst</i>	start type, default = 0 Table F17.4.6 lists the available options under the heading, "Start type."
TFX = <i>tfx</i>	the x coordinate of the point at which neutrons are to be started, default = 0.0 Use for start types 3, 4, and 6.
TFY = <i>tfy</i>	the y coordinate of the point at which neutrons are to be started, default = 0.0 Use for start types 3, 4, and 6.
TFZ = <i>tfz</i>	the z coordinate of the point at which neutrons are to be started, default = 0.0 Use for start types 3, 4, and 6.
NXS = <i>nbxs</i>	the x index of the unit's position in the global array, default = 0 Use for start types 2, 3, and 6.
NYS = <i>nbys</i>	the y index of the unit's position in the global array, default = 0 Use for start types 2, 3, and 6.
NZS = <i>nbzs</i>	the z index of the unit's position in the global array, default = 0 Use for start types 2, 3, and 6.
KFS = <i>kfis</i>	the mixture whose fission spectrum is to be used for starting neutrons that are not in a fissionable medium. Defaulted to the fissionable mixture having the smallest mixture number. Available for start types 3, 4, and 6.

Table F17.4.6 Starting distributions available in KENO-VI

Start type	Required data	Optional data	Starting distribution
0	None	NST XSM XSP YSM YSP ZSM ZSP RFL PSP	Uniform throughout fissile material within the volume defined by (1) the unrotated, untranslated geometry record in the first position of the global unit boundary record, (2) the boundary of the global array having the reflector key set false, or (3) a cuboid specified by XSM, XSP, YSM, YSP, ZSM, and ZSP
1	NST	XSM XSP YSM YSP ZSM ZSP RFL PSP	The starting points are chosen according to a cosine distribution throughout the volume of a cuboid defined XSM, XSP, YSM, YSP, ZSM, and ZSP. Points that are not in fissile material are discarded
2	NST NXS NYS NZS FCT	XSM XSP YSM YSP ZSM ZSP RFL PSP	An arbitrary fraction (FCT) of neutrons are started uniformly in the unit located at position NXS, NYS, NZS in the global array. The remainder of the neutrons are started in fissile material, from points chosen from a cosine distribution throughout the volume of a cuboid defined by XSM, XSP, YSM, YSP, ZSM, ZSP
3	NST TFX TFY TFZ NXS NYS NZS	KFS PSP	All neutrons are started at position TFX, TFY, TFZ within the unit located at position NXS, NYS, NZS in the global array
4	NST TFX TFY TFZ NBX	KFS PSP	All neutrons are started at position TFX, TFY, TFZ within units NBX in the global array
5	NST NBX	PSP	Neutrons are started uniformly in fissile material in units NBX in the global array
6	NST TFX TFY TFZ LNU ^a	NXS NYS NZS KFS PS6 PSP	The starting distribution is arbitrarily input. LNU is the final neutron to be started at a point TFX, TFY, TFZ relative to the global coordinate system or at a point TFX, TFY, TFZ, relative to the unit located at the global array position NXS, NYS, NZS

^a When entering data for start 6, LNU must be the last entry for each set of data and the LNU in each successive set of data must be larger than the previous value of LNU. A set of data consists of required and optional data. The last LNU entered should be equal to the number per generation (parameter NPG= in the parameter input, Sect. F17.4.3).

LNU = *lfin* the final neutron to be started at a point. Default = 0. Each *lfin* should be greater than zero and less than or equal to NPG. Each successive *lfin* should be greater than the previous one.
Use for start type 6.

NBX = *nboxst* the unit in which neutrons will be started. Default = 0
Use for start types 4 and 5.

FCT = *fract* the fraction of neutrons that will be started as a spike. Default = 0
Use for start type 2.

XSM = *xsm* the -X dimension of the cuboid in which the neutron will be started. For an array problem, XSM is defaulted to the minimum X coordinate of the global array. If the reflector key RFL is YES, and the outer reflector region is a cuboid, XSM is defaulted to the minimum X coordinate of the outer reflector region. If RFL is YES and the outer region of the reflector is not a cuboid, XSM must be entered in the start data and must fit inside the outer reflector region.
Available for start types 0, 1, and 2.

XSP = *xsp* the +X dimension of the cuboid in which the neutrons will be started. For an array problem, XSP is defaulted to the maximum X coordinate of the global array. If the reflector key RFL is YES, and the outer reflector region is a cuboid, XSP is defaulted to the maximum X coordinate of the outer reflector region. If RFL is YES and the outer region of the reflector is not a cuboid, XSP must be entered in the start data and must fit inside the outer reflector region. Available for start types 0, 1, and 2.

YSM = *ysm* the -Y dimension of the cuboid in which the neutron will be started. For an array problem, YSM is defaulted to the minimum Y coordinate of the global array. If the reflector key RFL is YES, and the outer reflector region is a cuboid, YSM is defaulted to the minimum Y coordinate of the outer reflector region, provided that region is a cuboid. If RFL is YES and the outer region of the reflector is not a cuboid, YSM must be entered in the start data and must fit inside the outer reflector region. Available for start types 0, 1, and 2.

YSP = *ysp* the +Y dimension of the cuboid in which the neutrons will be started. For an array problem, YSP is defaulted to the maximum Y coordinate of the global array. If the reflector key RFL is YES, and the outer reflector region is a cuboid, YSP is defaulted to the maximum Y coordinate of the outer reflector region, provided that region is a cuboid. If RFL is YES and the outer region of the reflector is not a cuboid, YSP must be entered in the start data and must fit inside the outer reflector region.
Available for start types 0, 1, and 2.

ZSM = *zsm* the -Z dimension of the cuboid in which the neutrons will be started. For an array problem, XSM is defaulted to the minimum Z coordinate of the global array. If the reflector key RFL is YES, and the outer reflector region is a cuboid, ZSM is defaulted to the minimum Z coordinate of the outer reflector region, provided that region is a cuboid. If RFL is YES and the outer region of the reflector is not a cuboid, ZSM must be entered in the start data and must fit inside the outer reflector region.
Available for start types 0, 1, and 2.

ZSP = *zsp* the +Z dimension of the cuboid in which the neutrons will be started. For an array problem, ZSP is defaulted to the maximum Z coordinate of the global array. If the reflector key RFL is YES, and the outer reflector region is a cuboid, ZSP is defaulted to the maximum Z coordinate of the outer reflector region, provided that region is a cuboid. If RFL is YES and the outer region of the reflector is not a cuboid, ZSP must be entered in the start data and must fit inside the outer reflector region.

Available for start types 0, 1, and 2.

RFL = *rflkey* the reflector key. If the reflector key is YES, neutrons can be started in the reflector. If it is NO, all the neutrons will be started in the array. Enter YES or NO. Default = YES.

Available for start types 0, 1, and 2.

PS6 = *lpst6* the key for printing start type 6 input data. If the key is YES, start type 6 data are printed. If it is NO, start type 6 data are not printed. Enter YES or NO. Default = NO.

Available for start type 6.

PSP = *lpstp* the key for printing the neutron starting points using the tracking format. If the key is YES, print the neutron starting points. If it is NO, do not print the starting points. Enter YES or NO. Default = NO.

Available for all start types.

END START

F17.4.9 EXTRA 1-D XSECS IDS DATA

EXTRA 1-D CROSS-SECTION IDS . . . Extra 1-D cross-section IDs need not be entered. They are allowed as input in order to simplify future modifications to calculate reaction rates, etc.

READ X1DS *EXTRA 1-D CROSS SECTION IDS* END X1DS

EXTRA 1-D CROSS SECTION IDS

Enter a 1-D identification number for each extra 1-D cross section to be used. These cross sections must be available on the mixture cross-section library. X1D entries are expected to be read (see integer PARAMETER data).

F17.4.10 MIXING TABLE DATA

CROSS-SECTION MIXING TABLE . . . A cross-section mixing table must be entered if KENO-VI is being run "stand alone" and an ICE mixed cross-section MORSE/KENO V.a format library is not being used. If the parameter LIB=, Sect. F17.4.3, is entered, mixing table data must be entered. A cross-section mixing table is entered in the form:

READ MIXT *XSEC PARAMETERS MIXING TABLE* END MIXT

The *XSEC PARAMETERS* include the number of scattering angles and the cross-section message cutoff value.

SCT = nsct where *nsct* is the number of discrete scattering angles, default = 1

The number of scattering angles specifies the number of discrete scattering angles to be used for the cross sections. It needs to be entered only once for a problem. If more than one value is entered, the last one is used for the problem. For assistance in determining the number of discrete scattering angles for the cross sections, see Sect. F17.5.4.3.

EPS = pbxs where *pbxs* is the value of the P_0 cross section for each transfer, above which generated warning messages will be printed, default = 3×10^{-5}

The cross-section message cutoff value is the value of the P_0 cross section for each energy transfer above which cross-section processing warning messages will be printed. The primary purpose of entering this cutoff value is to suppress printing these messages when they are generated during cross-section processing. For assistance in determining a value for EPS, see Sect. F17.5.4.4.

The *MIXING TABLE* is used to specify each mixture and the nuclide IDs and number densities used in the mixtures. It consists of (a) a *MIXTURE ID* and a set of (b) *NUCLIDE IDs*, and (c) *NUMBER DENSITIES* (atoms/b-cm).

(a) *MIXTURE ID* **MIX = mix**, where *mix* defines the mixture being described

(b) *NUCLIDE ID* **nucl** enter the nuclide ID number from the AMPX working-format cross-section library

(c) *NUMBER DENSITY* **dens** enter the number density (atoms/b-cm) associated with nuclide ID number *nucl*

REPEAT the sequence (b) (c) until the mixture has been completely described.

REPEAT the sequence (a) (b) (c) until all the mixtures have been described.

NOTE: If a given nuclide ID is entered more than once in the same mixture, the number densities for that nuclide are summed.

If a mixture number is used as a nuclide ID, it is treated as a nuclide and the number density associated with it is used as a density modifier. (If the density is entered as 1, the mixture is mixed in at full density. If it is entered as 0.5, the mixture is mixed in at 1/2 its full density.) A Monte Carlo formatted cross-section library is generated on the unit defined by the parameter **XSC=**. If this data set is saved, subsequent cases can utilize these mixtures without remixing.

F17.4.11 PLOT DATA

PLOT or PICTURE DATA . . . Printer plots or pictures of slices through the geometry can be printed showing mixture numbers, unit numbers, or bias ID numbers. The *PLOT DATA* can include the data for any or all types of pictures. A picture by mixture number is the default. The kind of picture is defined by the parameter **PIC=**. Printer plots are printed after the volumes are printed and before the final preparations for tracking are completed. *PLOT DATA* is not required for a problem but can be used to verify the problem description. Two types of plots are available: printer plots, which use either default symbols or symbols entered using the **NCH** option to represent the system geometry cross section, and screen plots, which are pixel plots of the system cross-

section using colors entered in the color table. The default option is the printer plot, which is included in the problem output. If **SCR=YES** is specified, a .gif plot of the 2-D system geometry cross section is generated in the directory where the problem is being run. The actual printing of the plot or picture can be suppressed by entering **PLT= NO** in the parameter data or picture data. This allows picture data to be kept in the problem data for reference purposes without actually printing the picture(s). Entering a value for **PLT** in the picture data will override any value entered in the parameter data. However, if a problem is restarted, the value of **PLT** from the parameter data is used. The upper-left and lower-right coordinates of the plot must be specified relative to the origin of the problem. See Sect. F17.5.9 for a discussion of plot origins and printer plot data.

Enter **PLOT DATA** in the form:

READ PLOT PICTURE PARAMETERS END PLOT

PICTURE PARAMETERS are entered using keywords followed by the appropriate data. The plot title and the plot character string must be contained within delimiters. As many picture parameters as are necessary to describe the plot should be entered. Multiple sets of plot data can be entered. The parameter input for each plot is terminated by a labeled or unlabeled **END**. The labeled **END** cannot use the word **PLOT** as the first four characters of the label. For example, **END PLT1** is a valid label, but **END PLOT1** is not. If an unlabeled **END** is used, it cannot start in column 1.

TTL= *delim ptitl delim* Enter a one-character delimiter *delim* to signal the beginning of the title (132 characters maximum). The title is terminated when *delim* is encountered the second time.
Default = title of the KENO-VI case

SCR= *plot type* Enter YES for a screen plot and NO for a printer plot. Default is NO

CLR=color This option is only used in conjunction with screen plots. It changes a color in the color tables. Input consists of 4 integers, the first one being the position in the color table and the next three being the red green and blue color values respectively.

PIC= *wrd* The picture type, *wrd*, is followed by one or more blanks and must be one of the keywords listed below. The picture type is initialized to MAT; the default is the value from the previous plot.

MAT

MIX

MIXT

MIXTURE

MEDI

MEDIA

These keywords will cause the printer plot to represent the mixture numbers used in the specified geometry slice.

BOX

BOXT

BOXTYPE

UNT

UNIT

UNITTYPE

These keywords will cause the printer plot to represent the units used in the specified geometry slice.

IMP
BIAS
BIASID
ID
WTS
WEIG
WEIGHTS
WGT
WGTS

These keywords will cause the printer plot to represent the bias numbers used in the specified geometry slice.

Picture coordinates Enter values for the upper-left and lower-right coordinates of the plot as described below. **Data must be entered for all nonzero coordinates unless all six values from the previous plot are to be used.**

Upper left coordinates Enter the X, Y, and Z coordinates of the upper-left-hand corner of the plot.

XUL= *fnam*(1) Enter the X coordinate of the upper-left-hand corner of the plot.
Default = value from previous plot; initialized to zero if any other coordinates are entered.

YUL= *fnam*(2) Enter the Y coordinate of the upper-left-hand corner of the plot.
Default = value from previous plot; initialized to zero if any other coordinates are entered.

ZUL= *fnam*(3) Enter the Z coordinate of the upper-left-hand corner of the plot.
Default = value from previous plot; initialized to zero if any other coordinates are entered.

Lower right coordinates Enter the X, Y, and Z coordinates of the lower-right-hand corner of the plot.

XLR= *fnam*(4) Enter the X coordinate of the lower-right-hand corner of the plot.
Default = value from previous plot; initialized to zero if any other coordinates are entered.

YLR= *fnam*(5) Enter the Y coordinate of the lower-right-hand corner of the plot.
Default = value from previous plot; initialized to zero if any other coordinates are entered.

ZLR= *fnam*(6) Enter the Z coordinate of the lower-right-hand corner of the plot.
Default = value from previous plot; initialized to zero if any other coordinates are entered.

Direction cosines across the page Enter direction numbers proportional to the direction cosines for the AX axis of the plot. The AX axis is from left to right across the page. If any one of the AX direction cosines are entered, the other two are set to zero. The direction cosines are normalized by the code.

UAX= <i>fnam</i>(7)	Enter the X component of the direction cosines for the AX axis of the plot. default = value from previous plot; initialized to zero if any other direction cosines are entered.
VAX= <i>fnam</i>(8)	Enter the Y component of the direction cosines for the AX axis of the plot. Default = value from previous plot; initialized to zero if any other direction cosines are entered.
WAX= <i>fnam</i>(9)	Enter the Z component of the direction cosines for the AX axis of the plot. Default = value from previous plot; initialized to zero if any other direction cosines are entered.
Direction cosines down the page	Enter direction numbers proportional to the direction cosines for the DN axis of the plot. The DN axis is from top to bottom down the page. If any one of the DN direction cosines are entered, the other two are set to zero. The direction cosines are normalized by the code.
UDN= <i>fnam</i>(10)	Enter the X component of the direction cosines for the DN axis of the plot. Default = value from previous plot; initialized to zero if any other direction cosines are entered.
VDN= <i>fnam</i>(11)	Enter the Y component of the direction cosines for the DN axis of the plot. Default = value from previous plot; initialized to zero if any other direction cosines are entered.
WDN= <i>fnam</i>(12)	Enter the Z component of the direction cosines for the DN axis of the plot. Default = value from previous plot; initialized to zero if any other direction cosines are entered.
Scaling parameters	Enter one or more scaling parameters to define the size of the printer plot. NOTE: If any of the scaling parameters are entered for a plot, the value of those that were not entered are recalculated. If none of the scaling parameters are specified for a plot, the values from the previous plot are used.
DLX= <i>fnam</i>(13)	Horizontal spacing between points on the plot. Default = value from previous plot; initialized to zero if NAX or NDN is entered.
DLD= <i>fnam</i>(14)	Vertical spacing between points on the plot. Default = value from previous plot; initialized to zero if NAX or NDN is entered.
	NOTE: If either DLX or DLD is entered, the code will calculate the value of the other. If both are entered, the plot may be distorted.
NAX= <i>inam</i>(15)	Number of intervals to be printed across the page. Default = value from previous plot; initialized to zero if DLX or DLD is entered.
NDN= <i>inam</i>(16)	Number of intervals to be printed down the page. Default = value from previous plot; initialized to zero if DLX or DLD is entered.

NOTE: If either **NAX** or **NDN** is entered, the code will calculate the value of the other. If both are entered, the plot may be distorted. If the coordinates of the lower-right-hand corner have been entered, only one item of (**DLX**, **DLD**, **NAX**, **NDN**) need be entered. If the coordinates have not been entered, it is necessary to enter both **NAX** and **NDN** in addition to either **DLX** or **DLD**. If the coordinates and **NAX** or **NDN** are entered, then **DLX** and/or **DLD** will be recomputed. The plot distortion for printers other than 8 lines per inch (lpi) and 6 lpi impact printers can be minimized by entering appropriate values for both **NAX** and **NDN**. For a printer that prints 15 characters per inch across the page and 10 characters per inch down the page, $NDN = NAX \times 10/15 \times DELTAD/DELTA A$, where:

DELTAD is the "length of the picture down the page" defined as the difference between the value of the ordinate of the upper-left corner of the plot and the lower-right corner of the plot. For example, if **Z** is to be printed down the page, **DELTAD** is the absolute value of difference between the upper-left (**ZUL**) and lower-right (**ZLR**) values of **Z**.

DELTA A is the "width of the picture across the page" defined as the difference between the value of the ordinate of the upper-left corner of the plot and the lower-right corner of the plot. For example, if **X** is to be printed across the page, **DELTA A** is the absolute value of difference between the lower-right (**XLR**) and upper-left (**XUL**) values of **X**.

If an **X-Y** slice is to be printed with **X** across the page and **Y** down the page and the upper-left coordinates of the plot are **X**=-10, **Y**=50, **Z**=12, and the lower-right coordinates are **X**=10, **Y**=-50, **Z**=12, then **DELTA A** is 20 and **DELTAD** is 100. If **NAX** is specified as 90, then **NDN** should be 300 to produce a printer plot having minimum distortion.

Miscellaneous parameters Enter miscellaneous parameters.

LPI= inam(17) Number of lines per inch that will be printed down a page for a screen plot. It is used to calculate either lines down the page or characters across the page in both **NAX** and **NDN** are not entered. Default = 8.

NCH= delim CHAR delim Enter a one-character delimiter to signal the beginning of a character string, **CHAR**. The character string is terminated when **delim** is encountered the second time. **CHAR** is a character string with each entry representing a media (mixture) number, unit number, or bias ID. These characters will be used in the plot. The first entry represents media, unit, or bias ID zero; the second entry represents the smallest media, unit, or bias ID used in the problem; the third, the next larger media, unit, or bias ID used in the problem; etc. For example, assume **PIC=MAT** is specified and 15 mixtures are defined in the mixing table and the geometry data use only mixtures 3 and 7. By default, a blank will be printed for mixture zero, a 1 will be printed for mixture 3, and a 2 will be printed for mixture 7. If you wish to print a zero for a void (mixture 0), a 3 for mixture 3, and a 7 for mixture 7, enter **NCH='037.'** See Sect. F17.5.9 for examples.

The default values of *CHAR* follow:

MEDIA	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SYMBOL		1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
MEDIA	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SYMBOL	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
MEDIA	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	
SYMBOL	W	X	Y	Z	#	,	\$	-	+	)		&	>	:	;	
MEDIA	47	48	49	50	51	52	53	54	55	56	57	58				
SYMBOL	.	-	%	*	"	=	!	(	@	<	/	0				

RUN= *fnam*(19)

Enter YES or NO. A value of YES means the problem will be executed if all the data were acceptable. A value of NO specifies the problem will be terminated after data checking is completed. The default value of **RUN** is YES. The value entered in the plot data will override the value entered in the parameter data, Sect. F17.4.3, unless the problem is being restarted.

PLT= *fnam*(20)

Enter YES or NO. A value of YES specifies that a plot is to be made. If plot data are entered, **PLT** is defaulted to YES. If it is desirable to retain the plot data in the problem input without generating a plot, **PLT**= NO should be entered. **PLT**= can also be entered in the parameter data, Sect. F17.4.3, but will be overridden by the value entered here unless the problem is being restarted.

F17.4.12 REFERENCES

1. N. M. Greene et al., *AMPX: A Modular Code System for Generating Coupled Multigroup Neutron-Gamma Libraries from ENDF/B*, ORNL/TM-3706, March 1976. Also see Sect. F2.3.8 of the SCALE manual.
2. J. R. Knight and L. M. Petrie, *16 and 123 Group Weighting Functions for KENO-V.a*, ORNL/TM-4660, 1975.

Tables summarizing KENO-VI input data follow.

Table F17.4.7 Summary of parameter data

TITLE: The title must be entered first (80 characters, including blanks) See Sect. F17.4.3

PARAMETERS: Format: READ PARAM enter parameter data here END PARAM

If parameters are entered, they must follow the title. See Sects. F17.4.3, F17.5.2, and F17.5.3.

KEY	STD.	DEFINITION	KEY	STD.	DEFINITION	KEY	STD.	DEFINITION	KEY	STD.	DEFINITION
RND=	given	random number	RUN=	YES	execute problem	MKH=	NO	matrix by hole	XSC=	14	mixed xsecs
TME=	120 min	execution time (min)	FLX=	NO	fluxes	CKH=	NO	cofactor k by hole	ALB=	79	albedo
TBA=	0.5 min	batch time (min)	FDN=	NO	fission densities	FMH=	NO	fiss. prod. by hole	WTS=	80	weights
WTA=	0.5	average weight	ADJ=	NO	adjoint calculation	HHL=	NO	MKH at highest level	LTB=	0	working xsecs
WTH=	3.0	wt. for splitting	AMX=	NO	all mixture xsecs	MKA=	NO	matrix by array	SKT=	16	scratch
WTL=	1/WTH	Russian Roulette wt.	XAP=	NO	xsec angles & probs.	CKA=	NO	cofactor k by array	RST=	0	read restart
GEN=	203	no. of generations	XS1=	NO	1-D xsecs	FMA=	NO	fiss. prod. by array	WRS=	0	write restart
NPG=	1000	no. per generation	XS2=	NO	2-D xsecs	HAL=	NO	MKA at highest level			
NSK=	3	generations skipped	PKI=	NO	fission spectrum	PLT=	YES	printer plots			
RES=	0	gens. between restart	P1D=	NO	extra 1-D xsecs	BUG=	NO	debug print			
NBK=	NPG+25	neutron bank positions	FAR=	NO	fiss. & abs.	TRK=	NO	print neutron tracks			
XNB=	0	extra bank entries	MKP=	NO	matrix by location	PWT=	NO	print avg. weight			
NFB=	NPG	fission bank positions	CKP=	NO	cofactor k by loc.	PGM=	NO	unprocessed geometry			
XFB=	0	extra bank entries	FMP=	NO	fiss. prod. by loc.	SMU=	NO	self-multiplication			
X1D=	0	no. of extra 1-D's	MKU=	NO	matrix by unit	NUB=	NO	neutrons per fission			
LNG=	1000000	words of storage	CKU=	NO	cofactor k by unit	PAX=	NO	albedo-xsec array			
BEG=	1	restart at this gen.	FMU=	NO	fiss. prod. by unit						
NG8=	200	blocks for d.a. unit	GAS=	NO	fiss. & abs. by reg.						
NL8=	512	length of d.a. block									
SIG=	given	standard deviation for problem termination									

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Table F17.4.8 Summary of array data

ARRAY Format: READ ARRAY array parameters data type orientation data END ARRAY See Sects. F17.5.5, F17.5.6, and F17.5.7.

Repeat the sequence ARRAY PARAMETERS DATA TYPE ORIENTATION DATA for each array used in the problem.

ARRAY PARAMETERS			DATA TYPE
KEYWORD	DEFAULT	DEFINITION	FILL LOOP
ARA=	none	no. defining the array	
TYP=	cuboidal	array type (cuboidal or triangular)	
NUX=	none	no. of units in X direction	
NUY=	none	no. of units in Y direction	
NUZ=	none	no. of units in Z direction	
GBL=	none	global, array number**	
COM=	none	delim comment delim optional comment is a maximum of 132 characters	

**If specified, it need be entered only once per problem.

ORIENTATION DATA FOR FILL

Enter unit numbers to define every position in the array. When entering data utilizing the options in this table, the count field and option field must be adjacent with no imbedded blanks. The operand field may be separated from the option field by one or more blanks. Orientation data for FILL is terminated by entering END FILL.

ORIENTATION DATA FOR LOOP

Enter the unit number and nine numbers that define the position(s) of that unit. Data for each of these ten entries are repeated until every position in the array has been defined. Orientation data for LOOP is terminated by entering END LOOP.

ENTER DATA IN THE FORM:

COUNT FIELD	OPTION FIELD	OPERAND FIELD	COMMENTS	DATA ENTRY	COMMENTS
i	R	j	stores j at the current position in the array	LTYPE	The unit or box type. LTYPE must be greater than 0.
i	*	j	stores j in the next i positions in the array	IX1	Starting position in the X direction. IX1 must be at least 1 and no larger than the value entered for NUX.
i	S	j	stores j in the next i positions in the array	IX2	Ending position in the X direction. IX2 must be at least 1 and no larger than the value of NUX.
	F	j	fills remainder of the array with unit no. j starting with the current array position	INCX	The number of units by which increments are made in the X direction.
i	A	j	sets the current position in the array to j	IY1	The starting position in the Y direction. IY1 must be at least 1 and less than the value entered for NUY.
	S		increments current position in the array by i allows skipping i positions. The value of i may be positive or negative	IY2	Ending position in the Y direction. IY2 must be at least 1 and no larger than the value of NUY.
i	Q	j	repeats the previous j entries i times. The default value of i is 1	INCY	The number of units by which increments are made in the positive Y direction.
i	N	j	repeats the previous j entries i times, inverting the sequence each time. The default value of i is 1	IZ1	Starting position in the Z direction. IZ1 must be at least 1 and no larger than NUZ.
i	B	j	starting with the entry at -i from the current position, store entries in inverse order until position -(i+j) is reached. Default value of i=1	IZ2	Ending position in the Z direction. IZ2 must be at least 1 and no larger than NUZ.
i	P	j	alternately stores j and -j in the next i positions of the array	INCZ	The number of units by which increments are made in the positive Z direction.
i	I	j k	provides the end points, j and k, with i entries linearly interpolated between them (i.e., a total of i+2 points). At least one blank must separate j and k. When used for an integer array, the I option should only be used to generate integer steps (i.e., (k-j)/(i+1) should be a whole number).		
	T		terminates the data reading for the array		

Table F17.4.9 Summary of biasing data

BIAS
(weighting)

Format: READ BIAS keyword correlation data auxiliary data END BIAS
See Sects. F17.4.7 and F17.5.8

KEYWORD	DESCRIPTION	MATERIAL	ID	ENERGY GROUPS	THICKNESS/ INCRBMENT	
ID=	CORRELATION DATA will be read next.					
	id	material ID. Enter from table at right to use weighting data from the library	concrete	301	16,27,123	5 cm
	ibgn	beginning bias ID	paraffin	400	16,27,123	3 cm
	iend	ending bias ID	water	500	16,27,123,218	3 cm
			graphite	6100	16,27,123	20 cm
WT=	AUXILIARY DATA will be read next.					
WTS=	AUXILIARY DATA will be read next.					
	wttitle	material title (12-character maximum)				
	id	material ID				
	nsets	number of sets of group structures				
	REPEAT	(THKINC, NUMINC, NGPWT, WTAvg) NSETS TIMES				
	thkinc	thickness per increment				
	numinc	number of increments				
	ngpwt	number of energy groups for this set of wts				
	wtavg	enter numinc x ngpwt values of wtavg				

For CORRELATION DATA, the material ID is chosen from material ID column above (the keyword is ID=).

For AUXILIARY DATA, the material ID is chosen by the user and the keyword is WT= or WTS=. When AUXILIARY DATA are entered, CORRELATION DATA must also be entered to use the data.

Beginning and ending bias IDs are defined by the user. The geometry specification that has the bias ID equal to the beginning bias ID utilizes the wt avg's from the first interval of material ID.

Table F17.4.10 Summary of boundary condition data

BNDS
(albedo or
boundary
conditions)

Format: READ BNDS face code albedo name END BNDS
See Sect. F17.4.7

The sequence FACE CODE ALBEDO NAME is entered as many times as necessary to define the appropriate albedo boundary conditions.
The default for all faces is vacuum.

FACE CODES FOR ENTERING BOUNDARY (ALBEDO) CONDITIONS

FACE CODE	DEFINITION	FACE CODE	DEFINITION	FACE CODE	DEFINITION	FACE CODE	DEFINITION
+XB=	positive X face	XFC=	both X faces	+YX=	positive X and Y faces	&ZY=	positive Y and Z faces
&XB=	positive X face	YFC=	both Y faces	&XY=	positive X and Y faces	-XY=	negative X and Y faces
-XB=	negative X face	ZFC=	both Z faces	&YX=	positive X and Y faces	-XZ=	negative X and Z faces
+YB=	positive Y face	+FC=	all positive faces	+XZ=	positive X and Z faces	-YZ=	negative Y and Z faces
&YB=	positive Y face	&FC=	all positive faces	+ZX=	positive X and Z faces	YXF=	all X and Y faces
-YB=	negative Y face	-FC=	all negative faces	&XZ=	positive X and Z faces	ZXF=	all X and Z faces
+ZB=	positive Z face	XYF=	all X and Y faces	&ZX=	positive X and Z faces	ZYF=	all Y and Z faces
&ZB=	positive Z face	XZF=	all X and Z faces	+YZ=	positive Y and Z faces	-YX=	negative X and Y faces
-ZB=	negative Z face	YZF=	all Y and Z faces	+ZY=	positive Y and Z faces	-ZX=	negative X and Z faces
ALL=	all 6 faces	+XY=	positive X and Y faces	+YZ=	positive Y and Z faces	-ZY=	negative Y and Z faces

Any albedo condition on any face is allowed if the global unit boundary record consists of only one geometry record label that references a cuboid

Any one albedo condition on all surfaces is allowed if the global unit boundary record contains only one geometry record label that references a shape composed of paired planes

Either a void, mirror, or white boundary condition on all surfaces is allowed if the global unit boundary record contains only one geometry record label.

If the global unit boundary record contains more than one entry only the void boundary condition is allowed. Void is the default

ALBEDO NAMES AVAILABLE ON THE KENO V.8 ALBEDO LIBRARY, FOR USE WITH THE FACE CODES

ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION
DP0H2O DP0H2O DP0 DP0	12-in. double P0 water differential albedo with 4 incident angles	CONC-4 CON4 CONC4	4-in. concrete differential albedo with 4 incident angles	VACUUM VOID VACU VAC	vacuum condition
H2O WATER	12-in. water differential albedo with 4 incident angles	CONC-8 CON8 CONC8	8-in. concrete differential albedo with 4 incident angles	SPECULAR MIRROR MIRR SPEC SPE MIR	mirror image reflection
PARAFFIN PARA WAX	12-in. paraffin differential albedo with 4 incident angles	CONC-12 CON12 CONC12	12-in. concrete differential albedo with 4 incident angles	PERIODIC PERI PER	periodic boundary condition
CARBON GRAPHITE C	200-cm carbon differential albedo with 4 incident angles	CONC-15 CON16 CONC16	16-in. concrete differential albedo with 4 incident angles	WHITE	white boundary condition
ETHYLENE POLY CH2	12-in. polyethylene differential albedo with 4 incident angles	CONC-24 CON24 CONC24	24-in. concrete differential albedo with 4 incident angles		

Table F17.4.11 Summary of geometry data

GEOMETRY
(region)

Format: READ GEOM geometry region data END GEOM
See Sects. F17.4.4, F17.5.1.2, F17.5.6, and F17.5.7.

GEOMETRY REGION DATA consist of SIMPLE GEOMETRY REGION DATA and EXTENDED GEOMETRY REGION DATA.

ENTER GEOMETRY REGION DATA IN THE FOLLOWING FORM:

GLOBAL SPECIFICATION

UNIT n

OPTIONAL GEOMETRY COMMENT

GEOMETRY, MODIFICATION, MEDIA, and BOUNDARY DATA

ENTER DATA IN THE FOLLOWING FORM:

GLOBAL Enter once to specify this unit as the global unit.

UNIT n

COM=delim comment delim This optional comment can be up to 132 characters. It must begin and end with a delimiter.

Geometry Keyword Label Input Parameters Optional origin data (ORIGIN) Optional chord data (CHORD) Optional rotation data (ROTATE degrees)

Media Keyword Input Parameters

Boundary Keyword Input Parameters Each unit must have one boundary record.

enter as many geometry and media descriptions as necessary to describe the unit and as many units as necessary to describe the system.

GEOMETRY REGION INPUT DATA REQUIREMENTS

TYPE OF DATA	KEYWORD	INPUT PARAMETERS	NOTES
GEOMETRY	CONE	Lbl Rt Zi Rb Zb	
	CUBOID	Lbl +X -X +Y -Y +Z -Z	
	CYLINDER	Lbl R Zi Zb	
	DODECAHEDRON	Lbl R	
	ECYLINDER	Lbl Rx Ry Zi Zb	
	ELLIPSOID	Lbl Rx Ry Rz	
	HEXPRISM	Lbl R Zi Zb	
	HOPPER	Lbl Lxt Lyt Zi Lxb Lyb Zb	
	PARALLELEPIPED	Lbl XDIST YDIST ZDIST PSI THETA PHI	
	PLANE*	Lbl XPL=a YPL=b ZPL=c CON=d	Data are entered after the = following the respective subordinate keyword. Only nonzero data are required.
MODIFICATION*	QUADRATIC*	Lbl AQU=a BQU=b CQU=c DQU=d EQU=e FQU=f GQU=g HQU=h IQU=i JQU=j	Data are entered after the = following the respective subordinate keyword. Only nonzero data are required.
	RHOMBOID	Lbl DX PSI	
	SPHERE	Lbl R	
	WEDGE	Lbl XBASE XPT YPT ZLNG	
	CHORD	+X= -X= +Y= -Y= +Z= -Z=	Only nonzero data are required.
MEDIA**	ORIGIN	X= Y= Z=	Only nonzero data are required.
	ROTATE	A1= A2= A3=	The body is rotated about the Origin using the Euler angle x-convention. Only nonzero data are required.
MEDIA**	MEDIA	Mid Bid i1 i2...	
	HOLE	Hid i1 i2...	The region boundary containing the hole must exactly match the boundary of the unit being placed in the hole.
MEDIA**	ARRAY	Aid i1 i2... PLACE nx ny nz xx yy zz	Place positions the array by placing the origin of the unit in array position nx ny nz at xx yy zz. The region boundary containing the array must be enclosed in or on the array boundary.
BOUNDARY	BOUNDARY	i1 i2 ...	Defines the overall volume of the unit.

*Modification Data can be entered in any order. Any combination of modification data can follow any geometry record.

**The Region Definition Vector, i1 i2 ..., should contain references to all geometry records which share a boundary with the region being defined.

Table F17.4.12 Summary of mixing table data

MIXTURES

Format: READ MIXT xsec parameters END MIXT

These data are entered only if an AMPX working-format library is being used, (LIB=) in the parameter data, Sect. F17.4.3. Do not enter if an ICE mixed library is used (XSC=) in the parameter data, Sects. F17.4.10 and F17.5.5.

XSEC PARAMETERS

consists of keywords and associated values.

These parameters, if entered, need be entered only once.

KEYWORD	DEFAULT	DEFINITION
SCT=	1	No. of discrete scattering angles 0 is isotropic 1 is P1 2 is P3 3 is P5
EPS=	0.00003	cross-section message cutoff value use to suppress message No. K5-60

MIXING TABLE DATA consists of

(1) a keyword and mixture ID for the mixture

The keyword is MIX=

The desired mixture number follows the keyword

(2) nuclide ID**

(3) number density**

**The sequence (2) (3) is repeated for each nuclide in the mixture.

REPEAT the sequence (1) (2)'s (3)'s until all the mixtures have been described.

Table F17.4.13 Summary of plot data

PLOT			Format: READ PLOT plot parameters END PLOT plot parameters must be entered for each plot that is to be made. See Sects. F17.4.1 and F17.5.9		
KEYWORD	DEFAULT	DEFINITION	KEYWORD	DEFAULT	DEFINITION
TTL=	prob. title	delim ptitl delim delim is a one-character delimiter that signals the beginning and end of the title. ptitl is the plot title (max. 132 char.)	UAX=	prev. plot 0 IF VAX OR WAX is read	X component of direction cosine for the AX axis of the plot (across)
PIC=	MAT	Type of picture: MIXTURE, UNIT NO. or BIAS ID NO. MIXTURE ----- MAT MIX MIXT MIXTURE MEDI MEDIA UNIT NO. ----- BOX BOXT BOXTYPE UNIT UNITTYPE BIAS ID NO. ----- IMP BIAS BIASID WTS WEIG WEIGHTS WGT WGTS	VAX=	prev. plot 0 IF UAX OR WAX is read	Y component of direction cosine for the AX axis of the plot (across)
			WAX=	prev. plot 0 IF UAX OR VAX is read	Z component of direction cosine for the AX axis of the plot (across)
			UDN=	prev. plot 0 IF VDN OR WDN is read	X component of direction cosine for the DN axis of the plot (down)
			VDN=	prev. plot 0 IF UDN OR WDN is read	Y component of direction cosine for the DN axis of the plot (down)
			WDN=	prev. plot 0 IF UDN OR VDN is read	Z component of direction cosine for the DN axis of the plot (down)
			DLX=		horizontal spacing between points on plot
			DLD=		vertical spacing between points on plot
			NAX=		no. of intervals to be printed across page
			NDN=		no. of intervals to be printed down page
			LPI=	8	lines per inch printed down the page
			NCH=	CHRS**	delim CHRS delim a one character delimiter signals the beginning and end of the character string
			RUN=	YES	YES allows the problem to execute NO terminates problem after data checking
			PLT=	YES	YES allows the plot(s) to be made NO allows reading the plot data without making a plot
XUL=	prev. plot	X coord. of upper left corner of plot	SCR=	NO	No specifies a printer plot. If yes, a .gif file is generated for each plot.
YUL=	prev. plot	Y coord. of upper left corner of plot			
ZUL=	prev. plot	Z coord. of upper left corner of plot			
XLR=	prev. plot	X coord. of lower right corner of plot	CLR=		Used only with SCR=YES to change colors. Input is 4 integers: 1st is the index into the color table, next 3 are the red, green and blue color values.
YLR=	prev. plot	Y coord. of lower right corner of plot			
ZLR=	prev. plot	Z coord. of lower right corner of plot			
PLOT ORIGIN:			**default values of CHRS are given below:		
(1) SINGLE UNIT - coincides with origin of geometry description.			MEDIA 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22		
(2) BASE ARRAY - at the most negative point of the global array			CHRS 1 2 3 4 5 6 7 8 9 A B C D E F G H I J K L M		
(3) REFLECTED ARRAY - coincides with the origin of the CORE or ARRAY description of the global array.			MEDIA 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42		
			CHRS N O P Q R S T U V W X Y Z # , \$ - +)		
			MEDIA 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58		
			CHRS & > : ; . - % * " = ! (@ < / 0		

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Table F17.4.14 Summary of starting data

START										
Format: READ START start data END START										
The default value of start type is zero. See Sect. F17.4.8.										
START TYPE	REQUIRED DATA	OPTIONAL DATA	STARTING DISTRIBUTION	START TYPE	REQUIRED DATA	OPTIONAL DATA	STARTING DISTRIBUTION	KEYWORD	DEFAULT	DEFINITION
0	none	NST XSM XSP YSM YSP ZSM ZSP RFL PSP	uniform	3	NST TFX TFY TFZ NXS NYS NZS	KFS PSP	spike	NST=	0	start type
								TFX=	0.0	X coordinate
								TFY=	0.0	Y coordinate
								TFZ=	0.0	Z coordinate
								NXS=	0	X index of unit pos.
								NYS=	0	Y index of unit pos.
								NZS=	0	Z index of unit pos.
								KFS=	**	fissile mixture no.
				4	NST TFX TFY TFZ NBX	KFS PSP	multiple spikes	LNU=	0	number of last neutron
								NBX=	0	source unit number
								FCT=	0	fraction
								XSM=	-X	-X of source cuboid
								XSP=	+X	+X of source cuboid
								YSM=	-Y	-Y of source cuboid
								YSP=	+Y	+Y of source cuboid
				5	NST NBX	PSP	in specified units	ZSM=	-Z	-Z of source cuboid
								ZSP=	+Z	+Z of source cuboid
				6	NST TFX TFY TFZ LNU*	NXS NYS NZS KFS PS6 PSP	arbitrary points	RFL=	NO	start in reflector
								PS6=	NO	print start 6 input
								PSP=	NO	print starting points
1	NST	XSM XSP YSM YSP ZSM ZSP RFL PSP	cosine							
2	NST NXS NYS NZS FCT	XSM XSP YSM YSP ZSM ZSP RFL PSP	cosine with fraction in specified unit							

*LNU must be the last entry for each set of start 6 data. The LNU of each successive set of data must be larger than the last.

**Defaulted to the fissionable mixture by the smallest mixture number.

Unless otherwise specified, the starting volume is defined by the unrotated, untranslated geometric shape specified in the first position in the global unit boundary record.

F17.5 NOTES FOR KENO-VI USERS

This section provides assorted tips primarily designed to assist the KENO-VI user with problem mock-ups. Some information concerning methods utilized by KENO-VI is also included.

F17.5.1 DATA ENTRY

The KENO-VI data input is entered in blocks that begin and end with keywords as described in Sect. F17.4.1. Only one set of parameter data can be entered for a problem. However, for other data blocks, it is possible to enter more than one block of the same kind of data. When this is done, only the last block of that kind of data is retained for use by the problem.

Within data blocks, a number, x , can be repeated n times by specifying nRx , $n*x$, or $n\$x$.

F17.5.1.1 *Multiple and Scattered Entries in the Mixing Table*

In the following examples, assume 1001 is the nuclide ID for hydrogen, 8016 is the nuclide ID for oxygen, 92235 is the nuclide ID for ^{235}U , and 92238 is the nuclide ID for ^{238}U . If a given nuclide ID is used more than once in the same mixture, the result is the summing of all the number densities associated with that nuclide. For example:

MIX=1 92235 4.3-2 92238 2.6-3 1001 3.7-2 92235 1.1-3 8016 1.8-2

would be the same as entering

MIX=1 92235 4.41-2 92238 2.6-3 1001 3.7-2 8016 1.8-2

A belated entry for a mixture can be made as follows:

MIX=1 1001 6.6-2 MIX=2 92235 4.3-2 92238 2.6-3 MIX=1 8016 3.3-2

This is the same as entering

MIX=1 1001 6.6-2 8016 3.3-2 MIX=2 92235 4.3-2 92238 2.6-3

F17.5.1.2 *Multiple Entries in Geometry Data*

Individual geometry regions cannot be replaced by adding an additional description. However, entire unit descriptions can be replaced by adding a new description having the same unit number. The last description entered for a unit is used in the calculation. For example:

READ GEOM UNIT 1 SPHERE 10 5.0 CUBOID 20 10.0 -10.0 10.0 -10.0 10.0 -10.0
MEDIA 1 1 10 MEDIA 0 1 20 -10 BOUNDARY 20
UNIT 2 CYLINDER 10 2.0 5.0 -5.0 CUBOID 20 10.0 -10.0 10.0 -10.0 10.0 -10.0

```

MEDIA 1 1 10 MEDIA 0 1 20 -10 BOUNDARY 20
UNIT 1 CUBOID 10 1.0 -1.5 2.5 -2.0 5.0 -6.0 CUBOID 20 10.0 -10.0 10.0 -10.0 10.0 -10.0
MEDIA 1 1 10 MEDIA 0 1 -10 20 BOUNDARY 20
END GEOM

```

is the same as entering

```

READ GEOM UNIT 1 CUBOID 10 1.0 -1.5 2.5 -2.0 5.0 -6.0
CUBOID 20 10.0 -10.0 10.0 -10.0 10.0 -10.0
MEDIA 1 1 10 BOUNDARY MEDIA 0 1 -10 20
UNIT 2 CYLINDER 10 2.0 5.0 -5.0 CUBOID 20 10.0 -10.0 10.0 -10 10.0 -10.0
MEDIA 1 1 10 MEDIA 0 1 -10 20 BOUNDARY 20 END GEOM

```

or

```

READ GEOM UNIT 2 CYLINDER 30 2.0 5.0 -5.0 CUBOID 40 6P10.0
MEDIA 1 1 30 MEDIA 0 1 -30 40 BOUNDARY 40
UNIT 1 CUBOID 20 1.0 -1.5 2.5 -2.0 5.0 -6.0 CUBOID 10 6P10.0
MEDIA 1 1 20 MEDIA 0 1 10 -20 BOUNDARY 10
END GEOM

```

The order of entry for unit descriptions is not important because the unit number is assigned as the value following the word UNIT. They need not be entered sequentially nor be numbered sequentially. It is perfectly acceptable to input Units 2, 3, and 5, omitting Units 1 and 4 as long as Units 1 and 4 are not referenced in the problem. It is also acceptable to scramble the order of entry as in entering Units 3, 2, and 5.

F17.5.2 DEFAULT LOGICAL UNIT NUMBERS FOR KENO-VI

The logical unit numbers for data utilized by KENO-VI are listed in Table F17.5.1.

F17.5.3 PARAMETER INPUT

When the parameter data block is input for a problem, the same keyword may be entered several times. The last value that is entered is used in the problem. Data may be entered as follows:

```

READ PARAM FLX=YES NGP=1000 TME=0.5 TME=1.0
NPG=50 TME=10.0 FLX=NO
NPG=500
END PARA

```

This input will result in the problem having FLX=NO, TME=10.0, and NPG=500. It may be more convenient for the user to insert a new value than to change the existing data.

Table F17.5.1. KENO-VI logical unit numbers

Function	Parameter name	Unit No.	Variable name
Problem input data (EBCDIC or ASCII)		5	INPT
Problem input data (binary)		95	BIN
Program output		6	OUTPT
Albedo data	ALB=	79	ALBDO
Scratch unit	SKT=	16	SKRT
Read restart data	RST=	0 ^a	RSTRT
		34 ^b	RSTRT
Write restart data	WRS=	0 ^a	WSTRT
		35 ^c	WSTRT
Direct access storage for input data		8	DIRECT(1)
Direct access storage for supergrouped data		9	DIRECT(2)
Direct access storage for cross-section mixing		10	DIRECT(3)
Mixed cross-section data set	XSC=	14 ^d	ICEXS
Group-dependent weights	WTS=	80	WTS
AMPX working format cross sections	LIB=	0 ^a	AMPXS

^aDefaulted to zero.

^bDefaulted to 34 if BEG= a number greater than 1 and RSTRT=0.

^cDefaulted to 35 if RES= a number greater than zero and WSTRT=0.

^dDefaulted to 0; if LIB= a number greater than zero, ICEXS is defaulted to 14.

Certain parameter default values should not be overridden unless the user has a very good reason to do so. These parameters are as follows:

1. **X1D=** defines the number of extra 1-D cross sections. The use of extra 1-D cross sections—other than the use of the fission cross section for calculating the average number of neutrons per fission—requires programming changes to the code;
2. **NFB=** defines the number of neutrons that can be entered in the fission bank;
3. **XFB=** defines the number of extra positions in the fission bank (the fission bank is where the information related to a fission is stored);
4. **NBK=** defines the number of neutrons that can be entered in the neutron bank;
5. **XNB=** defines the number of extra positions in the neutron bank (the neutron bank contains information about each history);
6. **WTH=** defines the factor that determines when splitting occurs;
7. **WTA=** defines the default average weight given to a neutron that survives Russian roulette;

8. **WTL=** defines the factor that determines when Russian roulette is played; and
9. **LNG=** sets the maximum words of storage available to the program.

It is recommended that **BUG=**, the flag for printing debug information, never be set to YES. The user would have to look at the FORTRAN coding to determine what information is printed. **BUG=YES** prints massive amounts of sparsely labeled information. The user should only rarely consider using **TRK=YES**. This keyword generates thousands of lines of well-labeled print that provides information about each history at key locations during the tracking procedure. All other parameters can be changed at will to provide features the user wishes to activate.

F17.5.4 CROSS SECTIONS

KENO-VI always uses cross sections from a mixed cross-section data file. The format of this file is the Monte Carlo processed cross-section file from ICE¹ (Sect. F8). A mixed cross-section file can be created by (1) executing ICE or (2) using an AMPX working-format library and entering mixing table data in KENO-VI.

F17.5.4.1 Use An ICE Mixed Cross-Section MORSE/KENO-Va Format Library

An ICE mixed cross-section MORSE/KENO-Va format library (premixed cross-section data file) from ICE or a previous KENO-VI case may be used. This file should be specified in the job control language on the unit number associated with the parameter **XSC=**. If a mixing table data block is entered, the premixed cross-section data file will be rewritten. Therefore, a mixing table should not be entered if a premixed cross-section data file is used. The user should verify that the mixtures created by ICE or the previous KENO-VI case are consistent with those used in the geometry data of the problem.

F17.5.4.2 Use an AMPX Working-Format Library

When an AMPX working-format library is used, a file definition must be specified in the job control language to specify the AMPX working-format library on the unit associated with the parameter **LIB=**. If the mixed cross-section data file is to be saved, a file definition must be specified in the job control language to specify the mixed cross-section file on the unit associated with the parameter **XSC=**.

Mixing table data must always be entered when an AMPX working format library is used. IDs used in the mixing table must match the IDs on the AMPX working-format library.

F17.5.4.3 Number of Scattering Angles

The number of scattering angles is defaulted to 1. This default is not adequate for many applications. The user should specify the scattering angle to be consistent with the cross sections being used. The number of scattering angles is entered in the cross-section mixing table by using the keyword **SCT=**. See Sect. F17.4.10.

The order of the last Legendre coefficient to be preserved in the scattering distribution is equal to $(2 \times \text{SCT} - 1)$. **SCT=1** could be used with a P_1 cross-section set such as the 16-group Hansen Roach cross-section library, and **SCT=2** for a P_3 cross-section set such as the SCALE 27-group cross-section library. Isotropic scattering is achieved by entering **SCT=0**.

F17.5.4.4 Cross-Section Message Cutoff

The cross-section message cutoff value, $pbxs$, is defaulted to 3×10^{-5} . Warning messages that are generated when errors are encountered in the P_L expansion of the group-to-group transfers will be suppressed if the P_0 cross section for that particular energy transfer is less than $pbxs$. The value of $pbxs$ is specified in the cross-section mixing table by using the keyword EPS=. See Sect. F17.4.10.

The default value of $pbxs$ is sufficient to ensure that warning messages will not be printed for most of the SCALE P_1 and P_3 cross-section libraries. However, the 238GROUPNDF5 library requires a value of $pbxs$ as large as 1×10^{-1} if P_3 cross sections are specified.

If the default value of $pbxs$ allows too many warning messages to be printed, a value can be determined from the printed messages by choosing a number larger than the P_0 component on the first line, as shown below.

THE LEGENDRE EXPANSION OF THE CROSS SECTION (P0-PN) IS

(P₀) (P₁) (P₂) ... (P_n)

THE MOMENTS CORRESPONDING TO THIS DISTRIBUTION ARE

(M₁) (M₂) ... (M_n)

THE MOMENTS CORRESPONDING TO THE GENERATED DISTRIBUTION ARE

(M₁) (M₂) ... (M_n)

THE LEGENDRE EXPANSION CORRESPONDING TO THESE MOMENTS IS

(P₀) (P₁) (P₂) ... (P_n)

___ MOMENTS WERE ACCEPTED

For the following messages, EPS=6.9-5 would cause all three messages to be suppressed. A value less than 5.615159-5 and greater than 4.767635-5 would suppress the second message, and a value less than 6.855362-5 and greater than 5.615159-5 would suppress the first two messages.

K6-60 THE ANGULAR SCATTERING DISTRIBUTION FOR MIXTURE 2 HAS BAD MOMENTS FOR THE TRANSFER FROM GROUP 28 TO GROUP 72

1 MOMENTS WERE ACCEPTED

THE LEGENDRE EXPANSION OF THE CROSS SECTION (P0-PN) IS

5.615159E-05 1.155527E-06 -2.804013E-05 -1.732067E-06

THE MOMENTS CORRESPONDING TO THIS DISTRIBUTION ARE

2.057870E-02 4.234578E-04 8.710817E-06

THE MOMENTS CORRESPONDING TO THE GENERATED DISTRIBUTION ARE

2.057870E-02 4.235078E-04 8.710817E-06

THE LEGENDRE EXPANSION CORRESPONDING TO THESE MOMENTS IS

5.615159E-05 1.155527E-06 -2.804011E-05 -1.732066E-06

THE WEIGHTS/ANGLES FOR THIS DISTRIBUTION ARE

9.999995E-01 5.268617E-07

2.057881E-02 -1.973451E-01

THE MOMENTS CORRESPONDING TO THIS DISTRIBUTION ARE

2.057870E-02 4.235078E-04 8.710817E-06

K6-60 THE ANGULAR SCATTERING DISTRIBUTION FOR MIXTURE 2 HAS BAD MOMENTS FOR THE TRANSFER FROM GROUP 31 TO GROUP 75

1 MOMENTS WERE ACCEPTED

THE LEGENDRE EXPANSION OF THE CROSS SECTION (P0-PN) IS

4.767635E-05 7.834378E-07 -2.381887E-05 -1.174626E-06

THE MOMENTS CORRESPONDING TO THIS DISTRIBUTION ARE

1.643242E-02 2.700205E-04 4.451724E-06
 THE MOMENTS CORRESPONDING TO THE GENERATED DISTRIBUTION ARE
 1.643242E-02 2.700282E-04 4.437279E-06
 THE LEGENDRE EXPANSION CORRESPONDING TO THESE MOMENTS IS
 4.767635E-05 7.834378E-07 -2.381885E-05 -1.174627E-06
 THE WEIGHTS/ANGLES FOR THIS DISTRIBUTION ARE
 9.999858E-01 1.420136E-05
 1.643265E-02 -2.334324E-07
 THE MOMENTS CORRESPONDING TO THIS DISTRIBUTION ARE
 1.643242E-02 2.700282E-04 4.437279E-06

K6-60 THE ANGULAR SCATTERING DISTRIBUTION FOR MIXTURE 2 HAS BAD MOMENTS FOR THE TRANSFER FROM GROUP 32 TO GROUP 74
 1 MOMENTS WERE ACCEPTED
 THE LEGENDRE EXPANSION OF THE CROSS SECTION (P0-PN) IS
 6.855362E-05 1.341944E-06 -3.423741E-05 -2.011613E-06
 THE MOMENTS CORRESPONDING TO THIS DISTRIBUTION ARE
 1.957510E-02 3.831484E-04 7.601939E-06
 THE MOMENTS CORRESPONDING TO THE GENERATED DISTRIBUTION ARE
 1.957510E-02 3.832207E-04 7.502292E-06
 THE LEGENDRE EXPANSION CORRESPONDING TO THESE MOMENTS IS
 6.855362E-05 1.341944E-06 -3.423740E-05 -2.011629E-06
 THE WEIGHTS/ANGLES FOR THIS DISTRIBUTION ARE
 9.999056E-01 9.437981E-05
 1.957695E-02 -1.848551E-06
 THE MOMENTS CORRESPONDING TO THIS DISTRIBUTION ARE
 1.957510E-02 3.832207E-04 7.502292E-06

The user need not attempt to suppress all the K6-60 messages. They are printed to inform the user of the fact that the moments of the angular distribution are not moments of a valid probability distribution. The third through sixth lines of the message list the original P_n coefficients and their moments. The seventh through tenth lines list the new corrected moments and their corresponding P_n coefficients.

The weights and angles that are printed in lines 11 through 13 were generated from the corrected moments. The last two lines of the message list the moments generated from those weights and angles. They should match line 8, the moments corresponding to the generated distribution.

For most criticality problems, the first moment contributions are much more significant than the contributions of the higher-order moments; thus the higher-order moments may not affect the results significantly. The user can look at the original moments and corrected moments and make a judgment as to the significance of the change in the moments.

F17.5.5 MIXING TABLE

Mixtures can be utilized in defining other mixtures. When defining mixture numbers, care should be taken to avoid using a mixture number that is identical to a nuclide ID number if the mixture is to be used in defining another mixture. If a mixture number is defined more than once, it results in a summing effect.

The nuclide mixing loop is done before the mixture mixing loop, which performs mixing in the order of data entry. Thus the order of mixing mixtures into other mixtures is important because a mixture must be defined before it can be used in another mixture. Some examples of correct and incorrect mixing are shown below, using 1001 as the nuclide ID for hydrogen, 8016 as the nuclide ID for oxygen, 92235 as the nuclide ID for ^{235}U , and 92238 as the nuclide ID for ^{238}U .

EXAMPLES OF CORRECT USAGE

1. READ MIXT MIX=1 1001 6.6-2 8016 3.3-2 MIX=2 1 0.5 END MIXT

This option results in mixture 1 being full-density water and mixture 2 being half-density water.

2. READ MIXT MIX=1 2 0.5 MIX=3 1 0.5 MIX=2 1001 6.6-2 8016 3.3-2 END MIXT

This option results in mixture 1 being half-density water, mixture 2 being full-density water, and mixture 3 being quarter-density water. Because the nuclide mixing loop is done first, mixture 2 is created first and is available to create mixture 1, which is then available to create mixture 3.

3. READ MIXT MIX=1 1001 6.6-2 8016 3.3-2 MIX=2 92235 7.5-4 92238 2.3-2 8016 4.6-2 1 .01 END MIXT

This option results in mixture 1 being full-density water and mixture 2 being uranium oxide containing 0.01 density water.

4. READ MIXT MIX=1 1001 6.6-2 8016 3.3-2 MIX=2 92235 4.4-2 92238 2.6-3 MIX=1 1 0.5 END MIXT

This option results in mixture 1 being water at 1.5 density (1001 9.9-2 and 8016 4.95-2) and mixture 2 is highly enriched uranium metal.

EXAMPLES OF INCORRECT USAGE

1. READ MIXT MIX=3 1 0.75 MIX=1 2 0.5 MIX=2 1001 6.6-2 8016 3.3-2 END MIXT

Here the intent is for mixture 2 to be full-density water, mixture 1 to be half-density water, and mixture 3 to be $3/8$ (0.75×0.5) density water. Instead, the result for mixture 3 is a void, mixture 1 is half-density water, and mixture 2 is full-density water. This situation occurs because the nuclide mixing loop is done first, thus defining mixture 2, and the mixture mixing loop is done next. Mixture 3 is defined to be mixture 1 multiplied by 0.75, but since mixture 1 has not been defined, 0.75 of zero is zero. Mixture 1 is then defined to be mixture 2 multiplied by 0.5. If the definition of mixture 1 preceded the definition of mixture 3, as in (2) under examples of correct usage, it would work correctly.

2. READ MIXT MIX=1 1001 6.6-2 8016 3.3-2 MIX=1001 92235 4.4-2 92238 2.6-3 MIX=2 1001 0.5 END MIXT

This option results in mixture 1 being full-density water, mixture 1001 being uranium metal, and mixture 2 being hydrogen with a number density of 0.5 because 1001 is the nuclide ID number for hydrogen. When a mixture number is identical to a nuclide ID and is used in mixing, that number is assumed to be a nuclide ID rather than a mixture number. The intent was for mixture 1 to be full-density water, mixture 1001 to be uranium metal, and mixture 2 to be half-density uranium metal.

F17.5.6 GEOMETRY

In general, KENO-VI geometry descriptions consist of (1) geometry data (Sect. F17.4.4) that define the geometrical shapes present in the problem, and (2) array data (Sect. F17.4.5) that define the placement of the units that were defined in the geometry data. The geometry data block is prefaced by READ GEOM, and the array data block is prefaced by READ ARRAY.

When a 3-D geometrical configuration is described as KENO-VI geometry data, it may be necessary to describe portions of the configuration individually. These individual partial descriptions of the configuration are called units. KENO-VI geometry modeling is subject to the following restrictions:

1. Units are composed of regions. These regions are created using geometric bodies and surfaces that are previously defined or created using quadratic equations. The geometric bodies and surfaces may intersect. Regions are defined relative to the geometric bodies and surfaces in a unit. Holes provide a means of creating complex geometries in a unit and then inserting the unit into existing units. For complex geometries the use of holes may decrease the CPU time required for the problem.
2. All geometrical surfaces must be describable as a set of quadratic equations.
3. When one or more units are utilized to describe an array, each unit used in the array must have a cuboid or hexagonal prism as its outer region.
4. When several units are utilized to describe an array, the adjacent faces of units in contact with each other must be the same size and shape.
5. Units are placed directly into regions using HOLES. Only one hole is allowed in a region. As many holes as will snugly fit without intersecting can be placed in a unit. The outer boundary of the unit in the hole must match exactly the region boundary. Holes are described in more detail in Sect. F17.5.6.1, and nested holes are described in Sect. F17.5.6.2.
6. Complicated systems may require multiple arrays to describe the system. Arrays may be placed in units. These units may be used to create other arrays that may be placed in other units either directly or by using holes. Multiple arrays are described in more detail in Sect. F17.5.6.3.

The geometry package allows any shape describable using quadratic equations to be enclosed or intersected by any other allowable shape. Geometry records are used to describe the geometric shapes contained in a unit. Regions are defined by specifying how they relate to the geometric shapes in the unit. An implication of this type of description is that an entire region volume, specified relative to the geometric shapes, contains only one mixture, hole, or array. Media records are used to specify the contents of each region. Material, hole, and array contents are specified using the keywords: Media, Hole, and Array, respectively, in the media records. A void is specified using the keyword Media with a mixture ID of zero.

If the problem contains arrays, each unit that is used in an array must have as its outer surface a rectangular parallelepiped or a hexagonal prism; therefore it may be necessary to define a void region that is used to achieve the required outer boundary. In order to describe the composite overall geometrical characteristics of the problem, these units may be arranged in either a rectangular or hexagonal array by specifying the number of units in the x, y, and z directions. Data must be entered to define the number assigned to the array and the placement of the individual units in the array. The array type is specified using the keyword TYP=, followed by

either square or triangular. If TYP is not entered, a cuboidal array is assumed. The array number, the number of units in the x, y, and z directions, the array type, and the placement data are called array data (Sect. 17.4.5).

An array may be placed in a region of any shape provided the region boundary is contained within the array or shares the array boundary. Only the section of the array contained within the region is recognized by the problem. A particle crosses into and out of the array when it crosses the region boundary. Arrays are positioned relative to the unit origin by placing the origin of a specified unit in the array at a specified location in the unit. The region boundary containing the array is defined using a vector definition array. A global array is not assumed. If a global array is required, such as for collecting matrix information, one must be specified.

To create a geometry mock-up from a physical configuration, the user should exercise a degree of ingenuity and keep in mind the restrictions mentioned earlier. It is important to realize there may be several ways of correctly describing the same physical configuration. Careful analysis of the system can pay off in terms of a simpler mock-up and shorter computer running time. A mock-up with fewer geometry regions may run faster than the same mock-up with extraneous regions. The number of units used can affect the running time, because a transformation of coordinates must be made every time a history moves from one unit into another. Thus if the size of a unit is small, relative to the neutron mean free path, a larger percentage of time is spent processing the transformation of coordinates. Because all boundaries in a unit must be checked for crossings, it may be more efficient to break up complex units into several smaller, simpler units. The trade-off involves the time required to process more boundary crossings vs the time required to transform coordinate systems when unit boundaries are crossed.

Geometry dimensions: The geometry dimensions utilized in KENO-VI require an entry for each required dimension. For example, a $20 \times 20 \times 2.5$ -cm rectangular parallelepiped would have been described as: CUBOID 1 10.0 -10.0 10.0 -10.0 1.25 -1.25. By using the P option (see Table F17.4.2), the same rectangular parallelepiped could be described as: CUBOID 1 4P10.0 2P1.25 where the first entry is the geometry word label and the remaining entries describe the geometry. The P option simply repeats the dimension following the P, the number of times stated before the P and reverses the sign every other time.

6P8.0 is equivalent to 8.0 -8.0 8.0 -8.0 8.0 -8.0.

Geometry comments: A comment can be entered for each unit in the geometry region data. Similarly, a comment can be entered for each array in the array definition data. A comment can be entered using the keyword COM=. This keyword is followed by a comment whose maximum length is 132 characters. The comment must be preceded and terminated by a delimiter character, which is the first nonblank character encountered after the COM=. One comment is allowed for each unit in the geometry region data. If multiple comments are entered for a unit, the last one is used. The comment can be entered anywhere after the UNIT NUMBER DESCRIPTION where a keyword is expected (Sect. F17.4.4). See the following example.

```
READ GEOM
UNIT 1
COM=*SPHERICAL METAL UNIT*
SPHERE 1 5.0
CUBOID 2 6P5.0
MEDIA 1 1 1 2
MEDIA 0 1 -1 2
BOUNDARY 2
UNIT 2
CYLINDER 1 5.0 2P5.0
```

CUBOID 2 6P5.0
 MEDIA 1 1 1 2
 COM=/CYLINDRICAL METAL UNIT/
 MEDIA 0 1 -1 2
 BOUNDARY 2
 UNIT 3
 SPHERE 1 5.0 CHORD +X=0.0
 MEDIA 1 1 1 2
 COM='HEMISPHERICAL METAL UNIT'
 CUBOID 2 6P5.0
 MEDIA 0 1 -1 2
 BOUNDARY 2
 UNIT 4
 COM='ARRAY OF SPHERICAL UNITS'
 CUBOID 1 6P15
 ARRAY 1 1 PLACE 2 2 2 3*0.0
 BOUNDARY 1
 UNIT 5
 CUBOID 1 6P15.0
 COM='ARRAY OF CYLINDRICAL UNITS'
 ARRAY 2 1 PLACE 2 2 2 3*0.0
 BOUNDARY 1
 UNIT 6
 COM='ARRAY OF HEMISPHERICAL UNITS'
 CUBOID 1 6P15.0
 ARRAY 3 1 PLACE 2 2 2 3*0.0
 BOUNDARY 1
 GLOBAL UNIT 7
 COM='ARRAY OF ARRAYS'
 CUBOID 1 4P15.0 2P45.0
 ARRAY 4 1 PLACE 1 1 2 3*0.0
 BOUNDARY 1
 END GEOM

One comment is allowed for each array in the ARRAY DEFINITION DATA. The rules governing these comments are the same as those listed above. However, the comment for an array must precede the UNIT ORIENTATION DESCRIPTION. It can precede the array number (Sect. F17.4.5). Examples of correct array comments are given below.

READ ARRAY
 COM='ARRA OF SPHERICAL METAL UNITS'
 ARA=1 NUX=3 NUY=3 NUZ=3 FILL F1 END FILL
 ARA=2 COM='ARRAY OF CYLINDRICAL METAL UNITS'
 NUX=3 NUY=3 NUZ=3 FILL F2 END FILL
 ARA=3 NUX=3 NUY=3 NUZ=3
 COM='ARRAY OF HEMISPHERICAL METAL UNITS'

FILL F3 END FILL

ARA=4 COM='COMPOSITE ARRA OF ARRAYS. Z=1 IS SPHERES, Z=2 IS CYLINDERS, Z=3 IS HEMISPHERES'

NUX=1 NUY=1 NUZ=3 FILL 4 5 6 END FILL

Some of the basics of KENO-VI geometry are illustrated in the following examples:

EXAMPLE 1. Assume a stack of six cylindrical disks, each 5 cm in radius and 2 cm thick. The bottom disk is composed of material 1, and the next disk is composed of material 2, etc., alternately throughout the stack. A square plate of material 3, 20 cm on a side and 2.5 cm thick, is centered on top of the stack. This configuration is shown in Fig. F17.5.1.

Figure F17.5.1 Stack of disks with a square cap

This problem can be described in a number of ways: as a set of stacked cylinders with a top plate, a set of nested cylinders with a top plate, and an array of cylinders with a top plate, to name just a few. Several alternative acceptable methods that could be used to describe this problem are given below.

This problem can be described using one unit. In this instance, the origin has been chosen at the center bottom of the bottom disk. The bottom disk is defined by the first cylinder description; the next disk is defined by the difference between the first and second cylinder descriptions. Since they both have a radius of 5.0 and a -z length of 0.0, the first cylinder containing material 1 exists from $z=0.0$ to $z=2.0$, and the second cylinder, containing material 2, exists from $z=2.0$ to $z=4.0$. When all the disks have been described, a void cuboid having the same x and y dimensions as the square plate and the same z dimensions as the stack of disks is defined. The square plate of material 3 is then defined on top of the stack. This method could be used in KENO-V.a to describe this problem. The geometry input is shown below.

Data description 1, Example 1.

```
READ GEOM
GLOBAL UNIT 1
CYLINDER 1 5.0 2.0 0.0
CYLINDER 2 5.0 4.0 2.0
CYLINDER 3 5.0 6.0 4.0
CYLINDER 4 5.0 8.0 6.0
CYLINDER 5 5.0 10.0 8.0
CYLINDER 6 5.0 12.0 10.0
CUBOID 7 10.0-10.0 10.0-10 12.0 0
CUBOID 8 10.0-10.0 10.0-10.0 14.5 0.0
MEDIA 1 1 1
MEDIA 2 1 -1 2
MEDIA 1 1 -2 3
MEDIA 2 1 -3 4
MEDIA 1 1 -4 5
MEDIA 2 1 -5 6
MEDIA 0 1 -1 -6 7
MEDIA 3 1 -7 8
BOUNDARY 8
END GEOM
```

An alternative description of the same example is given below. The origin has been chosen at the center of the disk of material 1, nearest the center of the stack. This disk of material 1 is defined by the first cylinder description, and the disks of material 2 on either side of it are defined by the second cylinder description. The top and bottom disks of material 1 are defined by the third cylinder, and the top disk of material 2 is defined by the last cylinder. The square plate is defined by the two cuboids. This method could also be used in KENO-V.a to describe the problem.

Data description 2, Example 1.

```
READ GEOM
GLOBAL UNIT 1
CYLINDER 10 5.0 1.0 -1.0
CYLINDER 20 5.0 3.0 -3.0
CYLINDER 30 5.0 5.0 -5.0
CYLINDER 40 5.0 7.0 -5.0
CUBOID 50 10.0-10.0 10.0-10.0 7.0 -5.0
CUBOID 60 10.0-10.0 10.0-10.0 9.5 -5.0
MEDIA 1 1 10
MEDIA 2 1 -10 20
MEDIA 1 1 -10 -20 30
MEDIA 2 1 -10 -20 -30 40
MEDIA 0 1 -30 -40 50
MEDIA 3 1 -40 -50 60
```

BOUNDARY 60
END GEOM

Example 1 can also be described as an array. Define three different unit types. Unit 1 will define a disk of material 1, Unit 2 will define a disk of material 2, and Unit 3 will define the square plate of material 3. The origin of each unit is defined at the center bottom of the disk or plate being described. The geometry input for this arrangement is shown below.

Data description 3, Example 1.

READ GEOM
UNIT 1
CYLINDER 1 5.0 2.0 0.0
CUBOID 2 10.0 -10.0 10.0 -10.0 2.0 0.0
MEDIA 1 1 1
MEDIA 0 1 -1 2
BOUNDARY 2
UNIT 2
CYLINDER 1 5.0 2.0 0.0
CUBOID 2 10.0 -10.0 10.0 -10.0 2.0 0.0
MEDIA 2 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
UNIT 3
CUBOID 1 10.0 -10.0 10.0 -10.0 2.5 0.0
MEDIA 3 1 1
BOUNDARY 1
GLOBAL UNIT 4
CUBOID 1 10 -10 10 -10 14.5 0.0
ARRAY 1 1 PLACE 1 1 1 3*0.0
BOUNDARY 1
END GEOM
READ ARRAY ARA=1 NUX=1 NUY=1 NUZ=7 FILL 1 2 1 2 1 2 3 END ARRAY

If the user wishes the origin of each unit to be at its center, the geometry region data can be input as shown below. The array data would be identical to that of data description 3, Example 1.

Data description 4, Example 1.

READ GEOM
UNIT 1
CYLINDER 1 5.0 1.0 -1.0
CUBOID 2 10.0 -10.0 10.0 -10.0 1.0 -1.0
MEDIA 1 1 1
MEDIA 0 1 -1 2
BOUNDARY 2
UNIT 2

```

CYLINDER 1 5.0 1.0 -1.0
CUBOID 2 10.0 -10.0 10.0 -10.0 1.0 -1.0
MEDIA 2 1 1
MEDIA 0 1 -1 2
BOUNDARY 2
UNIT 3
CUBOID 1 10.0 -10.0 10.0 -10.0 1.25 -1.25
MEDIA 3 1 1
BOUNDARY 1
GLOBAL UNIT 4
CUBOID 1 10 -10 10 -10 14.5 0.0
ARRAY 1 1 PLACE 1 1 1 0.0 0.0 1.0
BOUNDARY 1
END GEOM
READ ARRAY ARA=1 NUX=1 NUY=1 NUZ=7 FILL 1 2 1 2 1 2 3 END ARRAY

```

Be aware that each unit in a geometry description can have its origin defined independent of the other units. It would be correct to use Units 1 and 3 from data descriptions 3, and Unit 2 from data description 4. The array data would remain the same as data description 3, Example 1. The user should define the origin of each unit to be as convenient as possible for the chosen description. Care should be taken when assigning coordinates to the unit used to place the array in its surrounding region.

Another method of describing Example 1 as a bare array is to define Unit 1 to be a disk of material 1, topped by a disk of material 2. The origin has been chosen at the center bottom of the disk of material 1. Unit 2 is the square plate of material 3 with the origin at the center of the unit. The array consists of three Unit 1's, topped by a Unit 2, as shown below.

Data description 5, Example 1.

```

READ GEOM
UNIT 1
CYLINDER 1 5.0 2.0 0.0
CYLINDER 2 5.0 4.0 2.0
CUBOID 3 10.0 -10.0 10.0 -10.0 4.0 0.0
MEDIA 1 1 1
MEDIA 2 1 -1 2
MEDIA 0 1 -1 -2 3
BOUNDARY 3
UNIT 2
CUBOID 1 10.0 -10.0 10.0 -10.0 1.25 -1.25
MEDIA 3 1 1
BOUNDARY 1
GLOBAL UNIT 3
CUBOID 1 10 -10 10 -10 14.5 0.0
ARRAY 1 1 PLACE 1 1 1 3*0.0
BOUNDARY 1
END GEOM
READ ARRAY ARA=1 NUX=1 NUY=1 NUZ=4 FILL 3R1 2 END ARRAY

```


Example 1 can be described as a reflected array by treating the square plate as a reflector in the positive z direction. One means of describing this situation is to define Units 1 and 2 as in data description 3, Example 1. The origin of the global unit is defined to be at the center of the array. The corresponding input geometry is shown below.

Data description 6, Example 1.

```

READ GEOM
UNIT 1
CYLINDER 1 5.0 2.0 0.0
CUBOID 2 10.0-10.0 10.0-10.0 2.0 0.0
MEDIA 1 1 1
MEDIA 0 1 -1 2
BOUNDARY 2
UNIT 2
CYLINDER 1 5.0 2.0 0.0
CUBOID 2 10.0-10.0 10.0-10.0 2.0 0.0
MEDIA 2 1 1
MEDIA 0 1 -1 2
BOUNDARY 2
GLOBAL UNIT 3
CUBOID 1 10.0-10.0 10.0-10.0 6.0 -6.0
CUBOID 2 10.0-10.0 10.0-10.0 8.5 -6.0
ARRAY 1 1 PLACE 1 1 1 0.0 0.0 -6.0
MEDIA 3 1 -1 2
BOUNDARY 2
END GEOM
READ ARRAY ARA=1 NUX=1 NUY=1 NUZ=6 FILL 1 2 1 2 1 2 END ARRAY

```

The user could have chosen the origin of the global unit to be at the center bottom of the array in which case the geometry description for the global unit would be:

```

CUBOID 1 10.0-10.0 10.0-10.0 12.0 0.0
CUBOID 2 10.0-10.0 10.0-10.0 14.5 0.0
ARRAY 1 1 PLACE 1 1 1 3*0.0
MEDIA 3 1 -1 2
BOUNDARY 2

```

Any position in the array could be used to place the array within the region, keeping in mind the restriction that the region boundary must either coincide with the surface of the array or be contained within the array. If array position (1,1,3) was used to position the array in description 6 of example 1, the global unit would be:

```

CUBOID 1 10.0-10.0 10.0-10.0 12.0 0.0
CUBOID 2 10.0-10.0 10.0-10.0 14.5 0.0
ARRAY 1 1 PLACE 1 1 3 0.0 0.0 4.0
MEDIA 3 1 -1 2
BOUNDARY 2

```

A simpler method of describing Example 1 as a reflected array is to define only one unit as in data description 5, Example 1. The square plate is treated as a reflector as in data description 6, Example 1. The input for this arrangement is given below.

Data description 7, Example 1.

```
READ GEOM
UNIT 1
CYLINDER 1 5.0 2.0 0.0
CYLINDER 2 5.0 4.0 2.0
CUBOID 3 10.0 -10.0 10.0 -10.0 4.0 0.0
MEDIA 1 1 1
MEDIA 2 1 -1 2
MEDIA 0 1 -1 -2 3
BOUNDARY 3
GLOBAL UNIT 2
CUBOID 1 10.0 -10.0 10.0 -10.0 12.0 0.0
CUBOID 2 10.0 -10.0 10.0 -10.0 14.5 0.0
ARRAY 1 1 PLACE 1 1 1 3*0.0
MEDIA 3 1 -1 2
BOUNDARY 2
END GEOM
READ ARRAY ARA=1 NUX=1 NUY=1 NUZ=3 FILL F1 END FILL END ARRAY
```

Note that a global unit must be specified for each problem, including a single unit problem. Also each unit must have a boundary record specifying the outermost boundary of the unit.

EXAMPLE 2. Assume the stack of six disks in Example 1 is placed at the center bottom of a cylindrical container composed of material 6 whose inside diameter is 16.0 cm. The bottom and sides of the container are 0.25 cm thick, the top is open, and the total height of the container is 18.25 cm. Assume the square plate of Example 1 is centered on top of the container.

The geometry input can be described utilizing most of the data description methods associated with Example 1. One method of describing Example 2 as a single unit is given below.

Data description 1, Example 2.

```
READ GEOM
GLOBAL UNIT 1
CYLINDER 1 5.0 1.0 -1.0
CYLINDER 2 5.0 3.0 -3.0
CYLINDER 3 5.0 5.0 -5.0
CYLINDER 4 5.0 7.0 -5.0
CYLINDER 5 8.0 13.0 -5.0
CYLINDER 6 8.25 13.0 -5.25
CUBOID 7 10.0 -10.0 10.0 -10.0 13.0 -5.25
CUBOID 8 10.0 -10.0 10.0 -10.0 15.5 -5.25
MEDIA 1 1 1
```

MEDIA 2 1 -1 2
MEDIA 1 1 -1 -2 3
MEDIA 2 1 -1 -2 -3 4
MEDIA 0 1 -3 -4 5
MEDIA 6 1 -5 6
MEDIA 0 1 -5 -6 7
MEDIA 3 1 -6 -7 8
BOUNDARY 8
END GEOM

In the above description, the origin is defined to be at the center of the disk of material 1 nearest the center of the stack of cylinders. This disk is defined by the first cylinder description. The disks of material 2 above and below it are defined by the second cylinder description. The disks of material 1 above and below them are defined by the third cylinder description. The top disk of material 2 is defined by the fourth cylinder description. The void interior of the container is defined by the fifth cylinder description. The container is defined by the last cylinder description. The first cuboid description is used to define a void whose x and y dimensions are the same as the square plate, and whose z dimensions are the same as the container. The last cuboid description defines the square plate and the unit boundary. Omission of the first cuboid description would result in the container being encased in a solid cuboid of material 3. Thus both cuboids are necessary to properly define the square plate in this description.

Example 2 can be described as a reflected array. One of the descriptions uses only one unit and is similar to data description 7, example 1. This description is shown below.

Data description 2, Example 2.

READ GEOM
UNIT 1
CYLINDER 1 5.0 2.0 0.0
CYLINDER 2 5.0 4.0 2.0
CUBOID 3 5.0 -5.0 5.0 -5.0 4.0 0.0
MEDIA 1 1 1
MEDIA 2 1 -1 2
MEDIA 0 1 -1 -2 3
BOUNDARY 3

GLOBAL UNIT 2
CUBOID 1 5.0 -5.0 5.0 -5.0 12.0 0.0
ARRAY 1 1 PLACE 1 1 1 3*0.0
CYLINDER 2 8.0 18.0 0.0
MEDIA 0 1 -1 2
CYLINDER 3 8.25 18.0 -0.25
MEDIA 6 1 -1 -2 3
CUBOID 4 10.0 -10.0 10.0 -10.0 20.5 18.0
CUBOID 5 10.0 -10.0 10.0 -10.0 20.5 -0.25
MEDIA 3 1 -2 -3 4
MEDIA 0 1 -3 -4 5
BOUNDARY 5

END GEOM

READ ARRAY ARA NUX=1 NUY=1 NUZ=3 FILL F1 END FILL END ARRAY

In this data description, the first two cylinder descriptions define a disk of material 1 with a disk of material 2 directly on top of it. A tight-fitting void cuboid is placed around them so they can be stacked three high to achieve the stack of disks shown in Example 1, Fig. F17.5.1. This unit is used to build the array portion of the geometry description. The first cuboid in unit 2 contains the array of disks. Everything after the first cuboid is considered part of the reflector. The first cylinder in Unit 2 defines the void interior of the cylindrical container. The next cylinder defines the walls of the container. The next-to-last cuboid defines the square plate of material 3 that is sitting on top of the container. The last cuboid defines a void volume outside the container from its bottom to its top and having the same x and y dimensions as the square plate. Example 2 can be described as a reflected array regardless of the inner radius of the container because, unlike KENO-V.a, intersections are allowed and only the section of the array in the region boundary is considered part of the problem.

Another method to describe Example 2 is as an array composed of units that contain both the stack and container. This description requires a minimum of four units to describe the problem. This configuration is given below in data description 3, Example 2.

Data description 3, Example 2.

READ GEOM

UNIT 1

CYLINDER 1 8.25 0.25 0.0

CUBOID 2 10.0 -10.0 10.0 -10.0 0.25 0.0

MEDIA 6 1 1

MEDIA 0 1 2 -1

BOUNDARY 2

UNIT 2

CYLINDER 10 5.0 2.0 0.0

CYLINDER 20 5.0 4.0 0.0

CYLINDER 30 8.0 4.0 0.0

CYLINDER 40 8.25 4.0 0.0

CUBOID 50 10.0 -10.0 10.0 -10.0 4.0 0.0

MEDIA 1 1 10

MEDIA 2 1 20 -10

MEDIA 0 1 30 -20 -10

MEDIA 6 1 40 -30 -20 -10

MEDIA 0 1 50 -40 -30 -20 -10

BOUNDARY 50

UNIT 3

CYLINDER 1 8.0 3.0 -3.0

CYLINDER 2 8.25 3.0 -3.0

CUBOID 3 10.0 -10.0 10.0 -10.0 5.5 3.0

CUBOID 4 10.0 -10.0 10.0 -10.0 5.5 -3.0

MEDIA 0 1 1

MEDIA 6 1 2 -1

MEDIA 3 1 3 -2 -1

```

MEDIA 0 1 4 -3 -2- 1
BOUNDARY 4
GLOBAL UNIT 4
CUBOID 1 10.0 -10.0 10.0 -10.0 20.75 0.0
ARRAY 1 1 PLACE 1 1 1 3*0.0
BOUNDARY 1
END GEOM
READ ARRAY NUX=1 NUY=1 NUZ=5 FILL 1 3R2 3 END ARRAY

```

In the above description, Unit 1 is the bottom of the cylindrical container. The void cuboid is only as tall as the bottom of the container, and its x and y dimensions are the same as the square plate on top of the container. If all the units in the array utilize these same dimensions in the x and y directions, the restriction that adjacent faces of units in contact with each other be the same size and shape is satisfied. This array is stacked in the z direction, so all units must have the same overall dimensions in the x direction and in the y direction. Unit 2 will be used in the array three times to create the stack of disks. It contains a disk of material 1, topped by a disk of material 2. The portion of the container that contains the disks and the cuboid that defines the outer boundaries of the unit are included in Unit 2. Unit 3 describes the empty top portion of the container and the square plate on top of it. The z dimensions of Unit 3 were determined by subtracting three times the total z dimension of Unit 2 from the inside height of the container [$18.0 - (3 \times 4.0) = 6.0$]. This can also be determined from the overall height of the container by subtracting off the bottom thickness of the container and three times the height of Unit 2 [$18.25 - 0.25 - (3 \times 4.0) = 6.0$]. Unit 4 is the global unit that contains the array. The array is placed in the unit by aligning the bottom center of Unit 1 with the origin of Unit 4.

EXAMPLE 3. Refer to Example 1, Fig. F17.5.1, and imagine a hole 1.5 cm in diameter drilled along the centerline of the stack through the disks and the square plate. In KENO-V.a this hole would eliminate the possibility of describing the system as a single unit because the hole in the center of the alternating materials of the stack cannot be described in a manner that allows each successive geometry region to encompass the regions interior to it. However, KENO-VI can easily describe this configuration as a single unit.

Data description 1, Example 3.

```

READ GEOM
GLOBAL UNIT 1
CYLINDER 1 0.75 7.0 -5.0
CYLINDER 2 5.0 1.0 -1.0
CYLINDER 3 5.0 3.0 -3.0
CYLINDER 4 5.0 5.0 -5.0
CYLINDER 5 5.0 7.0 -5.0
CYLINDER 6 8.0 13.0 -5.0
CYLINDER 7 8.25 13.0 -5.25
CUBOID 8 10.0 -10.0 10.0 -10.0 15.5 13.0
CUBOID 9 10.0 -10.0 10.0 -10.0 15.5 -5.25
MEDIA 0 1 1
MEDIA 1 1 2 -1
MEDIA 2 1 -1 -2 3
MEDIA 1 1 -1 -2 -3 4
MEDIA 2 1 -1 -2 -3 -4 5

```

MEDIA 0 1 -1 -2 -3 -4 -5 6
 MEDIA 6 1 -1 -4 -5 -6 7
 MEDIA 3 1 -6 -7 8
 MEDIA 0 1 -7 -8 9
 BOUNDARY 9
 END GEOM

In data description 1, Example 3 above, Unit 1 contains the entire problem description. The first cylinder describes the 1.5-cm-diam hole through the stack. The next four cylinders define the stack. The sixth and seventh cylinders describe the void and container. The two cuboids describe the top plate and surrounding global region of void. The media cards are used to place the materials in the appropriate regions.

EXAMPLE 4. Assume two large cylinders, 2.5 cm in radius and 5 cm long, are connected by a smaller cylinder, 0.5 cm in radius and 10 cm long, as shown in Fig. F17.5.2. All of the cylinders are composed of material 1. By starting the geometry description in the small cylinder, this system can be described as a single unit.

Figure F17.5.2 Two large cylinders joined axially by a small cylinder

Data description 1, Example 4.

READ GEOM
 GLOBAL UNIT 1
 CYLINDER 1 0.5 5.0 -5.0
 CYLINDER 2 2.5 5.0 -5.0
 CYLINDER 3 2.5 10.0 -10.0
 MEDIA 1 1 1
 MEDIA 0 1 2 -1
 MEDIA 1 1 3 -2
 BOUNDARY 3
 END GEOM

The origin is at the center of the small cylinder, which is described by the first cylinder description. The second cylinder description defines a void cylinder surrounding the small cylinder. Its radius is the same as the large cylinders, and its height (length) coincides with that of the small cylinder. The last cylinder description defines the large cylinders on either end of the small cylinder. Because the problem was not rotated, the long axes of the cylinders are assumed to coincide with the z axis.

EXAMPLE 5. Assume two large cylinders with a center-to-center spacing of 15 cm, each having a radius of 2.5 cm and length of 5 cm, are connected radially by a small cylinder having a radius of 1.5 cm, as shown in Fig. F17.5.3.

Figure F17.5.3 Two large cylinders radially connected by a small cylinder

This system can be rigorously described in KENO-VI geometry because intersections are allowed. However, either the two large cylinders or the small connecting cylinder must be rotated. The small cylinder is rotated in description 1, example 5. The two large cylinders are rotated in description 2, example 5.

Data description 1, Example 5.

```

READ GEOM
GLOBAL UNIT 1
CYLINDER 1 2.5 2.5 -2.5
CYLINDER 2 2.5 2.5 -2.5 ORIGIN Y=15.0
CYLINDER 3 1.5 15.0 0.0 ROTATE A2=-90
CUBOID 4 5.0 -5.0 17.5 -2.5 2.5 -2.5
MEDIA 1 1 1
MEDIA 1 1 2
MEDIA 1 1 3 -1 -2
MEDIA 0 1 4 -3 -2 -1
BOUNDARY 4
END GEOM

```

The first and second cylinders define the two large cylinders, and the third cylinder describes the small connecting cylinder. The two large cylinders are oriented along the z axis. The second large cylinder is translated so its origin is at position (0.0, 15.0, 0.0). The small cylinder is rotated so that its centerline is parallel to the y axis. Region 1 consists of the material in the first large cylinder. Region 2 consists of the material in the second large cylinder. Region 3 consists of the material in the small cylinder but not in either of the large cylinders. Region 4 is the boundary region.

Data description 2, Example 5.

```
READ GEOMETRY
GLOBAL UNIT 1
CYLINDER 1 2.5 2.5 -2.5 ROTATE A2=90
CYLINDER 2 2.5 2.5 -2.5 ROTATE A2=90 ORIGIN Z=15.0
CYLINDER 3 1.5 15.0 0.0
CUBOID 4 2.5 -2.5 2.5 -2.5 17.5 -2.5
MEDIA 1 1 1
MEDIA 1 1 2
MEDIA 1 1 3 -1 -2
MEDIA 0 1 4 -3 -2 -1
BOUNDARY 4
END GEOM
```

Again, the first and second cylinders describe the two large cylinders. They are both rotated so their long axis is parallel to the y axis. The first large cylinder still maintains its origin at the unit origin. The origin of the second large cylinder is translated to position (0.0, 0.0, 15.0). The small connecting cylinder has its centerline along the z axis. The media data are identical to that of the previous problem description. It does not matter what order the rotation and translation data are listed after a geometry card. Rotations are always done about the origin prior to the translation. Only nonzero data need be entered for the ROTATE and ORIGIN options.

EXAMPLE 6. Assume two small cylinders, 1.0 cm in radius and 10 cm long, are connected by a large cylinder, 2.5 cm in radius and 5 cm long, as shown in Fig. F17.5.4.

Figure F17.5.4 Two small cylinders joined axially by a large cylinder

This problem is very similar to example 4. It can be described as a single unit. Unit 1 defines the large cylinder, and Unit 2 defines the small cylinder. The origin of each unit is at its center. The composite system consists of two Unit 2's and one Unit 1 as shown below. Assume the centerline of the cylinders lies along the z axis.

Data description 1, Example 6.

```

READ GEOM
GLOBAL UNIT 1
CYLINDER 1 1.0 12.5 -12.5
CYLINDER 2 2.5 2.5 -2.5
CUBOID 3 4P2.5 12.5 -12.5
MEDIA 1 1 1
MEDIA 1 1 2 -1
MEDIA 0 1 3 -2 -1
BOUNDARY 3
END GEOM

```

The first cylinder defines a long, narrow cylinder that includes the top and bottom small cylinders and the inner 1.0-radius cylinder of the large cylinder. The second cylinder defines the remainder of the large cylinder. The cuboid defines the boundary region. It is possible to represent this problem as a single unit because regions do not need to fully enclose all previous regions in the unit as KENO-V.a requires.

EXAMPLE 7. Assume an $11 \times 5 \times 3$ square-pitched array of spheres of material 1, radius 3.75 cm, with a center-to-center spacing of 10 cm in the x, y, and z directions. The data for this system are given below.

Data description 1, Example 7.

```

READ GEOM
UNIT 1
SPHERE 1 3.75
CUBOID 2 6P5.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
GLOBAL UNIT 2
CUBOID 10 55.0 -55.0 25.0 -25.0 15.0 -15.0
ARRAY 1 10 PLACE 6 3 2 3*0.0
BOUNDARY 10
END GEOM
READ ARRAY NUX=11 NUY=5 NUZ=3 FILL F1 END FILL END ARRAY

```

EXAMPLE 8. Assume an $11 \times 5 \times 3$ square-pitched array of spheres of material 1 whose radius is 3.75 cm, and whose center-to-center spacing is 10 cm in the x direction, 15 cm in the y direction, and 20 cm in the z direction. The input for this geometry is given below.

Data description 1, Example 8.

```
READ GEOM
UNIT 1
SPHERE 1 3.75
CUBOID 2 5.0 -5.0 7.5 -7.5 10.0 -10.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
GLOBAL UNIT 2
CUBOID 1 55.0 -55.0 37.5 -37.5 30.0 -30.0
ARRAY 1 1 PLACE 6 3 2 3*0.0
BOUNDARY 1
END GEOM
READ ARRAY NUX=11 NUY=5 NUZ=3 FILL F1 END FILL END ARRAY
```

EXAMPLE 9. Assume an $11 \times 5 \times 3$ square-pitched array of spheres of material 1 whose radius is 3.75 cm, and whose center-to-center spacing is 10 cm in the x, y, and z directions. This array is reflected by 30 cm of material 2 (water) on all faces, and weighted tracking (biasing) is to be used in the water reflector. The array spacing defines the perpendicular distance from the outer layer of spheres to the reflector to be 5 cm in the x, y, and z directions. The geometry input for this system is given below.

Data description 1, Example 9.

```
READ GEOM
UNIT 1
SPHERE 1 3.75
CUBOID 2 6P5.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
GLOBAL UNIT 2
CUBOID 1 55.0 -55.0 25.0 -25.0 15.0 -15.0
CUBOID 2 58.0 -58.0 28.0 -28.0 18.0 -18.0
CUBOID 3 61.0 -61.0 31.0 -31.0 21.0 -21.0
CUBOID 4 64.0 -64.0 34.0 -34.0 24.0 -24.0
CUBOID 5 67.0 -67.0 37.0 -37.0 27.0 -27.0
CUBOID 6 70.0 -70.0 40.0 -40.0 30.0 -30.0
CUBOID 7 73.0 -73.0 43.0 -43.0 33.0 -33.0
CUBOID 8 76.0 -76.0 46.0 -46.0 36.0 -36.0
CUBOID 9 79.0 -79.0 49.0 -49.0 39.0 -39.0
CUBOID 10 82.0 -82.0 52.0 -52.0 42.0 -42.0
CUBOID 11 85.0 -85.0 55.0 -55.0 45.0 -45.0
ARRAY 1 1 PLACE 6 3 2 3*0.0
MEDIA 2 2 2 -1
MEDIA 2 3 3 -2
MEDIA 2 4 4 -3
MEDIA 2 5 5 -4
```

```

MEDIA 2 6 6 -5
MEDIA 2 7 7 -6
MEDIA 2 8 8 -7
MEDIA 2 9 9 -8
MEDIA 2 10 10 -9
MEDIA 2 11 11 -10
BOUNDARY 11
END GEOM
READ ARRAY NUX=11 NUY=5 NUZ=3 FILL F1 END FILL END ARRAY
READ BIAS ID=500 2 11 END BIAS

```

The basic unit used to construct the array is defined in Unit 1. The array is positioned in Unit 2 (the global unit) using the ARRAY card and the PLACE option. The array is then surrounded by ten reflector regions, each 3.0 cm thick, on all sides. The first bias ID of the reflector is 2, so the last bias ID will be 11 because 10 regions are created. The biasing data block is necessary to apply the desired weighting or biasing function to the reflector. The biasing material ID is obtained from Table F17.4.5. If the biasing data block is omitted from the problem description, the ten reflector regions will not have a biasing function applied to them, and the default value of the average weight will be used. This omission may cause the problem to execute more slowly, and therefore require the use of more computer time.

EXAMPLE 10. Assume the reflector in Example 9 is present only on both x faces, both y faces, and the negative z face. The reflector is only 15.24 cm thick on these faces. The top of the array (positive z face) is unreflected.

Data description 1, Example 10.

```

READ GEOM
UNIT 1
SPHERE 1 3.75
CUBOID 2 6P5.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
GLOBAL UNIT 2
CUBOID 1 55.0 -55.0 25.0 -25.0 15.0 -15.0
CUBOID 2 58.0 -58.0 28.0 -28.0 15.0 -18.0
CUBOID 3 61.0 -61.0 31.0 -31.0 15.0 -21.0
CUBOID 4 64.0 -64.0 34.0 -34.0 15.0 -24.0
CUBOID 5 67.0 -67.0 37.0 -37.0 15.0 -27.0
CUBOID 6 70.0 -70.0 40.0 -40.0 15.0 -30.0
CUBOID 7 70.24 -70.24 40.24 -40.24 15.0 -30.24
ARRAY 1 1 PLACE 6 3 2 3*0.0
MEDIA 2 2 2 -1
MEDIA 2 3 3 -2
MEDIA 2 4 4 -3
MEDIA 2 5 5 -4
MEDIA 2 6 6 -5
MEDIA 2 7 7 -6

```

BOUNDARY 7
END GEOM
READ ARRAY NUX=11 NUY=5 NUZ=3 FILL F1 END FILL END ARRAY
READ BIAS ID=500 2 7 END BIAS

The first cuboid in Unit 2 represents the boundary for the array. The next five cuboids represent the first five regions around the array, each region being 3.0 cm thick in the +x, -x, +y, -y, and -z directions, and of zero thickness in the +z direction. A total thickness of 15 cm of reflector material is on the appropriate faces. The last cuboid represents the last 0.24 cm of material 2 on those faces. Thus, the total reflector thickness is 15.24 cm on each face of the array, except the top which has no reflector. The beginning bias ID is 2, and the ending bias ID is 7. The biasing material ID and thickness per region are obtained from Table F17.4.5. The thickness per region should be very nearly the thickness per region from the table to avoid overbiasing in the reflector. Partial increments at the outer region of a reflector are exempt from this recommendation.

EXAMPLE 11. Assume the array of example 7 has the central unit of the array replaced by a cylinder of material 4, 5 cm in radius and 10 cm tall. Assume a 20-cm-thick spherical reflector of material 3 (concrete) is positioned so its inner radius is 65 cm from the center of the array. The minimum inner radius of a spherical reflector for this array is 62.25 cm ($\sqrt{55^2 + 25^2 + 15^2}$). If the inner radius is smaller than this, the entire array cannot be contained within the spherical reflector.

Data description 1, Example 11.

READ GEOM
UNIT 1
SPHERE 1 3.75
CUBOID 2 6P5.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
UNIT 2
CYLINDER 1 5.0 5.0 -5.0
CUBOID 2 6P5.0
MEDIA 4 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
GLOBAL UNIT 3
CUBOID 1 55.0 -55.0 25.0 -25.0 15.0 -15.0
SPHERE 2 65.0
SPHERE 3 70.0
SPHERE 4 75.0
SPHERE 5 80.0
SPHERE 6 85.0
ARRAY 1 1 PLACE 6 3 2 3*0.0
MEDIA 0 1 2 -1
MEDIA 3 2 3 -2
MEDIA 3 3 4 -3
MEDIA 3 4 5 -4
MEDIA 3 5 6 -5

```

BOUNDARY 6
END GEOM
READ ARRAY NUX=11 NUY=5 NUZ=3 LOOP 1 1 11 1 1 5 1 1 3 1
2 6 6 1 3 3 1 2 2 1 END ARRAY
READ BIAS ID=301 2 5 END BIAS

```

Unit 1 describes the sphere and spacing utilized in the array. Unit 2 defines the cylinder that is located at the center of the array. Unit 3 defines the global unit. The ARRAY card defines the origin of the array to be at the center of the global unit. The sphere following the ARRAY card defines the inner radius of the reflector. The next four SPHERE cards will generate four spherical regions of material 3, each 5.0 cm thick. The first ten entries following the word LOOP fill the $11 \times 5 \times 3$ array with Unit 1. The next ten entries position Unit 2 at the center of the array ($x=6$, $y=3$, and $z=2$), replacing the Unit 1 that had been placed there by the first 10 entries. The biasing data block is used to apply the biasing function for concrete to the generated reflector regions.

EXAMPLE 12. Assume a data profile such as fission densities is desired in a cylinder at 1-cm intervals in the radial direction and 1.5-cm intervals axially. The cylinder, composed of material 1, has a radius of 5 cm and a height of 15 cm. The cylinders are then nested to create these regions. A biasing data block is not entered because default biasing is desired throughout the cylinder.

Data description 1, Example 12.

```

READ GEOM
GLOBAL UNIT 1
CYLINDER 1 1.0 1.5 -1.5
CYLINDER 2 2.0 3.0 -3.0
CYLINDER 3 3.0 4.5 -4.5
CYLINDER 4 4.0 6.0 -6.0
CYLINDER 5 5.0 7.5 -7.5
MEDIA 1 1 1
MEDIA 1 1 2 -1
MEDIA 1 1 3 -2
MEDIA 1 1 4 -3
MEDIA 1 1 5 -4
BOUNDARY 5
END GEOM

```

EXAMPLE 13. Assume a cross composed of two Plexiglas cylinders (material 3) having an inner diameter of 13.335 cm and an outer diameter of 16.19 cm. The bottom and side legs of the cross are closed by a 3.17-cm-thick piece of Plexiglas. From the center of the intersection the bottom and side legs are 91.44 cm long, and the top leg is 121.92 cm long. The cross is filled with a UO_2F_2 solution (material 1) to a height of 28.93 cm above the center of the cylinder intersection. The cross is then surrounded by a water reflector (material 2) that extends from the center of the intersection: 111.74 cm in the $\pm x$ directions, 20.64 cm in the $\pm y$ directions, 29.03 cm in the $+z$ direction, and -118.428 cm in the $-z$ direction. A schematic of the assembly is shown in Fig. F17.5.5.

Figure F17.5.5 Plexiglas UO_2F_2 -filled cross

Data description of Example 13.

```

READ GEOMETRY
GLOBAL UNIT 1
CYLINDER 10 13.335 28.93 -88.27
CYLINDER 20 13.335 121.92 -88.27
CYLINDER 30 16.19 121.92 -91.44
CYLINDER 40 13.335 88.27 -88.27 ROTATE A1=90. A2=90.
CYLINDER 50 16.19 91.44 -91.44 ROTATE A1=90. A2=90.
CUBOID 60 2P111.74 2P20.64 29.03 -118.428
CUBOID 70 2P111.74 2P20.64 121.92 -118.428
MEDIA 1 1 10
MEDIA 0 1 20 -10
MEDIA 3 1 30 -20 -40
MEDIA 1 1 40 -10
MEDIA 3 1 50 -40 -10 -30
MEDIA 2 1 60 -30 -50
MEDIA 0 1 70 -30 -60
BOUNDARY 70
END GEOMETRY

```

EXAMPLE 14. Assume a Y-shaped aluminum cylinder (material 2) with a 13.95-cm inner radius and a 0.16-cm wall thickness is filled with a UO_2F_2 solution (material 1). From the center where the Y intersects the cylinder, the bottom leg is 76.7 cm long, the top leg is 135.4 cm long, and the Y leg is 126.04 cm long canted at a 29.26-degree angle. The bottom of the bottom leg and the top of the Y leg are sealed with 1.3-cm caps. The Y cylinder is filled to a height of 52.8 cm above the center where the Y leg intersects the vertical cylinder. The cylinder is surrounded by a water reflector (material 3) that extends out 37.0 cm in the $\pm x$ direction, 100.0 and -37.0 cm in the $\pm y$ direction, and 135.4 and -99.6 in the $\pm z$ direction. A schematic of the assembly is shown in Fig. F17.5.6.

Figure F17.5.6 Y-shaped UO_2F_2 -filled aluminum cylinder

Data description of Example 14.

```

READ GEOMETRY
GLOBAL UNIT 1
COM='30 DEG Y CYLINDER'
CYLINDER 10 13.95 135.4 -75.4
CYLINDER 20 14.11 135.4 -76.7
CYLINDER 30 13.95 124.74 0.0 ROTATE A2=-29.26
CYLINDER 40 14.11 126.04 0.0 ROTATE A2=-29.26
CUBOID 50 2P37.0 100.0 -37.0 52.8 -75.4
CUBOID 60 2P37.0 100.0 -37.0 135.4 -99.6

```


MEDIA 1 1 10 50
MEDIA 2 1 20 -10 -30
MEDIA 1 1 30 50 -10
MEDIA 2 1 40 -30 -20 -10
MEDIA 0 1 10 -50
MEDIA 0 1 30 -50 -10
MEDIA 3 1 60 -20 -40
BOUNDARY 60
END GEOMETRY

F17.5.6.1 *Use of Holes in the Geometry*

Section F17.5.6 tells how KENO-VI geometry allows regions in a unit to intersect, thus eliminating the need for holes. Holes in KENO-VI, however, can be useful in simplifying the input of a problem and decreasing the total CPU time needed for a problem. A HOLE is a means of placing an entire unit within a geometry region. A separate HOLE description is required for every location in a geometry unit where another unit is to be placed. The information contained in a hole geometry card is: (1) the geometry word, HOLE, (2) the unit number of the unit to be placed, and (3) the region definition vector. A hole is placed inside the geometry region defined by the region definition vector. The boundary dimensions of the unit being placed in the hole must precisely match the boundary of the region containing the hole. Only one hole is allowed in a region and holes cannot intersect. Holes can be nested to any depth (see Sect. F17.5.6.2). It is not advisable to use holes that are tangent to other holes or geometry regions, although it is theoretically possible to do so. Frequently holes that are exactly tangent to each other or to other geometry regions may fail to run because the computer code finds that the regions are intersecting due to precision and roundoff. It is not uncommon for a problem that runs on an RISC-6000 to fail on an IBM mainframe using the same data. Therefore, it is recommended that tangency and boundaries shared with holes be avoided.

Tracking in regions that contain holes can be more efficient than tracking in regions that do not contain holes because every boundary region in a unit must be checked for a crossing whenever a crossing is possible. Putting small but complex geometries in a hole will lessen the number of boundaries that need to be checked for possible crossings. However, the indiscriminant use of holes is not advised since the particle must change coordinate systems every time a hole is entered or exited. Therefore, holes should be used carefully only when the system can be simplified significantly by their use.

EXAMPLE 15. One example of a unit that requires holes in KENO-VI but is better described not using holes in KENO-VI as shown in Fig. F17.5.7, representing nine close-packed rods in an annulus. The large rods are 1.4 cm in radius and composed of mixture 3. The small rods are 0.6 cm in radius and composed of mixture 1. The inside radius of the annulus is 3.6 cm, and the outside radius is 3.8 cm. The annulus is made of mixture 2. The rods and annulus are both 30 cm long. The annulus is centered in a cuboid having an 8-cm-square cross section and a length of 32 cm. All nonshaded areas are void.

Figure F17.5.7 Close-packed rods in an annulus

Data description of Example 15.

READ GEOM
 GLOBAL UNIT 1
 CYLINDER 1 0.6 2P15.0
 CYLINDER 2 0.6 2P15.0 ORIGIN X=2.0 Y=2.0
 CYLINDER 3 0.6 2P15.0 ORIGIN X=2.0 Y=2.0
 CYLINDER 4 0.6 2P15.0 ORIGIN X=2.0 Y=2.0
 CYLINDER 5 0.6 2P15.0 ORIGIN X=2.0 Y=2.0
 CYLINDER 6 1.4 2P15.0 ORIGIN X=2.0
 CYLINDER 7 1.4 2P15.0 ORIGIN Y=2.0
 CYLINDER 8 1.4 2P15.0 ORIGIN X=2.0
 CYLINDER 9 1.4 2P15.0 ORIGIN Y=2.0
 CYLINDER 10 3.6 2P15.0
 CYLINDER 11 3.8 2P15.0
 CUBOID 12 4P4.0 2P16.0
 MEDIA 1 1 1 -6 -7 -8 -9
 MEDIA 1 1 2 -9 -6

MEDIA 1 1 3 -6 -7
MEDIA 1 1 4 -7 -8
MEDIA 1 1 5 -8 -9
MEDIA 3 1 6 -2 -3 -1
MEDIA 3 1 7 -3 -4 -1
MEDIA 3 1 8 -4 -5 -1
MEDIA 3 1 9 -5 -2 -1
MEDIA 0 1 10 -1 -2 -3 -4 -5 -6 -7 -8 -9
MEDIA 2 1 11 -10
MEDIA 0 1 12 -11
BOUNDARY 12
END GEOM

The first CYLINDER description represents the middle small rod. The next four cylinder cards describe the four remaining small rods surrounding the middle rod. The ORIGIN modification card is used to shift the origin of each cylinder to the appropriate location. The following four cylinder cards represent the four large rods. Again the ORIGIN modification card is used to shift the origin of each cylinder to the appropriate location. Only the nonzero dimensions need to be entered in the ORIGIN data. The tenth cylinder card is the void in the annulus that contains the rods. The last cylinder card defines the outer surface of the annulus. Finally, the cuboid card describes the surrounding unit boundary.

An array of the unit shown in Fig. F17.5.7 can be easily represented using array description data. For example, a $5 \times 3 \times 2$ array of these shapes with a center-to-center spacing of 8 cm in x and y and 32 cm in z can be achieved by defining the global unit as the one containing the array and utilizing the following array data:

READ ARRAY NUX=5 NUY=3 NUZ=2 FILL F1 END FILL END ARRAY

or

*READ ARRAY NUX=5 NUY=3 NUZ=2 FILL 30*1 END FILL END ARRAY*

or

READ ARRAY NUX=5 NUY=3 NUZ=2 LOOP 1 1 5 1 1 3 1 1 2 1 END LOOP END ARRAY

F17.5.6.2 Nesting Holes

This section illustrates how holes are nested. Holes can be nested to any level. Consider the configuration that was illustrated in Fig. F17.5.7 and replace the large rods with a complicated geometric arrangement. The resultant figure is shown in Fig. F17.5.8. Figure F17.5.9 shows the complicated geometric arrangement that replaced the large rods of Fig. F17.5.7. Figure F17.5.10 shows a component of the arrangement shown in Fig. F17.5.9.

EXAMPLE 16. There is no predetermined "best way" to create a geometry mock-up for a given physical system. The user should decide the order that is most convenient. In order to describe the configuration using nested holes, Fig. F17.5.8, it may be most convenient to start the geometry mock-up at the deepest nesting level,

Figure F17.5.8 Configuration using nested holes

Figure F17.5.9 Complicated geometric arrangement represented by Unit 2

Figure F17.5.10 Geometric component represented by Unit 1

as shown in Fig. F17.5.10. The small cylinders are composed of mixture 1, and are each 0.1 cm in radius and 30 cm long. Five small cylinders are used in the schematic shown in Fig. F17.5.10. Their centers are located at (0,0,0) for the central one, at (0,-0.4,0) for the bottom one, at (0.4,0,0) for the right one, at (0,0.4,0) for the top one, and at (-0.4,0,0) for the left one. The rectangular parallelepipeds (cuboids) are composed of mixture 2. Each one is 30 cm long and 0.1 cm by 0.2 cm in cross section. The large cylinder containing the configuration is composed of mixture 3, is 30 cm long, and has a radius of 0.5 cm. A possible geometry mock-up for this system is described as follows:

1. define Unit 1 to contain the five small cylinders and four blocks,
2. define Unit 2 to contain the next two larger-sized cylinders and Unit 1 as holes, and
3. define Global Unit 3 to contain the large cylinders and Unit 2 as holes.

UNIT 1

CYLINDER 1 0.1 2P15.0

CYLINDER 2 0.1 2P15.0 ORIGIN Y=-0.4

CYLINDER 3 0.1 2P15.0 ORIGIN X=0.4

CYLINDER 4 0.1 2P15.0 ORIGIN Y=0.4

CYLINDER 5 0.1 2P15.0 ORIGIN X=-0.4

CUBOID 6 2P0.1 2P0.05 2P15.0 ORIGIN X=-0.2

CUBOID 7 2P0.1 2P0.05 2P15.0 ORIGIN X=0.2

CUBOID 8 2P0.05 2P0.1 2P15.0 ORIGIN Y=-0.2

CUBOID 9 2P0.05 2P0.1 2P15.0 ORIGIN Y=0.2
CYLINDER 10 0.5 2P15.0
MEDIA 1 1 1 -6 -7 -8 -9
MEDIA 1 1 2 -8
MEDIA 1 1 3 -7
MEDIA 1 1 4 -9
MEDIA 1 1 5 -6
MEDIA 2 1 6 -1 -5
MEDIA 2 1 7 -1 -3
MEDIA 2 1 8 -1 -2
MEDIA 2 1 9 -1 -4
MEDIA 3 1 -1 -2 -3 -4 -5 -6 -7 -8 -9 10
BOUNDARY 10

geometry card 1 places the central rod;
 geometry card 2 places the bottom cylinder;
 geometry card 3 places the cylinder at the right;
 geometry card 4 places the top cylinder;
 geometry card 5 places the cylinder at the left;
 geometry card 6 places the left cuboid whose length is in x;
 geometry card 7 places the right cuboid whose length is in x;
 geometry card 8 places the bottom cuboid whose length is in y;
 geometry card 9 places the top cuboid whose length is in y, and
 geometry card 10 is the surrounding cylinder that defines the system boundary.

Now that Fig. F17.5.10 has been described, consider Fig. F17.5.9. The large plain cylinders are composed of mixture 1 and are 0.5 cm in radius and 30 cm long. The cylindrical component of Unit 1 is the same size, an outer radius of 0.5 cm and a length of 30 cm. The small cylinders that are located in the interstices between the large cylinders are composed of mixture 2, are 0.2 cm in radius, and are 30 cm long. Unit 2, Fig. F17.5.9, is the annulus that contains the cylinders. Its origin is at its center. The annulus is composed of mixture 4, has a 1.3-cm inside radius and a 1.4-cm outer radius. The volume between the inner cylinders is void. The large cylinders each have a radius of 0.5 cm and are tangent; therefore, their origins are offset from the origin of the unit by 0.707107. This value is from $x^2 + y^2 = 1.0$ (radius unit 4 + radius unit 5), where x and y are equal. The geometry mock-up for this portion of the problem follows:

UNIT 2
CYLINDER 1 0.2 2P15.0
CYLINDER 2 0.2 2P15.0 ORIGIN X=0.707107 Y=0.707107
CYLINDER 3 0.2 2P15.0 ORIGIN X=-0.707107 Y=0.707107
CYLINDER 4 0.2 2P15.0 ORIGIN X=-0.707107 Y=-0.707107
CYLINDER 5 0.2 2P15.0 ORIGIN X=0.707107 Y=-0.707107
CYLINDER 6 0.5 2P15.0 ORIGIN X=0.707107
CYLINDER 7 0.5 2P15.0 ORIGIN X=-0.707107
CYLINDER 8 0.5 2P15.0 ORIGIN Y=0.707107
CYLINDER 9 0.5 2P15.0 ORIGIN Y=-0.707107
CYLINDER 10 1.3 2P15.0

CYLINDER 11 1.4 2P15.0
 MEDIA 2 1 1
 MEDIA 2 1 2
 MEDIA 2 1 3
 MEDIA 2 1 4
 MEDIA 2 1 5
 MEDIA 1 1 6 -8 -9
 MEDIA 1 1 7 -8 -9
 HOLE 1 8 -3 -6 ORIGIN Y=0.707107
 HOLE 1 9 -6 -7 ORIGIN Y=-0.707107
 MEDIA 0 1 10 -1 -2 -3 -4 -5 -6 -7 -8 -9
 MEDIA 4 1 11 -10
 BOUNDARY 11

In unit 2, cylinder 1 places a small cylinder of mixture 2 at the origin,
 cylinder 2 places the small cylinder of mixture 2 in the upper-right quadrant,
 cylinder 3 places the small cylinder of mixture 2 in the upper-left quadrant,
 cylinder 4 places the small cylinder of mixture 2 in the lower-left quadrant,
 cylinder 5 places the small cylinder of mixture 2 in the lower-right quadrant,
 cylinder 6 places the larger cylinder of mixture 1 at the right with its origin at (0.707107,0.0,0.0),
 cylinder 7 places the larger cylinder of mixture 1 at the left with its origin at (0.0,0.707107,0.0),
 cylinder 8 places the top cylinder that contains the geometric component defined in Unit 1,
 cylinder 9 places the bottom cylinder that contains the geometric component defined in Unit 1,
 cylinder 10 defines the inner surface of the annulus, and
 cylinder 11 defines the outer surface of the annulus and the unit boundary.

To complete the geometry mock-up, consider Fig. F17.5.8. Define Unit 3 to be the central rod and four outer rods of 0.6 cm radius and 30.0 cm length, and the large annulus of 3.6 cm inner radius, 3.8 cm outer radius, and 30 cm length centered in a cuboid having an 8-cm-square cross section and a length of 32 cm.

GLOBAL UNIT 3
 CYLINDER 1 0.6 2P15.0
 CYLINDER 2 0.6 2P15.0 ORIGIN X=2.0 Y=2.0
 CYLINDER 3 0.6 2P15.0 ORIGIN X=-2.0 Y=2.0
 CYLINDER 4 0.6 2P15.0 ORIGIN X=-2.0 Y=-2.0
 CYLINDER 5 0.6 2P15.0 ORIGIN X=2.0 Y=-2.0
 CYLINDER 6 1.4 2P15.0 ORIGIN X=2.0
 CYLINDER 7 1.4 2P15.0 ORIGIN Y=2.0
 CYLINDER 8 1.4 2P15.0 ORIGIN X=-2.0
 CYLINDER 9 1.4 2P15.0 ORIGIN Y=-2.0
 CYLINDER 10 3.6 2P15.0
 CYLINDER 11 3.8 2P15.0
 CUBOID 12 4P4.0 2P16.0
 MEDIA 2 1 1 -6 -7 -8 -9
 MEDIA 2 1 2 -6 -7
 MEDIA 2 1 3 -7 -8

MEDIA 2 1 4 -8 -9
MEDIA 2 1 5 -9 -6
HOLE 2 6 -1 -5 -2 ORIGEN X=2
HOLE 2 7 -1 -2 -3 ORIGEN Y=2
HOLE 2 8 -1 -3 -4 ORIGEN X=-2
HOLE 2 9 -1 -4 -5 ORIGEN Y=-2
MEDIA 0 1 10 -1 -2 -3 -4 -5 -6 -7 -8 -9
MEDIA 4 1 11 -10
MEDIA 0 1 12 -11
BOUNDARY 12

In unit 3, cylinder 1 defines the rod of mixture 2, centered in the annulus,
 cylinder 2 places a rod of mixture 2 in the upper-right quadrant of the annulus,
 cylinder 3 places a rod of mixture 2 in the upper-left quadrant of the annulus,
 cylinder 4 places a rod of mixture 2 in the lower-left quadrant,
 cylinder 5 places a rod of mixture 2 in the lower-right quadrant,
 cylinder 6 places the composite annulus of Unit 2 to the right of the central rod,
 cylinder 7 places the composite annulus of Unit 2 above the central rod,
 cylinder 8 places the composite annulus of Unit 2 to the left of the central rod,
 cylinder 9 places the composite annulus of Unit 2 below the central rod,
 cylinder 10 defines the void volume between the central rod and the annulus,
 cylinder 11 defines the outer surface of the annulus, and
 cuboid 12 defines the unit boundary

This problem illustrates two levels of hole nesting. The total input data for the problem is given below. The nuclide IDs are for the 16-group Hansen-Roach working format library. The mixtures used in this problem are not realistic or meaningful. However, the geometry description accurately recreates the geometry arrangement of Fig. F17.5.8. This problem includes the data for a printer plot to be used to verify the validity of the geometry description. The plot data specify a picture that is 260 characters wide, so the picture is generated in two pieces. The left half of the printer plot is shown in Fig. F17.5.11, and the right half is given in Fig. F17.5.11b. The user can tape the two halves together. If the plot were specified to be 130 characters wide, it would all print in one piece. However, some of the detail might have been lost.

Data description of Example 16.

=KENOVI
NESTED HOLES SAMPLE
READ PARAM RUN=NO LIB=41 TME=0.5 END PARAM
READ MIXT SCT=1 MIX=1 92500 4.7048-2 MIX=2 200 1.0 MIX=3 502 0.1
MIX=4 200 1.0
END MIXT
READ GEOM
UNIT 1
CYLINDER 1 0.1 2P15.0
CYLINDER 2 0.1 2P15.0 ORIGIN Y=-0.4
CYLINDER 3 0.1 2P15.0 ORIGIN X=0.4

CYLINDER 4 0.1 2P15.0 ORIGIN Y=0.4
 CYLINDER 5 0.1 2P15.0 ORIGIN X=-0.4
 CUBOID 6 2P0.1 2P0.05 2P15.0 ORIGIN X=-0.2
 CUBOID 7 2P0.1 2P0.05 2P15.0 ORIGIN X=0.2
 CUBOID 8 2P0.05 2P0.1 2P15.0 ORIGIN Y=-0.2
 CUBOID 9 2P0.05 2P0.1 2P15.0 ORIGIN Y=0.2
 CYLINDER 10 0.5 2P15.0
 MEDIA 1 1 1 -6 -7 -8 -9
 MEDIA 1 1 2 -8
 MEDIA 1 1 3 -7
 MEDIA 1 1 4 -9
 MEDIA 1 1 5 -6
 MEDIA 2 1 6 -1 -5
 MEDIA 2 1 7 -1 -3
 MEDIA 2 1 8 -1 -2
 MEDIA 2 1 9 -1 -4
 MEDIA 3 1 -1 -2 -3 -4 -5 -6 -7 -8 -9 10
 BOUNDARY 10
 UNIT 2
 CYLINDER 1 0.2 2P15.0
 CYLINDER 2 0.2 2P15.0 ORIGIN X=0.707107 Y=0.707107
 CYLINDER 3 0.2 2P15.0 ORIGIN X=-0.707107 Y=0.707107
 CYLINDER 4 0.2 2P15.0 ORIGIN X=-0.707107 Y=-0.707107
 CYLINDER 5 0.2 2P15.0 ORIGIN X=0.707107 Y=-0.707107
 CYLINDER 6 0.5 2P15.0 ORIGIN X=0.707107
 CYLINDER 7 0.5 2P15.0 ORIGIN X=-0.707107
 CYLINDER 8 0.5 2P15.0 ORIGIN Y=0.707107
 CYLINDER 9 0.5 2P15.0 ORIGIN Y=-0.707107
 CYLINDER 10 1.3 2P15.0
 CYLINDER 11 1.4 2P15.0
 MEDIA 2 1 1
 MEDIA 2 1 2
 MEDIA 2 1 3
 MEDIA 2 1 4
 MEDIA 2 1 5
 MEDIA 1 1 6 -8 -9
 MEDIA 1 1 7 -8 -9
 HOLE 1 8 -3 -6 ORIGIN Y=0.707107
 HOLE 1 9 -6 -7 ORIGIN Y=-0.707107
 MEDIA 0 1 10 -1 -2 -3 -4 -5 -6 -7 -8 -9
 MEDIA 4 1 11 -10
 BOUNDARY 11
 GLOBAL UNIT 3
 CYLINDER 1 0.6 2P15.0
 CYLINDER 2 0.6 2P15.0 ORIGIN X=2.0 Y=2.0
 CYLINDER 3 0.6 2P15.0 ORIGIN X=-2.0 Y=2.0
 CYLINDER 4 0.6 2P15.0 ORIGIN X=-2.0 Y=-2.0


```

CYLINDER 5 0.6 2P15.0 ORIGIN X=2.0 Y=-2.0
CYLINDER 6 1.4 2P15.0 ORIGIN X=2.0
CYLINDER 7 1.4 2P15.0 ORIGIN Y=2.0
CYLINDER 8 1.4 2P15.0 ORIGIN X=-2.0
CYLINDER 9 1.4 2P15.0 ORIGIN Y=-2.0
CYLINDER 10 3.6 2P15.0
CYLINDER 11 3.8 2P15.0
CUBOID 12 4P4.0 2P16.0
MEDIA 2 1 1 -6 -7 -8 -9
MEDIA 2 1 2 -6 -7
MEDIA 2 1 3 -7 -8
MEDIA 2 1 4 -8 -9
MEDIA 2 1 5 -9 -6
HOLE 2 6 -1 -5 -2 ORIGIN X=2
HOLE 2 7 -1 -2 -3 ORIGIN Y=2
HOLE 2 8 -1 -3 -4 ORIGIN X=-2
HOLE 2 9 -1 -4 -5 ORIGIN Y=-2
MEDIA 0 1 10 -1 -2 -3 -4 -5 -6 -7 -8 -9
MEDIA 4 1 11 -10
MEDIA 0 1 12 -11
BOUNDARY 12
END GEOM
READ PLOT TTL='X-Y SLICE AT Z MIDPOINT. NESTED HOLES'
XUL=-4.1 YUL=4.1 ZUL=0.0 XLR=4.1 YLR=-4.1 ZLR=0
UAX=1.0 VDN=-1.0 NAX=260 NCH=' *-X' END
END PLOT
END DATA
END

```

F17.5.6.3 Multiple Arrays

EXAMPLE 17. Section F17.5.6 demonstrates how units are composed of geometry regions and how these units can be stacked in an array. This same procedure can be extended to create multiple arrays. Furthermore, arrays can be used as building blocks within other arrays.

Consider Sample Problem 12 from Sect. F17.D. The description of this sample problem is restated below as Sample Problem 19.

This problem is a critical experiment consisting of a composite array^{1,2} of four highly enriched uranium metal cylinders and four cylindrical Plexiglas containers filled with uranyl nitrate solution. The metal units in this experiment are designated in Table II of ref. 1 as cylinder index 11 and reflector index 1. A photograph of the experiment is given in Fig. F17.D.3. The coordinate system is defined to be z up the page, y across the page, and x out of the page.

The Plexiglas containers have an inside radius of 9.525 cm and an outside radius of 10.16 cm. The inside height is 17.78 cm and the outside height is 19.05 cm. Four of these containers are stacked with a center-to-center spacing of 21.75 cm in the "y" direction and 20.48 cm in the "z" direction (vertical). This arrangement of four Plexiglas containers can be described as follows: mixture 2 is the uranyl nitrate and mixture 3 is Plexiglas, so the Plexiglas container with its appropriate spacing cuboid can be described as Unit 1. The array is considered to be bare and suspended with no supports.

Figure F17.5.11a Left half of printer plot

Figure F17.5.11b Right half of printer plot

UNIT 1
 CYLINDER 1 9.525 2P8.89
 CYLINDER 2 10.16 2P9.525
 CUBOID 3 4P10.875 2P10.24
 MEDIA 2 1 1
 MEDIA 3 1 2 -1
 MEDIA 0 1 3 -2
 BOUNDARY 3

The array of four Plexiglas containers can be described as array 1 in the array data as follows:

ARA=1 NUX=1 NUY=2 NUZ=2 FILL F1 END FILL

The four metal cylinders each have a radius of 5.748 cm and are 10.765 cm tall. They have a center-to-center spacing of 13.18 cm in the "y" direction and 12.45 cm in the "z" direction (vertical). Thus one of the metal cylinders with its appropriate spacing cuboid can be described as Unit 2. This array is also considered to be bare and unsupported.

UNIT 2
 CYLINDER 1 5.748 2P5.3825
 CUBOID 2 4P6.59 2P6.225
 MEDIA 1 1 1
 MEDIA 0 1 2 -1
 BOUNDARY 2

The array of four metal cylinders can be described as array 2 in the array data.

ARA=2 NUX=1 NUY=2 NUZ=2 FILL F2 END FILL

Now two arrays have been described. The overall dimensions of the array of Plexiglas containers is 21.75 cm in x, 43.5 cm in y, and 40.96 cm in z. The overall dimensions of the array of metal cylinders is 13.18 cm in x, 26.36 cm in y, and 24.9 cm in z.

In order to describe the composite array, these two arrays must be stacked together into an array. In order for them to be stacked into an array, the adjacent faces must match. This arrangement is accomplished by defining a Unit 3 which contains array 1, the array of Plexiglas solution containers. The overall dimensions of this unit are 21.75 cm in x, 43.5 cm in y, and 40.96 cm in z. The overall dimensions of the array need to be calculated. An array position needs to be chosen which is used to place the array in the unit. The array is placed in the unit by aligning the origin of the unit in the chosen array position with a calculated position in the surrounding unit. The chosen array position and the X, Y, and Z positions are entered after the keyword PLACE on the ARRAY card. Unit 3 is defined as follows:

UNIT 3
 CUBOID 1 2P10.875 2P21.75 2P20.48
 ARRAY 1 1 PLACE 1 1 1 0.0 -10.875 -10.24
 BOUNDARY 1

The array of metal cylinders will be defined to be Unit 4. However, this array is smaller in the y and z dimensions than the array of Plexiglas units; therefore, a void region must be placed around the array in those directions, so Unit 4 and Unit 3 will be the same size in y and z.

UNIT 4
CUBOID 1 2P6.59 2P13.18 2P12.45
CUBOID 2 2P6.59 2P21.75 2P20.48
ARRAY 2 1 PLACE 1 1 1 0.0 -6.59 -6.225
MEDIA 0 1 2 -1
BOUNDARY 2

Now that Unit 3 and Unit 4 have been defined, they must be placed in the global or universe array contained in the global unit. The global unit is specified by putting the keyword GLOBAL prior to the word unit.

GLOBAL UNIT 5
CUBOID 1 34.93 0.0 43.5 0.0 40.96 0.0
ARRAY 3 1 PLACE 1 1 1 6.59 21.75 20.48
BOUNDARY 1

The array of arrays is defined as the global array in the array data as follows:

GBL=3 ARA=3 NUX=2 NUY=1 NUZ=1 FILL 4 3 END FILL

This discussion completes the geometry description for the problem. The complete input description for the problem is given below. The nuclide IDs are for the 16-group Hansen-Roach working-format library.

Data description of Example 17.

=KENO-VI
SAMPLE PROBLEM 19 4 AQUEOUS 4 METAL ARRAY OF ARRAYS
READ PARAM LIB=41 RUN=NO END PARAM
READ MIXT SCT=1 MIX=1 92860 3.2275-3 92501 4.4802-2 MIX=2 1102 5.81-2
7100 1.9753-3 8100 3.6927-2 92501 9.8471-4 92860 7.7697-5
MIX=3 6100 3.5552-2 1102 5.6884-2 8100 1.4221-2 END MIXT
READ GEOM
UNIT 1
CYLINDER 1 9.525 2P8.89
CYLINDER 2 10.16 2P9.525
CUBOID 3 4P10.875 2P10.24
MEDIA 2 1 1
MEDIA 3 1 2 -1
MEDIA 0 1 3 -2
BOUNDARY 3
UNIT 2
CYLINDER 1 5.748 2P5.3825
CUBOID 2 4P6.59 2P6.225
MEDIA 1 1 1

```

MEDIA 0 1 2 -1
BOUNDARY 2
UNIT 3
CUBOID 1 2P10.875 2P21.75 2P20.48
ARRAY 1 1 PLACE 1 1 1 0.0 -10.875 -10.24
BOUNDARY 1
UNIT 4
CUBOID 1 2P6.59 2P13.18 2P12.45
CUBOID 2 2P6.59 2P21.75 2P20.48
ARRAY 2 1 PLACE 1 1 1 0.0 -6.59 -6.225
MEDIA 0 1 2 -1
BOUNDARY
GLOBAL UNIT 5
CUBOID 1 34.93 0.0 43.5 0.0 40.96 0.0
ARRAY 3 1 PLACE 1 1 1 6.59 21.75 20.48
BOUNDARY 1
END GEOM
READ ARRAY ARA=1 NUX=1 NUY=2 NUZ=2 FILL F1 END FILL
ARA=2 NUX=1 NUY=2 NUZ=2 FILL F2 END FILL GBL=3 ARA=3 NUX=2 NUY=1 NUZ=1
FILL 4 3 END FILL
END ARRAY
READ PLOT TTL='X-Y SLICE AT Z=10.24'
XUL=-1.0 YUL=44.5 ZUL=10.24 XLR=35.93 YLR=-1.0 ZLR=10.24
UAX=1.0 VDN=-1.0 NAX=130 NCH='*.-' PIC=MIX END
TTL='X-Z SLICE AT Y=10.875'
XUL=-1.0 YUL=10.875 ZUL=41.96 XLR=35.93 YLR=10.875 ZLR=-1.0
UAX=1.0 WDN=-1.0 PIC=MIX END END PLOT
END DATA
END

```

A printer plot of an x-y slice taken through the bottom layer of the array is shown in Fig. F17.5.12. A printer plot of an x-z slice taken through the left half of the array is shown in Fig. F17.5.13. These printer plots were used to verify the geometry mock-up.

STORAGE ARRAY

EXAMPLE 18. Consider a storage array of highly enriched uranium buttons, each 2.54 cm (1 in.) tall and 10.16 cm (4 in.) in diameter. These buttons are stored on stainless steel shelves with a center-to-center spacing of 60.96 cm (2 ft) between them. The shelves are 0.64 cm (1/4 in.) thick, 45.72 cm (18 in.) wide, 609.6 cm (20 ft) long, and are 45.72 cm (18 in.) from the top of a shelf to the bottom of the shelf above it. Each rack of storage shelves is four shelves high, with the first shelf being 15.24 cm (6 in.) above the floor. The storage room is 586.56 cm (19.5 ft) in the x direction by 1293.44 cm (43 ft) in the y direction, with 365.76 cm (12-ft) ceilings in the z direction. The walls, ceiling, and floor are composed of 30.48-cm- (1-ft-)thick concrete. All the aisles between the storage racks are 91.44 cm (3 ft) wide. The racks are arranged with their length in the y direction and an aisle between them. The array of racks are arranged with two in the y direction and five in the x direction. Mixture 1 is the uranium metal, mixture 2 is the stainless steel, and mixture 3 is the concrete.

Figure F17.5.12 x-y plot of mixed array

Figure F17.5.13 An x-z plot of mixed array

First, describe the metal button and its center-to-center spacing. The void vertical spacing has been chosen arbitrarily to extend from the bottom of the button to the next shelf above the button. The shelf of stainless steel is described under the button.

UNIT 1
CYLINDER 1 5.08 2.54 0.0
CUBOID 2 2P22.86 2P30.48 45.72 0.0
CUBOID 3 2P22.86 2P30.48 45.72 -.635
MEDIA 1 1 1
MEDIA 0 1 2 -1
MEDIA 2 1 3 -2 -1
BOUNDARY 3

Array 1 creates an array of these buttons that fills one shelf. Unit 2 then contains one of the shelves shown in Fig. F17.5.14.

ARA=1 NUX=1 NUY=10 NUZ=1 FILL F1 END FILL

UNIT 2
CUBOID 1 45.72 0.0 609.60 0.0 46.355 0.0
ARRAY 1 1 PLACE 1 1 1 22.86 30.48 0.635
BOUNDARY 1

Stack four Unit 2's vertically to obtain one of the racks shown in Fig. F17.5.14. One rack is defined by array 2.

ARA=2 NUX=1 NUY=1 NUZ=4 FILL F2 END FILL

Generate a Unit 3 that contains a rack of shelves and a Unit 4 that is the aisle between the ends of the two racks in the y direction.

UNIT 3
CUBOID 1 45.72 0.0 609.60 0.0 185.42 0.0
*ARRAY 2 1 PLACE 1 1 1 3*0.0*
BOUNDARY 1
UNIT 4
CUBOID 1 2P22.86 2P45.72 185.42 0.0
MEDIA 0 1 1
BOUNDARY 1

Stack Units 3 and 4 together in the y direction to create Unit 5 which contains both racks in the y direction and the aisle between them. This configuration is shown in Fig. F17.5.14.

ARA=3 NUX=1 NUY=3 NUZ=1 FILL 3 4 3 END FILL

Figure F17.5.14 Two racks of uranium buttons

UNIT 5

CUBOID 1 45.72 0.0 1310.64 0.0 185.42 0.0

ARRAY 3 1 PLACE 1 1 1 3*0.0

BOUNDARY 1

Create a Unit 6, which is an aisle 91.44 cm (3 ft) wide in the x direction and 1310.64 cm (43 ft) in the y direction (full length of the room).

UNIT 6

CUBOID 1 91.44 0.0 1310.64 0.0 185.42 0.0

MEDIA 0 1 1

BOUNDARY 1

Stack Units 5 and 6 in the x direction to achieve the array of racks in the room. Then put the 15.24-cm (6-in.) spacing below the bottom of the racks, the spacing between the top of the top rack and the ceiling, and add the concrete floor, walls, and ceiling around the array. Array 4 describes the array of racks in the room. The core description encompasses this array, and the first reflector descriptions are used to add the spacing between the top rack and the ceiling. The last two reflector descriptions add the ceiling, walls and floor. A perspective of the room is shown in Fig. F17.5.15.

GBL=4 ARA=4 NUX=9 NUY=1 NUZ=1 FILL 5 6 3Q2 5 END FILL

GLOBAL UNIT 7

CUBOID 1 594.36 0.0 1310.64 0.0 185.42 0.0

CUBOID 2 594.36 0.0 1310.64 0.0 350.52 -15.24

CUBOID 3 599.36 -5.00 1315.64 -5.00 355.52 -20.24

CUBOID 4 604.36 -10.00 1320.64 -10.00 360.52 -25.24

CUBOID 5 609.36 -15.00 1325.64 -15.00 365.52 -30.24

CUBOID 6 614.36 -20.00 1330.64 -20.00 370.52 -35.24

CUBOID 7 619.36 -25.00 1335.64 -25.00 375.52 -40.24

CUBOID 8 624.36 -30.00 1340.64 -30.00 380.52 -45.24

CUBOID 9 624.84 -30.48 1341.12 -30.48 381.00 -45.72

*ARRAY 4 1 PLACE 1 1 1 3*0.0*

MEDIA 0 1 2 -1

MEDIA 3 2 3 -2 -1

MEDIA 3 3 -3

MEDIA 3 4 5 -4

MEDIA 3 5 6 -5

MEDIA 3 6 7 -6

MEDIA 3 7 8 -7

MEDIA 3 8 9 -8

BOUNDARY 9

Figure F17.5.15 Entire storage array in the room

The final mock-up for this room is given below: The printer plots for this problem must be quite large in order to see all the detail because the array is sparse and the shelves are thin. Therefore, the printer plots for this system are not included as figures. The user can generate the printer plots if it is desirable to see them. The first two plots are two pages wide, and the last one is only one page wide. The nuclide IDs used in this problem are for the 16-group Hansen-Roach working-format library.

Data description of Example 18.

```
=KENOVI
STORAGE ARRAY
READ PARAMETERS TME=1.0 FDN=YES LIB=41
END PARAMETERS
READ MIXT SCT=1 MIX=1 92500 4.48006-2 92800 2.6578-3 92400 4.827-4
92600 9.57-5 MIX=2 200 1.0 MIX=3 301 1 END MIXT
READ GEOMETRY
UNIT 1
CYLINDER 1 5.08 2.54 0.0
CUBOID 2 2P22.86 2P30.48 45.72 0.0
CUBOID 3 2P22.86 2P30.48 45.72 -.635
MEDIA 1 1 1
MEDIA 0 1 2 -1
MEDIA 2 1 3 -2 -1
BOUNDARY 3
UNIT 2
CUBOID 1 45.72 0.0 609.60 0.0 46.355 0.0
ARRAY 1 1 1 PLACE 1 1 1 22.86 30.48 0.635
BOUNDARY 1
UNIT 3
CUBOID 1 45.72 0.0 609.60 0.0 185.42 0.0
ARRAY 2 1 1 PLACE 1 1 1 3*0.0
BOUNDARY 1
UNIT 4
CUBOID 1 2P22.86 2P45.72 185.42 0.0
MEDIA 0 1 1
BOUNDARY 1
UNIT 5
CUBOID 1 45.72 0.0 1310.64 0.0 185.42 0.0
ARRAY 3 1 1 PLACE 1 1 1 3*0.0
BOUNDARY 1
UNIT 6
CUBOID 1 91.44 0.0 1310.64 0.0 185.42 0.0
MEDIA 0 1 1
BOUNDARY 1
GLOBAL UNIT 7
CUBOID 1 594.36 0.0 1310.64 0.0 185.42 0.0
CUBOID 2 594.36 0.0 1310.64 0.0 350.52 -15.24
CUBOID 3 599.36 -5.00 1315.64 -5.00 355.52 -20.24
```

CUBOID 4 604.36 -10.00 1320.64 -10.00 360.52 -25.24
 CUBOID 5 609.36 -15.00 1325.64 -15.00 365.52 -30.24
 CUBOID 6 614.36 -20.00 1330.64 -20.00 370.52 -35.24
 CUBOID 7 619.36 -25.00 1335.64 -25.00 375.52 -40.24
 CUBOID 8 624.36 -30.00 1340.64 -30.00 380.52 -45.24
 CUBOID 9 624.84 -30.48 1341.12 -30.48 381.00 -45.72
 ARRAY 4 1 PLACE 1 1 1 3*0.0
 MEDIA 0 1 2 -1
 MEDIA 3 2 3 -2 -1
 MEDIA 3 3 4 -3
 MEDIA 3 4 5 -4
 MEDIA 3 5 6 -5
 MEDIA 3 6 7 -6
 MEDIA 3 7 8 -7
 MEDIA 3 8 9 -8
 BOUNDARY 9
 END GEOMETRY
 READ ARRAY
 ARA=1 NUX=1 NUY=10 NUZ=1 FILL F1 END FILL
 ARA=2 NUX=1 NUY=1 NUZ=4 FILL F2 END FILL
 ARA=3 NUX=1 NUY=3 NUZ=1 FILL 3 4 3 END FILL
 GBL=4 ARA=4 NUX=9 NUY=1 NUZ=1 FILL 5 6 3Q2 5 END FILL
 END ARRAY
 READ BIAS ID=301 2 8 END BIAS
 READ START NST=5 NBX=5 END START
 READ PLOT PLT=YES TTL='X-Z SLICE AT Y=30.48 WITH Z ACROSS AND X DOWN'
 XUL=594.8 YUL=30.48 ZUL=-1.0 XLR=-0.5 YLR=30.48 ZLR=186.0
 WAX=1.0 UDN=-1.0 NAX=260 NCH='*#.' END
 TTL='Y-Z SLICE OF LEFT RACKS, X=22.86 WITH Z ACROSS AND Y DOWN'
 XUL=22.86 YUL=1311.0 ZUL=-0.5 XLR=22.86 YLR=-3.0 ZLR=186.0
 WAX=1.0 VDN=-1.0 NAX=260 END
 TTL='X-Y SLICE OF ROOM THROUGH SHELF Z=0.3175 WITH X ACROSS AND Y DOWN'
 XUL=-1.0 YUL=1312.0 ZUL=0.3175 XLR=596.0 YLR=-2.5 ZLR=0.3175
 UAX=1.0 VDN=-1.0 NAX=130 END
 END PLOT
 END DATA
 END

F17.5.6.4 Arrays and Holes

Sections F17.5.6.1 and F17.5.6.2 describe the use of holes, and Sect. F17.5.6.3 describes multiple arrays and arrays of arrays. Holes can also be used to place arrays at locations in other units. This section contains examples to illustrate the combined use of arrays and holes.

EXAMPLE 19. A SIMPLE CASK

Consider a cylindrical, mild steel container having an inside radius of 4.15 cm and a radial wall thickness of 0.45 cm. The thickness of the ends of the container is 1.27 cm, and the inside height is 10.1 cm. Highly enriched uranium rods, 1 cm in diameter and 10 cm long, are banded together into square bundles of four. These bundles are then positioned in the mild steel container as shown in Fig. F17.5.16. The rods are positioned on the floor of the container and have a 0.1-cm gap between their tops and the top of the container. Material 1 is uranium and material 2 is steel.

Figure F17.5.16 Uranium rods in a cylindrical container

To generate the geometry description for this system, define Unit 1 to be one uranium rod and its associated square-pitch, close-packed spacing region and Unit 2 to be a void cuboid with the same square pitch.

UNIT 1
CYLINDER 1 0.5 2P5.0
CUBOID 2 4P0.5 2P5.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2

UNIT 2
 CUBOID 1 4P0.5 2P5.0
 MEDIA 0 1 1
 BOUNDARY 1

Define array 1 to be the central square 10×10 array, consisting of 32 rods and 68 void positions that can be used to represent the array shown in Fig. F17.5.16.

ARA=1 NUX=10 NUY=10 NUZ=1 FILL 14*2 1 1 8*2 1 1 7*2 4*1 4*2 8*1 2 2 8*1 4*2 4*1 7*2 1 1 8*2
 1 1 14*2 END FILL

Now place array 1 in Unit 3. The first cylinder card defines the array boundary. Everything external to this boundary is not considered part of the problem. The positions in the array that do not contain rods are filled with cuboids consisting of void. The array boundary must either coincide with the outer boundary of the array or be contained within the array. An exterior void region is placed around the array boundary to coincide with the size of the interior radius of the container. The 10×10 array with the array boundary is shown in Fig. 17.5.16a.

Figure F17.5.16a The 10×10 array of uranium 32 rods and 68 void cuboids with the array boundary

UNIT 3
CYLINDER 1 4.15 5.0 -5.0
CYLINDER 2 4.15 5.1 -5.0
ARRAY 1 1 PLACE 5 5 1 -0.5 -0.5 -0.0
MEDIA 0 1 2 -1
BOUNDARY 2

The unit containing the array is now placed within the global unit using a hole media card. The location of the hole is determined using ORIGIN data to match the origin of the unit in the hole with a X, Y, Z position in the surrounding unit. In this problem the origin of the unit needs to be at position (0,0,0). Since only nonzero data must be entered, ORIGIN data are not needed for this problem. The boundary region consists of the steel container.

GLOBAL UNIT 4
CYLINDER 1 4.15 5.1 -5.0
CYLINDER 2 4.6 6.37 -6.27
HOLE 3 1 ORIGIN X=0.0 Y=0.0 Z=0.0
MEDIA 2 1 2 -1
BOUNDARY 2

The overall problem description is shown below. Two of the printer plots used for verification of this mock-up are shown in Figs. F17.5.17 and F17.5.18.

Data description of Example 19.

=KENO VI
CASK ARRAY
READ PARAMETERS TME=1.0 FDN=YES LIB=41 GEN=10
END PARAMETERS
READ MIXT SCT=1 MIX=1 92500 4.48006-2 92800 2.6578-3 92400 4.827-4
92600 9.57-5 MIX=2 100 1.0 END MIXT
READ GEOMETRY
UNIT 1
CYLINDER 1 0.5 2P5.0
CUBOID 2 4P0.5 2P5.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
UNIT 2
CUBOID 1 4P0.5 2P5.0
MEDIA 0 1 1
BOUNDARY 1
UNIT 3
CYLINDER 1 4.15 5.0 -5.0
CYLINDER 2 4.15 5.1 -5.0
ARRAY 1 1 PLACE 5 5 1 -0.5 -0.5 -0.0

Figure F17.5.17 An x-y slice of uranium rods in a cylindrical container

Figure F17.5.18 An x-z slice of uranium rods in a cylindrical container

```

MEDIA 0 1 2 -1
BOUNDARY 2
GLOBAL UNIT 4
CYLINDER 1 4.15 5.1 -5.0
CYLINDER 2 4.6 6.37 -6.27
HOLE 3 1 ORIGIN X=0.0 Y=0.0 Z=0.0
MEDIA 2 1 2 -1
BOUNDARY 2
END GEOM
READ ARRAY
ARA=1 NUX=10 NUY=10 NUZ=1 FILL 14*2 1 1 8*2 1 1 7*2 4*1 4*2 8*1 2 2 8*1 4*2 4*1 7*2 1 1
8*2 1 1 14*2 END FILL
END ARRAY
READ PLOT TTL='X-Z SLICE AT Y=0.25 WITH X ACROSS AND Z DOWN'
XUL=-5.0 YUL=0.25 ZUL=6.5 XLR=5.0 YLR=0.25 ZLR=-6.5
UAX=1.0 WDN=-1.0 NAX=130 NCH=' *0' END
TTL='X-Y SLICE AT Z=0.0 WITH X ACROSS AND Y DOWN'
XUL=-5.0 YUL=5.0 ZUL=0.0 XLR=5.0 YLR=-5.0 ZLR=0.0
UAX=1.0 VDN=-1.0 NAX=130 END
END PLOT
END DATA
END

```

EXAMPLE 20. A TYPICAL PWR SHIPPING CASK

Consider a typical PWR shipping cask, illustrated in Fig. F17.5.19. The interior and exterior of the cask is carbon steel (mixture 7) and a depleted uranium gamma shield (mixture 6) is present in the annulus. The shipping cask contains seven PWR fuel assemblies. Each assembly is a 17×17 array of fuel rods with water holes as shown. Each assembly is contained in stainless steel (mixture 5). Each fuel rod is clad with Zircaloy (mixture 2) and is composed of 4% enriched UO_2 (mixture 1). Rods of B_4C (mixture 4) clad with stainless steel are positioned between the fuel assemblies. The entire cask is filled with water (mixture 3).

To describe the geometry of the cask, start by defining some simple units, as shown in Fig. F17.5.20. Unit 1 represents a fuel rod and its associated square-pitch spacing region. Unit 2 represents a water hole in a fuel assembly.

```

UNIT 1
CYLINDER 1 .41148 365.76 0.0
CYLINDER 2 .48133 365.76 0.0
CUBOID 3 .63754 -.63754 .63754 -.63754 365.76 0.0
MEDIA 1 1 1
MEDIA 2 1 2 -1
MEDIA 3 1 3 -2 -1
BOUNDARY 3

UNIT 2
CUBOID 1 .63754 -.63754 .63754 -.63754 365.76 0.0
MEDIA 3 1 1
BOUNDARY 1

```

Figure F17.5.19 Typical PWR shipping cask

Figure F17.5.20 Simple units

Units 3, 4, and 6 represent the B₄C rods with their various spacings, and Unit 5 is a water hole that is used in association with some of the B₄C rods.

UNIT 3

CYLINDER 1 .584 365.76 0.0

CYLINDER 2 .635 365.76 0.0

CUBOID 3 .9912 -.9912 2.2352 -1.27 365.76 0.0

MEDIA 4 1 1

MEDIA 5 1 2 -1

MEDIA 3 1 3 -2 -1

BOUNDARY 3

UNIT 4

CYLINDER 1 .584 365.76 0.0

CYLINDER 2 .635 365.76 0.0

CUBOID 3 .9912 -.9912 1.2702 -2.235 365.76 0.0

MEDIA 4 1 1

MEDIA 5 1 2 -1

MEDIA 3 1 3 -2 -1

BOUNDARY 3

UNIT 5

CUBOID 1 .9912 -.9912 1.7526 -1.7526 365.76 0.0

MEDIA 3 1 1

BOUNDARY 1

UNIT 6

CYLINDER 1 .584 365.76 0.0

CYLINDER 2 .635 365.76 0.0

CUBOID 3 1.1875215 -1.1875215 1.883706 -1.883706 365.76 0.0

MEDIA 4 1 1

MEDIA 5 1 2 -1

MEDIA 3 1 3 -2 -1

BOUNDARY 3

Units 1 and 2 are stacked together into array 1 to form the array of fuel pins and water holes in a fuel assembly, as shown in Fig. F17.5.21. This array is then encompassed with a layer of water and a layer of stainless steel to complete a fuel assembly (Unit 7), as shown in Fig. F17.5.22.

ARA=1 NUX=17 NUZ=17 NUZ=1 FILL

39R1 2 2Q3 8R1 2 9R1 2 22R1 2 4Q3 38R1 2 4Q3

Q51 22R1 2 Q10 Q9 2Q3 39R1 END FILL

UNIT 7

CUBOID 1 10.83818 -10.83818 10.83818 -10.83818 365.76 0.0

CUBOID 2 11.112495 -11.112495 11.112495 -11.112495 365.76 0.0

CUBOID 3 11.302238 -11.302238 11.302238 -11.302238 365.76 0.0

ARRAY 1

Figure F17.5.21 Fuel pin array

Figure F17.5.22 Fuel assembly

```

ARRAY 1 1 PLACE 9 9 1 3*0.0
MEDIA 3 1 2 -1
MEDIA 5 1 3 -2 -1
BOUNDARY 3

```

An array of Unit 6's is created to represent the array of B₄C rods that is positioned between the fuel assemblies. This array of B₄C rods is placed directly in the problem, as shown in Fig. F17.5.23.

```

ARA=2 NUX=2 NUY=6 NUZ=1 FILL F6 END FILL

```

The next step is to create the central array of three fuel assemblies with B₄C rods between them. This configuration is accomplished by placing fuel assemblies (Unit 7) and B₄C rod arrays (Array 2) into a unit (unit 8). The resultant geometry is shown in Fig. F17.5.24.

```

UNIT 8
CUBOID 1 11.302238 -11.302238 11.302238 -11.302238 365.76 0.0
CUBOID 2 -16.052324 -38.656800 11.302238 -11.302238 365.76 0.0
CUBOID 3 38.656800 16.052324 11.302238 -11.302238 365.76 0.0
CUBOID 4 -11.302238 -16.052324 11.302238 -11.302238 365.76 0.0
CUBOID 5 16.052324 11.302238 11.302236 -11.302236 365.76 0.0
CUBOID 6 38.052324 -38.052324 11.302236 -11.302236 365.76 0.0
HOLE 7 1 -4 -5
HOLE 7 2 -4 ORIGIN X= -27.354562
HOLE 7 3 -5 ORIGIN X= 27.354562
ARRAY 2 4 -1 -2 PLACE 1 1 1 -14.8648025 -9.418530 0.0
ARRAY 2 5 -1 -3 PLACE 1 1 1 12.4897595 -9.418530 0.0
MEDIA 0 1 6 -5 -4 -3 -2 -1
BOUNDARY 7

```

Units 3, 4, and 5 are used to define the arrays of B₄C rods that fit above and below the central array, as shown in Fig. F17.5.25.

```

ARA=3 NUX=39 NUY=1 NUZ=1 FILL 3 5 2Q2 3 4 2Q2 5 4 3 2Q2 5 3 4 2Q2 5 4 3 2Q2 5 2Q2 3
END FILL
ARA=4 NUX=39 NUY=1 NUZ=1 FILL 4 5 2Q2 4 3 2Q2 5 3 4 2Q2 5 4 3 2Q2 5 3 4 2Q2 5 2Q2 4
END FILL

```

Figure F17.5.23 2×6 array of B_4C rods

Figure F17.5.24 Central array

Figure F17.5.25 Long B₄C rod arrays

Unit 8 is positioned between arrays 3 and 4, forming the central section of the global unit, as shown in Fig. F17.5.26. The description below shows how the three central fuel assemblies and B₄C rods are combined. This is the case of the global unit.

Figure F17.5.26 Central section of global unit with long B₄C arrays

CUBOID 1 38.052324 -38.052324 11.302236 -11.302236 365.76 0.0
CUBOID 2 38.052324 -38.052324 14.807436 11.302236 365.76 0.0
CUBOID 3 38.052324 -38.052324 11.302236 -14.807436 365.76 0.0
HOLE 8 1
ARRAY 3 2 -1 PLACE 20 1 1 0.0 13.054836 0.0
ARRAY 4 3 -1 PLACE 20 1 1 0.0 13.054836 0.0

Next, Unit 7 and array 2 are stacked together to form the array of two fuel assemblies separated by B₄C rods, as shown in Fig. F17.5.27. This arrangement is designated as unit 9. The origin of unit 9 is specified at the center of the B₄C array in the x and y directions and the bottom of the array in the z direction.

UNIT 9

CUBOID 1 2.375043 -2.375043 11.302236 -11.302236 365.76 0.0
CUBOID 2 -2.375043 -24.979519 11.302238 -11.302238 365.76 0.0
CUBOID 3 24.979519 2.375043 11.302238 -11.302238 365.76 0.0
CUBOID 4 24.979519 -23.7919975 11.302238 -11.302238 365.76 0.0
ARRAY 2 1 PLACE 1 1 1 -1.1875215 -9.418530 0.0
HOLE 7 2 -1 ORIGIN X=-13.67728
HOLE 7 3 -1 ORIGIN X=13.67728
MEDIA 0 1 4 -3 -2 -1
BOUNDARY 4

Figure F17.5.27 Two fuel assemblies and B₄C rods

All necessary subassemblies that make up the shipping cask have been built. The shipping cask is now assembled by first specifying the origin of the central section (see Fig. F17.5.26) to be at the center of the array in x and y and the bottom of the array in the z direction. A cylinder of water defining the interior of the shipping cask is described around the array. A HOLE is used to place a Unit 9 (Fig. F17.5.27) below the array, and a second HOLE is used to place another Unit 9 above the array. At this point a cylinder of steel is placed around the water, which is in turn encased by depleted uranium. The depleted uranium is then contained in the outer steel cylinder of the shipping cask. The lid is then placed on the shipping cask and a boundary region is defined that encloses the entire cask assembly. This information completes the shipping cask description of Fig. F17.5.19. The geometry data for this shipping cask are shown below. The plot data have been included for verification of the geometry description. However, the plot generated by this data is quite large and is therefore not included in this document.

READ GEOM

UNIT 1

CYLINDER 1 .41148 365.76 0.0

CYLINDER 2 .48133 365.76 0.0

CUBOID 3 .63754 -.63754 .63754 -.63754 365.76 0.0

MEDIA 1 1 1

MEDIA 2 1 2 -1

MEDIA 3 1 3 -2 -1

BOUNDARY 3

UNIT 2

CUBOID 1 .63754 -.63754 .63754 -.63754 365.76 0.0

MEDIA 3 1 1

BOUNDARY 1

UNIT 3

CYLINDER 1 .584 365.76 0.0

CYLINDER 2 .635 365.76 0.0

CUBOID 3 .9912 -.9912 2.2352 -1.27 365.76 0.0

MEDIA 4 1 1

MEDIA 5 1 2 -1

MEDIA 3 1 3 -2 -1

BOUNDARY 3

UNIT 4

CYLINDER 1 .584 365.76 0.0

CYLINDER 2 .635 365.76 0.0

CUBOID 3 .9912 -.9912 1.2702 -2.235 365.76 0.0

MEDIA 4 1 1

MEDIA 5 1 2 -1

MEDIA 3 1 3 -2 -1

BOUNDARY 3

UNIT 5

CUBOID 1 .9912 -.9912 1.7526 -1.7526 365.76 0.0

MEDIA 3 1 1

BOUNDARY 1

UNIT 6

CYLINDER 1 .584 365.76 0.0

CYLINDER 2 .635 365.76 0.0

CUBOID 3 1.1875215 -1.1875215 1.883706 -1.883706 365.76 0.0

MEDIA 4 1 1

MEDIA 5 1 2 -1

MEDIA 3 1 3 -2 -1

BOUNDARY 3

UNIT 7

CUBOID 1 10.83818 -10.83818 10.83818 -10.83818 365.76 0.0

CUBOID 2 11.112495 -11.112495 11.112495 -11.112495 365.76 0.0

CUBOID 3 11.302238 -11.302238 11.302238 -11.302238 365.76 0.0

ARRAY 1 1 PLACE 9 9 1 3*0.0

MEDIA 3 1 2 -1

MEDIA 8 1 3 -2 -1
 BOUNDARY 3
 UNIT 8
 CUBOID 1 11.302238 -11.302238 11.302238 -11.302238 365.76 0.0
 CUBOID 2 -16.052324 -38.656800 11.302238 -11.302238 365.76 0.0
 CUBOID 3 38.656800 16.052324 11.302238 -11.302238 365.76 0.0
 CUBOID 4 -11.302238 -16.052324 11.302238 -11.302238 365.76 0.0
 CUBOID 5 16.052324 11.302238 11.302236 -11.302236 365.76 0.0
 CUBOID 6 38.052324 -38.052324 11.302236 -11.302236 365.76 0.0
 HOLE 7 1
 HOLE 7 2 -1 ORIGIN X=-27.354562
 HOLE 7 3 -2 -1 ORIGIN X= 27.354562
 ARRAY 2 4 -1 -2 PLACE 1 1 1 -14.8648025 -9.418530 0.0
 ARRAY 2 5 -1 -3 PLACE 1 1 1 12.4897595 -9.418530 0.0
 MEDIA 0 1 6 -5 -4 -3 -2 -1
 BOUNDARY 6
 UNIT 10
 CUBOID 1 1.1875215 -1.1875215 11.302236 -11.302236 365.76 0.0
 CUBOID 2 -1.1875215 -23.7919975 11.302238 -11.302238 365.76 0.0
 CUBOID 3 23.7919975 1.1875215 11.302238 -11.302238 365.76 0.0
 CUBOID 4 23.7919975 -23.7919975 11.302238 -11.302238 365.76 0.0
 ARRAY 2 1 PLACE 1 1 1 3*0.0
 HOLE 7 2 -1 ORIGIN X=-12.4897595
 HOLE 7 3 -1 ORIGIN X=12.4897595
 MEDIA 0 1 4 -3 -2 -1
 BOUNDARY 4
 GLOBAL UNIT 11
 CUBOID 1 38.052324 -38.052324 11.302236 -11.302236 365.76 0.0
 CUBOID 2 38.052324 -38.052324 13.284638 11.302236 365.76 0.0
 CUBOID 3 38.052324 -38.052324 11.302236 -13.284638 365.76 0.0
 CUBOID 4 23.7919975 -23.7919975 35.889114 13.284638 365.76 0.0
 CUBOID 5 23.7919975 -23.7919975 -13.284638 -35.889114 365.76 0.0
 CYLINDER 6 47.625 419.10 -11.43
 CYLINDER 7 48.895 419.10 -14.605
 CYLINDER 8 59.06 419.10 -24.13
 CYLINDER 9 47.625 429.26 421.64
 CYLINDER 10 63.01 434.34 -27.94
 HOLE 8 1
 ARRAY 3 2 -1 PLACE 20 1 1 0.0 12.293438 0.0
 ARRAY 4 3 -1 PLACE 20 1 1 0.0 12.293438 0.0
 HOLE 9 4 -2 ORIGIN Y=24.586876
 HOLE 9 5 -3 ORIGIN Y=-24.586876
 MEDIA 3 1 6 -5 -4 -3 -2 -1
 MEDIA 7 1 7 -6 -5 -4 -3 -2 -1
 MEDIA 6 1 8 -7
 MEDIA 7 1 9
 MEDIA 6 1 10 -9 -8

```

BOUNDARY 10
END GEOM
READ ARRAY
ARA=1 NUX=17 NUY=17 NUZ=1 FILL
39R1 2 2Q3 8R1 2 9R1 2 22R1 2 4Q3 38R1 2 4Q3
Q51 22R1 2 Q10 Q9 2Q3 39R1      END FILL
ARA=2 NUX=2 NUY=6 NUZ=1  FILL F6      END FILL
ARA=3 NUX=5 NUY=1 NUZ=1  FILL 7 8 7 8 7 END FILL
ARA=4 NUX=39 NUY=1 NUZ=1  FILL 3 5 2Q2 3 4 2Q2 5 4 3 2Q2 5 3 4 2Q2
5 4 3 2Q2 5 2Q2 3      END FILL
ARA=5 NUX=39 NUY=1 NUZ=1  FILL 4 5 2Q2 4 3 2Q2 5 3 4 2Q2 5 4 3 2Q2
5 3 4 2Q2 5 2Q2 4      END FILL
ARA=6 NUX=1 NUY=3 NUZ=1  FILL 11 9 10 END FILL
ARA=7 NUX=3 NUY=1 NUZ=1  FILL 7 8 7  END FILL
END ARRAY
READ PLOT
TTL=? SHIPPING CASK IF-300 X-Y SLICE ?
XUL=-63 YUL=63 ZUL=180 XLR=63 YLR=-63 ZLR=180
UAX=1 VDN=-1 NAX=350
PLT=NO
END PLOT

```

F17.5.6.5 Triangular Pitched Arrays (Sample problem 20)

EXAMPLE 21. Triangular pitched arrays can be described in KENO-VI by defining the units that make up the array as hexprism and in the array data block setting TYP=TRIANGULAR. This includes close-packed triangular pitched arrays. Since the arrays are constructed by stacking hexprisms care must be taken to ensure the array boundary is completely enclosed within the stacked unit. Below is an example of a triangular pitched array.

The first and second unit are the hexprisms that make up the array. Unit 1 is the fuel cell that is stacked in a triangular pitched or hexagonal lattice. Unit 2 is a dummy unit that is used to fill in the array so the array boundary is contained within the stacked units. Since the array is not moderated unit 2 contains void. Figure F17.5.28 shows an X-Y cross-section schematic of units 1 and 2.

```

UNIT 1
COM='SINGLE CELL FUEL CAN IN HEXPRISM'
CYLINDER 10 10.16 18.288 0.0
CYLINDER 20 10.312 18.288 -0.152
HEXPRISM 30 10.503 18.288 -0.152
MEDIA 1 1 10
MEDIA 2 1 20 -10
MEDIA 0 1 30 -20 -10
BOUNDARY 30

```

```

UNIT 2
COM='EMPTY CELL'
HEXPRISM 10 10.503 18.288 -0.152
MEDIA 0 1 10
BOUNDARY 10

```

Figure F17.5.28 Fuel cell and empty cell set up as hexprisms

Unit 3 is the global unit that contains the array and array boundary. The array is an unmoderated triangular pitched assembly of 7 cells. Figure F17.5.29 shows an X-Y cross-section schematic of the assembly.

```

GLOBAL UNIT 3
COM='7 CYLINDERS IN A CIRCLE WITH CYLINDRICAL BOUNDARY'
CYLINDER 10 32.000 18.288 -0.152
ARRAY 1 10 PLACE 3 3 1 3*0.0
BOUNDARY 10
READ ARRAY GBL=1 ARA=1 TYP=TRIANGULAR NUX=5 NUY=5 NUZ=1
FILL 7*2 2*1 2*2 3*1 2*2 2*1 7*2 END FILL END ARRAY

```

Figure F17.5.29 Seven cylinders stacked in a triangular pitched array with a cylindrical array boundary

The overall problem description is shown below. The working format library used in the mixing table was generated from the 27groupndf4 master library using BONAMI and NITAWL and stored in unit 4. An X-Y cross-section printer plot used for verification of this mock-up is shown in Fig. F17.5.30.

Data description of Example 21.

```
=KENOVI
SAMPLE PROBLEM 20 TRIANGULAR PITCHED ARRAY 7 PINS IN A CIRCLE
READ PARAMETERS LNG=20000 LIB=4 END PARAMETERS
READ MIXT SCT=2
MIX=1 892235 1.37751E-03 892238 9.92354E-05 808016 3.32049E-02
      809019 2.95349E-03 801001 6.05028E-02
MIX=2 1413027 6.02374E-02
END MIXT
READ GEOMETRY
UNIT 1
COM='SINGLE CELL FUEL CAN IN HEXPRISM'
CYLINDER 10 10.16 18.288 0.0
CYLINDER 20 10.312 18.288 -0.152
HEXPRISM 30 10.503 18.288 -0.152
MEDIA 1 1 10
MEDIA 2 1 20 -10
MEDIA 0 1 30 -20 -10
BOUNDARY 30
```

Figure F17.5.30 X-Y slice of 7 cylinders in a triangular pitched array


```

UNIT 2
COM='EMPTY CELL'
HEXPRISM 10 10.503 18.288 -0.152
MEDIA 0 1 10
BOUNDARY 10
GLOBAL UNIT 3
CYLINDER 10 32.000 18.288 -0.152
COM='7 CYLINDERS IN A CIRCLE WITH CYLINDRICAL BOUNDARY'
ARRAY 1 10 PLACE 3 3 1 3*0.0
BOUNDARY 10
END GEOMETRY
READ ARRAY GBL=1 TYP=TRIANGULAR NUX=5 NUY=5 NUZ=1
FILL 7*2 2*1 2*2 3*1 2*2 2*1 7*2 END FILL END ARRAY
END DATA
END

```

F17.5.7 ALTERNATIVE SAMPLE PROBLEM MOCK-UPS

The geometry data for KENO-VI can often be described correctly in several ways. Some alternative geometry descriptions are given here for sample problems 12 and 13. (See Appendix F17.D.)

F17.5.7.1 Sample Problem 12, First Alternative

This mock-up maintains the same overall unit dimensions that were used in sample problem 12. In sample problem 12, the origin of Unit 1, the solution cylinder, is at the center of the unit; the origin of Units 2, 3, 4, and 5, the metal cylinders, are at the center of the cylinders. In this mock-up, the unit numbers remain the same and the origin of each unit is at the center of the unit. In each unit the cylinder is offset by specifying the position of its centerline relative to the origin of the unit.

```

READ GEOM
UNIT 1
CYLINDER 1 9.525 8.89 -8.89
CYLINDER 2 10.16 9.525 -9.525
CUBOID 3 10.875 -10.875 10.875 -10.875 10.24 -10.24
MEDIA 2 1 1
MEDIA 3 1 2 -1
MEDIA 0 1 3 -2
BOUNDARY 3
UNIT 2
CYLINDER 1 5.748 9.3975 -1.3675 ORIG X=4.285 Y=4.285
CUBOID 2 10.875 -10.875 10.875 -10.875 10.24 -10.24
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2

```

```

UNIT 3
CYLINDER 1 5.748 9.3975 -1.3675 ORIG X=4.285 Y=-4.285
CUBOID 2 10.875 -10.875 10.875 -10.875 10.24 -10.24
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
UNIT 4
CYLINDER 1 5.748 1.3675 -9.3975 ORIG X=4.285 Y=4.285
CUBOID 2 10.875 -10.875 10.875 -10.875 10.24 -10.24
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
UNIT 5
CYLINDER 1 5.748 1.3675 -9.3975 ORIG X=4.285 Y=-4.285
CUBOID 2 10.875 -10.875 10.875 -10.875 10.24 -10.24
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
GLOBAL UNIT 6
CUBOID 1 21.75 -21.75 21.75 -21.75 20.48 -20.48
ARRAY 1 PLACE 1 1 1 -10.875 -10.875 -10.24
BOUNDARY 1
END GEOM
READ ARRAY ARA=1 NUX=2 NUY=2 NUZ=2 FILL 2 1 3 1 4 1 5 1 END ARRAY

```

F17.5.7.2 Sample Problem 12, Second Alternative

In this mock-up, the outer boundaries of the system are made as close fitting as possible on all six faces. The origin of each unit is located at the center of the cylinder. The origin of the global unit is the point in the array where units 1 through 8 meet. Units 1, 3, 5, and 7 contain the metal cylinders. Units 2, 4, 6, and 8 contain the solution cylinders.

```

READ GEOM
UNIT 1
CYLINDER 1 5.748 5.3825 -5.3825
CUBOID 2 6.59 -5.748 6.59 -14.445 6.225 -13.54
MEDIA 1 1 1
MEDIA 0 1 2 -1
BOUNDARY 2
UNIT 2
CYLINDER 1 9.525 8.89 -8.89
CYLINDER 2 10.16 9.525 -9.525
CUBOID 3 10.16 -10.875 10.875 -10.16 10.24 -9.525
MEDIA 2 1 1
MEDIA 3 1 2 -1
MEDIA 0 1 3 -2

```

BOUNDARY 3
 UNIT 3
 CYLINDER 1 5.748 5.3825 -5.3825
 CUBOID 2 6.59 -5.748 14.444 -6.59 6.225 -13.54
 MEDIA 1 1 1
 MEDIA 0 1 2 -1
 BOUNDARY 2
 UNIT 4
 CYLINDER 1 9.525 8.89 -8.89
 CYLINDER 2 10.16 9.525 -9.525
 CUBOID 3 10.16 -10.875 10.16 -10.875 10.24 -9.525
 MEDIA 2 1 1
 MEDIA 3 1 2 -1
 MEDIA 0 1 3 -2
 BOUNDARY 3
 UNIT 5
 CYLINDER 1 5.748 5.3825 -5.3825
 CUBOID 2 6.59 -5.748 6.59 -14.445 13.54 -6.225
 MEDIA 1 1 1
 MEDIA 0 1 2 -1
 BOUNDARY 2
 UNIT 6
 CYLINDER 1 9.525 8.89 -8.89
 CYLINDER 2 10.16 9.525 -9.525
 CUBOID 3 10.16 -10.875 10.875 -10.16 9.525 -10.24
 MEDIA 2 1 1
 MEDIA 3 1 2 -1
 MEDIA 0 1 3 -2
 BOUNDARY 3
 UNIT 7
 CYLINDER 1 5.748 5.3825 -5.3825
 CUBOID 2 6.59 -5.748 14.445 -6.59 13.54 -6.225
 MEDIA 1 1 1
 MEDIA 0 1 2 -1
 BOUNDARY 2
 UNIT 8
 CYLINDER 1 9.525 8.89 -8.89
 CYLINDER 2 10.16 9.525 -9.525
 CUBOID 3 10.16 -10.875 10.16 -10.875 9.525 -10.24
 MEDIA 2 1 1
 MEDIA 3 1 2 -1
 MEDIA 0 1 3 -2
 BOUNDARY 3
 GLOBAL UNIT 9
 CUBOID 1 20.035 -12.748 20.67 -20.67 19.765 -19.765
 ARRAY 1 1 PLACE 1 1 1 -7.00 -6.225 -6.225
 BOUNDARY 1

END GEOM

READ ARRAY ARA=1 NUX=2 NUY=2 NUZ=2 FILL 6I1 8 END FILL END ARRAY

F17.5.7.3 Sample Problem 13, Alternative

This mock-up maintains the same overall unit dimensions that were used in sample problem 13, Appendix F17.D. In sample problem 13, the origin of the unit is located at the center of the ring in the x and y directions and the base of the ring in the z direction. The uranium metal cuboids are directly placed in the problem. In this mock-up, the problem is set up as an array of three units. The origin of Units 1 and 2 are located at the center of the cylinder. In Unit 3, the origin is at the center of the unit.

READ GEOM

UNIT 1

CUBOID 1 0.2566 -12.4434 6.35 -6.35 3.81 -3.81

CYLINDER 2 13.97 3.81 -3.81

CYLINDER 3 19.05 3.81 -3.81

CUBOID 4 19.05 -19.05 19.05 -19.05 3.81 -3.81

MEDIA 1 1 1

MEDIA 0 1 2 -1

MEDIA 1 1 3 -2 -1

MEDIA 0 1 4 -3 -2 -1

BOUNDARY 4

UNIT 2

CUBOID 1 12.4434 -0.2566 6.35 -6.35 4.28 -4.28

CYLINDER 2 13.97 4.28 -4.28

CYLINDER 3 19.05 4.28 -4.28

CUBOID 4 19.05 -19.05 19.05 -19.05 4.28 -4.28

MEDIA 1 1 1

MEDIA 0 1 2 -1

MEDIA 1 1 3 -2 -1

MEDIA 0 1 4 -3 -2 -1

BOUNDARY 4

UNIT 3

CUBOID 1 12.4434 -0.2566 6.35 -6.35 1.308 -1.308

CUBOID 2 19.05 -19.05 19.05 -19.05 1.308 -1.308

MEDIA 1 1 1

MEDIA 0 1 2 -1

BOUNDARY 2

GLOBAL UNIT 4

CUBOID 1 19.05 -19.05 19.05 -19.05 6.896 -11.90

ARRAY 1 1 PLACE 1 2 1 0.0 0.0 0.0

BOUNDARY 1

END GEOM

READ ARRAY ARA=1 NUX=1 NUY=1 NUZ=3 FILL 1 2 3 END ARRAY

F17.5.8 BIASING OR WEIGHTING DATA

Section F17.2.3 discusses the basis of weighting or biasing. The use of biasing data in reflected problems has been illustrated in Examples 9, 10, and 11 of Sect. F17.5.6. Section F17.4.7 discusses the input directions for entering biasing data.

Every MEDIA-type card requires a bias ID to associate that geometry region with a biasing or weighting function. A biasing or weighting function is a set of energy-dependent values of the average weight that are applicable in a given region. The default function for all bias IDs is constant through all energy groups and is defined to be the default value of weight average which can be specified in the parameter data. A bias ID can be associated with a biasing function, other than default, by specifying it in the biasing input data. This function can be chosen from the weighting library or can be input from biasing data. Table F17.4.5 lists the materials and energy-group structures for biasing functions available from the weighting library.

In general, the use of biasing should be restricted to external reflectors unless the user has generated correct biasing functions for other applications. Improper use of biasing functions can result in erroneous answers without giving any indication that they are invalid. Caution should be exercised in the generation and use of biasing functions.

Biasing functions are most applicable to thick external reflectors. Their use can significantly reduce the amount of computer time required to obtain answers in KENO-VI. If the user wishes to use a biasing function for a concrete reflector, for example, the following steps must be included in preparing the input data:

1. The geometry region data must define the shape and dimensions of the reflector, using the mixture ID for concrete and a sequence of bias IDs that associate the geometry region with the appropriate interval of the concrete weighting function. CAUTION: THE THICKNESS OF EACH REGION UTILIZING BIASING FUNCTIONS MUST MATCH OR VERY NEARLY MATCH THE INCREMENT THICKNESS OF THE WEIGHTING DATA. NO CHECK IS MADE ON THE REQUIREMENT. IT IS THE USER'S RESPONSIBILITY TO ENSURE CONSISTENCY.
2. Biasing data must be entered. These data must include the material ID for the reflector material (from Table F17.4.5 or as specified on cards) and a beginning and ending bias ID. The beginning bias ID is used to select the first set of energy-dependent average weights, and the subsequent sets of energy-dependent average weights are assigned consecutive IDs until the ending bias ID is reached.

Small deviations in reflector region thickness are allowed, such as using three generated regions with a thickness per region of 5.08 cm to generate a 15.24-cm-thick reflector of concrete, or using five generated regions with a thickness per region of 3.048 cm to generate a 15.24-cm-thick reflector of water. See Table F17.4.5 for a list of the increment thickness for each material in the weighting library. It is acceptable for the thickness of the last reflector, and thus the region, to be significantly different than the increment thickness. For example, a reflector card specifying five generated regions with a thickness per region of 3.0 cm could be followed by a reflector card specifying one region with a thickness per region of 0.24 cm. Assume material 2 is water and a 15.24-cm-thick cuboidal reflector of water surrounding a cube of material 1, 20 cm on a side, is desired. The required reflector description and biasing data could be entered as follows:

GLOBAL UNIT 1
CUBOID 1 6P10.0
CUBOID 2 6P13.0
CUBOID 3 6P16.0
CUBOID 4 6P19.0
CUBOID 5 6P22.0
CUBOID 6 6P25.0
CUBOID 7 6P25.24
MEDIA 1 1 1
MEDIA 2 2 2 -1
MEDIA 2 3 3 -2
MEDIA 2 4 4 -3
MEDIA 2 5 5 -4
MEDIA 2 6 6 -5
MEDIA 2 7 7 -6
BOUNDARY 7
READ BIAS ID=500 2 7 END BIAS

The same 15.24-cm-thick reflector can be described by including the extra 0.24 cm in the last region as shown below:

GLOBAL UNIT 1
CUBOID 1 6P10.0
CUBOID 2 6P13.0
CUBOID 3 6P16.0
CUBOID 4 6P19.0
CUBOID 5 6P22.0
CUBOID 6 6P25.24
MEDIA 1 1 1
MEDIA 2 2 2 -1
MEDIA 2 3 3 -2
MEDIA 2 4 4 -3
MEDIA 2 5 5 -4
MEDIA 2 6 6 -5
BOUNDARY 6
READ BIAS ID=500 2 6 END BIAS

Here the weighting functions associated with bias IDs 2, 3, 4, and 5 each have a thickness of 3.0 cm, corresponding exactly to the increment thickness for water in Table F17.4.5. Bias ID 6 is used for the last generated region, which is 3.24 cm thick.

The following examples illustrate the use of biasing data. Suppose the user wishes to use the weighting function for water from Table F17.4.5 for bias IDs 2 through 6. The biasing input data would then be:

READ BIAS ID=500 2 6 END BIAS

The energy-dependent values of weight average for the first 3-cm interval of water will be used for weighting the geometry regions that specify a bias of ID of 2. The energy-dependent values of weight average

for the second 3-cm interval of water will be used for geometry regions that specify a bias ID of 3, etc. Thus the energy-dependent values of weight average for the fifth 3-cm interval of water will be used for geometry regions that specify a bias ID of 6. Geometry regions that use bias IDs other than 2, 3, 4, 5, and 6 will use the default value of weight average that is constant for all energies as a biasing function.

Several sets of biasing data can be entered at once. Assume the user wishes to use the weighting function for concrete from Table F17.4.5 for bias IDs 2 through 4 and the weighting function for water for bias IDs 5 through 7. The appropriate input data block is:

READ BIAS ID=301 2 4 ID=500 5 7 END BIAS

The energy-dependent values of weight average for the first 5-cm interval of concrete will be used for the geometry regions that specify a bias ID of 2, the energy-dependent values of weight average for the second 5-cm interval of concrete will be used for the geometry regions that specify a bias ID of 3, and the energy-dependent values of weight average for the third 5-cm interval of concrete will be used for the geometry regions that specify a bias ID of 4. The energy-dependent values of weight average for the first 3-cm interval of water will be used for geometry regions that specify a bias ID of 5, the values for the second 3-cm interval of water will be used for geometry regions that specify a bias ID of 6, and the values for the third 3-cm interval of water will be used for geometry regions that specify a bias ID of 7. The default value of weight average will be used for all bias IDs outside the range 2 through 7.

If the biasing data block defines the same bias ID more than once, the value that is entered last supersedes previous entries. Assume the following data block is entered.

READ BIAS ID=400 2 7 ID=500 5 7 END BIAS

Then the data for paraffin (ID=400) will be used for bias IDs 2, 3, and 4, and the data for water (ID=500) will be used for bias IDs 5, 6, and 7.

EXAMPLE 1. USE OF BIASING DATA

Assume a 5-cm-radius sphere of material 2 is reflected by a 20-cm-thickness of material 1 (concrete). The concrete reflector is spherical and close fitting upon the sphere of material 2. The mixing table must specify material 1 and material 2. Material 1 must be defined as concrete. The geometry and biasing data should be entered as follows:

***READ GEOM
GLOBAL UNIT 1
SPHERE 1 5.0
SPHERE 2 10.0
SPHERE 3 15.0
SPHERE 4 20.0
SPHERE 5 25.0
MEDIA 2 1 1
MEDIA 1 2 2 -1
MEDIA 1 3 3 -2
MEDIA 1 4 4 -3
MEDIA 1 5 5 -4
BOUNDARY 5***

END GEOM
READ BIAS ID=301 2 5 END BIAS

In the above example, the bias ID for the first reflector region is 2; the second, 3; the third, 4; and the fourth, 5. The biasing data block specifies that the biasing function for material ID 301 (concrete) will be used from the weighting library. The energy-dependent weighting function of the first 5 cm of concrete is represented by bias ID 2, the second 5-cm interval by bias ID 3, the third 5-cm interval by bias ID 4, and the fourth 5-cm interval by bias ID 5.

F17.5.9 PRINTER PLOTS

Printer plots are generated only if a plot data block has been entered for the problem and PLT=NO has not been entered in the parameter data or the plot data. See Sect. F17.4.11 for a description of plot data. When a printer plot is to be made, the user **MUST** correctly specify the upper left-hand corner of the plot with respect to the origin of the plot. The origin of a plot is defined as the origin of the global unit.

Printer plots can represent mixture numbers, unit numbers or bias ID numbers. A title can be entered for each plot. If plot titles are omitted, the title of the KENO-VI case will be printed for each plot title until a plot title is entered. If a plot title is entered and a subsequent plot title is omitted, the last plot title prior to the omitted one will be used for the omitted one.

The upper-left and lower-right coordinates define the area (i.e., the slice and its location) for which the plot is to be made. The direction cosines across the page and the direction cosines down the page define the direction of the vector across the page and the vector down the page with respect to the geometry coordinate system. One of the simplest ways of generating a plot is to specify the desired coordinates of the upper-left and lower-right corners of the plot. Determine which plot axis is to be across the page and which is to be down. The sign of the direction cosine should be consistent with the direction of that component when moving from the upper-left to lower-right corner. For example, to draw a plot of an x-z slice at y=5.0 with x across the page and z down the page for a system whose x coordinates range from 0.0 to 10.0 and whose z coordinates range from 0.0 to 20.0, the upper-left coordinate could be XUL=0.0 YUL=5.0 ZUL=20.0 and the lower-right coordinates could be XLR=10.0 YLR=5.0 ZLR=0.0. Since x is to be plotted across the page with x=0.0 at the left and x=10.0 at the right, only the x component of the direction cosines across the page need be entered. It should be positive because going from 0.0 to 10.0 is moving in the positive direction. Thus UAX=1.0 would be entered for the direction cosines across the page. VAX and WAX could be omitted. Z is to be plotted down the page with z=20.0 at the top and z=0.0 at the bottom. Therefore, only the z component of the direction cosines down the page need to be defined. It should be negative because moving from 20.0 to 0.0 is moving in the negative direction. Thus WDN=-1.0 would be entered for the direction cosines down the page. UDN and VDN could be omitted. The sign of the direction cosines should be consistent with the coordinates of the upper-left and lower-right corners in order to get a plot.

It is not necessary that the plot be made for a slice orthogonal to one of the axes. Plots can be made of slices cut at any desired angle, but the user should exercise caution and be well aware of the distortion of shapes that can be introduced. (Nonorthogonal slices through cylinders plot as ellipses.)

The user can specify the horizontal and vertical spacing between points on the plot. It is usually advisable to enter one or the other. Entering both of them can cause distortion of the plot. DLX= is used to specify the horizontal spacing between points, and DLD= is used to specify the vertical spacing between points. When only one of them is specified, the code calculates the correct value of the other such that the plot will not be distorted. The spacing for an undistorted plot is defined as $DLD \cdot LPI = DLX \cdot CPI$, where LPI is the number

of lines per inch printed vertically and CPI is the number of characters per inch horizontally. These parameters are a function of the printer or print chain. The vertical distortion factor, VDIS, is then defined by $VDIS = (DLD * LPI) / (DLX * CPI)$. The code then calculates the number of intervals that will be printed across the page and down the page if both the upper-left and lower-right coordinates of the plot were entered. In some instances, it can be desirable to distort a plot by entering both DLX and DLD. It might be desirable to compress one dimension relative to another. If $DLX=0.5$ and $DLD=5.0$ are entered as data for a printer that prints 10 characters per inch across and 8 lines per inch down, the portion of the plot that is printed in the vertical direction will be reduced by a factor of 8 relative to the portion printed in the horizontal direction $((5.0 * 8) / (0.5 * 10))$. That is, if the coordinates specify a perfect square, the plot will be a rectangle that is about 8 times as wide as it is tall.

DLX or DLD can be specified by the user to be small enough to show the desirable detail in the plot. The plot is generated by starting at the upper-left corner of the plot and generating a point every DLX across the page; then moving down DLD and repeating the generation of the points across the page.

NAX specifies the number of intervals that will be printed across the page. It may be convenient for the user to specify the number of characters that can be printed across the page on the printer that will be used. Larger plots can be created by specifying multiples of this number. In that case, the plot must be taped together to see the overall plot. The plot will print one page wide and full length. Then the next page width and full length will be printed, etc., until the entire plot is completed.

NDN specifies the number of intervals that will be printed down the page. If both NAX and NDN are entered, the plot may be distorted. If one of them is entered, the value of the other will be calculated so the plot will not be distorted.

LPI, the number of lines per inch that are printed on a page, can be entered to be consistent with the printer that will be used. The default value is 8 lines per inch. This parameter must be entered only once for a problem. It should be entered in the data for the first plot, so all the plots will be printed in the same manner.

When a plot is being made, the first character represents the coordinates of the upper-left corner. The value of DELV is added to the coordinate that is to be printed across the page, and the next character is printed. DELV is added to that value to determine the location of the next character. That is, a point is determined every DELV across the page and a character is printed for each point. When a line has been completed, a new line is begun DELU from the first line. This procedure is repeated until the plot is complete. Some examples of printer plots are shown in Sects. F17.5.6.1, F17.5.6.2, F17.5.6.3, and F17.5.6.4. Further examples are shown below.

EXAMPLE 1. SINGLE UNIT WITH CENTERED ORIGIN

Consider two concentric cylinders in a cuboid. The inner cylinder is 5.2 cm in diameter. The outer cylinder has an inside diameter of 7.2 cm and an outside diameter of 7.6 cm. Both cylinders are 30 cm high. They are contained in a tight-fitting box whose wall thickness is 0.5 cm and whose top and bottom are each 1.0 cm thick. The inner cylinder is composed of mixture 1, the outer cylinder is made of mixture 4, and the box is made of mixture 2. The problem can be described with its origin at the center of the inner cylinder. The problem description for this arrangement is shown below:

=KENOVI

SINGLE UNIT CONCENTRIC CYLINDERS IN CUBOID WITH ORIGIN AT CENTER

READ PARAM RUN=NO LIB=41 TME=0.5 END PARAM

READ MIXT SCT=1 MIX=1 92500 4.7048-2 MIX=2 200 1.0 MIX=3 502 0.1

MIX=4 200 1.0

END MIXT

```

READ GEOM
GLOBAL UNIT 1
CYLINDER 1 2.6 2P15.0
CYLINDER 2 3.6 2P15.0
CYLINDER 3 3.8 2P15.0
CUBOID 4 4P3.8 2P15.0
CUBOID 5 4P4.3 2P16.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
MEDIA 4 1 3 -2 -1
MEDIA 0 1 4 -3 -2 -1
MEDIA 2 1 5 -4
BOUNDARY 5
END GEOM
READ PLOT TTL='X-Y SLICE AT Z MIDPOINT. SINGLE UNIT CONCENTRIC CYLS.'
XUL=-4.6 YUL=4.6 ZUL=0.0 XLR=4.6 YLR=-4.6 ZLR=0.0
UAX=1.0 VDN=-1.0 NAX=130 NCH=' *-X' END
PIC=UNIT NCH='01' END
END PLOT
END DATA
END

```

The plot data block included above is set up to draw a mixture map of an x-y slice taken at the half-height ($z=0.0$) and a unit map for the same slice. The code will print question marks for points outside the range of the problem geometry description. By setting the plot dimensions slightly larger than the geometry dimensions, a border of question marks will be printed around the specified plot. This border verifies that the outer boundaries of the geometry are contained within the plot dimensions. In the above example, the geometry dimensions extend from $x=-4.3$ to $x=4.3$, from $y=-4.3$ to $y=4.3$, and from $z=-16.0$ to $z=16.0$. An x-y slice is to be printed at the half-height ($z=0.0$). The desired plot data set the upper left-hand corner of the plot to be $x=-4.6$ and $y=4.6$. The lower right-hand corner of the plot is specified as $x=4.6$ and $y=-4.6$. These data are entered by specifying the upper left-hand corner as $XUL=-4.6$ $YUL=4.6$ $ZUL=0.0$ and the lower right-hand corner as $XLR=4.6$ $YLR=-4.6$ $ZLR=0.0$. It is desired to print x across the page and y down the page. Therefore, the x direction cosine is specified across the page, in the direction from $x=-4.6$ to $x=4.6$ as $UAX=1.0$. The y direction cosine is specified down the page, from $y=4.6$ to $y=-4.6$ as $VDN=-1.0$. It was desirable for the plot to be one page wide (130 characters), so the number of characters across the page was specified as $NAX=130$. An arbitrary choice was made to print a blank for a void, a * for mixture 1, a - for mixture 2, and a . for mixture 4. Mixture 3 was not used in the problem, so a character did not have to be entered for it in the character string. Thus a character string of $NCH=' *-.'$ would have been sufficient, but a string of $NCH=' *-X'$ was entered. Since only three mixtures were used, only the first four characters were utilized. The blank represents a void, the * represents the smallest mixture number used in the problem (mixture 1), the - represents the next smallest mixture number used in the geometry description (mixture 2), and the . represents the largest mixture number used in the geometry (mixture 4). The resultant printer plot and associated data are shown in Figs. F17.3.31 and F17.3.32. A second printer plot covering the same area shows a unit map rather than a mixture map. This unit map and associated data are shown in Figs. F17.3.33 and F17.3.34.

x-y slice at z midpoint. single unit concentric cyls.

mixture map

```
mixture 0 1 2 4
symbol * - .
      upper left      lower right
      coordinates      coordinates
x      -4.6000E+00      4.6000E+00
y      4.6000E+00      -4.6000E+00
z      0.0000E+00      0.0000E+00
      u axis      v axis
      (down)      (across)
x      .00000      1.00000
y      -1.00000      .00000
z      .00000      .00000
nu= 86  nv= 130  delu= 1.0615E-01  delv= 7.0769E-02
```

Figure F17.5.31 Associated data for single unit mixture map

Figure F17.5.32 Mixture map of single unit with centered origin

x-y slice at z midpoint. single unit concentric cyls.

unit 1		unit map	
symbol 1			
	upper left		lower right
	coordinates		coordinates
x	-4.6000E+00		4.6000E+00
y	4.6000E+00		-4.6000E+00
z	0.0000E+00		0.0000E+00
	u axis		v axis
	(down)		(across)
x	.00000		1.00000
y	-1.00000		.00000
z	.00000		.00000
nu=	86	nv=	130
		delu=	1.0698E-01
		delv=	7.0769E-02

Figure F17.5.33 Associated data for single unit map

Figure F17.5.34 Unit map printer plot for single unit with centered origin

Figure F17.5.34 shows a block of 1's surrounded by a border of ?'s. This arrangement indicates that the entire slice specified in the plot data was part of Unit 1. For this problem the entire volume is Unit 1.

EXAMPLE 2. SINGLE UNIT WITH OFFSET ORIGIN

The physical problem is the same as that described in Example 1, two concentric cylinders in a cuboid. The dimensions are exactly the same. The difference is in the choice of the origin. In this geometry description, the origin was specified as the most negative point of the unit. Thus the cylinders must have an origin specified to center them in the cuboid, and the cuboid extends from 0.0 to 8.6 in x and y and from 0.0 to 32 in z, as shown in the problem description below:

```
=KENOVI
SINGLE UNIT CONCENTRIC CYLINDERS IN CUBOID WITH ORIGIN AT CORNER
READ PARAM RUN=NO LIB=41 TME=0.5 END PARAM
READ MIXT SCT=1 MIX=1 92500 4.7048-2 MIX=2 200 1.0 MIX=3 502 0.1
MIX=4 200 1.0
END MIXT
READ GEOM
GLOBAL UNIT 1
CYLINDER 1 2.6 31.0 1.0 ORIGIN X=4.3 Y=4.3
CYLINDER 2 3.6 31.0 1.0 ORIGIN X=4.3 Y=4.3
CYLINDER 3 3.8 31.0 1.0 ORIGIN X=4.3 Y=4.3
CUBOID 4 8.1 0.5 8.1 0.5 31.0 1.0
CUBOID 5 8.6 0.0 8.6 0.0 32.0 0.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
MEDIA 4 1 3 -2 -1
MEDIA 0 1 4 -3 -2 -1
MEDIA 2 1 5 -4
BOUNDARY 5
END GEOM
READ PLOT TTL='X-Y SLICE AT Z MIDPOINT. SINGLE UNIT CONCENTRIC CYLS.'
XUL=-0.3 YUL=8.9 ZUL=16.0 XLR=8.9 YLR=-0.3 ZLR=16.0
UAX=1.0 VDN=-1.0 NAX=130 NCH=' *.X' END
PIC=UNIT NCH='01' END
END PLOT
END DATA
END
```

The plot data included above will draw a mixture map of an x-y slice taken at the half-height ($z=16.0$). It will also draw a unit map of the same slice. The plot dimensions extend 0.3 cm beyond the problem dimensions to provide a border of question marks around the plot. The associated plot data specification for the mixture map is shown in Fig. F17.5.35, the mixture map is shown in Fig. F17.5.36, and the associated plot data for the unit map is shown in Fig. F17.5.37. The unit map is identical to Fig. F17.5.34 and is not included. Note that Fig. F17.5.36 is identical to Fig. F17.5.29.

x-y slice at z midpoint. single unit concentric cyls.

```

mixture 0 1 2 4
symbol * - .
upper left      lower right
coordinates      coordinates
x   -3.0000E-01  8.9000E+00
y   8.9000E+00  -3.0000E-01
z   1.6000E+01  1.6000E+01
      u axis      v axis
      (down)      (across)
x       .00000    1.00000
y      -1.00000    .00000
z       .00000    .00000
nu=   86  nv=  130  delu= 1.0615E-01  delv= 7.0769E-02

```

Figure F17.5.35 Associated data for mixture map of single unit with offset origin

Figure F17.5.36 Mixture map of single unit with offset origin

x-y slice at z midpoint. single unit concentric cyls.

unit 1		unit map	
symbol 1			
	upper left coordinates		lower right coordinates
x	-3.0000E-01		8.9000E+00
y	8.9000E+00		-3.0000E-01
z	1.6000E+01		1.6000E+01
	u axis (down)		v axis (across)
x	.00000		1.00000
y	-1.00000		.00000
z	.00000		.00000
nu=	86	nv=	130
		delu=	1.0698E-01
		delv=	7.0769E-02

Figure F17.5.37 Associated data for unit map of a single unit with offset origin

EXAMPLE 3. A $2 \times 2 \times 2$ UNREFLECTED ARRAY OF CONCENTRIC CYLINDERS IN CUBOIDS

The physical representation of this example is a $2 \times 2 \times 2$ array of the configuration described in Example 1 of this section. The input data description for this array is given below:

```
=KENOVI
2x2x2 BARE ARRAY OF CONCENTRIC CYLINDERS IN CUBOID
READ PARAM RUN=NO LIB=41 TME=8.5 END PARAM
READ MIXT SCT=1 MIX=1 92500 4.7048-2 MIX=2 200 1.0 MIX=3 502 0.1
MIX=4 200 1.0
END MIXT
READ GEOM
UNIT 1
CYLINDER 1 2.6 2P15.0
CYLINDER 2 3.6 2P15.0
CYLINDER 3 3.8 2P15.0
CUBOID 4 4P3.8 2P15.0
CUBOID 5 4P4.3 2P16.0
MEDIA 1 1 1
MEDIA 0 1 2 -1
MEDIA 4 1 3 -2 -1
MEDIA 0 1 4 -3 -2 -1
MEDIA 2 1 -5 -4
BOUNDARY 5
GLOBAL UNIT 2
CUBOID 1 17.2 0.0 17.2 0.0 64.0 0.0
ARRAY 1 1 PLACE 1 1 1 4.3 4.3 16.0
BOUNDARY 1
END GEOM
READ ARRAY ARA=1 NUX=2 NUY=2 NUZ=2 FILL F1 END FILL END ARRAY
```



```

READ PLOT TTL='X-Y SLICE AT HALF HEIGHT OF BOTTOM LAYER'
XUL=-0.3 YUL=17.5 ZUL=16.0 XLR=17.5 YLR=-0.3 ZLR=16.0
UAX=1.0 VDN=-1.0 NAX=130 NCH=' *-X' END
TTL='X-Z SLICE THROUGH FRONT ROW, Y=12.9.'
XUL=-1.0 YUL=12.9 ZUL=65.0 XLR=18.2 YLR=12.9 ZLR=-1.0
UAX=1.0 WDN=-1.0 NAX=60 END
END PLOT
END DATA
END

```

As stated at the beginning of Sect. F17.5.9, the origin of the plot is located at the most negative point of the array. Each individual unit in the array is 8.6 cm wide in x and y and is 32 cm high in z. Since the array has two units stacked in each direction, the array is 17.2 cm wide in x and y and is 64 cm high. Therefore, the array exists from x=0.0 to x=17.2, from y=0.0 to y=17.2 and from z=0.0 to z=64.0.

The first printer plot is to generate an x-y slice through the array at the half-height of the first layer, as shown in Fig. F17.5.38. This plot occurs at z=16.0 cm. It is desirable to define the outer boundaries of the array by setting the boundaries of the plot larger than the array. In this case, the boundaries were arbitrarily set 0.3 cm larger than the array, resulting in a border of question marks around the array. If the plot were to exclude everything external to the array, the following coordinates could have been entered: XUL=0.0 YUL=17.2 ZUL=16.0 XLR=17.2 YLR=0.0 ZLR=16.0. These coordinate choices would have eliminated all the question marks. The existing picture was made using XUL=-0.3 YUL=17.5 ZUL=16.0 XLR=17.5 YLR=-0.3 ZLR=16.0.

The second printer plot is to generate an x-z slice through the center of the front row of the array. In order to obtain a boundary of question marks, the coordinates of x and z were arbitrarily set 1.0 cm larger than the boundaries of the array. The center of the front row occurs at y=12.9. The coordinates of the plot were: XUL=-1.0 ZUL=65.0 YUL=12.9 XLR=18.2 ZLR=-1.0 YLR=12.9. The plot was defined to be half a page wide by entering NAX=60. The resultant mixture map is shown in Fig. F17.5.39.

EXAMPLE 4. A $2 \times 2 \times 2$ REFLECTED ARRAY WITH THE ORIGIN AT THE MOST NEGATIVE POINT OF THE ARRAY

The array is the array described in Example 3 of this section and has a 15.24-cm (6-in.) concrete reflector on all faces. The input data description for this array is given below.

```

=KENOV
2x2x2 REFLECTED ARRAY OF CONCENTRIC CYLINDERS IN CUBOID
READ PARAM RUN=NO LIB=41 TME=0.5 END PARAM
READ MIXT SCT=1 MIX=1 92500 4.7048-2 MIX=2 200 1.0 MIX=3 301 1.0
MIX=4 200 1.0
END MIXT
READ GEOM
UNIT 1
CYLINDER 1 2.6 2P15.0
CYLINDER 2 3.6 2P15.0
CYLINDER 3 3.8 2P15.0
CUBOID 4 4P3.8 2P15.0
CUBOID 5 4P4.3 2P16.0
MEDIA 1 1 1

```

Figure F17.5.38 x-y plot of $2 \times 2 \times 2$ bare array

Figure F17.5.39 x-z plot of $2 \times 2 \times 2$ bare array

```

MEDIA 0 1 2 -1
MEDIA 4 1 3 -2 -1
MEDIA 0 1 4 -3 -2 -1
MEDIA 2 1 5 -4
BOUNDARY 5
GLOBAL UNIT 2
CUBOID 1 17.2 0.0 17.2 0.0 64.0 0.0
CUBOID 2 22.20 -5.00 22.20 -5.00 69.00 -5.00
CUBOID 3 27.20 -10.00 27.20 -10.00 74.00 -10.00
CUBOID 4 32.20 -15.00 32.20 -15.00 79.00 -15.00
CUBOID 5 32.44 -15.24 32.44 -15.24 79.24 -15.24
ARRAY 1 1 PLACE 1 1 1 4.3 4.3 16.0
MEDIA 3 2 2 -1
MEDIA 3 3 3 -2
MEDIA 3 4 4 -3
MEDIA 3 5 5 -4
BOUNDARY 5
END GEOM
READ BIAS ID=301 2 5 END BIAS
READ ARRAY ARA=1 NUX=2 NUY=2 NUZ=2 FILL F1 END FILL END ARRAY
READ PLOT TTL='X-Y SLICE AT HALF HEIGHT OF BOTTOM LAYER.INCLUDES REFL.'
XUL=-16.24 YUL=33.44 ZUL=16.0 XLR=33.44 YLR=-16.24 ZLR=16.0
UAX=1.0 VDN=-1.0 NAX=130 NCH='*-X' END
TTL='X-Y SLICE AT HALF HEIGHT OF BOTTOM LAYER, INCLUDE 3 CM OF REFL.'
XUL=-3.0 YUL=20.2 ZUL=16.0 XLR=20.2 YLR=-3.0 ZLR=16.0
UAX=1.0 VDN=-1.0 NAX=130 NCH='*-X' END
TTL='X-Z SLICE THROUGH FRONT ROW, Y=12.9. INCLUDE REFLECTOR'
XUL=-16.24 YUL=12.9 ZUL=80.24 XLR=33.44 YLR=12.9 ZLR=-16.24
UAX=1.0 WDN=-1.0 NAX=130 END
TTL='X-Z SLICE THROUGH FRONT ROW, Y=12.9. INCLUDE 3 CM OF REFLECTOR'
XUL=-3.0 YUL=12.9 ZUL=67.0 XLR=20.2 YLR=12.9 ZLR=-3.0
UAX=1.0 WDN=-1.0 NAX=130 END
END PLOT
END DATA
END

```

The ARRAY record, associated with the first geometry record in global unit 2, specifies the coordinates of the most negative point of the array to be (0.0,0.0,0.0) and the most positive point to be (17.2,17.2,64.0). Thus the reflected array extends from -15.24 cm to +32.44 cm in x and y and from -15.24 to +79.24 in z.

The first printer plot for this example shows an x-y slice through the array and reflector at the half-height of the bottom layer. A border of question marks is used to verify that the entire reflector has been shown. This border is accomplished by arbitrarily setting the picture boundaries 1 cm beyond the reflector boundaries. The coordinates used for this plot are: XUL = -16.24 YUL = 33.44 ZUL = 16.0 XLR = 33.44 YLR = -16.24 ZLR = 16.0. The plot data description is shown in Fig. F17.5.40, and the plot is shown in Fig. F17.5.41.

x-y slice at half height of bottom layer includes refl.

```

                                mixture map
mixture 0 1 2 3 4
symbol  * - . x
        upper left      lower right
        coordinates      coordinates
x      -1.6240E+01      3.3440E+01
y      3.3440E+01      -1.6240E+01
z      1.6000E+01      1.6000E+01
        u axis          v axis
        (down)          (across)
x          .00000      1.00000
y         -1.00000      .00000
z          .00000      .00000
nu=   86   nv=  130   delu= 5.7323E-01   delv= 3.8215E-01
```

Figure F17.5.40 Plot data for x-y slice of example 4

Figure F17.5.41 x-y plot of $2 \times 2 \times 2$ reflected array

The next printer plot is the same as the previous plot, except the plot includes only the first 3 cm of the reflector. This results in the picture being large enough to show more detail. The coordinates used for this plot are: XUL=-3.0 YUL=20.2 ZUL=16.0 XLR=20.2 YLR=-3.0 ZLR=16.0. This plot data description is given in Fig. F17.5.42, and the plot is shown in Fig. F17.5.43.

x-y slice at half height of bottom layer, include 3 cm of refl.

mixture					mixture map	
	0	1	2	3	4	
symbol	*	-	.	.	x	
	upper left			lower right		
	coordinates			coordinates		
x	-3.0000E+00			2.0200E+01		
y	2.0200E+01			-3.0000E+00		
z	1.6000E+01			1.6000E+01		
	u axis			v axis		
	(down)			(across)		
x	.00000			1.00000		
y	-1.00000			.00000		
z	.00000			.00000		
nu=	86	nv=	130	delu=	2.6769E-01	delv= 1.7846E-01

Figure F17.5.42 Plot data for enlarged x-y slice of example 4

Figure F17.5.43 Enlarged x-y plot of $2 \times 2 \times 2$ reflected array

The third printer plot for this example is an x-z slice through the center of the front row. An extra 1 cm is included in the coordinates to provide a border of question marks around the plot. The coordinates are: XUL=-16.24 YUL=12.9 ZUL=80.24 XLR=33.44 YLR=12.9 ZLR=-16.24. The resultant plot data and plot are shown in Figs. F17.5.44 and F17.5.45.

x-z slice through front row, y=12.9, including reflector.

mixture map

mixture	0	1	2	3	4
symbol	*	-	.	.	x
	upper left		lower right		
	coordinates		coordinates		
x	-1.6240E+01		3.3440E+01		
y	1.2900E+01		1.2900E+01		
z	8.0240E+01		-1.6240E+01		
	u axis		v axis		
	(down)		(across)		
x	.00000		1.00000		
y	.00000		.00000		
z	-1.00000		.00000		
nu=	168	nv=	130	delu=	5.7323E-01 delv= 3.8215E-01

Figure F17.5.44 Plot data for x-z slice of example 4

Figure F17.5.45 x-z plot for $2 \times 2 \times 2$ reflected array

The last printer plot for this example is the same as the previous one, except only 3 cm of the reflector is included in the plot. The plot data and associated plot are shown in Figs. F17.5.46 and F17.5.47.

x-z slice through front row, y=12.9, include 3 cm of reflector.

mixture map

mixture	0	1	2	3	4
symbol	*	-	.	.	x
	upper left		lower right		
	coordinates		coordinates		
x	-3.0000E+00		2.0200E+01		
y	1.2900E+01		1.2900E+01		
z	6.7000E+01		-3.0000E+00		
	u axis		v axis		
	(down)		(across)		
x	.00000		1.00000		
y	.00000		.00000		
z	-1.00000		.00000		
nu=	261	nv=	130	delu=	2.6769E-01 delv= 1.7846E-01

Figure F17.5.46 Plot data for enlarged x-z slice of example 4

Figure F17.5.47 Enlarged x-z plot of $2 \times 2 \times 2$ reflected array

0.04267 minutes were required for this picture. total elapsed time is .12800 minutes.

Figure F17.5.47 (continued)

EXAMPLE 5. A $2 \times 2 \times 2$ REFLECTED ARRAY WITH THE ORIGIN CENTERED IN THE ARRAY

This example is physically identical to Example 4. The difference is in the specification of the origin. The bare array is 17.2 cm wide in x and y and 64 cm high. The origin (0,0,0) can be placed at the exact center of the array by specifying the most negative point of the array as $x=-8.6$, $y=-8.6$ and $z=-32.0$. This positioning is done using the CUBOID card in association with the PLACE section of the ARRAY card. Because the origin is located at a different position, the coordinates of the plots will also be different. The input data description for this example is given below.

```
=KENOVI
2x2x2 REFLECTED ARRAY OF CONCENTRIC CYLINDERS IN CUBOID
READ PARAM RUN=NO LIB=41 TME=0.5 END PARAM
READ MIXT SCT=1 MIX=1 92500 4.7048-2 MIX=2 200 1.0 MIX=3 301 1.0
MIX=4 200 1.0
END MIXT
READ GEOM
UNIT 1
CYLINDER 1 2.6 2P15.0
CYLINDER 2 3.6 2P15.0
CYLINDER 3 3.8 2P15.0
CUBOID 4 4P3.8 2P15.0
CUBOID 5 4P4.3 2P16.0
MEDIA 1 1
MEDIA 0 1 2 -1
MEDIA 4 1 3 -2 -1
MEDIA 0 1 4 -3 -2 -1
MEDIA 2 1 5 -4
BOUNDARY 5
GLOBAL UNIT 2
CUBOID 1 8.6 -8.6 8.6 -8.6 32.0 -32.0
CUBOID 2 13.6 -13.6 13.6 -13.6 37.0 -37.0
CUBOID 3 18.6 -18.6 18.6 -18.6 42.0 -42.0
CUBOID 4 23.6 -23.6 23.6 -23.6 47.0 -47.0
CUBOID 5 23.84 -23.84 23.84 -23.84 47.24 -47.24
ARRAY 1 1 PLACE 1 1 1 -4.3 -4.3 -16.0
MEDIA 3 2 2 -1
MEDIA 3 3 3 -2
MEDIA 3 4 4 -3
MEDIA 3 5 5 -4
BOUNDARY 5
END GEOM
READ BIAS ID=301 2 5 END BIAS
READ ARRAY ARA=1 NUX=2 NUY=2 NUZ=2I FILL F1 END FILL END ARRAY
READ PLOT TTL='X-Y SLICE AT HALF HEIGHT OF BOTTOM LAYER INCLUDES REFL.'
XUL=-24.84 YUL=24.84 ZUL=-8.0 XLR=24.84 YLR=-24.84 ZLR=-8.0
UAX=1.0 VDN=-1.0 NAX=130 NCH='*=X' END
TTL='X-Y SLICE AT HALF HEIGHT OF BOTTOM LAYER, INCLUDE 3 CM OF REFL.'
```

```

XUL=-11.6 YUL=11.6 ZUL=-8.0 XLR=11.6 YLR=-11.6 ZLR=-8.0
UAX=1.0 VDN=-1.0 NAX=130 NCH='*.X' END
TTL='X-Z SLICE THROUGH FRONT ROW. Y=4.3 INCLUDE REFLECTOR'
XUL=-24.84 YUL=4.3 ZUL=48.24 XLR=24.84 YLR=4.3 ZLR=-48.24
UAX=1.0 WDN=-1.0 NAX=130 END
TTL='X-Z SLICE THROUGH FRONT ROW, Y=4.3 INCLUDE 3 CM OF REFLECTOR'
XUL=-11.6 YUL=4.3 ZUL=35.0 XLR=11.6 YLR=4.3 ZLR=-35.0
UAX=1.0 WDN=-1.0 NAX=130 END
END PLOT
END DATA
END

```

The first printer plot for this example covers identically the same area as the first printer plot for Example 4. The plot data for this plot and the actual plot are given in Figs. F17.5.48 and F17.5.49.

```

x-y slice at half height of bottom layer. includes refl.

mixture map

mixture 0 1 2 3 4
symbol * = . x
      upper left      lower right
      coordinates      coordinates
x      -2.4840E+01      2.4840E+01
y      2.4840E+01      -2.4840E+01
z      -8.0000E+00      -8.0000E+00
      u axis      v axis
      (down)      (across)
x      .00000      1.00000
y      -1.00000      .00000
z      .00000      .00000
nu= 86  nv= 130  delu= 5.7323E-01  delv= 3.8215E-01

```

Figure F17.5.48 Plot data for x-y slice of example 5

Figure F17.5.49 The x-y plot of $2 \times 2 \times 2$ reflected array with centered origin

The Example 5 plot data and associated plots for an enlarged x-y plot, an x-z plot and an enlarged x-z plot are given in Figs. F17.5.50 through F17.5.55.

x-y slice at half height of bottom layer, include 3 cm of refl.

mixture map

mixture	0	1	2	3	4
symbol	*	-	.	x	
	upper left		lower right		
	coordinates		coordinates		
x	-1.1600E+01		1.1600E+01		
y	1.1600E+01		-1.1600E+01		
z	-8.0000E+00		-8.0000E+00		
	u axis		v axis		
	(down)		(across)		
x	.00000		1.00000		
y	-1.00000		.00000		
z	.00000		.00000		
nu=	86	nv=	130	delu=	2.6769E-01 delv= 1.7846E-01

Figure F17.5.50 Plot data for an enlarged x-y slice of example 5

Figure F17.5.51 Enlarged z-y plot of $2 \times 2 \times 2$ reflected array with centered origin

```

x-z slice through front row. y=4.3  include reflector
                                mixture map

mixture  0 1 2 3 4
symbol   * - . x
          upper left      lower right
          coordinates      coordinates
x        -2.4840E+01      2.4840E+01
y         4.3000E+00      4.3000E+00
z         4.8240E+01     -4.8240E+01
          u axis          v axis
          (down)         (across)
x          .00000         1.00000
y          .00000         .00000
z         -1.00000         .00000
nu= 168   nv= 130   delu= 5.7323E-01   delv= 3.8215E-01

```

Figure F17.5.52 Plot data for x-z slice of example 5

Figure F17.5.53 x-z plot of reflected $2 \times 2 \times 2$ array with centered origin

x-z slice through front row, y=4.3, include 3 cm of reflector

mixture map

```
mixture 0 1 2 3 4
symbol * - . x
      . upper left      lower right
      coordinates      coordinates
x      -1.1600E+01      1.1600E+01
y      4.3000E+00      4.3000E+00
z      3.5000E+01      -3.5000E+01
      u axis      v axis
      (down)      (across)
x      .00000      1.00000
y      .00000      .00000
z      -1.00000      .00000
nu= 261      nv= 130      delu= 2.6769E-01      delv= 1.7846E-01
```

Figure F17.5.54 Plot data for enlarged x-z slice of example 5

Figure F17.5.55 Enlarged x-z plot of reflected $2 \times 2 \times 2$ array with centered origin

Figure F17.5.55 (continued)

EXAMPLE 6. NESTED HOLES

Refer to the nested hole description of Sect. F17.5.6.2. The mixture map for this problem is shown in two parts in Figs. F17.5.11 and F17.5.12. This example is one that involves a reasonably complicated placement of units; therefore, it might be useful to the user to generate both a mixture map and a unit map for the problem. Because an enlarged printer plot of the mixture map was already presented in Figs. F17.5.11 and F17.5.12, the mixture map in this section was reduced to fit on one page width by changing NAX from 260 to 130. The resultant mixture map is shown in Fig. F17.5.56. The plot data and actual plot for the unit map are shown in Figs. F17.5.57 and F17.5.58. The data description for Example 6 follows.

Figure F17.5.56 Mixture map of nested holes problem

x-y slice at z midpoint. nested holes, unit map.

unit map

```
unit 1 2 3
symbol 1 - .
      upper left      lower right
      coordinates    coordinates
x      -4.1000E+00      4.1000E+00
y       4.1000E+00     -4.1000E+00
z       0.0000E+00      0.0000E+00
      u axis      v axis
      (down)     (across)
x       .00000      1.00000
y      -1.00000      .00000
z       .00000      .00000
nu=   86   nv= 130   delu= 9.5349E-02   delv= 6.3077E-02
```

Figure F17.5.57 Plot data for unit map of nested holes

Figure F17.5.58 Unit map of nested holes problem

=KENOVI
 NESTED HOLES SAMPLE
 READ PARAM RUN=NO LIB=41 TME=0.5 END PARAM
 READ MIXT SCT=1 MIX=1 92500 4.7048-2 MIX=2 200 1.0 MIX=3 502 0.1
 MIX=4 200 1.0
 END MIXT
 READ GEOM
 UNIT 1
 CYLINDER 1 0.1 2P15.0
 CYLINDER 2 0.1 2P15.0 ORIGIN Y=-0.4
 CYLINDER 3 0.1 2P15.0 ORIGIN X=0.4
 CYLINDER 4 0.1 2P15.0 ORIGIN Y=0.4
 CYLINDER 5 0.1 2P15.0 ORIGIN X=-0.4
 CUBOID 6 2P0.1 2P0.05 2P15.0 ORIGIN X=-0.2
 CUBOID 7 2P0.1 2P0.05 2P15.0 ORIGIN X=0.2
 CUBOID 8 2P0.05 2P0.1 2P15.0 ORIGIN Y=-0.2
 CUBOID 9 2P0.05 2P0.1 2P15.0 ORIGIN Y=0.2
 CYLINDER 10 0.5 2P15.0
 MEDIA 1 1 1 -6 -7 -8 -9
 MEDIA 1 1 2 -8
 MEDIA 1 1 3 -7
 MEDIA 1 1 4 -9
 MEDIA 1 1 5 -6
 MEDIA 2 1 6 -1 -5
 MEDIA 2 1 7 -1 -3
 MEDIA 2 1 8 -1 -2
 MEDIA 2 1 9 -1 -4
 MEDIA 3 1 -1 -2 -3 -4 -5 -6 -7 -8 -9 10
 BOUNDARY 10
 UNIT 2
 CYLINDER 1 0.2 2P15.0
 CYLINDER 2 0.2 2P15.0 ORIGIN X=0.707107 Y=0.707107
 CYLINDER 3 0.2 2P15.0 ORIGIN X=-0.707107 Y=0.707107
 CYLINDER 4 0.2 2P15.0 ORIGIN X=-0.707107 Y=-0.707107
 CYLINDER 5 0.2 2P15.0 ORIGIN X=0.707107 Y=-0.707107
 CYLINDER 6 0.5 2P15.0 ORIGIN X=0.707107
 CYLINDER 7 0.5 2P15.0 ORIGIN X=-0.707107
 CYLINDER 8 0.5 2P15.0 ORIGIN Y=0.707107
 CYLINDER 9 0.5 2P15.0 ORIGIN Y=-0.707107
 CYLINDER 10 1.3 2P15.0
 CYLINDER 11 1.4 2P15.0
 MEDIA 2 1 1
 MEDIA 2 1 2
 MEDIA 2 1 3
 MEDIA 2 1 4
 MEDIA 2 1 5
 MEDIA 1 1 6 -8 -9

MEDIA 1 1 7-8-9
 HOLE 1 8-3-6 ORIGIN Y=0.707107
 HOLE 1 9-6-7 ORIGIN Y=-0.707107
 MEDIA 0 1 10-1-2-3-4-5-6-7-8-9
 MEDIA 4 1 11-10
 BOUNDARY 11
 GLOBAL UNIT 3
 CYLINDER 1 0.6 2P15.0
 CYLINDER 2 0.6 2P15.0 ORIGIN X=2.0 Y=2.0
 CYLINDER 3 0.6 2P15.0 ORIGIN X=-2.0 Y=2.0
 CYLINDER 4 0.6 2P15.0 ORIGIN X=-2.0 Y=-2.0
 CYLINDER 5 0.6 2P15.0 ORIGIN X=2.0 Y=-2.0
 CYLINDER 6 1.4 2P15.0 ORIGIN X=2.0
 CYLINDER 7 1.4 2P15.0 ORIGIN Y=2.0
 CYLINDER 8 1.4 2P15.0 ORIGIN X=-2.0
 CYLINDER 9 1.4 2P15.0 ORIGIN Y=-2.0
 CYLINDER 10 3.6 2P15.0
 CYLINDER 11 3.8 2P15.0
 CUBOID 12 4P4.0 2P16.0
 MEDIA 2 1 1-6-7-8-9
 MEDIA 2 1 2-6-7
 MEDIA 2 1 3-7-8
 MEDIA 2 1 4-8-9
 MEDIA 2 1 5-9-6
 HOLE 2 6-1-5-2 ORIGIN X=2
 HOLE 2 7-1-2-3 ORIGIN Y=2
 HOLE 2 8-1-3-4 ORIGIN X=-2
 HOLE 2 9-1-4-5 ORIGIN Y=-2
 MEDIA 0 1 10-1-2-3-4-5-6-7-8-9
 MEDIA 4 1 11-10
 MEDIA 0 1 12-11
 BOUNDARY 12
 END GEOM
 READ PLOT TTL='X-Y SLICE AT Z MIDPOINT. NESTED HOLES'
 XUL=-4.1 YUL=4.1 ZUL=0.0 XLR=4.1 YLR=-4.1 ZLR=0
 UAX=1.0 VDN=-1.0 NAX=130 NCH='*-X' END
 TTL='X-Y SLICE AT Z MIDPOINT. NESTED HOLES, UNIT MAP.'
 NCH='*1-.'
 PIC=UNIT END
 END PLOT
 END DATA
 END

The plot data description shown in Fig. F17.5.57 shows the symbols that represent each unit in the geometry mock-up. The unit map is shown in Fig. F17.5.58. The user can utilize this map to verify the correct placement of the units. Note that the unit map prints the units that are present at the deepest nesting level for the 2-D slice. It does not show any detail within a unit.

EXAMPLE 7. LARGE STORAGE ARRAY

The storage array described in Sect. F17.5.6.3 and Fig. F17.5.15 is such a sparse array that the mixture map had to be very large in order to show the detail of the shelves and uranium buttons. The mixture maps for this configuration were not presented in Sect. F17.5.6.3, but the data description was listed so the user could generate them. It may be useful to generate a unit map for this kind of problem. The data description for generating unit maps for this storage array is given below.

```

READ PLOT PLT=YES PIC=UNIT
TTL='X-Z SLICE AT Y=30.48 WITH Z ACROSS AND X DOWN'
XUL=624.84 YUL=30.48 ZUL=-15.0 XLR=-30.48 YLR=30.48 ZLR=201.0
WAX=1.0 UDN=-1.0 NAX=60 NDN=60 NCH=' 1234567' END
TTL='X-Y SLICE OF ROOM THROUGH SHELF Z=0.3175 WITH X ACROSS AND Y DOWN'
XUL=-30.48 YUL=1341.0 ZUL=0.3175 XLR=624.84 YLR=-30.4 ZLR=0.3175
UAX=1.0 VDN=-1.0 NAX=60 NDN=60 END
END PLOT

```

The plot data and unit map for an x-z slice through the array at y = 30.48 cm are given in Figs. F17.5.59 and F17.5.60. The unit maps have been intentionally distorted by restricting the x direction, which extends from 624.84 cm to -30.48 cm to 60 lines. The z direction, which extends from the bottom of the reflector at -30.84 cm to just about the array at 201.0 cm, is printed in 60 characters. Since the x direction is larger then the z direction, the plot is considerably compressed in the x direction. This unit map was created with z across the page and x down the page. Thus the unit map shows five rows of shelves in the x direction represented by 1's for Unit 1, with the aisles represented by 6's for Unit 6. The borders of Unit 7's are part of the concrete floor, walls, and ceilings.

Figure F17.5.59 Plot data for x-z slice of storage array

Figure F17.5.60 x-z plot of storage array

The plot data and unit map for an x-y slice through the shelf are given in Figs. F17.5.61 and F17.5.62. The unit maps have been intentionally distorted by restricting the y direction, which extends from 1341.0 cm to -30.48 cm to 60 lines. The x direction, which extends from -30.84 cm to 624.84 cm, is also printed in 60 characters. Since the y direction is larger than the x direction the plot is considerably compressed in the y direction. This unit map was created with x across the page and y down the page. This shows 5 rows of shelves in the x direction represented by 1's for Unit 1 and separated by aisles of 6's for Unit 6. Two rows of shelves are in the y direction, represented by 1's for Unit 1 and separated by aisles of 4's for Unit 4. The border of 7's are the concrete walls.

```

unit      1 2 3 4 5 6 7
symbol    1. 2. 3. 4. 5. 6. 7.

          upper left      lower right
          coordinates      coordinates
x         -3.0480E+01      6.2484E+02
y         -1.3410E+03      -3.0400E+01
z         -3.1750E-01      3.1750E-01

          u axis          v axis
          (down)          (across)
x          .00000         1.00000
y         -1.00000         .00000
z          .00000         .00000
nu= 60      nv= 60      delv= 2.2857E+01      delv= 1.0922E+01

```

[illegible]NUREG/CR-0200,
Vol. 2, Rev. 5

F17.5.10 RESTART CAPABILITIES

Restart data can be written and used for restarting a problem. This type of data is saved by specifying file definition data in the job control language on the unit associated with parameter WRS= when it is written, and RST= when it is read. Most input data can be changed *only* if the problem is restarted with the first generation. However, certain parameter data can be changed if the problem is restarted at a generation greater than 1.

Parameters that can be changed when a problem is restarted at a generation greater than 1 include: RND=, TME=, TBA=, GEN=, RES=, LNG=, BEG=, AMX=, XAP=, XS1=, XS2=, PKI=, P1D=, CKU=, CKP=, CKH=, CKA=, FMU=, FMP=, FMH=, FMA=, BUG=, TRK=, PWT=, PGM=, RUN=, PLT=, NB8=, NL8=, and PAX=. All logical unit numbers can be changed.

If NSK= is changed, it will cause the fluxes, fission densities, leakage, absorptions, and fissions to be incorrect.

FLX=, FDN=, FAR=, MKU=, MKP=, MKH= and MKA= can be changed subject to the following restrictions:

1. If the original problem written to a particular restart file specified YES and the restarted problem specifies NO, the data will be calculated but not printed. A warning message will be printed.
2. If the original problem written to a particular restart file specified NO and the restarted problem specifies YES, an error message is printed and the problem is terminated.

The parameters RUN= and PLT= differ from other parameters because they can be set in the parameter data and overridden in the plot data. Their values are stored in a common block that is written out if a problem is to be restarted. Therefore, when a problem is run, the value entered in the plot data will override the value that was entered in the parameter data. However, if the problem is restarted, the value from the restart file will be used unless it is overridden by entering additional data.

If WRS= is defined in the parameter data and RES= is not entered, a full restart data file is not written. The input data are written on the restart data file, but the calculated data are not. When the restart data file is written in this manner, it can only be used to restart a problem at the first generation. Any desired data can be overridden when a problem is restarted at the first generation by reading in the desired data.

To write a complete restart data file, both WRS= and RES= must be specified in the parameter data. However, WRS= is defaulted to 35 if a value greater than zero is entered for RES=. In this case, a file definition data for Unit 35 must be supplied by the user in order to save the restart data.

A problem that is restarted can also write a restart data file. These data are written on the same data file if no entry for WRS= is made in the parameter data. It can be written on a different unit if WRS= is so specified in the parameter data and the proper file definition data are included in the job control language. If a restarted problem does not have RES=0 specified in the parameter data, it will continue writing calculated restart data. Therefore, the user can run a long problem a little bit at a time by allowing the restarted problem to write restart data and then restarting the problem with those data. This procedure can be done in sequence until the desired number of generations have been completed.

For example, consider a problem that is to run 500,000 histories (500 generations of 1000 histories per generation) and the amount of computer time available at any given time is quite limited. On the first pass, GEN=500 NPG=1000 RES=500 WRS=35 should be included in the parameter data and a unit specification for Unit 35 should be included in the job control language when the problem is run. Note that 35 is an arbitrary number chosen by the user. KENO-VI will automatically pull the job before it runs out of time or I/Os. A restart data file will be written on Unit 35 for the last generation that was completed. If the user wishes to restart the

problem by reading the data from Unit 35 and writing a new restart file on the same unit, the parameter data for the second and all subsequent passes would be: READ PARAM BEG=500 RST=35 END PARAM.

If the user wishes to run additional histories to improve convergence, BEG should be set to 1 greater than the last generation saved on the restart file. For example, if a problem was originally run with GEN=100, RES=100 WRS=35, then the restart problem should specify BEG=101 GEN=200 RST=35, in order to run an additional 100 generations.

The random sequence can be changed when a problem is restarted by entering a different random number in the parameter data. The starting random number is acceptable for changing the random sequence of a problem that is to be restarted at a generation greater than 1.

Note that if a problem is restarted from one unit and restart data are written to another unit, the new problem description becomes the "original problem" for the new restart dataset.

Parameter data can be changed by entering new values for the desired options, which has the effect of inputting additional data within the parameter data block as explained in Sect. F17.5.3. However, all other data blocks that are to be changed must be entered as an entire data block and will completely replace that data block from the restart problem. When a problem is restarted and some of the data are overridden, the original restart data blocks are retained on the unit defined by WRS=, if it is the same as the unit defined by RST=. If the unit number associated with WRS= is different from the unit number associated with RST=, the resultant data blocks are written on the unit number associated with WRS=. For example, if the original problem is a single unit problem with RST=95 and WRS=95, and an array data block is entered to change it to an array problem, the original single unit problem data blocks remain on Unit 95. However, if the single unit problem is restarted with RST=95 and WRS=96 and an array data block is entered to change the problem to an array problem, the original single unit data blocks remain on Unit 95 and the resultant array problem data blocks are retained on Unit 96.

When a problem is restarted, the only way to change data in a data block is to reenter a new data block. For example, if in the original problem an array data block was entered as: READ ARRAY ARA=1 NUX=11 NUY=5 NUZ=3 END ARRAY and the problem is to be restarted at the first generation as an $11 \times 5 \times 6$ array, the following data block must be entered: READ ARRAY ARA=1 NUX=11 NUY=5 NUZ=6 END ARRAY.

Section F17.2.6 contains some information pertaining to the restart capability. Other information may be found in Sect. F17.4.3. The structure of the restart file is listed in Table F17.5.2, and the variables referenced in that table are listed in Table F17.5.3.

F17.5.11 RANDOM SEQUENCE

The random number package utilized by KENO-VI always starts with the same seed and thus always reproduces the same sequence of random numbers. The current random number is printed at various places in the KENO-VI printout, and any of them except the one printed in the parameter table can be used to activate a different random sequence. The user can rerun a problem with a different random sequence by simply entering a hexadecimal random number, other than the starting random number, in the parameter data. The last digit of the random number should always be an odd number. For example, by entering RND=A10C1893E6D5 in the parameter data, the problem will be run with a different random sequence.

Table F17.5.2 Structure of RESTART file

Record No.	Contents
(1)	TITLE(20), NBA, NPB, NSKIP, NRSTRT, NBANK, NFBNK, NXBNK, NXFBK, NUMX1D, RFLT(6), RNDNUM, LOG(33) (This record contains the title and parameter data.)
(2)	MT(LMT) LMT = 5 + NUMX1D (This record contains the identifiers of the 1-D cross-section arrays.)
(3 to NUMPT+2)	NDX = 1, NUMPT NUMPT = 11 <ul style="list-style-type: none"> (a) NDX,NREC (This record contains the index for each type of data and the number of records of data associated with each type of data.) (b) NREC - 1 record of data (These records contain the data associated with the specified type of data.) <p>NDX = 1 (geometry data)</p> <ul style="list-style-type: none"> (b1) LLNGTH, KMAX, NQUAD, MAXSFU, REGTOT, SECTOT, MAXREG, NIAR, NGWRDS, MAXGWD, MAXSEC, NGBLU, NBOXT, MAXMIX, MAXIMP, NUMHOL, NUCOM, EXRFL (b2) MAT(REGTOT), IMP(REGTOT), IGEOM(REGTOT), IGWDPT(0:NGWRDS), ARANDX(REGTOT), NSURFT(NBOXT), NSU(NBOXT), KBNDSQ((NBOXT), KBNDSM(NBOXT), KBNDSX(NBOXT), KBNDSG(NBOXT), NGWPU(NBOXT), IBNDS(NBOXT), BOXBND(3,NBOXT), ARABND(3,NIAR), IRFPOS(3,NIAR), QC(NQUAD,11), REGION(NAXGWD, REGTOT), SECTOR(SECTOT), HOLROT(3,3,NUMHOL), KHOLE(NUMHOL), LHOLU(NUMHOL), HOLX(NUMHOL), HOLY(NUMHOL), HOLZ(NUMHOL), ICOMC(NBOXT), UCOMNT(33,NUCOM) <p>NDX = 2 (array data)</p> <ul style="list-style-type: none"> (b1) LLNGTH, NGLOBL, MAXARA, NACOM, LSGUN, MBOX, LFIL (b2) NBXMAX(MAXARA), NBYMAX(MAXARA), NBZMAX(MAXARA), ITYPE(MAXARA), LPT(MAXARA), LNG(MAXARA), ICOMA(MAXARA), ACOMNT(33,NACOM) <p>I = 1, MAXARA (The following records are written for each array.)</p>

Table F17.5.2 (continued)

Record No.	Contents
	(b3) LBA(NBXMAX(I),NBYSMAX(I),NBZMAX(I))
	NDX = 3 (mixing table data)
	(b1) LLNGTH, NMIX, NSCT, MIX, MIXT, NPL, PBXS
	(b2) MIXTUR(NMIX), NUC(NMIX), DEN(NMIX)
	NDX = 4 (extra data)
	(b1) LLNGTH, LNEXTR
	(b2) D(LLNGTH)
	NDX = 5 (weighting function by energy group and importance reg.)
	(b1) LLNGTH, NIMP
	(b2) WTAVG(NGP,NIMP)
	NDX = 6 (start data)
	(b1) LLNGTH, NTYPST, TFX, TFY,TFZ, NBXS, NBYS, NBZS, KFIS, LFIN, NBOXST, FRACT, FISVOL, XSM, XSP, YSM, YSP, ZSM, ZSP, RFLKEY, LPRT6, LPSTP
	(b2) IF (NTYPST .EQ. 6) NUBANK(LFIN,LBANK0)
	NDX = 7 (albedo data)
	(b1) LLNGTH, NALB, NANG, NG, INTR(6), RNAME(2,6), IDALB(6), NBXL(6), LNXX
	IF (NALB .GT. 0)
	(b2) NABS(3,NALB), LABS(3,NALB)
	(b3) MAL(3,NANG,NG)
	(b4) EALB(NG+1) (group boundaries)
	I = 1,NALB

Table F17.5.2 (continued)

Record No.	Contents
	(b5(i)) PLIM(NANG), CPOL(NANG), SPOL(NANG)
	(b6(i)) ALB(LENG) (LENG is the length of the albedos for a given angle.)
	(b7(i)) A(LENG,NANG)
	NDX = 8 (mixed cross sections)
	(b1) LLNGTH, NMAT, NGP, MAXANG
	(b2) LXS(MANG,MATT) MANG = 2*NSCT + 4
	I = 1, MATT for each existing mixture
	(b3(i)) ID(50) the mixture information record
	(b4(i)) X1D(NN1D,NGP+1) NN1D = ID(28) No. of 1-Ds
	(b5(i)) MWA(3,NGP)
	(b6(i)) P0(LNG) LNG = MWA(2,NGP)
	J = 1, NSCT
	(b7(i,j)) ANG(LNG)
	(b8(i,j)) PRB(LNG)
	NDX = 9 (energies and inverse velocities)
	(b1) LLNGTH
	(b2) E(NGP+1), VINV(NGP)
	NDX = 10 (plot data)
	(b1) LLNGTH, NUMPLT
	I = 1, NUMPLT
	(b2(i)) XL, YL, ZL, XR, YR, ZR, VX, VY, VZ, UX, UY, UZ, DELV, DELU, NV, NU, LPIC, NSTOR(49)

Table F17.5.2 (continued)

Record No.	Contents
NDX = 11 (biasing data)	
	(b1) LLNGTH, NUMIDS, NCS, NTSETS
	IF ((NUMIDS + NCS).GT.0),
	(b2) ID(NUMIDS), IBGN(NUMIDS), IEND(NUMIDS), WTTITL(3,NUMIDS), NCID(NCS), NCSETS(NCS), CRDTTL(3,NCS), NCTHK(NTSETS), NUMINC(NTSETS), NGPWTS(NTSETS), IPTWT(NTSETS)
	I = 1, NCS
	J = 1, NSETS(I)
	(b3(i,j)) WTAVG(NGPWTS(j,i),NUMINC(j,i))
(14 to END)	Calculated data as listed below
	(a) IGEN, RND, NPB, NGP, KMAX, LBANK, NBANK, DLIF(15), LIF(20), LOJIC(36), EFFK(I), I=1, IGEN (This record contains parameter data, COMMON /LIFETM/ part of COMMON /LOGIC/ and k-effectives by generation.)
	(b) NUBANK(LBANK, NBANK)
	(c) IF(LOJIC(4)) FISDEN(KMAX,3) (If fission densities are calculated, the fission densities are written on the restart file.)
	(d) IF(LOJIC(10)) TP(MATDIM, MATDIM, 3), SNP(MATDIM), SP(MATDIM) (If matrix data by position are calculated, the matrix by position data are written on the restart file.)
	(e) IF(LOJIC(7)) TU(NBOXT, NBOXT, 3), SNU(NBOXT), SU(NBOXT) (If matrix data by unit are calculated, the matrix by unit data are written on the restart file.)
	(f) IF(LOJIC(13)) TH(NUMHOL, NUMHOL, 3), SNH(NUMHOL), SH(NUMHOL) (If matrix data by hole are calculated, the matrix by hole data are written on the restart file.)

Table F17.5.2 (continued)

Record No.	Contents
	<p>(g) IF(LOJIC(17)) TA(NUMARA,NUMARA,3), SNA(NUMARA), SA(NUMARA) (If matrix data by array are calculated, the matrix by array data are written on the restart file.)</p> <p>(h) 1 to NGP (the following records are written for each energy group)</p> <p>(h1) IGROUP, FLEAK(3)</p> <p>(h2) FMABS(LREG,3), FMFIS(LREG,3)</p> <p>(h3) IF(LOJIC(3)) FLUX(KMAX,3)</p> <p>Repeat (a through h) until LOJIC(34) is TRUE (i.e., until the last generation is completed).</p>

Table F17.5.3 Key of RESTART file variables

TITLE	80-character KENO-VI problem title
NBA	Number of generations in the KENO-VI problem
NPB	Number of histories per generation
NSKIP	Number of generations to be skipped in averaging k-effective
NRSTRT	Number of generations between writing restart data
NBANK	Number of positions in the neutron bank
NFBNK	Number of positions in the fission bank
NXBNK	Number of extra entries in the neutron bank
NXFBK	Number of extra entries in the fission bank
NUMX1D	Number of extra 1-D cross sections
RFLT	Contains tmax, tbtc, dwtav, wthigh, wtlow, tsigma
TBTCH	Time allowed for each generation
RNDNUM	Random number with which the problem will be started
LOG	First 33 positions of COMMON /LOGIC/
LMT	Number of 1-D cross-section identifiers. $LMT = 5 + NUMX1D$
MT	Array containing the 1-D cross-section identifiers
NUMPT	Number of kinds of data that are written on the restart file
NDX	Index for the type of data
NREC	Number of records for the specified type of data
NDX = 1	Geometry data
LLNGTH	The length of record b2
KMAX	Number of geometry regions used
NQUAD	Number of quadratic equations in the problem
MAXSFU	Maximum number of surfaces in a unit
REGTOT	Number of MEDIA type cards read in the geometry data
SECTOT	Number of sectors x number of geometry cards in a unit summed over all units
MAXREG	Maximum number of regions in a unit
NIAR	Number of arrays read in the problem
NGWRDS	Number of geometry words in the problem
MAXGWD	Largest number of geometry words in a unit
MAXSEC	Largest number of sectors in a unit
NGBLU	The global unit number
NBOX	Largest unit number in the geometry data
NBOXT	NBOX + the number extra units generated by KENO-VI
MAXMIX	Largest mixture number encountered in the geometry data
MAXIMP	Largest biasing number encountered in the geometry data
NUMHOL	Number of holes in the geometry data
NUCOM	The number of units having comments in the geometry region data
EXRFL	Logical flag. Value is TRUE if a reflector is present
MAT	Array containing the mixtures used in the geometry
IMP	Array containing the bias IDs used in the geometry
IGWDPT	Array containing the offset to the last quadratic for each geometry word in QC
ARANDX	Array containing the offset for each array into ARABNDS

Table F17.5.3 (continued)

NSURFT	Array containing the number of quadratic equations in each unit
NSU	Array containing the number of sectors in each unit
KBNSDQ	Array of offsets to the first quadratic of each unit in the QC array
KBNDQM	Array of pointers into the SECTOR array
NKBNDQX	Array of offsets of the first entry for each unit into the SECTOR array
KBNDQD	Array of offsets of the first entry of each unit into the IGWDPT array
NGWPU	Array containing the number of geometry words in each unit
IBNDS	Array of offsets into IGWDPT to first boundary quadratic in a unit
BOXBND	Array containing the most negative boundary for each unit
ARABND	Array containing the most negative boundary for each array
IRFPOS	Array containing the array position of the reference unit used to position the array
QC	Array containing the coefficients of the quadratic equations for each surface
REGION	Array of sector data based on geometry input cards
SECTOR	Array containing information relating each sector to each geometry card for each unit
HOLROT	Array containing rotation data for each hole
KHOLE	Region number that contains the hole
LHOLU	Unit that is placed in the hole
HOLX	X coordinate of the origin of the unit in the hole with respect to the unit that contains the hole
HOLY	Y coordinate of the origin of the unit in the hole with respect to the unit that contains the hole
HOLZ	Z coordinate of the origin of the unit in the hole with respect to the unit that contains the hole
ICOMC	The index into the comment array for a unit
UCOMNT	Comments associated with units specified in the geometry region data
NDX = 2	Array or unit orientation data
LLNGTH	Length of the b2 record
NGLOBL	Global array number
MAXARA	Largest array number encountered in the array data
NACOM	The number of arrays having comments in the array data
LSGUN	Logical flag. Value is TRUE if there is no array present
MBOX	A logical variable that is set .TRUE. if arrays are used.
NBXMAX	Number of units in the X direction of each array
NBYMAX	Number of units in the Y direction of each array
NBZMAX	Number of units in the Z direction of each array
ITYPE	Pitch indicator, 1 for square-pitched arrays, 2 for triangular-pitched arrays
LPT	Pointer to locate the beginning of each unit orientation array
LNG	Length of each unit orientation array
ICOMA	The index into the comment array for arrays
LBA	Contains the unit orientation arrays for all arrays
MAXARA	The largest array number

Table F17.5.3 (continued)

NACOM	Number of array comments
ACOMNT	Comments
NDX = 3	Mixing table data
LLNGTH	Length of b2 record
NMIX	Number of entries in the mixing table
NSCT	Number of scattering angles
MIX	Number of different mixtures to be mixed
MIXT	Largest mixture number to be mixed
NPL	Order of Legendre coefficients + 1
MIXTUR	Array of mixture numbers used in the mixing table
NUC	Array of the nuclide ID numbers used in the mixing table
DEN	Array of the number densities used in the mixing table
NDX = 4	Extra data
LLNGTH	Length of b2 record
LENGTH	D(LENGTH) is the data contained in the b2 record
LNSTR	Length of the extra data
NDX = 5	Weighting function
LLNGTH	Length of b2 record
NIMP	Number of biasing regions
WTAVG	Average weight by energy group and biasing region
NDX = 6	Start data (initial source distribution)
LLNGTH	Length of b2 record
NTYPST	Start type to define the initial source distribution
TFX	X coordinate of neutron starting point
TFY	Y coordinate of neutron starting point
TFZ	Z coordinate of neutron starting point
NBXS	X index of unit's position in the global array
NBYS	Y index of unit's position in the global array
NBZS	Z index of unit's position in the global array
KFIS	Mixture whose fission spectrum is used for initial source
LFIN	Last neutron to be started at the specified point
NBOXST	Unit in which neutrons will be started
FRACT	Fraction of initial source to be started as a spike
FISVOL	Fraction of global system that contains fissile material
XSM	-X dimension of cuboid in which neutrons will be started
XSP	+X dimension of cuboid in which neutrons will be started
YSM	-Y dimension of cuboid in which neutrons will be started

Table F17.5.3 (continued)

YSP	+Y dimension of cuboid in which neutrons will be started
ZSM	-Z dimension of cuboid in which neutrons will be started
ZSP	+Z dimension of cuboid in which neutrons will be started
RFLKEY	Logical variable. Set TRUE if neutrons can be started in reflector
LPRT6	Logical variable. Set TRUE to print start type 6 data
LPSTP	Logical variable. Set TRUE to print initial source points
NUBANK	The neutron bank. The variables that are used from the neutron bank are: X(NPB),Y(NPB),Z(NPB),NBX(NPB),NBY(NPB),NBZ(NPB)
LFIN	The last neutron for which start type 6 data was entered
LBANK	The number of positions per neutron in the neutron bank
NPB	Number of histories per generation
X	X coordinate of neutron starting point for start type 6
Y	Y coordinate of neutron starting point for start type 6
Z	Z coordinate of neutron starting point for start type 6
NBX	X index of unit's position in the global array for start type 6
NBY	Y index of unit's position in the global array for start type 6
NBZ	Z index of unit's position in the global array for start type 6
NDX = 7	Albedo data
LLNGTH	Length of b2 record
NALB	Number of different differential albedos to be used
NANG	Number of angles available in the albedo function
NG	Number of energy groups available in the albedo function
INTR	Type of boundary condition for each face
RNAMES	Name of boundary condition
IDALB	Index to the correct set of albedo data
NBXL	Specifies the face where the history will reenter
LNXX	Logical flag. Set TRUE for either specular or differential reflection
NABS	Pointers into the albedo data for each albedo used
LABS	Length of the albedo data for each albedo used
MAL	Pointer array for albedos
EALB	Energy boundaries for albedos
PLIM	Incident polar angle bins
CPOL	Cosine of returning polar angle
SPOL	Sine of returning polar angle
ALB	Probabilities for the returning energy group
A	Probabilities for the returning angle
LENG	Length of albedo data for a given angle
NDX = 8	Mixed cross sections
LLNGTH	Length of b2 record
NMAT	Number of mixtures used in the problem
NGP	Number of energy groups from the cross-section file

Table F17.5.3 (continued)

MAXANG	Number of scattering angles
LXS	Length of each cross-section set
MANG	$2 \cdot \text{NSCT} + 4$
ID	Head record from mixed cross-section file
X1D	1-D cross sections
NN1D	Number of 1-D cross sections (ID(28))
MWA	Pointer array for cross sections
P0	Group-to-group transfer probabilities
ANG	Scattering angles
PRB	Probabilities for scattering at angle ANG
LNG	Length of the P0 arrays
NDX = 9	Energies and inverse velocities
LLNGTH	Length of b2 record
NGP	Number of energy groups
E	Energy group bounds
VINV	Inverse velocities
NDX = 10	Plot data
LLNGTH	Length of b2 record
NUMPLT	Number of plots to be generated
XL	X coordinate of the upper-left corner of the plot
YL	Y coordinate of the upper-left corner of the plot
ZL	Z coordinate of the upper-left corner of the plot
XR	X coordinate of the lower-right corner of the plot
YR	Y coordinate of the lower-right corner of the plot
ZR	Z coordinate of the lower-right corner of the plot
VX	X component of the direction cosine for the across axis of the plot
VY	Y component of the direction cosine for the across axis of the plot
VZ	Z component of the direction cosine for the across axis of the plot
UX	X component of the direction cosine for the down axis of the plot
UY	Y component of the direction cosine for the down axis of the plot
UZ	Z component of the direction cosine for the down axis of the plot
DELV	Horizontal spacing between points on the plot
DELU	Vertical spacing between points on the plot
NV	Number of characters across the plot
NU	Number of characters down the plot
LPIC	Plot type indicator. LPIC=1 mixture, LPIC=2 unit, LPIC=3 bias ID
NSTOR	An array that contains PTITL and TABLE. The first 33 words are PTITL and the last 16 are TABLE.
NDX = 11	Biasing data

Table F17.5.3 (continued)

LLNGTH	Length of b2 record
NUMIDS	Number of bias IDs requested
NCS	Number of bias IDs entered from cards
NTSETS	Total number of group structures for all IDs
ID	ID number or set of weights to be read from WTS file
IBGN	Beginning importance region number assigned to ID
IEND	Ending importance region number assigned to ID
WTTTL	Title associated with the ID
NCID	ID to be read from cards
NCSETS	Number of group structures to be read from cards
CRDTTL	Title associated with the ID read from cards
NCTHK	Thickness per increment from cards
NUMINC	Number of increments from cards
NGPWTS	Number of energy groups for this set of weights
IPTWT	Pointer into the weights from cards
WTAVG	Weighting function by energy group and importance region
Calculated data	
IGEN	Generation for which this set of restart data was written
RND	Last random number that was used
NPB	Number of generations
NGP	Number of histories per generation
KMAX	Number of geometry regions used
LBANK	Number of positions per neutron in the neutron bank
NBANK	Number of positions in the neutron bank
DLIF	The double precision portion of COMMON/LIFETM/
LIF	The single precision portion of COMMON /LIFETM/
LOJIC	An array equivalenced to COMMON /LOGIC/
EFFK	Array containing k-effectives by generation
NUBANK	The neutron bank, NBANK by LBANK
FISDEN	Array containing the fission densities
TP	Fission production matrix by array position
SNP	Eigenvector of the fission production matrix by array position
SP	Source vector by array position
TU	Fission production matrix by unit
SNU	Eigenvector of the fission production matrix by unit
SU	Source vector by unit
TH	Fission production matrix by hole
SNH	Eigenvector of the fission production matrix by hole
SH	Source vector by hole
TA	Fission production matrix by array
SNA	Eigenvector of the fission production matrix by array
SA	Source vector by array

Table F17.5.3 (continued)

IGROUP	Current energy group
FLEAK	Leakage fraction
FMABS	Absorption fraction
FMFIS	Total fission production
FLUX	Flux
LOJIC(4)	Key indicating whether to calculate fission densities Specified by entering FDN= in the parameter data
LOJIC(10)	Key indicating whether to calculate matrix data by position Specified by entering MKP= in the parameter data
LOJIC(7)	Key indicating whether to calculate matrix data by unit Specified by entering MKU= in the parameter data
LOJIC(13)	Key indicating whether to calculate matrix data by hole Specified by entering MKH= in the parameter data
LOJIC(17)	Key indicating whether to calculate matrix data by array Specified by entering MKA= in the parameter data
LOJIC(3)	Key indicating whether to calculate fluxes Specified by entering FLX= in the parameter data

F17.5.12 MATRIX K-EFFECTIVE

Matrix k-effective calculations provide an alternative method of calculating the k-effective of the system. Cofactor k-effectives and source vectors are additional information that can be provided when the matrix k-effective is calculated. The necessary source and fission weight data are collected during the neutron tracking procedure in subroutine TRACK. This information is converted to a FISSION PRODUCTION MATRIX, which is the number of next generation neutrons produced at J by a neutron born at I. The principal eigenvalue of the fission probability matrix is the matrix k-effective. KENO-VI offers four alternatives when calculating matrix k-effective as discussed below:

1. If MKP=YES is specified in the parameter data, the fission production matrix is collected by array position or position index. The position index is used to reference a given location in a 3-D lattice. For a $2 \times 2 \times 2$ array there are eight unique position indices as follows:

POSITION INDEX	POSITION X	POSITION Y	POSITION Z
1	1	1	1
2	2	1	1
3	1	2	1
4	2	2	1
5	1	1	2
6	2	1	2
7	1	2	2
8	2	2	2

The fission production matrix is the number of next-generation neutrons produced at index J by a neutron born at index I. This matrix is used to calculate the matrix k-effective, cofactor k-effectives and the source vector by position index. Because the size of the fission probability matrix is the square of the array size (for a $4 \times 4 \times 4$ array there are 4096 entries), it can use vast amounts of computer memory.

2. If MKU=YES is specified in the parameter data, the fission production matrix is collected by unit. It is the number of next-generation neutrons produced in unit J by a neutron born in unit I. This matrix is used to calculate the matrix k-effective, cofactor k-effectives and source vector by unit.
3. If MKH=YES is specified in the parameter data, the fission production matrix is collected by hole number. Matrix information can be collected at either the highest hole nesting level (first level of nesting) or the deepest hole nesting level. HHL=YES specifies that the matrix information will be collected at the first nesting level. By default, the matrix information is collected at the deepest nesting level. The fission production matrix is the number of next-generation neutrons produced in hole J by a neutron born in hole I. This matrix is used to calculate the matrix k-effective, cofactor k-effectives and the source vector by hole.
4. If MKA=YES is specified in the parameter data, the fission production matrix is collected by array number. It can be collected at the highest array level (first level of nesting) or at the deepest array level. HAL=YES specifies that the matrix information will be collected at the first nesting level. By default,

the matrix information is collected at the deepest nesting level. The fission production matrix is the number of next-generation neutrons produced in array J by a neutron born in array I. This matrix is used to calculate the matrix k-effective, cofactor k-effectives and the source vector by array.

The user can simultaneously utilize all methods of calculating the matrix k-effective. The results are labeled in the printout. Matrix k-effectives cannot be calculated for a single unit problem. If the user wishes to calculate matrix information for a single unit the geometry data must include a second global unit that contains a $1 \times 1 \times 1$ array composed of the first unit. An array data block consisting of READ ARRAY ARA=1 NBX=1 NBY=1 NBZ=1 FILL 1 END FILL END ARRAY must also be included. These actions convert the single unit problem into a $1 \times 1 \times 1$ array.

A cofactor k-effective is the eigenvalue of the fission production matrix, reduced by the row and column that references the specified unit or position index. The difference between the k-effective for the system and the cofactor k-effective for a unit or position index is an indication of the in situ k-effective of that unit or the contribution that unit makes to the k-effective of the system. The cofactor k-effective of a unit devoid of fissile material should approximate the k-effective of the system.

F17.5.13 DEVIATIONS

When a deviation is calculated by KENO-VI, it is the standard deviation of the mean. A large sample and a normal distribution are assumed for this calculation. If these assumptions are not true, the deviations cannot be assumed to be correct. If results are correlated, the calculated deviations will be in error.

F17.5.14 GENERATION TIME AND LIFETIME

The generation time and lifetime calculations utilize the average velocity. The validity of these calculations is determined by how accurately the average velocity represents the spectrum over the range of the energy group. The lifetime and generation time calculated by KENO-VI are not kinetics parameters. The lifetime is the average lifespan of a neutron (in seconds) from the time it is born until it is absorbed or leaks from the system. The generation time is the average time (in seconds) between successive neutron generations.

F17.5.15 REFERENCES

1. S. K. Fraley, *Users Guide for ICE-II*, ORNL/CSD/TM-9/R1, Union Carbide Corp., Nucl. Div., Oak Ridge Natl. Lab., July 1977.
2. J. T. Thomas, "Critical Three-Dimensional Arrays of U(93.2)-Metal Cylinders," *Nucl. Sci. Eng.* **52**, 350 (November 1973).
3. J. T. Thomas, *Critical Three-Dimensional Arrays of Neutron-Interacting Units, Part II*, ORNL/TM-868, Union Carbide Corp., Nucl. Div., Oak Ridge Natl. Lab., July 1964.

F17.6 DESCRIPTION OF OUTPUT

This section contains a brief description and explanation of the KENO-VI output. Portions of the printout will not be printed for every problem. Some printout is optional and is so noted in this section.

F17.6.1 HEADER PAGE

The first page of print from KENO-VI is the header page. A sample header page is shown in Fig. F17.6.1.

The first line of block letters prints KENO-VI. The second line of block letters gives the job name from the job control language. The third line gives the date the job was run as month/day/year. The last line prints the time when the execution of the problem began (hour/minute/second) in terms of a 24-h clock, with midnight being 2400 h. The header page is printed from subroutine MESSAGE.

11	666666666666		555555555555	333333333333		555555555555	TTTTTTTTTTTT	
111	66666666666666		55555555555555	33333333333333		55555555555555	TTTTTTTTTTTT	
1111	66	:::	55	33	33	55	TT TT	
11	66	:::	55		33	55	TT	
11	66	:::	55		33	55	TT	
11	66666666666666		555555555555	333		555555555555	TT	
11	66666666666666		55555555555555	333		55555555555555	TT	
11	66	66	:::	55	33	55	TT	
11	66	66	:::	55	33	55	TT	
11	66	66	:::	55	55	33	55	TT
11111111	6666666666666666		5555555555555555	3333333333333333		5555555555555555	TT	
11111111	6666666666666666		555555555555	33333333333333		555555555555	TT	

Program verification information (Fig. F17.6.2) is printed after the header page. It lists the name of the program, the date the load module was created, the library that contains the load module, the computer code name from the configuration control table, and the revision number. The job name, date, and time of execution are also printed. This information may be used for quality assurance purposes.

Figure F17.6.2 Sample program verification table

F17.6.3 TABLES OF PARAMETER DATA

The first two tables printed by KENO-VI list the numeric parameters and logical parameters that are used in the problem. They should always be examined by the user to verify that the parameter data block was input as desired. Examples of these tables are shown in Figs. F17.6.3 and F17.6.4.

```

*****
***
***          sample problem 18  1f27  critical experiment          ***
***
*****
***          numeric parameters          ***
***
***          tme          maximum problem time (min)          30.00          ***
***
***          tba          time per generation (min)          .50          ***
***
***          gen          number of generations          53          ***
***
***          npg          number per generation          350          ***
***
***          nsk          number of generations to be skipped          3          ***
***
***          beg          beginning generation number          1          ***
***
***          res          generations between checkpoints          0          ***
***
***          xld          number of extra 1-d cross sections          1          ***
***
***          nbk          neutron bank size          375          ***
***
***          xnb          extra positions in neutron bank          0          ***
***
***          nfb          fission bank size          350          ***
***
***          xfb          extra positions in fission bank          0          ***
***
***          sig          cut off standard deviation          .0000          ***
***
***          wta          default value of weight average          .5000          ***
***
***          wth          weight high for splitting          3.0000          ***
***
***          wtl          weight low for russian roulette          .3333          ***
***
***          rnd          starting random number          000008B827100001          ***
***
***          nb8          number of d.a. blocks on unit 8          200          ***
***
***          nl8          length of d.a. blocks on unit 8          512          ***
***
***          adj          mode of calculation          forward          ***
***
***          input data written on restart unit          no          ***
***
***          binary data interface          no          ***
***
*****
*****
*****

```

Figure F17.6.3 Sample table of numeric parameter data

```

*****
*****
***
***          sample problem 18  1f27  critical experiment
***
*****
*****          logical parameters          *****
***
*** run  execute problem after checking data  yes          plt  plot picture map(s)          yes ***
***
*** flx  compute flux                          yes          fdn  compute fission densities          yes ***
***
*** smu  compute avg unit self-multiplication  no           nub  compute nu-bar & avg fission group          yes ***
***
*** mku  compute matrix k-eff by unit number  yes           mkp  compute matrix k-eff by unit location          no  ***
***
*** cku  compute cofactor k-eff by unit number yes           ckp  compute cofactor k-eff by unit location          no  ***
***
*** fmu  print fiss prod matrix by unit number yes          fmp  print fiss prod matrix by unit location          no  ***
***
*** mkh  compute matrix k-eff by hole number  yes           mka  compute matrix k-eff by array number          yes ***
***
*** ckh  compute cofactor k-eff by hole number yes          cka  compute cofactor k-eff by array number          yes ***
***
*** fmh  print fiss prod matrix by hole number yes          fma  print fiss prod matrix by array number          yes ***
***
*** hhl  collect matrix by highest hole level  no           hal  collect matrix by highest array level          no  ***
***
*** amx  print all mixed cross sections        yes          far  print fis. and abs. by region          yes ***
***
*** xs1  print 1-d mixture x-sections          yes          pax  print xsec-albedo correlation tables          yes ***
***
*** xs2  print 2-d mixture x-sections          yes          pwt  print weight average array          yes ***
***
*** xap  print mixture angles & probabilities  yes          pgm  print input geometry          yes ***
***
*** pki  print fission spectrum                yes          bug  print debug information          no  ***
***
*** pld  print extra 1-d cross sections        yes          trk  print tracking information          no  ***
***
*****
*****
parameter input completed
.....  0 io's were used reading the parameter data  .....

```

Figure F17.6.4 Sample table of logical parameter data

The title of the problem is printed at the top of each table. The first table, shown in Fig. F17.6.3, lists the numeric parameter data. It contains a triple column that lists the applicable parameter keyword used to input the data, a brief explanation of its meaning, and the associated data value. The last two entries in this table are slightly different than the others because a keyword is not listed with them. The INPUT DATA WRITTEN ON RESTART UNIT is set YES if a unit number is provided for writing restart data (WRS=). The BINARY DATA INTERFACE is set YES if a unit number is provided for reading restart data (RST=).

The second table, shown in Fig. F17.6.4, lists the logical parameter data. It contains two triple columns, each listing the applicable parameter keyword, a brief explanation of the parameter's function, and the value associated with the parameter. Messages concerning the parameter data may be printed at the bottom of the table. If the problem is one that is being restarted, the title of the parent case is printed at the bottom of the table. If the restart title or messages are not printed, the bottom section of the table is omitted. If the user desires to change some of the data in these tables, the appropriate parameter keyword must be entered in the parameter data, followed by an equal sign and the desired value. Following this table is a statement affirming the completion of the parameter input and a statement of the number of I/Os used in reading the parameter data.

At this point, the unprocessed input geometry, shown in Fig. F17.6.5, may be printed as described in Sect. F17.6.4. These data are followed by a statement affirming the completion of the data reading and a table listing the geometry parameter summary data, as shown in Fig. F17.6.5a.

F17.6.4 UNPROCESSED GEOMETRY INPUT DATA

This printout is optional and is usually used to locate code difficulties, to show all the geometry input data when only part of it is used in the problem, or to show the order in which units were entered. It is considered debug information and is printed only if PGM=YES is specified in the parameter input data as described in Sect. F17.4.3. Standard KENO-VI use does not require printing these data because the processed geometry that is used in the problem is always printed. See Sects. F17.6.15 and F17.6.16 for examples of the standard printed KENO-VI geometry data. An example of the data printed in the unprocessed geometry input data is shown in Fig. F17.6.5. The unprocessed geometry is printed by subroutine KENOG.

When the unprocessed geometry input is printed, the problem title is located at the top of the page, followed by the heading "GEOMETRY DESCRIPTION INPUT." The region-dependent geometry information is then printed. If the problem contains a unit orientation array, the problem title is printed again, followed by the unit orientation and a statement affirming the completion of the data input. A summary table of the geometry input data is then printed, as shown in Fig. F17.6.5a. This table contains summations of the different geometry parameters used in the problem such as number of units, quadratic equation, geometry words, and holes.

```

sample problem 18 1f27 critical experiment geometry description input
1 cylinder radius = 9.5200 +z= 8.7804 -z= -8.7804
2 cylinder radius = 9.5200 +z= 8.9896 -z= -8.7804
3 cylinder radius = 10.160 +z= 9.6296 -z= -9.4204
4 cuboid +x = 18.450 -x = -18.450 +y = 18.450 -y = -18.450 +z = 17.895 -z = -17.685
sector data associated with media 1 and importance region 1
1
icnt/irgsec(ii),ii=1,icnt 1 1
sector data associated with media 0 and importance region 1
-1 2
icnt/irgsec(ii),ii=1,icnt 2 -1 2 2
sector data associated with media 2 and importance region 1
-1 -2 3
icnt/irgsec(ii),ii=1,icnt 3 -1 -2 3
sector data associated with media 0 and importance region 1
4 -2 -3
icnt/irgsec(ii),ii=1,icnt 3 4 -2 -3
1 cuboid +x = 18.440 -x = -55.340 +y = 55.340 -y = -18.440 +z = 53.360 -z = -17.780
2 cuboid +x = 18.440 -x = -55.340 +y = 55.340 -y = -18.440 +z = -17.800 -z = -53.360
3 cuboid +x = 55.340 -x = 18.460 +y = 55.340 -y = -18.440 +z = 53.360 -z = -53.360
4 cuboid +x = 55.340 -x = -55.340 +y = -18.460 -y = -55.340 +z = 53.360 -z = -53.360
5 cuboid +x = 55.350 -x = -55.350 +y = 55.350 -y = -55.350 +z = 53.370 -z = -53.370
sector data associated with array 1
the origin of the unit at array position ( 1, 1, 1)
is positioned at x= -36.900 y= 0.00000E+00 z= -.10460 relative to the origin of the unit.
1
icnt/irgsec(ii),ii=1,icnt 1 1
sector data associated with array 2
the origin of the unit at array position ( 1, 1, 1)
is positioned at x= -36.900 y= 0.00000E+00 z= -35.685 relative to the origin of the unit.
2 -1
icnt/irgsec(ii),ii=1,icnt 2 2 -1
sector data associated with array 3
the origin of the unit at array position ( 1, 1, 1)
is positioned at x= 36.900 y= 0.00000E+00 z= -35.685 relative to the origin of the unit.
3 -2 -1
icnt/irgsec(ii),ii=1,icnt 3 3 -2 -1
sector data associated with array 4
the origin of the unit at array position ( 1, 1, 1)
is positioned at x= -36.900 y= -36.900 z= -35.685 relative to the origin of the unit.
4 -3 -2 -1
icnt/irgsec(ii),ii=1,icnt 4 4 -3 -2 -1
sector data associated with media 0 and importance region 1
5 -4 -3 -2 -1
icnt/irgsec(ii),ii=1,icnt 5 5 -4 -3 -2 -1
1 cuboid +x = 55.350 -x = -55.350 +y = 55.350 -y = -55.350 +z = 53.370 -z = -53.370
2 cuboid +x = 58.350 -x = -58.350 +y = 58.350 -y = -58.350 +z = 56.370 -z = -56.370
3 cuboid +x = 61.350 -x = -61.350 +y = 61.350 -y = -61.350 +z = 59.370 -z = -59.370
4 cuboid +x = 64.350 -x = -64.350 +y = 64.350 -y = -64.350 +z = 62.370 -z = -62.370
5 cuboid +x = 67.350 -x = -67.350 +y = 67.350 -y = -67.350 +z = 65.370 -z = -65.370
6 cuboid +x = 70.590 -x = -70.590 +y = 70.590 -y = -70.590 +z = 68.610 -z = -68.610
sector data associate with hole 1 containing unit 2
1
sector data associated with media 3 and importance region 2
-1 2
icnt/irgsec(ii),ii=1,icnt 2 -1 2
sector data associated with media 3 and importance region 3
-2 3
icnt/irgsec(ii),ii=1,icnt 2 -2 3 3
sector data associated with media 3 and importance region 4
-3 4
icnt/irgsec(ii),ii=1,icnt 2 -3 4 4
sector data associated with media 3 and importance region 5
-4 5
icnt/irgsec(ii),ii=1,icnt 2 -4 5 5
sector data associated with media 3 and importance region 6
6 -5
icnt/irgsec(ii),ii=1,icnt 2 6 -5

```

Figure F17.6.5 Example of unprocessed geometry input data

```

*****
***
***
***** geometry parameters *****
***
***
***      niar      number of independent array references      4      ***
***
***      ngblu     global unit number                          3      ***
***
***      nboxt     number of units in the problem              3      ***
***
***      nquad     number of quadratics in the problem          42     ***
***
***      ngwrds    number of geometry words read               15     ***
***
***      maxgwd    maximum geometry words in a unit            6      ***
***
***      maxsfu    largest number of surfaces in a unit         18     ***
***
***      maxreg    largest number of media in a unit            6      ***
***
***      regtot    number of spatial volumes defined            15     ***
***
***      sectot    number of entries in the sector array        77     ***
***
***      nucom     number of comments in the geometry data      0      ***
***
***      numhol    number of holes in the problem               1      ***
***
*****
***** data reading completed *****

```

Figure F17.6.5a Sample table of geometry input data

```

*****
***
***      sample problem 18  1f27  critical experiment      ***
***
*****
***
***      unit      data set name      volume      unit function      ***
***      number          name          name          ***
***      -----      -      -      -      ***
***      xsc  14      ft14f001          mixed cross sections      ***
***
***      alb  79      /scale/datalib/albedos      input albedos      ***
***
***      wts  80      /scale/datalib/weights      input weights      ***
***
***      skt  16      unknown          write scratch data      ***
***
***      lib  41      /home/lmp/scale/data/hrxsecs      input ampx working library      ***
***      8      ft08f001          input data direct access      ***
***
***      9      ft08f001          super grouped direct access      ***
***
***      10     ft08f001          xsec mixing direct access      ***
***
*****
..... 0 io's were used preparing input data .....

```

Figure F17.6.6 Sample table of data sets used in the problem

F17.6.5 TABLE OF DATA SETS USED IN THE PROBLEM

This table, printed from subroutine DATAIN, lists unit numbers that are specified in the parameter data or are defaulted in the code, and information pertinent to them. This information is given in the following order, left to right: (1) the keyword used in the parameter data to define the unit number, (2) the unit number, (3) the data set name, (4) the name of the volume on which the data set resides, and (5) the type of data contained on the data set. For UNIX systems the volume name is left blank. This table can be useful for quality assurance purposes. Information for units whose default values have not been overridden are printed even though they may not be used in the problem. Information for every unit specified in the parameter data is also printed. Units 8, 9, and 10 are the direct-access devices, and their unit numbers are fixed within the code. This table is followed by a statement of the number of I/Os used preparing the input data and writing it on the direct access data sets. It should be carefully scrutinized to verify that the desired data set name is associated with the proper unit number and volume. An example of this table is shown in Fig. F17.6.6.

F17.6.6 MIXING TABLE DATA

These data are printed by subroutine PRTMIX only if a mixing table data block is entered in the problem. It is not considered optional because it cannot be suppressed. A sample of the mixing table data is shown in Fig. F17.6.7.

The data printed in this table include the problem title and the number of scattering angles. This is followed by the entry number, the mixture number, the nuclide ID number, and the number density of each entry, printed in columnar form. After all the entries have been printed, the number of I/Os used in mixing the cross sections is printed. If extra 1-D cross sections were specified in the problem (see X1D=, Sect. F17.4.3), the extra 1-D cross-section IDs will be printed under the heading "1-D Cross-Section Array ID Numbers." If $\bar{v}$ is to be calculated (see NUB=, Sect. F17.4.3), six ID numbers will be printed. The ID number for the total cross section, Σ_T , is 1; the ID number for the sum of the transfer array normalized by Σ_T is 2002; the ID number for $v\Sigma_f$ is 1452; the normalized absorption cross section, Σ_{abs}/Σ_T , ID number is 27; the normalized fission cross section, Σ_f/Σ_T , ID number is 18; the fission spectrum, χ , ID number is 1018. χ is summed and normalized to 1.0. Other ID numbers that appear in this list have been specified by the user. If the number of blocks on the direct-access data set are insufficient to hold the cross-section data, a message is printed stating: THE NUMBER OF DIRECT ACCESS BLOCKS ON UNIT ____ HAS BEEN INCREASED TO _____. If the problem is to write a restart data set (RES=, Sect. F17.4.3), a message is printed stating that restart information was written and the restart I/O unit number is specified. This sequence is followed by a statement of the number of I/Os used in preparing the cross sections. The user should examine the mixing table carefully to verify that the proper nuclides are specified for the proper mixtures and that all the number densities are correct. The mixing table is printed in subroutine PRTMIX. Following this table is a statement of the unit number from which the cross-section data were read and a list of the cross-section IDs and their titles. This information is printed by subroutine MIXMIX. The 1-D cross-section array ID numbers are then printed.

```

sample problem 18 1f27 critical experiment
mixing table
number of scattering angles = 1

```

```

cross section message threshold =3.0E-05

```

entry	mixture	nuclide	density
1	1	92508	9.84350E-04
2	1	92852	7.76600E-05
3	1	7100	1.97460E-03
4	1	8100	3.70860E-02
5	1	1102	5.80760E-02
6	2	602	1.00000E+00
7	3	1102	8.25710E-02
8	3	6100	3.96970E-02
9	4	502	1.00000E-09

```

cross sections read from the ampx working library on unit 41

```

```

502 de/e water 0.9982g/cc h=.066742, o=.033371
602 de/e plexiglas 1.182g/cc h=.056884, c=.035552, o=.014221
1102 hydrogen de/e hansen roach
6100 carbon hansen roach
7100 nitrogen hansen roach
8100 oxygen hansen roach
92508 u-235-8r sig p = 1000 hansen roach
92852 u-238 sig p = 20000 hansen roach
..... 0 io's were used mixing cross-sections .....
1-d cross section array id numbers
1 2002 1452 27 18 1018
..... 0 io's were used preparing the cross sections .....

```

Figure F17.6.7 Example of mixing table data

F17.6.7 ALBEDO CROSS-SECTION CORRESPONDENCE

Printing the albedo cross-section correspondence tables is optional. The headings for the tables are printed in subroutine CORRE, then subroutine RATIO prints the data. These tables are printed only if PAX=YES is specified in the parameter data as described in Sect. F17.4.3. Examples of these tables are shown in Figs. F17.6.8 and F17.6.9.

The table shown in Fig. F17.6.8 contains, left to right, the cross-section energy group, the lower and upper lethargy bounds, the corresponding albedo energy groups, and the cumulative probability associated with each albedo energy group for choosing the albedo energy group corresponding to the cross-section energy group. The table shown in Fig. F17.6.9 is the inverse of the table shown in Fig. F17.6.8. It provides the cumulative probabilities for choosing the cross-section energy group corresponding to the albedo energy group. The information in these tables is automatically generated by KENO-VI.

cumulative probabilities for choosing the corresponding albedo group for each xsec group							
xsec energy group	cross section group lethargy boundaries		albedo group	probability	albedo group	probability	albedo group probability
1	.00000E+00	.12040E+01	1	1.00000			
2	.12040E+01	.19661E+01	2	1.00000			
3	.19661E+01	.24079E+01	3	1.00000			
4	.24079E+01	.32189E+01	4	1.00000			
5	.32189E+01	.46052E+01	5	1.00000			
6	.46052E+01	.63771E+01	6	1.00000			
7	.63771E+01	.81117E+01	7	1.00000			
8	.81117E+01	.98082E+01	8	1.00000			
9	.98082E+01	.11513E+02	9	1.00000			
10	.11513E+02	.12717E+02	10	1.00000			
11	.12717E+02	.13816E+02	11	1.00000			
12	.13816E+02	.15019E+02	12	1.00000			
13	.15019E+02	.16118E+02	13	1.00000			
14	.16118E+02	.17034E+02	14	1.00000			
15	.17034E+02	.18421E+02	15	1.00000			
16	.18421E+02	.19807E+02	16	1.00000			

Figure F17.6.8 Cumulative probabilities for correlating the albedo energy group to the cross-section energy group

cumulative probabilities for choosing the corresponding xsec group for each albedo group							
albedo energy group	albedo group lethargy boundaries		xsec group	probability	xsec group	probability	xsec group probability
1	-.40547E+00	.12040E+01	1	1.00000			
2	.12040E+01	.19661E+01	2	1.00000			
3	.19661E+01	.24079E+01	3	1.00000			
4	.24079E+01	.32189E+01	4	1.00000			
5	.32189E+01	.46052E+01	5	1.00000			
6	.46052E+01	.63771E+01	6	1.00000			
7	.63771E+01	.81117E+01	7	1.00000			
8	.81117E+01	.98082E+01	8	1.00000			
9	.98082E+01	.11513E+02	9	1.00000			
10	.11513E+02	.12717E+02	10	1.00000			
11	.12717E+02	.13816E+02	11	1.00000			
12	.13816E+02	.15019E+02	12	1.00000			
13	.15019E+02	.16118E+02	13	1.00000			
14	.16118E+02	.17034E+02	14	1.00000			
15	.17034E+02	.18421E+02	15	1.00000			
16	.18421E+02	.23026E+02	16	1.00000			

Figure F17.6.9 Cumulative probabilities for correlating the cross-section energy group to the albedo energy group

F17.6.8 1-D MACROSCOPIC CROSS SECTIONS

The decision to print the 1-D mixture cross sections is optional. They are printed in subroutine PRT1DS only if XS1=YES is specified in the parameter data as described in Sect. F17.4.3. When the 1-D cross sections are to be printed, they are printed a group at a time for each mixture. The 1-D mixture cross sections for a mixture are shown in Fig. F17.6.10.

When the 1-D mixture cross sections are printed, the problem title is printed at the top of the page. The mixture ID and MIXTURE INDEX numbers are then printed. ID is the mixture number from the mixing table, and MIXTURE INDEX is the index used to reference it, followed by a heading to identify the different 1-D cross sections. GROUP is the energy group, SGT is the total cross section for the mixture, NAP is the nonabsorption probability, ABP is the absorption probability, NFP is the production probability, CHI is the fission spectrum, MWA1 is the pointer for the first position of the cross sections for the energy group, MWA2 is the pointer for the last position of the cross sections for the energy group, and MWA3 contains the group for the transfer corresponding to the first position. SUM is the sum of the absorption probability and the nonabsorption probability. The absorption probability is defined as the absorption cross section divided by the total cross section. The nonabsorption probability is the sum of the group-to-group transfers for this group, divided by the total cross section. The production probability is defined as the fission production cross section divided by the total cross section, $\nu\Sigma_f/\Sigma_T$. The nonabsorption probability and the production probability are not true probabilities in that they may be greater than 1. This is because the nonabsorption probability has the (n,2n) transfer array summed into the total transfer array twice, and the (n,3n) is summed three times, etc.

F17.6.9 EXTRA 1-D CROSS SECTIONS

Printing the extra 1-D cross sections is optional. They are printed in subroutine PRT1DS if P1D=YES is specified in the parameter data (Sect. F17.4.3). Extra 1-D cross sections are not used in KENO-VI unless NUB=YES is specified in the parameter data or the user has altered the code to access and utilize other 1-D cross sections. If NUB=YES is specified, the extra 1-D cross section is the fission cross section, and is used to calculate the average number of neutrons per fission. This is printed only for fissile mixtures as shown in Fig. F17.6.10. The fission cross-section heading is XSEC ID 18, and it follows the table of 1-D cross sections.

F17.6.10 2-D MACROSCOPIC CROSS SECTIONS

The decision to print the 2-D mixture cross sections is optional. They are printed in subroutine PRT2DS only if XS2=YES is specified in the parameter data. They are printed after the 1-D cross sections for the mixture. A heading is printed, followed by the transfer data. An example of the 2-D mixture cross sections is given in Fig. F17.6.11.

F17.6.11 PROBABILITIES AND ANGLES

Printing the probabilities and angles is optional. They are printed if the number of scattering angles is greater than zero and XAP=YES is specified in the parameter data as described in Sect. F17.4.3. The probabilities and angles are printed for each mixture by subroutine PRT2DS. An example of the probabilities is shown in Fig. F17.6.12, and an example of the angles is shown in Fig. F17.6.13. If the group-to-group transfer for a mixture is isotropic, the first angle for that transfer will be set to -2.0 as a flag to the code.

```

sample problem 18 1f27 critical experiment
mixture id = 1 mixture index = 1

group  sgt      nap      abp      nfp      chi      mwa1      mwa2      mwa3      sum
1  1.39944E-01  9.76695E-01  2.33045E-02  2.59767E-02  2.04000E-01  1  6  1  1.00000E+00
2  1.77770E-01  9.91346E-01  8.65391E-03  1.82268E-02  5.48000E-01  7  12  2  1.00000E+00
3  3.19702E-01  9.95623E-01  4.37705E-03  9.53099E-03  7.16000E-01  13  18  3  1.00000E+00
4  3.83997E-01  9.96305E-01  3.69464E-03  7.65954E-03  8.96000E-01  19  24  4  1.00000E+00
5  5.44520E-01  9.96969E-01  3.03092E-03  6.35962E-03  9.86000E-01  25  30  5  1.00000E+00
6  8.24261E-01  9.96191E-01  3.80898E-03  7.31460E-03  1.00000E+00  31  36  6  1.00000E+00
7  9.89720E-01  9.94467E-01  5.53306E-03  1.02342E-02  1.00000E+00  37  42  7  1.00000E+00
8  1.04405E+00  9.89315E-01  1.06849E-02  1.82530E-02  1.00000E+00  43  48  8  1.00000E+00
9  1.06120E+00  9.73740E-01  2.62602E-02  4.24972E-02  1.00000E+00  49  54  9  1.00000E+00
10 1.09463E+00  9.45115E-01  5.48852E-02  8.26186E-02  1.00000E+00  55  60  10 1.00000E+00
11 1.09554E+00  9.44429E-01  5.55713E-02  7.55643E-02  1.00000E+00  61  66  11 1.00000E+00
12 1.10314E+00  9.37344E-01  6.26558E-02  6.09451E-02  1.00000E+00  67  71  12 1.00000E+00
13 1.07433E+00  9.61400E-01  3.85995E-02  6.73441E-02  1.00000E+00  72  75  13 1.00000E+00
14 1.28920E+00  9.35180E-01  6.48206E-02  1.30946E-01  1.00000E+00  76  78  14 1.00000E+00
15 1.83807E+00  8.75203E-01  1.24797E-01  2.42731E-01  1.00000E+00  79  80  15 1.00000E+00
16 3.38272E+00  8.16191E-01  1.83809E-01  3.67874E-01  1.00000E+00  81  81  16 1.00000E+00

xsec id 18 grp.
1  8.85189E-03
2  6.96651E-03
3  3.76749E-03
4  3.07612E-03
5  2.58521E-03
6  2.98555E-03
7  4.17721E-03
8  7.45021E-03
9  1.73458E-02
10 3.37219E-02
11 3.08426E-02
12 2.48756E-02
13 2.74874E-02
14 5.34473E-02
15 9.90739E-02
16 1.50153E-01

```

Figure F17.6.10 Example of macroscopic 1-D cross sections

```

scattering transfer array for material 1
from grp 1 grp 2 grp 3 grp 4 grp 5 grp 6 grp 7 grp 8 grp 9 grp 10
to grp
+ 0 2.54209E-01 3.10539E-01 2.98182E-01 3.71084E-01 4.55319E-01 4.72411E-01 4.56823E-01 4.47266E-01 4.48962E-01 3.30557E-01
+ 1 4.48688E-01 2.73107E-01 4.37470E-01 4.85849E-01 4.56102E-01 4.37482E-01 4.45877E-01 4.54113E-01 3.88724E-01 4.51241E-01
+ 2 1.04476E-01 2.31550E-01 1.97693E-01 1.18779E-01 7.31741E-02 7.39104E-02 7.95987E-02 6.85965E-02 1.07909E-01 1.52634E-01
+ 3 1.06680E-01 1.39556E-01 5.49774E-02 2.00378E-02 1.25166E-02 1.32261E-02 1.23322E-02 2.02416E-02 3.82178E-02 4.37863E-02
+ 4 6.46550E-02 3.86576E-02 9.48767E-03 3.33964E-03 2.35355E-03 2.12183E-03 3.59935E-03 6.85965E-03 1.07909E-02 1.30236E-02
+ 5 2.12918E-02 6.59086E-03 2.18946E-03 9.10810E-04 5.34899E-04 8.48732E-04 1.77017E-03 2.92379E-03 5.39546E-03 8.75725E-04
from grp 11 grp 12 grp 13 grp 14 grp 15 grp 16
to grp
+ 0 3.02946E-01 3.19203E-01 2.89136E-01 3.46347E-01 8.10619E-01 1.00000E+00
+ 1 4.94030E-01 4.59900E-01 4.33884E-01 4.94691E-01 1.89381E-01
+ 2 1.35724E-01 1.32774E-01 2.07145E-01 1.58962E-01
+ 3 4.03578E-02 6.63872E-02 6.98356E-02
+ 4 2.02070E-02 2.17359E-02
+ 5 6.73566E-03

```

Figure F17.6.11 Example of 2-D macroscopic cross sections

```

probability 1 array for material 1
from grp 1 grp 2 grp 3 grp 4 grp 5 grp 6 grp 7 grp 8 grp 9 grp 10
to grp
+ 0 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
transfers from grp+ 1 to grp+ 4 are the same as above
+ 5 1.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
from grp 11 grp 12 grp 13 grp 14 grp 15 grp 16
to grp
+ 0 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
+ 1 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
+ 2 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00
+ 3 1.00000E+00 1.00000E+00 1.00000E+00
+ 4 1.00000E+00 1.00000E+00
+ 5 1.00000E+00

```

Figure F17.6.12 Example of macroscopic probabilities

```

angle 1 array for material 1
from grp 1 grp 2 grp 3 grp 4 grp 5 grp 6 grp 7 grp 8 grp 9 grp 10
to grp
+ 0 2.50717E-02 1.37955E-01 1.34616E-02 7.28156E-02 2.88056E-01 4.28189E-01 4.40454E-01 4.42506E-01 4.43150E-01 3.70214E-01
+ 1 5.38829E-01 6.16596E-01 5.69298E-01 5.77713E-01 5.52605E-01 5.45150E-01 5.49196E-01 5.50241E-01 5.78041E-01 6.17541E-01
+ 2 5.20566E-01 5.65012E-01 4.67921E-01 3.16948E-01 2.26608E-01 2.37321E-01 2.40919E-01 2.54098E-01 3.31771E-01 3.63001E-01
+ 3 3.82358E-01 3.49483E-01 2.25674E-01 1.21212E-01 1.02564E-01 1.01604E-01 1.10048E-01 1.41667E-01 1.88235E-01 2.02564E-01
+ 4 2.36583E-01 1.70493E-01 9.61538E-02 4.54545E-02 4.54545E-02 3.33333E-02 6.55738E-02 8.19672E-02 1.04167E-01 1.20690E-01
+ 5 1.19735E-01 5.00000E-02 2.00000E+00 2.00000E+00 2.00000E+00 2.00000E+00 3.33333E-02 3.84615E-02 6.25000E-02 7.05128E-02
from grp 11 grp 12 grp 13 grp 14 grp 15 grp 16
to grp
+ 0 3.37214E-01 3.36073E-01 3.09208E-01 5.56326E-01 4.45358E-01 2.52418E-01
+ 1 6.18647E-01 6.19905E-01 6.40449E-01 6.23199E-01 3.81259E-01
+ 2 3.56907E-01 3.79019E-01 4.00109E-01 1.81818E-01
+ 3 2.11405E-01 2.26734E-01 1.28824E-01
+ 4 1.25000E-01 7.23514E-02
+ 5 4.16667E-02

```

Figure F17.6.13 Example of macroscopic angles

F17.6.12 TABLE OF ADDITIONAL INFORMATION

This table contains information determined by the input data and is printed by subroutine NSUPG. An example of this table is shown in Fig. F17.6.14.

This table should be examined by the user to verify the problem data. The NUMBER OF ENERGY GROUPS is read either from the Monte-Carlo-formatted library, identified by the keyword XSC and the unit function name MIXED CROSS SECTIONS from the Table of Data Sets in Sect. F17.6.5, or from the restart unit, identified by the keyword RST and the unit function name, READ RESTART DATA. The NO. OF FISSION SPECTRUM SOURCE GROUP is the number of different energy groups for which a fission spectrum is defined. In the present version, this number should always be 1. The NO. OF SCATTERING ANGLES IN XSECS is the number of scattering angles to be used in processing the cross sections. The default value is 1 and may be overridden by specifying the parameter SCT= in the mixing table input as described in Sect. F17.4.10. One scattering angle yields P_1 cross sections, two scattering angles yield P_2 cross sections, three scattering angles yield P_3 cross sections, etc. ENTRIES/NEUTRON IN THE NEUTRON BANK specifies the number of pieces of data that are banked for each history during tracking. ENTRIES/NEUTRON IN THE FISSION BANK is the amount of data stored for each source neutron for each generation.

The NUMBER OF MIXTURES USED is the number of different mixtures (media) used in the geometry data utilized by the problem. This value may be less than the total number of different mixtures specified in the geometry data if portions of the geometry data are not used in the problem.

The NUMBER OF BIAS IDS USED is the number of different biasing regions used in the problem. This will always be 1 unless a biasing data block is entered in the problem as described in Sect. F17.4.7.

The NUMBER OF DIFFERENTIAL ALBEDOS USED is the number of different differential albedo reflectors used in the problem. This value will always be zero unless the boundary condition data specify the use of differential albedo reflection on one or more faces of the system as described in Sect. F17.4.6. Also check the BOUNDARY CONDITION data printed in this table. The number of different differential albedos specified on the faces should be consistent with the NUMBER OF DIFFERENTIAL ALBEDOS USED. Specular, mirror, vacuum, and periodic are not differential albedos. Be aware that several different keywords may be used to specify the same differential albedo. See Table F17.4.4 for a list of differential albedo keywords.

The TOTAL INPUT GEOMETRY REGIONS is the number of geometry regions specified in the problem input. This is defined by the MEDIA-type record used in describing the data. The MEDIA records start with the words MEDIA, ARRAY, and HOLE. The NUMBER OF GEOMETRY REGIONS USED is the number of geometry regions used in the problem. It may be less than or equal to the TOTAL INPUT GEOMETRY REGIONS. (The LARGEST GEOMETRY UNIT NUMBER is the largest unit number used in the problem.) The LARGEST ARRAY NUMBER is the largest array number specified in the array data. (See Sect. F17.4.5.)

USE LATTICE GEOMETRY is determined by the logical flag that indicates whether or not the problem is a single-unit problem. This should be YES for any problem that is not a single-unit problem and NO for a single-unit problem. By definition, a single-unit problem is a problem that does not utilize array data in any form. Section F17.4.5 describes array data. The GLOBAL ARRAY NUMBER is the number of the array designated as the global array. Any array in a problem can be designated the global array. The global array is used only when matrix data are being collected.

The NUMBER OF UNITS IN THE GLOBAL X/Y/Z DIR. defines the size of the global array in terms of the number of units that are located along the edge of the array boundaries in the x/y/z directions. For a single unit, all three of these values should be zero. For a simple $1 \times 1 \times 1$ array consisting of one unit type, all three of these numbers should be 1.

```

*****
***
***      sample problem 18   1f27   critical experiment      ***
***
*****
*****
***      ***** additional information *****      ***
***
***      number of energy groups          16      use lattice geometry          yes      ***
***
***      no. of fission spectrum source group 1      global array number          0      ***
***
***      no. of scattering angles in xsecs    1      number of units in the global x dir.    0      ***
***
***      entries/neutron in the neutron bank 28      number of units in the global y dir.    0      ***
***
***      entries/neutron in the fission bank 15      number of units in the global z dir.    0      ***
***
***      number of mixtures used              3      use a global reflector                  yes      ***
***
***      number of bias id's used             6      use nested holes                        no       ***
***
***      number of differential albedos used   1      number of holes                         1       ***
***
***      total input geometry regions          15      maximum hole nesting level             1       ***
***
***      number of geometry regions used       15      use nested arrays                       no       ***
***
***      largest geometry unit number          3      number of arrays used                   4       ***
***
***      largest array number                  4      maximum array nesting level             1       ***
***
***
***      +x boundary condition          vacuum      -x boundary condition          vacuum      ***
***
***      +y boundary condition          vacuum      -y boundary condition          vacuum      ***
***
***      +z boundary condition          vacuum      -z boundary condition          h2o       ***
***
*****

```

Figure F17.6.14 Sample table of additional information

USE GLOBAL REFLECTOR indicates if the global array is reflected.

USE NESTED HOLES is set YES if holes are nested deeper than one level.

NUMBER OF HOLES is the number of HOLES that are entered in the geometry region data (Sect. F17.4.4).

The MAXIMUM HOLE NESTING LEVEL is the deepest level of hole nesting.

USE NESTED ARRAYS is set YES if arrays are nested deeper than one level.

The NUMBER OF ARRAYS USED is the number of array descriptions (Sect. F17.4.5) actually used in the problem description.

MAXIMUM ARRAY NESTING LEVEL is the deepest level of array nesting.

Six BOUNDARY CONDITIONS are printed near the bottom of the table. They show the type of boundary condition that is applied to each face of the system. These should all be VACUUM unless albedo boundary conditions are applied to one or more faces of the system as described in Sect. F17.4.6. Also refer to the NUMBER OF DIFFERENTIAL ALBEDOS USED, discussed previously in the description of this table of information.

F17.6.13 TABLE OF SPACE AND SUPERGROUP INFORMATION

Another table printed by KENO-VI, as shown in Fig. F17.5.15, summarizes the space requirements for the problem and prints information related to the supergroups. This table is printed by subroutines NSUPG and LIMLN.

This table contains information about the space requirements of the problem and the number of supergroups used in the problem. The table is basically self-explanatory.

The TOTAL SPACE AVAILABLE is the amount of memory (in words) available to contain the data for the problem. The NONSUPERGROUP STORAGE is the number of words of memory containing nonsupergrouped data. Following this information are statements concerning the amount of storage available for supergrouped data, the amount of storage available for constructing the supergroups, the amount of storage available for each supergroup, the number of words of storage needed for the largest supergroup, the amount of storage needed to run the problem, and the amount of storage that would be necessary to run the problem with one supergroup, and the number of words of storage that will be used to run this problem.

The bottom portion of this table contains information about the supergroups. Warning and error messages may appear in this portion of the table. The printed supergroup data include the supergroup number, the first energy group in the supergroup, the last energy group in the supergroup, the length (in words) of the cross-section data for the supergroup, the length (in words) of the albedo data for the supergroup, and the total length (in words) of all the data for the supergroup. This information is printed for each supergroup.

F17.6.14 ARRAY SUMMARY

The arrays that are used in the problem are summarized in the table shown in Fig. F17.6.16. This table is printed by subroutine PRTARA whenever more than one array is used in the problem.

The ARRAY NUMBER is the number by which the array is designated in the input data. The number of units in the x, y, and z directions is listed for each array. The global array is flagged by the word GLOBAL. The NESTING LEVEL indicates the level of nesting for each array. Arrays can be nested to any level, limited only by the capability of the computer. A nesting level of 1 is the highest or first nesting level. The larger the number in the nesting level column, the deeper the nesting level.

```

*****
***                                     ***
***      sample problem 18   1f27   critical experiment      ***
***                                     ***
*****
***                                     ***
***      ***** space and supergroup information *****    ***
***                                     ***
***      30000 words is the total space available.           ***
***                                     ***
***      18899 words were used for non-supergroup storage.    ***
***                                     ***
***      11101 words of storage are available for supergrouped data. ***
***                                     ***
***      29626 words of storage are available for constructing the supergroups. ***
***                                     ***
***      11062 words of storage are available to each supergroup. ***
***                                     ***
***      690 words are needed for the largest group.          ***
***                                     ***
***      19733 words of storage is sufficient to run this problem. ***
***                                     ***
***      26768 words of storage will allow the problem to run with one supergroup. ***
***                                     ***
***      26928 words of storage will be used to run this problem. ***
***                                     ***
*****
*****
***                                     ***
***      supergroup      starting      ending      xsec      albedo      total ***
***      group           group         group        length    length     length ***
***                                     ***
***      1                1             16          243        544        7830 ***
***                                     ***
*****
..... 0 io's were used in supergrouping .....

```

Figure F17.6.15 Sample table of space and supergroup information

```

*****
**                                     **
**      array      units in   units in   units in   nesting ***
**      number     x dir.    y dir.    z dir.    level  ***
**                                     **
**      1          2         2         2         1   **
**                                     **
**      2          2         2         1         1   **
**                                     **
**      3          1         2         3         1   **
**                                     **
**      4          3         1         3         1   **
**                                     **
*****
..... 0 io's were used loading the data .....

```

Figure F17.6.16 Examples of array summary

F17.6.15 GEOMETRY DATA

The geometry region data utilized by the problem are printed by subroutine PRTJOM and cannot be suppressed. They should be carefully examined by the user to verify the mixture number, bias ID, and geometry specifications used in the problem. If geometry region data are input but are not referenced in the unit orientation array data, they will not be printed here. An example would be to input geometry region data describing Units 1, 2, 3, and 4 and to utilize only Units 1, 3, and 4 in the unit orientation array. Then the geometry region data for Unit 2 will not be printed. An example of the geometry region printout for a problem is given in Fig. F17.6.17.

The problem title and a heading are printed at the top of each page. The unit number followed by the GEOMETRY data for that unit is then printed. Each geometry record type used in the unit, numbered in the order they appear in the unit, is printed out. Following each geometry record type is the set of quadratic equations that describe the input geometry for that geometry record. The MEDIA data, consisting of four columns, is then listed in the order it appears in the problem. The first column contains the media-type record. The second column contains the media/hole/array number. The third column contains the bias ID number if the media-type record is MEDIA and is otherwise blank. The fourth column contains the sector definition array, which describes the region location relative to the GEOMETRY records listed above for that unit.

The data consisting of the unit number, GEOMETRY data, and MEDIA data are repeated for each unit used in the problem. The global unit has a heading printed before the unit number to identify it as the global unit.

F17.6.16 UNIT ORIENTATION DESCRIPTION

Each unit orientation description defines the location of units in the 3-D lattice that represents the specified array. The array that is described is identified in the heading: UNIT ORIENTATION DESCRIPTION FOR ARRAY _____. The arrays used in the problem are stacked together to represent the physical problem being analyzed. The unit orientation description is not printed if only Unit 1 is described in the problem. The user should carefully examine the unit orientation descriptions to ensure the proper placement of the units in each lattice. A sample unit orientation description is shown in Fig. F17.6.18.

If a very large array is utilized by the problem, its unit orientation description may be spread over several pages. When checking the printout, the user should pay careful attention to the headings that indicate the portion of each lattice being printed. The unit orientation descriptions are printed in subroutine PRTLBA.

F17.6.17 VOLUME INFORMATION

Three tables of volumes are printed by subroutine VOLUME and cannot be suppressed. Currently, the volume data contained in these tables are meaningless. Future work on KENO-VI includes calculating the volumes of each region as is done in KENO-V.a. The first table printed will include the volume of each individual region and the cumulative volumes for each region in the unit. The second table will list the number of times each unit is used in the problem and the total volume of each region throughout the entire problem description. The third table will list the total volume of each mixture used in the problem. An example of the volume printout is given in Fig. F17.6.19.

sample problem 18 1f27 critical experiment
 geometry description for those units utilized in this problem

```

----- unit 1 -----
1      cylinder
-1.000x**2 -1.000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 90.630
2      cylinder
-1.000x**2 -1.000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 90.630
3      cylinder
-1.000x**2 -1.000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 78.932
4 boundary cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 103.226
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 90.715
5 boundary cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 340.402
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 340.402
.000x**2 .000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 316.473
media 1 imp sector
media 0 1 1 definitions
media 2 1 -1 2
media 3 1 -1 -2 3
media 4 1 4 -2 -3

----- unit 2 -----
1 boundary cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz -36.900x .000y .000z 1020.470
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x 36.900y .000z 1020.470
2 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz -36.900x .000y .000z 1020.470
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x 36.900y .000z 1020.470
3 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x 36.900y .000z 1020.470
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x 36.900y .000z 1020.470
4 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x 36.900y .000z 1020.470
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x 36.900y .000z 1020.470
5 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x 36.900y .000z 1020.470
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x 36.900y .000z 1020.470
media 1 imp sector
media 2 1 1 definitions
media 3 1 -1 2
media 4 1 -1 -2 3
media 5 1 4 -2 -3

----- unit 3 -----
1 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 3063.622
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 3063.622
2 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 3404.723
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 3404.723
3 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 3177.577
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 3177.577
4 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 3763.823
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 3763.823
5 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 3524.797
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 3524.797
6 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 4140.922
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 4140.922
7 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 3890.017
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 3890.017
8 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 4536.022
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 4536.022
9 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 4273.237
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 4273.237
10 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 4982.948
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 4982.948
11 cuboid
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 4707.332
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 4707.332
hole 1 imp sector
media 3 2 1 definitions
media 4 3 -1 2
media 5 3 -2 3
media 6 4 -3 4
media 7 5 -4 5
media 8 6 -5 6

```

Figure F17.6.17 Example of geometry region data

```

sample problem 18  1f27  critical experiment
----- unit orientation description for array  1 -----
z layer  1, x column  1 to  2 left to right  y row  1 to  2 bottom to top
1 1
1 1
1 1
-z layer  2, x column  1 to  2 left to right  y row  1 to  2 bottom to top
1 1
1 1

```

Figure F17.6.18 Example of unit orientation description

```

sample problem 18  1f27  critical experiment
volumes for those units utilized in this problem
geometry
unit  region  region  volume  cumulative
1      1      1      1.00000E+00 cm**3  1.00000E+00 cm**3
      2      2      1.00000E+00 cm**3  1.00000E+00 cm**3
      3      3      1.00000E+00 cm**3  1.00000E+00 cm**3
      4      4      1.00000E+00 cm**3  1.00000E+00 cm**3
2      1      5      1.00000E+00 cm**3  1.00000E+00 cm**3
      2      6      1.00000E+00 cm**3  1.00000E+00 cm**3
      3      7      1.00000E+00 cm**3  1.00000E+00 cm**3
      4      8      1.00000E+00 cm**3  1.00000E+00 cm**3
      5      9      1.00000E+00 cm**3  1.00000E+00 cm**3
3      1     10      1.00000E+00 cm**3  1.00000E+00 cm**3
      2     11      1.00000E+00 cm**3  1.00000E+00 cm**3
      3     12      1.00000E+00 cm**3  1.00000E+00 cm**3
      4     13      1.00000E+00 cm**3  1.00000E+00 cm**3
      5     14      1.00000E+00 cm**3  1.00000E+00 cm**3
      6     15      1.00000E+00 cm**3  1.00000E+00 cm**3

unit  uses  region  mixture  total volume
1      27      1      1      2.70000E+01 cm**3
      2      0      2.70000E+01 cm**3
      3      2      2.70000E+01 cm**3
      4      0      2.70000E+01 cm**3
2      1      1      1.00000E+00 cm**3
      2      1.00000E+00 cm**3
      3      1.00000E+00 cm**3
      4      1.00000E+00 cm**3
      5      0      1.00000E+00 cm**3
3      1      1     -1      1.00000E+00 cm**3
      2      3      1.00000E+00 cm**3
      3      3      1.00000E+00 cm**3
      4      3      1.00000E+00 cm**3
      5      3      1.00000E+00 cm**3
      6      3      1.00000E+00 cm**3

total mixture volumes
mixture  total volume
0      5.50000E+01 cm**3
1      2.70000E+01 cm**3
2      2.70000E+01 cm**3
3      5.00000E+00 cm**3

```

Figure F17.6.19 Sample volume information

The unit number is printed under the heading UNIT. The REGION refers to the number of the geometry region within the unit determined by the order of the MEDIA records in the unit. The geometry regions within a unit are numbered sequentially, starting with 1. GEOMETRY REGION refers to the entry number for the individual geometry region. These regions are numbered sequentially, starting with 1, through the TOTAL INPUT GEOMETRY REGIONS defined in Sect. F17.6.12. The VOLUME is the net volume of the individual region. The CUMULATIVE VOLUME is calculated from the dimensions of the region. In the second table, USES indicates the number of times the unit is used in the problem. MIXTURE is the mixture number used in the region. A minus sign indicates an array or unit, placed in a hole, in that region. TOTAL VOLUME is the total volume of that region, determined by multiplying the VOLUME of the region by the number of times the unit containing that region is used in the problem. In the third table, the mixtures used in the problem are listed along with their total volumes. For example, assume region 1 is a cube 3 cm on a side, region 2 is a cube 4 cm on a side, and region 3 is a cube 5 cm on a side. The CUMULATIVE VOLUME of region 1 is 9 cc, of region 2 is 16 cc, and region 3 is 25 cc. The VOLUME of region 1 is 9 cc, region 2 is 5 cc (16-9), and region 3 is 9 cc (25-16). The TOTAL VOLUME of each region is determined by multiplying the VOLUME for a region by the number of times the unit containing that region is used in the problem. The number of times a unit is used in the problem is listed under the heading USES.

F17.6.18 BIASING INFORMATION

This table specifies the weighting or biasing data to be used in the problem. An example of biasing information is given in Fig. F17.6.20.

The user is responsible for determining from the input data whether the group-dependent weights (*wtavg*) for the specified material(s) were obtained from the weighting library or were entered by the user. The group-dependent weights can be printed for verification purposes as shown in Sect. F17.6.19.

```

*****
***                                     ***
***                               biasing information                               ***
***                                     ***
*** weighting intervals 1 to 5 for paraffi ,mat id=400 will be used for bias id's 2 to 6 ***
***                                     ***
*** a default weight of .500 will be used for all other bias id's.                 ***
***                                     ***
*****

```

Figure F17.6.20 Biasing information

F17.6.19 GROUP-DEPENDENT WEIGHTS

Printing the group-dependent weights is optional. They are printed by subroutine PRTWTS if PWT=YES (Sect. F17.4.3) is entered in the parameter data. An example of the printed group-dependent weights is shown in Fig. F17.6.21.

The title is printed at the top of the table. The average weight (*wtavg*) is printed for each energy group and each BIAS ID. The BIAS ID number printed at the top of the column corresponds to the BIAS ID used in the geometry region description and printed in the biasing information.

sample problem 18 1f27 critical experiment

group dependent weights

energy group	bias id 1	bias id 2	bias id 3	bias id 4	bias id 5	bias id 6
1	5.00000E-01	5.96000E-01	8.46000E-01	1.28000E+00	2.08000E+00	3.51000E+00
2	5.00000E-01	5.89000E-01	8.73000E-01	1.50000E+00	2.87000E+00	5.88000E+00
3	5.00000E-01	5.83000E-01	9.15000E-01	1.80000E+00	4.17000E+00	1.07000E+01
4	5.00000E-01	5.77000E-01	9.72000E-01	2.17000E+00	5.80000E+00	1.73000E+01
5	5.00000E-01	5.94000E-01	1.14000E+00	2.99000E+00	9.42000E+00	3.28000E+01
6	5.00000E-01	6.40000E-01	1.44000E+00	4.46000E+00	1.61000E+01	6.19000E+01
7	5.00000E-01	6.71000E-01	1.63000E+00	5.38000E+00	2.02000E+01	7.86000E+01
8	5.00000E-01	6.84000E-01	1.75000E+00	6.02000E+00	2.30000E+01	9.01000E+01
9	5.00000E-01	6.87000E-01	1.84000E+00	6.57000E+00	2.54000E+01	9.97000E+01
10	5.00000E-01	6.73000E-01	1.88000E+00	6.95000E+00	2.71000E+01	1.07000E+02
11	5.00000E-01	6.48000E-01	1.89000E+00	7.12000E+00	2.79000E+01	1.10000E+02
12	5.00000E-01	6.31000E-01	1.95000E+00	7.48000E+00	2.94000E+01	1.16000E+02
13	5.00000E-01	7.68000E-01	2.65000E+00	1.03000E+01	4.05000E+01	1.59000E+02
14	5.00000E-01	8.18000E-01	2.97000E+00	1.16000E+01	4.56000E+01	1.80000E+02
15	5.00000E-01	8.24000E-01	3.05000E+00	1.19000E+01	4.70000E+01	1.85000E+02
16	5.00000E-01	8.91000E-01	3.52000E+00	1.39000E+01	5.46000E+01	2.15000E+02

1f27 xy plot at z=0.0

Figure F17.6.21 Example of biasing data

F17.6.20 PICTURE OR PLOT REPRESENTATION

Printer plots representing 2-D slices through the geometrical description of the problem are optional. They are created if picture or plot data are entered as specified in Sect. F17.4.11 unless PLT=NO is specified either in the plot data or the parameter data (Sect. F17.4.3). A sample picture and its associated data are shown in Figs. F17.6.22 and F17.6.23.

Figure F17.6.22 summarizes the data used to generate the picture or plot. Figure F17.6.23 is an example of a printer plot of the 2-D slice specified through the geometrical description of the problem.

In Fig. F17.6.22, the plot title is printed at the top of the page. If a plot title was not entered in the plot data, the plot title is defaulted to the problem title. The title is followed by a heading that specifies the type of picture (MIXTURE MAP, BIAS ID MAP or UNIT MAP). This heading is followed by a table that correlates the symbols to be used in the printer plot with the mixture numbers, bias ID numbers or unit numbers that were used in the problem. The coordinates of the upper-left corner and lower-right corner of the picture are then printed. This is followed by the direction cosines down and across the page. NU is the number of characters printed in the "U" direction, NV is the number of characters printed in the "V" direction, DELU is the incremental distance, in cm, represented by each character in the "U" direction, and DELV is the incremental distance, in cm, represented by each character in the "V" direction.

```

1f27 xy plot at z=0.0
mixture 0 1 2 3
symbol * - 3
upper left      lower right
coordinates      coordinates
x   -7.1000E+01  7.1000E+01
y    7.1000E+01 -7.1000E+01
z    0.0000E+00  0.0000E+00
u axis          v axis
(down)          (across)
x      .00000    1.00000
y     -1.00000    .00000
z      .00000    .00000
nu=   68  nv=  130  delu= 2.0632E+00  delv= 1.0923E+00

```

Figure F17.6.22 Summary of picture symbols and coordinates

Figure F17.6.23 shows a printer plot of a 2-D slice specified through the geometrical description of the problem. These plots aid the user in verifying that the problem is described correctly. Any number of plots can be made.

Figure F17.6.23 Sample plot representation

F17.6.21 CONCLUDE PRETRACKING EDITS

Prior to calculating the k-effectives for each generation, KENO-VI prints a final edit as shown in Fig. F17.6.24.

```

..... 0 io's were used in keno-v before tracking .....
..... .06400minutes were used processing data. ....
volume fraction of fissile material in the system= .23684E+00
start type 0 was used.
the neutrons were started with a flat distribution in a cuboid defined by:
+x= 7.05900E+01 -x=-7.05900E+01 +y= 7.05900E+01 -y=-7.05900E+01 +z= 6.86100E+01 -z=-6.86100E+01
.02133 minutes were required for starting. total elapsed time is .08533 minutes.
```

Figure F17.6.24 Pretracking edits

The information printed in this edit includes the number of I/Os used prior to tracking, the time in minutes used for preparing and processing the data prior to preparing the initial source distribution, and the volume fraction of fissile material in the system. The volume fraction of fissile material in the core is currently meaningless. Future plans for KENO-VI include the ability to calculate volumes and volume fractions. If RFL=NO (Sect. F17.4.8) was specified in the start data, the volume fraction message is changed to: VOLUME FRACTION OF FISSILE MATERIAL IN THE CORE =.

Most of the remaining data printed in this edit are related to the choice of the initial neutron source distribution. Once the initial source distribution has been prepared, the time required for preparing them (starting) is printed, as well as the total cumulative time used by the code. Start type 0, which generates a flat, random distribution over all fissile material in the problem, is the default source distribution.

F17.6.22 PRINT STARTING POINTS

This printout is optional and is used to verify the initial source starting points. An example of this information is given in Fig. F17.6.25.

The information pertinent to the initial source distribution is printed two lines at a time and appears under the designated headings. For example, the coordinates X, Y, and Z are printed on one line and the direction cosines U, V, and W are printed directly under them. The data printed for each source neutron include the following:

NEUTRON is the ID number of the neutron.

X, Y, and Z are the coordinates of the starting point relative to the coordinate system of the unit.

WT is the current weight (WT is always 1.0 for a neutron when it is started).

K is the region number that contains the point X, Y, Z.

NBX, NBY, NBZ are the coordinates of the unit within the array.

where	neutron random number	x u	y v	z w	wt etausd	k now	nbx kcor	nby llc	nbz kcol	lstc lsth	nhol ig	ll nsig	kr sg	ki
start	350	-2.93389E+00	4.55407E+00	4.68300E+00	1.00000E+00	1	2	1	3	0	1	1	1	0
	0000334768F44690	3.78162E-01	4.60779E-01	8.02917E-01	0.00000E+00	4	8	0	0	3	3	1		
start	349	-4.00210E+00	6.15422E+00	5.93966E+00	1.00000E+00	1	3	1	2	0	1	1	1	0
	0000334768F44690	2.08141E-01	2.01154E-01	-9.57191E-01	0.00000E+00	4	8	0	0	1	1	1		
start	348	-2.80915E+00	2.29649E+00	3.72475E+00	1.00000E+00	1	2	1	1	0	1	1	1	0
	0000334768F44690	-7.35305E-01	1.49356E-01	6.61074E-01	0.00000E+00	4	6	0	0	1	1	1		
start	347	3.94031E+00	-6.48469E+00	1.03994E+00	1.00000E+00	1	1	1	1	0	1	1	1	0
	0000334768F44690	3.18453E-01	-2.49655E-01	-9.14473E-01	0.00000E+00	4	6	0	0	4	4	1		
start	346	5.68195E+00	-4.41095E-01	-3.78734E+00	1.00000E+00	1	2	2	2	0	1	1	1	0
	0000334768F44690	3.83747E-01	-8.02679E-01	4.56557E-01	0.00000E+00	4	5	0	0	4	4	1		
start	345	-1.29827E+00	-1.33806E+00	-5.75073E+00	1.00000E+00	1	1	1	2	0	1	1	1	0
	0000334768F44690	-3.05448E-01	-9.31668E-01	-1.96713E-01	0.00000E+00	4	7	0	0	2	2	1		
start	344	3.16313E-02	8.62766E+00	3.12925E+00	1.00000E+00	1	2	1	1	0	1	1	1	0
	0000334768F44690	-8.19429E-01	2.34186E-01	5.23157E-01	0.00000E+00	4	8	0	0	4	4	1		
start	343	2.31603E+00	-3.41755E+00	8.47753E+00	1.00000E+00	1	3	1	1	0	1	1	1	0
	0000334768F44690	2.50993E-01	-9.44899E-01	-2.10163E-01	0.00000E+00	4	8	0	0	2	2	1		
start	342	7.92013E+00	-3.31669E+00	-6.54100E+00	1.00000E+00	1	1	1	1	0	1	1	1	0
	0000334768F44690	1.75156E-02	9.23284E-01	3.83718E-01	0.00000E+00	4	8	0	0	3	3	1		
start	341	8.17152E+00	7.80831E-01	4.88753E+00	1.00000E+00	1	2	1	2	0	1	1	1	0
	0000334768F44690	-4.58036E-01	8.74804E-01	-1.57864E-01	0.00000E+00	4	8	0	0	1	1	1		
start	340	2.25991E+00	-7.97285E+00	1.27218E+00	1.00000E+00	1	1	2	1	0	1	1	1	0
	0000334768F44690	4.04771E-01	4.06303E-01	8.19193E-01	0.00000E+00	4	5	0	0	1	1	1		
start	339	-7.11336E+00	-5.01182E+00	-1.35331E-01	1.00000E+00	1	1	2	2	0	1	1	1	0
	0000334768F44690	-8.35758E-01	4.92574E-01	-2.42650E-01	0.00000E+00	4	5	0	0	2	2	1		
start	338	-4.42523E+00	1.73051E+00	4.17569E+00	1.00000E+00	1	1	2	1	0	1	1	1	0
	0000334768F44690	2.08661E-01	-9.69024E-01	1.32109E-01	0.00000E+00	4	7	0	0	2	2	1		

Figure F17.6.25 Example of initial source points

LSTC is the last unit where the neutron resided

NHOL is the hole where the neutron currently resides.

LL is the unit or box type number.

KR is the mixture number present at the starting point.

KI is the bias ID number at the point.

RANDOM NUMBER is the current random number.

U, V, and W are the direction cosines defining the direction the history is traveling.

ETAUSD is the amount of the distance to collision already traversed.

NOW is the array where the neutron currently resides.

KCOR is the core boundary region of the array where the neutron currently resides.

LLC is the unit surrounding the array the unit is in.

KCOL is the region number in which the last collision occurred.

IG is the energy group.

NSIG is the position of the group IG in the supergroup.

SG is the supergroup number.

When starting points are printed, many of the above named variables have not been initialized. For starting, the variables of interest are X, Y, Z, U, V, W, NBX, NBY, NBZ, and LL.

F17.6.23 K-EFFECTIVES BY GENERATION

At the completion of each generation, KENO-VI prints the k-effective for that generation and associated information. An example of this printout is given in Fig. F17.6.26.

The k-effectives for each generation are printed in subroutine FISFLX. The headings are printed by subroutine GUIDE. The problem title is printed at the top of the page. A descriptive heading is printed at the top of each column of data. The data that are printed include (1) the generation number, (2) the k-effective calculated for the generation, (3) the elapsed CPU time in minutes, (4) the average value of k-effective through the current generation (excluding the *nskip-1* generations), (5) the deviation associated with the average k-effective, (6) the matrix k-effective for the generation, and (7) the deviation associated with the matrix k-effective. The last two columns are filled with zeros if the user did not specify matrix k-effective calculations. The matrix k-effective is the largest eigenvalue of the fission production matrix. Matrix information can be calculated based on (1) position index, (2) unit number, (3) hole number, and (4) array number. The matrix k-effective printed in the sixth column is based on this order. If the matrix k-effective is calculated by position index, it is the one printed in the sixth column. The matrix k-effective by unit number is given second preference, followed by hole number and then array number.

After the last generation, a message is printed to indicate why execution was terminated. If matrix k-effectives were calculated, this information is followed by a message stating the method used to determine the matrix k-effectives printed under the heading "MATRIX K-EFFECTIVE," as shown in Fig. F17.6.26.

sample problem 18 1f27 critical experiment

generation	generation k-effective	elapsed time minutes	average k-effective	avg k-eff deviation	matrix k-effective	matrix k-eff deviation
1	9.55981E-01	1.92000E-01	1.00000E+00	0.00000E+00	9.55979E-01	0.00000E+00
2	9.85743E-01	3.20000E-01	1.00000E+00	0.00000E+00	9.70861E-01	1.48842E-02
3	9.81019E-01	4.26667E-01	9.81019E-01	0.00000E+00	9.74246E-01	9.23697E-03
4	9.75411E-01	5.33333E-01	9.78215E-01	2.80419E-03	9.74537E-01	6.53871E-03
5	1.02908E+00	6.61333E-01	9.95171E-01	1.70332E-02	9.85446E-01	1.20268E-02
6	1.00068E+00	7.89333E-01	9.96547E-01	1.21227E-02	9.87984E-01	1.01431E-02
7	1.01941E+00	8.96000E-01	1.00112E+00	1.04444E-02	9.92473E-01	9.67729E-03
8	1.06116E+00	1.00267E+00	1.01113E+00	1.31479E-02	1.00106E+00	1.19984E-02
9	1.09419E+00	1.10933E+00	1.02299E+00	1.62569E-02	1.01141E+00	1.48002E-02
10	9.53752E-01	1.23733E+00	1.01434E+00	1.65265E-02	1.00564E+00	1.44391E-02
11	9.85589E-01	1.36533E+00	1.01114E+00	1.49210E-02	1.00382E+00	1.31874E-02
12	9.68067E-01	1.49333E+00	1.00684E+00	1.40237E-02	1.00084E+00	1.24016E-02
13	9.81856E-01	1.60000E+00	1.00457E+00	1.28866E-02	9.99378E-01	1.50099E-02
14	1.02367E+00	1.72800E+00	1.00616E+00	1.18711E-02	1.00111E+00	1.07885E-02
15	1.04387E+00	1.85600E+00	1.00906E+00	1.12986E-02	1.00396E+00	1.04404E-02
16	9.42642E-01	1.98400E+00	1.00431E+00	1.14860E-02	1.00013E+00	1.04915E-02
17	9.97040E-01	2.09067E+00	1.00383E+00	1.07038E-02	9.99949E-01	9.85605E-02
18	1.07760E+00	2.19733E+00	1.00844E+00	1.10231E-02	1.00426E+00	1.02454E-02
19	9.80882E-01	2.30400E+00	1.00682E+00	1.04805E-02	1.00303E+00	9.76909E-03
20	9.02059E-01	2.43200E+00	1.00100E+00	1.14678E-02	9.97983E-01	1.05537E-02
21	9.91126E-01	2.53867E+00	1.00048E+00	1.08599E-02	9.97657E-01	1.00440E-02
22	9.39241E-01	2.64533E+00	9.97418E-01	1.07479E-02	9.95001E-01	9.93809E-03
23	9.94304E-01	2.77333E+00	9.97269E-01	1.02244E-02	9.94971E-01	9.49623E-03
24	1.00598E+00	2.90133E+00	9.97665E-01	9.75662E-03	9.95429E-01	9.10327E-03
25	9.81224E-01	2.98667E+00	9.96950E-01	9.35014E-03	9.94861E-01	8.75014E-03
26	9.91740E-01	3.11467E+00	9.96733E-01	8.95471E-03	9.94741E-01	8.40740E-03
27	9.90335E-01	3.22133E+00	9.96477E-01	8.59287E-03	9.94578E-01	8.09182E-03
28	9.46905E-01	3.32800E+00	9.94571E-01	8.47306E-03	9.92875E-01	7.98133E-03
29	9.27620E-01	3.45600E+00	9.92091E-01	8.52194E-03	9.90625E-01	8.02325E-03
30	9.06063E-01	3.56267E+00	9.89019E-01	8.76789E-03	9.87806E-01	8.24758E-03
31	1.00100E+00	3.69067E+00	9.89432E-01	8.47023E-03	9.88232E-01	7.98861E-03
32	9.72119E-01	3.79733E+00	9.88855E-01	8.20334E-03	9.87728E-01	7.75137E-03
33	9.65558E-01	3.92533E+00	9.88103E-01	7.96981E-03	9.87056E-01	7.54264E-03
34	9.48828E-01	4.03200E+00	9.86876E-01	7.81373E-03	9.85932E-01	7.40311E-03
35	1.00807E+00	4.16000E+00	9.87518E-01	7.60043E-03	9.86564E-01	7.21605E-03
36	9.70213E-01	4.26667E+00	9.87009E-01	7.39105E-03	9.86110E-01	7.02736E-03
37	1.01056E+00	4.41600E+00	9.87682E-01	7.20825E-03	9.86771E-01	6.86649E-03
38	9.90428E-01	4.54400E+00	9.87758E-01	7.00558E-03	9.86867E-01	6.68391E-03
39	1.05722E+00	4.65067E+00	9.89635E-01	7.06747E-03	9.88671E-01	6.75549E-03
40	1.01137E+00	4.75733E+00	9.90207E-01	6.90272E-03	9.89238E-01	6.60886E-03
41	9.93761E-01	4.88533E+00	9.90299E-01	6.72401E-03	9.89349E-01	6.44657E-03
42	1.12885E+00	4.99200E+00	9.93762E-01	7.41284E-03	9.92670E-01	7.11412E-03
43	9.71069E-01	5.09867E+00	9.93209E-01	7.25093E-03	9.92168E-01	6.96495E-03
44	9.99904E-01	5.22667E+00	9.93368E-01	7.07798E-03	9.92343E-01	6.80706E-03
45	1.08103E+00	5.35467E+00	9.95407E-01	7.20582E-03	9.94314E-01	6.93963E-03
46	1.00679E+00	5.50400E+00	9.95666E-01	7.04490E-03	9.94585E-01	6.79251E-03
47	1.00537E+00	5.61067E+00	9.95881E-01	6.88994E-03	9.94815E-01	6.65035E-03
48	1.02227E+00	5.73867E+00	9.96455E-01	6.76288E-03	9.95387E-01	6.53554E-03
49	1.07336E+00	5.86667E+00	9.98091E-01	6.81669E-03	9.96978E-01	6.59562E-03
50	9.79966E-01	5.97333E+00	9.97714E-01	6.68384E-03	9.96638E-01	6.47120E-03
51	1.03354E+00	6.08000E+00	9.98445E-01	6.58671E-03	9.97361E-01	6.38403E-03
52	9.79903E-01	6.20800E+00	9.98074E-01	6.46428E-03	9.97026E-01	6.26887E-03
53	1.02787E+00	6.33600E+00	9.98658E-01	6.36314E-03	9.97608E-01	6.17675E-03

keno message number k6-123 execution terminated due to completion of the specified number of generations.
the matrix k-effective is the largest eigenvalue of the fission production by unit number matrix.

Figure F17.6.26 Example of k-effectives by generation

The user should examine this portion of the printed results to ensure that the two methods of calculating k-effective are in acceptable agreement and to verify that the average value of k-effective has become relatively stable. If the k-effectives appear to be oscillating or drifting significantly, the user should consider rerunning the problem with a larger number of histories per generation.

If a problem is restarted, the generation numbers and k-effectives are printed and the words FROM RESTART UNIT are printed in the elapsed time column. All other columns are blank. When the generation at which the problem is to be restarted is reached, the print reverts to the normal format as shown in Fig. F17.6.26.

F17.6.24 FINAL K-EFFECTIVE EDIT

The final edit of the k-effectives is printed by subroutine KEDIT following the k-effectives by generation. The title is printed at the top of the page, followed by the lifetime and the generation time and their associated deviations. The lifetime and generation time calculated by KENO-VI are not kinetics parameters. The lifetime is the average lifespan of a neutron (in seconds) from the time it is born until it is absorbed or leaks from the system. The generation time is the average time (in seconds) between successive neutron generations. If NUB=YES is specified in the parameter data, (Sect. F17.4.3) the average number of neutrons per fission, NUBAR and its associated deviation are printed and the AVERAGE FISSION GROUP (the average energy group at which fission occurs) and its associated deviation are printed. If SMU=YES is specified in the parameter data, the average self-multiplication of a unit and its associated deviation is printed. This self-multiplication results from fissions caused by neutrons born in the unit. Fissions caused by neutrons that exit the unit and return are not included. Then the final k-effective edit is printed as shown in Fig. F17.6.27.

The final k-effective edit prints the average k-effective and its associated deviation and the limits of k-effective for the 67, 95, and 99% confidence intervals. The number of histories used in calculating the average k-effective is also printed. This is done skipping various numbers of generations. The user should carefully examine the final k-effective edit to determine if the average k-effective is relatively stable. If a noticeable drift is apparent as the number of initial generations skipped increases, it may indicate a problem in converging the source. If this appears to be the case, the problem should be rerun with a better initial source distribution and should be run for a sufficient number of generations that the average k-effective becomes stable.

F17.6.25 PLOT OF AVERAGE K-EFFECTIVE BY GENERATION RUN

This plot consists of average k-effectives plotted vs the number of generations run. The limits of 1 standard deviation are plotted on each side of each average k-effective. These average k-effectives are not necessarily the same as the average k-effectives described in Sect. F17.6.23. The code omits the k-effectives of the first *nskip* generations when the average k-effectives for this plot are calculated. Although the k-effective of the *nskip* + 1 generation is summed into the average k-effective, it is not plotted because standard deviations cannot be calculated for a single point. Thus if *nskip* is 3 (i.e., the first three generations are skipped), the first value plotted is the average k-effective corresponding to the fifth generation run. The dotted line represents the value of the average k-effective corresponding to the smallest deviation when the average k-effective and its deviation are computed for each generation over the range of *nskip*+2 through the total number of generations. Figure F17.6.28 is an example of this type of plot. The primary use for this plot is to determine if the problem has source convergence difficulties.

lifetime = 1.38892E-04 + or - 2.38902E-05			sample problem 18 1f27 critical experiment					
nu bar = 2.45311E+00 + or - 4.42297E-05			generation time = 3.91864E-05 + or - 8.51522E-07					
			average fission group = 1.45973E+01 + or - 6.94393E-03					
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	deviation of variance (per cent)	
3	.99901 + or - .00648	.99253 to 1.00549	.98605 to 1.01197	.97957 to 1.01846	17500	23.2217		
4	.99949 + or - .00660	.99290 to 1.00609	.98630 to 1.01269	.97970 to 1.01928	17150	23.2287		
5	.99888 + or - .00671	.99217 to 1.00558	.98546 to 1.01229	.97876 to 1.01900	16800	23.5308		
6	.99884 + or - .00685	.99199 to 1.00569	.98514 to 1.01254	.97829 to 1.01939	16450	23.4550		
7	.99839 + or - .00699	.99140 to 1.00538	.98442 to 1.01236	.97743 to 1.01935	16100	23.5944		
8	.99700 + or - .00700	.99000 to 1.00400	.98300 to 1.01099	.97600 to 1.01799	15750	24.8216		
9	.99479 + or - .00679	.98799 to 1.00158	.98120 to 1.00838	.97440 to 1.01517	15400	26.6241		
10	.99574 + or - .00689	.98886 to 1.00263	.98197 to 1.00951	.97508 to 1.01640	15050	26.9694		
11	.99598 + or - .00705	.98894 to 1.00303	.98189 to 1.01008	.97484 to 1.01712	14700	26.8762		
12	.99666 + or - .00719	.98948 to 1.00385	.98229 to 1.01104	.97510 to 1.01823	14350	26.9732		
17	.99650 + or - .00790	.98860 to 1.00440	.98071 to 1.01230	.97281 to 1.02020	12600	28.9327		
22	.99946 + or - .00799	.99147 to 1.00744	.98349 to 1.01543	.97550 to 1.02341	10850	34.3414		
27	1.00076 + or - .00950	.99125 to 1.01026	.98175 to 1.01976	.97224 to 1.02927	9100	33.7045		
32	1.01266 + or - .00947	1.00319 to 1.02214	.99371 to 1.03161	.98424 to 1.04109	7350	38.8785		
37	1.02267 + or - .01080	1.01187 to 1.03347	1.00108 to 1.04426	.99028 to 1.05506	5600	42.2001		
42	1.01646 + or - .01091	1.00556 to 1.02737	.99465 to 1.03827	.98375 to 1.04918	3850	40.1501		
47	1.01948 + or - .01450	1.00499 to 1.03398	.99049 to 1.04848	.97599 to 1.06298	2100	56.3393		

Figure F17.6.27 Example of the final k-effective edit

sample problem 18 1f27 critical experiment
 plot of average k-effective by generation run.
 the line represents k-eff = .9990 + or - .0065 which occurs for 53 generations run.
 .9754 1.0027 1.0300

Figure F17.6.28 Sample plot of average k-effective by generation run

F17.6.26 PLOT OF AVERAGE K-EFFECTIVE BY GENERATION SKIPPED

This plot illustrates the average k-effective vs the number of generations skipped, as shown in Fig. F17.6.29. The limits of 1 standard deviation are plotted on either side of the average k-effective. The dotted line represents the value of the average k-effective corresponding to the smallest deviation. The average k_{eff} and the minimum standard deviation (σ) of the system are listed at the top of the plot. These are determined by computing an average k_{eff} and σ for each number of generations skipped over the range of $n\text{skip}+1$ to $n\text{gen}-2$. The average k_{eff} and σ for a given number of generations skipped is calculated by batching the generation k_{eff} s differently and keeping the largest σ calculated. The plot is essentially a plot of the data described in Sect. F17.6.24 plotted over the range of $n\text{skip} + 1$ to $n\text{gen} - 2$, where $n\text{gen}$ is the number of generations run. It is useful for determining if source convergence has been achieved.

F17.6.27 FINAL EDIT OF FISSIONS, ABSORPTIONS, AND LEAKAGE

This table is printed by subroutine KEDIT after the final k-effective edit. It prints the fission fraction for each group and the fission production, absorptions, and leakage with their associated percent deviation. If FAR=YES is specified in the parameter data, the fission production and absorptions and their percent deviation are also printed for each geometry region utilized in the problem. The FISSIONS, ABSORPTIONS, and LEAKAGE are given in units of neutrons per source neutron. Examples of the final edits of fissions, absorptions, and leakage are shown in Figs. F17.6.30 and F17.6.31.

If FAR=NO is specified, region-dependent fissions and absorptions are not printed. Figure F17.6.30 demonstrates the printout if FAR=NO.

If FAR=YES is specified in the parameter data, the fissions, and absorptions for each geometry region are printed for each energy group as shown in Fig. F17.6.31. Leakage is not collected by geometry region but rather represents the leakage from the system. In both figures, GROUP is the energy group number, FISSION FRACTION is the fraction of the fissions that occur in that energy group. The percentage deviation for the fission fraction is the same as that of the fissions in the same group. The heading UNIT refers to the unit and REGION to the region number within the specified unit. The geometry regions are numbered sequentially within each unit, starting with 1. The sum of the fissions for every region for a given energy group is the total printed for that energy group. The same is true of absorptions. The fissions, absorptions, and leakages are given in units of "per source neutron." The SYSTEM TOTAL is the sum, over all the energy groups, of the fissions, absorptions and leakage. The associated percentage deviation is printed for each.

The sum of the leakage and absorptions printed for the system total should be close to 1. The fissions printed for the system total should be the same as the first k-effective printed in the final k-effective edit described in Sect. F17.6.24. If differential albedos are used, the leakage does not include the weight lost in the albedo reflection. A message stating the weight lost in the albedo is printed. This weight loss is due to absorptions in the albedo reflector and leakage from the albedo reflector. No leakage is associated with faces having specular, mirror image, or periodic reflection. Thus there is no leakage associated with an infinite problem. The total elapsed time and final random number are printed at the end of this edit.

F17.6.28 MATRIX K-EFFECTIVE BY UNIT LOCATION

The matrix k-effective by unit location (also referred to as array position or position index) is calculated if MKP=YES is specified in the parameter data (Sect. F17.4.3). It is the largest eigenvalue of the fission production matrix, collected by position index. The position index is a number referencing a position in a 3-D lattice. An example of the matrix k-effective by unit locations is given in Fig. F17.6.32. It is contained within two rows of asterisks to draw attention to it.

Figure F17.6.29 Sample plot of average k-effective by generation skipped

kenovi sample problem 2 case 2c8 bare with 8 unit types matrix cal
skipping 3 generations

group	fission fraction	unit	region	fissions	percent deviation	absorptions	percent deviation	leakage	percent deviation
1	.1430			1.43511E-01	1.5000	5.06782E-02	1.5000	7.58911E-02	1.9424
2	.2406			2.41572E-01	.9401	9.84058E-02	.9401	1.47103E-01	1.4153
3	.1402			1.40755E-01	1.3565	6.09022E-02	1.3565	8.95706E-02	1.5378
4	.2313			2.32167E-01	1.1095	1.05587E-01	1.1095	1.46626E-01	1.0692
5	.1974			1.98175E-01	1.3537	9.41517E-02	1.3537	9.50593E-02	1.3858
6	.0467			4.69053E-02	2.7491	2.43717E-02	2.7491	1.18674E-02	3.8742
7	.0008			8.05573E-04	20.0775	4.34537E-04	20.0775	1.21626E-04	31.4931
8	.0000			0.00000E+00	.0000	0.00000E+00	.0000	0.00000E+00	.0000
9	.0000			0.00000E+00	.0000	0.00000E+00	.0000	0.00000E+00	.0000
10	.0000			0.00000E+00	.0000	0.00000E+00	.0000	0.00000E+00	.0000
11	.0000			0.00000E+00	.0000	0.00000E+00	.0000	0.00000E+00	.0000
12	.0000			0.00000E+00	.0000	0.00000E+00	.0000	0.00000E+00	.0000
13	.0000			0.00000E+00	.0000	0.00000E+00	.0000	0.00000E+00	.0000
14	.0000			0.00000E+00	.0000	0.00000E+00	.0000	0.00000E+00	.0000
15	.0000			0.00000E+00	.0000	0.00000E+00	.0000	0.00000E+00	.0000
16	.0000			0.00000E+00	.0000	0.00000E+00	.0000	0.00000E+00	.0000
system total =				1.00389E+00	.4635	4.34531E-01	.4709	5.66239E-01	.3376
elapsed time =				.83200 minutes					
random number=				0000273130731F14					

Figure F17.6.30 Sample of the final edit of fissions, absorptions, and leakage with region-dependent information suppressed

sample problem 18 1f27 critical experiment

group	fission fraction	unit	region	fissions	percent deviation	absorptions	percent deviation	skipping 3 generations leakage	percent deviation				
15	.1850			1.84769E-01	1.2445	1.05365E-01	1.2592	0.00000E+00	.0000				
		1	1	1.84769E-01	1.2445	9.49967E-02	1.2445						
			2	0.00000E+00	.0000	0.00000E+00	.0000						
			3	0.00000E+00	.0000	7.06826E-04	3.2280						
			4	0.00000E+00	.0000	0.00000E+00	.0000						
		2	1	0.00000E+00	.0000	0.00000E+00	.0000						
			2	0.00000E+00	.0000	0.00000E+00	.0000						
			3	0.00000E+00	.0000	0.00000E+00	.0000						
			4	0.00000E+00	.0000	0.00000E+00	.0000						
			5	0.00000E+00	.0000	0.00000E+00	.0000						
		3	1	0.00000E+00	.0000	0.00000E+00	.0000						
			2	0.00000E+00	.0000	4.89387E-03	2.2892						
			3	0.00000E+00	.0000	2.50874E-03	5.0362						
			4	0.00000E+00	.0000	1.02395E-03	15.1271						
			5	0.00000E+00	.0000	5.30936E-04	43.4492						
			6	0.00000E+00	.0000	7.03715E-04	69.8467						
16	.6063			6.05662E-01	.8630	7.29098E-01	7.2582	8.84374E-03	100.0000				
		1	1	6.05662E-01	.8630	3.02620E-01	.8630						
			2	0.00000E+00	.0000	0.00000E+00	.0000						
			3	0.00000E+00	.0000	8.38855E-03	2.0907						
			4	0.00000E+00	.0000	0.00000E+00	.0000						
		2	1	0.00000E+00	.0000	0.00000E+00	.0000						
			2	0.00000E+00	.0000	0.00000E+00	.0000						
			3	0.00000E+00	.0000	0.00000E+00	.0000						
			4	0.00000E+00	.0000	0.00000E+00	.0000						
			5	0.00000E+00	.0000	0.00000E+00	.0000						
		3	1	0.00000E+00	.0000	0.00000E+00	.0000						
			2	0.00000E+00	.0000	1.57178E-01	2.2761						
			3	0.00000E+00	.0000	1.20358E-01	3.8172						
			4	0.00000E+00	.0000	6.92781E-02	16.3281						
			5	0.00000E+00	.0000	4.42942E-02	51.5053						
			6	0.00000E+00	.0000	2.69816E-02	67.5988						
system total =				9.99011E-01	.6488	9.73385E-01	5.5176	2.10446E-02	42.6261				
the weight lost in the albedo portion of the problem =						1.3472E-03 + or - .0003							
elapsed time				6.33600 minutes									
random number=				000035AB2AB34C1B									

Figure F17.6.31 Sample of the final edit of fissions, absorptions, and leakage by region


```

kenovi sample problem 2 case 2c8 bare with 8 unit types matrix cal
*****
position k-effective= 1.00224E+00 + or - 7.92895E-03
the position k-effective is the largest eigenvalue of the fission production by position index matrix.
*****

```

Figure F17.6.32 Example of matrix k-effective by unit location

F17.6.29 FISSION PRODUCTION BY POSITION INDEX MATRIX

To obtain this information, the user must specify MKP=YES and FMP=YES in the parameter data. It is then printed by subroutine MATRIX. The number of entries in the fission production matrix by position index is the array size + 1 squared. Thus for a $2 \times 2 \times 2$ array there are 81 entries, and for a $4 \times 4 \times 4$ array there are 4225 entries in the fission production matrix by position index. The last position in the matrix contains information for all neutrons outside the array. An example of the fission production matrix by position index for a $2 \times 2 \times 2$ array is shown in Fig. F17.6.33.

The position index definition is given in Sect. F17.6.31. For each position index in the array, the number of next-generation neutrons produced at position index J per neutron born at position index I is determined. The fission production matrix by position index is used to determine the matrix k-effective, cofactor k-effective, and source vector by position index.

```

fission production by position index matrix
(i, j) p is the number of next generation neutrons produced at position index j by a neutron born at
position index i.

(1, 1) 7.37E-01 (1, 2) 5.38E-02 (1, 3) 5.67E-02 (1, 4) 2.75E-02 (1, 5) 6.41E-02 (1, 6) 2.44E-02
(1, 7) 2.57E-02 (1, 8) 1.57E-02 (1, 9) 0.00E+00

(2, 1) 5.84E-02 (2, 2) 7.12E-01 (2, 3) 2.18E-02 (2, 4) 5.34E-02 (2, 5) 2.17E-02 (2, 6) 7.56E-02
(2, 7) 1.62E-02 (2, 8) 2.18E-02 (2, 9) 0.00E+00

(3, 1) 5.60E-02 (3, 2) 3.02E-02 (3, 3) 7.28E-01 (3, 4) 6.03E-02 (3, 5) 2.76E-02 (3, 6) 2.31E-02
(3, 7) 6.46E-02 (3, 8) 2.45E-02 (3, 9) 0.00E+00

(4, 1) 2.70E-02 (4, 2) 5.74E-02 (4, 3) 5.05E-02 (4, 4) 7.45E-01 (4, 5) 1.84E-02 (4, 6) 2.65E-02
(4, 7) 2.65E-02 (4, 8) 6.99E-02 (4, 9) 0.00E+00

(5, 1) 6.73E-02 (5, 2) 2.49E-02 (5, 3) 2.37E-02 (5, 4) 1.57E-02 (5, 5) 7.18E-01 (5, 6) 5.89E-02
(5, 7) 5.51E-02 (5, 8) 2.68E-02 (5, 9) 0.00E+00

(6, 1) 2.82E-02 (6, 2) 6.74E-02 (6, 3) 2.00E-02 (6, 4) 2.34E-02 (6, 5) 5.75E-02 (6, 6) 7.19E-01
(6, 7) 2.89E-02 (6, 8) 4.83E-02 (6, 9) 0.00E+00

(7, 1) 2.87E-02 (7, 2) 1.97E-02 (7, 3) 6.14E-02 (7, 4) 3.07E-02 (7, 5) 5.54E-02 (7, 6) 2.48E-02
(7, 7) 7.36E-01 (7, 8) 5.61E-02 (7, 9) 0.00E+00

(8, 1) 1.48E-02 (8, 2) 2.55E-02 (8, 3) 2.83E-02 (8, 4) 6.15E-02 (8, 5) 2.97E-02 (8, 6) 5.26E-02
(8, 7) 5.51E-02 (8, 8) 7.32E-01 (8, 9) 0.00E+00

(9, 1) 0.00E+00 (9, 2) 0.00E+00 (9, 3) 0.00E+00 (9, 4) 0.00E+00 (9, 5) 0.00E+00 (9, 6) 0.00E+00
(9, 7) 0.00E+00 (9, 8) 0.00E+00 (9, 9) 0.00E+00

```

Figure F17.6.33 Sample fission production matrix by position index

F17.6.30 SOURCE VECTOR BY POSITION INDEX

This information is printed by subroutine MATRIX only if MKP=YES is specified in the parameter data. The source vector by position index is the eigenvector of the fission production matrix by position index and should sum to 1.0. It represents the fission source for the specified locations in the three-dimensional (3-D) lattice representing the physical problem being analyzed. The position index is defined in Sect. F17.6.31. An example of the source vector by position index is shown in Fig. F17.6.34. The average self-multiplication by array position is the overall average of the self-multiplication of all units used in the problem.

kenovi sample problem 2 case 2c8 bare with 8 unit types matrix cal
source vector by position index

index	vector
1	1.30419E-01
2	1.21533E-01
3	1.21295E-01
4	1.30846E-01
5	1.21621E-01
6	1.24876E-01
7	1.26689E-01
8	1.22721E-01
9	0.00000E+00

average self multiplication by array position
the number of next generation neutrons produced in a unit located at a given position in the array by a neutron born in that same unit is 7.28552E-01 + or - 2.55906E-03

Figure F17.6.34 Example of source vector by position index

F17.6.31 COFACTOR K-EFFECTIVE BY POSITION INDEX

These data are printed by subroutine MATRIX only if MKP=YES is specified in the parameter data. This input means that the fission production matrix is collected by position index. Calculating and printing cofactor k-effectives by position index can be avoided by specifying CKP=NO in the parameter data. An example of the cofactor k-effective by position index is shown in Fig. F17.6.35. See Appendix F17. D for a description of the problem used for the example.

kenovi sample problem 2 case 2c8 bare with 8 unit types matrix cal		
position	position	
index	x y z	unit
1	1 1 1	1
2	2 1 1	2
3	1 2 1	3
4	2 2 1	4
5	1 1 2	5
6	2 1 2	6
7	1 2 2	7
8	2 2 2	8

cofactor	
k-effective	deviation
9.63636E-01	8.40749E-03
9.66479E-01	8.52423E-03
9.63035E-01	8.29432E-03
9.61876E-01	8.42579E-03
9.65870E-01	8.56486E-03
9.65145E-01	8.47661E-03
9.62904E-01	8.29280E-03
9.65581E-01	8.24400E-03

Figure F17.6.35 Example of cofactor k-effective by position index

The cofactor k-effective for a given position index is the largest eigenvalue of the fission production matrix collected by position index, reduced by the row and column associated with that position index. Thus the cofactor k-effective is the value of k-effective for the system calculated without the fission source of the unit located at the specified position index.

The POSITION INDEX is a number referencing a position in a three-dimensional (3-D) lattice. POSITION is the x, y, and z location within the lattice. UNIT is the unit located at the specified location in the lattice. Thus in Fig. F17.6.35, Unit 1 is located at the lower left-hand front corner of the array or 3-D lattice representing the problem ($x=1, y=1, z=1$) and the corresponding POSITION INDEX is 1. POSITION INDEX 8 is the top right-hand back corner of the lattice, POSITION $x=2, y=2, z=2$ and the unit located at that position is UNIT 8.

F17.6.32 MATRIX K-EFFECTIVE BY UNIT NUMBER

The matrix k-effective by unit number (unit k-effective) is the largest eigenvalue of the fission production by unit matrix. It is calculated only if MKU=YES is specified in the parameter data (Sect. F17.4.3). An example of the matrix k-effective by unit is given in Fig. F17.6.36.

```
kenovi sample problem 2 case 2c8 bare with 8 unit types matrix cal
*****
unit k-effective= 1.00224E+00 + or - 7.92895E-03
the unit k-effective is the largest eigenvalue of the fission production by unit number
matrix.
*****
```

Figure F17.6.36 Example of matrix k-effective by unit number

F17.6.33 FISSION PRODUCTION BY UNIT NUMBER MATRIX

These data are printed by subroutine MATRIX only if MKU=YES is specified in the parameter data, which results in the code calculating the fission production matrix by unit. Thus for each unit in the array, the number of next-generation neutrons produced in Unit J per neutron born in Unit I is determined. This is the fission production matrix by unit, and it is used to determine the matrix k-effective by unit, the cofactor k-effective by unit, and the source vector by unit. An example of the fission production matrix by unit is shown in Fig. F17.6.37.

fission production by unit number matrix

(i, j) p is the number of next generation neutrons produced in unit j by a neutron born in unit i.

(1, 1) 7.37E-01	(1, 2) 5.38E-02	(1, 3) 5.67E-02	(1, 4) 2.75E-02	(1, 5) 6.41E-02	(1, 6) 2.44E-02
(1, 7) 2.57E-02	(1, 8) 1.57E-02	(1, 9) 0.00E+00			
(2, 1) 5.84E-02	(2, 2) 7.12E-01	(2, 3) 2.18E-02	(2, 4) 5.34E-02	(2, 5) 2.17E-02	(2, 6) 7.56E-02
(2, 7) 1.62E-02	(2, 8) 2.18E-02	(2, 9) 0.00E+00			
(3, 1) 5.60E-02	(3, 2) 3.02E-02	(3, 3) 7.28E-01	(3, 4) 6.03E-02	(3, 5) 2.76E-02	(3, 6) 2.31E-02
(3, 7) 6.46E-02	(3, 8) 2.45E-02	(3, 9) 0.00E+00			
(4, 1) 2.70E-02	(4, 2) 5.74E-02	(4, 3) 5.05E-02	(4, 4) 7.45E-01	(4, 5) 1.84E-02	(4, 6) 2.65E-02
(4, 7) 2.65E-02	(4, 8) 6.99E-02	(4, 9) 0.00E+00			
(5, 1) 6.73E-02	(5, 2) 2.49E-02	(5, 3) 2.37E-02	(5, 4) 1.57E-02	(5, 5) 7.18E-01	(5, 6) 5.89E-02
(5, 7) 5.51E-02	(5, 8) 2.68E-02	(5, 9) 0.00E+00			
(6, 1) 2.82E-02	(6, 2) 6.74E-02	(6, 3) 2.00E-02	(6, 4) 2.34E-02	(6, 5) 5.75E-02	(6, 6) 7.19E-01
(6, 7) 2.89E-02	(6, 8) 4.83E-02	(6, 9) 0.00E+00			
(7, 1) 2.87E-02	(7, 2) 1.97E-02	(7, 3) 6.14E-02	(7, 4) 3.07E-02	(7, 5) 5.54E-02	(7, 6) 2.48E-02
(7, 7) 7.36E-01	(7, 8) 5.61E-02	(7, 9) 0.00E+00			
(8, 1) 1.48E-02	(8, 2) 2.55E-02	(8, 3) 2.83E-02	(8, 4) 6.15E-02	(8, 5) 2.97E-02	(8, 6) 5.26E-02
(8, 7) 5.51E-02	(8, 8) 7.32E-01	(8, 9) 0.00E+00			
(9, 1) 0.00E+00	(9, 2) 0.00E+00	(9, 3) 0.00E+00	(9, 4) 0.00E+00	(9, 5) 0.00E+00	(9, 6) 0.00E+00
(9, 7) 0.00E+00	(9, 8) 0.00E+00	(9, 9) 0.00E+00			

Figure F17.6.37 An example of the fission probability matrix by unit

F17.6.34 SOURCE VECTOR BY UNIT NUMBER

These data are printed by subroutine MATRIX only if MKU=YES is specified in the parameter data. The source vector by unit is the eigenvector of the fission production matrix by unit. It represents the fission source for the units used in the problem. The components of the source vector should sum to 1.0. An example of the source vector by unit is given in Fig. F17.6.38. The average self-multiplication by unit is printed following the source vector. This value of self-multiplication includes those histories born in the unit which cause fissions in the same unit regardless of whether or not it exited and then returned. Therefore, this value will not agree with the value printed for the self-multiplication of the unit in Sect. F17.6.24 if the problem utilizes multiple units, the system is reflected, or a differential albedo is used in the problem.

F17.6.35 COFACTOR K-EFFECTIVE BY UNIT NUMBER

Cofactor k-effectives are printed by subroutine MATRIX only if MKU=YES is specified in the parameter data. Calculating and printing cofactor k-effectives by unit can be avoided by specifying CKU=NO in the parameter data. The cofactor k-effective for a given unit is the k-effective of the system calculated without the fission source of that unit. This calculation is accomplished by determining the eigenvalue of the fission production matrix by unit after it has been reduced by the row and column associated with that unit. An example of the cofactor k-effective by unit is given in Fig. F17.6.39.

```
kenovi sample problem 2 case 2c8 bare with 8 unit types matrix cal
source vector by unit

unit      vector
1      1.30419E-01
2      1.21533E-01
3      1.21295E-01
4      1.30846E-01
5      1.21621E-01
6      1.24876E-01
7      1.26689E-01
8      1.22721E-01
9      0.00000E+00

      average self multiplication by unit
the number of next generation neutrons produced in a unit by
a neutron born in that same unit is 7.28552E-01 + or - 2.55906E-03
```

Figure F17.6.38 Example of the source vector by unit

```
kenovi sample problem 2 case 2c8 bare with 8 unit types matrix cal
cofactor
unit      k-effective      deviation
1      9.63636E-01      8.40749E-03
2      9.66479E-01      8.52423E-03
3      9.63035E-01      8.29432E-03
4      9.61876E-01      8.42579E-03
5      9.65870E-01      8.56486E-03
6      9.65145E-01      8.47661E-03
7      9.62904E-01      8.29280E-03
8      9.65581E-01      8.24400E-03
9      1.00223E+00      7.92840E-03
```

Figure F17.6.39 Example of cofactor k-effective by unit number

F17.6.36 MATRIX K-EFFECTIVE BY HOLE NUMBER

The matrix k-effective by hole number is calculated if MKH=YES was specified in the parameter data, Sect. F17.4.3. It is the largest eigenvalue of the fission production matrix collected by hole number. An example of the matrix k-effective by hole number is given in Fig. F17.6.40.

```

sample problem 18 1f27 critical experiment
*****
hole k-effective= 1.00185E+00 + or - 1.22626E-02
the hole k-effective is the largest eigenvalue of the fission production by hole number matrix.
*****

```

Figure F17.6.40 Example of matrix k-effective by hole number

F17.6.37 FISSION PRODUCTION BY HOLE NUMBER MATRIX

This fission production matrix is collected by hole number. It is printed only if MKH=YES and FMH=YES were specified in the parameter data, Sect. F17.4.3. An example of this fission production matrix is given in Fig. F17.6.41. This matrix indicates the number of next-generation neutrons produced in hole number J by a neutron born in hole number I.

```

fission production by hole number matrix
( i, j) p is the number of next generation neutrons produced in hole j by a neutron born in hole i.

( 1, 1) 7.14E-01 ( 1, 2) 7.78E-02 ( 1, 3) 1.01E-01 ( 1, 4) 1.22E-01
( 2, 1) 1.41E-01 ( 2, 2) 6.74E-01 ( 2, 3) 8.18E-02 ( 2, 4) 1.19E-01
( 3, 1) 1.21E-01 ( 3, 2) 5.91E-02 ( 3, 3) 6.99E-01 ( 3, 4) 1.29E-01
( 4, 1) 9.86E-02 ( 4, 2) 5.59E-02 ( 4, 3) 8.23E-02 ( 4, 4) 7.42E-01

```

Figure F17.6.41 Example of fission production matrix by hole

F17.6.38 SOURCE VECTOR BY HOLE NUMBER

This information is printed by subroutine MATRIX only if MKH=YES is specified in the parameter data, Sect. F17.4.3. The source vector by hole is the eigenvalue of the fission production matrix by hole number. The source vector should sum to 1.0. An example of the source vector by hole is shown in Fig. F17.6.42. The average self-multiplication by hole is the overall average of the self-multiplication of all the holes in the problem.

```

sample problem 18 1f27 critical experiment
source vector by hole

hole      vector
1      2.86593E-01
2      1.63832E-01
3      2.27434E-01
4      3.22141E-01

average self multiplication by hole
the number of next generation neutrons produced in a hole by
a neutron born in that same hole is 7.12928E-01 + or - 6.34054E-03

```

Figure F17.6.42 Example of source vector by hole number

F17.6.39 COFACTOR K-EFFECTIVE BY HOLE NUMBER

The cofactor k-effective by hole number is calculated if CKH=YES is entered in the parameter data, Sect. F17.4.3. The cofactor k-effective for a given hole is the k-effective of the system calculated without the fission source of that hole. This calculation is done by determining the eigenvalue of the fission production matrix by hole after it has been reduced by the row and column associated with that hole. An example of the cofactor k-effective by hole number is given in Fig. F17.6.43.

sample problem 18		1f27	critical	experiment
		cofactor		
hole	unit	k-effective	deviation	
1	2	8.81048E-01	1.45277E-02	
2	3	9.34888E-01	1.30223E-02	
3	4	9.10727E-01	1.26868E-02	
4	5	8.89370E-01	1.48242E-02	

Figure F17.6.43 Example of cofactor k-effective by hole number

F17.6.40 MATRIX K-EFFECTIVE BY ARRAY NUMBER

The matrix k-effective by array number is calculated if MKA=YES is entered in the parameter data, Sect. F17.4.3. It is the largest eigenvalue of the fission production matrix collected by array number. An example is given in Fig. F17.6.44. The number of next-generation neutrons produced in array number J by a neutron born in array number I is given in this fission production matrix.

```
sample problem 18  1f27  critical experiment
*****
array k-effective= 1.00185E+00 + or - 1.22626E-02
the array k-effective is the largest eigenvalue of the fission production by array number
matrix.
*****
```

Figure F17.6.44 Example of matrix k-effective by array number

F17.6.41 FISSION PRODUCTION BY ARRAY NUMBER MATRIX

The fission production matrix collected by array number is shown in Fig. F17.6.45. It is printed only if MKA=YES and FMA=YES are specified in the parameter data (Sect. F17.4.3).

```

fission production by array number matrix
( i, j) p is the number of next generation neutrons produced in array j by a neutron born in array i.
( 1, 1) 7.14E-01 ( 1, 2) 7.78E-02 ( 1, 3) 1.01E-01 ( 1, 4) 1.22E-01
( 2, 1) 1.41E-01 ( 2, 2) 6.74E-01 ( 2, 3) 8.18E-02 ( 2, 4) 1.19E-01
( 3, 1) 1.21E-01 ( 3, 2) 5.91E-02 ( 3, 3) 6.99E-01 ( 3, 4) 1.29E-01
( 4, 1) 9.86E-02 ( 4, 2) 5.59E-02 ( 4, 3) 8.23E-02 ( 4, 4) 7.42E-01

```

Figure F17.6.45 An example of the fission production matrix by array number

F17.6.42 SOURCE VECTOR BY ARRAY NUMBER

This information is printed by subroutine MATRIX only if MKA=YES is specified in the parameter data (Sect. F17.4.3). The source vector by array number is the eigenvector of the fission production matrix by array number. The source vector should sum to 1.0. An example of the source vector by array number is shown in Fig. F17.6.46. The average self-multiplication by array number is the overall self-multiplication of all the arrays in the problem.

```

sample problem 18  1f27  critical experiment                source vector by array

array      vector
  1      2.86593E-01
  2      1.63832E-01
  3      2.27434E-01
  4      3.22141E-01

          average self multiplication by array
the number of next generation neutrons produced in an array by
a neutron born in that same array is  7.12928E-01 + or - 6.34054E-03

```

Figure F17.6.46 Example of source vector by array number

F17.6.43 COFACTOR K-EFFECTIVE BY ARRAY NUMBER

The cofactor k-effective by array number is calculated if CKA=YES is entered in the parameter data (Sect. F17.4.3). The cofactor k-effective for a given array is the k-effective of the system calculated without the fission source of that array. This calculation is achieved by determining the eigenvector of the fission production matrix by array after reducing it by the row and column associated with the specified array. Figure F17.6.47 is an example of the cofactor k-effective by array number.

```

sample problem 18  1f27  critical experiment
array      array      cofactor
index      number      k-effective      deviation
  1          1      8.81048E-01      1.45277E-02
  2          2      9.34888E-01      1.30223E-02
  3          3      9.10727E-01      1.26868E-02
  4          4      8.89370E-01      1.48242E-02

```

Figure F17.6.47 Example of cofactor k-effective by array number

F17.6.44 FISSION DENSITY EDIT

The fission density edit is optional. Subroutine KEDIT prints the fission density for each geometry region if FDN=YES is specified in the parameter data. An example of the fission density edit is shown in Fig. F17.6.48.

The UNIT is the unit number from the geometry data, the REGION is the region number relative to the unit, the FISSION DENSITY is the fissions/(cc source-neutron) for that geometry region, the PERCENT DEVIATION is the uncertainty associated with the fission density, and the TOTAL FISSIONS is the total number of fissions per source neutron in the geometry region.

```
kenovi sample problem 2 case 2c8 bare with 8 unit types matrix cal
**** fission densities ****
```

unit	region	fission density	percent deviation	total fissions
1	1	1.316E-01	2.44	1.316E-01
	2	0.000E+00	.00	0.000E+00
2	1	1.217E-01	1.88	1.217E-01
	2	0.000E+00	.00	0.000E+00
3	1	1.222E-01	2.41	1.222E-01
	2	0.000E+00	.00	0.000E+00
4	1	1.311E-01	2.06	1.311E-01
	2	0.000E+00	.00	0.000E+00
5	1	1.239E-01	1.79	1.239E-01
	2	0.000E+00	.00	0.000E+00
6	1	1.256E-01	2.14	1.256E-01
	2	0.000E+00	.00	0.000E+00
7	1	1.268E-01	2.38	1.268E-01
	2	0.000E+00	.00	0.000E+00
8	1	1.209E-01	2.63	1.209E-01
	2	0.000E+00	.00	0.000E+00

Figure F17.6.48 Example of the fission density edit

F17.6.45 FLUX EDIT

Printing the fluxes is optional. They are printed by subroutine PRTFLX only if FLX=YES is specified in the parameter data. The fluxes are printed for each unit and each geometry region in the unit for every energy group. A sample of a flux edit is given in Fig. F17.6.49.

sample problem 18 1f27 critical experiment								
fluxes for unit 1			region 1		region 2		region 3	
group	flux	percent deviation	flux	percent deviation	flux	percent deviation	flux	percent deviation
1	4.591E-02	2.60	3.484E-04	7.80	1.058E-02	3.55	1.269E-01	2.78
2	8.954E-02	1.72	6.445E-04	7.34	2.227E-02	3.16	2.575E-01	2.07
3	4.254E-02	2.28	2.735E-04	7.96	1.274E-02	4.16	1.144E-01	3.34
4	5.984E-02	1.70	4.034E-04	10.34	1.739E-02	3.77	1.498E-01	3.23
5	5.898E-02	1.42	3.564E-04	7.11	2.026E-02	3.75	1.646E-01	2.74
6	4.006E-02	1.88	2.456E-04	7.87	1.735E-02	4.18	1.216E-01	3.32
7	3.146E-02	1.92	2.252E-04	12.05	1.414E-02	4.05	1.065E-01	3.94
8	2.766E-02	1.84	1.745E-04	10.03	1.243E-02	4.62	9.311E-02	4.29
9	2.543E-02	1.81	1.783E-04	9.70	1.232E-02	5.31	8.840E-02	4.62
10	1.659E-02	2.51	1.266E-04	9.97	9.890E-03	5.67	6.730E-02	3.91
11	1.421E-02	2.48	9.449E-05	12.27	7.372E-03	5.50	5.593E-02	5.57
12	1.416E-02	2.76	8.552E-05	13.27	7.395E-03	5.24	5.707E-02	4.43
13	1.272E-02	2.54	8.081E-05	19.55	6.840E-03	5.59	5.130E-02	5.54
14	9.517E-03	2.39	6.425E-05	12.73	5.822E-03	7.08	4.114E-02	5.88
15	1.821E-02	2.14	1.947E-04	12.16	1.761E-02	4.15	1.094E-01	4.50
16	3.013E-02	1.98	7.287E-04	6.26	1.586E-01	2.06	9.496E-01	2.42

Figure F17.6.49 An example of a flux edit

The title of the problem is printed at the top of the page. The heading FLUXES FOR UNIT ____ indicates the geometry unit for which fluxes are being printed. The region numbers relative to the unit are identified by the heading REGION _____. The geometry regions within each unit are numbered sequentially, beginning with one. GROUP is the heading for the energy groups. The headings FLUX and PERCENT DEVIATION are printed for each geometry region in the unit. The flux and its associated percentage deviation are printed for every energy group and every geometry region. The flux is in units of neutrons/cm²/source neutron.

F17.6.46 FREQUENCY DISTRIBUTIONS

Subroutine FREAK is responsible for printing the frequency distributions that are the last data printed for a problem. A frequency distribution consists of a bar graph indicating the number of generations having k-effective in a specified interval. The intervals are determined by the code, based on the upper and lower limits of the k-effectives calculated for the generations. One asterisk is printed for each generation k-effective. Four frequency distributions are printed as shown in Fig. F17.6.50.

kenovi sample problem 2 case 2c8 bare with 8 unit types matrix cal

```
frequency for generations 4 to 103
*
0.8803 to 0.9034 *
0.9034 to 0.9265 *****
0.9265 to 0.9496 *****
0.9496 to 0.9727 *****
0.9727 to 0.9958 *****
0.9958 to 1.0189 *****
1.0189 to 1.0420 *****
1.0420 to 1.0651 *****
1.0651 to 1.0882 *****
1.0882 to 1.1113 *****
1.1113 to 1.1344 *
```

```
frequency for generations 29 to 103
0.8803 to 0.9034 ***
0.9034 to 0.9265 *****
0.9265 to 0.9496 *****
0.9496 to 0.9727 *****
0.9727 to 0.9958 *****
0.9958 to 1.0189 *****
1.0189 to 1.0420 *****
1.0420 to 1.0651 *****
1.0651 to 1.0882 *****
1.0882 to 1.1113 *****
1.1113 to 1.1344 *
```

```
frequency for generations 54 to 103
0.8803 to 0.9034 ***
0.9034 to 0.9265 ***
0.9265 to 0.9496 ***
0.9496 to 0.9727 *****
0.9727 to 0.9958 *****
0.9958 to 1.0189 *****
1.0189 to 1.0420 *****
1.0420 to 1.0651 *****
1.0651 to 1.0882 *****
1.0882 to 1.1113 ***
1.1113 to 1.1344 *
```

```
frequency for generations 79 to 103
0.8803 to 0.9034 *
0.9034 to 0.9265 *
0.9265 to 0.9496 *****
0.9496 to 0.9727 *****
0.9727 to 0.9958 *****
0.9958 to 1.0189 *****
1.0189 to 1.0420 *****
1.0420 to 1.0651 *****
1.0651 to 1.0882 *****
1.0882 to 1.1113 *****
1.1113 to 1.1344 *****
```

```
*****
congratulations! you have successfully traversed the perilous path through keno vi in 0.40533 minutes
*****
```

Figure F17.6.50 Example of frequency distributions

F17.7 WARNING MESSAGES AND ERROR MESSAGES

KENO-VI prints warning and error messages that are identified by K6-, followed by a unique number, such as K6-2. For additional information concerning the message, simply look up the identifier number in this section.

Warning messages appear when a possible error is encountered. If the code alters data, that fact is stated in the message. It is the responsibility of the user to verify correct usage whenever a warning message is printed.

When an error is encountered, the error flag MFLAG is set true and an error message is printed. The code stops if the error is too severe to continue. The warning and error messages in this section may show an underscore ____ or a numbered underscore (1), where data will be printed by the code. The explanation of the message will show an underscore or a numbered underscore to indicate the corresponding data.

F17.7.1 MESSAGES

K6-2 *** ERROR *** ERROR *** THE NUMBER OF ENERGY GROUPS IS OUT OF RANGE FOR THE CROSS SECTION LIBRARY ON UNIT _____. THE JOB CONTROL LANGUAGE MAY NOT SPECIFY A VALID DATA SET ON THIS UNIT OR THE MODULE THAT WAS TO CREATE THE CROSS SECTION LIBRARY ON THIS UNIT MAY HAVE FAILED.

This message occurs in subroutine INITAL after subroutine PARAM has been executed. Check unit number _____ to see that it was properly specified in the job control language. Verify that the data set name associated with this unit number is the correct one. This information is given in the printout in the third table. Make sure the module that generated the cross sections executed properly and that the data were saved or passed correctly. When this message is printed for an AMPX working-format library, a STOP 108 is executed. When this message is printed for a mixed cross-section format library, a STOP 109 is executed.

K6-3 *** WARNING *** THE CROSS SECTION LIBRARY ON UNIT ____ HAS ____ ENERGY GROUPS.

This message is printed in subroutine INITAL after the call to PARAM. It is activated if the cross-section library has more than 300 energy groups. The largest standard cross-section library in the SCALE system contains 238 energy groups.

K6-4 INVALID INPUT PARAMETER NAME _____

This message comes from subroutine PARAM. The keyword for entering parameter data was misspelled. A list of allowed keywords is given in Table F17.4.1 in the KENO-VI input outline.

K6-5 ***** AN ERROR WAS ENCOUNTERED IN THE ALPHANUMERIC PARAMETER DATA. THE DATA WERE _____ *****

This message comes from subroutine PARAM. The keyword for the alphanumeric parameter data was entered correctly, but the data associated with it were not YES or NO as is required. The _____ in the error message could be something like FLX=YEX instead of FLX=YES.

K6-6 ***** WARNING ***** READ FLAG FOUND WHEN LOOKING FOR END FLAG.
PARAMETER INPUT ASSUMED COMPLETE

This message occurs in subroutine PARAM. It indicates that the keywords END PARAMETERS were not found. The keywords READ ____ were found instead. The code assumes the parameter data are complete and proceed normally.

K6-7 ATTEMPT TO FIND END PARAMETER FLAG WAS UNSUCCESSFUL

This message from subroutine PARAM occurs during the reading of the parameter data if the word END is found and it is not followed by the word PARAMETERS. A STOP 118 may be executed when this message is printed.

K6-8 ***** AN END OF FILE WAS ENCOUNTERED WHILE ATTEMPTING TO READ PARAMETER
DATA *****

This self-explanatory message is from subroutine PARAM. A STOP 118 may be executed when this message is printed.

K6-9 *** DUE TO INCONSISTENCIES BETWEEN INPUT AND RESTART DATA, FISSIONS AND
ABSORPTIONS BY REGION WILL BE CALCULATED BUT NOT PRINTED. INPUT DATA SET
FAR=NO, BUT DATA FROM THE RESTART UNIT SPECIFIED YES.

This message occurs in subroutine PARTBL. It is mostly self-explanatory. The original problem (parent case) that wrote the restart data specified data inconsistent with the parameter data input to the restarted problem. The title of the parent case is given at the end of the parameter tables. The specification of the restart unit RST is given in the third table of the KENO-VI output.

K6-10 *** DUE TO INCONSISTENCIES BETWEEN INPUT AND RESTART DATA, FLUXES WILL BE
CALCULATED BUT NOT PRINTED. INPUT DATA SET FLX=NO, BUT DATA FROM THE
RESTART UNIT SPECIFIED YES.

This message occurs in subroutine PARTBL. It is basically self-explanatory. The original problem (parent case) that wrote the restart data specified data that did not agree with the parameter data input to the restarted problem. The title of the parent case is given at the end of the parameter tables. The specification of the restart unit RST is given in the third table of the KENO-VI output.

K6-11 *** ERROR *** A BOUNDARY GEOMETRY WORD WAS NOT SPECIFIED FOR UNIT ____.

This self-explanatory message is from subroutine KENOG. A BOUNDARY record must be associated with each unit identifying the outermost region of the unit.

K6-12 *** WARNING *** INPUT PARAMETER NBK WAS ENTERED AS _____. IT WAS CHANGED
TO _____. AT LEAST _____ POSITIONS ARE NECESSARY TO ACCOMMODATE THE
NEUTRON BANK DATA.

This self-explanatory message is from subroutine PARTBL. NBK should not be entered as input data unless it is known that the default value is inadequate.

K6-13 *** ERROR *** MEDIA DATA MUST BE ENTERED FOR UNIT ____.

This message is from subroutine KENOG. Either another UNIT record or an END GEOM record was encountered prior to inputting MEDIA data for the current unit.

K6-14 ***** ERROR - KEYWORD _____ IS NOT A VALID MIXING TABLE KEYWORD. *****

This message is from subroutine MIXIT. It can only be encountered if a mixing table is expected (i.e., READ MIX or READ MIXT has been entered as data). At this point the only valid keywords are MIX=, EPS= or SCT=. The keyword that was entered is printed in the message. See Sect. F17.4.10 for assistance in setting up the mixing table data. A common error made by KENO-IV users is to enter a negative nuclide ID number in the mixing table. The code will interpret this to be a keyword. A whole list of K6-14 error messages will be generated as the code reads through the mixing table in search of a valid keyword. The code considers any character string that does not begin with a number to be a keyword.

K6-15 MIXING TABLE TOO BIG

This message is from subroutine MIXIT. It indicates that additional core space is necessary to allow entry of the existing mixing table. A STOP 114 is executed in conjunction with this message and a traceback may be printed from subroutine STOP.

K6-16 *** ERROR *** ERROR *** A VALUE MUST BE ENTERED FOR LIB IN THE PARAMETER INPUT SO CROSS SECTIONS CAN BE MIXED.

This message is from subroutine DATAIN. It occurs when a mixing table has been read but the unit number for the AMPX working library is undefined. This situation is corrected by entering LIB=_____ in the parameter input data and making sure the desired AMPX working library is properly defined as being on that unit in the job control language.

K6-17 UNRECOGNIZABLE GEOMETRY WORD _____

This message is from subroutine KENOG. In the process of reading the geometry data, the word ____ was encountered when a geometry word was expected. Several of these messages may be generated. A message is generated for each word of data that is read, until a valid geometry word is found. The data are out of phase or the geometry word is misspelled. Check the previous geometry record for a mixture ID, a bias ID, and the proper number of dimensions. See Sect. F17.4.4 for a list of accepted geometry words.

K6-18 ***** ERROR ***** INVALID INDEX INTO KEYWRD ARRAY. INP=_____, CHECK SUBROUTINE KENOG FOR A CODE ERROR.

This message is from subroutine KENOG. This message usually means that a code error was introduced when changes were made to the program. Check subroutine KENOG, function LCOMPR, and KEYWRD data block.

K6-19 ***** ERROR ***** THE GLOBAL UNIT HAS NOT BEEN SPECIFIED.

This self-explanatory message from subroutine KENOG indicates that a global unit has not been specified. The outermost unit in the problem must be specified as the GLOBAL UNIT. See Sect. F17.4.4 to determine the correct specification.

K6-20 ***** ERROR ***** GEOMETRY WORD INDEX OUT OF RANGE ON SCRATCH UNIT ____ FOR
GEOMETRY WORD NUMBER ____ INP=____ GWRD=____.

This message from subroutine READGM means that INP is negative or larger than NP when the geometry data are read from the scratch unit, SKRT. This usually means that a code error was introduced when changes were made to the program. True geometry errors should be detected when the scratch unit, SKRT, is written. A STOP 125 is executed when this message is printed.

K6-21 _____ IS AN INVALID PARAMETER NAME FOR BIASING DATA. ID= OR WT= OR WTS=
SHOULD HAVE BEEN ENTERED.

This self-explanatory message is from subroutine RDBIAS. See Sect. F17.4.7 for assistance in determining the proper procedure for entering biasing data.

K6-22 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS
REQUIRED ADDITIONAL REGION SIZE.

PERTINENT CONSTANTS

This message from subroutine WATES indicates that the allocated computer storage will not hold the weighting or biasing array. The first number printed is the amount of storage, in words, needed to hold the data. The second number is the allocated computer storage in words. The third number is the minimum additional region size, in units of K bytes necessary to hold the biasing or weighting data to this point. Increase the region size for the "go step" in the job control language by the additional required region size (the third number) and resubmit the problem. A STOP 150 is executed when this message is printed.

K6-23 *** ERROR *** ERROR *** NO ____ ENERGY GROUP WEIGHTS WERE FOUND FOR ID ____
*** ERROR *** ERROR ***

This message from subroutine WATES occurs if the weights requested in the biasing information were not on the standard weights data set and were not entered using biasing data. See Table F17.4.5 for the weights that are available on the standard data set. The procedure for entering weights in the biasing data is explained in Sect. F17.4.7.

K6-24 INCORRECT FLAG RETURNED FROM AREAD. IRET=_____

This message from subroutine RDBIAS indicates that an error was encountered while reading the biasing data. The biasing data were not entered properly. See Sect. F17.4.7 for assistance.

K6-25 THE FIRST NUMBER IS THE STORAGE NEEDED; THE SECOND, THE AMOUNT ALLOCATED. PERTINENT CONSTANTS ____

This message is from subroutine ARAYIN or subroutine GEOMIN. It indicates that additional core space is required to allow the use of the array definition data or the geometry region data. At least ____ words of storage are needed to run the problem but only ____ words of storage are available. Increase the amount of computer storage requested in the job control language to correspond to the amount needed. A STOP 100 or 155 is executed in conjunction with this message, and a traceback may be printed from subroutine STOP.

K6-26 SET NUMBER ____ OF THE UNIT ORIENTATION DATA CONTAINS ____ ERROR(S)

This message from subroutine RDBOX is triggered when input errors are recognized in the unit orientation data. A set of unit orientation data consists of ten numbers as shown in the companion message K6-27. The number of errors printed in this message is a lower bound. More errors may actually exist. This message often means that a number was omitted or a blank was omitted when entering the unit orientation data.

K6-27 LTYPE=____ IX1=____ IX2=____ INCX=____ IY1=____ IY2=____ INCY=____ IZ1=____ IZ2=____ INCZ=____

This message is a companion message for K6-26. It indicates how the unit orientation data description for the set named in K6-26 was entered. See Sect. F17.4.5 for information pertaining to unit orientation data.

K6-28 THE ABOVE UNIT ORIENTATION RECORD(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 LARGER THAN NBYMAX OR IZ2 IS LARGER THAN NBZMAX
4. LTYPE IS LESS THAN 1 OR GREATER THAN NBOX

This self-explanatory message is from subroutine RDBOX. It pertains to the input orientation data for LOOP. See Sect. F17.4.5 for input instructions.

K6-29 *** ERROR *** THE ARRAY SIZE HAS BEEN SPECIFIED INCORRECTLY.
NBXMAX=____ NBYMAX=____ NBZMAX=____
UNIT ORIENTATION DATA CANNOT BE READ UNLESS NBXMAX, NBYMAX, AND NBZMAX ARE GREATER THAN ZERO.

This message from subroutine ARAYIN indicates that the array definition data were incorrectly specified. It occurs only if one or more of NBXMAX, NBYMAX, or NBZMAX is less than 1. In the array information data these are entered in the form NUX=____ NUY=____ NUZ=____. See Sect. F17.4.5. If a unit orientation data description is to be entered, NBXMAX, NBYMAX, and NBZMAX must all be greater than zero.

K6-30 END ____ FLAG WAS NOT FOUND. ____ WAS READ INSTEAD.

This message from subroutine ARAYIN occurs if the unit orientation data description is terminated with the incorrect END flag.

K6-31 ____ IS AN INVALID PARAMETER NAME IN THE ARRAY DATA.

This message is written from subroutine ARAYIN if the array data block contains an incorrect keyword. The allowed keywords include NUX= NUY= NUZ= FILL and LOOP. See Sect. F17.4.5 for additional assistance. A STOP 101 is executed when this message is printed.

K6-32 *** AN ERROR EXISTS IN UNIT ORIENTATION ARRAY NUMBER ____ ***

This message from subroutine SORTA is printed when an error is recognized in the array description. The type of error that will trigger the message is for a position in the unit orientation array to be undefined, zero, negative or greater than NBOX, the number of input units. K6-33 is a companion message.

K6-33 UNIT ____ IS INVALID AT X INDEX= ____ Y INDEX= ____ Z INDEX= ____

This message comes from subroutine SORTA. It is printed for each position in the unit orientation array that is in error. The message is printed a maximum of 10 times. Refer to Sect. F17.4.5 for assistance in correcting the error(s).

K6-34 ***** ERROR ***** THE NUMBER OF MIXTURES REQUESTED IN THE GEOMETRY IS ____
THE NUMBER OF MIXTURE CROSS SECTIONS IS ____.

This message from subroutine FLDATA occurs if the number of mixture cross sections from the restart unit, RSTRT, does not equal the number of mixtures requested in the geometry for a restarted problem.

K6-35 ***** ERROR ***** IN THE ALBEDO INPUT DATA ____ IS AN INVALID FACE CODE NAME.

This message is from subroutine RDREF. It occurs if an invalid face code name was entered in the albedo data. See Table F17.4.3 in Sect. F17.4.6 for a list of acceptable face code names.

K6-36 A PERIODIC BOUNDARY CONDITION WAS SPECIFIED WITH A NON-COMPATIBLE
BOUNDARY CONDITION ON THE OPPOSING FACE. THE PROBLEM WILL NOT BE RUN.

This self-explanatory message is from subroutine RDREF. If a periodic boundary condition is specified on one x face, it must also be specified on the other x face, etc.

K6-37 ***** ERROR AVERAGE NU-BAR AND AVG. FISSION GROUP WAS SPECIFIED, BUT THE
FISSION XSEC ID (18) WAS NOT FOUND IN THE EXTRA 1-D ARRAY (MT).

This message is from subroutine IDX1D. It indicates that the parameter data contained NUB=YES but the corresponding necessary type of data was absent from the extra 1-D array. This can be due to a code error or an error concerning the extra 1-D data (X1D= in the parameter data).

K6-38 INPUT DATA INDICATED NO EXTRA 1-D XSEC IDS TO BE READ, BUT A READ FLAG WAS ENCOUNTERED.

This message from subroutine DATAIN is printed when the parameter data did not specify X1D= and the words READ X1DS were encountered later in the data. If extra 1-D data are to be used, X1D= must be entered in the parameter data and appropriate code modifications must be made to properly utilize the extra 1-D data.

K6-39 INVALID START PARAMETER NAME ____

This message is from subroutine RDSTRT. It indicates that an invalid start parameter name was encountered when the start data block was being read. A list of allowed start parameter names is contained in Sect. F17.4.8.

K6-40 LNU FOR START TYPE 6 WAS ENTERED AS _____. IT WAS CHANGED TO _____ WHICH IS THE VALUE ENTERED FOR NFB.
THE LARGEST VALUE NEEDED FOR LNU IS NPG. THE LARGEST VALUE ALLOWED FOR LNU IS NFB. BOTH NPG AND NFB ARE PARAMETER DATA.

This self-explanatory message is from subroutine RDSTRT. See Sect. F17.4.8 for assistance in determining a valid value for LNU. NFB, the fission bank size, is the largest value allowed for LNU. NPG, the number of histories per generation, is the smallest value allowed for LNU.

K6-41 *** ERROR *** ALPHANUMERIC START DATA MUST BE ENTERED AS YES OR NO. THE DATA READ WERE _____.

This self-explanatory message is from subroutine RDSTRT. See Sect. F17.4.8 for assistance concerning start data.

K6-42 END _____ FLAG WAS NOT FOUND. _____ WAS READ INSTEAD.

This message is from subroutine DATAIN. It occurs when the READ _____ and END _____ do not match. When entering data blocks, each block must start with READ _____ and end with END _____.

K6-43 ***** AN END OF FILE WAS ENCOUNTERED BEFORE AN END DATA WAS FOUND. THE PROBLEM WILL NOT RUN. *****

This message is from subroutine DATAIN. It occurs when an end of file is encountered while reading data.

K6-44 ***** ERROR ***** SECTOR DATA WAS NOT FOUND FOR ARRAY

This self-explanatory message is from subroutine ARRAY. This message usually means that sector data was left off the ARRAY media record. See Sect. F17.4.4 for assistance in specifying an array.

K6-45 ***** ILLEGAL DATA BLOCK IDENTIFIER _____ *****

This message from subroutine DATAIN is printed whenever an invalid data block identifier is encountered. This situation can be caused by having the data out of order, by omitting data or by misspelling data. A block identifier consists of the words READ XXXX, where XXXX is a keyword identifying the type of data to be read. Acceptable keywords are listed in Table F17.4.1 (Sect. F17.4.1).

Consider the following examples:

ERROR MESSAGE EXAMPLE 1

```
READ PARAM TME=2.9 FLX=YES XSC=38 END PARAM
READ GOEM GLOBAL UNIT 1
CYLINDER 1 5.0 5.0 -5.0 MEDIA 1 1 1 BOUNDARY 1 END GEOM
END DATA
END
```

The following message would occur:

***** ILLEGAL DATA BLOCK IDENTIFIER READ GOEM *****

The keyword GEOM was misspelled as GOEM. The correct data block identifier is READ GEOM.

ERROR MESSAGE EXAMPLE 2

```
READ PARAM TME=2.9 FLX=YES XSC=38 END PARAM
END GEOM
CYLINDER 1 5.0 5.0 -5.0 MEDIA 1 1 1 BOUNDARY 1 END GEOM
END DATA
END
```

The following message would occur:

***** ILLEGAL DATA BLOCK CYLINDER *****

The words END GEOM are read and recognized as the end of a data block. The words CYLI and NDER are then read as the data block identifier. Since CYLI is not END, the code assumes it is at the beginning of a data block that is identified by the keyword NDER, which is not one of the acceptable keywords.

ERROR MESSAGE EXAMPLE 3

```
READ PARAM TME=2.9 FLX=YES XSC=38 END PARAM
END GEOM
READ GEOM
GLOBAL UNIT 1
CYLINDER 1 5.0 5.0 -5.0 MEDIA 1 1 1 BOUNDARY 1
END GEOM
```

END DATA
END

In this example, no errors will be found and the problem will run correctly. The END PARAM signals the end of the parameter data block. The first END GEOM signals the end of a geometry block, the READ GEOM signals the beginning of a geometry block, the second END GEOM signals the end of a geometry block, and the END DATA signals the end of the problem.

K6-46 ***** IPT= _____ IS OUTSIDE THE ALLOWABLE LIMIT OF _____

This self-explanatory message is from subroutine DATAIN. It is indicative of a code error. IPT is the index into the LPOINT array, which contains the direct-access pointers for the various types of data.

LPOINT(1) is the pointer for the geometry region data.
LPOINT(2) is the pointer for the array description (unit orientation) data.
LPOINT(3) is the pointer for the mixing table data.
LPOINT(4) is the pointer for extra data.
LPOINT(5) is the pointer for the biasing or weighting data.
LPOINT(6) is the pointer for the start data.
LPOINT(7) is the pointer for the albedo data.
LPOINT(8) is the pointer for the mixed cross-section data.
LPOINT(9) is the pointer for the energy and inverse velocity data.
LPOINT(10) is the pointer for the plot data.
LPOINT(11) is the pointer for the biasing input data.
LPOINT(12) is the pointer for albedo-xsec energy correspondence.
A STOP 152 is executed when this message is printed.

K6-48 *** ERROR *** AN ERROR WAS ENCOUNTERED WHILE ATTEMPTING TO READ RESTART
DATA FROM UNIT _____ NDX=_____ NREC=_____

This message is from subroutine RDRST. It indicates that the restart data associated with the index NDX had the wrong number of records. This message can also be caused by a code error introduced as the result of making changes in the code.

NDX=1 is the geometry data. NREC should be 3.
NDX=2 is the array description data. NREC should be 3 or more.
NDX=3 is the mixing table data. NREC should be 3.
NDX=4 is the extra data. NREC must be set by the user.
NDX=5 is the biasing or weight data. NREC should be 3.
NDX=6 is the start data. NREC should be 3.
NDX=7 is the albedo data. NREC should be at least 2.
NDX=8 is the mixed cross-section data.
NDX=9 is the energy and inverse velocity data.
NDX=10 is the plot data.
NDX=11 is the biasing input data.
NDX=12 is the albedo-xsec energy correspondence.

A STOP 123 is executed when this message is printed.

K6-49 ____ WORDS ARE NEEDED TO HOLD THE ALBEDO DATA. BUT ONLY ____ WORDS ARE AVAILABLE.

This message from subroutine RDALB is self-explanatory. More space is needed to contain the albedo data. A STOP 120 is executed when this message is printed.

K6-50 THE SPACE AVAILABLE IN SUBROUTINE RDICE IS _____. MORE IS NEEDED.

This self-explanatory message from subroutine RDICE indicates that more space is needed to store the macroscopic cross sections in ICE format. A STOP 122 is executed when this message is printed.

K6-51 ***** ERROR ***** THE ____ FACE REQUESTED A DIFFERENTIAL ALBEDO THAT IS NOT ON THE ALBEDO DATA SET. THE REQUESTED ALBEDO NAME IS _____.

This self-explanatory message is from subroutine ALBRD. A list of the albedos that are on the standard albedo data set is given in Table F17.4.4 (Sect. F17.4.6).

K6-52 MIXTURE NUMBER TOO LARGE

This self-explanatory message is from subroutine MIXCRS. A STOP 111 is executed in conjunction with this message, and a traceback may be printed from subroutine STOP.

K6-53 NOT ENOUGH STORAGE TO MIX

This message from subroutine MIXER indicates that more storage is necessary in order to do the cross-section mixing operations. A STOP 112 is executed in conjunction with this message, and a traceback may be printed from subroutine STOP.

K6-54 NOT ENOUGH STORAGE TO MAKE ANGLES

This message from subroutine MIXER indicates that more storage is necessary to perform the calculations required to make the angles during the cross-section mixing operations. A STOP 113 is executed in conjunction with this message, and a traceback may be printed from subroutine STOP.

K6-55 ***** ERROR FOUND IN MIXING CROSS SECTIONS *****
THE FOLLOWING NUCLIDE(S) SPECIFIED IN THE MIXING TABLE WERE NOT FOUND ON THE CROSS SECTION LIBRARY.

ENTRY	NUCLIDE ID
.	.
.	.
.	.

This self-explanatory message is from subroutine MIXMIX. Either a nuclide ID was misspelled, or it was not in the cross-section library.

K6-56 ERROR - MIXTURE ____ LACKS EITHER NU*FISSION OR CHI DATA.

This message from subroutine NORMID indicates that a mixture that contains fissile material is missing the nu-fission cross section or the fission spectrum. A STOP 115 is executed when this message is printed.

K6-57 NOT ENOUGH STORAGE TO MAKE ANGLES AND PROBS

This self-explanatory message from subroutine MAKANG indicates that more storage is needed to complete the cross-section mixing operations. Resubmit the problem and request more storage space in the job control language. A STOP 110 is executed in conjunction with this message, and a traceback may be printed from subroutine STOP.

K6-58 This message appears in two forms, listed below:

K6-58 ** ERROR **** ERROR ** INVALID BIAS ID ____ IN REGION ____ OF UNIT ____.

This form of message K6-58 is from subroutine READGM. It is printed if a negative or zero bias ID is encountered anywhere in the geometry data. The error flag (MFLAG) is not activated so the problem will execute if the unit containing the error is not utilized in the unit orientation array. If that unit is used in the unit orientation array, the following form of message K6-58 will also be printed.

K6-58 *** ERROR *** INVALID BIAS ID IN REGION ABOVE.

This form of message K6-58 is from subroutine PRTJOM. It is printed if a negative or zero bias ID is entered for the specified geometry region. The problem will not execute if this form of message K6-58 is printed. Review Sect. F17.4.4 for correct geometry data specification information.

K6-59 THE CALCULATION WAS TERMINATED BECAUSE OF EXCESSIVE SPLITTING

This message from subroutine GUIDE is printed only if message K6-128 is printed 50 or more times for a given generation. This message indicates that the problem and/or the code is incapable of achieving a reasonable solution. If changes have been made in the code, they should be carefully scrutinized. If a biasing data block has been entered (Sect. F17.4.7), it should be checked carefully.

K6-60 THE ANGULAR SCATTERING DISTRIBUTION FOR MIXTURE ____ HAS BAD MOMENTS FOR THE TRANSFER FROM GROUP ____ TO GROUP ____.
____ MOMENTS WERE ACCEPTED.

THE LEGENDRE EXPANSION OF THE CROSS SECTION (P_0 - P_N) IS

(P_0) (P_1) (P_2) ... (P_n)

THE MOMENTS CORRESPONDING TO THIS DISTRIBUTION ARE

(M_1) (M_2) ... (M_n)

THE MOMENTS CORRESPONDING TO THE GENERATED DISTRIBUTION ARE

(M_1) (M_2) ... (M_n)

THE LEGENDRE EXPANSION CORRESPONDING TO THESE MOMENTS IS

(P_0) (P_1) (P_2) ... (P_n)

THE WEIGHTS/ANGLES FOR THIS DISTRIBUTION ARE

(W_1) (W_2) ... (W_m)

(A_1) (A_2) ... (A_m)

THE MOMENTS CORRESPONDING TO THIS DISTRIBUTION ARE

(M_1) (M_2) ... (M_n)

This message from subroutine BADMOM indicates that the moments from the cross-section data are incorrect for the group transfer shown. The code replaces the incorrect moments with acceptable moments and proceeds normally. The moments printed in the last line of the message should match those printed in the eighth line. The user can suppress these messages by entering an appropriate value for the "cross-section message cutoff parameter," EPS= in the mixing table data, Sect. F17.4.10. See Sect. F17.5.4.4 for assistance in determining an appropriate value.

K6-61 ***ERROR*** _____ IS NOT A VALID UNIT NUMBER. A UNIT NUMBER MUST BE A POSITIVE INTEGER.

This error message from subroutine KENOG indicates a unit number less than or equal to zero was specified. Unit numbers must be positive, nonzero integers.

K6-62 ***** ERROR ***** INSUFFICIENT DATA FOLLOWING THE KEYWORD ARRAY

This self-explanatory message is from subroutine ARRAY. The data following the keyword ARRAY are misspelled or incomplete. See Sect. F17.4.5 for assistance in determining the correct method for inputting array data.

K6-63 NOT ENOUGH IOs ARE LEFT TO PRINT THE FLUXES.

This message from subroutine FITFLX is self-explanatory. The number of IOs specified in the job control language must be increased, and the problem must be rerun if printed fluxes are required. All other results are unaffected by the failure to print the fluxes.

K6-64 THE ANGULAR SCATTERING DISTRIBUTION FOR MIXTURE _____ HAS BAD MOMENTS FOR THE TRANSFER FROM GROUP _____ TO GROUP _____. MOMENTS WERE ACCEPTED. THE P0 COEFFICIENT IS _____.

This message from subroutine BADMOM is printed to inform the user that the cross sections were altered by the code because the moments from the cross-section data were incorrect for the group transfer shown. The P_0 coefficient was larger than the "cross-section message cutoff parameter," EPS, but the relative change in the moments was smaller than EPS.

K6-65 ** WARNING ** AN AMPX WORKING LIBRARY WAS SPECIFIED ON UNIT ____ BUT NO MIXING DATA WAS READ. MIXED CROSS SECTIONS FORM UNIT ____ WILL BE USED.
** WARNING**

This message from subroutine ICEMIX occurs if the parameter data specified LIB=____ but no cross-section mixing data block was entered. The cross-section mixing data block begins with READ MIXT. See Sect. F17.4.3 for parameter data and Sect. F17.4.10 for mixing table information.

K6-66 ** WARNING ** ____ MIXTURES WERE REQUESTED IN THE GEOMETRY, BUT ONLY ____ MIXTURES ARE ON THE MIXED CROSS SECTION LIBRARY. ** WARNING **

This message from subroutine ICEMIX indicates that more mixtures were requested in the geometry region data than were available on the mixed cross-section library. See Sect. F17.4.3 for the specification of the unit number of the mixed cross-section library (XSC=), Sect. F17.4.10 for the specification of the mixing table, and Sect. F17.4.4 to determine the mixtures used in the geometry region data.

K6-67 ***** ERROR ***** THE ADJOINT INPUT PARAMETER WAS ____ BUT THE ADJOINT INDICATOR FROM THE MIXTURE CROSS SECTION LIBRARY WAS _____. KENO WILL NOT EXECUTE.

This message from subroutine ICEMIX occurs if the adjoint input parameter ADJ= specified a forward calculation and the cross sections were adjointed or the adjoint input parameter specified an adjoint calculation and the cross sections were not adjointed. T indicates true, F indicates false.

K6-68 THE MIXED CROSS SECTION LIBRARY ON UNIT ____ IS COMPLETELY COUPLED. KENO WILL NOT BE EXECUTED.

This message is from subroutine ICEMIX. It indicates that the mixed cross-section library is a completely coupled neutron-gamma library and therefore cannot be used for a KENO-VI calculation. A STOP 106 is executed when this message is printed.

K6-69 THE AMOUNT OF REMAINING SPACE IS INSUFFICIENT TO CONTAIN THE NECESSARY DATA. LIMIT=_____.

This message from subroutine RDTAPE indicates that more storage is needed to allow processing of the premixed ice format cross-section data. A STOP 124 is executed when this message is printed.

K6-70 ERROR IN SUBROUTINE WRTRST. NDX=_____

This message from subroutine WRTRST occurs only if the type of data to be written on the restart (WSTRT) unit is undefined (i.e., NDX is less than 1 or greater than 12). NDX is the index in the LPOINT array

as described in messages K6-46 and K6-48. This error is usually caused by code errors that were introduced when changes were made to the code. A STOP 133 is executed when this message is printed.

K6-71 INSUFFICIENT SPACE ALLOWED IN SUBROUTINE ALBWRT. _____ WORDS ARE ALLOWED, BUT _____ WORDS WERE REQUESTED.

This message from subroutine WRTALB indicates that more core storage is needed to allow loading the albedo data from the direct-access device into core. A STOP 105 is executed when this message is printed. Resubmit the problem, requesting more storage space in the job control language.

K6-72 ARRAY IS TOO LARGE TO FIT IN SPACE ALLOTTED IN SUBROUTINE WRTICE.

This message is from subroutine WRTICE. It indicates that more storage is needed to allow loading the mixed cross-section data from the direct-access device into core. A STOP 132 is executed when this message is printed. Resubmit the problem, requesting more storage space in the job control language.

K6-73 ***** ERROR ***** _____ MIXTURES WERE REQUESTED IN THE GEOMETRY DATA, BUT ONLY _____ OF THESE WERE FOUND IN THE MIXED CROSS SECTIONS. ***** ERROR *****

This self-explanatory message is from subroutine BOOK3. Either the wrong mixed cross-section data set (XSC= from the parameter data, Sect. F17.4.3) is being used, or one or more mixture numbers are in error in the geometry region data (see Sect. F17.4.4).

K6-74 ***** _____ WORDS OF STORAGE WERE ALLOCATED TO RUN THIS PROBLEM, BUT _____ WORDS ARE REQUIRED FOR THE INPUT DATA. *****

This self-explanatory message is from subroutine BOOK3. Additional storage is required to run this problem. Alter the job control language to request sufficient storage.

K6-75 *** NOT ENOUGH STORAGE TO PRINT ONE DIMENSIONAL CROSS SECTIONS. _____ LOCATIONS ARE NEEDED, BUT ONLY _____ ARE AVAILABLE

This self-explanatory message is from subroutine PRTXS. Additional storage must be requested in the job control language in order to print the 1-D mixture cross sections.

K6-76 *** NOT ENOUGH STORAGE TO PRINT TWO DIMENSIONAL CROSS SECTIONS. _____ LOCATIONS ARE NEEDED, BUT ONLY _____ ARE AVAILABLE.

This self-explanatory message is from subroutine PRTXS. Additional storage is needed to print the 2-D mixture cross sections. More storage must be requested in the job control language.

K6-77 *** NOT ENOUGH STORAGE TO PRINT ANGLES AND PROBABILITIES. _____ LOCATIONS ARE NEEDED, BUT ONLY _____ ARE AVAILABLE.

This self-explanatory message is from subroutine PRTXS. Additional storage must be requested in the job control language to print the angles and probabilities for the mixture cross sections.

K6-78 ***** WARNING ***** MORE SPACE MAY BE NEEDED THAN IS INDICATED.

This message is from subroutine NSUPG. In the process of supergrouping the energy-dependent information, the code ran out of available storage space. An attempt has been made to estimate the amount of storage needed, but the estimate may be low. Resubmit the job and request sufficient storage in the job control language.

K6-79 THIS PROBLEM IS TOO LARGE FOR THE AMOUNT OF CORE THAT WAS ALLOCATED.

This message is from subroutine NSUPG. It occurs during the process of determining the number of supergroups if the amount of storage is found to be insufficient to contain the energy-dependent information associated with one of the energy groups. Change the job control language to allow more storage. A STOP 116 is executed in conjunction with this message, and a traceback may be printed from subroutine STOP.

K6-80 _____ WORDS OF STORAGE WERE ALLOCATED, BUT AT LEAST _____ ADDITIONAL WORDS ARE NEEDED TO HOLD THE INPUT DATA. EVEN MORE SPACE WILL BE NECESSARY TO RUN THE PROBLEM.

This message from subroutine NSUPG is printed if the available storage is too small to hold the input data. Change the job control language to allow more storage.

K6-81 THE AVAILABLE SPACE IS TOO SMALL TO CONTAIN THE DATA OF THE LARGEST ENERGY GROUP. MAXL=_____ LFTLNG=_____ LTOT=_____ LTOTAL=_____ NSG=_____ This message is from subroutine NSUPG.

MAXL is the size of the energy-dependent data associated with the largest energy group.

LFTLNG is the amount of space available to the super group.

LTOT is the total length of the cross-section data.

LTOTAL is the total length of the albedo data.

NSG is the supergroup being processed.

A STOP 117 is executed when this message is printed. Increase LNG, make sure the system memory limit is sufficient, and resubmit the problem.

K6-82 TOO MANY STORAGE LOCATIONS REQUIRED. _____ WORDS OF STORAGE ARE NEEDED, BUT ONLY _____ ARE AVAILABLE.

This self-explanatory message is from subroutine POINT. To run the problem, the job control language must be changed to increase the amount of storage to be consistent with that specified in the message.

K6-83 ***** FOR ARRAY _____ THE _____ DIMENSIONS OF UNIT _____ AT (_____, _____, _____) DO NOT MATCH THOSE OF UNIT _____ AT (_____, _____, _____)*****
FOR UNIT _____ + _____ = _____ AND - _____ = _____ WHILE FOR UNIT _____ + _____ = _____ AND - _____ = _____.

This message is from subroutine ARASIZ. The common faces of adjacent units must be the same size and shape. This message occurs whenever this requirement is not met. One or more of the dimensions of the

units specified in the message may be incorrect, or the array definition data may be incorrect. Carefully check the input data relating to the geometry region data and the array definition data as described in Sects. F17.4.4 and F17.4.5.

K6-84 ***** UNIT ____ IN UNIT ORIENTATION ARRAY NUMBER ____ IS UNDEFINED IN THE INPUT DATA *****

This message from subroutine ARASIZ occurs when the array description data block specifies a unit that was not defined in the geometry region data. Verify the geometry region data and the array definition data as described in Sects. F17.4.4 and F17.4.5.

K6-85 UNIT ____ AT POSITION X=____ Y=____ Z=____ IN UNIT ORIENTATION ARRAY NUMBER ____ IS INVALID BECAUSE IT IS LESS THAN ZERO OR LARGER THAN THE LARGEST UNIT NUMBER IN THE INPUT DATA.

This message from subroutine ARASIZ occurs if the unit number named in the message is less than or equal to zero or greater than NBOX (the number of different box types). The position of the offending unit is also given. This error usually results from leaving some positions undefined in the unit orientation array or from erroneous data in the unit orientation data. (This includes extra data, misspelled data and omitted data.) See Sect. F17.4.5 for additional information.

K6-86 GEOMETRY WORD INDEX OUT OF RANGE. IGEOM=____ IN SUBROUTINE PRTJOM.

This message from subroutine PRTJOM is self-explanatory. The printed value of IGEOM must be greater than zero and less than 27 to be valid. If the geometry words (see *fgeom* in Sect. F17.4.4) are correct, this message is due to a code error that has been introduced when changes were made to the code.

K6-87 ***** ERROR ***** INSUFFICIENT DATA FOLLOWED THE KEYWORD "MEDIA".

This message from subroutine MEDIA is self-explanatory. Either the material, bias ID or sector data were not included on the media record, or noninteger data were inadvertently entered. See Sect. F17.4.4 for additional information on the type of data required on a MEDIA record.

K6-88 ***** ERROR ***** SECTOR DATA WAS NOT FOUND FOR MEDIA ____.

This message from subroutine MEDIA is self-explanatory. Either the material, bias ID or sector data were not included on media record ____ or noninteger data were inadvertently entered. See Sect. F17.4.4 for additional information on the type of data required on a MEDIA record.

K6-89 *** ERROR *** VOLUME HAS BEEN MULTIPLY DEFINED. NEUTRON ____ UNIT ____ AT POINT X1=____ Y1=____ Z1=____ MOVING IN DIRECTION U=____ V=____ W=____ THIS POINT WAS LOCATED INSIDE THE FOLLOWING REGIONS.
REGION NUMBER = ____
.
.
.
REGION NUMBER = ____.

This message is from subroutine TRACK. It is caused by incorrectly specifying the vector definition arrays in the media records of a unit. It can be caused by incorrectly specifying regions that share a common boundary so the boundary between regions is contained in only one region. See Sect. F17.4.4 for more information concerning vector definition arrays on MEDIA records.

K6-90 THE UNIT ORIENTATION DESCRIPTION MAY APPEAR TO BE INCORRECT BECAUSE THE ARRAY SIZE WAS INCORRECTLY SPECIFIED.

This warning message from subroutine PRTLBA occurs if NBXMAX, NBYMAX or NBZMAX (NUX=, NUZ=, NUZ=) from the array data, Sect. F17.4.5, was incorrectly specified.

K6-95 REGION NUMBER _____ IN UNIT NUMBER _____ CONTAINS AN ERROR IN THE DIMENSIONS.

This message from subroutine VOLUME indicates an error in the geometry input data such that the negative dimension specification for a cube or cuboid is larger than the positive dimension specification (i.e., the -x dimension is greater than the +x dimension, or the -y dimension is greater than the +y dimension or the -z dimension is greater than the +z dimension). This message is also printed if the magnitude of the chord for a cylinder or sphere is larger than the radius. See Sect. F17.4.4 for assistance in specifying the geometry correctly.

K6-96 THE VOLUME DEFINED BY GEOMETRY RECORD ____ IS NEGATIVE.

This message from subroutine VOLUME is printed whenever a negative volume is calculated. This can result from the positive dimension being smaller than the negative dimension on a face of a geometry region. It can also be the result of roundoff when the volumes are calculated. Either the geometry regions are incorrectly specified, or the data are out of order, or the dimensions are so tight fitting that roundoff causes the net volume of the region to be negative. If the error is caused by roundoff, adjust the appropriate dimensions slightly. See Sect. F17.4.4.

K6-97 ERROR ERROR. THE VOLUME FOR UNIT ____ IS NEGATIVE.

This message is from subroutine VOLUME. A negative volume for a unit can be caused by having a unit consisting of one region and having a positive dimension smaller than the negative dimension on one or more faces. Message K6-95 or K6-96 may accompany this message. See Sect. F17.4.4 for assistance in specifying the geometry data correctly.

K6-99 This message appears in three forms, listed below:

K6-99 *** ERROR IN UNIT ____ *** THE LAST GEOMETRY REGION OF A UNIT UTILIZED IN THE UNIT ORIENTATION DESCRIPTION OF THE ARRAY DATA MUST BE A CUBOID.

This message is from subroutine ARASIZ. It can occur when a single unit problem whose outer region is not a cuboid is specified as a $1 \times 1 \times 1$ array. To eliminate this message, add a cuboidal outer region containing void, or remove the array data. If the problem is an array problem with the array type either defaulted or specified as cuboidal, be sure each unit used in the unit orientation description ends with a cuboid. See Sects. F17.4.4 and F17.4.5.

K6-99 *** ERROR IN UNIT ____ *** THE LAST GEOMETRY REGION OF A UNIT UTILIZED IN THE UNIT ORIENTATION DESCRIPTION OF THE ARRAY DATA MUST BE A HEXPRISM.

This message is from subroutine ARASIZ. It can occur when a single unit problem whose outer region is not a hexprism is specified as a 1x1x1 array. To eliminate this message, add a hexagonal outer region containing void, or remove the array data. If the problem is an array problem with the array type specified as triangular, be sure each unit used in the unit orientation description ends with a hexprism. See Sects. F17.4.4 and F17.4.5.

K6-99 *** ERROR IN UNIT ____ *** THE ARRAY TYPE SPECIFIED IN THIS UNIT IS UNDEFINED. SPECIFY IF THE ARRAY TYPE IS CUBOID OR HEXPRISM.

This message is from subroutine ARASIZ. It can occur if the array type, TYP=, is incorrectly specified in the array data. Check the spelling of the array type. See Sect. F17.4.5.

K6-100 THIS PROBLEM WILL NOT BE RUN BECAUSE ERRORS WERE ENCOUNTERED IN THE INPUT DATA.

This message is from subroutine BOOK5 and indicates that other error messages were printed in the problem output. Find these messages and correct the data accordingly. A STOP 129 is executed when this message is printed.

K6-101 *** ERROR *** NO FISSILE MATERIAL WAS FOUND IN SUBROUTINE START.

This message is from subroutine START. It indicates that none of the mixtures utilized in this problem have a fission spectrum associated with them. Either the geometry data did not specify a fissionable mixture number, the mixing table is incorrect, the wrong mixed cross-section data set was accessed, or the mixed cross-section data set was incorrectly or incompletely made. A STOP 128 is executed in conjunction with this message, and a traceback may be printed from subroutine STOP.

K6-102 *** ERROR *** THE START DATA SPECIFIES THAT NEUTRONS CAN BE STARTED IN THE REFLECTOR. HOWEVER NEUTRONS WILL NOT BE STARTED BECAUSE THE OUTER REGION OF THE REFLECTOR IS NOT A CUBE OR CUBOID. NEUTRONS CAN BE STARTED FOR THE EXISTING GEOMETRY IF XSM, XSP, YSM, YSP, ZSM AND ZSP ARE ENTERED AS START DATA. XSM, XSP, YSM, YSP, ZSM AND ZSP MUST FIT WITHIN THE OUTER REGION OF THE REFLECTOR. *** ERROR ***

This message is from subroutine START. Start type 0 allows starting points throughout noncuboidal regions. If a start type other than 0 or 6 is desired and the outermost region of the reflector is not a cuboid, data must be input to specify an imaginary cube or cuboid within this outer region. See Sect. F17.4.8 for assistance in specifying these data.

K6-103 START TYPE ____ IS OUT OF RANGE.

This message from subroutine START indicates that the start type was less than zero or greater than 6. The start type is defined by entering the keyword NST= followed by the desired start type in the start data. The available starting options are given in Table F17.4.6 (Sect. F17.4.8).

K6-104 A POSIT ERROR INDICATES THAT THE POINT X=___ Y=___ Z=___ DOES NOT OCCUR WITHIN UNIT ___. IF XSM, XSP, YSM, YSP, ZSM AND ZSP ARE ENTERED IN THE START DATA, VERIFY THAT THEY FIT WITHIN THE OVERALL COORDINATES OF THE SYSTEM. THE OVERALL COORDINATES MAY NOT BE PRINTED FOR A BARE ARRAY.

If XSM, XSP, YSM, YSP, ZSM, ZSP were entered in the start data. Verify that they fit within the overall coordinates of the system. The overall coordinates may not be printed for a bare array. This message from subroutine START may result from precision difficulties. It is allowed to occur a maximum of five times before being considered fatal. A code error may be the cause of this message if it becomes fatal.

K6-105 ***** WARNING, ONLY ___ INDEPENDENT STARTING POSITIONS WERE GENERATED. *****

This message is from subroutine START. KENO-VI must have *npb* (NPG=, see parameter data, Sect. F17.4.3) starting positions. This message is to inform the user that fewer than *npb* starting positions were generated. The remaining starting positions are randomly selected from those that were generated, thus giving duplicate starting positions. If the number of independent starting positions is nearly *npb*, the starting distribution is probably acceptable. If it is much smaller than *npb*, a different start type should be used to give a better starting distribution. See the start data in Sect. F17.4.8 for assistance.

K6-106 POSIT ERROR --- UNIT ___ HAS MULTIPLY DEFINED SPACE
X=___ Y=___ Z=___ SECTOR INSIDE ___

This message from subroutine POSIT is usually the result of an incorrectly specified starting point for the initial source distribution when NST=3, 4 or 6 is specified in the start data. The starting point may not be consistent with the unit's position in the global array. The message can also be caused by a code error that was introduced when changes were made to the code. X, Y, Z is the location of the neutron and SECTOR INSIDE is the sectors which contain that point. See Sect. F17.4.4 for correct geometry words.

K6-107 POSIT ERROR X=___ Y=___ Z=___ UNIT=___

This message from subroutine POSIT may result from precision difficulties or a code error. X, Y, Z is the location of the neutron in unit UNIT. K6-104 is a companion message.

K6-108 POSITION (_____, _____, _____) IS NOT VALID FOR THE POSITION OF THE SPIKE FOR START TYPE 2.

This message from subroutine START2 indicates that NXS, NYS or NZS was entered as zero. See Sect. F17.4.8 for the correct start data specification.

K6-109 ***** INVALID GEOMETRY TYPE IN START. IGEO=___ *****

This message from subroutine STRTSU is probably the result of a code error.

K6-110 ***** ERROR ERROR THE PROBLEM WILL NOT BE EXECUTED BECAUSE NO FISSILE MATERIAL WAS FOUND. *****

This message from subroutine VOLFIS occurs when the volume of fissile material is found to be zero. Check to be sure the fissile material was correctly specified in the geometry data, check the volume of the fissile material in the printout to be sure it is nonzero, verify that the mixing table is correct or the correct ice mixed cross-section data set is used if a mixing table is not used. A STOP 131 is executed when this message is printed.

K6-111 ** RESTART DATA IS NOT AVAILABLE FOR RESTARTING WITH GENERATION ____
AS SPECIFIED IN THE INPUT DATA **
** HOWEVER, AVAILABLE RESTART DATA WAS ALLOWED RESTARTING WITH
GENERATION ____ **

This message from subroutine RDCALC indicates that *nbas* (BEG=, Sect. F17.4.3) was not consistent with the set of restart data that was to be used. A set of restart data is written every *nrstrt* (RES=, Sect. F17.4.3). The value of *nbas* should be 1 greater than one of these generations.

K6-112 ERROR IN RESTART. PARAMETER DATA AND RESTART DATA DO NOT AGREE.
NUMBER PER GENERATION FROM RESTART, NPBT=____
NUMBER PER GENERATION FROM INPUT DATA, NPB=____
NUMBER OF ENERGY GROUPS FROM RESTART, NGPT=____
NUMBER OF ENERGY GROUPS FROM INPUT DATA, NGP=____

This message is from subroutine RDCALC. A restarted problem MUST use the same number per generation and the same number of energy groups as the parent problem that wrote the restart data. Verify that the correct data set is mounted on unit *rstrt*. (RST=, Sect. F17.4.3). This message can also be caused by a code error.

K6-113 ERROR IN RESTART. PARAMETER DATA AND RESTART DATA DO NOT AGREE.
FISSION DENSITIES, FLUXES, OR REGION DEPENDENT FISSIONS AND ABSORPTIONS
WERE REQUESTED, BUT THE GEOMETRY DATA IS INCONSISTENT.
NUMBER OF GEOMETRY REGIONS FROM RESTART, KREFT=____
NUMBER OF GEOMETRY REGIONS FROM INPUT DATA, KREFM=____

This message is from subroutine RDCALC. Verify that the correct data set is accessed on unit *rstrt* (RST=, Sect. F17.4.3). A code error can also cause this message.

K6-114 *** ERROR ***** ERROR *** PARAMETER DATA SPECIFIED FLUXES BUT THE RESTART
DATA DID NOT INCLUDE FLUXES.

This message is from subroutine RDCALC. The restarted problem can turn off fluxes if the parent case that wrote the restart data set calculated fluxes. However, if the parent case did not calculate fluxes, the restarted problem cannot calculate fluxes either if the correct restart data set was accessed on *rstrt* (RST=, Sect. F17.4.3). The parameter data FLX=YES must be removed from the input data, or FLX=NO must be entered later in the parameter data of the restarted problem.

K6-115 *** ERROR ***** ERROR *** PARAMETER DATA SPECIFIED REGION DEPENDENT
FISSIONS AND ABSORPTIONS, BUT THEY WERE NOT INCLUDED ON RESTART.

This message is from subroutine RDCALC. The restarted problem specified FAR=YES in the parameter data block, but the parent case that wrote the restart data set did not calculate region-dependent fissions and absorptions. The restarted problem can turn off region-dependent data if the parent case calculated them, but cannot turn them on if they were not calculated by the parent case. Verify that the correct restart data set is accessed on *rstrt* (RST=, Sect. F17.4.3). Remove FAR=YES from the parameter data of the restarted problem or add FAR=NO later in the parameter data. Section F17.5.3 illustrates methods of changing the parameter input data.

K6-116 *** ERROR ***** ERROR *** EXECUTION IS TERMINATED *** ERROR ***
*** ERROR ***

This message from subroutine RDCALC is a companion to messages K6-112 through K6-115. A STOP 121 is executed when this message is printed.

K6-117 THE CALCULATION WAS TERMINATED BECAUSE ERRORS WERE ENCOUNTERED IN THE START DATA.

This message is from subroutine GUIDE. It will be accompanied by one or more of messages K6-101 through K6-104 or K6-106 through K6-110. A STOP 130 is executed when this message is printed.

K6-118 EXECUTION TERMINATED. RAKBAR HAS BECOME ZERO OR NEGATIVE.

This message is from subroutine GUIDE. If this message appears without other error messages, a code error is the probable cause.

K6-119 JOB PULLED GENERATION=____ NEUTRON=____

This message from subroutine GUIDE indicates that the problem is looping, or the time allotted for each generation, *tbtc* (TBA=, Sect. F17.4.3) is too small. If *tbtc* (TBA=) is increased significantly and the message occurs again for the same generation and the same neutron, it is due to a code error.

K6-120 EXECUTION TERMINATED DUE TO INSUFFICIENT IO'S. APPROXIMATELY ____ IOs ARE NEEDED PER GENERATION, BUT ONLY ____ REMAIN.

This message is from subroutine GUIDE. The problem can be resubmitted if more histories are desired. Be sure to change the job control language to request sufficient IOs to allow the problem to run.

K6-121 EXECUTION TERMINATED DUE TO INSUFFICIENT TIME IN THE JOB STEP. ____ SECONDS ARE NEEDED PER GENERATION, BUT ONLY ____ REMAIN IN THE JOB STEP.

This message is from subroutine GUIDE. If more histories are desired, change the job control language to allow adequate time and resubmit the problem.

K6-122 EXECUTION TERMINATED DUE TO EXCEEDING THE TIME SPECIFIED FOR THE PROBLEM.

This message is from subroutine GUIDE. If more histories are desired, increase *tmax* (TME=, Sect. F17.4.3) to allow computation of the desired number of histories.

K6-123 EXECUTION TERMINATED DUE TO COMPLETION OF THE SPECIFIED NUMBER OF GENERATIONS.

This message from subroutine GUIDE states that the requested number of histories have been completed. If more histories are desired, increase the number of generations (GEN=, Sect. F17.4.3).

K6-124 ***** ERROR ***** THE OPTION TO USE EXTRA 1-D'S WAS SPECIFIED BUT ID NO. _____ WAS NOT FOUND IN THE EXTRA 1-D ARRAY.

This self-explanatory message is from function INDX. If extra 1-Ds are specified in the parameter data (X1D=, Sect. F17.4.3), extra 1-D IDs must be entered as data. See Sect. F17.4.9. A STOP 107 is executed when this message is printed.

K6-125 EXCEEDED NEUTRON BANK SIZE

This message from subroutine BANKER indicates that the number of banked particles exceeds the bank size. This situation can be corrected by increasing *nbank* (NBK=, Sect. F17.4.3).

K6-129 *** ERROR IN SUBROUTINE ALBEDO *** FACE NUMBER _____ USES _____
ALBEDO NUMBER=_____ INCIDENT XSEC ENERGY GROUP=_____
INCIDENT ALBEDO ENERGY GROUP=_____
INCIDENT ANGLE INDEX=_____
RANDOM NUMBER=_____.

This message from subroutine ALBEDO indicates that a code error was encountered when trying to determine the output energy group during the albedo treatment.

K6-130 *** ERROR IN SUBROUTINE ALBEDO *** FACE NUMBER _____ USES _____ALBEDO
NUMBER=_____ RETURNING XSEC ENERGY GROUP=_____
INCIDENT ALBEDO ENERGY GROUP=_____
INCIDENT ANGLE INDEX=_____
RETURNING ALBEDO ENERGY GROUP=_____
RANDOM NUMBER=_____.

This message from subroutine ALBEDO indicates that a code error was encountered while trying to compute the returning angle in the albedo treatment.

K6-131 NO FISSIONS

This message from subroutine NSTART indicates that none of the generations encountered a fissile material so no fission points were generated.

K6-132 WARNING....ONLY _____ INDEPENDENT FISSION POINTS WERE GENERATED

This message from subroutine NSTART indicates that less than *npb* (NPG=, Sect. F17.4.3) fission points were generated during the previous generation. Because *npb* fission points are required by the code, the remaining fission points are randomly selected from those that were generated, thus utilizing duplicate fission points. If the number of fission points is considerably less than *npb* for most of the generations, the answer can be affected.

K6-133 NUMBER OF GENERATIONS RUN WAS INSUFFICIENT TO EDIT

This message from subroutine KEDIT occurs if the number of generations completed is less than *nskip*+1 (NSK=, Sect. F17.4.3). In this instance, the summaries for the problem cannot be printed.

K6-134 FLUXES FOR UNIT ____ WILL NOT FIT IN CORE.

This message from subroutine FITFLX indicates that the flux array is too large for the available core space. More space can be allocated in the job control language if desired.

K6-137 INPUT DATA SAID TO PRINT WEIGHTS, BUT THEY WERE NOT PRINTED BECAUSE THE NUMBER OF ENERGY GROUPS EXCEEDS THE AVAILABLE SPACE.

This message is from subroutine MASTER. In order to accommodate the specified number of energy groups, more computer storage must be requested in the job control language.

K6-138 ***** A WEIGHT OF 0.0 INDICATES THAT WEIGHTS WERE NOT READ OR GENERATED FOR THE BIAS ID. *****
***** WEIGHTS OF 0.0 WILL BE DEFAULTED TO 0.5 PRIOR TO EXECUTION *****

This message is from subroutine PRTWTS. It is printed to alert the user that weights were not entered, defaulted, or generated. This message may appear as the result of a code error.

K6-139 ***** ERROR ***** NO VALID MIXTURES WERE FOUND IN THE GEOMETRY DESCRIPTION.

This message from subroutine ICEMIX indicates that the geometry data did not specify any valid mixtures. Check the geometry data (Sect. F17.4.4) and correct any errors that are found. This message can also be triggered if the unit orientation data description is not properly entered for geometry having more than one unit.

K6-140 ***ERROR*** NOT ENOUGH STORAGE FOR START TYPE 6 DATA. 1ST IS AMT NEEDED,
2ND IS AMT AVAILABLE.
PERTINENT CONSTANTS (1) (2)

This message from subroutine SAVST6 indicates that more computer storage is necessary to run this problem. At least (1) words of storage are needed to run the problem, but only (2) words of storage were available. Increase the amount of computer storage requested in the job control language to correspond to the amount of storage needed. A STOP 126 is executed in conjunction with this message and a traceback may be printed from subroutine STOP.

K6-141 DATA CANNOT BE CHANGED WHEN A PROBLEM IS RESTARTED AT A GENERATION GREATER THAN ONE.

This message from subroutine DATAIN is printed if data other than parameter data are entered for a problem being restarted at a generation greater than one. If data other than certain parameter data are to be changed, the problem must be restarted with the first generation. The error flag is set so the problem will not execute.

K6-142 NO GEOMETRY DATA HAS BEEN SPECIFIED IN THE INPUT DATA.

This message from subroutine DATAIN indicates that a geometry data block was not entered for the problem either as input data or from the restart unit. Correct the data and resubmit the problem. A STOP 135 is executed in conjunction with this message, and a traceback may be printed from subroutine STOP.

K6-143 UNIT ORIENTATION DATA IS REQUIRED IF MORE THAN ONE UNIT TYPE IS SPECIFIED IN THE GEOMETRY DATA.

This self-explanatory message is from subroutine DATAIN. Enter an array i or unit orientation data block as described in Sects. F17.4.5 and F17.5.6. A STOP 136 is executed in conjunction with this message, and a traceback may be printed from subroutine STOP.

K6-144 DUE TO INCONSISTENCIES BETWEEN INPUT AND RESTART DATA, MATRIX INFORMATION BY UNIT TYPE WILL BE CALCULATED BUT NOT PRINTED. INPUT DATA SET MKU=NO, BUT DATA FROM THE RESTART UNIT SPECIFIED YES.

This self-explanatory warning message is from subroutine PARTBL. The matrix information by unit type cannot be eliminated if it was calculated by the original problem (parent case) that wrote the restart data. However, printing it can be avoided. Verify that the correct problem is being used for restarting the problem (the title is printed at the bottom of the parameter tables). Also verify the specification of the restart unit, RST, in the third table of the output.

K6-145 DUE TO INCONSISTENCIES BETWEEN INPUT AND RESTART DATA, MATRIX INFORMATION BY UNIT LOCATION WILL BE CALCULATED BUT NOT PRINTED. INPUT DATA SET MKP=NO, BUT DATA FROM THE RESTART UNIT SPECIFIED YES.

This self-explanatory warning message is from subroutine PARTBL. The matrix information by unit location (also called array position or position index) cannot be eliminated if it was calculated by the original problem (parent case) that wrote the restart data. However, printing it can be avoided. Verify that the correct problem is being used for restarting the problem (the title is printed at the bottom of the parameter tables). Also verify the specification of the restart unit, RST, in the third table of the output.

K6-146 * ERROR ***** ERROR *** PARAMETER DATA SPECIFIED MATRIX INFORMATION BY UNIT TYPE BUT IT WAS NOT FOUND ON THE RESTART UNIT.**

This message from subroutine RDCALC is printed if a restarted problem requests matrix information by unit type when it was not requested and calculated by the original problem (parent case) that wrote the restart data. Verify that the correct restart data are being used and that the restart unit (RST) is correctly specified.

Eliminate the request for matrix information by unit type (MKU=, in the parameter data) if it is not necessary. The problem must be restarted with the first generation (BEG=1, in the parameter data) if matrix information by unit type is required and was not calculated by the parent case. A STOP 121 is executed in conjunction with this message.

K6-147 *** ERROR ***** ERROR *** PARAMETER DATA SPECIFIED MATRIX INFORMATION BY UNIT LOCATION BUT IT WAS NOT FOUND ON THE RESTART UNIT.

This message from subroutine RDCALC is printed if a restarted problem requests matrix information by unit location (also called array position or position index) when it was not requested and calculated by the original problem (parent case) that wrote the restart data. Verify that the correct restart data are being used and that the restart unit (RST) is correctly specified in the first table following the parameter table. Eliminate the request for matrix information by unit location (MKP=, in the parameter data) if it is not necessary. If matrix information by unit location is required and if it was not calculated by the parent case, the problem must be restarted with the first generation (BEG=1, in the parameter data). A STOP 121 is executed in conjunction with this message.

K6-149 A CROSS SECTION LIBRARY WAS SPECIFIED FOR A RESTARTED PROBLEM, BUT MIXING TABLE DATA WERE NOT AVAILABLE. THE PROBLEM WILL NOT EXECUTE.

This message from subroutine RDRST means that LIB= was entered in the parameter data block and a mixing table data block was not available. A flag is set to terminate execution when the data reading has been completed. If cross sections are to be used from the restart unit (RST=), eliminate the LIB= or XSC= from the parameter data. If new cross sections are to be mixed, LIB= must be specified in the parameter data. The IDs in the mixing table must be available on the cross-section library specified by LIB=. A problem can be restarted using a new mixed cross-section library by specifying XSC= in the parameter data.

K6-151 *** ERROR *** _____ IS AN INVALID ARRAY TYPE IN THE ARRAY DEFINITION DATA

This message from subroutine ARAYIN indicates that a parameter name was misspelled or the data were out of order. See Sect. F17.4.5 for a list of the array parameter names. A stop 137 is executed in conjunction with this message.

K6-152 *** ERROR *** IRET=_____ A PREMATURE TERMINATION WAS ENCOUNTERED WHILE READING ARRAY DATA.
IRET=1 INDICATES AN END WAS FOUND. IRET=2 INDICATES AN END OF FILE.

This message from subroutine ARAYIN indicates that an array number was specified without entering the corresponding UNIT ORIENTATION DESCRIPTION. See Sects. F17.4.5 and F17.5.6 for assistance.

K6-153 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS ADDITIONAL REGION SIZE NEEDED.

This message from subroutine SORTA indicates that the allocated computer storage is too small to allow loading the unit orientation data prior to determining the nesting level of the arrays defined by the unit orientation data. The first number printed is the amount of storage, in words, needed to hold these data. The second number is the amount of computer storage that was allocated, and the third number is the minimum

additional region size, in units of Kbytes, necessary to hold these data. Increase the region size for the "go step" in the job control language by the additional required region size (the third number) and resubmit the problem. A STOP 138 is executed in conjunction with this message.

K6-154 *** ERROR *** LEVELA= ____ IS LARGER THAN ____ THE ____ NUMBER OF ARRAYS.

This message from subroutine SORTA indicates that the array data specified in the problem are recursively nested. An example of this is the following:

array 1 contains array 3, array 2 contains array 1, array 3 contains array 2

Thus the definition of array 1 and array 3 are intertwined in a never-ending loop. Correct the array data (Sect. F17.4.5) and resubmit the problem. If the input data did not specify recursive nesting, a code error has occurred. A STOP 139 is executed in conjunction with this message.

K6-155 *** ERROR *** THE NESTING FLAG OR NUMBER OF ARRAY LEVELS HAS BEEN DESTROYED BY A CODE ERROR.
THE ORIGINAL NESTING FLAG WAS SET ____ IT IS NOW SET ____.
THE ORIGINAL NESTING LEVEL WAS ____ IT IS NOW ____.

This self-explanatory message is from subroutine LODARA. A STOP 140 is executed in conjunction with this message.

K6-156 *** ERROR *** MIXTURE ____ CONTAINS AT LEAST ONE ZERO VALUE FOR THE TOTAL CROSS SECTION.

This message is from subroutine XSECID. All the total cross sections must be positive. Zero total cross sections can occur if all the components of a mixture are mixed with a zero number density. Correct the mixing table for the specified mixture and resubmit the problem.

K6-157 *** ERROR *** THE FIRST HOLE IN A UNIT MUST FOLLOW A VALID GEOMETRY REGION.

This message is from subroutine READGM. If holes are to be utilized in the geometry region data (Sect. F17.4.4), they must follow the region in which they are to be placed. This message indicates that HOLE was the first geometry description in a unit or was placed inside an ARRAY description. Correct the geometry region data and resubmit the problem.

K6-158 *** ERROR *** ERROR IN THE NUMBER OF HOLES. IHOL= ____ NUMHOL= ____

This message is from subroutine READGM. A code error is the probable cause of this error.

K6-159 *** ERROR *** ARRAY NUMBER ____ SPECIFIED IN THE GEOMETRY REGION DATA WAS NOT ENTERED IN THE ARRAY DATA.

This message from subroutine SORTA occurs if the array number specified for an ARRAY region description of the GEOMETRY data (Sect. F17.4.4) did not have the corresponding UNIT ORIENTATION

DATA entered in the ARRAY DATA (Sect. F17.4.5). A STOP 142 is executed in conjunction with this message when it is printed from subroutine SORTA. Correct the data and resubmit the problem.

K6-160 THE HOLES ARE RECURSIVELY NESTED.

This message from subroutine HOLE indicates that the geometry region data description (Sect. F17.4.4) specifies holes that are recursively nested. This situation can happen if a unit contains a hole whose definition traces back to the same unit or are defined in terms of each other. A simple example of recursive nesting follows:

```
UNIT 1 CUBOID 1 6PI0.0 HOLE 2 1 3*0.0 BOUNDARY 1
UNIT 2 CUBOID 1 6PI0.0 HOLE 1 1 3*0.0 BOUNDARY 1
```

Thus unit 1 contains unit 2, and unit 2 contains unit 1. Check the geometry region data for recursive nesting. In the absence of recursive nesting, a code error is the probable cause of this message. A STOP 143 is executed when this message occurs and a traceback is printed.

K6-163 *** ERROR *** ARRAY NUMBER ____ IS ____ WORDS LONG, BUT ONLY ____ WORDS ARE AVAILABLE WHEN WRITING RESTART. THE RESTART FILE WILL BE INCOMPLETE. THE PROBLEM WILL NOT EXECUTE.

This message is from subroutine WRTARA. It indicates that the available computer storage is too small to hold the array data from the direct-access device. This situation in turn will cause the restart data file to be incomplete. Increase the requested storage space in the job control language and resubmit the problem.

K6-164 *** WARNING *** ARRAY NUMBER ____ IS ____ WORDS LONG, BUT ONLY ____ WORDS ARE AVAILABLE WHEN READING RESTART. THIS ARRAY WILL NOT BE AVAILABLE. THE PROBLEM WILL NOT EXECUTE IF THIS ARRAY IS USED.

This message is from subroutine RDARA. It occurs when the restart data file is being loaded from the restart unit and the allocated space is insufficient to hold the data for the specified array. Resubmit the problem, requesting more storage space in the job control language.

K6-168 INSUFFICIENT DATA FOLLOWING THE KEYWORD "HOLE".

This self-explanatory message is from subroutine RDARA. Check the data following the keyword "HOLE." Either the data are missing or noninteger data were inadvertently entered. See Sect. F17.4.4.

K6-170 ***** ERROR ***** SECTOR DATA WAS NOT FOUND FOR HOLE ____

This self-explanatory message is from subroutine HOLEIN. Check the sector data following the HOLE media record corresponding to hole number _____. Either the data are missing or noninteger data were inadvertently entered. See Sect. F17.4.4.

K6-171 ERROR - DIRECTION COSINES DOWN THE PAGE WERE ALL INPUT AS ZERO.

This message from subroutine RDPLLOT indicates that the values for UDN=, VDN= and WDN= were all zero. A zero value vector does not define a direction, so an error has occurred. See Sect. F17.4.11 for information concerning direction cosines down the page.

K6-172 ERROR - DIRECTION COSINES ACROSS THE PAGE WERE ALL INPUT AS ZERO.

This message from subroutine RDPLLOT indicates that the values for UAX=, VAX= and WAX= were all zero. This message is an error because a zero value vector does not define a direction. See Sect. F17.4.11 for assistance in defining direction cosines across the page.

K6-173 ERRORS WERE DETECTED IN THE INPUT DATA FOR THIS PICTURE. IT WILL NOT BE DRAWN.

This message from subroutine RDPLLOT is a companion to messages K6-174, K6-180, K6-171 and K6-172. Correct the error that triggered the companion message, and resubmit the problem.

K6-174 ERROR IN KENO PICTURE DATA - _____ SHOULD BE ENTERED AS _____ YES OR _____ NO.

This self-explanatory message is from subroutine RDPLLOT. Correct the error and resubmit the problem. See Sect. F17.4.11 for assistance.

K6-175 DUE TO INCONSISTENCIES BETWEEN INPUT AND RESTART DATA, MATRIX INFORMATION BY HOLE WILL BE CALCULATED BUT NOT PRINTED. INPUT DATA SET MKH= NO, BUT DATA FROM THE RESTART UNIT SPECIFIED YES.

This self-explanatory warning message is from subroutine PARTBL. The matrix information by hole cannot be eliminated if it was calculated by the original problem (parent case) that wrote the restart data. However, printing it can be avoided. Verify that the correct problem is being used for restarting the problem (the title is printed at the bottom of the parameter tables). Also, verify the specification of the restart unit, RST, in the third table of the computer output.

K6-176 DUE TO INCONSISTENCIES BETWEEN INPUT AND RESTART DATA, MATRIX INFORMATION BY ARRAY WILL BE CALCULATED BUT NOT PRINTED. INPUT DATA SET MKA=NO, BUT DATA FROM THE RESTART UNIT SPECIFIED YES.

This self-explanatory warning message is from subroutine PARTBL. The matrix information by array cannot be eliminated if it was calculated by the original problem (parent case) that wrote the restart data. However, printing it can be avoided. Verify that the correct problem is being used for restarting the problem (the title is printed at the bottom of the parameter tables). Also, verify the specification of the restart unit, RST, in the third table in the computer output.

K6-177 ***ERROR *** ERROR *** PARAMETER DATA SPECIFIED MATRIX INFORMATION BY HOLE BUT IT WAS NOT FOUND ON THE RESTART UNIT.

This message from subroutine RDCALC is printed if a restarted problem requests matrix information by hole when it was not requested and calculated by the original problem (parent case) that wrote the restart data.

Verify that the correct restart data file is being used and that the restart unit (RST) is correctly specified. Eliminate the request for matrix information by hole (MKH=, in the parameter data) if it is not necessary. The problem must be restarted with the first generation (BEG = 1, in the parameter data) if matrix information by hole is required and was not calculated by the parent case. A STOP 121 is executed in conjunction with this message.

K6-178 *** ERROR *** ERROR *** PARAMETER DATA SPECIFIED MATRIX INFORMATION BY ARRAY BUT IT WAS NOT FOUND ON THE RESTART UNIT.

This message from subroutine RDCALC is printed if a restarted problem requests matrix information by array (also called array position or position index) when it was not requested and calculated by the original problem (parent case) that wrote the restart data. Verify that the correct restart data are being used and that the restart unit (RST) is correctly specified in the first table following the parameter tables. Eliminate the request for matrix information by array (MKA=, in the parameter data) if it is not necessary. If matrix information by array is required and if it was not calculated by the parent case, the problem must be restarted with the first generation (BEG = 1, in the parameter data). A STOP 121 is executed in conjunction with this message.

K6-180 ERROR IN KENO PICTURE DATA - KEYWORD _____ IS NOT VALID.

This message from subroutine RDPLLOT indicates that the plot or picture data are out of order or a keyword is incorrectly spelled. See Sect. F17.4.11 for a list of correct keywords.

K6-181 ***ERROR*** LPIC IS OUT OF RANGE. LPIC= _____.

This message from subroutine PRTPLT indicates that a code error has occurred or the type of plot (PIC=) was not properly specified. *lpic*=1 for a mixture map, *lpic*=2 for a unit map and *lpic*=3 for a bias ID map. Any other values of *lpic* are invalid.

K6-182 INSUFFICIENT SPACE FOR PLOTTING ARRAYS. FIRST NOS ARE STORAGE NEEDED AND ALLOCATED. LAST IS REQUIRED ADDITIONAL REG. SIZE.

This message from subroutine BOOK5 is accompanied by a STOP 147. It indicates that the allocated computer storage will not hold the plot data. The first number printed is the amount of storage, in words, needed to hold these data. The second number is the amount of computer storage that was allocated, and the third number is the minimum additional region size, in units of Kbytes, necessary to hold the data. Increase the region size for the "go step" in the job control language by this third number and resubmit the problem. If additional computer storage is not available, eliminate the fluxes, fissions and absorptions by region, matrix information or other space consuming options (see Sect. F17.4.3).

K6-184 ***** _____ WORDS OF STORAGE ARE NEEDED FOR THE WEIGHTS, BUT ONLY _____ WORDS ARE AVAILABLE. *****

This message from subroutine RDBIAS indicates that the allocated computer storage is not sufficient to process the biasing or weighting data for the problem. Increase the region size in the "go step" of the job control language. The additional required region size is four times (the difference of the two numbers plus 1023) divided by 1024. A STOP 151 is executed when this message is printed.

K6-185 *** ERROR *** THE NUMBER OF SETS OF BIASING CORRELATION DATA EXCEEDS THE NUMBER THAT WAS WRITTEN WHEN THE BIASING DATA WAS READ. ____ WERE WRITTEN, BUT AN ATTEMPT WAS MADE TO READ ____.

This message from subroutine WAITIN is accompanied by a STOP 148. It is indicative of a code error, unless accompanied by error messages related to the biasing input data.

K6-186 *** ERROR *** THE NUMBER OF SETS OF BIASING AUXILIARY DATA EXCEEDS THE NUMBER THAT WAS WRITTEN WHEN THE BIASING DATA WAS READ. ____ WERE WRITTEN, BUT AN ATTEMPT WAS MADE TO READ ____.

This message from subroutine WAITIN is accompanied by a STOP 149. It is indicative of a code error, unless accompanied by error messages related to the biasing input data.

K6-187 ***** WARNING - INTERVALS IN THE ABOVE RANGE WERE NOT USED. THIS COULD LEAD TO IMPROPER BIASING. *****

This message from subroutine LODWTS is printed to remind the user that at least one of the specified intervals was not utilized in the problem, which can result in improper biasing. Biasing should not be used between fissile units. When biasing is used, it should be flat, or increasing, as distance from the fissile material increases, and flat, or decreasing, as a history moves toward fissile material. See Sect. F17.5.8 for additional assistance.

K6-188 *** ERROR *** HOLE NUMBER ____ REFERENCES UNDEFINED UNIT NUMBER ____.

This message is printed by subroutine HOLE and READGM if the unit number referenced by the hole is less than 1 or greater than the largest unit number in the geometry data. The message is printed by subroutine HOLE if the unit number referenced by the hole is larger than zero and not greater than the largest unit number in the geometry data, but is a unit number for which all data are missing otherwise it is printed by subroutine READGM. Specify a valid unit number (lhole - see GEOMETRY DESCRIPTION, Sect. F17.4.4) and resubmit the problem.

K6-190 ERROR IN PICTURE DATA - OPTION ____ IS NOT VALID FOR KEYWORD PIC=.

This message from subroutine RDPLOT indicates an incorrect option associated with the keyword PIC=. See Sect. F17.4.11. Acceptable options include MAT, MIX, MIXT, MEDI, BOX, BOXT, UNT, UNIT, IMP, BIAS, WTS, WGT, WGTS or WEIGH.

K6-191 ***** ERROR ***** START TYPE ____ IS INVALID FOR A PROBLEM THAT DOES NOT HAVE A GLOBAL ARRAY. ***** ERROR *****

This message from subroutine DATAIN occurs if the start type (NST= in the start data, Sect. F17.4.8) is 2, 3, 4, or 5. A global array is required in order to use the specified start type.

K6-192 MATRIX INFORMATION BY ARRAY WAS SPECIFIED AS YES IN THE PARAMETER DATA (MKA=), BUT IS NOT ALLOWED BECAUSE ARRAY DATA WERE NOT SPECIFIED.

This warning message from subroutine DATAIN is self-explanatory. The code redefines the problem, so matrix information will not be collected by array number.

K6-193 MATRIX INFORMATION BY HOLE WAS SPECIFIED AS YES IN THE PARAMETER DATA (MKH=), BUT IS NOT ALLOWED BECAUSE HOLE DATA WERE NOT SPECIFIED.

This warning message from subroutine DATAIN is self-explanatory. The code redefines the problem, so matrix information will not be collected by hole number.

K6-194 MATRIX INFORMATION BY UNIT LOCATION WAS SPECIFIED AS YES IN THE PARAMETER DATA (MKP=), BUT IS NOT ALLOWED BECAUSE A GLOBAL ARRAY WAS NOT SPECIFIED.

This warning message from subroutine DATAIN is self-explanatory. The code redefines the problem, so matrix information will not be collected by unit location.

K6-195 ***** ERROR ***** CHARACTER STRING EXCEEDS THE SPECIFIED LENGTH. CHECK FOR ENDING DELIMITER.

This error message is from subroutine RCHRS. It indicates that either the character string exceeds 132 characters or the ending delimiter was omitted for TTL= (plot title, Sect. F17.4.11) or for COM= (unit comment, Sect. F17.4.4, or array comment, Sect. F17.4.5). A STOP 153 is executed when this message is printed.

K6-196 A PROBLEM CANNOT BE RESTARTED WHEN RESTART DATA DO NOT EXIST FOR THE SPECIFIED GENERATION AND THE NEXT GENERATION FOR WHICH RESTART DATA ARE AVAILABLE IS LARGER THAN THE REQUESTED NUMBER OF GENERATIONS. EXECUTION IS TERMINATED.

This message from subroutine RDCALC indicates that a problem was to be restarted but the requested number of generations (GEN=, Sect. F17.4.3) was smaller than the beginning generation number (BEG=, Sect. F17.4.3). The beginning generation number for a restarted problem is the generation at which the calculation of k-effectives and associated information is resumed. Therefore, the number of generations to be run must be larger than the beginning generation number. Correct the data and resubmit the problem. A STOP 154 is executed when this message is printed.

K6-198 *** ERROR *** ARRAY ____ CONTAINS AN ERROR IN THE INPUT DATA.

This message from subroutine ARAYIN is printed as the result of an error in the FILL input data for the specified array. One or more messages from the library routine YREAD should immediately precede this message and indicate the nature of the error. Correct the data and resubmit the problem. Messages K6-32, K6-33, and/or K6-85 may also print as a result of this error.

K6-199 *** ERROR *** AN ARRAY WAS SPECIFIED IN THE GLOBAL UNIT, BUT ARRAY DATA WERE NOT ENTERED

This message from subroutine SORTA occurs if array data are not entered when the global unit geometry specifies an array. A STOP 156 is executed in conjunction with this message. Enter the appropriate array data and resubmit the problem.

K6-200 *** ERROR *** START TYPE 6 WAS SPECIFIED IN THE START DATA, BUT THE STARTING POINTS WERE NOT SPECIFIED.

This message from subroutine RDSTRT indicates that start type 6 was specified but the corresponding starting points were not included in the START data block. Enter the corresponding starting points or change the start type. See Sect. F17.4.8.

K6-201 *** WARNING *** NEUTRON ____ SPECIFIED A POSITION IN THE GLOBAL ARRAY. THE GLOBAL UNIT DID NOT CONTAIN AN ARRAY SO THE POSITION WAS IGNORED.

This warning message from subroutine START6 indicates that extraneous data were specified in the start type 6 data. Verify that the correct global unit is specified.

K6-202 *** ERROR *** ONLY START TYPES 0, 1, OR 6 ARE VALID FOR A PROBLEM WITHOUT AN ARRAY IN THE GLOBAL UNIT.

This message from subroutine START indicates that the specified start type is not valid for the problem. Choose an appropriate start type. A STOP 157 is executed when this message is printed.

K6-204 EXECUTION TERMINATED DUE TO ACHIEVING THE STANDARD DEVIATION SPECIFIED FOR THE PROBLEM.

This message from subroutine GUIDE states that the requested standard deviation has been achieved. If a lower standard deviation is desired decrease the requested standard deviation (SIG=, Sect. F17.4.3).

K6-206 *** ERROR *** THE UNIT SPECIFIED FOR STARTING IS NOT USED IN THE PROBLEM OR IS UNDEFINED.

This message from subroutine START indicates that the unit in which neutrons are to be started is undefined. Verify that the global unit or array is correctly specified. Check the start data for start types 4 and 5 (Sect. F17.4.8) to be sure NBX= is correctly specified. A STOP 158 is executed when this message is printed.

K6-207 *** ERROR *** THE STARTING ARRAY POSITION IS INVALID.

This message from subroutine START indicates that the array position NXS, NYS, or NZS is not valid for start types 3 or 6. NXS, NYS, and NZS must be larger than zero and no larger than NBXMAX, NBYMAX, and NBZMAX of the global array, respectively. Verify that the global unit or array is correctly specified. Correct the start data (Sect. F17.4.8) and resubmit the problem. A STOP 159 is executed when this message is printed.

K6-208 *** WARNING *** THE FRACTION OF NEUTRONS STARTED AS A SPIKE WAS LESS THAN ZERO. IT HAS BEEN RESET TO ZERO.

This message from subroutine START indicates that FCT= was incorrectly specified in the start data for start type 2. The resultant starting distribution is a cosine distribution throughout the volume of a cuboid defined by XSM, XSP, YSM, YSP, ZSM, and ZSP (see Sect. F17.4.8). If a "spike" was desired, set FCT= to a positive number between 0.0 and 1.0. If FCT=0.0 is specified, a cosine distribution without a "spike" is used as the starting distribution. If FCT=1.0 is specified, all the neutrons are started as a "spike" (i.e., they are started uniformly in the unit located at position NXS, NYS, NZS in the global array, as indicated in Sect. F17.4.8).

K6-209 *** WARNING *** THE FRACTION OF NEUTRONS STARTED AS A SPIKE WAS GREATER THAN ONE. IT HAS BEEN RESET TO ONE.

This message from subroutine START indicates that FCT= was incorrectly specified in the start type 2 data. The code reset FCT=1 so all of the neutrons are started as a "spike" (i.e., they are started uniformly in the unit located at NXS, NYS, NZS in the global array, as indicated in Sect. F17.4.8).

K6-210 *** ERROR *** THE UNIT SPECIFIED FOR STARTING IS NOT IN THE GLOBAL ARRAY.

This message from subroutine START indicates that the unit specified by NBX= does not occur in the global array. Verify that the global array is correctly specified and that the unit specified by NBX= is correct (see Sect. F17.4.8).

K6-211 *** ERROR *** THE NUMBER OF SETS OF BIAS FACTORS FROM RECORDS EXCEEDS THE NUMBER THAT WAS WRITTEN WHEN THE BIASING DATA WAS READ.
____ WERE WRITTEN BUT AN ATTEMPT WAS MADE TO READ ____.

This message from subroutine WAITIN is indicative of a code error. A STOP 161 is executed when this message is printed.

K6-212 *** ERROR *** THE BIASING DATA SPECIFIED IBGN= __ AND IEND= __. IBGN MUST BE LARGER THAN ZERO AND IEND MUST BE AT LEAST AS LARGE AS IBGN. THE PROBLEM WILL NOT BE RUN.

This message from subroutine RDBIAS indicates an error in the biasing data. The biasing correlation data are order dependent. The order of data entry is: ID=nn ibgn iend, where nn is an ID number from Table F17.4.5 and ibgn is the beginning BIAS ID and iend is the ending BIAS ID (see Sects. F17.4.7 and F17.5.8). In order to continue checking the input data, if ibgn is less than or equal to zero, it is set to 1. Similarly, if iend is less than ibgn, it is set to ibgn.

K6-213 *** ERROR *** INSUFFICIENT SPACE ALLOCATION. MASTER WAS NOT CALLED.

This error message is printed from subroutine KENOVI when KENO-VI is executed in the "stand-alone mode" and from subroutine O0O019 when executed as part of a CSAS analytical sequence. The message indicates that the job control language must be altered to provide more computer memory to be utilized by the problem. A STOP 162 is executed when this message is printed.

K6-214 *** ERROR *** THE BASE OF A TRIANGULAR FACE OF A WEDGE CANNOT BE ZERO.

This self-explanatory message is from subroutine WEDGE. The input data for the wedge following the keyword WEDGE are incorrect. See Sect. F17.4.4.

K6-215 *** ERROR *** THE Y COORDINATE OF A TRIANGULAR FACE OF A WEDGE CANNOT BE ZERO.

This self-explanatory message is from subroutine WEDGE. The input data for the wedge following the keyword WEDGE are incorrect. See Sect. F17.4.4.

K6-216 ***** ERROR ***** XNB= __ IS THE MAXIMUM VALUE THAT CAN BE SPECIFIED IN THE PARAMETER DATA. XNB MUST BE SMALL ENOUGH TO FIT IN THE EXTRA ARRAY OF COMMON NUTRON.

This message from subroutine FLDATA indicates that the value of XNB was set too large. Decrease the size of XNB and retry the problem.

K6-217 *** ERROR *** DIFFERENTIAL ALBEDOS CANNOT BE USED IN AN ADJOINT PROBLEM.

This self-explanatory message is from subroutine FLDATA. Describe reflector material in the mixing table and the geometry instead of using differential albedos or run the problem in the forward mode.

K6-218 ***** ERROR ***** TO START IN A GLOBAL QUADRATIC GEOMETRY, IGEO = __ VALUES FOR XSM, XSP, YSM, YSP, ZSM, AND ZSP MUST BE ENTERED AS START DATA.

This self-explanatory error message is from subroutine STRTSU. A GLOBAL QUADRATIC GEOMETRY implies an infinite media. The boundary of the starting points must be entered. See Sect. F17.4.8.

K6-219 ***ERROR***THE START DATA SPECIFIED __ STARTING POINTS CHOSEN FROM A COSINE DISTRIBUTION BUT NONE WERE FOUND.

This message from subroutine START is printed if start type 2 was specified and the code was unable to start any neutrons in the cuboid defined by XSM, XSP, YSM, YSP, ZSM, ZSP. Verify that fissile material exists within that cuboid. If it doesn't, respecify the starting cuboid to contain fissile material or choose a different start type. If message K6-105 states that only 0 independent starting points were generated, it indicates that the code was unable to start any neutrons in the spike specified by start type 2. Verify that the unit specified for the spike contains fissile material. If only a very small fraction of the volume of this unit is fissile, it may be necessary to input a larger value for the KENO-VI parameter "TMAX=" or choose a different start type. The problem will not be run if message K6-219 is printed.

K6-220 ERROR IN PICTURE DATA.

IF THE COORDINATE OF THE LOWER RIGHT-HAND CORNER IS ENTERED, ONE OF THE PLOT PARAMETERS DLX, DLD, NAX, OR NDN MUST BE ENTERED. CURRENT VALUES ARE LISTED BELOW. TITLE:

(Problem title is listed here)

	<u>UPPER-LEFT COORDINATES</u>	<u>UPPER-RIGHT COORDINATES</u>
X	xu	xl
Y	yu	yl
Z	zu	zl

	<u>U AXIS (DOWN)</u>	<u>V AXIS (ACROSS)</u>
X	ud	ua
Y	vd	va
Z	wd	wa

NDN= 0 NAX= 0 DLD= 0.0000E+00 DLX= 0.0000E+00

This message from subroutine RDPlot indicates that the coordinates of the lower-right-hand corner of the plot were specified in the input data without specifying one of the following plot parameters: (1) NDN, the number of characters down the page, (2) NAX, the number of characters across the page, (3) DLD, the vertical spacing between points, or DLX, the horizontal spacing between points. The problem will not be run. To correct the error, specify NDN, NAX, DLD, or DLX in the plot data and resubmit the problem. See Sect. F17.4.11 and F17.5.9 for assistance.

K6-221 ***** ERROR ***** THE LENGTH OF THE EDGE ALONG THE BASE OF THE X-AXIS FOR A RHOMBOID MUST BE GREATER THAN 0.0. CHECK GEOMETRY WORD ____.

This self-explanatory message is from subroutine RHOMB. Check the data following the keyword RHOMB. See Sect. F17.4.4.

K6-222 ***** ERROR ***** THE ANGLE BETWEEN THE Y-AXIS AND THE Y-EDGE OF THE BASE MUST BE BETWEEN 0 AND 90 DEGREES. CHECK GEOMETRY WORD ____.

This self-explanatory message is from subroutine RHOMB. Check the data following the keyword RHOMB. See Sect. F17.4.4.

K6-223 ***** ERROR ***** THE NUMBER OF SCATTERING ANGLES, SCT, ENTERED IN THE MIXING TABLE MUST NOT EXCEED 13. SCT = ____ WAS ENTERED.

This self-explanatory message is from subroutine MIXIT. Adjust the data following the keyword SCT= in the parameter data. See Sect. F17.4.3.

K6-224 *** ERROR *** THE HEIGHT OF A WEDGE CANNOT BE ZERO.

This self-explanatory message is from subroutine WEDGE. The input data for the wedge following the keyword WEDGE are incorrect. See Sect. F17.4.4.

K6-225 ***** ERROR ***** TO START IN A GLOBAL PLANE GEOMETRY, IGEO = __ VALUES FOR XSM, XSP, YSM, YSP, ZSM, AND ZSP MUST BE ENTERED AS START DATA.

This self-explanatory error message is from subroutine STRTSU. A GLOBAL PLANE GEOMETRY implies an infinite media. The boundary of the starting points must be entered. See Sect. F17.4.8.

K6-226 ***** ERROR ***** XDIST, YDIST, AND ZDIST SPECIFIED FOR A PPIPED MUST BE GREATER THAN 0.0.

This self-explanatory message is from subroutine PPIPED. Check the data following the keyword PPIPED. See Sect. F17.4.4.

K6-227 ***** ERROR ***** PSI, THETA, AND PHI SPECIFIED FOR A PARALLELEPIPED MUST BE GREATER THAN OR EQUAL TO 0.0 AND LESS THAN 90.0.

This self-explanatory message is from subroutine PPIPED. Check the data following the keyword PPIPED. See Sect. F17.4.4.

K6-228 ***** ERROR ***** THE CALCULATION WAS TERMINATED BECAUSE THE SAME SPACE IS DEFINED IN MULTIPLE REGIONS

This message from subroutine GUIDE is printed only if message K6-89 is printed 10 or more times for a given generation. This indicates that the problem defines the same space in multiple regions. If changes have been made in the code, they should be carefully scrutinized. It is probably caused by not correctly specifying the vector definition arrays in the media records of a unit. It can be caused by not correctly specifying regions that share a common boundary so the boundary between regions is contained in only one region. See Sect. F17.4.4 for more information concerning vector definition arrays on MEDIA records.

K6-229 ***** ERROR ***** IN UNIT __ , __ GEOMETRY RECORDS WERE SPECIFIED BUT __ WAS SPECIFIED IN A SECTOR DEFINITION ARRAY.

This message from subroutine KENOG is printed if a geometry record, larger than the total number of geometry specified in a unit, is referenced in the sector definition array of a media record for that unit.

K6-230 ***** ERROR ***** THE CALCULATION WAS TERMINATED BECAUSE A GEOMETRY WORD IN UNIT __ PRODUCES AN IMAGINARY BOUNDARY.

This message from subroutine PNTCHK should only be produced by the geometry word QUADRATIC when used as part of an array boundary. The boundary produces imaginary results. Check the coefficients of the geometry word.

K6-231 ***** ERROR ***** THE CALCULATION WAS TERMINATED BECAUSE ARRAY __ IS NOT PROPERLY POSITIONED IN REGION __ OF UNIT __.
THE ARRAY BOUNDARY IS OUTSIDE THE __ SIDE BY __.

This message from subroutine PNTCHK is printed only if an array is placed in a region such that there is space in the region not occupied by the array. Reposition your array.

K6-232 ***** ERROR ***** IN UNIT _____ MORE THAN ONE GEOMETRY RECORD IS SPECIFIED AS NUMBER _____.

This error message from subroutine READGM means more than one geometry record in the specified unit was given the same label.

K6-233 ***** ERROR ***** A VECTOR DEFINITION ARRAY IN UNIT _____ REFERENCES GEOMETRY RECORD _____ WHICH HAS NOT BEEN SPECIFIED.

This error message from subroutine KLANGA means a geometry record was specified in a vector definition array that has not been defined in the specified unit.

K6-234 ***** ERROR ***** IN UNIT _____ THE USE OF GEOMETRY LABEL _____ IN THE BOUNDARY DEFINITION VECTOR CONFLICTS WITH VECTOR DEFINITION GEOMETRY LABEL _____.

This error message from subroutine KLANGA means a geometry label used in the unit boundary definition vector has the opposite sign of the same geometry label used in a media, array, or hole definition vector in the same unit. The geometry labels used in the unit boundary definition vector do not need to be repeated in the other definition vectors in the unit. If they are repeated they need to have the same sign as those used in the boundary definition vector.

K6-235 ***** ERROR ***** BOUNDARY SECTOR DATA WAS NOT BOUND FOR UNIT _____.

This error message from subroutine BNDRY means a boundary record is present in the specified unit but does not contain sector data.

K6-236 ***** ERROR ***** THE UNIT _____ BOUNDARY RECORD CONTAINS MORE THAN ONE POSITIVE GEOMETRY RECORD LABEL.

This error message from subroutine JOMCHK is printed when the boundary record of a unit used in an array contains more than one positive geometry record label. When a unit is used in an array, the boundary record must contain only one positive geometry record label that is consistent with the type of array it is used in.

K6-237 ***** ERROR ***** THE GLOBAL UNIT BOUNDARY IS NOT DEFINED BY A SINGLE CUBOID BUT CONTAINS MULTIPLE ALBEDOS.

This error message from subroutine JOMCHK indicates more than one albedo type was specified for the problem but a single cuboid was not used to define the global unit boundary. Multiple albedo types are only allowed if a single cuboid is used to define the global unit boundary.

K6-238 ***** ERROR ***** THE GLOBAL UNIT BOUNDARY USES MULTIPLE GEOMETRY WORDS BUT NOT THE VOID ALBEDO.

This error message from subroutine JOMCHK indicates an albedo other than void was specified with a global unit boundary definition vector containing more than one geometry record label. Multiple geometry

record labels are allowed in the global unit boundary definition vector only for the void albedo on all surfaces. Void is the default boundary condition.

K6-239 ***** ERROR ***** ALBEDO OTHER THAN VOID WHITE OR REFLECTED USED WITH NONPAIRED PLANE BOUNDARY.

This error message from subroutine JOMCHK indicates an albedo other than void, white, or mirror is specified but the global unit boundary definition vector is specified by a nonpaired plane geometry record. Only void, mirror, or white albedo conditions may be used when the global boundary uses nonpaired planes.

F17.7.2 STOP CODES

The STOP codes that are encountered in KENO VI are listed in tabular form, indicating the subroutine where they occur and the associated error message. A STOP is executed whenever a fatal error is recognized. Look up the associated message number to determine the appropriate corrective measures. A traceback may be generated whenever subroutine STOP is called to print a message. If no traceback is indicated in the STOP CODE table, a stop is executed as soon as the associated message is printed, as shown in the following:

<u>STOP NO.</u>	<u>SUBROUTINE</u>	<u>TRACEBACK</u>	<u>ASSOCIATED MESSAGE</u>
20			See Sect. F17.7.3
100	ARRAYIN	Yes	K6-25
101	ARRAYIN	No	K6-31
105	WRTALB	No	K6-71
106	ICEMIX	No	K6-68
107	INDX	No	K6-124
108	INITAL	No	K6-2
109	INITAL	No	K6-2
110	MAKANG	Yes	K6-57
111	MIXCRS	Yes	K6-52
112	MIXER	Yes	K6-53
113	MIXER	Yes	K6-54
114	MIXIT	Yes	K6-15
115	NORMID	No	K6-56
116	NSUPG	Yes	K6-79
117	NSUPG	No	K6-81
118	PARAM	No	K6-7 or K6-8
120	RDALB	No	K6-49
121	RDCALC	No	K6-116 or K6-146 or K6-147 or K6-177 or K6-178
122	RDICE	No	K6-50
123	RDRST	No	K6-48
124	RDTAPE	No	K6-69
125	READGM	No	K6-20
126	SAVST6	Yes	K6-140
128	START	Yes	K6-101
129	BOOK5	No	K6-100
130	BOOK1	No	K6-117 or K6-128 or K6-228
131	VOLFIS	No	K6-110
132	WRTICE	No	K6-72
133	WRTRST	No	K6-70
135	DATAIN	Yes	K6-142
136	DATAIN	Yes	K6-143
137	ARRAYIN	No	K6-151
138	SORTA	Yes	K6-153
139	SORTA	No	K6-154
140	LODARA	No	K6-155
142	SORTA	No	K6-159
143	HOLE	No	K6-160
147	BOOK5	Yes	K6-182
148	WAITIN	No	K6-185
149	WAITIN	No	K6-186

<u>STOP NO.</u>	<u>SUBROUTINE</u>	<u>TRACEBACK</u>	<u>ASSOCIATED MESSAGE</u>
150	WATES	Yes	K6-22
151	RDBIAS	No	K6-184
152	DATAIN	No	K6-46
153	RCHRS	Yes	K6-195
154	RDCALC	No	K6-196
155	GEOMIN	Yes	K6-25
156	SORTA	Yes	K6-199
157	START	No	K6-202
158	START	No	K6-206
159	START	No	K6-207
160	START	No	K6-210
161	WAITIN	No	K6-211
162	KENO-VI, 000019	Yes	K6-213

F17.7.3 MESSAGES ASSOCIATED WITH STOP 20 IN KENO-VI

The error messages that are associated with a STOP 20 in KENO-VI are listed below in numerical order. Look up the appropriate message number to determine corrective measures.

LMP001 DA ERROR – INVALID UNIT NUMBER.
THE LOGICAL UNIT NUMBER IS ____.

This message from the subroutine library direct-access routines indicates that an invalid unit number was specified as a direct-access device. In KENO-VI, this message is indicative of a code error.

LMP002 DA ERROR – FORTRAN USING THIS UNIT.
THE LOGICAL UNIT NUMBER IS ____.

This message from the subroutine library direct-access routines indicates that the specified unit number is open as a sequential dataset rather than a direct-access dataset. In KENO-VI, this error may be caused by entering a direct-access unit number for LIB= or XSC=.

LMP003 DA ERROR – DCB NOT OPEN.
THE LOGICAL UNIT NUMBER IS ____.

This message from the subroutine library direct-access routines indicates that the program attempted to read or write on a direct-access device, but the data control block was not open. In KENO-VI this message is indicative of a code error.

LMP004 DA ERROR – UNABLE TO OPEN DCB.
THE LOGICAL UNIT NUMBER IS ____.

This message from the subroutine library direct-access routines indicates that the program is unable to open the data control block for the direct-access device. This message indicates that the job control language did not include proper specification of the above named unit.

LMP005 DA ERROR – RELATIVE BLOCK NOT IN DATA SET.
RELATIVE BLOCK NUMBER IS ____.

This message from the subroutine library direct-access routines indicates that the number of direct-access blocks is too small for the problem. Increase the number of direct access blocks in the KENO-VI parameter data by entering the parameter NB8=nnn, where nnn is larger. For example, if the relative block number is 201, try increasing the number of direct-access blocks to 300 or more.

LMP006 DA ERROR – INVALID BLOCK LENGTH.
THE BLOCK LENGTH IS ____.

This message from the subroutine library direct-access routines indicates that the length of the direct-access blocks is invalid. A valid block length must be positive. This message is indicative of a code error.

LMP007 DA ERROR – DCB ALREADY OPEN.
THE LOGICAL UNIT NUMBER IS ____.

This message from the subroutine library direct-access routines indicates that the data control block for the above named unit was previously opened and not closed.

LMP008 DA ERROR – PERMANENT I/O ERROR.

This message from the subroutine library direct-access routines indicates that a permanent IO error has occurred.

F17.A ALPHABETICAL INDEX OF SUBROUTINES

This section provides a convenient alphabetical index of the subroutines used in KENO-VI, the subroutines that call it, and the subroutines it calls.

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
ALBEDO	TRACK	DAZIRN FLTRN
ALBRD	DIFALB	ALBUSE
ALBUSE	ALBRD	INQUIR IO RITE
ALOCAT	KENOV1 000019	
ANGLES	PRANG	FIND Q
ARALBA	JOMITY	PRTLBA
ARASIZ	CORSIZ	LSCAN
ARRAYIN	DATAIN	AREAD BOX CLEAR IREAD RCHRS RDBOX STOP YREAD
AREAD	ARRAYIN ARRAY CHORD DATAIN KENOG MIXIT ORIGIN PARAM PLANE QUAD RCHRS RDBIAS RDPLT RDREF RDSTRT ROTATE	
ARRAY	KENOG	AREAD DREAD IREAD LCOMPR LREAD
ARSCAN	SORTA	
BADMMOM	PRANG	
BANKER	GUIDE	MOVE
BIRITE	PARAM	
BNDRY	KENOG	IREAD LREAD

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
BOOK1	MASTER	FITFLX FREAK JSTIME KEDIT
BOOK2	MASTER	DATAIN IOSDUN OPENDA
BOOK3	MASTER	CORRE ICEMIX IOSDUN MIXER NSUPG POINT WRTRST
BOOK4	MASTER	JOMITY LODWT5
BOOK5	MASTER	CLEAR GUIDE IOSDUN JSTIME PRTPLT STOP
BOX	ARAYIN	
BOXC	LOADIT	
CHKSTR	GUIDE	MOVE TRKWRT
CHOOSE	START4 START5	FLTRN
CHORD	KENOG	AREAD CLEAR DREAD LCOMPR
CLEAR	ARAYIN BOOK5 CHORD CONE CORRE CROSS CUBOID CYLNDR DATAIN DODECA ECYL ELLIPS FILLSG GEOMIN GUIDE HOLE HOPPER HUNTER HXPRSM KENOG KLANGA LODARA	

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
CLEAR (cont.)	LODWTS	
	MAKANG	
	MATK	
	MESH	
	MIXCRS	
	NNITL	
	NSTART	
	PARAM	
	PLANE	
	PPIPED	
	PRTPLT	
	QUAD	
	RDALB	
	RDICE	
	RDPLT	
	RDSTRT	
	RDTAPE	
	RELATE	
	RGUSED	
	RHOMB	
	RTARA	
	SAVST6	
	SORTA	
	SPHERE	
	START	
	TRACK	
	UNTCRS	
	VOLUME	
	WEDGE	
CLOSDA	KENOV	
	MIXER	
	000019	
CLRNIT	RDPLT	
CMPRS	MIXMIX	
CONE	KENOG	CLEAR DREAD
CORRE	BOOK3	CLEAR INQUIR RATIO REED RITE
CORSIZ	JOMITY	ARASIZ LOCBOX
CREAD	RDREF	
CROSS	TRACK	CLEAR
CRSPRD	PPIPED RHOMB	
CUBOID	KENOG	CLEAR DREAD
CYLNR	KENOG	CLEAR DREAD

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
DATAIN	BOOK2	ARAYIN AREAD CLEAR EXTRA FLDATA GEOMIN IDX1D IOWRT MIXIT RDBIAS RDPLLOT RDREF RDRST RDSTRT RT RTARA SAVST6 STOP WRTPLT
DAZIRN	ALBIN STRTSU TRACK	
DGTISO	SORTBK START STRTSU TRACK	
DIFALB	FLDATA	ALBRD
DITTO	KENOG	
DODECA	KENOG	CLEAR DREAD
DOTPRD	TRACK	
DREAD	ARRAY CHORD CONE CUBOID CYLNDR DODECA ECYL ELLIPS HOPPER HXPRSM ORIGIN PLANE PPIPED QUAD RHOMB ROTATE SPHERE WEDGE	
ECYL	KENOG	CLEAR DREAD
EDITOR	KEDIT	

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
ELLIPS	KENOG	CLEAR DREAD
EXPRN	TRACK	
EXTRA	DATAIN	
FILLSG	NSUPG	CLEAR FIL2D INQUIR RD REED RITE RT SGALB SGWT
FIL2D	FILLSG	RD
FIND	ANGLES GETMUS	Q
FINDBX	LOCATE TRACK	
FISFLX	GUIDE	JSTIME LOOPER MATK STATIS
FITFLX	BOOK1	IOLEFT PRTFLX RD
FLDATA	DATAIN	DIFALB REED RGUSED RITE SORTA SORTR WATES
FLTRN	ALBIN CHOOSE NSTART START START0 START1 START5 START6 STRTSU TRACK	
FREAD	MIXIT PARAM RDBIAS RDPLT RDSTRT	
FREAK	BOOK1	
FREECR	NSUPG	
FSABED	KEDIT	

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
GEOMIN	DATAIN	CLEAR KENOG READGM STOP
GETMUS	PRANG	FIND Q
GETPTR	RCHRS	
GOCURS	VOLUME	HUNTER
GTVOLS	VOLUME	
GUIDE	BOOK5	BANKER CHKSTR CLEAR FISFLX INDX INQUIR IOLEFT JSTIME NSTART PULL RD RDCALC REED RESET RITE START TRACK WRTCAL
HOLE	LODARA SORTA	CLEAR STOP
HOLEIN	KENOG	IREAD LREAD
HOPPER	KENOG	CLEAR DREAD
HROTRN	LOCATE TRACK	MOVE
HUNTER	GOCURS VOLUME	CLEAR MOVE
HXPRSM	KENOG	CLEAR DREAD
ICEMIX	BOOK3	RDTAPE
ICOMPA	START6	
IDX1D	DATAIN	IREAD
INDX	GUIDE	
INITAL	KENOV1 000019	IOLEFT JSTIME MESSAGE OPNFIL PARAM

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
INITAL (cont.)		PARTBL SCANON
INQUIR	ALBUSE CORRE FILLSG GUIDE MIXIT NNITL NSUPG PRANG PRTPLT RDALB RDARA RDICE RDRST RDTAPE RDWTS RT RTARA SAVST6 SGALB WAITIN WATES WRTALB WRTICE WRTPLT WRTRST	
IO	ALBUSE MAKTAP MIXMIX RDALB RDARA RDBIAS RDCALC RDICE RDPLT RDRST RDSTRT RDTAPE RDWTS SAVST6 WAITIN WATES WRTALB WRTARA WRTCAL WRTICE WRTPLT WRTRST WRTWTS	
IOLEFT	FITFLX GUIDE INITAL IOSDUN	
IONUMS	000019	

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
IOSDUN	BOOK2 BOOK3 BOOK5 JOMITY	IOLEFT
-----	-----	-----
IOWRT	DATAIN	
-----	-----	-----
IREAD	ARRAYIN ARRAY HOLEIN IDX1D KENOG MEDIA MIXIT PARAM RDBIAS RDBOX RDPLLOT RDSTRT	
-----	-----	-----
IXALB	LIMLN NSUPG	
-----	-----	-----
JLL2	MIXER	
-----	-----	-----
JOMITY	BOOK4	ARALBA CORSIZ IOSDUN LOADIT PRTJOM VOLUME
-----	-----	-----
JSTIME	BOOK1 BOOK5 FISFLX GUIDE INITAL KEDIT MATRIX PRTPLT START	
-----	-----	-----
EDIT	BOOK1	EDITOR JSTIME LOOPER MATRIX PLTKEF RNDOUT
-----	-----	-----
KENOG	GEOMIN	AREAD ARRAY CHORD CLEAR CONE CUBOID CYLNDR DITTO DODECA ECYL ELLIPS HOLEIN HOPPER HXPRSM IREAD

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
KENOG (cont.)		LCOMPR MEDIA ORIGIN PLANE PIPED QUAD RCHRS RHOMB ROTATE
		ROTRNS SPHERE WEDGE
KENOV1		ALOCAT CLOSDA INITAL MASTER OPNFIL STOP
KLANGA	READGM	CLEAR PRTSEC
LABL	MATRIX	
LCOMPR	ARRAY CHORD KENOG ORIGIN PLANE QUAD ROTATE	
LDWRT	TRACK	
LEGEND	PRANG	
LIBEQL	PARAM	
LIMLN	NSUPG	IXALB
LOADIT	JOMITY	BOXC LODALB LODARA PRTARA REED
LOCATE	MESH START	FINDBX HROTRN MOVE POSIT
LOCBOX	CORSIZ LODARA SORTA START TKARRY TRACK	
LODALB	LOADIT	REED

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
LODARA	LOADIT	CLEAR HOLE LOCBOX REED
LODRGC	RGUSED	
LODWTS	BOOK4	CLEAR PRTWTS RD REED
LOOPER	FISFLX KEDIT	REED RITE
LREAD	ARRAY HOLEIN MEDIA MIXIT	
LSCAN	ARASIZ RGUSED START	
MAKANG	MIXER	CLEAR PRANG REED STOP
MAKTAP	MIXER	IO REED SCOOT
MASTER	KENOV1 000019	BOOK1 BOOK2 BOOK3 BOOK4 BOOK5
MATK	FISFLX MATRIX	CLEAR
MATRIX	KEDIT	JSTIME LABL MATK
MEDIA	KENOG	IREAD LREAD
MESSAGE	INITAL	
MESH	PRINT	CLEAR LOCATE
MGCHRD	MIX2D	
MIXCRS	MIXER	CLEAR STOP
MIXER	BOOK3	CLOSDA JLL2 MAKANG MAKTAP MIXCRS MIXMIX

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
MIXER (cont.)		OPENDA REED STOP XLNTHS
MIXIT	DATAIN	AREAD FREAD INQUIR IREAD LREAD RDMIXT RITE STOP
MIXMIX	MIXER	CMPRS IO MIX1D MIX2D MIX2M NNITL NORM1D NORM2D PRTMIX REED RITE SUMSCT
MIX1D	MIXMIX	
MIX2D	MIXMIX	MGCHRD
MIX2M	MIXMIX	
MOVE	BANKER CHKSTR HROTRN HUNTER LOCATE NSTART RESET SAVST6 SORTBK START START6 TKARRY TRACK VOLUME WATES	
NNITL	MIXMIX	CLEAR INQUIR RITE
NORM1D	MIXMIX	
NORM2D	MIXMIX	
NORMAL	TRACK	
NSTART	GUIDE	CLEAR FLTRN MOVE SORTBK

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
NSUPG	BOOK3	FILLSG FREECR INQUIR IXALB LIMLN OPENDA POINT PRATBL PRTXS REED RITE STOP
OPENDA	BOOK2 MIXER NSUPG	
OPNFIL	INITAL KENOVI 000019 PARAM RDSTRT	
ORIGIN	KENOG	AREAD DREAD LCOMPR
000019		ALOCAT CLOSDA INITAL IONUMS MASTER OPNFIL SETBIN STOP
PARAM	INITAL	AREAD BIRITE CLEAR FREAD IREAD LIBEQL OPNFIL RNDIN RNDOUT TIMFAC ZREAD
PARTBL	INITAL	RNDOUT
PERIOD	TRACK	
PLANE	KENOG	AREAD CLEAR DREAD LCOMPR
PLTKEF	KEDIT	
POINT	NSUPG	
POSIT	LOCATE	STOP

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
PIPED	KENOG	CLEAR CRSPRD DREAD
PRANG	MAKANG	ANGLES BADMOM GETMUS INQUIR LEGEND RD RITE
PRATBL	NSUPG	RTADJ
PRINT	PRTPLT	MESH
PRTARA	LOADIT	
PRTFLX	FITFLX	
PRTJOM	JOMITY	
PRTLBA	ARALBA	
PRTMIX	MIXMIX	
PRTPLT	BOOK5	CLEAR INQUIR JSTIME PRINT REED RELATE UNTCRS
PRTPOS	TRACK	
PRTSEC	KLANGA	
PRTWTS	LODWTS	
PRTXS	NSUPG	PRT1D PRT1DS PRT2DS REED
PRT1D	PRTXS	
PRT1DS	PRTXS	
PRT2DS	PRTXS	
PULL	GUIDE	
Q	ANGLES FIND GETMUS	
QUAD	KENOG	AREAD CLEAR DREAD LCOMPR VEXCAV
RATIO	CORRE	

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
RCHRS	ARAYIN KENOG RDPLT	AREAD GETPTR RCRDLN RSTPTR STOP
RCOLOR	RDPLT	AREAD IREAD
RCRDLN	RCHRS	
RD	FILLSG FIL2D FITFLX GUIDE LODWT PRANG SGALB SGWT	
RDALB	RDRST	CLEAR INQUIR IO RITE
RDARA	RDRST	INQUIR IO RITE
RDBIAS	DATAIN	AREAD FREAD IO IREAD WAITIN
RDBOX	ARAYIN	IREAD
RDCALC	GUIDE	IO RDGRP RITE RNDIN SHUFL STOP
RDGRP	RDCALC	
RDICE	RDRST	CLEAR INQUIR IO RITE
RDMIXT	MIXIT	
RDPLT	DATAIN	AREAD CLEAR FREAD IO IREAD RCHRS
RDREF	DATAIN	AREAD CREAD

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
RDRST	DATAIN	INQUIR IO RDALB RDARA RDICE RDWTS RITE
RDSTRT	DATAIN	AREAD CLEAR FREAD IO IREAD OPNFIL
RDTAPE	ICEMIX	CLEAR INQUIR IO RITE XSEC1D XTENDA
RDWTS	RDRST	INQUIR IO RITE
READGM	GEOMIN	KLANGA ROTHOL
REED	CORRE FILLSG FLDATA GUIDE LOADIT LODALB LODARA LODWTS LOOPER MAKANG MAKTAP MIXER MIXMIX NSUPG PRTPLT PRTXS SGALB SORTA START6 WATES WRTALB WRTARA WRTICAL WRTICE WTRST WRTWTS	
RELATE	PRTPLT	CLEAR
RESET	GUIDE	MOVE
RGUSED	FLDATA	CLEAR LODRGC LSCAN

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
RHOMB	KENOG	CLEAR CRSPRD DREAD
RITE	ALBUSE CORRE FILLSG FLDATA GUIDE LOOPER MIXIT MIXMIX NNITL NSUPG PRANG RDALB RDARA RDCALC RDICE RDRST RDTAPE RDWTS RT RTARA SAVST6 WAITIN WATES WRTPLT	
RNDIN	PARAM RDCALC	
RNDOUT	KEDIT PARAM PARTBL TRKWRT WRTCAL WTRST	
ROTATE	KENOG	AREAD DREAD LCOMPR
ROTHOL	READGM	
ROTRNS	KENOG	
RSTPTR	RCHRS	
RT	DATAIN FILLSG	INQUIR RITE
RTADJ	PRATBL	
RTARA	DATAIN	CLEAR INQUIR RITE
SAVST6	DATAIN	CLEAR INQUIR IO MOVE RITE STOP

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
SCANON	INITAL	
SCOOT	MAKTAP	
SETBIN	000019	
SFLRA	TRACK	
SGALB	FILLSG	INQUIR RD REED
SGWT	FILLSG	RD
SHUFL	RDCALC	
SORTA	FLDATA	ARSCAN CLEAR HOLE LOCBOX REED STOP
SORTBK	NSTART	DGTISO MOVE
SORTR	FLDATA	
SPHERE	KENOG	CLEAR DREAD
START	GUIDE	CLEAR DGTISO FLTRN JSTIME LOCATE LOCBOX LSCAN MOVE START0 START1 START2 START3 START4 START5 START6 STOP STRTSU VOLFFIS
START0	START	FLTRN
START1	START START2	FLTRN
START2	START	START1 START5
START3	START	
START4	START	CHOOSE
START5	START START2	CHOOSE FLTRN

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
START6	START	FLTRN ICOMPA MOVE REED
STATIS	FISFLX	
STOP	ARRAYIN BOOK5 DATAIN GEOMIN HOLE KENOVI MAKANG MIXCRS MIXER MIXIT NSUPG 000019 POSIT RCHRS RDCALC SAVST6 SORTA START WATES	
STRTSU	START	DAZIRN DGTISO FLTRN
SUMSCT	MIXMIX	
TIMFAC	PARAM	
TKARRY	TRACK	LOCBOX MOVE
TRACK	GUIDE	ALBEDO ALBIN CLEAR CROSS DAZIRN DGTISO EXPRN FINDBX FLTRN HROTRN LDWRT LOCBOX MOVE PRTPOS SFLRA TKARRY TRKWRT
TRKWRT	TRACKR	RNDOUT
UNTCRS	PRTPLT	CLEAR
VEXCAV	QUAD	
VOLFIS	START	

SUBROUTINE NAME	CALLING SUBROUTINE	CALLED SUBROUTINE
VOLUME	JOMITY	CLEAR GOCURS GTVOLS HUNTER MOVE
WAITIN	RDBIAS	INQUIR IO RITE
WATES	FLDATA	INQUIR IO MOVE REED RITE STOP
WEDGE	KENOG	CLEAR DREAD
WRTALB	WRTRST	INQUIR IO REED
WRTARA	WRTRST	IO REED
WRTCAL	GUIDE	IO REED RNDOUT WRTGRP
WRTGRP	WRTCAL	
WRTICE	WRTRST	INQUIR IO REED
WRTPLT	DATAIN	INQUIR IO RITE
WRTRST	BOOK3	INQUIR IO REED RNDOUT WRTALB WRTARA WRTICE WRTWTS
WRTWTS	WRTRST	IO REED
XLNTHS	MIXER	
XSEC1D	RDTAPE	
XTENDA	RDTAPE	
YREAD	ARAYIN	
ZREAD	PARAM	

F17.B ALPHABETICAL INDEX OF COMMONS

This section lists the labeled common blocks used in KENO-VI and an alphabetical listing of the subroutines that reference them.

COMMON NAME	SUBROUTINE	COMMON NAME	SUBROUTINE
ALBDAT	ALBEDO	ANGLE	ANGLES
	ALBRD		BADMOM
	ALBUSE		FIND
	BOOK3		GETMUS
	CORRE		LEGEND
	DATAIN		PRANG
	DIFALB		Q
	FILLSG	BLKLNC	BOOK2
	FLDATA		FITFLX
	GUIDE		GUIDE
	KEDIT		NSUPG
	LIMLN		PARAM
	LOADIT		PRATBL
	NSUPG		RDTAPE
	PARAM	BOUNDY	CORSIZ
	POINT		TRACK
	PRATBL		
	RDALB	DIMEN	ARASIZ
	RDREF		ARRAYN
	RDRST		BOOK1
	SGALB		BOOK2
	TRACK		BOOK3
	WRTALB		BOOK4
	WRTRST		BOOK5
ALBNAM	ALBEDO		BOX
	ALBRD		BOXC
	ALBUSE		CORRE
	BOOK3		CORSIZ
	CORRE		CROSS
	DATAIN		DATAIN
	DIFALB		EDITOR
	FILLSG		FILLSG
	FLDATA		FIL2D
	GUIDE		FISFLX
	KEDIT		FITFLX
	LIMLN		FLDATA
	LOADIT		GEOMIN
	NSUPG		GUIDE
	PARAM		HROTRN
	POINT		ICEMIX
	PRATBL		INITAL
	RDALB		JOMITY
	RDREF		KEDIT
	RDRST		KENOG
	SGALB		LIMLN
	TRACK		LOCATE
	WRTALB		LOCBOX
	WRTRST		

COMMON NAME	SUBROUTINE	COMMON NAME	SUBROUTINE
DIMEN (continued)	LODARA LOOPER MATRIX MESH MIXER MIXIT NSTART NSUPG PARAM PARTBL POINT PRATBL PRINT PRTJOM PRTPLT RDBIAS RDBOX RDCALC RDGRP RDICE RDRST RDSTRT RDTAPE READGM RESET RGUSED RTARA SORTA SORTR START STATIS TKARRY TRACK VOLFIS VOLUME WRTCAL WRTGRP WRTICE WRTRST XSEC1D	DRTACS (continued)	LODWTS LOADIT LODARA MIXER MIXIT NSUPG PRANG PRTPLT RDALB RDARA RDICE RDRST RDTAPE RDWTS RT RTARA SAVST6 SGALB SGWT SORTA START6 WAITIN WATES WRTALB WRTICE WRTPLT WRTRST WRTWTS
		ERRFLG	ARAYIN INTAL PRTLBA
		FINAL	BOOK1 BOOK2 BOOK5 FISFLX GUIDE INTAL KEDIT MATRIX PRTPLT START STATIS TKARRY TRACK WRTCAL
DRTACS	ALBUSE BOOK2 BOOK3 CORRE DATAIN FILLSG FIL2D FLDATA GUIDE INTAL		

COMMON NAME	SUBROUTINE	COMMON NAME	SUBROUTINE
LIFETM	BOOK1 EDITOR FISFLX GUIDE KEDIT RDCALC	LOGIC (continued)	RDREF READGM RESET RDRST RDTAPE RTARA SORTA SORTR START STATIS TKARRY TRACK TRKWRT VOLFIS VOLUME WATES WRTCAL WRTGRP WRTRST
LOGIC	BOOK1 BOOK2 BOOK3 BOOK4 BOOK5 ALBRD ARASIZ ARAYIN CHKSTR CORRE CORSIZ DATAIN EDITOR FILLSG FIL2D FISFLX FITFLX FLDATA GUIDE ICEMIX IDX1D INITAL JOMITY KEDIT KENOG LOCATE LOOPER MATRIX MESH MIXER NSUPG PARAM PARTBL POINT POSIT PRTJOM PRTPLT PRTXS RATIO RDBIAS RDBOX RDCALC RDGRP	LOWBND	ALBEDO CORSIZ FILLSG FISFLX GOCURS GUIDE HROTRN HUNTER KEDIT LOCATE LODARA MESH POINT PRINT PRTJOM PRTPLT RESET START TKARRY TRACK VOLUME
		LPNT	BOOK2 BOOK3 BOOK4 BOOK5 START6

COMMON NAME	SUBROUTINE	COMMON NAME	SUBROUTINE
MATRX	FLDATA MATRIX PRATBL SORTA RESET	PICTTL (continued)	PRINT PRTPLT RDPLLOT RELATE
MSTR	BOOK1 BOOK2 BOOK3 BOOK4 BOOK5	POINTR	BOOK1 BOOK3 BOOK4 BOOK5 DATAIN FILLSG ICEMIX LOADIT NSUPG POINT RDCALC WRTCAL
NUTRON	ALBEDO CHKSTR CHOOSE CROSS FINDBX FLDATA GUIDE HROTRN LOCATE MESH NSTART RESET SHUFL START START0 START1 START2 START3 START4 START5 START6 STRTSU TKARRY TRACK TRKWRT	RTRN	CONE CUBOID CYLNDR DITTO DODECA ECYL ELLIPS HOLEIN HOPPER HXPRSM KENOG ORIGIN PLANE PIPED QUAD READGM RHOMB ROTATE ROTHOL ROTRNS SPHERE WEDGE
PCOLOR	PCOLOR		
PICT	CLRNIT MESH PRINT PRTPLT RDPLLOT RELATE	RUNTYP	BIRITE DATAIN INITAL KENOVI O0O019 PARAM PARTBL
PICTTL	CLRNIT MESH		

COMMON NAME	SUBROUTINE	COMMON NAME	SUBROUTINE
STDATA	CHKSTR DATAIN RDRST RDSTRT START START0 START1 START2 START3 DATAIN	UNIT (continued)	CHORD CONE CORRE CORSIZ CROSS CUBOID CYLINDR EDITOR ELLIPS FILLSG FIL2D FISFLX FITFLX FLDATA FREAK GEOMIN GUIDE HOLEIN HOPPER HROTRN HXPRSM ICEMIX IDX1D INDX INITAL JOMITY KEDIT KENOG KENOVI LDWRT LIMLN LOADIT LODARA LODWTS LOOPER MAKANG MAKTAP MATK MATRIX MEDIA MIXER MIXIT MIXMIX NNITL NSTART NSUPG ORIGIN O0O019 PARAM PARTBL
TITL	EDITOR FITFLX FREAK GUIDE INITAL KEDIT KENOG MATRIX NSUPG PARAM POINT PRTJOM PRTLBA PRTMIX PARTBL PRATBL PRTWTS PRTXS RDBOX RDPLLOT RDTAPE VOLUME WRTRST		
UNIT	ALBEDO ALBRD ALBUSE ANGLES ARASIZ ARAYIN ARRAY BNDRY BOOK1 BOOK2 BOOK3 BOOK4 BOOK5 BOX CHKSTR		

COMMON NAME	SUBROUTINE	COMMON NAME	SUBROUTINE
UNIT (continued)	PLANE	UNIT (continued)	ROTHOL
	POINT		SGWT
	POSIT		SHUFL
	PPIPED		SORTA
	PRANG		SORTR
	PRINT		SPHERE
	PRTARA		START
	PRTFLX		START2
	PRTJOM		START6
	PRTLBA		STATIS
	PRTPLT		STRTSU
	PRTPOS		TKARRY
	PRTXS		TRACK
	QUAD		TRKWRT
	RATIO		VEXCAV
	RDALB		VOLFIS
	RDBIAS		VOLUME
	RDBOX		WAITIN
	RDCALC		WATES
	RDGRP		WEDGE
	RDICE		WRTALB
	RDPLT		WRTCAL
	RDREF		WRTGRP
	RDRST		WRTICE
	RDSTRT		WRTRST
	RDTAPE		WRTWTS
	RDWTS		RT
	READGM		RTARA
	RHOMB		SAVST6
	ROTATE		SGALB

F17.C KENO-VI INPUT SUMMARY

This appendix consists of a summary of the KENO-VI input data requirements.

Table F17.C.1 Summary of parameter data

TITLE:			The title must be entered first (80 characters, including blanks) See Sect. F17.4.3		
PARAMETERS: Format: READ PARAM enter parameter data here END PARAM			If parameters are entered, they must follow the title. See Sects. F17.4.3, F17.5.2, and F17.5.3.		
KEY	STD.	DEFINITION	KEY	STD.	DEFINITION
RND=	given	random number	RUN=	YES	execute problem
TME=	30 min	execution time (min)	FLX=	NO	fluxes
TBA=	0.5 min	batch time (min)	FDN=	NO	fission densities
WTA=	0.5	average weight	ADJ=	NO	adjoint calculation
WTH=	3.0	wt. for splitting	AMX=	NO	all mixture xsecs
WTL=	1/WIH	Russian Roulette wt.	XAP=	NO	xsec angles & probs.
GEN=	103	no. of generations	XS1=	NO	1-D xsecs
NPG=	300	no. per generation	XS2=	NO	2-D xsecs
NSK=	3	generations skipped	PKI=	NO	fission spectrum
RES=	0	gens. between restart	P1D=	NO	extra 1-D xsecs
NBK=	NPG+25	neutron bank positions	FAR=	NO	fiss. & abs.
XNB=	0	extra bank entries	MKP=	NO	matrix by location
NFB=	NPG	fission bank positions	CKP=	NO	cofactor k by loc.
XFB=	0	extra bank entries	FMP=	NO	fiss. prod. by loc.
X1D=	0	no. of extra 1-D's	MKU=	NO	matrix by unit
LNG=	1000000	words of storage	CKU=	NO	cofactor k by unit
BEG=	1	restart at this gen.	FMU=	NO	fiss. prod. by unit
NG8=	200	blocks for d.a. unit			
NL8=	512	length of d.a. block			
SIG=	given	standard deviation to terminate problem			
			MKH=	NO	matrix by hole
			CKH=	NO	cofactor k by hole
			FMH=	NO	fiss. prod. by hole
			HHL=	NO	MKH at highest level
			MKA=	NO	matrix by array
			CKA=	NO	cofactor k by array
			FMA=	NO	fiss. prod. by array
			HAL=	NO	MKA at highest level
			PLT=	YES	printer plots
			BUG=	NO	debug print
			TRK=	NO	print neutron tracks
			PWT=	NO	print avg. weight
			PGM=	NO	unprocessed geometry
			SMU=	NO	self-multiplication
			NUB=	NO	neutrons per fission
			PAX=	NO	albedo-xsec array
			XSC=	14	mixed xsecs
			ALB=	79	albedo
			WTS=	80	weights
			LTB=	0	working xsecs
			SKT=	16	scratch
			RST=	0	read restart
			WRS=	0	write restart

Table F17.C.2 Summary of array data

ARRAY Format: READ ARRAY array parameters data type orientation data END ARRAY

See Sects. F17.5.5, F17.5.6, and F17.5.7.

Repeat the sequence ARRAY PARAMETERS DATA TYPE ORIENTATION DATA for each array used in the problem.

ARRAY PARAMETERS			DATA TYPE
KEYWORD	DEFAULT	DEFINITION	FILL LOOP
ARA=	1	no. defining the array	
TYP=	cuboidal	array type (cuboidal or triangular)	
NUX=	1	no. of units in X direction	
NUY=	1	no. of units in Y direction	
NUZ=	1	no. of units in Z direction	
GBL=	none	global, array number*	
COM=	none	delim comment delim optional comment is a maximum of 132 characters	

*If specified, it need be entered only once per problem.

ORIENTATION DATA FOR FILL

Enter unit numbers to define every position in the array. When entering data utilizing the options in this table, the count field and option field must be adjacent with no imbedded blanks. The operand field may be separated from the option field by one or more blanks. Orientation data for FILL are terminated by entering END FILL.

ORIENTATION DATA FOR LOOP

Enter the unit number and nine numbers that define the position(s) of that unit. Data for each of these ten entries are repeated until every position in the array has been defined. Orientation data for LOOP are terminated by entering END LOOP.

ENTER DATA IN THE FORM:

COUNT FIELD	OPTION FIELD	OPERAND FIELD	COMMENTS	DATA ENTRY	COMMENTS
i	R	j	stores j at the current position in the array	LTYPE	The unit or box type. LTYPE must be greater than 0.
i	*	j	stores j in the next i positions in the array	IX1	Starting position in the X direction. IX1 must be at least 1 and no larger than the value entered for NUX.
i	\$	j	stores j in the next i positions in the array	IX2	Ending position in the X direction. IX2 must be at least 1 and no larger than the value of NUX.
	F	j	fills remainder of the array with unit no. j starting with the current array position	INCX	The number of units by which increments are made in the X direction.
i	A	j	sets the current position in the array to j	IY1	The starting position in the Y direction. IY1 must be at least 1 and less than the value entered for NUY.
	S	j	increments current position in the array by i allows skipping i positions. The value of i may be positive or negative	IY2	Ending position in the Y direction. IY2 must be at least 1 and no larger than the value of NUY.
i	Q	j	repeats the previous j entries i times. The default value of i is 1	INCY	The number of units by which increments are made in the positive Y direction.
i	N	j	repeats the previous j entries i times, inverting the sequence each time. The default value of i is 1	IZ1	Starting position in the Z direction. IZ1 must be at least 1 and no larger than NUZ.
i	B	j	starting with the entry at -i from the current position, store entries in inverse order until position -(i+j) is reached. Default value of i=1	IZ2	Ending position in the Z direction. IZ2 must be at least 1 and no larger than NUZ.
i	P	j	alternately stores j and -j in the next i positions of the array	INCZ	The number of units by which increments are made in the positive Z direction.
i	I	j k	provides the end points, j and k, with i entries linearly interpolated between them (i.e., a total of i+2 points). At least one blank must separate j and k. When used for an integer array, the I option should only be used to generate integer steps (i.e., (k-j)/(i+1) should be a whole number).		
	T		terminates the data reading for the array		

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Table F17.C.3 Summary of biasing data

BIAS (weighting) Format: READ BIAS keyword correlation data auxiliary data END BIAS
See Sects. F17.4.7 and F17.5.8

KEYWORD	DESCRIPTION	MATERIAL	ID	ENERGY GROUPS	THICKNESS/ INCREMENT	
ID=	CORRELATION DATA will be read next.					
	id	material ID. Enter from table at right to use weighting data from the library	concrete	301	16,27,123	5 cm
	ibgn	beginning bias ID	paraffin	400	16,27,123	3 cm
	icnd	ending bias ID	water	500	16,27,123,218	3 cm
			graphite	6100	16,27,123	20 cm
WT=	AUXILIARY DATA will be read next.					
WTS=	AUXILIARY DATA will be read next.					
	wttil	material title (12-character maximum)				
	id	material ID				
	nsets	number of sets of group structures				
	REPEAT	(THKINC, NUMINC, NGPWT, WTAVG) NSETS TIMES				
	thkinc	thickness per increment				
	numinc	number of increments				
	ngpwt	number of energy groups for this set of wts				
	wtavg	enter numinc x ngpwt values of wtavg				

For CORRELATION DATA, the material ID is chosen from material ID column above (the keyword is ID=).

For AUXILIARY DATA, the material ID is chosen by the user and the keyword is WT= or WTS=. When AUXILIARY DATA are entered, CORRELATION DATA must also be entered to use the data.

Beginning and ending bias IDs are defined by the user. The geometry specification that has the bias ID equal to the beginning bias ID utilizes the wt av from the first interval of material ID.

Table F17.C.4 Summary of boundary condition data

BNDS
(albedo or
boundary
conditions)

Format: READ BNDS face code albedo name END BNDS
See Sect. F17.4.7

The sequence FACE CODE ALBEDO NAME is entered as many times as necessary to define the appropriate albedo boundary conditions.
The default for all faces is vacuum.

FACE CODES FOR ENTERING BOUNDARY (ALBEDO) CONDITIONS

FACE CODE	DEFINITION	FACE CODE	DEFINITION	FACE CODE	DEFINITION	FACE CODE	DEFINITION
+XB=	positive X face	XFC=	both X faces	+XY=	positive X and Y faces	&ZY=	positive Y and Z faces
&XB=	positive X face	YFC=	both Y faces	&XY=	positive X and Y faces	-XY=	negative X and Y faces
-XB=	negative X face	ZFC=	both Z faces	&YX=	positive X and Y faces	-XZ=	negative X and Z faces
+YB=	positive Y face	+FC=	all positive faces	+XZ=	positive X and Z faces	-YZ=	negative Y and Z faces
&YB=	positive Y face	&FC=	all positive faces	+ZX=	positive X and Z faces	YXF=	all X and Y faces
-YB=	negative Y face	-FC=	all negative faces	&XZ=	positive X and Z faces	ZXF=	all X and Z faces
+ZB=	positive Z face	XYF=	all X and Y faces	&ZX=	positive X and Z faces	ZYF=	all Y and Z faces
&ZB=	positive Z face	XZF=	all X and Z faces	+YZ=	positive Y and Z faces	-YX=	negative X and Y faces
-ZB=	negative Z face	YZF=	all Y and Z faces	+ZY=	positive Y and Z faces	-ZX=	negative X and Z faces
ALL=	all 6 faces	+XY=	positive X and Y faces	&YZ=	positive Y and Z faces	-ZY=	negative Y and Z faces

Any albedo condition on any face is allowed if the global unit boundary record consists of only one geometry record label that references a cuboid

Any one albedo condition on all surfaces is allowed if the global unit boundary record contains only one geometry record label that references a shape composed of paired planes

Either a void, mirror, or white boundary condition on all surfaces is allowed if the global unit boundary record contains only one geometry record label.

If the global unit boundary record contains more than one entry only the void boundary condition is allowed. Void is the default

ALBEDO NAMES AVAILABLE ON THE KENO V.a ALBEDO LIBRARY, FOR USE WITH THE FACE CODES

ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION
DP0H2O DP0H2O DP0 DP0	12-in. double P0 water differential albedo with 4 incident angles	CONC-4 CON4 CONC4	4-in. concrete differential albedo with 4 incident angles	VACUUM VOID VACU VAC	vacuum condition
H2O WATER	12-in. water differential albedo with 4 incident angles	CONC-8 CON8 CONC8	8-in. concrete differential albedo with 4 incident angles	SPECULAR MIRROR MIRR SPEC SPE MIR	mirror image reflection
PARAFFIN PARA WAX	12-in. paraffin differential albedo with 4 incident angles	CONC-12 CON12 CONC12	12-in. concrete differential albedo with 4 incident angles	PERIODIC PERI PER	periodic boundary condition
CARBON GRAPHITE C	200-cm carbon differential albedo with 4 incident angles	CONC-15 CON16 CONC16	16-in. concrete differential albedo with 4 incident angles		
ETHYLENE POLY CH2	12-in. polyethylene differential albedo with 4 incident angles	CONC-24 CON24 CONC24	24-in. concrete differential albedo with 4 incident angles		

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GEOMETRY REGION INPUT DATA REQUIREMENTS

*The Region Definition Vector, $i1 \ i2 \ \dots$, should contain references to all geometry records which share a boundary with the region being defined.

Table F17.C.6 Summary of mixing table data

MIXTURES

Format: READ MIXT xsec parameters END MIXT
These data are entered only if an AMPX working-format library is being used (LIB=) in the parameter data, Sect. F17.4.3. Do not enter if an ICE mixed library is used, (XSC=) in the parameter data, Sects. F17.4.10 and F17.5.5.

XSEC PARAMETERS

consists of keywords and associated values.
These parameters, if entered, need be entered only once.

KEYWORD	DEFAULT	DEFINITION
SCT=	1	No. of discrete scattering angles 0 is isotropic 1 is P1 2 is P3 3 is P5
EPS=	.00003	cross-section message cutoff value use to suppress message No. K5-60

MIXING TABLE DATA consist of

- (1) a keyword and mixture ID for the mixture
The keyword is MIX=
The desired mixture number follows the keyword
- (2) nuclide ID**
- (3) number density**

**The sequence (2) (3) is repeated for each nuclide in the mixture.

REPEAT the sequence (1) (2)'s (3)'s until all the mixtures have been described.

F17.C.7

Table F17.C.7 Summary of plot data

PLOT Format: READ PLOT plot parameters END PLOT plot parameters must be entered for each plot that is to be made. See Sects. F17.4.1 and F17.5.9					
KEYWORD	DEFAULT	DEFINITION	KEYWORD	DEFAULT	DEFINITION
TTL=	problem title	delim ptid delim delim is a one-character delimiter that signals the beginning and end of the title. ptid is the plot title (max. 132 char.)	UAX=	prev. plot 0 IF VAX OR WAX is read	X component of direction cosine for the AX axis of the plot (across)
PIC=	MAT	Type of picture: MIXTURE, UNIT NO. or BIAS ID NO.	VAX=	prev. plot 0 IF UAX OR WAX is read	Y component of direction cosine for the AX axis of the plot (across)
		MIXTURE ----- MAT MIX MIXT MIXTURE MEDI MEDIA	WAX=	prev. plot 0 IF UAX OR VAX is read	Z component of direction cosine for the AX axis of the plot (across)
		UNIT NO. ----- BOX BOXT BOXTYPE UNT UNIT UNITTYPE	UDN=	prev. plot 0 IF VDN OR WDN is read	X component of direction cosine for the DN axis of the plot (down)
		BIAS ID NO. ----- IMP BIAS BIASID WTS WEIG WEIGHTS WGT WGTS	VDN=	prev. plot 0 IF UDN OR WDN is read	Y component of direction cosine for the DN axis of the plot (down)
			WDN=	prev. plot 0 IF UDN OR VDN is read	Z component of direction cosine for the DN axis of the plot (down)
			DLX=		horizontal spacing between points on plot vertical spacing between points on plot no. of intervals to be printed across page no. of intervals to be printed down page lines per inch printed down the page delim CHRS delim a one character delimiter signals the beginning and end of the character string YES allows the problem to execute NO terminates problem after data checking YES allows the plot(s) to be made NO allows reading the plot data without making a plot
			DLD=		
			NAX=		
			NDN=		
			LPI=	8	
			NCH=	CHRS**	
			RUN=	YES	
			PLT=	YES	
XUL=	prev. plot	X coord. of upper-left corner of plot	SCR=	NO	No specified a printer plot. If YES, a .gif file is generated for each plot in the directory where the problem is being run
YUL=	prev. plot	Y coord. of upper-left corner of plot			
ZUL=	prev. plot	Z coord. of upper-left corner of plot			
XLR=	prev. plot	X coord. of lower-right corner of plot	CLR=		Used only with SCR=YES to change colors in the color table. Input is 4 integers: 1st is index into color table, the next 3 are the red, green, and blue color values in the color table
YLR=	prev. plot	Y coord. of lower-right corner of plot			
ZLR=	prev. plot	Z coord. of lower-right corner of plot			
PLOT ORIGIN: (1) GLOBAL UNIT - coincides with origin of global unit geometry description.			**default values of CHRS are given below: MEDIA 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 CHRS 1 2 3 4 5 6 7 8 9 A B C D E F G H I J K L M MEDIA 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 CHRS N O P Q R S T U V W X Y Z # , \$ - +) MEDIA 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 CHRS & > : ; . - % * " = ! (@ < / 0		

Table F17.C.8 Summary of starting data

START Format: READ START enter start data here END START
The default value of start type is zero. See Sect. F17.4.8.

START TYPE	REQUIRED DATA	OPTIONAL DATA	STARTING DISTRIBUTION	START TYPE	REQUIRED DATA	OPTIONAL DATA	STARTING DISTRIBUTION	KEYWORD	DEFAULT	DEFINITION
0	none	NST XSM XSP YSM YSP ZSM ZSP RFL PSP	uniform	3	NST TFX TFY TFZ NXS NYS NZS	KFS PSP	spike	NST =	0	start type
1	NST	XSM XSP YSM YSP ZSM ZSP RFL PSP	cosine	4	NST TFX TFY TFZ NBX	KFS PSP	multiple spikes	TFX =	0.0	X coordinate
2	NST NXS NYS NZS FCT	XSM XSP YSM YSP ZSM ZSP RFL PSP	cosine with fraction in specified unit	5	NST NBX	PSP	in specified units	TFY =	0.0	Y coordinate
				6	NST TFX TFY TFZ LNU*	NXS NYS NZS KFS PS6 PSP	arbitrary points	TFZ =	0.0	Z coordinate
								NXS =	0	X index of unit pos.
								NYS =	0	Y index of unit pos.
								NZS =	0	Z index of unit pos.
								KFS =		fissile mixture no.
								LNU =	0	number of last neutron
								NBX =	0	source unit number
								FCT =	0	fraction
								XSM =	-X	-X of source cuboid
								XSP =	+X	+X of source cuboid
								YSM =	-Y	-Y of source cuboid
								YSP =	+Y	+Y of source cuboid
								ZSM =	-Z	-Z of source cuboid
								ZSP =	+Z	+Z of source cuboid
								RFL =	NO	start in reflector
								PS6 =	NO	print start 6 input
								PSP =	NO	print starting points

*LNU must be the last entry for each set of start 6 data. The LNU of each successive set of data must be larger than the last.

**Defaulted to the fissile mixture having the smallest mixture number.

Unless otherwise specified, the starting volume is defined by the unrotated, untranslated geometric shape specified by the label in the first position in the global unit boundary record.

F17.C.9

F17.D SAMPLE PROBLEMS

This section contains sample problems to demonstrate some of the options available in KENO-VI. All the options of KENO V.a are available in KENO VI. When KENO VI is run as a part of SCALE, the driver allows KENO VI to be executed each time it encounters an "=KENOVI". These KENO-VI problems are set up to run as stand-alone KENO-VI. A working format cross-section set was generated on unit 4, using BONAMI and NITAWL, for use with this problem set.

F17.D.1 KENO-VI SAMPLE PROBLEM DATA

A brief problem description and the associated record input data are included for each KENO-VI sample problem. Different options may be easily activated by making changes in the data. These problems use a 27-group AMPX working-format library on Unit 4 which was generated using BONAMI and NITAWL from the 27groupndf4 master library. The nuclide identifiers for this library are consistent with the SCALE 4.3 identifiers created by CSAS. Input data to create this library are given in Sect. F17.D.2. The unit number is defined by the parameter LIB= in the parameter data.

SAMPLE PROBLEM 1 2C8 BARE

This simple $2 \times 2 \times 2$ array of uranium metal cylinders is described in the article "Critical Three-Dimensional Arrays of U(93.2)-Metal Cylinders"¹ by J. T. Thomas. This critical experiment is designated in Table II of that article as cylinder index 11 and reflector index 1. Figure F17.D.1 shows the critical experiment.

INPUT DATA

```
=KENOVI
KENOVI SAMPLE PROBLEM 1 CASE 2C8 BARE
READ PARAMETERS
GEN=103 NPG=300 LNG=20000 FLX=YES FDN=YES FAR=YES LIB=4
END PARAMETERS
READ MIXT SCT=2
MIX=1 1092234 4.82716E-04 1092235 4.47971E-02 1092236 9.57231E-05
1092238 2.65767E-03
END MIXT
READ GEOMETRY
UNIT 1
COM='SINGLE 2C8 UNIT CENTERED'
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL UNIT 2
CUBOID 10 4P13.74 2P13.01
COM='2X2X2 2C8 ARRAY'
```

Figure F17.D.1. Critical 2C8 bare assembly

```

ARRAY 1 +10 PLACE 1 1 1 2R-6.87 -6.505
BOUNDARY 10
END GEOMETRY
READ ARRAY GBL=1 NUX=2 NUY=2 NUZ=2 FILL F1 END ARRAY
END DATA
END

```

SAMPLE PROBLEM 2 CASE 2C8 BARE WITH 8 UNIT TYPES MATRIX CALCULATION

This problem is the same as sample problem 1 except it is set up as a mixed box problem with each unit of the array defined as a different unit type. Matrix k-effectives will be calculated for this problem by both unit type and array position. The print flags are set to print all matrix data.

INPUT DATA

```

=KENOVI
KENOVI SAMPLE PROBLEM 2 CASE 2C8 BARE WITH 8 UNIT TYPES MATRIX CAL
READ PARAM
GEN=103 NPG=300 LNG=20000 LIB=4 FLX=YES FDN=YES MKU=YES FMU=YES MKP=YES
FMP=YES END PARAMETERS
READ MIXT SCT=2
MIX=1 1092234 4.82716E-04 1092235 4.47971E-02 1092236 9.57231E-05
1092238 2.65767E-03
END MIXT
READ GEOMETRY UNIT 1
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 2
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 3
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 4
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20

```

```

UNIT 5
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 6
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 7
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 8
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL UNIT 9
CUBOID 10 4P13.74 2P13.01
COM='2X2X2 2C8 ARRAY'
ARRAY 1 +10 PLACE 1 1 1 2R-6.87 -6.505
BOUNDARY 10
END GEOMETRY
READ ARRAY GBL=1 NUX=2 NUZ=2 LOOP 10*1 3*2 7*1 3 1 1 1 2 2 1
1 1 1 4 2 2 1 2 2 1 1 1 1 5 6*1 2 2 1 6 2 2 1 1 1 1 2 2 1
7 1 1 1 2 2 1 2 2 1 8 2 2 1 2 2 1 2 2 1 END ARRAY
END DATA
END

```

SAMPLE PROBLEM 3 2C8 15.24-CM PARAFFIN REFL

A $2 \times 2 \times 2$ array of uranium metal cylinders is reflected by 6 in. of paraffin on all faces. This critical experiment¹ is designated as cylinder index 11 and reflector index 5 in Table II of ref. 1. Figure F17.D.2 shows half of the critical experiment, which consisted of the half shown and the mirror image of it. These two assemblies were moved together to achieve criticality. The top reflector is missing in Fig. F17.D.2, but it was present when criticality was achieved.

Figure F17.D.2. Half of the paraffin reflected 2C8 assembly before the top reflector was added

INPUT DATA

```
=KENOVI
KENO-VI SAMPLE PROBLEM 3 2C8 15.24 CM PARAFFIN REFL
READ PARAM
GEN=103 NPG=300 LNG=20000 LIB=4 FLX=YES FDN=YES PWT=YES END PARAM
READ MIXT
MIX=1 1092234 4.82716E-04 1092235 4.47971E-02 1092236 9.57231E-05
1092238 2.65767E-03 MIX=2 10006012 3.97311E-02 10001001 8.26407E-02
SCT=2
END MIXT
READ GEOMETRY
UNIT 1
COM='SINGLE 2C8 UNIT CENTERED'
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P11.74 2P11.375
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL UNIT 2
COM='2X2X2 2C8 ARRAY WITH REFLECTOR'
CUBOID 10 4P23.48 2P22.75
CUBOID 20 26.48 -26.48 26.48 -26.48 25.75 -25.75
CUBOID 30 29.48 -29.48 29.48 -29.48 28.75 -28.75
CUBOID 40 32.48 -32.48 32.48 -32.48 31.75 -31.75
CUBOID 50 35.48 -35.48 35.48 -35.48 34.75 -34.75
CUBOID 60 38.72 -38.72 38.72 -38.72 37.99 -37.99
ARRAY 1 +10 PLACE 1 1 1 2R-11.74 -11.375
MEDIA 2 2 -10 +20
MEDIA 2 3 -20 +30
MEDIA 2 4 -30 +40
MEDIA 2 5 -40 +50
MEDIA 2 6 60 -50
BOUNDARY 60
END GEOMETRY
READ BIAS ID=400 2 6 END BIAS
READ ARRAY GBL=1 NUX=2 NUY=2 NUZ=2 FILL F1 END ARRAY
END DATA
END
```

SAMPLE PROBLEM 4 2C8 15.24-CM PARAFFIN REFL AUTOMATIC REFL

This problem is the same as sample problem 3, except it is set up using more reflector regions.

INPUT DATA

```
=KENOVI COND=500
KENO-VI SAMPLE PROBLEM 4 2C8 15.24 CM PARAFFIN REFL
```

```

READ PARAM
GEN=103 NPG=300 LNG=20000 LIB=4 FLX=YES FDN=YES PWT=YES END PARAM
READ MIXT SCT=2
MIX=1 1092234 4.82716E-04 1092235 4.47971E-02 1092236 9.57231E-05
1092238 2.65767E-03 MIX=2 10006012 3.97311E-02 10001001 8.26407E-02
END MIXT
READ GEOMETRY
UNIT 1
COM='SINGLE 2C8 UNIT CENTERED'
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P11.74 2P11.375
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL UNIT 2
COM='2X2X2 2C8 ARRAY WITH REFLECTOR'
CUBOID 10 4P23.48 2P22.75
CUBOID 20 26.48 -26.48 26.48 -26.48 25.75 -25.75
CUBOID 30 29.48 -29.48 29.48 -29.48 28.75 -28.75
CUBOID 40 32.48 -32.48 32.48 -32.48 31.75 -31.75
CUBOID 50 35.48 -35.48 35.48 -35.48 34.75 -34.75
CUBOID 60 38.48 -38.48 38.48 -38.48 37.75 -37.75
CUBOID 70 38.72 -38.72 38.72 -38.72 37.99 -37.99
ARRAY 1 +10 PLACE 1 1 1 2R-11.74 -11.375
MEDIA 2 2 -10 +20
MEDIA 2 3 -20 +30
MEDIA 2 4 -30 +40
MEDIA 2 5 -40 +50
MEDIA 2 6 60 -50
MEDIA 2 7 70 -60
BOUNDARY 70
END GEOMETRY
READ BIAS ID=400 2 7 END BIAS
READ ARRAY GBL=1 NUX=2 NUY=2 NUZ=2 FILL F1 END ARRAY
END DATA
END

```

SAMPLE PROBLEM 5 2C8 12-INCH PARAFFIN ALBEDO REFLECTOR

This problem is the same as samples problems 3 and 4 except the reflector is represented by a 12-in. paraffin albedo. Note the decrease in execution time when using an albedo reflector instead of doing actual tracking. Note also that k-effective is somewhat higher for this system, probably due to the small edge size of the system.²

INPUT DATA

```

=KENOVI COND=500
KENOVI SAMPLE PROBLEM 5 2C8 12 INCH PARAFFIN ALBEDO REFLECTOR
READ PARA

```

```

GEN=103 NPG=300 LNG=20000 FLX=YES FAR=YES FDN=YES LIB=4 END PARA
READ MIXT MIX=1 1092234 4.82716E-04 1092235 4.47971E-02
1092236 9.57231E-05 1092238 2.65767E-03 SCT=2 END MIXT
READ BOUNDS ALL=PARAFFIN END BOUNDS
READ GEOMETRY
UNIT 1
COM='SINGLE 2C8 UNIT CENTERED'
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P11.74 2P11.375
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL UNIT 2
CUBOID 10 4P23.48 2P22.75
COM='2X2X2 2C8 ARRAY'
ARRAY 1 +10 PLACE 1 1 1 2R-11.74 -11.375
BOUNDARY 10
END GEOMETRY
READ ARRAY GBL=1 NUX=2 NUY=2 NUZ=2 FILL F1 END ARRAY
END DATA
END

```

SAMPLE PROBLEM 6 ONE 2C8 UNIT (SINGLE UNIT)

One of the 2C units is described and run as a single-unit problem, and its k-effective is calculated.

INPUT DATA

```

=KENOVI COND=500
KENOVI SAMPLE PROBLEM 6 ONE 2C8 UNIT (SINGLE UNIT)
READ PARA
GEN=103 NPG=300 LNG=20000 LIB=4 FLX=YES FDN=YES FAR=YES END PARA
READ MIXT
SCT=2 MIX=1 1092234 4.82716E-04 1092235 4.47971E-02 1092236
9.57231E-05 1092238 2.65767E-03 END MIXT
READ GEOMETRY
GLOBAL UNIT 1
COM='SINGLE 2C8 UNIT CENTERED'
CYLINDER 10 5.748 5.3825 -5.3825
MEDIA 1 1 10
BOUNDARY 10
END GEOMETRY
END DATA
END

```


SAMPLE PROBLEM 7 BARE 2C8 USING SPECULAR REFLECTION

One of the 2C8 units¹ is described and the $2 \times 2 \times 2$ array is simulated by using specular reflection on the positive x, y, and z faces of the unit. This problem is a simulation of sample problem 1.

INPUT DATA

```
=KENOVI
KENO-VI SAMPLE PROBLEM 7 BARE 2C8 USING SPECULAR REFLECTION
READ PARA
GEN=103 NPG=300 LNG=20000 FLX=YES FDN=YES FAR=YES LIB=4 END PARAMETERS
READ MIXT MIX=1 1092234 4.82716E-04 1092235 4.47971E-02
1092236 9.57231E-05 1092238 2.65767E-03 SCT=2 END MIXT
READ GEOMETRY
GLOBAL UNIT 1
COM='SINGLE 2C8 UNIT CENTERED'
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
END GEOMETRY
READ BOUNDS +FC=SPECULAR END BOUNDS END DATA
READ PLOT
LPI=6
TTL='XY SLICE AT Z=0'
XUL=-7.0 YUL=7.0 ZUL=0.0 XLR=7.0 YLR=-7.0 ZLR=0.0
UAX=1 VDN=-1 NAX=130 NCH='*' END PLT1
TTL='XZ SLICE AT Y=0.0'
XUL=-7.0 YUL=0.0 ZUL=7.0 XLR=7.0 YLR=0.0 ZLR=-7.0
UAX=1 VDN=0 WDN=-1 NAX=130 NCH='*'
END PLOT
END DATA
END
```

SAMPLE PROBLEM 8 INFINITELY LONG CYLINDER FROM 2C8 UNIT

The fuel cylinder radius from sample problem 1 is used. The length of the cylinder is arbitrarily chosen to be 20 cm, and the unit is specularly reflected on the top and bottom to create an infinitely long cylinder.

INPUT DATA

```
=KENOVI COND=500
KENO-VI SAMPLE PROBLEM 8 INFINITELY LONG CYLINDER FROM 2C8 UNIT
READ PARAMETERS GEN=103 NPG=300 LNG=20000 LIB=4 END PARAMETERS
READ MIXT MIX=1 1092234 4.82716E-04 1092235 4.47971E-02
1092236 9.57231E-05 1092238 2.65767E-03 SCT=2
END MIXTURES
READ GEOMETRY
```



```

GLOBAL UNIT 1
COM='SINGLE 2C8 UNIT CENTERED'
CYLINDER 10 5.748 2P10.0
CUBOID 20 4P6.87 2P10.0
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
END GEOMETRY
READ BOUNDS ZFC=MIRROR END BOUNDS
READ PLOT
PLT=NO LPI=6
TTL='XY SLICE AT Z=0.0'
XUL=-7 YUL=7 ZUL=0.0 XLR=7 YLR=-7 ZLR=0.0
UAX=1 VDN=-1 NAX=130 NCH='*' END PLT1
TTL='XZ SLICE AT Y=0.0'
XUL=-7 YUL=0.0 ZUL=11 XLR=7 YLR=0.0 ZLR=-11
UAX=1 VDN=0 WDN=-1 NAX=130 NCH='*'
END PLOT
END DATA
END

```

SAMPLE PROBLEM 9 INFINITE ARRAY OF 2C8 UNITS

The geometry description from sample problem 1 is used, and the cuboid is specularly reflected on all faces to create an infinite array of 2C8 units having an edge-to-edge spacing of 2.244 cm in the x and y directions and 2.245 cm in the z direction.

INPUT DATA

```

=KENOVI
KENO-VI SAMPLE PROBLEM 9 INFINITE ARRAY OF 2C8 UNITS
READ PARAMETERS
GEN=103 NPG=300 LNG=20000 LIB=4 GEN=33 END PARAMETERS
READ MIXTURES SCT=2
MIX=1 1092234 4.82716E-04 1092235 4.47971E-02 1092236 9.57231E-05
1092238 2.65767E-03
END MIXT
READ GEOMETRY
GLOBAL UNIT 1
COM='SINGLE 2C8 UNIT CENTERED'
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
END GEOMETRY
READ BOUNDS ALL=MIRROR END BOUNDS
READ PLOT
LPI=6
TTL='XY SLICE AT Z=0'

```

```

XUL=-7.0 YUL=7.0 ZUL=0.0 XLR=7.0 YLR=-7.0 ZLR=0.0
UAX=1 VDN=-1 NAX=130 NCH='*' END PLT1
TTL='XZ SLICE AT Y=0.0'
XUL=-7.0 YUL=0.0 ZUL=7.0 XLR=7.0 YLR=0.0 ZLR=-7.0
UAX=1 VDN=0 WDN=-1 NAX=130 NCH='*'
END PLOT
END DATA
END

```

SAMPLE PROBLEM 10 2C8 BARE WRITE RESTART

This problem is the same as sample problem 1, a $2 \times 2 \times 2$ array of metal cylinders. Restart information is written on unit 94 after the completion of every fifth generation.

INPUT DATA

```

=KENOVI
SAMPLE PROBLEM 10 CASE 2C8 BARE WRITE RESTART
READ PARAMETERS
GEN=103 NPG=300 LNG=20000 FLX=YES FDN=YES FAR=YES LIB=4 RES=5 WRS=94
END PARAMETERS
READ MIXT MIX=1 1092234 4.82716E-04 1092235 4.47971E-02
1092236 9.57231E-05 1092238 2.65767E-03 SCT=2 END MIXTURES
READ GEOMETRY
UNIT 1
COM='SINGLE 2C8 UNIT CENTERED'
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 4P6.87 2P6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL UNIT 2
CUBOID 10 4P13.74 2P13.01
COM='2X2X2 2C8 ARRAY'
ARRAY 1 +10 PLACE 1 1 1 2R-6.87 -6.505
BOUNDARY 10
END GEOMETRY
READ ARRAY GBL=1 NUX=2 NUZ=2 FILL F1 END ARRAY
READ PLOT PLT=NO LPI=6
TTL='XY SLICE AT Z=6.505'
XUL=-13.74 YUL=13.74 ZUL=6.505 XLR=13.74 YLR=-13.74 ZLR=6.505
UAX=1 VDN=-1 NAX=130 NCH='*' END PLT1
TTL='XZ SLICE AT Y=6.87'
XUL=-13.74 YUL=6.87 ZUL=13.01 XLR=13.74 YLR=6.87 ZLR=-13.01
UAX=1 VDN=0 WDN=-1 NAX=130 NCH='*'
END PLOT
END DATA
END

```

SAMPLE PROBLEM 11 2C8 BARE READ RESTART DATA

This problem is a restart of sample problem 10. The problem is restarted from the tenth set of restart data that was written by sample problem 10 (i.e., it restarts with the fifty-first generation).

INPUT DATA

```
=KENOVI  
SAMPLE PROBLEM 11 2C8 BARE READ RESTART DATA  
READ PARAM BEG=51      RST=94 RES=0 END PARAM  
END DATA  
END
```

SAMPLE PROBLEM 12 4 AQUEOUS 4 METAL

This problem is a critical experiment consisting of a composite array^{1,3} of four highly enriched uranium metal cylinders and four cylindrical plexiglas containers filled with uranyl nitrate solution. The metal units in this experiment are designated in Table II of ref. 1 as cylinder index 11 and reflector index 1. A photograph of the experiment is given in Fig. F17.D.3.

Figure F17.D.3. Critical assembly of 4 solution units and 4 metal units

INPUT DATA

=KENOVI COND=500
SAMPLE PROBLEM 12 4 AQUEOUS 4 METAL MIXED UNITS
READ PARAM
GEN=103 NPG=300 LNG=20000 LIB=4 FLX=YES FDN=YES NUB=YES SMU=YES
MKU=YES FMP=YES FMU=YES END PARAM
READ MIXT SCT=2
MIX=1 1092234 4.82716E-04 1092235 4.47971E-02 1092236 9.57231E-05
1092238 2.65767E-03
MIX=2 2001001 5.77964E-02 2007014 2.13092E-03 2008016 3.74130E-02
2092234 1.06784E-05 2092235 9.84599E-04 2092236 5.29385E-06
2092238 6.19413E-05
MIX=3 11001001 5.68187E-02 11006012 3.55117E-02 11008016 1.42047E-02
END MIXT
READ GEOM
UNIT 1
CYLINDER 10 9.525 8.89 -8.89
CYLINDER 20 10.16 9.525 -9.525
CUBOID 30 10.875 -10.875 10.875 -10.875 10.24 -10.24
MEDIA 2 1 10
MEDIA 3 1 -10 20
MEDIA 0 1 30 -20
BOUNDARY 30
UNIT 2
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 6.59 -15.16 6.59 -15.16 6.225 -14.255
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 3
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 6.59 -15.16 15.16 -6.59 6.225 -14.255
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 4
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 6.59 -15.16 6.59 -15.16 14.255 -6.225
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 5
CYLINDER 10 5.748 5.3825 -5.3825
CUBOID 20 6.59 -15.16 15.16 -6.59 14.255 -6.225
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL
UNIT 6
CUBOID 10 43.5 0.0 43.5 0.0 40.96 0.0

```

ARRAY 1 +10 PLACE 1 1 1 15.16 15.16 14.255
BOUNDARY 10
END GEOM
READ ARRAY NUX=2 NUZ=2 NUX=2 LOOP
1 3R2 1 2 1 1 2 1 2 9R1 3 3R1 2 2 1 3R1 4 6R1 2 2 1 5 3R1 2 2 1 2 2 1
END ARRAY
READ PLOT
TTL='X-Y @Z=15.16 LOWER LEFT QUARTER OF ARRAY TO COMPARISON WITH SMP12A'
XUL=-0.5 YUL=44.0 ZUL=15.16 XLR=44.5 YLR=21.0 ZLR=15.16
UAX=1.0 VDN=-1.0 NCH='*.3' NAX=130
END PLT1
TTL='X-Z @Y=15.16 LOWER LEFT QUARTER OF ARRAY TO COMPARISON WITH SMP12A'
XUL=-0.5 YUL=15.16 ZUL=21.0 XLR=44.16 YLR=15.16 ZLR=-0.5
UAX=1.0 WDN=-1.0 NCH='*.3' NAX=130
END PLT2
TTL='X-Y PLOT OF ENTIRE ARRAY AT Z=15.16'
XUL=-0.5 YUL=44.0 ZUL=15.16 XLR=44.5 YLR=-1.0 ZLR=15.16
UAX=1.0 VDN=-1.0 NCH='*.3' NAX=130
END PLT3
TTL='X-Z PLOT OF ENTIRE ARRAY AT Y=15.16'
XUL=-0.5 YUL=15.16 ZUL=41.0 XLR=44.16 YLR=15.16 ZLR=-1.0
UAX=1.0 WDN=-1.0 NCH='*.3' NAX=130
END PLT4
END PLOT
END DATA
END

```

SAMPLE PROBLEM 13 TWO CUBOIDS IN A CYLINDRICAL ANNULUS

This critical experiment⁴ consists of two assemblies of 93.2% ²³⁵U-enriched uranium metal ($\rho = 18.69$ g/cc) stacked vertically. The bottom assembly contains a uranium metal cuboid offset to the left within a uranium metal cylindrical annulus. The top assembly contains a uranium metal cuboid offset to the right within a uranium metal cylindrical annulus. The cuboid extends above the annulus. A drawing of the two sections and the total assembly is given in Fig. F17.D.4.

Figure F17.D.4 Drawing of two cuboids in an annulus critical assembly

INPUT DATA

```
=KENOVI COND=500
SAMPLE PROBLEM 13 TWO CUBOIDS IN A CYLINDRICAL ANNULUS
READ PARAM
GEN=103 NPG=300 LNG=20000 LIB=4 END PARAM
READ MIXT SCT=2
MIX=1 3092234 4.80915E-04 3092235 4.46299E-02 3092236 9.53659E-05
3092238 2.64775E-03
END MIXT
READ GEOM
UNIT 1
CUBOID 10 6.35 -6.35 6.35 -6.35 7.62 0.0
CYLINDER 20 13.97 7.62 0.0 ORIG X=-6.0934
CYLINDER 30 19.05 7.62 0.0 ORIG X=-6.0934
CUBOID 40 12.9566 -25.1434 19.05 -19.05 7.62 0.0
MEDIA 1 1 10
MEDIA 0 1 20 -10
MEDIA 1 1 30 -20
MEDIA 0 1 40 -30
BOUNDARY 40
UNIT 2
CUBOID 10 6.35 -6.35 6.35 -6.35 8.56 0.0
CYLINDER 20 13.97 8.56 0.0 ORIGIN X=6.0934
CYLINDER 30 19.05 8.56 0.0 ORIGIN X=6.0934
CUBOID 40 25.1434 -12.9566 19.05 -19.05 8.56 0.0
MEDIA 1 1 10
MEDIA 0 1 20 -10
MEDIA 1 1 30 -20
MEDIA 0 1 40 -30
BOUNDARY 40
UNIT 3
CUBOID 10 6.35 -6.35 6.35 -6.35 2.616 0.0
CUBOID 20 25.1434 -12.9566 19.05 -19.05 2.616 0.0
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL UNIT 4
CUBOID 10 12.9566 -25.1434 2P19.05 18.796 0.
ARRAY 1 10 PLACE 1 1 1 3R0.
BOUNDARY 10
END GEOM
READ ARRAY NUX=1 NUY=1 NUZ=3 FILL 1 2 3 T END ARRAY END DATA
END
```

SAMPLE PROBLEM 14 U METAL CYLINDER IN AN ANNULUS

This critical experiment⁴ consists of a 93.2 ²³⁵U-enriched uranium metal cylinder within a cylindrical annulus of the same material as shown in Fig. F17.D.5. The uranium metal specification is identical to that used in sample problem 13.

INPUT DATA

```
=KENOVI COND=500
SAMPLE PROBLEM 14 U METAL CYLINDER IN AN ANNULUS
READ PARAM GEN=103 NPG=300 LNG=20000 LIB=4
END PARAM
READ MIXT SCT=2
MIX=1 3092234 4.80915E-04 3092235 4.46299E-02 3092236 9.53659E-05
3092238 2.64775E-03
END MIXT
READ GEOM
GLOBAL UNIT 1
CYLINDER 10 8.89 10.109 0.0 ORIG X=5.08
CYLINDER 20 13.97 10.109 0.0
CYLINDER 30 19.05 10.109 0.0
MEDIA 1 1 10
MEDIA 0 1 20 -10
MEDIA 1 1 30 -20 -10
BOUNDARY 30
END GEOM
READ PLOT
TTL='X-Y SLICE AT Z=5.0'
XUL=-19.1 YUL=19.1 ZUL=5.0 XLR=19.5 YLR=-19.5 ZLR=5.0
UAX=1 VDN=-1 NAX=130 NCH='*' END PLT1
TTL='Y-Z SLICE AT X=0.0'
XUL=0.0 YUL=-19.5 ZUL=10.2 XLR=0.0 YLR=19.5 ZLR=-1.0
VAX=1 WDN=-1 NAX=130 NCH='*' END PLT2
END PLOT
END DATA
END
```

Figure F17.D.5. Drawing of the cylinder in an annulus critical assembly

SAMPLE PROBLEM 15 SMALL WATER REFLECTED SPHERE ON PLEXIGLAS COLLAR

This critical experiment⁵ is a small highly enriched uranium sphere supported by a plexiglas doughnut in a tank of water. The sphere extends down through the hole of the doughnut. However, the KENO VI geometry package cannot rigorously describe a doughnut; therefore, the KENO VI mockup of this problem describes the doughnut as an annular cylindrical plate and the sphere is supported by it. Both are contained in a cylindrical tank of water. A drawing of the experiment is given in Fig. F17.D.6. This drawing shows the sphere above the cylindrical collar for the sake of clarity. The sphere is actually supported by the collar and extends into the opening in its center. The actual experiment utilized a torus or doughnut instead of a cylindrical collar.

INPUT DATA

```
=KENOVI
SAMPLE PROBLEM 15 SMALL WATER REFLECTED SPHERE ON PLEXIGLAS COLLAR
READ PARAM
GEN=103 NPG=300 LNG=20000 LIB=4 FLX=YES FDN=YES END PARAM
READ MIXT SCT=2
MIX=1 4092234 5.65801E-04 4092235 4.70211E-02 4092236 9.58966E-05
      4092238 4.65935E-04
MIX=2 11001001 5.68187E-02 11006012 3.55117E-02 11008016 1.42047E-02
MIX=3 12001001 6.67514E-02
MIX=3 12008016 3.33757E-02
END MIXT
READ START RFL=NO END START
READ GEOM
UNIT 1
SPHERE 10 6.5537
CYLINDER 20 4.1275 -5.09066 -7.63065
CYLINDER 30 12.7 -5.09066 -7.63065
CUBOID 40 4P12.7 6.5537 -7.63065
MEDIA 1 1 10
MEDIA 3 1 20 -10
MEDIA 2 1 30 -20 -10
MEDIA 3 1 40 -30 -20 -10
BOUNDARY 40
GLOBAL UNIT 2
CUBOID 10 4P12.7 6.5537 -7.63065
CYLINDER 20 17.97 6.5537 -7.63065
CYLINDER 30 20.97 9.5537 -10.63065
CYLINDER 40 23.97 12.5537 -13.63065
CYLINDER 50 26.97 15.5537 -16.63065
CYLINDER 60 29.97 18.5537 -19.63065
CYLINDER 70 32.97 21.5537 -22.63065
ARRAY 1 10 PLACE 1 1 1 0.0 0.0 0.0
MEDIA 3 1 20 -10
MEDIA 3 2 30 -20 -10
MEDIA 3 3 40 -30
MEDIA 3 4 50 -40
```

```

MEDIA 3 5 60 -50
MEDIA 3 6 70 -60
BOUNDARY 70
END GEOM
READ ARRAY NUX=1 NUY=1 NUZ=1 FILL 1 END FILL END ARRAY
READ BIAS ID=500 2 6 END BIAS
READ PLOT TTL='X-Z SLICE THROUGH THE CENTER OF THE SPHERE'
XUL=-20.0 ZUL=10.0 YUL=0.0 XLR=20.0 YLR=0.0 ZLR=-10.0
UAX=1.0 WDN=-1.0 NAX=130 NCH='*0-'
END PLOT
END DATA
END

```

Figure F17.D.6 Drawing of a critical assembly consisting of a uranium sphere on a plexiglas collar with a cylindrical water reflector

SAMPLE PROBLEM 16 UO2F2 INFINITE SLAB K-INFINITY

This problem solves for the k-infinity of an infinite number of slabs of uranyl fluoride solution contained in pyrex glass and separated by borated uranyl fluoride solution. The uranyl fluoride slab is 4.958 cm thick, 93.2% enriched, and has a density of 578.7 g U/L. The pyrex glass is 1.27 cm thick and is present on both faces of the uranyl fluoride solution. A total of 27.46 cm of borated solution separates the pyrex glass of adjacent slabs of solution. 1.482×10^{-27} atoms of boron per milliliter are present in the borated solution.

INPUT DATA

```
=KENOVI
SAMPLE PROBLEM 16 UO2F2 INFINITE SLAB K-INFINITY
READ PARAMETERS
GEN=103 NPG=300 LNG=20000 LIB=4 AMX=YES XAP=NO  END PARAMETERS
READ MIXT SCT=2
MIX=1 5009019 2.96286E-03 5001001 6.04824E-02 5008016 3.32041E-02
      5092235 1.38188E-03 5092238 9.95503E-05
MIX=2 13011023 2.39502E-03 13013027 4.97719E-04 13014000 1.80267E-02
      13005010 9.08241E-04 13005011 3.68719E-03 13008016 4.49173E-02
MIX=3 6009019 2.96286E-03 6001001 6.04824E-02 6008016 3.32041E-02
      6092235 1.38188E-03 6092238 9.95503E-05
      6005010 2.92803E-04 6005011 1.18870E-03
END MIXT
READ GEOMETRY
GLOBAL UNIT 1
CUBOID 10 2.479 -2.479 100.0 -100.0 100.0 -100.0
CUBOID 20 3.749 -3.749 100.0 -100.0 100.0 -100.0
CUBOID 30 17.479 -17.479 100.0 -100.0 100.0 -100.0
MEDIA 1 1 10
MEDIA 2 1 20 -10
MEDIA 3 1 30 -20 -10
BOUNDARY 30
END GEOM
READ BOUNDS ALL=MIRROR END BOUNDS
END DATA
END
```

SAMPLE PROBLEM 17 93% UO2F2 SOLUTION SPHERE ADJOINT CALCULATION

A single 93% enriched uranyl fluoride sphere is run as an adjoint calculation. The result for the forward and adjoint k-effectives should be the same within statistical error when the problem is run both ways.

INPUT DATA

```
=KENOVI  COND=500
SAMPLE PROBLEM 17 93% UO2F2 SOLUTION SPHERE ADJOINT CALCULATION
READ PARAMETERS
GEN=103 NPG=300 LNG=20000 LIB=4 AMX=YES PWT=YES
```

```

ADJ=YES
END PARAMETERS
READ MIXT SCT=2
MIX=1 7001001 6.54785E-02 7008016 3.34202E-02 7009019 6.80923E-04
      7092235 3.16909E-04 7092238 2.35521E-05
END MIXTREAD GEOMETRY
GLOBAL UNIT 1
SPHERE 10 16.0
MEDIA 1 1 10
BOUNDARY 10
END GEOM
END DATA
END

```

SAMPLE PROBLEM 18 1F27 DEMONSTRATION OF OPTIONS

A reflected cubic array of 27 cylinders of aqueous uranyl nitrate in plexiglas bottles.⁶ The walls of the bottles were 0.64-cm thick, and each bottle was filled with 5 L of 92.6% enriched solution at a concentration of 415 g/L, a specific gravity of 1.555 and 0.39* mg excess nitrate/g soln. The $3 \times 3 \times 3$ array was surrounded by a 6-in. paraffin reflector. Most of the print options available in KENO-VI are exercised in this problem. A perspective of this critical experiment is shown in Fig. F17.D.7. A photograph of one of the experiments utilized 27 of the plexiglas bottles is shown in Fig. F17.D.8. Sample problem 18 has 15.24 cm of paraffin on all six faces rather than the 2.54-cm plexiglas shown on five faces.

INPUT DATA

```

=KENOVI COND=500
SAMPLE PROBLEM 18 1F27 CRITICAL EXPERIMENT
READ PARA
GEN=103 NPG=300 LNG=35000 GEN=53 NPG=350 FDN=YES NUB=YES LIB=4
MKU=YES FMU=YES MKH=YES FMH=YES MKA=YES FMA=YES RND=F12C09ED2195
PWT=YES FAR=YES FLX=YES AMX=YES PAX=YES PGM=YES
END PARA
READ MIXT
SCT=2
MIX=1 2001001 5.77964E-02 2007014 2.13092E-03 2008016 3.74130E-02
      2092234 1.06784E-05 2092235 9.84599E-04 2092236 5.29385E-06
      2092238 6.19413E-05
MIX=2 11001001 5.68187E-02 11006012 3.55117E-02 11008016 1.42047E-02
MIX=3 10006012 3.97311E-02 10001001 8.26407E-02
MIX=4 15008016 3.33757E-11 15001001 6.67514E-11
END MIXT
EAD BOUNDS -ZB=H2O END BOUNDS
READ GEOM
UNIT 1

```

*From experimental facility documents (not reported in ORNL/TM-719).

CYLINDER 10 9.52 8.7804 -8.7804
 CYLINDER 20 9.52 8.9896 -8.7804
 CYLINDER 30 10.16 9.6296 -9.4204
 CUBOID 40 18.45 -18.45 18.45 -18.45 17.8946 -17.6854
 MEDIA 1 1 10
 MEDIA 0 1 -10 20
 MEDIA 2 1 -10 -20 30
 MEDIA 0 1 40 -20 -30
 BOUNDARY 40
 UNIT 2
 CUBOID 10 18.45 -55.35 55.35 -18.45 53.37 -17.79
 CUBOID 20 18.45 -55.35 55.35 -18.45 -17.79 -53.37
 CUBOID 30 55.35 18.45 55.35 -18.45 53.37 -53.37
 CUBOID 40 55.35 -55.35 -18.45 -55.35 53.37 -53.37
 CUBOID 50 55.35 -55.35 55.35 -55.35 53.37 -53.37
 ARRAY 1 10 PLACE 1 1 1 -36.90 0.0 -0.1046
 ARRAY 2 20 -10 PLACE 1 1 1 -36.90 0.0 -35.6846
 ARRAY 3 30 -20 -10 PLACE 1 1 1 36.90 0.0 -35.6846
 ARRAY 4 40 -30 -20 -10 PLACE 1 1 1 -36.90 -36.90 -35.6846
 MEDIA 0 1 50 -40 -30 -20 -10
 BOUNDARY 50
 GLOBAL UNIT 3
 CUBOID 10 55.35 -55.35 55.35 -55.35 53.37 -53.37
 CUBOID 20 58.35 -58.35 58.35 -58.35 56.37 -56.37
 CUBOID 30 61.35 -61.35 61.35 -61.35 59.37 -59.37
 CUBOID 40 64.35 -64.35 64.35 -64.35 62.37 -62.37
 CUBOID 50 67.35 -67.35 67.35 -67.35 65.37 -65.37
 CUBOID 60 70.59 -70.59 70.59 -70.59 68.61 -68.61
 ARRAY 5 10 PLACE 1 1 1 3*0.0
 MEDIA 3 2 -10 20
 MEDIA 3 3 -20 30
 MEDIA 3 4 -30 40
 MEDIA 3 5 -40 50
 MEDIA 3 6 60 -50
 BOUNDARY 60
 END GEOM
 READ BIAS ID=400 2 6 END BIAS
 READ ARRAY
 ARA=1 NUX=2 NUY=2 NUZ=2 FILL F1 END FILL
 ARA=2 NUX=2 NUY=2 NUZ=1 FILL F1 END FILL
 ARA=3 NUX=1 NUY=2 NUZ=3 FILL F1 END FILL
 ARA=4 NUX=3 NUY=1 NUZ=3 FILL F1 END FILL
 GBL=5 ARA=5 NUX=1 NUY=1 NUZ=1 FILL F2 END FILL
 END ARRAY
 READ PLOT
 TTL=' 1F27 XY PLOT AT Z=0.0 '
 XUL=-71.0 YUL=71.0 ZUL=0.0
 XLR=71.0 YLR=-71.0 ZLR=0.0
 UAX=1 VDN=-1 NAX=130 NCH=' *-3 '
 END PLT1
 TTL='UNIT MAP 1F27 XY PLOT AT Z=0.0 '
 PIC='UNIT NCH=' 123456'
 END PLOT END DATA
 END

Figure F17.D.7 Perspective of critical 1F27 experiment

Figure F17.D.8 View of a 27-unit cubic array with 2.54-cm-thick plexiglas reflector on five sides and a 15.24-cm-thick paraffin base

SAMPLE PROBLEM 19 4 AQUEOUS 4 METAL ARRAY OF ARRAYS (SAMP PROB 12)

This critical experiment was described previously as SAMPLE PROBLEM 12. The input data given below utilize the array of arrays option. See Fig. F17.D.3.

INPUT DATA

```
=KENOVI COND=500
SAMPLE PROBLEM 19 4 AQUEOUS 4 METAL ARRAY OF ARRAYS (SAMP PROB 12)
READ PARAM GEN=103 NPG=300 LNG=20000 LIB=4 FLX=YES FDN=YES NUB=YES SMU=YES MKP=YES
MKU=YES FMP=YES FMU=YES END PARAM
READ MIXT
MIX=1 1092234 4.82716E-04 1092235 4.47971E-02 1092236 9.57231E-05
      1092238 2.65767E-03
MIX=2 2001001 5.77964E-02 2007014 2.13092E-03 2008016 3.74130E-02
      2092234 1.06784E-05 2092235 9.84599E-04 2092236 5.29385E-06
      292238 6.19413E-05
MIX=3 11001001 5.68187E-02 11006012 3.55117E-02 11008016 1.42047E-02
SCT=2
END MIXT
READ GEOMETRY
UNIT 1
COM='URANYL NITRATE SOLUTION IN A PLEXIGLAS CONTAINER'
CYLINDER 10 9.525 2P8.89
CYLINDER 20 10.16 2P9.525
CUBOID 30 4P10.875 2P10.24
MEDIA 2 1 10
MEDIA 3 1 -10 20
MEDIA 0 1 30 -20
BOUNDARY 30
UNIT 2
COM='URANIUM METAL CYLINDER'
CYLINDER 10 5.748 2P5.3825
CUBOID 20 4P6.59 2P6.225
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 3
COM='1X2X2 ARRAY OF SOLUTION UNITS'
CUBOID 10 21.75 0.0 43.5 0.0 40.96 0.0
ARRAY 1 +10 PLACE 1 1 1 10.875 10.875 10.240
BOUNDARY 10
UNIT 4
COM='1X2X2 ARRAY OF METAL UNITS PADDED TO MATCH SOLUTION ARRAY'
CUBOID 10 13.18 0.0 26.36 0.0 24.9 0.0
CUBOID 20 13.18 0.0 34.93 -8.57 32.93 -8.03
ARRAY 2 +10 PLACE 1 1 1 6.59 6.59 6.225
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL UNIT 5
```



```

COM='GLOBAL UNIT OF ARRAYS 1 AND 2'
CUBOID 10 34.93 0.0 43.5 0.0 40.96 0.0
ARRAY 3 +10 PLACE 1 1 1 0 8.57 8.03
BOUNDARY 10
END GEOM
READ ARRAY ARA=1 NUX=1 NUY=2 NUZ=2 FILL F1 END FILL
ARA=2 NUX=1 NUY=2 NUZ=2 FILL F2 END FILL GBL=3 ARA=3 NUX=2 NUY=1 NUZ=1
COM='COMPOSITE ARRAY OF SOLUTION AND METAL UNITS'
FILL 4 3 END FILL
END ARRAY
READ PLOT
TTL=' X-Y SLICE AT Z=14.255 THRU LOWER UNITS @ METAL UNIT AXIS MIDPOINT'
XUL=-0.5 YUL=44 ZUL=14.255 XLR=36 YLR=-1 ZLR=14.255
UAX=1.0 VDN=-1.0 NAX=130 NCH='.12' END PLT1
TTL=' X-Y SLICE AT Z=26.705 THRU UPPER UNITS @ METAL UNIT AXIS MIDPOINT'
XUL=-0.5 YUL=44 ZUL=26.705 XLR=36 YLR=-1 ZLR=26.705
UAX=1.0 VDN=-1.0 NAX=130 NCH='.12' END PLT2
TTL=' X-Z SLICE AT Y=15.16 THROUGH A UNIT 1 AND A UNIT 2'
XUL=-0.5 YUL=15.16 ZUL=41. XLR=36 YLR=15.16 ZLR=-1
UAX=1.0 WDN=-1.0 NAX=130 END PLT3
TTL=' X-Z SLICE AT Y=28.34 THROUGH A UNIT 1 AND A UNIT 2'
XUL=-0.5 YUL=28.34 ZUL=41. XLR=36 YLR=28.34 ZLR=-1
UAX=1.0 WDN=-1.0 NAX=130 END PLT4
TTL=' Y-Z SLICE AT X=6.59 THROUGH ALL 4 UNITS 2'
XUL=6.59 YUL=-1 ZUL=41. XLR=6.59 YLR=45 ZLR=-1
VAX=1.0 WDN=-1.0 NAX=130 END PLT5
TTL=' Y-Z SLICE AT X=24.055 THROUGH ALL 4 UNITS 1'
XUL=24.055 YUL=-1 ZUL=41. XLR=24.055 YLR=45 ZLR=-1
VAX=1.0 WDN=-1.0 NAX=130 END PLT6
END PLOT
END DATA
END

```

SAMPLE PROBLEM 20 TRIANGULAR-PITCHED ARRAY

This problem is a critical experiment⁷ consisting of seven cylinders in a triangular-pitched unreflected array. The central cylinder has six cylinders arranged around it. The surface-to-surface separation between the units is 0.15 in. Each unit consists of a 60-mil-thick aluminum can with an 8-in. inside diameter, filled with a solution of 93.2% enriched uranyl fluoride with a $H/^{235}U$ atomic ratio of 44.3 and a density of 576.87 g U/L. The apparatus for conducting this experiment is shown in Fig. F17.D.9.

Figure F17.D.9 Typical arrangement for critical experiments with interacting arrays of aluminum cylinders containing enriched ^{235}U solutions

INPUT DATA

```
=KENOVI
SAMPLE PROBLEM 20 TRIANGULAR PITCHED ARRAY 7 PINS IN A CIRCLE
READ PARAMETERS GEN=103 NPG=300 LNG=20000 LIB=4 END PARAMETERS
READ MIXT SCT=2
MIX=1 8092235 1.37751E-03 8092238 9.92354E-05 8008016 3.32049E-02
      8009019 2.95349E-03 8001001 6.05028E-02
MIX=2 14013027 6.02374E-02
END MIXT
READ GEOMETRY
UNIT 1
COM='SINGLE CELL FUEL CAN IN HEXPRISM'
CYLINDER 10 10.16 18.288 0.0
CYLINDER 20 10.312 18.288 -0.152
HEXPRISM 30 10.503 18.288 -0.152
MEDIA 1 1 10
MEDIA 2 1 20 -10
MEDIA 0 1 30 -20
BOUNDARY 30
UNIT 2
COM='EMPTY CELL'
HEXPRISM 10 10.503 18.288 -0.152
MEDIA 0 1 10
BOUNDARY 10
GLOBAL UNIT 3
CYLINDER 10 31.500 18.288 -0.152
COM='7 CYLINDERS IN A CIRCLE WITH CYLINDRICAL BOUNDARY'
ARRAY 1 10 PLACE 3 3 1 3*0.0
BOUNDARY 10
END GEOMETRY
READ ARRAY GBL=1 TYP=TRIANGULAR NUX=5 NUY=5 NUZ=1
FILL 7*2 2*1 2*2 3*1 2*2 2*1 7*2 END FILL END ARRAY
READ PLOT
TTL='XY SLICE AT Z=9.0'
LPI=6
XUL=-33.0 YUL=33.0 ZUL=9.0 XLR=33.0 YLR=-33.0 ZLR=9.0
UAX=1 VDN=-1 NAX=130 NDN=68 NCH='*/*' END PLT1
TTL='XZ SLICE AT Y=0.0'
XUL=-33.0 YUL=0.0 ZUL=20.0 XLR=33.0 YLR=0.0 ZLR=-2.0
UAX=1 VDN=0 WDN=-1 NAX=130 NDN=20 NCH='*/*' END PLT2
TTL='YZ SLICE AT X=0.0'
XUL=0.0 YUL=-33.0 ZUL=20.0 XLR=0.0 YLR=33.0 ZLR=-2.0
UAX=0 VAX=1 WDN=-1 NAX=130 NDN=20 NCH='*/*' END PLT3
END PLOT
END DATA
END
```

SAMPLE PROBLEM 21 PARTIALLY FILLED SPHERE

This critical experiment⁸ consisted of a partially filled, unreflected spherical container. This aluminum container had an inside diameter of 27.244 in. and a wall thickness of 1/16 in. It is referred to in the report as the 27.3-in.-diam vessel. The sphere was 98% filled with uranyl fluoride at an enrichment of 4.89% with an H/²³⁵U atomic ratio of 1099. The height of the solution in the sphere was 64.6 cm above the bottom of the sphere. A schematic diagram of the apparatus used in the experiment is given in Fig. F17.D.10. The steel tank was ignored.

INPUT DATA

```
=KENOVI
SAMPLE PROBLEM 21 PARTIALLY FILLED SPHERE
READ PARAM
GEN=103 NPG=300 LNG=20000 LIB=4 END PARAM
READ MIXT SCT=2
MIX=1 9001001 6.15670E-02 9008016 3.32845E-02 9009019 2.50098E-03
      9092234 2.54223E-07 9092235 6.18922E-05 9092238 1.18834E-03
MIX=2 14013027 6.02374E-02
END MIXT
READ GEOM
GLOBAL UNIT 1
SPHERE 10 34.6 CHORD -Z=30.0
SPHERE 20 34.6
SPHERE 30 34.759
MEDIA 1 1 10
MEDIA 0 1 20 -10
MEDIA 2 1 30 -20 -10
BOUNDARY 30
END GEOM
END DATA
END
```

Figure F17.D.10 Schematic of bare partially filled sphere experiment inside a 9.5-ft-diam, 9-ft-high steel tank

SAMPLE PROBLEM 22 CASE 2C8 BARE WITH 3 NESTED HOLES, EACH IS EQUAL VOLUME

The physical representation of this sample problem is the critical experiment described in sample problem 1. It is a simple $2 \times 2 \times 2$ array of 93.2% enriched uranium metal cylinders. This sample problem defines a uranium cylinder in a void spacing cuboid using nested holes. Eight of these units are stacked together in a $2 \times 2 \times 2$ array.

INPUT DATA

```
=KENOVI
SAMPLE PROBLEM 22 CASE 2C8 BARE WITH 3 NESTED, EQUAL VOLUME HOLES
READ PARAMETERS
GEN=103 NPG=300 LNG=20000 FLX=YES FDN=YES FAR=YES LIB=4 END PARAMETERS
READ MIXT
SCT=2 MIX=1 1092234 4.82716E-04 1092235 4.47971E-02 1092236 9.57231E-05
1092238 2.65767E-03 END MIXT
READ GEOMETRY
UNIT 1
CYLINDER 10 3.621 2P3.3907
MEDIA 1 1 10
BOUNDARY 10
UNIT 2
CYLINDER 10 3.621 2P3.3907
CYLINDER 20 4.5622 2P4.2721
HOLE 1 10
MEDIA 1 1 20 -10
BOUNDARY 20
UNIT 3
CYLINDER 10 4.5622 2P4.2721
CYLINDER 20 5.2224 2P4.8903
HOLE 2 10
MEDIA 1 1 20 -10
BOUNDARY 20
UNIT 4
CYLINDER 10 4.5622 2P4.8903
CYLINDER 20 5.748 2P5.3825
CUBOID 30 6.87 -6.87 6.87 -6.87 6.505 -6.505
HOLE 3 10
MEDIA 1 1 20 -10
MEDIA 0 1 30 -20
BOUNDARY 30
GLOBAL UNIT 5
CUBOID 10 20.61 -6.87 20.61 -6.87 19.515 -6.505
ARRAY 1 10 PLACE 1 1 1 3*0.0
BOUNDARY 10
END GEOMETRY
READ ARRAY NUX=2 NUY=2 NUZ=2 FILL F4 END FILL END ARRAY
END DATA
END
```

SAMPLE PROBLEM 23 CASE 2C8 BARE AS STACKED CYLINDERS

The physical representation of this sample problem is the critical experiment described in sample problem 1. This sample problem describes each of the eight units in the critical $2 \times 2 \times 2$ array using hemicylinders with different chord sizes and directions.

INPUT DATA

```
=KENOVI
SAMPLE PROBLEM 23 CASE 2C8 BARE AS MIXED UNROTATED ZCYLINDERS
READ PARAMETERS
GEN=103 NPG=300 FDN=YES LIB=4 END PARAMETERS
READ MIXT SCT=2 MIX=1 1092234 4.82716E-04 1092235 4.47971E-02
1092236 9.57231E-05 1092238 2.65767E-03 END MIXT
READ GEOMETRY
UNIT 1
COM='-X HALF OF UNIT 3'
CYLINDER 10 5.748 5.3825 -5.3825 CHORD -X=0.0
CUBOID 20 0.0 -6.87 6.87 -6.87 6.505 -6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 2
COM='+X HALF OF UNIT 3'
CYLINDER 10 5.748 5.3825 -5.3825 CHORD +X=0.0
CUBOID 20 6.87 0.0 6.87 -6.87 6.505 -6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 3
COM='CYLINDER COMPOSED OF EQUAL HALVES (ZHEMICYLINDERS WITH X RADII)'
CUBOID 10 6.87 -6.87 6.87 -6.87 6.505 -6.505
ARRAY 1 10 PLACE 1 1 1 0.0 0.0 0.0
BOUNDARY 10
UNIT 4
COM='-X PORTION (MORE THAN HALF) OF UNIT 6'
CYLINDER 10 5.748 5.3825 -5.3825 CHORD -X=3.0
CUBOID 20 3.0 -6.87 6.87 -6.87 6.505 -6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 5
COM='+X PORTION (LESS THAN HALF) OF UNIT 6'
CYLINDER 10 5.748 5.3825 -5.3825 CHORD +X=3.0
CUBOID 20 6.87 3.0 6.87 -6.87 6.505 -6.505
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 6
```

COM='CYLINDER COMPOSED OF UNEQUAL HALVES (ZHEMICYLINDERS WITH X RADII)'
 CUBOID 10 6.87 -6.87 6.87 -6.87 6.505 -6.505
 ARRAY 2 10 PLACE 1 1 1 3*0.0
 BOUNDARY 10
 UNIT 7
 COM='CYLINDER OF A SINGLE ZHEMICYLINDER IN THE -X DIRECTION'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -X=5.748
 CUBOID 20 6.87 -6.87 6.87 -6.87 6.505 -6.505
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 8
 COM='CYLINDER OF A SINGLE ZHEMICYLINDER IN THE +X DIRECTION'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +X=-5.748
 CUBOID 20 6.87 -6.87 6.87 -6.87 6.505 -6.505
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 9
 COM='-Y HALF OF UNIT 11'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -Y=0.0
 CUBOID 20 6.87 -6.87 0.0 -6.87 6.505 -6.505
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 10
 COM='+Y HALF OF UNIT 11'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +Y=0.0
 CUBOID 20 6.87 -6.87 6.87 0.0 6.505 -6.505
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 11
 COM='CYLINDER COMPOSED OF EQUAL HALVES (ZHEMICYLINDERS WITH Y RADII)'
 CUBOID 10 6.87 -6.87 6.87 -6.87 6.505 -6.505
 ARRAY 3 10 PLACE 1 1 1 0.0 0.0 0.0
 BOUNDARY 10
 UNIT 12
 COM='-Y PORTION (MORE THAN HALF) OF UNIT 14'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -Y=3.0
 CUBOID 20 6.87 -6.87 3.0 -6.87 6.505 -6.505
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 13
 COM='+Y PORTION (LESS THAN HALF) OF UNIT 14'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +Y=3.0
 CUBOID 20 6.87 -6.87 6.87 3.0 6.505 -6.505
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20

SAMPLE PROBLEM 24 CASE 2C8 BARE AS STACKED X-ROTATED CYLINDERS

F17.D.34

INPUT DATA

=KENOVI

SAMPLE PROBLEM 24 CASE 2C8 BARE AS MIXED X-ROTATED CYLINDERS

READ PARAMETERS

GEN=103 NPG=300 RND=4C6A61962572 FDN=YES LIB=4 END PARAMETERS

READ MIXT MIX=1 1092234 4.82716E-04 1092235 4.47971E-02

1092236 9.57231E-05 1092238 2.65767E-03 SCT=2 END MIXT

READ GEOMETRY

UNIT 1

COM='-Y HALF OF UNIT 3'

CYLINDER 10 5.748 5.3825 -5.3825 CHORD -X=0.0 ROTATE A1=90 A2=90

CUBOID 20 6.505 -6.505 0.0 -6.87 6.87 -6.87

MEDIA 1 1 10

MEDIA 0 1 20 -10

BOUNDARY 20

UNIT 2

COM='+Y HALF OF UNIT 3'

CYLINDER 10 5.748 5.3825 -5.3825 CHORD +X=0.0 ROTATE A1=90 A2=90

CUBOID 20 6.505 -6.505 6.87 0.0 6.87 -6.87

MEDIA 1 1 10

MEDIA 0 1 20 -10

BOUNDARY 20

UNIT 3

COM='CYLINDER COMPOSED OF EQUAL HALVES (XHEMICYLINDERS WITH Y RADII)'

CUBOID 10 6.505 -6.505 6.87 -6.87 6.87 -6.87

ARRAY 1 10 PLACE 1 1 1 0.0 0.0 0.0

BOUNDARY 10

UNIT 4

COM='-Y PORTION (MORE THAN HALF) OF UNIT 6'

CYLINDER 10 5.748 5.3825 -5.3825 CHORD -X=3.0 ROTATE A1=90 A2=90

CUBOID 20 6.505 -6.505 3.0 -6.87 6.87 -6.87

MEDIA 1 1 10

MEDIA 0 1 20 -10

BOUNDARY 20

UNIT 5

COM='+Y PORTION (LESS THAN HALF) OF UNIT 6'

CYLINDER 10 5.748 5.3825 -5.3825 CHORD +X=3.0 ROTATE A1=90 A2=90

CUBOID 20 6.505 -6.505 6.87 3.0 6.87 -6.87

MEDIA 1 1 10

MEDIA 0 1 20 -10

BOUNDARY 20

UNIT 6

COM='CYLINDER COMPOSED OF UNEQUAL HALVES (XHEMICYLINDERS WITH Y RADII)'

CUBOID 10 6.505 -6.505 6.87 -6.87 6.87 -6.87

ARRAY 2 10 PLACE 1 1 1 3*0.0

BOUNDARY 10

UNIT 7

COM='CYLINDER OF A SINGLE XHEMICYLINDER IN THE -Y DIRECTION'

CYLINDER 10 5.748 5.3825 -5.3825 CHORD -X=5.748 ROTATE A1=90 A2=90

CUBOID 20 6.505 -6.505 6.87 -6.87 6.87 -6.87

MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 8
 COM='CYLINDER OF A SINGLE XHEMICYLINDER IN THE +Y DIRECTION'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +X=-5.748 ROTATE A1=90 A2=90
 CUBOID 20 6.505 -6.505 6.87 -6.87 6.87 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 9
 COM='-Z HALF OF UNIT 11'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -Y=0.0 ROTATE A1=90 A2=90
 CUBOID 20 6.505 -6.505 6.87 -6.87 0.0 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 10
 COM='+Z HALF OF UNIT 11'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +Y=0.0 ROTATE A1=90 A2=90
 CUBOID 20 6.505 -6.505 6.87 -6.87 6.87 0.0
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 11
 COM='CYLINDER COMPOSED OF EQUAL HALVES (XHEMICYLINDERS WITH Z RADII)'
 CUBOID 10 6.505 -6.505 6.87 -6.87 6.87 -6.87
 ARRAY 3 10 PLACE 1 1 1 0.0 0.0 0.0
 BOUNDARY 10
 UNIT 12
 COM='-Z PORTION (MORE THAN HALF) OF UNIT 14'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -Y=3.0 ROTATE A1=90 A2=90
 CUBOID 20 6.505 -6.505 6.87 -6.87 3.0 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 13
 COM='+Z PORTION (LESS THAN HALF) OF UNIT 14'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +Y=3.0 ROTATE A1=90 A2=90
 CUBOID 20 6.505 -6.505 6.87 -6.87 6.87 3.0
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 14
 COM='CYLINDER COMPOSED OF UNEQUAL HALVES (XHEMICYLINDERS WITH Z RADII)'
 CUBOID 10 6.505 -6.505 6.87 -6.87 6.87 -6.87
 ARRAY 4 10 PLACE 1 1 1 3*0.0
 BOUNDARY 10
 UNIT 15
 COM='CYLINDER OF A SINGLE XHEMICYLINDER IN THE -Z DIRECTION'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -Y=5.748 ROTATE A1=90 A2=90

```

CUBOID 20 6.505 -6.505 6.87 -6.87 6.87 -6.87
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
UNIT 16
COM='CYLINDER OF A SINGLE XHEMICYLINDER IN THE +Z DIRECTION'
CYLINDER 10 5.748 5.3825 -5.3825 CHORD +Y=-5.748 ROTATE A1=90 A2=90
CUBOID 20 6.505 -6.505 6.87 -6.87 6.87 -6.87
MEDIA 1 1 10
MEDIA 0 1 20 -10
BOUNDARY 20
GLOBAL UNIT 17
CUBOID 10 13.01 -13.01 13.74 -13.74 13.74 -13.74
ARRAY 5 10 PLACE 1 1 1 -6.505 -6.87 -6.87
BOUNDARY 10
END GEOMETRY
READ ARRAY
COM='ARRAY 1 DEFINES UNIT 3 (XHEMICYLINDERS WITH Y RADII)'
ARA=1 NUX=1 NUY=2 NUZ=1 FILL 1 2 END FILL
COM='ARRAY 2 DEFINES UNIT 6 (XHEMICYLINDERS WITH Y RADII)'
ARA=2 NUX=1 NUY=2 NUZ=1 FILL 4 5 END FILL
COM='ARRAY 3 DEFINES UNIT 11 (XHEMICYLINDERS WITH Z RADII)'
ARA=3 NUX=1 NUY=1 NUZ=2 FILL 9 10 END FILL
COM='ARRAY 4 DEFINES UNIT 14 (XHEMICYLINDERS WITH Z RADII)'
ARA=4 NUX=1 NUY=1 NUZ=2 FILL 12 13 END FILL
COM='ARRAY 5 DEFINES THE TOTAL 2C8 PROBLEM'
ARA=5 NUX=2 NUY=2 NUZ=2 FILL 3 7 6 8 11 15 14 16 END FILL
END ARRAY
END DATA
END

```

SAMPLE PROBLEM 25 CASE 2C8 BARE AS MIXED YHEMICYLINDERS

The physical representation of this sample problem is the critical experiment described in sample problem 1 except the long axis of the cylinders are oriented along the y-axis. This sample problem describes each of the eight units in the critical $2 \times 2 \times 2$ array using hemicylinders with different chord sizes and directions whose long axes are rotated in the y-direction.

INPUT DATA

```

=KENOVI
SAMPLE PROBLEM 25 CASE 2C8 BARE AS MIXED Y-ROTATED CYLINDERS
READ PARAMETERS
GEN=103 NPG=300 FDN=YES LIB=4 END PARAMETERS
READ MIXT MIX=1 1092234 4.82716E-04 1092235 4.47971E-02
1092236 9.57231E-05 1092238 2.65767E-03 SCT=2 END MIXT
READ GEOMETRY
UNIT 1

```

COM='-X HALF OF UNIT 3'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -Y=0.0 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 0.0 -6.87 6.505 -6.505 6.87 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 2
 COM='+X HALF OF UNIT 3'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +Y=0.0 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 0.0 6.505 -6.505 6.87 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 3
 COM='CYLINDER COMPOSED OF EQUAL HALVES (YHEMICYLINDERS WITH X RADII)'
 CUBOID 10 6.87 -6.87 6.505 -6.505 6.87 -6.87
 ARRAY 1 10 PLACE 1 1 1 0.0 0.0 0.0
 BOUNDARY 10
 UNIT 4
 COM='-X PORTION (MORE THAN HALF) OF UNIT 6'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -Y=3.0 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 3.0 -6.87 6.505 -6.505 6.87 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 5
 COM='+X PORTION (LESS THAN HALF) OF UNIT 6'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +Y=3.0 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 3.0 6.505 -6.505 6.87 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 6
 COM='CYLINDER COMPOSED OF UNEQUAL HALVES (YHEMICYLINDERS WITH X RADII)'
 CUBOID 10 6.87 -6.87 6.505 -6.505 6.87 -6.87
 ARRAY 2 10 PLACE 1 1 1 3*0.0
 BOUNDARY 10
 UNIT 7
 COM='CYLINDER OF A SINGLE YHEMICYLINDER IN THE -X DIRECTION'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -Y=5.748 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 -6.87 6.505 -6.505 6.87 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 8
 COM='CYLINDER OF A SINGLE YHEMICYLINDER IN THE +X DIRECTION'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +Y=-5.748 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 -6.87 6.505 -6.505 6.87 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20

UNIT 9
 COM='-Z HALF OF UNIT 11'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -X=0.0 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 -6.87 6.505 -6.505 0.0 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 10
 COM='+Z HALF OF UNIT 11'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +X=0.0 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 -6.87 6.505 -6.505 6.87 0.0
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 11
 COM='CYLINDER COMPOSED OF EQUAL HALVES (YHEMICYLINDERS WITH Z RADII)'
 CUBOID 10 6.87 -6.87 6.505 -6.505 6.87 -6.87
 ARRAY 3 10 PLACE 1 1 1 0.0 0.0 0.0
 BOUNDARY 10
 UNIT 12
 COM='-Z PORTION (MORE THAN HALF) OF UNIT 14'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -X=3.0 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 -6.87 6.505 -6.505 3.0 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 13
 COM='+Z PORTION (LESS THAN HALF) OF UNIT 14'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +X=3.0 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 -6.87 6.505 -6.505 6.87 3.0
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 14
 COM='CYLINDER COMPOSED OF UNEQUAL HALVES (YHEMICYLINDERS WITH Z RADII)'
 CUBOID 10 6.87 -6.87 6.505 -6.505 6.87 -6.87
 ARRAY 4 10 PLACE 1 1 1 3*0.0
 BOUNDARY 10
 UNIT 15
 COM='CYLINDER OF A SINGLE YHEMICYLINDER IN THE -Z DIRECTION'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD -X=5.748 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 -6.87 6.505 -6.505 6.87 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10
 BOUNDARY 20
 UNIT 16
 COM='CYLINDER OF A SINGLE YHEMICYLINDER IN THE +Z DIRECTION'
 CYLINDER 10 5.748 5.3825 -5.3825 CHORD +X=-5.748 ROTATE A1=180 A2=90 A3=90
 CUBOID 20 6.87 -6.87 6.505 -6.505 6.87 -6.87
 MEDIA 1 1 10
 MEDIA 0 1 20 -10

```

BOUNDARY 20
GLOBAL UNIT 17
CUBOID 10 13.74 -13.74 13.01 -13.01 13.74 -13.74
ARRAY 5 10 PLACE 1 1 1 -6.87 -6.505 -6.87
BOUNDARY 10
END GEOMETRY
READ ARRAY
COM='ARRAY 1 DEFINES UNIT 3 (YHEMICYLINDERS WITH Z RADII)'
ARA=1 NUX=2 NUZ=1 FILL 1 2 END FILL
COM='ARRAY 2 DEFINES UNIT 6 (YHEMICYLINDERS WITH Z RADII)'
ARA=2 NUX=2 NUZ=1 FILL 4 5 END FILL
COM='ARRAY 3 DEFINES UNIT 11 (YHEMICYLINDERS WITH X RADII)'
ARA=3 NUX=1 NUZ=2 FILL 9 10 END FILL
COM='ARRAY 4 DEFINES UNIT 14 (YHEMICYLINDERS WITH X RADII)'
ARA=4 NUX=1 NUZ=2 FILL 12 13 END FILL
COM='ARRAY 5 DEFINES THE TOTAL 2C8 PROBLEM'
GBL=5 ARA=5 NUX=2 NUZ=2 FILL 3 7 6 8 11 15 14 16 END FILL
END ARRAY
END DATA
END

```

F17.D.2 SAMPLE PROBLEM WORKING FORMAT LIBRARY

The KENO VI sample problems use nuclide IDs that are consistent with the SCALE 4.3 CSAS nuclide ID naming convention. The first time a nuclide is encountered, its ZA number is used. Nuclides are identified by the ZA number plus 1000000 times the mixture number. Either CSASN or the BONAMI/NITAWL explicit sequence can be used to create a problem-dependent working-format cross-section library suitable for use with the sample problems. CSASN or the BONAMI/NITAWL sequence can (1) be run alone with logical unit 4 of the job control language saved for later use with the KENO-VI sample problems, or (2) be placed in the job stream in front of the KENO VI sample problems

The CSASN SCALE control module is easy to use because it calculates the necessary resonance data required to create the problem-dependent AMPX working-format library. It is recommended that the SCALE 4.3 version of CSASN be used if it is operational at the installation where the problems are to be run. CSASN is one of the control modules associated with CSAS4 or CSAS6 and is automatically operational if CSAS4 or CSAS6 is operational. See Sect. C4 or C6 of the SCALE manual for assistance in using CSASN. If the SCALE DRIVER and the control modules are not operational at your installation, the SCALE 4.3 version of BONAMI and NITAWL should be used to create the problem-dependent AMPX working format cross-section library. Obtaining accurate resonance data for BONAMI and NITAWL may be difficult. See Sect. F1 and F2 of the SCALE manual for assistance in using BONAMI and NITAWL.

The KENO-VI sample problem input data are independent of energy group structure. However, if a cross-section library containing BONARENKO shielding factors is used, BONAMI must be run before NITAWL to provide the Bondarenko corrections necessary for the this library. If CSASN is used to create the AMPX working-format cross-section library, the Bondarenko corrections are automatically performed when necessary. To use a different master library, simply supply the desired master cross-section library name in the CSASN data.

See Sects. M7.5.3, M7.5.4, and C4.5.2 for additional information and examples. See Sect. M4 for information about the master format cross-section libraries that are available in SCALE.

Data for both CSASN and the BONAMI/NITAWL sequence are provided to create a problem-dependent AMPX working-format cross-section library suitable for use with the KENO-VI sample problems. These data,

which include all of the mixtures used in the 25 KENO-VI sample problems, will create an AMPX working-format cross-section library. The nuclide IDs from the BONAMI/NITAWL sequence match those in the KENO-VI sample problem mixing tables.. *This cross-section library is problem-specific and is not appropriate for use with other problems.* None of the KENO-VI sample problems involve arrays of pins. Therefore, Dancoff corrections have not been incorporated into any of the nuclides in this library.

F17.D.2.1 CSASN Data

The CSASN input data to produce an AMPX working-format cross-section library for the KENO-VI sample problems are given on the following page.

```
=CSASN
CSASN TO PREPARE 27 GROUP WORKING FORMAT XSEC LIB FOR KENOVA SMP PRBS
27GROUP INF
'URANIUM METAL FOR SMP PRBS 1,2,3,4,5,6,7,8,9,10,11,12,19,22,23,24,25
URANIUM 1 DEN=18.76 1 293 92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
'URANYL NITRATE SOLUTION FOR SMP PRBS 12,18,19
SOLNUO2(NO3)2 2 415 9.783-3 SPG=1.555 1.0 293 92235 92.6 92238 5.9
92234 1.0 92236 0.5 END
'URANIUM METAL FOR SMP PRBS 13,14
URANIUM 3 DEN=18.69 1 293 92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
'URANIUM METAL FOR SMP PRB 15
URANIUM 4 DEN=18.794 1 293 92235 97.67 92238 0.98
92234 1.17 92236 0.20 END
'URANYL FLUORIDE SOLUTION FOR SMP PRB 16
SOLNUO2F2 5 578.7 0 1.0 293 92235 93.2 92238 6.8 END
'BORATED URANYL FLUORIDE SOLUTION FOR SMP PRB 16
SOLNUO2F2 6 578.7 0 1.0 293 92235 93.2 92238 6.8 END
BORON 6 DEN=.0266 END
'URANYL FLUORIDE SOLUTION FOR SMP PRB 17
SOLNUO2F2 7 133 0 1.0 293 92235 93.0 92238 7 END
'URANYL FLUORIDE SOLUTION FOR SMP PRB 20
SOLNUO2F2 8 576.87 0 1.0 293 92235 93.2 92238 6.8 END
'URANYL FLUORIDE SOLUTION FOR SMP PRB 21
SOLNUO2F2 9 494 0 SPG= 1.56 1 293 92235 4.89 92238 95.09 92234 0.02 END
'PARAFFIN FOR SMP PRBS 3,4
PARA(H2O) 10 END
'PLEXIGLAS FOR SMP PRBS 12,15,19
PLEXIGLAS 11 END
'WATER FOR SMP PRBS 15
H2O 12 END
'PYREX GLASS FOR SMP PRB 16
PYREX 13 END
'ALUMINUM FOR SMP PRB 21
AL 14 END
'LOW DENSITY WATER FOR SMP PRB 18
H2O 15 1-9 END
END COMP
END
```


F17.D.2.2 BONAMI Data

The BONAMI input data to produce an AMPX working-format cross-section library for the KENO-VI sample problems are given below. This input is only required if BONDARENKO shielding factors are used for the referenced nuclides in the specified master cross-section library. If the SCALE DRIVER is not used, the first (=BONAMI) and last (END) records should be omitted from the BONAMI data.

=BONAMI

0\$\$ 82 A4 1

1\$\$ 2 20 79 0 0 0

2** .0001 1.35 1T

3\$\$ 1 2 3 4 5 6 7 8 9 16 17 20

1 2 3 4 5 6 7 8 9 16 17 20

1 2 3 4 9 16 17 20

1 2 3 4 16 17 20

2 2 5 6 7 8 9 11 12 13 15 18 19 2 5 6 7 8 9 10 11 12 15

18 19 5 6 7 8 9 6 13 6 13 10 11 13 14 13 13

4\$\$ 92235 92235 92235 92235 92235 92235 92235 92235 92235 92235

92235

92238 92238 92238 92238 92238 92238 92238 92238 92238 92238

92238

92234 92234 92234 92234 92234 92234 92234 92234

92236 92236 92236 92236 92236 92236 92236

7014 8016 8016 8016 8016 8016 8016 8016 8016

8016 8016 8016 8016 1001 1001 1001 1001 1001 1001

1001 1001 1001 1001 1001 9019 9019 9019 9019 9019

5010 5010 5011 6012 6012 13027 13027 14000 11023

5** 4.47971E-02 9.84601E-04 4.46299E-02 4.70211E-02 1.38188E-03

1.38188E-03 3.16910E-04 1.37751E-03 6.18924E-05 4.47708E-02

9.49269E-04 9.49269E-04

2.65767E-03 6.19414E-05 2.64776E-03 4.65936E-04 9.95504E-05

9.95504E-05 2.35521E-05 9.92356E-05 1.18834E-03 2.73631E-03

4.71245E-02 4.71245E-02

4.82717E-04 1.06784E-05 4.80915E-04 5.65802E-04 2.54224E-07

4.74857E-04 9.77784E-07 9.77784E-07

9.57232E-05 5.29386E-06 9.53660E-05 9.58967E-05 1.71704E-05

2.90843E-06 2.90843E-06

2.13092E-03 3.74130E-02 3.32040E-02 3.32040E-02 3.34202E-02

3.32049E-02 3.32845E-02 1.42047E-02 3.33757E-02 4.49174E-02

3.33757E-11 3.33757E-02 3.33757E-02 5.77964E-02 6.04824E-02

6.04824E-02 6.54785E-02 6.05029E-02 6.15670E-02 8.26407E-02

5.68187E-02 6.67514E-02 6.67514E-11 6.67514E-02 6.67514E-02

2.96286E-03 2.96286E-03 6.80924E-04 2.95349E-03 2.50098E-03

2.92804E-04 9.08242E-04 1.18870E-03 3.68719E-03 3.97311E-02

3.55117E-02 4.97719E-04 6.02374E-02 1.80268E-02 2.39502E-03

10\$\$ 1092235 2092235 3092235 4092235 5092235 6092235 7092235

8092235 9092235 16092235 17092235 20092235

1092238 2092238 3092238 4092238 5092238 6092238 7092238

8092238 9092238 16092238 17092238 20092238

1092234 2092234 3092234 4092234 9092234 16092234 17092234

```

20092234
1092236 2092236 3092236 4092236 16092236 17092236 20092236
2007014
2008016 5008016 6008016 7008016 8008016 9008016 11008016
12008016 13008016 15008016 18008016 19008016
2001001 5001001 6001001 7001001 8001001 9001001 10001001
11001001 12001001 15001001 18001001 19001001
5009019 6009019 7009019 8009019 9009019
6005010 13005010 6005011 13005011 10006012 11006012 13013027
14013027
13014000 13011023
6$$$ 18 17 19 14I1 16 20
7** 3.302 9.144 10.9355 15I15.9355 95.9355
8** F293 9** F0 A2 .0952248 E
11$$$ F0 2T
END

```

F17.D.2.3 NITAWL Data

The NITAWL input data to produce an AMPX working-format cross-section library for the KENO-VI sample problems are given below. If the SCALE DRIVER is not used, the first (=NITAWL) and last (END) records should be omitted from the NITAWL data.

```

=NITAWL
0$$$ 1 E 1$$$ 2001 79 A8 40 2 E 1T
2$$$
1092235 2092235 3092235 4092235 5092235 6092235 7092235 8092235
9092235 16092235 17092235 20092235
1092238 2092238 3092238 4092238 5092238 6092238 7092238 8092238
9092238 16092238 17092238 20092238
1092234 2092234 3092234 4092234 9092234 16092234 17092234 20092234
1092236 2092236 3092236 4092236 16092236 17092236 20092236
2007014
2008016 5008016 6008016 7008016 8008016 9008016 11008016 12008016
13008016 15008016 18008016 19008016
2001001 5001001 6001001 7001001 8001001 9001001 10001001 11001001
12001001 15001001 18001001 19001001
5009019 6009019 7009019 8009019 9009019
6005010 13005010
6005011 13005011
10006012 11006012
13013027 14013027
13014000
13011023
3**
1092235 293.00 0 0.0 0.0 0.0 4.47971E-02 1 238.051 4.92413E-01
1 234.370 1.35581E-01 1 1.0000
2092235 293.00 0 0.0 0.0 0.0 9.84601E-04 1 1.008 1.19749E+03
1 15.767 1.64828E+02 1 1.0000
3092235 293.00 0 0.0 0.0 0.0 4.46299E-02 1 238.051 4.92413E-01

```

1 234.370 1.35581E-01 1 1.0000
 4092235 293.00 0 0.0 0.0 0.0 4.70211E-02 1 234.041 1.26346E-01
 1 237.634 1.03660E-01 1 1.0000
 5092235 293.00 0 0.0 0.0 0.0 1.38188E-03 1 1.008 8.92870E+02
 1 16.294 9.84222E+01 1 1.0000
 6092235 293.00 0 0.0 0.0 0.0 1.38188E-03 1 1.008 8.92870E+02
 1 15.951 1.02996E+02 1 1.0000
 7092235 293.00 0 0.0 0.0 0.0 3.16910E-04 1 1.008 4.21496E+03
 1 16.068 4.03814E+02 1 1.0000
 8092235 293.00 0 0.0 0.0 0.0 1.37751E-03 1 1.008 8.96007E+02
 1 16.294 9.87105E+01 1 1.0000
 9092235 293.00 0 0.0 0.0 0.0 6.18924E-05 1 1.008 2.02927E+04
 1 17.317 2.32155E+03 1 1.0000
 16092235 293.00 0 0.0 0.0 0.0 4.47708E-02 1 238.051 5.07281E-01
 1 234.110 1.15394E-01 1 1.0000
 17092235 293.00 2 9.14400E+00 4.10601E-03 3.30200E+00 9.49269E-04
 1 238.051 4.12036E+02 1 235.538 4.29860E-02 1 1.0000
 20092235 293.00 1 5.84200E+00 1.00000E+00 0.00000E+00 9.49269E-04
 1 238.051 4.12036E+02 1 235.538 4.29860E-02 1 1.0000
 1092238 293.00 0 0.0 0.0 0.0 2.65767E-03 1 235.044 1.76985E+02
 1 234.370 2.28531E+00 1 1.0000
 2092238 293.00 0 0.0 0.0 0.0 6.19414E-05 1 1.008 1.90349E+04
 1 16.689 2.77866E+03 1 1.0000
 3092238 293.00 0 0.0 0.0 0.0 2.64776E-03 1 235.044 1.76985E+02
 1 234.370 2.28531E+00 1 1.0000
 4092238 293.00 0 0.0 0.0 0.0 4.65936E-04 1 235.044 1.05963E+03
 1 234.329 1.49116E+01 1 1.0000
 5092238 293.00 0 0.0 0.0 0.0 9.95504E-05 1 1.008 1.23941E+04
 1 17.868 1.50367E+03 1 1.0000
 6092238 293.00 0 0.0 0.0 0.0 9.95504E-05 1 1.008 1.23941E+04
 1 17.427 1.56716E+03 1 1.0000
 7092238 293.00 0 0.0 0.0 0.0 2.35521E-05 1 1.008 5.67151E+04
 1 16.448 5.56657E+03 1 1.0000
 8092238 293.00 0 0.0 0.0 0.0 9.92356E-05 1 1.008 1.24377E+04
 1 17.862 1.50767E+03 1 1.0000
 9092238 293.00 0 0.0 0.0 0.0 1.18834E-03 1 1.008 1.05690E+03
 1 16.245 1.13160E+02 1 1.0000
 16092238 293.00 0 0.0 0.0 0.0 2.73631E-03 1 235.044 1.71798E+02
 1 234.110 1.88805E+00 1 1.0000
 17092238 293.00 2 9.14400E+00 4.10601E-03 3.30200E+00 4.71245E-02
 1 235.044 2.11511E-01 1 235.538 8.65905E-04 1 1.0000
 20092238 293.00 1 5.84200E+00 1.00000E+00 0.00000E+00 4.71245E-02
 1 235.044 2.11511E-01 1 235.538 8.65905E-04 1 1.0000
 1092234 293.00 0 0.0 0.0 0.0 4.82717E-04 1 235.044 9.74421E+02
 1 237.963 4.77791E+01 1 1.0000
 2092234 293.00 0 0.0 0.0 0.0 1.06784E-05 1 1.008 1.10414E+05
 1 16.727 1.61556E+04 1 1.0000
 3092234 293.00 0 0.0 0.0 0.0 4.80915E-04 1 235.044 9.74422E+02
 1 237.963 4.77791E+01 1 1.0000
 4092234 293.00 0 0.0 0.0 0.0 5.65802E-04 1 235.044 8.72604E+02
 1 237.634 8.61464E+00 1 1.0000

9092234 293.00 0 0.0 0.0 0.0 2.54224E-07 1 1.008 4.94039E+06
 1 17.392 5.67741E+05 1 1.0000
 16092234 293.00 0 0.0 0.0 0.0 4.74857E-04 1 235.044 9.89970E+02
 1 238.035 4.82075E+01 1 1.0000
 17092234 293.00 2 9.14400E+00 4.10601E-03 3.30200E+00 9.77784E-07
 1 238.051 4.00020E+05 1 235.047 1.02250E+04 1 1.0000
 20092234 293.00 1 5.84200E+00 1.00000E+00 0.00000E+00 9.77784E-07
 1 238.051 4.00020E+05 1 235.047 1.02250E+04 1 1.0000
 1092236 293.00 0 0.0 0.0 0.0 9.57232E-05 1 235.044 4.91385E+03
 1 237.291 2.83392E+02 1 1.0000
 2092236 293.00 0 0.0 0.0 0.0 5.29386E-06 1 1.008 2.22720E+05
 1 16.732 3.25986E+04 1 1.0000
 3092236 293.00 0 0.0 0.0 0.0 9.53660E-05 1 235.044 4.91385E+03
 1 237.291 2.83392E+02 1 1.0000
 4092236 293.00 0 0.0 0.0 0.0 9.58967E-05 1 235.044 5.14847E+03
 1 235.606 1.02279E+02 1 1.0000
 16092236 293.00 0 0.0 0.0 0.0 1.71704E-05 1 235.044 2.73781E+04
 1 237.319 1.61309E+03 1 1.0000
 17092236 293.00 2 9.14400E+00 4.10601E-03 3.30200E+00 2.90843E-06
 1 238.051 1.34482E+05 1 235.043 3.43057E+03 1 1.0000
 20092236 293.00 1 5.84200E+00 1.00000E+00 0.00000E+00 2.90843E-06
 1 238.051 1.34482E+05 1 235.043 3.43057E+03 1 1.0000
 13011023 293.00 0 0.0 0.0 0.0 2.39502E-03 1 15.995 7.03292E+01
 1 18.466 2.41785E+01 1 1.0000

3T

3\$\$

1092235 14s 2092235 14s 3092235 14s 4092235 14s 5092235 14s
 6092235 14s 7092235 14s 8092235 14s 9092235 14s 16092235 14s
 17092235 14s 20092235 14s
 1092238 14s 2092238 14s 3092238 14s 4092238 14s 5092238 14s
 6092238 14s 7092238 14s 8092238 14s 9092238 14s 16092238 14s
 17092238 14s 20092238 14s
 1092234 14s 2092234 14s 3092234 14s 4092234 14s 9092234 14s
 16092234 14s 17092234 14s 20092234 14s
 1092236 14s 2092236 14s 3092236 14s 4092236 14s 16092236 14s
 17092236 14s 20092236 14s
 13011023 14s e
 END

F17.D.3 REFERENCES

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2. G. E. Whitesides and J. T. Thomas, "The Use of Differential Current Albedos in Monte Carlo Criticality Calculations," *Trans. Am. Nucl. Soc.* **12**, 889 (November 1969).
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4. D. C. Irving and J. T. Mihalczo, "Monte Carlo Calculations for Enriched Uranium Metal Assemblies," *Trans. Am. Nucl. Soc.* 7, 284 (November 1964).
5. Cleo C. Byers et al., "Critical Measurements of a Water-Reflected Enriched Uranium Sphere," *Trans. Am. Nucl. Soc.* 27, 412 (November 1977).
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7. J. K. Fox, L. W. Gilley, D. Callihan, *Critical Mass Studies, Part IX Aqueous U-235 Solutions*, ORNL-2367, Union Carbide Corp., Nucl. Div., Oak Ridge Natl. Lab., February 1958.
8. D. F. Cronin, *Critical Mass Studies, Part X Uranium of Intermediate Enrichment*, ORNL-2968, Union Carbide Corp., Nucl. Div., September 1960.

F17.E SELECTED OUTPUT FROM KENO V.a SAMPLE PROBLEMS

The computer output on the following pages is an example of the output for sample problems 4 and 19 described in Sect. F17.D.

[illegible]

```
*****
*****                               *****
*****      program verification information      *****
*****                               *****
*****      code system:    scale version:    4.2      *****
*****                               *****
*****-----*****
*****                               *****
*****                               *****
*****      program: kenovi      *****
*****                               *****
*****      creation date: 06/23/95      *****
*****                               *****
*****      library: /scale/exe      *****
*****                               *****
*****                               *****
*****      production code: kenovi      *****
*****                               *****
*****      version: 2.0      *****
*****                               *****
*****      jobname: dfz      *****
*****                               *****
*****      date of execution: 07/12/95      *****
*****                               *****
*****      time of execution: 14:58:22      *****
*****                               *****
*****-----*****
*****-----*****
*****-----*****
*****-----*****
```



```

*****
***                               ***
***      keno-vi sample problem 4  2c8  15.24 cm paraffin refl      ***
***                               ***
*****      numeric parameters      *****
***                               ***
***      tme      maximum problem time (min)      30.00      ***
***      tba      time per generation (min)      .50      ***
***      gen      number of generations      103      ***
***      npg      number per generation      300      ***
***      nsk      number of generations to be skipped      3      ***
***      beg      beginning generation number      1      ***
***      res      generations between checkpoints      0      ***
***      xld      number of extra 1-d cross sections      1      ***
***      nbk      neutron bank size      325      ***
***      xnb      extra positions in neutron bank      0      ***
***      nfb      fission bank size      300      ***
***      xfb      extra positions in fission bank      0      ***
***      sig      cut off standard deviation      .0000      ***
***      wta      default value of weight average      .5000      ***
***      wth      weight high for splitting      3.0000      ***
***      wtl      weight low for russian roulette      .3333      ***
***      rnd      starting random number      00000BB827100001      ***
***      nb8      number of d.a. blocks on unit 8      200      ***
***      nl8      length of d.a. blocks on unit 8      512      ***
***      adj      mode of calculation      forward      ***
***      input data written on restart unit      no      ***
***      binary data interface      no      ***
***                               ***
*****

```

```

*****
***
***          keno-vi sample problem 4  2c8  15.24 cm paraffin refl
***
*****          logical parameters          *****
***
*** run  execute problem after checking data  yes          plt  plot picture map(s)          yes ***
*** flx  compute flux                        yes          fdn  compute fission densities        yes ***
*** smu  compute avg unit self-multiplication  no          nub  compute nu-bar & avg fission group    yes ***
*** mku  compute matrix k-eff by unit number  no          mkp  compute matrix k-eff by unit location  no ***
*** cku  compute cofactor k-eff by unit number no          ckp  compute cofactor k-eff by unit location no ***
*** fmu  print fiss prod matrix by unit number no          fmp  print fiss prod matrix by unit location no ***
*** mkh  compute matrix k-eff by hole number  no          mka  compute matrix k-eff by array number  no ***
*** ckh  compute cofactor k-eff by hole number no          cka  compute cofactor k-eff by array number no ***
*** fmh  print fiss prod matrix by hole number no          fma  print fiss prod matrix by array number no ***
*** hhl  collect matrix by highest hole level no          hal  collect matrix by highest array level no ***
*** amx  print all mixed cross sections        no          far  print fis. and abs. by region        no ***
*** xs1  print 1-d mixture x-sections          no          gas  print far by group                    no ***
*** xs2  print 2-d mixture x-sections          no          pax  print xsec-albedo correlation tables  no ***
*** xap  print mixture angles & probabilities  no          pwt  print weight average array          yes ***
*** pki  print fission spectrum                no          pgm  print input geometry                no ***
*** pld  print extra 1-d cross sections        no          bug  print debug information              no ***
***                                           trk  print tracking information          no ***
***
*****
parameter input completed

.....  0 io's were used reading the parameter data  .....

***** data reading completed *****

```

```

*****
***                               ***
***      keno-vi sample problem 4  2c8  15.24 cm paraffin refl  ***
***                               ***
*****
***                               ***
***      unit      data set name      volume      unit function      ***
***      number      -----      name      -----      ***
***                               ***
***      xsc  14      ft14f001                               mixed cross sections  ***
***                               ***
***      alb  79      /scale/datalib/albedos                input albedos        ***
***                               ***
***      wts  80      /scale/datalib/weights                input weights        ***
***                               ***
***      skt  16      unknown                                write scratch data    ***
***                               ***
***      lib  4      ft04f001                                input ampx working library  ***
***                               ***
***                               8      ft08f001                input data direct access  ***
***                               ***
***                               9      unknown                super grouped direct access  ***
***                               ***
***                               10     unknown                xsec mixing direct access  ***
***                               ***
*****

```

..... 0 io's were used preparing input data

cross sections read from the ampx working library on unit 4

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

mixing table

number of scattering angles = 2
cross section message threshold =3.0E-05

mixture = 1		density(g/cc) = 18.760				nuclide title		
nuclide	atom-dens.	wgt. frac.	za	awt				
08/12/94 92234	4.82716E-04	9.99999E-03	92234	234.0405	uranium-234	endf/b-iv mat 1043		updated
08/12/94 92235	4.47971E-02	9.32000E-01	92235	235.0441	uranium-235	endf/b-iv mat 1261		updated
08/12/94 92236	9.57231E-05	2.00000E-03	92236	236.0458	u-236 1163 sigo=5+4 newxlacs p-3 293k f-1/e-m(1.+5)			updated
08/12/94 92238	2.65767E-03	5.60000E-02	92238	238.0510	uranium-238	endf/b-iv mat 1262		updated
mixture = 2		density(g/cc) = .92999						
nuclide	atom-dens.	wgt. frac.	za	awt		nuclide title		
08/12/94 1001001	8.26407E-02	1.48689E-01	1001	1.0077	hydrogen	endf/b-iv mat 1269/thrm1002		updated
08/12/94 6012	3.97311E-02	8.51311E-01	6000	12.0001	carbon-12	endf/b-iv mat 1274/thrm1065		updated

1001001	hydrogen	endf/b-iv mat 1269/thrm1002	updated 08/12/94
6012	carbon-12	endf/b-iv mat 1274/thrm1065	updated 08/12/94
92234	uranium-234	endf/b-iv mat 1043	updated 08/12/94
92235	uranium-235	endf/b-iv mat 1261	updated 08/12/94
92236	u-236 1163 sigo=5+4 newxlacs p-3 293k f-1/e-m(1.+5)		updated 08/12/94
92238	uranium-238	endf/b-iv mat 1262	updated 08/12/94

0keno message number k6-222

2 transfers for mixture 2 were corrected for bad moments.

..... 0 io's were used mixing cross-sections

1-d cross section array id numbers

1 2002 1452 27 18 1018

..... 0 io's were used preparing the cross sections

```

*****
***      keno-vi sample problem 4  2c8  15.24 cm paraffin refl      ***
***      ***** additional information *****                      ***
***      number of energy groups      27      use lattice geometry      yes ***
***      no. of fission spectrum source group 1      global array number      1 ***
***      no. of scattering angles in xsecs  2      number of units in the global x dir.      2 ***
***      entries/neutron in the neutron bank 24      number of units in the global y dir.      2 ***
***      entries/neutron in the fission bank 14      number of units in the global z dir.      2 ***
***      number of mixtures used      2      use a global reflector      yes ***
***      number of bias id's used      7      use nested holes      no ***
***      number of differential albedos used 0      number of holes      0 ***
***      total input geometry regions      9      maximum hole nesting level      0 ***
***      number of geometry regions used      9      use nested arrays      no ***
***      largest geometry unit number      2      number of arrays used      1 ***
***      largest array number      1      maximum array nesting level      1 ***
***      +x boundary condition      vacuum      -x boundary condition      vacuum ***
***      +y boundary condition      vacuum      -y boundary condition      vacuum ***
***      +z boundary condition      vacuum      -z boundary condition      vacuum ***
*****

```

```

*****
***      keno-vi sample problem 4  2c8  15.24 cm paraffin refl      ***
***      ***** space and supergroup information *****          ***
***      20000 words is the total space available.                  ***
***      14083 words were used for non-supergroup storage.          ***
***      5917 words of storage are available for supergrouped data. ***
***      19880 words of storage are available for constructing the supergroups. ***
***      5857 words of storage are available to each supergroup.    ***
***      340 words are needed for the largest group.                ***
***      14639 words of storage is sufficient to run this problem.  ***
***      18799 words of storage will allow the problem to run with one supergroup. ***
***      18976 words of storage will be used to run this problem.  ***
***
*****
***      starting      ending      xsec      albedo      total
***      supergroup    group      group    length    length    length
***
***      1              1          27        678         0        4656
***
*****
.....  0 io's were used in supergrouping  .....
.....  0 io's were used loading the data   .....

```

```

*****
***
***
***** geometry parameters *****
***
***
***      niar      number of independent array references      1      ***
***
***      ngblu     global unit number                          2      ***
***
***      nboxt     number of units in the problem              2      ***
***
***      nquad     number of quadratics in the problem          26     ***
***
***      ngwrds    number of geometry words read               9      ***
***
***      maxgwd    maximum geometry words in a unit            7      ***
***
***      maxsfu    largest number of surfaces in a unit         21     ***
***
***      maxreg    largest number of media in a unit            7      ***
***
***      regtot    number of spatial volumes defined            9      ***
***
***      sectot    number of entries in the sector array        53     ***
***
***      nucom     number of comments in the geometry data      2      ***
***
***      numhol    number of holes in the problem               0      ***
***
*****

```

keno-vi sample problem 4 2c8 15.24 cm paraffin refl
 geometry description for those units utilized in this problem

```

----- unit 1 -----
single 2c8 unit centered
1 cylinder 10
-1.000x**2 -1.000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 33.040
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 28.971
2 cuboid 20
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 137.828
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 137.828
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 129.391
sector
definitions
media 1 1 10
media 0 1 20 -10
boundary 20

```

***** global *****
 ----- unit 2 -----

```

2x2x2 2c8 array with reflector
1 cuboid 10
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 551.310
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 551.310
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 517.562
2 cuboid 20
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 701.190
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 701.190
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 663.062
3 cuboid 30
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 869.070
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 869.070
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 826.562
4 cuboid 40
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 1054.950
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 1054.950
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 1008.062
5 cuboid 50
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 1258.830
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 1258.830
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 1207.562
6 cuboid 60
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 1480.710
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 1480.710
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 1425.062
7 cuboid 70
-1.000x**2 .000y**2 .000z**2 .000xy quadratic surfaces
.000x**2 -1.000y**2 .000z**2 .000xy .000xz .000yz .000x .000y .000z 1499.238
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 1499.238
.000x**2 .000y**2 -1.000z**2 .000xy .000xz .000yz .000x .000y .000z 1443.240
sector
definitions
array 1 1 10
media 2 2 -10 20
media 2 3 -20 30
media 2 4 -30 40
media 2 5 -40 50
media 2 6 -50 60
media 2 7 -60 70
boundary 70

```

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

----- unit orientation description for array 1 -----

```

z layer 1, x column 1 to 2 left to right y row 1 to 2 bottom to top
1 1
1 1
-z layer 2, x column 1 to 2 left to right y row 1 to 2 bottom to top
1 1
1 1

```


keno-vi sample problem 4 2c8 15.24 cm paraffin refl
volumes for those units utilized in this problem

unit	region	geometry region	volume	cumulative volume
1	1	1	1.00000E+00 cm**3	1.00000E+00 cm**3
	2	2	1.00000E+00 cm**3	1.00000E+00 cm**3
2	1	3	1.00000E+00 cm**3	1.00000E+00 cm**3
	2	4	1.00000E+00 cm**3	1.00000E+00 cm**3
	3	5	1.00000E+00 cm**3	1.00000E+00 cm**3
	4	6	1.00000E+00 cm**3	1.00000E+00 cm**3
	5	7	1.00000E+00 cm**3	1.00000E+00 cm**3
	6	8	1.00000E+00 cm**3	1.00000E+00 cm**3
	7	9	1.00000E+00 cm**3	1.00000E+00 cm**3

unit	uses	region	mixture	total volume
1	8	1	1	8.00000E+00 cm**3
		2	0	8.00000E+00 cm**3
2	1	1		1.00000E+00 cm**3
		2	2	1.00000E+00 cm**3
		3	2	1.00000E+00 cm**3
		4	2	1.00000E+00 cm**3
		5	2	1.00000E+00 cm**3
		6	2	1.00000E+00 cm**3
		7	2	1.00000E+00 cm**3

total mixture volumes	
mixture	total volume
0	8.00000E+00 cm**3
1	8.00000E+00 cm**3
2	6.00000E+00 cm**3

```

*****
***
***          biasing information          ***
***
*** weighting intervals 1 to 6 for paraffin ,mat id= 400 will be used for bias id's 2 to 7 ***
***
*** a default weight of .500 will be used for all other bias id's. ***
***
*****

```

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

group dependent weights

energy group	bias id 1	bias id 2	bias id 3	bias id 4	bias id 5	bias id 6	bias id 7
1	5.00000E-01	6.18390E-01	8.85090E-01	1.25430E+00	1.80190E+00	2.61220E+00	3.80230E+00
2	5.00000E-01	5.91790E-01	8.52020E-01	1.33350E+00	2.23270E+00	3.89200E+00	6.93920E+00
3	5.00000E-01	5.90830E-01	8.85190E-01	1.52270E+00	2.90060E+00	5.87640E+00	1.23420E+01
4	5.00000E-01	5.86770E-01	9.05420E-01	1.68610E+00	3.57900E+00	8.22490E+00	1.98220E+01
5	5.00000E-01	5.81890E-01	9.30070E-01	1.88130E+00	4.43390E+00	1.14320E+01	3.10120E+01
6	5.00000E-01	5.74820E-01	9.87290E-01	2.28780E+00	6.30330E+00	1.90190E+01	5.96620E+01
7	5.00000E-01	5.87290E-01	1.15630E+00	3.20150E+00	1.04420E+01	3.60420E+01	1.23200E+02
8	5.00000E-01	6.20770E-01	1.41080E+00	4.44510E+00	1.57830E+01	5.64360E+01	1.91970E+02
9	5.00000E-01	6.57610E-01	1.64320E+00	5.50540E+00	2.00300E+01	7.15900E+01	2.40440E+02
10	5.00000E-01	6.87950E-01	1.83600E+00	6.38830E+00	2.34660E+01	8.35140E+01	2.77740E+02
11	5.00000E-01	6.92740E-01	1.94220E+00	6.96040E+00	2.56820E+01	9.09270E+01	2.99680E+02
12	5.00000E-01	6.98060E-01	2.06680E+00	7.59760E+00	2.80730E+01	9.87930E+01	3.22680E+02
13	5.00000E-01	7.01860E-01	2.17810E+00	8.12680E+00	3.00000E+01	1.05060E+02	3.40830E+02
14	5.00000E-01	7.12050E-01	2.33100E+00	8.78950E+00	3.23810E+01	1.12840E+02	3.63710E+02
15	5.00000E-01	7.34300E-01	2.53080E+00	9.60390E+00	3.53030E+01	1.22520E+02	3.92830E+02
16	5.00000E-01	7.84110E-01	2.80270E+00	1.06540E+01	3.91200E+01	1.35510E+02	4.33480E+02
17	5.00000E-01	7.83000E-01	2.82230E+00	1.07360E+01	3.93890E+01	1.36290E+02	4.35350E+02
18	5.00000E-01	8.11260E-01	2.96800E+00	1.12930E+01	4.14180E+01	1.43220E+02	4.57120E+02
19	5.00000E-01	8.32890E-01	3.08460E+00	1.17400E+01	4.30330E+01	1.48700E+02	4.74160E+02
20	5.00000E-01	8.41560E-01	3.14930E+00	1.19880E+01	4.38940E+01	1.51420E+02	4.81790E+02
21	5.00000E-01	8.37120E-01	3.15740E+00	1.20190E+01	4.39320E+01	1.51180E+02	4.79580E+02
22	5.00000E-01	8.36030E-01	3.17070E+00	1.20670E+01	4.40680E+01	1.51460E+02	4.79740E+02
23	5.00000E-01	8.61360E-01	3.32330E+00	1.26400E+01	4.60960E+01	1.58130E+02	4.99640E+02
24	5.00000E-01	8.86690E-01	3.46960E+00	1.31820E+01	4.79880E+01	1.64220E+02	5.17330E+02
25	5.00000E-01	9.02200E-01	3.55250E+00	1.34830E+01	4.90100E+01	1.67360E+02	5.25870E+02
26	5.00000E-01	9.20350E-01	3.64340E+00	1.38170E+01	5.01620E+01	1.71010E+02	5.36250E+02
27	5.00000E-01	9.43470E-01	3.74870E+00	1.42020E+01	5.14930E+01	1.75220E+02	5.48200E+02

..... 0 io's were used in keno-v before tracking

..... .0000minutes were used processing data.

volume fraction of fissile material in the system= .36364E+00

start type 0 was used.

the neutrons were started with a flat distribution in a cuboid defined by:

+x= 3.87200E+01 -x=-3.87200E+01 +y= 3.87200E+01 -y=-3.87200E+01 +z= 3.79900E+01 -z=-3.79900E+01

.02133 minutes were required for starting. total elapsed time is .02133 minutes.

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

generation	generation k-effective	elapsed time minutes	average k-effective	avg k-eff deviation	matrix k-effective	matrix k-eff deviation
1	1.05232E+00	6.40000E-02	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	1.03003E+00	1.28000E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	1.02401E+00	1.92000E-01	1.02401E+00	0.00000E+00	0.00000E+00	0.00000E+00
4	9.74890E-01	2.13333E-01	9.99448E-01	2.45582E-02	0.00000E+00	0.00000E+00
5	1.02300E+00	2.77333E-01	1.00730E+00	1.62072E-02	0.00000E+00	0.00000E+00
6	1.02899E+00	3.41333E-01	1.01272E+00	1.26783E-02	0.00000E+00	0.00000E+00
7	9.79124E-01	3.84000E-01	1.00600E+00	1.18994E-02	0.00000E+00	0.00000E+00
8	1.03230E+00	4.48000E-01	1.01038E+00	1.06586E-02	0.00000E+00	0.00000E+00
9	1.06259E+00	5.12000E-01	1.01784E+00	1.16950E-02	0.00000E+00	0.00000E+00
10	1.01395E+00	5.76000E-01	1.01736E+00	1.01399E-02	0.00000E+00	0.00000E+00
11	9.02205E-01	6.18667E-01	1.00456E+00	1.56100E-02	0.00000E+00	0.00000E+00
12	1.00224E+00	6.61333E-01	1.00433E+00	1.39639E-02	0.00000E+00	0.00000E+00
13	9.62315E-01	7.25333E-01	1.00051E+00	1.31957E-02	0.00000E+00	0.00000E+00
14	9.77535E-01	7.89333E-01	9.98596E-01	1.21972E-02	0.00000E+00	0.00000E+00
15	9.46200E-01	8.32000E-01	9.94565E-01	1.19217E-02	0.00000E+00	0.00000E+00
16	1.09511E+00	8.96000E-01	1.00175E+00	1.31684E-02	0.00000E+00	0.00000E+00
17	1.00411E+00	9.60000E-01	1.00190E+00	1.22601E-02	0.00000E+00	0.00000E+00
18	1.01688E+00	1.00267E+00	1.00284E+00	1.15064E-02	0.00000E+00	0.00000E+00
19	9.38776E-01	1.04533E+00	9.99072E-01	1.14465E-02	0.00000E+00	0.00000E+00
20	1.05753E+00	1.10933E+00	1.00232E+00	1.12699E-02	0.00000E+00	0.00000E+00
21	1.00952E+00	1.15200E+00	1.00270E+00	1.06670E-02	0.00000E+00	0.00000E+00
22	9.86390E-01	1.19467E+00	1.00188E+00	1.01524E-02	0.00000E+00	0.00000E+00
23	9.47884E-01	1.25867E+00	9.99312E-01	9.99337E-03	0.00000E+00	0.00000E+00
24	9.20649E-01	1.32267E+00	9.95736E-01	1.01771E-02	0.00000E+00	0.00000E+00
25	9.98392E-01	1.36533E+00	9.95852E-01	9.72524E-03	0.00000E+00	0.00000E+00
26	9.61672E-01	1.40800E+00	9.94427E-01	9.41950E-03	0.00000E+00	0.00000E+00
27	9.72450E-01	1.47200E+00	9.93548E-01	9.07753E-03	0.00000E+00	0.00000E+00
28	1.04718E+00	1.51467E+00	9.95611E-01	8.96207E-03	0.00000E+00	0.00000E+00
29	9.61118E-01	1.55733E+00	9.94334E-01	8.71787E-03	0.00000E+00	0.00000E+00
30	1.01641E+00	1.62133E+00	9.95122E-01	8.43767E-03	0.00000E+00	0.00000E+00
31	9.53034E-01	1.66400E+00	9.93671E-01	8.26986E-03	0.00000E+00	0.00000E+00
32	1.17266E+00	1.70667E+00	9.99637E-01	9.97139E-03	0.00000E+00	0.00000E+00
33	1.00927E+00	1.77067E+00	9.99948E-01	9.64937E-03	0.00000E+00	0.00000E+00
34	8.86708E-01	1.81333E+00	9.96409E-01	9.99069E-03	0.00000E+00	0.00000E+00
35	1.07450E+00	1.87733E+00	9.98776E-01	9.96814E-03	0.00000E+00	0.00000E+00
36	9.36499E-01	1.92000E+00	9.96944E-01	9.84245E-03	0.00000E+00	0.00000E+00
37	9.47681E-01	1.96267E+00	9.95536E-01	9.66019E-03	0.00000E+00	0.00000E+00
38	9.69118E-01	2.02667E+00	9.94803E-01	9.41666E-03	0.00000E+00	0.00000E+00
39	1.04915E+00	2.09067E+00	9.96271E-01	9.27565E-03	0.00000E+00	0.00000E+00
40	1.06399E+00	2.13333E+00	9.98053E-01	9.20244E-03	0.00000E+00	0.00000E+00
41	1.04602E+00	2.19733E+00	9.99283E-01	9.04735E-03	0.00000E+00	0.00000E+00
42	9.6534E-01	2.24000E+00	9.98435E-01	8.85896E-03	0.00000E+00	0.00000E+00
43	9.73261E-01	2.30400E+00	9.97821E-01	8.66198E-03	0.00000E+00	0.00000E+00
44	1.06292E+00	2.34667E+00	9.99371E-01	8.59413E-03	0.00000E+00	0.00000E+00
45	9.55318E-01	2.38933E+00	9.98346E-01	8.45420E-03	0.00000E+00	0.00000E+00
46	1.06056E+00	2.47467E+00	9.99760E-01	8.37995E-03	0.00000E+00	0.00000E+00
47	1.03734E+00	2.53867E+00	1.00060E+00	8.23408E-03	0.00000E+00	0.00000E+00
48	1.06522E+00	2.58133E+00	1.00200E+00	8.17470E-03	0.00000E+00	0.00000E+00
49	9.89311E-01	2.62400E+00	1.00173E+00	8.00344E-03	0.00000E+00	0.00000E+00
50	1.07420E+00	2.68800E+00	1.00324E+00	7.97905E-03	0.00000E+00	0.00000E+00
51	1.01924E+00	2.75200E+00	1.00357E+00	7.82134E-03	0.00000E+00	0.00000E+00
52	1.06604E+00	2.79467E+00	1.00482E+00	7.76451E-03	0.00000E+00	0.00000E+00
53	1.04927E+00	2.85867E+00	1.00569E+00	7.66050E-03	0.00000E+00	0.00000E+00
54	9.90373E-01	2.94400E+00	1.00539E+00	7.51751E-03	0.00000E+00	0.00000E+00
55	9.96628E-01	2.98667E+00	1.00523E+00	7.37616E-03	0.00000E+00	0.00000E+00
56	9.35001E-01	3.05067E+00	1.00393E+00	7.35418E-03	0.00000E+00	0.00000E+00
57	9.95944E-01	3.09333E+00	1.00378E+00	7.22069E-03	0.00000E+00	0.00000E+00
58	1.10795E+00	3.15733E+00	1.00564E+00	7.33053E-03	0.00000E+00	0.00000E+00
59	1.05006E+00	3.20000E+00	1.00642E+00	7.24282E-03	0.00000E+00	0.00000E+00
60	9.19054E-01	3.24267E+00	1.00492E+00	7.27452E-03	0.00000E+00	0.00000E+00
61	9.65863E-01	3.30667E+00	1.00425E+00	7.18073E-03	0.00000E+00	0.00000E+00
62	9.52853E-01	3.37067E+00	1.00340E+00	7.11182E-03	0.00000E+00	0.00000E+00
63	9.70607E-01	3.41333E+00	1.00286E+00	7.01489E-03	0.00000E+00	0.00000E+00
64	1.08541E+00	3.47733E+00	1.00419E+00	7.02809E-03	0.00000E+00	0.00000E+00
65	1.01429E+00	3.54133E+00	1.00435E+00	6.91749E-03	0.00000E+00	0.00000E+00
66	9.28092E-01	3.60533E+00	1.00316E+00	6.91202E-03	0.00000E+00	0.00000E+00
67	1.01887E+00	3.66933E+00	1.00340E+00	6.80914E-03	0.00000E+00	0.00000E+00
68	1.02995E+00	3.71200E+00	1.00380E+00	6.71723E-03	0.00000E+00	0.00000E+00
69	1.01593E+00	3.75467E+00	1.00398E+00	6.61869E-03	0.00000E+00	0.00000E+00
70	1.08576E+00	3.81867E+00	1.00519E+00	6.63061E-03	0.00000E+00	0.00000E+00
71	9.36529E-01	3.86133E+00	1.00419E+00	6.60914E-03	0.00000E+00	0.00000E+00
72	1.03625E+00	3.92533E+00	1.00465E+00	6.53012E-03	0.00000E+00	0.00000E+00
73	9.84095E-01	3.98933E+00	1.00436E+00	6.44400E-03	0.00000E+00	0.00000E+00
74	9.38039E-01	4.01067E+00	1.00344E+00	6.42029E-03	0.00000E+00	0.00000E+00
75	1.00237E+00	4.07467E+00	1.00342E+00	6.33175E-03	0.00000E+00	0.00000E+00
76	1.04787E+00	4.13867E+00	1.00403E+00	6.27441E-03	0.00000E+00	0.00000E+00
77	9.60502E-01	4.18133E+00	1.00344E+00	6.21733E-03	0.00000E+00	0.00000E+00
78	9.76534E-01	4.22400E+00	1.00309E+00	6.14518E-03	0.00000E+00	0.00000E+00
79	9.30093E-01	4.30933E+00	1.00214E+00	6.13850E-03	0.00000E+00	0.00000E+00
80	9.69117E-01	4.35200E+00	1.00172E+00	6.07406E-03	0.00000E+00	0.00000E+00
81	1.04409E+00	4.39467E+00	1.00226E+00	6.02062E-03	0.00000E+00	0.00000E+00
82	8.84657E-01	4.45867E+00	1.00079E+00	6.12393E-03	0.00000E+00	0.00000E+00
83	1.10813E+00	4.50133E+00	1.00211E+00	6.19136E-03	0.00000E+00	0.00000E+00

84	9.57290E-01	4.54400E+00	1.00156E+00	6.13977E-03	0.00000E+00	0.00000E+00
85	9.60983E-01	4.60800E+00	1.00108E+00	6.08502E-03	0.00000E+00	0.00000E+00
86	1.16050E+00	4.67200E+00	1.00297E+00	6.30458E-03	0.00000E+00	0.00000E+00
87	9.75571E-01	4.71467E+00	1.00265E+00	6.23831E-03	0.00000E+00	0.00000E+00
88	1.02697E+00	4.75733E+00	1.00293E+00	6.17182E-03	0.00000E+00	0.00000E+00
89	9.38932E-01	4.82133E+00	1.00220E+00	6.14467E-03	0.00000E+00	0.00000E+00
90	1.03860E+00	4.86400E+00	1.00261E+00	6.08851E-03	0.00000E+00	0.00000E+00
91	1.04515E+00	4.90667E+00	1.00309E+00	6.03865E-03	0.00000E+00	0.00000E+00
92	9.97060E-01	4.97067E+00	1.00302E+00	5.97156E-03	0.00000E+00	0.00000E+00
93	1.04236E+00	5.01333E+00	1.00345E+00	5.92137E-03	0.00000E+00	0.00000E+00
94	1.01219E+00	5.07733E+00	1.00355E+00	5.85743E-03	0.00000E+00	0.00000E+00
95	1.03387E+00	5.14133E+00	1.00388E+00	5.80327E-03	0.00000E+00	0.00000E+00
96	9.71395E-01	5.16267E+00	1.00353E+00	5.75159E-03	0.00000E+00	0.00000E+00
97	9.62189E-01	5.22667E+00	1.00310E+00	5.70734E-03	0.00000E+00	0.00000E+00
98	1.07200E+00	5.29067E+00	1.00381E+00	5.69300E-03	0.00000E+00	0.00000E+00
99	1.02765E+00	5.33333E+00	1.00406E+00	5.63936E-03	0.00000E+00	0.00000E+00
100	1.07155E+00	5.37600E+00	1.00475E+00	5.62384E-03	0.00000E+00	0.00000E+00
101	1.05471E+00	5.44000E+00	1.00525E+00	5.58958E-03	0.00000E+00	0.00000E+00
102	1.01308E+00	5.52533E+00	1.00533E+00	5.53395E-03	0.00000E+00	0.00000E+00
103	9.21325E-01	5.56800E+00	1.00450E+00	5.54166E-03	0.00000E+00	0.00000E+00

kono message number k6-123

execution terminated due to completion of the specified number of generations.

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

lifetime = 2.68453E-04 + or - 2.04323E-05 generation time = 7.47191E-05 + or - 1.83147E-06
 nu bar = 2.56302E+00 + or - 1.26827E-03 average fission group = 9.64538E+00 + or - 6.51398E-02
 energy(ev) of the average lethargy causing fission = 1.19057E+04 + or - 6.65147E+02

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	deviation of variance (per cent)
3	1.00430	+ or - .00559	.99871 to 1.00990	.99312 to 1.01549	.98752 to 1.02109	30000	14.5545
4	1.00460	+ or - .00564	.99896 to 1.01024	.99332 to 1.01589	.98767 to 1.02153	29700	14.5554
5	1.00441	+ or - .00570	.99872 to 1.01011	.99302 to 1.01581	.98732 to 1.02151	29400	14.5600
6	1.00416	+ or - .00575	.99841 to 1.00991	.99266 to 1.01566	.98691 to 1.02141	29100	14.5881
7	1.00442	+ or - .00581	.99862 to 1.01023	.99281 to 1.01603	.98701 to 1.02184	28800	14.5742
8	1.00413	+ or - .00586	.99827 to 1.00999	.99241 to 1.01584	.98655 to 1.02170	28500	14.6166
9	1.00350	+ or - .00589	.99762 to 1.00939	.99173 to 1.01528	.98584 to 1.02117	28200	14.8415
10	1.00339	+ or - .00595	.99744 to 1.00934	.99149 to 1.01529	.98554 to 1.02124	27900	14.8228
11	1.00449	+ or - .00591	.99858 to 1.01040	.99267 to 1.01632	.98676 to 1.02223	27600	15.0389
12	1.00452	+ or - .00598	.99854 to 1.01049	.99256 to 1.01647	.98659 to 1.02245	27300	14.9985
17	1.00495	+ or - .00617	.99878 to 1.01112	.99261 to 1.01730	.98643 to 1.02347	25800	15.5482
22	1.00514	+ or - .00646	.99868 to 1.01161	.99221 to 1.01807	.98575 to 1.02454	24300	15.8499
27	1.00810	+ or - .00671	1.00139 to 1.01481	.99468 to 1.02152	.98797 to 1.02823	22800	16.3120
32	1.00655	+ or - .00669	.99986 to 1.01325	.99317 to 1.01994	.98647 to 1.02663	21300	15.2633
37	1.00925	+ or - .00674	1.00251 to 1.01599	.99577 to 1.02273	.98903 to 1.02947	19800	16.1417
42	1.00847	+ or - .00712	1.00136 to 1.01559	.99424 to 1.02271	.98713 to 1.02982	18300	16.9725
47	1.00764	+ or - .00753	1.00010 to 1.01517	.99257 to 1.02270	.98504 to 1.03023	16800	18.0166
52	1.00419	+ or - .00798	.99621 to 1.01217	.98822 to 1.02015	.98024 to 1.02813	15300	19.5567
57	1.00536	+ or - .00866	.99669 to 1.01402	.98803 to 1.02268	.97937 to 1.03134	13800	20.0210
62	1.00611	+ or - .00894	.99718 to 1.01505	.98824 to 1.02398	.97930 to 1.03292	12300	22.7483
67	1.00648	+ or - .00964	.99684 to 1.01612	.98720 to 1.02576	.97756 to 1.03540	10800	24.8960
72	1.00416	+ or - .01059	.99357 to 1.01474	.98299 to 1.02533	.97240 to 1.03591	9300	27.8887
77	1.00754	+ or - .01211	.99543 to 1.01965	.98332 to 1.03176	.97121 to 1.04387	7800	29.6757
82	1.01864	+ or - .01271	1.00593 to 1.03135	.99322 to 1.04406	.98051 to 1.05677	6300	33.4440
87	1.01431	+ or - .01127	1.00305 to 1.02558	.99178 to 1.03685	.98051 to 1.04812	4800	33.7550
92	1.01657	+ or - .01438	1.00220 to 1.03095	.98782 to 1.04533	.97344 to 1.05971	3300	42.7123

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

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	deviation of variance (per cent)
97	1.02672	+ or - .02319	1.00352 to 1.04991	.98033 to 1.07311	.95714 to 1.09630	1800	79.9852

keno-vi sample problem 4 2c8 15.24 cm paraffin refl
 plot of average k-effective by generation run.
 the line represents k-eff = 1.0043 + or - .0056 which occurs for 103 generations run.

kono-vi sample problem 4 2c8 15.24 cm paraffin refl

plot of average k-effective by generation skipped.
the line represents $k_{\text{eff}} = 1.0043 \pm 0.0056$ which occurs for 4 generations skipped.

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

skipping 3

generations

group	fission fraction	unit	region	fissions	percent deviation	absorptions	percent deviation	leakage	percent deviation
1	.0184			1.84701E-02	5.8334	5.54209E-03	5.5607	1.96663E-03	13.8332
2	.1020			1.02450E-01	1.7364	3.54026E-02	1.7363	5.33815E-03	9.6385
3	.1261			1.26693E-01	1.6160	4.85950E-02	1.6159	4.93048E-03	14.3449
4	.0759			7.62752E-02	1.9710	3.08251E-02	1.9709	1.47340E-03	24.8223
5	.1112			1.11671E-01	1.2601	4.75181E-02	1.2601	2.94632E-03	27.2082
6	.1489			1.49504E-01	1.3214	6.81557E-02	1.3213	3.02096E-03	38.6906
7	.1106			1.11064E-01	1.7378	5.51231E-02	1.7376	2.03781E-03	62.7555
8	.0311			3.11845E-02	3.5181	1.74295E-02	3.5150	6.34005E-04	100.0000
9	.0113			1.13691E-02	5.9914	6.55085E-03	5.9603	0.00000E+00	.0000
10	.0124			1.24042E-02	5.6597	7.29867E-03	5.5985	0.00000E+00	.0000
11	.0127			1.27907E-02	6.3373	8.03674E-03	6.1943	0.00000E+00	.0000
12	.0075			7.50082E-03	6.7521	4.88644E-03	6.4147	0.00000E+00	.0000
13	.0062			6.25951E-03	7.8526	4.32592E-03	7.0035	0.00000E+00	.0000
14	.0063			6.37577E-03	7.7963	4.80257E-03	6.5197	0.00000E+00	.0000
15	.0031			3.09272E-03	10.6119	2.63966E-03	8.0315	0.00000E+00	.0000
16	.0019			1.91460E-03	15.8373	1.45083E-03	10.9290	0.00000E+00	.0000
17	.0014			1.42425E-03	20.4165	1.01748E-03	15.9454	0.00000E+00	.0000
18	.0009			9.27781E-04	21.7149	6.64004E-04	15.1611	0.00000E+00	.0000
19	.0013			1.26621E-03	22.7931	1.01547E-03	13.3114	0.00000E+00	.0000
20	.0068			6.86497E-03	8.4038	4.98914E-03	5.3925	0.00000E+00	.0000
21	.0017			1.67639E-03	20.5226	1.57909E-03	11.2471	0.00000E+00	.0000
22	.0042			4.18869E-03	11.4219	4.37557E-03	6.0389	2.55520E-03	100.0000
23	.0285			2.85962E-02	4.5659	4.36570E-02	3.1665	0.00000E+00	.0000\
24	.0642			6.44390E-02	3.3302	1.40858E-01	3.8733	1.72443E-02	100.0000
25	.0498			4.99716E-02	3.6577	1.35130E-01	3.9578	0.00000E+00	.0000
26	.0469			4.70630E-02	3.8095	1.82018E-01	4.1159	0.00000E+00	.0000
27	.0088			8.86754E-03	8.0502	7.66408E-02	4.8079	0.00000E+00	.0000
system total =				1.00430E+00	.5570	9.40527E-01	2.4250	4.21473E-02	41.6057

elapsed time 5.56800 minutes

random number= 000037F7146C0979

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

**** fission densities ****

unit	region	fission density	percent deviation	total fissions
1	1	1.255E-01	.56	1.004E+00
	2	0.000E+00	.00	0.000E+00
2	1	0.000E+00	.00	0.000E+00
	2	0.000E+00	.00	0.000E+00
	3	0.000E+00	.00	0.000E+00
	4	0.000E+00	.00	0.000E+00
	5	0.000E+00	.00	0.000E+00
	6	0.000E+00	.00	0.000E+00
	7	0.000E+00	.00	0.000E+00

global unit

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

fluxes for unit 1				
		region 1		
		region 2		
group	flux	percent deviation	flux	percent deviation
1	9.598E-03	5.20	2.838E-02	5.33
2	9.093E-02	1.98	2.547E-01	1.91
3	1.137E-01	1.54	3.279E-01	1.59
4	7.125E-02	2.15	2.000E-01	2.20
5	1.110E-01	1.46	3.132E-01	1.50
6	1.664E-01	1.35	4.523E-01	1.26
7	1.170E-01	1.73	3.276E-01	1.83
8	3.190E-02	3.24	1.384E-01	3.07
9	1.389E-02	6.06	8.608E-02	3.35
10	1.230E-02	5.67	7.854E-02	3.83
11	1.111E-02	6.23	7.152E-02	4.57
12	7.136E-03	6.57	4.820E-02	4.79
13	6.563E-03	7.85	4.301E-02	5.40
14	6.823E-03	7.16	4.481E-02	5.02
15	3.015E-03	10.56	2.019E-02	8.05
16	1.618E-03	15.07	1.223E-02	10.51
17	1.001E-03	21.18	4.978E-03	14.14
18	5.960E-04	21.54	4.400E-03	14.38
19	6.735E-04	23.66	8.777E-03	12.93
20	3.900E-03	8.37	2.725E-02	5.85
21	1.152E-03	21.40	7.493E-03	11.52
22	2.579E-03	11.28	1.858E-02	8.83
23	1.713E-02	4.94	1.293E-01	3.72
24	3.781E-02	3.47	2.750E-01	2.63
25	2.923E-02	3.93	1.943E-01	3.14
26	2.738E-02	3.77	1.864E-01	3.20
27	5.231E-03	8.25	3.825E-02	5.56

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

fluxes for global unit			region 2		region 3		region 4		region 5		region 6	
group	flux	percent deviation	flux	percent deviation	flux	percent deviation	flux	percent deviation	flux	percent deviation	flux	percent
deviation												
1	0.000E+00	.00	4.946E-02	5.82	4.863E-02	6.81	4.292E-02	7.91	3.245E-02	11.04	2.298E-02	12.68
2	0.000E+00	.00	3.826E-01	1.98	3.200E-01	2.84	2.122E-01	3.80	1.234E-01	4.72	6.949E-02	7.02
3	0.000E+00	.00	4.832E-01	1.55	3.605E-01	2.16	2.185E-01	3.14	1.295E-01	4.60	7.154E-02	7.37
4	0.000E+00	.00	3.078E-01	2.13	2.232E-01	2.94	1.244E-01	4.31	6.372E-02	7.22	3.538E-02	10.04
5	0.000E+00	.00	4.738E-01	1.56	3.222E-01	2.24	1.658E-01	3.51	8.231E-02	5.88	4.517E-02	13.59
6	0.000E+00	.00	7.167E-01	1.07	4.415E-01	1.79	2.113E-01	2.92	9.564E-02	6.50	4.359E-02	13.76
7	0.000E+00	.00	7.086E-01	1.14	3.890E-01	1.54	1.755E-01	3.80	8.106E-02	9.38	3.718E-02	19.32
8	0.000E+00	.00	4.816E-01	1.21	2.799E-01	1.75	1.347E-01	4.93	5.375E-02	9.85	1.404E-02	34.07
9	0.000E+00	.00	3.625E-01	1.29	2.301E-01	2.25	9.696E-02	4.65	4.055E-02	16.04	2.309E-02	41.29
10	0.000E+00	.00	3.070E-01	1.10	2.106E-01	1.95	9.619E-02	5.30	3.972E-02	17.72	2.659E-02	49.87
11	0.000E+00	.00	3.094E-01	1.23	2.181E-01	2.20	9.780E-02	5.61	2.974E-02	15.34	1.478E-02	47.03
12	0.000E+00	.00	2.043E-01	1.30	1.497E-01	2.04	7.553E-02	7.30	3.066E-02	23.09	2.542E-02	69.69
13	0.000E+00	.00	1.862E-01	1.56	1.450E-01	2.86	6.045E-02	7.16	4.038E-02	33.65	1.393E-02	60.73
14	0.000E+00	.00	1.937E-01	1.49	1.463E-01	3.06	6.938E-02	7.91	4.053E-02	22.42	2.274E-02	50.22
15	0.000E+00	.00	9.120E-02	2.12	7.647E-02	3.95	3.479E-02	9.54	1.960E-02	26.88	8.887E-03	75.83
16	0.000E+00	.00	4.907E-02	2.89	4.181E-02	4.04	1.940E-02	13.00	1.376E-02	36.28	7.458E-03	69.25
17	0.000E+00	.00	2.393E-02	4.50	1.925E-02	6.22	1.091E-02	17.46	6.639E-03	55.60	3.852E-03	100.00
18	0.000E+00	.00	2.180E-02	4.29	1.629E-02	6.66	8.576E-03	19.15	5.343E-03	40.71	0.000E+00	.00
19	0.000E+00	.00	4.040E-02	3.29	3.075E-02	4.65	2.177E-02	33.54	1.263E-02	34.07	3.264E-03	59.54
20	0.000E+00	.00	1.251E-01	2.17	1.021E-01	3.88	5.595E-02	10.61	3.647E-02	22.66	1.139E-02	48.07
21	0.000E+00	.00	4.095E-02	3.30	3.260E-02	6.78	1.742E-02	14.26	9.322E-03	34.90	5.610E-03	59.47
22	0.000E+00	.00	9.799E-02	2.68	8.628E-02	3.97	5.807E-02	13.34	4.736E-02	26.54	7.647E-03	50.54
23	0.000E+00	.00	8.213E-01	1.75	8.837E-01	3.52	5.801E-01	6.99	3.591E-01	15.67	9.286E-02	32.52
24	0.000E+00	.00	1.934E+00	1.66	2.215E+00	3.27	1.459E+00	6.98	9.681E-01	16.72	2.871E-01	29.99
25	0.000E+00	.00	1.484E+00	1.60	1.703E+00	3.34	1.178E+00	6.69	6.794E-01	17.62	2.022E-01	34.61
26	0.000E+00	.00	1.518E+00	1.65	1.749E+00	3.56	1.129E+00	6.98	6.716E-01	18.32	1.905E-01	35.44
27	0.000E+00	.00	3.551E-01	1.80	4.016E-01	3.86	2.596E-01	7.50	1.794E-01	20.93	5.211E-02	41.35

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

fluxes for global unit
region 7

group	flux	percent deviation
1	3.501E-03	35.92
2	5.483E-03	23.16
3	4.652E-03	21.53
4	1.483E-03	38.68
5	3.753E-03	39.54
6	2.250E-03	37.83
7	6.510E-04	60.09
8	1.531E-04	100.00
9	0.000E+00	.00
10	5.947E-04	100.00
11	2.362E-03	100.00
12	8.608E-04	100.00
13	0.000E+00	.00
14	0.000E+00	.00
15	0.000E+00	.00
16	0.000E+00	.00
17	0.000E+00	.00
18	0.000E+00	.00
19	0.000E+00	.00
20	0.000E+00	.00
21	0.000E+00	.00
22	1.001E-03	100.00
23	0.000E+00	.00
24	4.139E-03	100.00
25	2.138E-03	78.23
26	0.000E+00	.00
27	0.000E+00	.00

keno-vi sample problem 4 2c8 15.24 cm paraffin refl

frequency for generations 4 to 103

```
.8694 to .8924 **
.8924 to .9155 *
.9155 to .9386 ++++++
.9386 to .9617 ++++++++
.9617 to .9848 ++++++++
.9848 to 1.0079 ++++++++
1.0079 to 1.0310 ++++++++
1.0310 to 1.0541 ++++++++
1.0541 to 1.0772 ++++++++
1.0772 to 1.1003 ***
1.1003 to 1.1234 **
1.1234 to 1.1465 *
1.1465 to 1.1696 *
1.1696 to 1.1927 *
```

frequency for generations 29 to 103

```
.8694 to .8924 **
.8924 to .9155 *
.9155 to .9386 ++++++
.9386 to .9617 ++++++++
.9617 to .9848 ++++++++
.9848 to 1.0079 ++++++
1.0079 to 1.0310 ++++++++
1.0310 to 1.0541 ++++++++
1.0541 to 1.0772 ++++++++
1.0772 to 1.1003 **
1.1003 to 1.1234 **
1.1234 to 1.1465 *
1.1465 to 1.1696 *
1.1696 to 1.1927 *
```

frequency for generations 54 to 103

```
.8694 to .8924 *
.8924 to .9155 *
.9155 to .9386 ++++++
.9386 to .9617 ++++++
.9617 to .9848 ++++++++
.9848 to 1.0079 ++++++
1.0079 to 1.0310 ++++++++
1.0310 to 1.0541 ++++++++
1.0541 to 1.0772 ***
1.0772 to 1.1003 **
1.1003 to 1.1234 **
1.1234 to 1.1465 *
1.1465 to 1.1696 *
1.1696 to 1.1927 *
```

frequency for generations 79 to 103

```
.8694 to .8924 *
.8924 to .9155 *
.9155 to .9386 **
.9386 to .9617 ***
.9617 to .9848 +++++
.9848 to 1.0079 *
1.0079 to 1.0310 +++++
1.0310 to 1.0541 +++++
1.0541 to 1.0772 ***
1.0772 to 1.1003 *
1.1003 to 1.1234 *
1.1234 to 1.1465 *
1.1465 to 1.1696 *
1.1696 to 1.1927 *
```

congratulations! you have successfully traversed the perilous path through keno vi in 5.56800 minutes

11	666666666666		2222222222	555555555555		2222222222	666666666666
111	6666666666666		222222222222	555555555555		222222222222	6666666666666
1111	66	22	22	55	22	22	66
11	66	22	22	55	22	22	66
11	66	22	22	55	22	22	66
11	666666666666	22	555555555555		22	666666666666	
11	6666666666666	22	555555555555		22	6666666666666	
11	66	66	22	55	22	66	66
11	66	66	22	55	22	66	66
11	66	66	22	55	22	66	66
11111111	66666666666666	22222222222222	55555555555555	22222222222222	66666666666666		
11111111	66666666666666	22222222222222	55555555555555	22222222222222	66666666666666		

```
*****  
*****  
*****  
***** program verification information *****  
***** code system: scale version: 4.2 *****  
*****  
*****  
*****  
***** program: kenovi *****  
***** creation date: 06/23/95 *****  
***** library: /scale/exe *****  
*****  
***** production code: kenovi *****  
***** version: 2.0 *****  
***** jobname: dfz *****  
***** date of execution: 07/12/95 *****  
***** time of execution: 16:25:26 *****  
*****  
*****  
*****
```



```

*****
***                                     ***
***               sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12) ***
***                                     ***
*****               numeric parameters               *****
***                                     ***
***               tme               maximum problem time (min)               30.00 ***
***               tba               time per generation (min)               .50 ***
***               gen               number of generations               103 ***
***               npg               number per generation               300 ***
***               nsk               number of generations to be skipped               3 ***
***               beg               beginning generation number               1 ***
***               res               generations between checkpoints               0 ***
***               xld               number of extra 1-d cross sections               1 ***
***               nbk               neutron bank size               325 ***
***               xnb               extra positions in neutron bank               0 ***
***               nfb               fission bank size               300 ***
***               xfb               extra positions in fission bank               0 ***
***               sig               cut off standard deviation               .0000 ***
***               wta               default value of weight average               .5000 ***
***               wth               weight high for splitting               3.0000 ***
***               wtl               weight low for russian roulette               .3333 ***
***               rnd               starting random number               00000BB827100001 ***
***               nb8               number of d.a. blocks on unit 8               200 ***
***               nl8               length of d.a. blocks on unit 8               512 ***
***               adj               mode of calculation               forward ***
***               input data written on restart unit               no ***
***               binary data interface               no ***
***                                     ***
*****

```

```

*****
***
*** sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)
***
***** logical parameters *****
***
*** run execute problem after checking data yes plt plot picture map(s) yes ***
*** flx compute flux yes fdn compute fission densities yes ***
*** smu compute avg unit self-multiplication yes nub compute nu-bar & avg fission group yes ***
*** mku compute matrix k-eff by unit number yes mkp compute matrix k-eff by unit location yes ***
*** cku compute cofactor k-eff by unit number no ckp compute cofactor k-eff by unit location no ***
*** fmu print fiss prod matrix by unit number yes fmp print fiss prod matrix by unit location yes ***
*** mkh compute matrix k-eff by hole number no mka compute matrix k-eff by array number no ***
*** ckh compute cofactor k-eff by hole number no cka compute cofactor k-eff by array number no ***
*** fmh print fiss prod matrix by hole number no fma print fiss prod matrix by array number no ***
*** hhl collect matrix by highest hole level no hal collect matrix by highest array level no ***
*** amx print all mixed cross sections no far print fis. and abs. by region no ***
*** xs1 print 1-d mixture x-sections no gas print far by group no ***
*** xs2 print 2-d mixture x-sections no pax print xsec-albedo correlation tables no ***
*** xap print mixture angles & probabilities no pwt print weight average array no ***
*** pki print fission spectrum no pgm print input geometry no ***
*** pld print extra 1-d cross sections no bug print debug information no ***
*** trk print tracking information no ***
***
*****
parameter input completed

..... 0 io's were used reading the parameter data .....

***** data reading completed *****

```

```

*****
***
***               sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)
***
*****
***
***      unit      data set name      volume      unit function
***      number      -----      name      -----
***
***      xsc  14      ft14f001              mixed cross sections
***
***      alb  79      /scale/datalib/albedos      input albedos
***
***      wts  80      /scale/datalib/weights      input weights
***
***      skt  16      unknown      write scratch data
***
***      lib  4      ft04f001      input amp working library
***
***           8      ft08f001      input data direct access
***
***           9      unknown      super grouped direct access
***
***          10      unknown      xsec mixing direct access
***
*****

```

..... 0 io's were used preparing input data

cross sections read from the amp working library on unit 4

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

mixing table

number of scattering angles = 2
cross section message threshold -3.0E-05

mixture = 1		density(g/cc) = 18.760				
nuclide	atom-dens.	wgt. frac.	za	awt	nuclide title	
92234	4.82716E-04	9.99999E-03	92234	234.0405	uranium-234	endf/b-iv mat 1043 updated 08/12/94
92235	4.47971E-02	9.32000E-01	92235	235.0441	uranium-235	endf/b-iv mat 1261 updated 08/12/94
92236	9.57231E-05	2.00000E-03	92236	236.0458	u-236 1163 sigo-5+4 newxlacs p-3 293k f-1/e-m(1.+5)	updated 08/12/94
92238	2.65767E-03	5.60000E-02	92238	238.0510	uranium-238	endf/b-iv mat 1262 updated 08/12/94

mixture = 2		density(g/cc) = 1.5547				
nuclide	atom-dens.	wgt. frac.	za	awt	nuclide title	
1001	5.77964E-02	6.22048E-02	1001	1.0077	hydrogen	endf/b-iv mat 1269/thml002 updated 08/12/94
7014	2.13092E-03	3.18719E-02	7014	14.0033	nitrogen-14	endf/b-iv mat 1275 updated 08/12/94
8016	3.74130E-02	6.38986E-01	8016	15.9904	oxygen-16	endf/b-iv mat 1276 updated 08/12/94
292234	1.06784E-05	2.66936E-03	92234	234.0405	uranium-234	endf/b-iv mat 1043 updated 08/12/94
292235	9.84599E-04	2.47184E-01	92235	235.0441	uranium-235	endf/b-iv mat 1261 updated 08/12/94
292236	5.29385E-06	1.33468E-03	92236	236.0458	u-236 1163 sigo-5+4 newxlacs p-3 293k f-1/e-m(1.+5)	updated 08/12/94
292238	6.19413E-05	1.57493E-02	92238	238.0510	uranium-238	endf/b-iv mat 1262 updated 08/12/94

mixture = 3		density(g/cc) = 1.1799				
nuclide	atom-dens.	wgt. frac.	za	awt	nuclide title	
1101001	5.68187E-02	8.05783E-02	1001	1.0077	hydrogen	endf/b-iv mat 1269/thml002 updated 08/12/94
1106012	3.55117E-02	5.99750E-01	6000	12.0001	carbon-12	endf/b-iv mat 1274/thml065 updated 08/12/94
1108016	1.42047E-02	3.19672E-01	8016	15.9904	oxygen-16	endf/b-iv mat 1276 updated 08/12/94

1001	hydrogen	endf/b-iv mat 1269/thml002	updated 08/12/94
1101001	hydrogen	endf/b-iv mat 1269/thml002	updated 08/12/94
1106012	carbon-12	endf/b-iv mat 1274/thml065	updated 08/12/94
7014	nitrogen-14	endf/b-iv mat 1275	updated 08/12/94
8016	oxygen-16	endf/b-iv mat 1276	updated 08/12/94
1108016	oxygen-16	endf/b-iv mat 1276	updated 08/12/94
92234	uranium-234	endf/b-iv mat 1043	updated 08/12/94
292234	uranium-234	endf/b-iv mat 1043	updated 08/12/94
92235	uranium-235	endf/b-iv mat 1261	updated 08/12/94
292235	uranium-235	endf/b-iv mat 1261	updated 08/12/94
92236	u-236 1163 sigo-5+4 newxlacs p-3 293k f-1/e-m(1.+5)		updated 08/12/94
292236	u-236 1163 sigo-5+4 newxlacs p-3 293k f-1/e-m(1.+5)		updated 08/12/94
92238	uranium-238	endf/b-iv mat 1262	updated 08/12/94
292238	uranium-238	endf/b-iv mat 1262	updated 08/12/94

keno message number k6-222 2 transfers for mixture 2 were corrected for bad moments.

keno message number k6-222 3 transfers for mixture 3 were corrected for bad moments.

..... 0 io's were used mixing cross-sections

1-d cross section array id numbers
1 2002 1452 27 18 1018

..... 0 io's were used preparing the cross sections

```

*****
***                                     ***
***      sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)      ***
***                                     ***
*****
***                                     ***
***      ***** additional information *****                                     ***
***                                     ***
*** number of energy groups          27      use lattice geometry          yes ***
*** no. of fission spectrum source group 1      global array number          3 ***
*** no. of scattering angles in xsecs      2      number of units in the global x dir.      2 ***
*** entries/neutron in the neutron bank 32      number of units in the global y dir.      1 ***
*** entries/neutron in the fission bank 19      number of units in the global z dir.      1 ***
*** number of mixtures used            3      use a global reflector          yes ***
*** number of bias id's used           1      use nested holes              no ***
*** number of differential albedos used  0      number of holes                  0 ***
*** total input geometry regions        9      maximum hole nesting level        0 ***
*** number of geometry regions used      9      use nested arrays              yes ***
*** largest geometry unit number         5      number of arrays used            3 ***
*** largest array number                 3      maximum array nesting level      2 ***
***                                     ***
*** +x boundary condition              vacuum      -x boundary condition              vacuum ***
*** +y boundary condition              vacuum      -y boundary condition              vacuum ***
*** +z boundary condition              vacuum      -z boundary condition              vacuum ***
***                                     ***
*****

```

```

*****
***
***      sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)
***
*****
***
***      ***** space and supergroup information *****
***
***      20000 words is the total space available.
***
***      18415 words were used for non-supergroup storage.
***
***      1585 words of storage are available for supergrouped data.
***
***      19843 words of storage are available for constructing the supergroups.
***
***      1501 words of storage are available to each supergroup.
***
***      477 words are needed for the largest group.
***
***      19108 words of storage is sufficient to run this problem.
***
***      24920 words of storage will allow the problem to run with one supergroup.
***
***      20000 words of storage will be used to run this problem.
***
*****
***
***      supergroup      starting      ending      xsec      albedo      total
***      supergroup      group      group      length      length      length
***
***      1          1          3          234          0          1233
***      2          4          7          264          0          1425
***      3          8          12         225          0          1341
***      4         13         19         206          0          1409
***      5         20         27         170          0          1337
***
*****
***
***      0 io's were used in supergrouping
***
*****
***
***      array      units in      units in      units in      nesting
***      number      x dir.      y dir.      z dir.      level
***
***      1          1          2          2          2
***
***      2          1          2          2          2
***
***      3 global    2          1          1          1
***
*****
***
***      0 io's were used loading the data
***
*****

```

```

*****
***
***
***** geometry parameters *****
***
***
***      niar      number of independent array references      3      ***
***
***      ngblu      global unit number                          5      ***
***
***      nboxt      number of units in the problem              5      ***
***
***      nquad      number of quadratics in the problem          24     ***
***
***      ngwrds      number of geometry words read              9      ***
***
***      maxgwd      maximum geometry words in a unit           3      ***
***
***      maxsfu      largest number of surfaces in a unit        7      ***
***
***      maxreg      largest number of media in a unit           3      ***
***
***      regtot      number of spatial volumes defined           9      ***
***
***      sectot      number of entries in the sector array        19     ***
***
***      nucom      number of comments in the geometry data      5      ***
***
***      numhol      number of holes in the problem              0      ***
***
*****

```

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)
 geometry description for those units utilized in this problem

```

----- unit 1 -----
uranyl nitrate solution in a plexiglas container
1      cylinder      10
      quadratic surfaces
      -1.000x**2    -1.000y**2    .000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    90.726
      .000x**2      .000y**2    -1.000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    79.032
2      cylinder      20
      quadratic surfaces
      -1.000x**2    -1.000y**2    .000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    103.226
      .000x**2      .000y**2    -1.000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    90.726
3      cuboid        30
      quadratic surfaces
      -1.000x**2    .000y**2      .000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    118.266
      .000x**2    -1.000y**2    .000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    118.266
      .000x**2    .000y**2    -1.000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    104.858
      sector
      imp      definitions
media  2      1      10
media  3      1     -10  20
media  0      1      30 -20
boundary      30

----- unit 2 -----
uranium metal cylinder
1      cylinder      10
      quadratic surfaces
      -1.000x**2    -1.000y**2    .000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    33.040
      .000x**2      .000y**2    -1.000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    28.971
2      cuboid        20
      quadratic surfaces
      -1.000x**2    .000y**2      .000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    43.428
      .000x**2    -1.000y**2    .000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    43.428
      .000x**2    .000y**2    -1.000z**2    .000xy    .000xz    .000yz    .000x    .000y    .000z    38.751
      sector
      imp      definitions
media  1      1      10
media  0      1      20 -10
boundary      20

----- unit 3 -----
1x2x2 array of solution units
1      cuboid        10
      quadratic surfaces
      -1.000x**2    .000y**2      .000z**2    .000xy    .000xz    .000yz    21.750x    .000y    .000z    .000
      .000x**2    -1.000y**2    .000z**2    .000xy    .000xz    .000yz    .000x    43.500y    .000z    .000
      .000x**2    .000y**2    -1.000z**2    .000xy    .000xz    .000yz    .000x    .000y    40.960z    .000
      sector
      imp      definitions
array  1      10
boundary 10

----- unit 4 -----
1x2x2 array of metal units padded to match solution array
1      cuboid        10
      quadratic surfaces
      -1.000x**2    .000y**2      .000z**2    .000xy    .000xz    .000yz    13.180x    .000y    .000z    .000
      .000x**2    -1.000y**2    .000z**2    .000xy    .000xz    .000yz    .000x    26.360y    .000z    .000
      .000x**2    .000y**2    -1.000z**2    .000xy    .000xz    .000yz    .000x    .000y    24.900z    .000
2      cuboid        20
      quadratic surfaces
      -1.000x**2    .000y**2      .000z**2    .000xy    .000xz    .000yz    13.180x    .000y    .000z    .000
      .000x**2    -1.000y**2    .000z**2    .000xy    .000xz    .000yz    .000x    26.360y    .000z    299.350
      .000x**2    .000y**2    -1.000z**2    .000xy    .000xz    .000yz    .000x    .000y    24.900z    264.428
      sector
      imp      definitions
array  2      10
media  0      1      20 -10
boundary 20

***** global *****
----- unit 5 -----
global unit of arrays 1 and 2
1      cuboid        10
      quadratic surfaces
      -1.000x**2    .000y**2      .000z**2    .000xy    .000xz    .000yz    34.930x    .000y    .000z    .000
      .000x**2    -1.000y**2    .000z**2    .000xy    .000xz    .000yz    .000x    43.500y    .000z    .000
      .000x**2    .000y**2    -1.000z**2    .000xy    .000xz    .000yz    .000x    .000y    40.960z    .000
      sector
      imp      definitions
array  3      10
boundary 10
  
```



```

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)
----- unit orientation description for array 1 -----
z layer 1, x column 1 to 1 left to right y row 1 to 2 bottom to top
1
1
z layer 2, x column 1 to 1 left to right y row 1 to 2 bottom to top
1
1
----- unit orientation description for array 2 -----
z layer 1, x column 1 to 1 left to right y row 1 to 2 bottom to top
2
2
-z layer 2, x column 1 to 1 left to right y row 1 to 2 bottom to top
2
2
----- unit orientation description for array 3 -----
composite array of solution and metal units
z layer 1, x column 1 to 2 left to right y row 1 to 1 bottom to top
4 3

```

sample problem 19 4 aqueous 4 metal array of arrays (smp prob 12)
volumes for those units utilized in this problem

unit	region	geometry region	volume	cumulative volume
1	1	1	1.00000E+00 cm**3	1.00000E+00 cm**3
	2	2	1.00000E+00 cm**3	1.00000E+00 cm**3
	3	3	1.00000E+00 cm**3	1.00000E+00 cm**3
2	1	4	1.00000E+00 cm**3	1.00000E+00 cm**3
	2	5	1.00000E+00 cm**3	1.00000E+00 cm**3
3	1	6	1.00000E+00 cm**3	1.00000E+00 cm**3
4	1	7	1.00000E+00 cm**3	1.00000E+00 cm**3
	2	8	1.00000E+00 cm**3	1.00000E+00 cm**3
5	1	9	1.00000E+00 cm**3	1.00000E+00 cm**3

unit	uses	region	mixture	total volume
1	4	1	2	4.00000E+00 cm**3
		2	3	4.00000E+00 cm**3
		3	0	4.00000E+00 cm**3
2	4	1	1	4.00000E+00 cm**3
		2	0	4.00000E+00 cm**3
3	1	1		1.00000E+00 cm**3
4	1	1		1.00000E+00 cm**3
		2	0	1.00000E+00 cm**3
5	1	1		1.00000E+00 cm**3

total mixture volumes	
mixture	total volume
0	9.00000E+00 cm**3
1	4.00000E+00 cm**3
2	4.00000E+00 cm**3
3	4.00000E+00 cm**3

```

*****
***                                     ***
***               biasing information   ***
***                                     ***
*** a default weight of .500 will be used for all bias id's. ***
***                                     ***
*****

```

```

..... 0 io's were used in keno-v before tracking .....
..... .02133minutes were used processing data. ....

```

volume fraction of fissile material in the system= .38095E+00

start type 0 was used.

the neutrons were started with a flat distribution in a cuboid defined by:

+x= 3.49300E+01 -x= 0.00000E+00 +y= 4.35000E+01 -y= 0.00000E+00 +z= 4.09600E+01 -z= 0.00000E+00

.00000 minutes were required for starting. total elapsed time is .02133 minutes.

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

generation keno message number	generation k-effective number k6-132	elapsed time minutes warning....only	average k-effective 267 independent	avg k-eff deviation fission points were	matrix k-effective generated	matrix k-eff deviation
1	7.66024E-01	2.13333E-02	1.00000E+00	0.00000E+00	7.83855E-01	0.00000E+00
2	9.38291E-01	4.26667E-02	1.00000E+00	0.00000E+00	8.97564E-01	1.01336E-01
3	9.66243E-01	4.26667E-02	9.66243E-01	0.00000E+00	9.14966E-01	5.96036E-02
4	1.00734E+00	4.26667E-02	9.86789E-01	2.05463E-02	9.53405E-01	6.22936E-02
5	9.07602E-01	6.40000E-02	9.60393E-01	2.89387E-02	9.56865E-01	6.28099E-02
6	9.57428E-01	8.53333E-02	9.59652E-01	2.04762E-02	9.61773E-01	6.00777E-02
7	1.05669E+00	8.53333E-02	9.79059E-01	2.50642E-02	9.82765E-01	6.09066E-02
8	1.10116E+00	1.06667E-01	9.99409E-01	2.88602E-02	9.90786E-01	5.45231E-02
9	1.10255E+00	1.06667E-01	1.01414E+00	2.84961E-02	1.00220E+00	4.86219E-02
10	1.02324E+00	1.06667E-01	1.01528E+00	2.47045E-02	1.00405E+00	4.34626E-02
11	1.14941E+00	1.28000E-01	1.03018E+00	2.63967E-02	1.01487E+00	4.04249E-02
12	9.35704E-01	1.49333E-01	1.02073E+00	2.54301E-02	1.00840E+00	3.75113E-02
13	9.59340E-01	1.49333E-01	1.01515E+00	2.36698E-02	1.00556E+00	3.53034E-02
14	1.01802E+00	1.70667E-01	1.01539E+00	2.16088E-02	1.00522E+00	3.26037E-02
15	9.99063E-01	1.92000E-01	1.01414E+00	1.99169E-02	1.00481E+00	3.05648E-02
16	1.07506E+00	1.92000E-01	1.01849E+00	1.89459E-02	1.00946E+00	2.89452E-02
17	1.01466E+00	1.92000E-01	1.01823E+00	1.76395E-02	1.01003E+00	2.75420E-02
keno message number k6-132	warning....only	296 independent	fission points were generated			
18	9.47762E-01	1.92000E-01	1.01383E+00	1.70780E-02	1.00565E+00	2.59399E-02
19	1.01894E+00	2.13333E-01	1.01413E+00	1.60448E-02	1.00557E+00	2.44866E-02
20	9.87500E-01	2.34667E-01	1.01265E+00	1.51993E-02	1.00525E+00	2.33060E-02
21	9.33306E-01	2.34667E-01	1.00847E+00	1.49713E-02	1.00268E+00	2.23544E-02
22	1.04988E+00	2.56000E-01	1.01054E+00	1.43531E-02	1.00570E+00	2.14367E-02
23	9.02897E-01	2.56000E-01	1.00542E+00	1.45831E-02	1.00247E+00	2.08415E-02
24	1.04664E+00	2.56000E-01	1.00729E+00	1.40301E-02	1.00402E+00	2.00991E-02
25	9.99120E-01	2.77333E-01	1.00694E+00	1.34110E-02	1.00450E+00	1.94233E-02
26	1.09381E+00	2.98667E-01	1.01055E+00	1.33405E-02	1.00902E+00	1.88625E-02
27	9.64773E-01	2.98667E-01	1.00872E+00	1.29261E-02	1.00740E+00	1.83023E-02
28	9.04862E-01	3.20000E-01	1.00473E+00	1.30457E-02	1.00510E+00	1.83017E-02
29	9.72398E-01	3.41333E-01	1.00353E+00	1.26102E-02	1.00389E+00	1.82303E-02
30	9.88587E-01	3.41333E-01	1.00300E+00	1.21632E-02	1.00323E+00	1.80317E-02
31	1.03125E+00	3.41333E-01	1.00397E+00	1.17766E-02	1.00336E+00	1.75519E-02
32	9.66574E-01	3.62667E-01	1.00273E+00	1.14454E-02	1.00280E+00	1.70535E-02
33	1.12385E+00	3.62667E-01	1.00663E+00	1.17393E-02	1.00670E+00	1.68599E-02
34	9.68236E-01	3.84000E-01	1.00543E+00	1.14297E-02	1.00642E+00	1.65707E-02
35	1.03058E+00	3.84000E-01	1.00619E+00	1.11041E-02	1.00738E+00	1.64420E-02
36	1.05318E+00	4.05333E-01	1.00758E+00	1.08608E-02	1.00853E+00	1.62703E-02
37	1.01871E+00	4.26667E-01	1.00789E+00	1.05508E-02	1.00818E+00	1.59709E-02
38	1.05509E+00	4.26667E-01	1.00921E+00	1.03370E-02	1.00946E+00	1.55677E-02
39	9.83623E-01	4.26667E-01	1.00851E+00	1.00775E-02	1.00934E+00	1.52476E-02
40	1.10613E+00	4.48000E-01	1.01108E+00	1.01395E-02	1.01192E+00	1.50791E-02
41	1.03181E+00	4.48000E-01	1.01161E+00	9.89034E-03	1.01193E+00	1.47503E-02
42	1.07090E+00	4.69333E-01	1.01310E+00	9.75320E-03	1.01305E+00	1.44444E-02
43	1.03679E+00	4.90667E-01	1.01367E+00	9.52987E-03	1.01373E+00	1.41244E-02
44	1.05677E+00	4.90667E-01	1.01470E+00	9.35664E-03	1.01422E+00	1.38713E-02
45	1.06848E+00	4.90667E-01	1.01595E+00	9.22165E-03	1.01504E+00	1.38070E-02
46	1.06380E+00	5.12000E-01	1.01704E+00	9.07502E-03	1.01647E+00	1.36907E-02
47	1.06224E+00	5.12000E-01	1.01804E+00	8.92774E-03	1.01725E+00	1.34867E-02
48	1.13320E+00	5.33333E-01	1.02055E+00	9.08326E-03	1.01938E+00	1.34012E-02
49	9.98548E-01	5.54667E-01	1.02008E+00	8.90022E-03	1.01877E+00	1.31955E-02
50	9.61480E-01	5.76000E-01	1.01886E+00	8.79793E-03	1.01839E+00	1.29485E-02
51	1.03020E+00	5.76000E-01	1.01909E+00	8.61962E-03	1.01894E+00	1.27361E-02
52	9.27334E-01	5.76000E-01	1.01725E+00	8.64255E-03	1.01699E+00	1.25846E-02
53	1.03050E+00	5.97333E-01	1.01751E+00	8.47537E-03	1.01688E+00	1.23602E-02
54	1.02054E+00	5.97333E-01	1.01757E+00	8.31099E-03	1.01701E+00	1.21453E-02
55	1.01085E+00	6.18667E-01	1.01745E+00	8.15366E-03	1.01679E+00	1.20240E-02
56	1.04757E+00	6.18667E-01	1.01800E+00	8.02067E-03	1.01712E+00	1.19359E-02
57	1.02074E+00	6.40000E-01	1.01805E+00	7.87364E-03	1.01764E+00	1.19392E-02
58	9.34674E-01	6.40000E-01	1.01656E+00	7.87382E-03	1.01651E+00	1.21162E-02
59	1.05164E+00	6.40000E-01	1.01718E+00	7.75888E-03	1.01706E+00	1.21847E-02
60	1.01307E+00	6.61333E-01	1.01711E+00	7.62427E-03	1.01701E+00	1.24888E-02
61	1.10038E+00	6.61333E-01	1.01852E+00	7.62568E-03	1.01816E+00	1.29250E-02
62	1.06235E+00	6.82667E-01	1.01925E+00	7.53301E-03	1.01851E+00	1.31459E-02
63	1.06503E+00	7.04000E-01	1.02000E+00	7.44640E-03	1.01911E+00	1.29891E-02
64	1.01986E+00	7.04000E-01	1.02000E+00	7.32532E-03	1.01928E+00	1.31282E-02
65	1.08213E+00	7.25333E-01	1.02098E+00	7.27527E-03	1.02047E+00	1.34135E-02
66	9.62545E-01	7.25333E-01	1.02007E+00	7.21867E-03	1.01950E+00	1.35088E-02
67	9.75206E-01	7.25333E-01	1.01938E+00	7.14019E-03	1.01853E+00	1.36395E-02
68	1.02603E+00	7.46667E-01	1.01948E+00	7.03189E-03	1.01852E+00	1.37736E-02
69	9.75495E-01	7.46667E-01	1.01883E+00	6.95719E-03	1.01783E+00	1.39108E-02
70	1.04304E+00	7.68000E-01	1.01918E+00	6.86336E-03	1.01809E+00	1.38588E-02
71	9.97267E-01	7.68000E-01	1.01886E+00	6.77061E-03	1.01724E+00	1.37483E-02
72	1.09516E+00	7.89333E-01	1.01995E+00	6.76161E-03	1.01830E+00	1.36257E-02
73	1.01785E+00	8.10667E-01	1.01992E+00	6.66576E-03	1.01801E+00	1.34444E-02
74	1.04521E+00	8.10667E-01	1.02028E+00	6.58190E-03	1.01855E+00	1.32779E-02
75	9.94144E-01	8.10667E-01	1.01992E+00	6.50097E-03	1.01777E+00	1.31191E-02
76	1.00068E+00	8.32000E-01	1.01966E+00	6.41779E-03	1.01762E+00	1.29719E-02
77	1.11551E+00	8.32000E-01	1.02094E+00	6.45935E-03	1.01901E+00	1.29111E-02
78	1.08147E+00	8.53333E-01	1.02173E+00	6.42337E-03	1.01977E+00	1.27638E-02
79	9.62230E-01	8.74667E-01	1.02096E+00	6.38632E-03	1.01877E+00	1.26085E-02
80	1.01192E+00	8.74667E-01	1.02084E+00	6.30498E-03	1.01870E+00	1.24520E-02
81	1.03051E+00	8.74667E-01	1.02097E+00	6.22586E-03	1.01840E+00	1.23166E-02

82	1.03003E+00	8.96000E-01	1.02108E+00	6.14859E-03	1.01845E+00	1.21759E-02
83	9.92268E-01	8.96000E-01	1.02072E+00	6.08262E-03	1.01806E+00	1.20397E-02
84	1.01649E+00	9.17333E-01	1.02067E+00	6.00820E-03	1.01818E+00	1.19353E-02
85	1.02330E+00	9.38667E-01	1.02070E+00	5.93546E-03	1.01833E+00	1.18126E-02
86	9.92399E-01	9.38667E-01	1.02037E+00	5.87404E-03	1.01785E+00	1.16888E-02
87	8.91626E-01	9.60000E-01	1.01885E+00	5.99888E-03	1.01653E+00	1.15902E-02
88	9.19713E-01	9.60000E-01	1.01770E+00	6.03975E-03	1.01546E+00	1.14812E-02
89	9.77252E-01	9.60000E-01	1.01723E+00	5.98800E-03	1.01485E+00	1.13723E-02
90	1.05494E+00	9.81333E-01	1.01766E+00	5.93504E-03	1.01531E+00	1.13617E-02
91	9.85871E-01	9.81333E-01	1.01731E+00	5.87884E-03	1.01515E+00	1.13296E-02
92	9.30061E-01	1.00267E+00	1.01634E+00	5.89343E-03	1.01437E+00	1.12229E-02
93	1.00741E+00	1.02400E+00	1.01624E+00	5.82913E-03	1.01440E+00	1.11048E-02
94	9.64425E-01	1.02400E+00	1.01567E+00	5.79286E-03	1.01380E+00	1.10428E-02
95	9.92586E-01	1.02400E+00	1.01543E+00	5.73561E-03	1.01345E+00	1.09262E-02
96	9.19276E-01	1.02400E+00	1.01440E+00	5.76572E-03	1.01256E+00	1.08677E-02
97	1.01622E+00	1.04533E+00	1.01442E+00	5.70474E-03	1.01242E+00	1.07951E-02
98	1.01975E+00	1.06667E+00	1.01448E+00	5.64528E-03	1.01247E+00	1.07242E-02
99	1.06121E+00	1.06667E+00	1.01496E+00	5.60751E-03	1.01293E+00	1.06484E-02
100	1.09792E+00	1.08800E+00	1.01581E+00	5.61419E-03	1.01358E+00	1.05702E-02
101	1.00695E+00	1.08800E+00	1.01572E+00	5.55791E-03	1.01369E+00	1.05067E-02
102	9.72192E-01	1.10933E+00	1.01528E+00	5.51924E-03	1.01340E+00	1.04936E-02
103	1.02963E+00	1.10933E+00	1.01542E+00	5.46617E-03	1.01324E+00	1.04766E-02

keno message number k6-123 execution terminated due to completion of the specified number of generations.

the matrix k-effective is the largest eigenvalue of the fission production by position index matrix.
there are nbxmax * nbymax * nbzmax positions in an array.

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

lifetime = 4.47772E-06 + or - 8.99083E-08 generation time = 5.31792E-06 + or - 1.24913E-07
 nu bar = 2.50608E+00 + or - 1.40421E-03 average fission group = 1.41476E+01 + or - 9.90757E-02
 energy(ev) of the average lethargy causing fission = 1.85333E+02 + or - 1.66111E+01
 self multiplication = 1.01225E+00 + or - 5.92558E-03

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	deviation of variance (per cent)
3	1.01592	+ or - .00550	1.01042 to 1.02141	1.00492 to 1.02691	.99942 to 1.03241	30000	13.2575
4	1.01600	+ or - .00555	1.01045 to 1.02156	1.00489 to 1.02711	.99934 to 1.03266	29700	13.2262
5	1.01711	+ or - .00550	1.01161 to 1.02261	1.00611 to 1.02811	1.00061 to 1.03360	29400	13.4186
6	1.01772	+ or - .00552	1.01220 to 1.02324	1.00668 to 1.02876	1.00116 to 1.03429	29100	13.5929
7	1.01732	+ or - .00556	1.01175 to 1.02288	1.00619 to 1.02844	1.00063 to 1.03401	28800	13.6570
8	1.01644	+ or - .00555	1.01088 to 1.02199	1.00533 to 1.02754	.99978 to 1.03309	28500	13.9239
9	1.01552	+ or - .00553	1.00999 to 1.02105	1.00445 to 1.02659	.99892 to 1.03212	28200	14.2077
10	1.01544	+ or - .00559	1.00984 to 1.02103	1.00425 to 1.02662	.99866 to 1.03221	27900	14.1736
11	1.01398	+ or - .00546	1.00852 to 1.01944	1.00306 to 1.02490	.99760 to 1.03036	27600	13.8415
12	1.01484	+ or - .00545	1.00939 to 1.02029	1.00394 to 1.02574	.99849 to 1.03119	27300	14.1486
17	1.01493	+ or - .00569	1.00925 to 1.02062	1.00356 to 1.02631	.99788 to 1.03199	25800	14.4451
22	1.01663	+ or - .00586	1.01076 to 1.02249	1.00490 to 1.02836	.99903 to 1.03422	24300	15.1754
27	1.01763	+ or - .00592	1.01170 to 1.02355	1.00578 to 1.02948	.99986 to 1.03540	22800	15.9811
32	1.02079	+ or - .00603	1.01476 to 1.02682	1.00872 to 1.03286	1.00269 to 1.03889	21300	16.7464
37	1.01942	+ or - .00623	1.01319 to 1.02564	1.00697 to 1.03187	1.00074 to 1.03809	19800	17.2931
42	1.01695	+ or - .00647	1.01048 to 1.02342	1.00402 to 1.02988	.99755 to 1.03635	18300	18.2226
47	1.01332	+ or - .00682	1.00650 to 1.02014	.99967 to 1.02697	.99285 to 1.03379	16800	19.2924
52	1.01363	+ or - .00682	1.00681 to 1.02045	1.00000 to 1.02726	.99318 to 1.03408	15300	20.3986
57	1.01228	+ or - .00751	1.00477 to 1.01979	.99726 to 1.02731	.98974 to 1.03482	13800	20.2128
62	1.00982	+ or - .00776	1.00207 to 1.01758	.99431 to 1.02534	.98655 to 1.03310	12300	22.7435
67	1.00828	+ or - .00830	.99998 to 1.01658	.99168 to 1.02488	.98337 to 1.03318	10800	25.4805
72	1.00519	+ or - .00906	.99614 to 1.01425	.98708 to 1.02331	.97803 to 1.03236	9300	27.6581
77	.99953	+ or - .00972	.98981 to 1.00924	.98009 to 1.01896	.97038 to 1.02867	7800	28.2542
82	.99388	+ or - .01097	.98291 to 1.00485	.97194 to 1.01582	.96097 to 1.02679	6300	31.7664
87	.99721	+ or - .01267	.98454 to 1.00988	.97187 to 1.02255	.95920 to 1.03522	4800	33.3090
92	1.00796	+ or - .01442	.99354 to 1.02238	.97912 to 1.03681	.96469 to 1.05123	3300	49.1956
97	1.03128	+ or - .01785	1.01343 to 1.04912	.99558 to 1.06697	.97773 to 1.08482	1800	60.5636

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)
 plot of average k-effective by generation run.
 the line represents k-eff = 1.0159 + or - .0055 which occurs for 103 generations run.

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)
 plot of average k-effective by generation skipped.
 the line represents $k\text{-eff} = 1.0173 \pm 0.0058$ which occurs for 8 generations skipped.

generations

group	fission fraction	unit	region	fissions	percent deviation	absorptions	percent deviation	leakage	percent deviation
1	.0123			1.24655E-02	6.6666	3.88820E-03	6.1950	7.83278E-03	5.9845
2	.0625			6.35159E-02	2.1827	2.33323E-02	2.0541	6.08748E-02	2.3655
3	.0793			8.05211E-02	2.3803	3.11063E-02	2.3604	7.25412E-02	2.1864
4	.0458			4.65431E-02	2.7027	1.89026E-02	2.6884	4.09507E-02	2.6661
5	.0677			6.87411E-02	2.2946	2.92850E-02	2.2917	5.64617E-02	2.3303
6	.0962			9.77272E-02	1.9496	4.46347E-02	1.9449	8.60874E-02	1.7621
7	.0750			7.62107E-02	2.2772	3.78283E-02	2.2767	6.36809E-02	2.1848
8	.0217			2.20593E-02	3.4673	1.23315E-02	3.4638	2.74690E-02	3.5364
9	.0096			9.77563E-03	4.9486	5.62997E-03	4.9260	1.53279E-02	3.8018
10	.0132			1.33839E-02	3.5625	7.86698E-03	3.5310	1.29909E-02	5.5904
11	.0218			2.21227E-02	2.1970	1.39416E-02	2.1617	1.09830E-02	5.1337
12	.0248			2.52000E-02	1.9682	1.65951E-02	1.9094	7.98579E-03	6.7602
13	.0216			2.19422E-02	1.9776	1.64050E-02	1.8446	6.23545E-03	6.5188
14	.0179			1.81605E-02	1.9966	1.54396E-02	1.8081	7.31300E-03	6.3897
15	.0042			4.27608E-03	4.7513	3.03728E-03	4.3635	3.26536E-03	9.7744
16	.0027			2.79214E-03	6.6016	1.66086E-03	5.9505	1.70334E-03	12.3468
17	.0038			3.83612E-03	3.7370	2.21248E-03	3.6515	5.05704E-04	21.1090
18	.0047			4.77205E-03	3.7644	2.44824E-03	3.7120	4.63957E-04	25.5494
19	.0059			5.97526E-03	3.1278	2.92542E-03	3.0292	1.32827E-03	13.6647
20	.0243			2.47236E-02	1.9082	1.21004E-02	1.8661	3.62457E-03	8.3223
21	.0125			1.26708E-02	3.0670	6.49619E-03	3.0389	9.44617E-04	15.5483
22	.0275			2.79321E-02	2.1938	1.48221E-02	2.1833	1.72465E-03	10.5998
23	.0718			7.29737E-02	1.7029	3.76834E-02	1.6914	3.53760E-03	7.3288
24	.0974			9.89196E-02	1.5358	4.99746E-02	1.5292	3.61187E-03	6.8975
25	.0708			7.19368E-02	1.5435	3.62318E-02	1.5338	1.85105E-03	8.8398
26	.0777			7.89842E-02	1.8086	3.98216E-02	1.8039	1.64156E-03	10.5867
27	.0273			2.77547E-02	2.7373	1.40494E-02	2.7153	4.04768E-04	20.5533
system total =				1.01592E+00	.5413	5.00651E-01	.5574	5.01342E-01	.5180
elapsed time				1.10933 minutes					
random number=				0000760C32983B88					

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

position k-effective= 1.01345E+00 + or - 1.04790E-02
the position k-effective is the largest eigenvalue of the fission production by position index matrix.

elapsed time 1.10933 minutes

fission production by position index matrix

(i, j) p is the number of next generation neutrons produced at position index j by a neutron born at position index i.

(1, 1) 9.01E-01 (1, 2) 1.86E-01 (1, 3) 0.00E+00

(2, 1) 1.04E-01 (2, 2) 8.42E-01 (2, 3) 0.00E+00

(3, 1) 0.00E+00 (3, 2) 0.00E+00 (3, 3) 0.00E+00

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

source vector by position index

index	vector
1	4.79801E-01
2	5.20199E-01
3	0.00000E+00

average self multiplication by array position

the number of next generation neutrons produced in a unit located at a given position in the array by a neutron born in that same unit is $8.69919E-01 \pm 7.11086E-03$

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

unit k-effective= 1.01345E+00 + or - 1.04790E-02
the unit k-effective is the largest eigenvalue of the fission production by unit number matrix.

elapsed time 1.10933 minutes

fission production by unit number matrix
(i, j) p is the number of next generation neutrons produced in unit j by a neutron born in unit i.

(1, 1)	8.42E-01	(1, 2)	1.04E-01	(1, 3)	0.00E+00	(1, 4)	0.00E+00	(1, 5)	0.00E+00
(2, 1)	1.86E-01	(2, 2)	9.01E-01	(2, 3)	0.00E+00	(2, 4)	0.00E+00	(2, 5)	0.00E+00
(3, 1)	0.00E+00	(3, 2)	0.00E+00	(3, 3)	0.00E+00	(3, 4)	0.00E+00	(3, 5)	0.00E+00
(4, 1)	0.00E+00	(4, 2)	0.00E+00	(4, 3)	0.00E+00	(4, 4)	0.00E+00	(4, 5)	0.00E+00
(5, 1)	0.00E+00	(5, 2)	0.00E+00	(5, 3)	0.00E+00	(5, 4)	0.00E+00	(5, 5)	0.00E+00

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

source vector by unit

unit	vector
1	5.20199E-01
2	4.79801E-01
3	0.00000E+00
4	0.00000E+00
5	0.00000E+00

average self multiplication by unit

the number of next generation neutrons produced in a unit by
a neutron born in that same unit is 8.69919E-01 + or - 5.02814E-03

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

**** fission densities ****

unit	region	fission density	percent deviation	total fissions
1	1	1.327E-01	1.20	5.308E-01
	2	0.000E+00	.00	0.000E+00
	3	0.000E+00	.00	0.000E+00
2	1	1.213E-01	1.26	4.851E-01
	2	0.000E+00	.00	0.000E+00
3	1	0.000E+00	.00	0.000E+00
4	1	0.000E+00	.00	0.000E+00
	2	0.000E+00	.00	0.000E+00
5	1	0.000E+00	.00	0.000E+00

global unit

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

fluxes for unit 1			region 2		region 3	
group	flux	percent deviation	flux	percent deviation	flux	percent deviation
1	1.936E-02	8.05	4.241E-03	12.04	7.563E-03	8.78
2	1.773E-01	2.61	4.086E-02	3.69	7.166E-02	3.45
3	2.110E-01	2.09	5.217E-02	3.13	8.127E-02	2.43
4	1.207E-01	2.13	2.860E-02	3.56	4.843E-02	3.59
5	1.707E-01	1.84	4.018E-02	3.24	6.887E-02	3.40
6	2.627E-01	1.46	6.492E-02	2.44	1.058E-01	2.40
7	2.279E-01	1.29	5.955E-02	2.39	8.608E-02	2.67
8	1.647E-01	1.44	3.641E-02	2.51	5.073E-02	3.32
9	1.243E-01	1.68	2.404E-02	3.34	2.905E-02	4.28
10	1.107E-01	1.62	2.109E-02	2.97	2.603E-02	4.76
11	1.035E-01	1.53	1.994E-02	3.14	2.181E-02	4.71
12	6.447E-02	1.70	1.253E-02	3.94	1.567E-02	6.10
13	5.359E-02	1.69	9.955E-03	4.18	1.301E-02	5.77
14	5.395E-02	1.85	1.036E-02	4.03	1.401E-02	5.44
15	2.484E-02	2.43	4.633E-03	5.52	5.885E-03	8.15
16	1.475E-02	3.25	2.962E-03	7.14	3.446E-03	10.19
17	6.547E-03	4.05	1.128E-03	10.35	1.263E-03	18.39
18	5.177E-03	3.53	7.991E-04	13.97	1.047E-03	20.38
19	9.996E-03	3.10	1.724E-03	7.78	2.640E-03	13.36
20	3.251E-02	1.95	6.452E-03	4.25	8.227E-03	8.06
21	9.356E-03	3.00	1.902E-03	7.71	2.183E-03	13.61
22	1.528E-02	2.52	3.056E-03	6.88	3.711E-03	9.90
23	3.657E-02	1.71	8.851E-03	4.06	9.758E-03	6.33
24	3.254E-02	1.68	9.871E-03	4.42	1.127E-02	6.36
25	1.658E-02	1.68	6.142E-03	4.89	6.634E-03	6.83
26	1.237E-02	2.07	5.194E-03	5.76	5.511E-03	8.59
27	2.245E-03	3.29	1.235E-03	9.93	1.494E-03	14.98

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

fluxes for unit 2			region 2		
region 1			region 2		
group	flux	percent deviation	flux	percent deviation	
1	1.203E-02	6.25	6.181E-03	7.72	
2	1.026E-01	2.12	5.081E-02	3.26	
3	1.286E-01	2.42	6.315E-02	2.83	
4	8.009E-02	2.97	3.866E-02	3.42	
5	1.228E-01	2.36	5.663E-02	2.48	
6	1.955E-01	1.90	9.139E-02	2.17	
7	1.369E-01	2.19	6.312E-02	2.64	
8	2.626E-02	4.02	1.545E-02	4.96	
9	6.403E-03	8.48	7.113E-03	8.48	
10	3.387E-03	9.92	4.885E-03	9.77	
11	2.375E-03	9.91	3.864E-03	10.69	
12	1.726E-03	13.74	2.539E-03	13.62	
13	1.522E-03	14.96	2.485E-03	14.55	
14	1.573E-03	11.51	2.731E-03	13.60	
15	5.363E-04	21.66	9.046E-04	23.10	
16	1.946E-04	36.75	4.997E-04	26.74	
17	8.655E-05	35.63	3.108E-04	39.22	
18	7.330E-05	43.54	1.030E-04	52.15	
19	1.520E-04	34.80	2.838E-04	30.54	
20	4.567E-04	17.72	1.518E-03	16.56	
21	1.608E-04	28.36	3.514E-04	32.36	
22	2.633E-04	22.37	4.960E-04	28.56	
23	7.266E-04	14.47	1.161E-03	12.76	
24	7.437E-04	15.44	1.302E-03	14.52	
25	3.899E-04	18.31	7.765E-04	19.39	
26	2.024E-04	26.95	3.610E-04	22.70	
27	1.118E-04	46.80	1.666E-04	38.36	

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

fluxes for unit	3	
region	1	
group	flux	percent deviation
1	0.000E+00	.00
2	0.000E+00	.00
3	0.000E+00	.00
4	0.000E+00	.00
5	0.000E+00	.00
6	0.000E+00	.00
7	0.000E+00	.00
8	0.000E+00	.00
9	0.000E+00	.00
10	0.000E+00	.00
11	0.000E+00	.00
12	0.000E+00	.00
13	0.000E+00	.00
14	0.000E+00	.00
15	0.000E+00	.00
16	0.000E+00	.00
17	0.000E+00	.00
18	0.000E+00	.00
19	0.000E+00	.00
20	0.000E+00	.00
21	0.000E+00	.00
22	0.000E+00	.00
23	0.000E+00	.00
24	0.000E+00	.00
25	0.000E+00	.00
26	0.000E+00	.00
27	0.000E+00	.00

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

fluxes for unit 4				region 2			
		region 1					
group	flux	percent deviation		flux	percent deviation		
1	0.000E+00	.00		2.634E-02	10.16		
2	0.000E+00	.00		2.284E-01	4.20		
3	0.000E+00	.00		2.791E-01	3.80		
4	0.000E+00	.00		1.567E-01	4.31		
5	0.000E+00	.00		2.400E-01	3.82		
6	0.000E+00	.00		3.648E-01	3.04		
7	0.000E+00	.00		2.713E-01	3.05		
8	0.000E+00	.00		9.770E-02	5.89		
9	0.000E+00	.00		5.388E-02	8.49		
10	0.000E+00	.00		3.566E-02	10.61		
11	0.000E+00	.00		3.305E-02	11.25		
12	0.000E+00	.00		2.370E-02	12.02		
13	0.000E+00	.00		1.898E-02	13.74		
14	0.000E+00	.00		2.018E-02	12.85		
15	0.000E+00	.00		9.610E-03	18.29		
16	0.000E+00	.00		5.653E-03	24.94		
17	0.000E+00	.00		1.627E-03	40.56		
18	0.000E+00	.00		1.575E-03	43.50		
19	0.000E+00	.00		3.614E-03	27.28		
20	0.000E+00	.00		1.252E-02	15.49		
21	0.000E+00	.00		1.874E-03	35.37		
22	0.000E+00	.00		3.835E-03	24.48		
23	0.000E+00	.00		8.211E-03	16.59		
24	0.000E+00	.00		1.047E-02	15.09		
25	0.000E+00	.00		6.181E-03	20.99		
26	0.000E+00	.00		3.063E-03	24.76		
27	0.000E+00	.00		1.972E-03	41.78		

sample problem 19 & aqueous & metal array of arrays (samp prob 12)

fluxes for global unit		
region 1		
group	flux	percent deviation
1	0.000E+00	.00
2	0.000E+00	.00
3	0.000E+00	.00
4	0.000E+00	.00
5	0.000E+00	.00
6	0.000E+00	.00
7	0.000E+00	.00
8	0.000E+00	.00
9	0.000E+00	.00
10	0.000E+00	.00
11	0.000E+00	.00
12	0.000E+00	.00
13	0.000E+00	.00
14	0.000E+00	.00
15	0.000E+00	.00
16	0.000E+00	.00
17	0.000E+00	.00
18	0.000E+00	.00
19	0.000E+00	.00
20	0.000E+00	.00
21	0.000E+00	.00
22	0.000E+00	.00
23	0.000E+00	.00
24	0.000E+00	.00
25	0.000E+00	.00
26	0.000E+00	.00
27	0.000E+00	.00

F17.E.53

NURBG/CR-0200,
Vol. 2, Rev. 5

sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)

```
frequency for generations 4 to 103
.8759 to .8990 *
.8990 to .9221 *****
.9221 to .9452 *****
.9452 to .9683 *****
.9683 to .9914 *****
.9914 to 1.0145 *****
1.0145 to 1.0376 *****
1.0376 to 1.0607 *****
1.0607 to 1.0838 *****
1.0838 to 1.1068 *****
1.1068 to 1.1299 **
1.1299 to 1.1530 **
```

```
frequency for generations 29 to 103
.8759 to .8990 *
.8990 to .9221 **
.9221 to .9452 ***
.9452 to .9683 *****
.9683 to .9914 *****
.9914 to 1.0145 *****
1.0145 to 1.0376 *****
1.0376 to 1.0607 *****
1.0607 to 1.0838 *****
1.0838 to 1.1068 *****
1.1068 to 1.1299 **
1.1299 to 1.1530 *
```

```
frequency for generations 54 to 103
.8759 to .8990 *
.8990 to .9221 **
.9221 to .9452 **
.9452 to .9683 ***
.9683 to .9914 *****
.9914 to 1.0145 *****
1.0145 to 1.0376 *****
1.0376 to 1.0607 *****
1.0607 to 1.0838 *****
1.0838 to 1.1068 *****
1.1068 to 1.1299 *
1.1299 to 1.1530
```

```
frequency for generations 79 to 103
.8759 to .8990 *
.8990 to .9221 **
.9221 to .9452 *
.9452 to .9683 **
.9683 to .9914 ***
.9914 to 1.0145 *****
1.0145 to 1.0376 *****
1.0376 to 1.0607 *
1.0607 to 1.0838 *
1.0838 to 1.1068 *
1.1068 to 1.1299
1.1299 to 1.1530
```

congratulations! you have successfully traversed the perilous path through keno vi in 1.10933 minutes

F17.F. LIST OF KENO V.a VALIDATION REPORTS

This section contains a list of KENO validation reports in reverse chronological order. This list includes validation reports for KENO V.a and older versions of KENO. These reports form the basis of the validation reports to be done on KENO-VI.

- ORNL-6512 *Validation Studies Based on Data From Criticality Experiments Performed With Mixed Oxide Fuel Pins Moderated by Plutonium-Uranium-Gadolinium Nitrate Solutions*, G. R. Smolen, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab. (to be published).
- ORNL-6511 *Validation Studies Based on Data From Plutonium-Uranium Nitrate Critical Experiments Conducted in Annular Geometry*, G. R. Smolen, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab. (to be published).
- ORNL-6510 *Validation Studies Based on Data From Plutonium-Uranium Nitrate Critical Experiments Conducted in Slab and Cylindrical Geometries*, G. R. Smolen, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., December 1989.
- NEACRP-L-306 *Standard Problem Exercise on Criticality Codes for Dissolving Fissile Oxides in Acids*, OECD, Paris, France, 1989.
- Y/DD-419 *Validation Check Cases of SCALE77 on the ORGDP IBM-3083*, W. C. Jordan, H. R. Dyer, J. C. Turner, Martin Marietta Energy Systems, Inc., Oak Ridge Y-12 Plant, January 1989.
- ORNL-6449 *Validation Studies Based on Data From Low Concentration Mixed Pu + U Aqueous Critical Experiments*, G. R. Smolen, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., August 1988.
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Washington, DC 20545

- ORNL-6443 *Validation Studies Performed With Water- and Organic-Moderated and Reflected Mixed Oxide Fuel Pin Critical Experiments*, G. R. Smolen, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., June 1988.
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- ORNL/CSD/TM-242 *Recalculation of a Few Bare Plutonium Critical Arrays*, H. R. Dyer, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., April 1987.
- ORNL/CSD/TM-238 *Validation of KENO-V.a Comparison with Critical Experiments*, W. C. Jordan, N. F. Landers, L. M. Petrie, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., December 1986.
- ORNL/TM-9668 *Validation Studies for KENO-IV with Mixed Plutonium-Uranium Critical Experiments*, R. T. Primm III, Martin Marietta Energy Systems Inc., Oak Ridge Natl. Lab., November 1985.
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- ORNL/CFRP-84/20 *Validation of the SCALE Code System and One Cross-Section Library for Plutonium and Gadolinium Solutions*, R. L. Sanders, University of Tennessee, July 1985.
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 Washington, DC 20545
- ORNL/CSD/TM-223 *Validation of KENO-V.a and Two Cross-Section Libraries for Criticality Calculations of Low-Enriched Uranium Systems*, M. E. Easter, Martin Marietta Energy Systems Inc., Oak Ridge Natl. Lab., July 1985.
- ORNL/TM-9402 *Validation of the SCALE Code System and Two Cross-Section Libraries for Plutonium Benchmark Experiments*, M.E. Easter, University of Tennessee, R. T. Primm III, Martin Marietta Energy Systems Inc., Oak Ridge Natl. Lab., January 1985.
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- ORNL/CSD/TM-224 *Assessment of Computational Performance in Nuclear Criticality*, L. M. Petrie, J. T. Thomas, Martin Marietta Energy Systems Inc., Oak Ridge Natl. Lab., January 1985.
- ORNL/CSD/TM-221 *Validation of the Monte Carlo Criticality Program KENO-V.a for Highly Enriched Uranium Systems*, J. R. Knight, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., November 1984.
- CSNI Report No. 78 *Standard Problem Exercise on Criticality Codes for Large Arrays of Packages on Fissile Materials*, CSNI Working Group, OECD, Paris, France, August 1984.
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- CSNI Report No. 71 *Standard Problem Exercise on Criticality Codes for Spent LWR Fuel Transport Containers*, CSNI Group of Experts on Nuclear Criticality Safety Computations, OECD, Paris, France, May 1982.
- NUREG/CR-1917 *Validation of Three Cross-Section Libraries Used with the SCALE System for Criticality Safety Analysis*, ORNL/NUREG/CSD/TM-19, A. M. Hathout et al., U.S. Nuclear Regulatory Commission, June 1981.
- Y-2234 *Validation of the Monte Carlo Criticality Program KENO-IV and the Hansen-Roach "Sixteen-Energy Group Cross-Sections for High Assay Uranium Systems"*, G. R. Handley, L. C. Masters, R. V. Stachowiak, Union Carbide Corp., Nuclear Div., Oak Ridge Y-12 Plant, April 1981.
- Trans. Am. Nucl. Soc.*
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- Y-1948 *Validation of the KENO code for Nuclear Criticality Safety Calculations of Moderated, Low-Enriched Uranium Systems*, G. R. Handley and C. M. Hopper, Union Carbide Corp., Nuclear Div., Oak Ridge Y-12 Plant, 1974.
- Y-1858 *Validation Checks of the ANISN and KENO Codes by Correlation with Experimental Data*, G. R. Handley and C. M. Hopper, Union Carbide Corp., Oak Ridge Y-12 Plant, 1972.