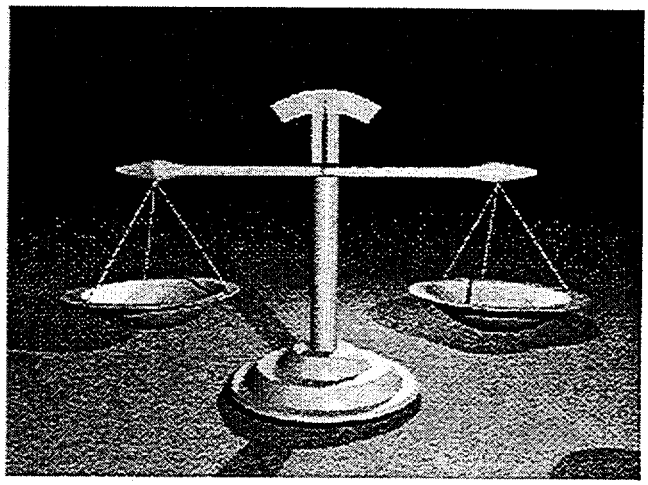
NUREG/CR-0200, Rev. 6
ORNL/NUREG/CSD-2/R6
Vol. 1, Part 1

SCALE

Version 4.4

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



Control Modules, Part 1

Oak Ridge National Laboratory

Prepared for
U.S. Nuclear Regulatory Commission

NUREG/CR-0200, Rev. 6
ORNL/NUREG/CSD-2/R6
Vol. 1, Part 1

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

Control Modules
C4, C6

Manuscript Completed: February 2000
Date Published: May 2000

Oak Ridge National Laboratory
Managed by Lockheed Martin Energy Research Corp.
Oak Ridge, TN 37831

Prepared for
Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
NRC Job Code B0009

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ABSTRACT

SCALE, a modular code system for Standardized Computer Analyses Licensing Evaluation, has been developed by Oak Ridge National Laboratory at the request of the U.S. Nuclear Regulatory Commission. The SCALE system utilizes well-established computer codes and methods within standard analysis sequences that (1) allow an input format designed for the occasional user and/or novice, (2) automate the data processing and coupling between modules, and (3) provide accurate and reliable results. System development has been directed at problem-dependent cross-section processing and analysis of criticality safety, shielding, heat transfer, and depletion/decay problems. Since the initial release of SCALE in 1980, the code system has been heavily used for evaluation of nuclear fuel facility and package designs. This revision documents Version 4.4 of the system.

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***Cancelled. Included in Section C4.

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*Obsolete with SCALE-4.0 release.
**Not included in SCALE-4.4 release.
***Cancelled. Included in Section C4.

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*Obsolete with SCALE-4.0 release.
**Not included in SCALE-4.4 release.
***Cancelled. Included in Section C4.

PREFACE

Introduction

This Manual represents Revision 6 of the user documentation for the modular code system referred to as SCALE. The previous revision documented version 4.3 of SCALE, released in October 1995. This revision documents version 4.4a of SCALE. Prior to the release of version 4.4a, SCALE 4.4 was released in September 1998. Many minor corrections and enhancements have been made since that time and are being included in SCALE 4.4a. The corrections and enhancements in versions 4.4a and 4.4 are documented separately below. All modifications in version 4.4 are included in version 4.4a.

Background

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, D1, S1- S5, and H1), Volume 2 for the functional module documentation (Sections F1- F17), and Volume 3 for the documentation of data libraries, and subroutine libraries, and miscellaneous utilities (Sections M1- M17).

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 AMPX[1] 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 newer criticality control module to provide automated problem-dependent cross-section processing and criticality calculations via the 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. An alternative sequence for depletion/decay calculations is ORIGEN-ARP (Section D1), which interpolates pre-generated ORIGEN-S cross-section libraries versus enrichment, burnup, and moderator density. 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.

A 238-energy-group neutron cross-section library based on ENDF/B-V[2] is the latest cross-section library in SCALE. 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.[3] These libraries are available in this version of SCALE.

Technical Assistance and Updates

To obtain technical assistance regarding the installation and use of SCALE, download software updates, or report problems, you may contact us through the following channels:

- E-mail questions to **scalehelp@ornl.gov**
- The SCALE Users Electronic Notebook on the Web:
  http://www-rsicc.ornl.gov/ENOTE/enotscal.html
- SCALE Web Site (including Download, Training, Benchmarks, and Newsletter pages):
  http://www.cped.ornl.gov/cad_nea/text/scale-home.html
- SCALE Newsletter:
  http://www.cped.ornl.gov/cad_nea/text/scale_news.html
- FAX to SCALE Help, 815-327-6460 or 865-576-3513

Significant Updates in SCALE 4.4a

A significant number of updates have been made to SCALE since the initial release of SCALE 4.4 in September 1998. Most of these updates were minor corrections or enhancements. Because some of these updates could be important to SCALE users, this interim release of SCALE 4.4a is being made available.

SAS4 and PICTURE were enhanced to allow the generation of two-dimensional (2-D) plots when the "PARM=CHECK" option is used. This option is similar to the plotting option in the CSAS criticality sequences. Another innovation was the addition of an option that allows users to specify an X-Y, X-Z, or Y-Z plot and have the code automatically calculate the cosines used for the plot.

A discrepancy in scoring boundary crossings of surface detectors was corrected in MORSE. Contributions to user-specified surface detectors in MORSE in SCALE 4.4 could have been underestimated because of a failure to determine which surface detector to score. This failure was due to the comparison of a single precision variable to a double precision variable. Most affected cases would have a zero result for the surface detector, indicating that no particles have crossed the surface detector boundary. Detector location coordinates of four digits or less would not be expected to experience this problem.

A coding error introduced in QAD-CGGP in SCALE 4.4 has been identified and corrected. Because of inconsistent array dimensions, if more than a very limited number of bodies are input in one zone, the additional zone data are lost or stored incorrectly. This situation typically causes the code to fail. Though extremely unlikely, it might be possible for a case like this to run if the incorrectly stored geometry happened to be valid. SCALE 4.4 users should check under the "input zone data" header in the QAD-CGGP output to verify that the zone data agree with their input.

SAS2 was corrected to fix an error introduced in SCALE 4.4 that caused the PARM=OLDSAS2 option to fail. Another discrepancy introduced in SCALE 4.4 caused spent fuel isotopic data written to file FT72F001 to be incorrect in certain cases. This error, which has been corrected, occurred in cases where burnable poison rods or other inserts are removed from or inserted into the fuel assembly between fuel cycles. SAS2 can now correctly handle multiple fuel zones in the path B model. A minor discrepancy was corrected where invalid characters were being written to title records in the ORIGEN-S binary library. Some text editors could not read the SAS2 output file when invalid characters were present.

A large number of enhancements were made to XSDRNPM. The Fortran source for XSDRNPM was converted to Fortran 90 free format. The input/output units were all moved to the 0$ array. The energy of the

average lethargy causing fission was added to the balance tables. The output files from the balance tables and the activities were modified and converted to ASCII files. A new ASCII file was created that contains the input and derived data from a problem. The coarse mesh generation algorithm used in rebalancing the inner iterations was modified to correct a problem that prevented convergence for a very small class of problems. The code was modified to recycle if the final iteration performed after convergence failed the convergence test. For group banding cases, convergence is now reset after initial convergence to an order of magnitude less than overall convergence to prevent looping through iterations and never converging. The default value for flux convergence tolerance, PTC, was reduced from 10^{-4} to 10^{-5}. The calculation of activities by interval, an option that was available many years ago, was reintroduced in the code.

The XSDRNPM mesh generation algorithm in MIPLIB was modified to address two problems: (a) insufficient number of mesh intervals for thick reflectors of low absorbing material and (b) too many mesh intervals for highly absorbing regions. New input options to override the automatic mesh generation were added. Although this enhancement was designed primarily for CSAS1X, it potentially affects all control modules except SAS2H that use XSDRNPM.

KENO-VI was modified to detect intersecting HOLEs in the global unit. A problem will now terminate if intersecting HOLEs are detected in the global unit. Intersecting HOLEs are illegal in KENO-VI geometry but were not detected in the global unit in SCALE 4.4. Intersecting HOLEs in units other than the global unit are detected during tracking of particles through the intersecting regions. Several corrections were made to KENO-VI to prevent a particle from becoming lost and causing the code to enter an infinite loop.

MORSE was updated to correct a problem in determining the correct day of the week for dates after December 31, 1999.

Many other minor changes included in SCALE 4.4a are listed under "SCALE 4.4a Minor Modifications."

SCALE 4.4a Minor Modifications

In addition to the major enhancements noted above, SCALE 4.4a contains many minor modifications, including corrections to errors in SCALE 4.4 and changes to improve portability to different computing platforms. Note that some of these modifications may be duplicate listings of items mentioned in the previous section.

PICTURE **MRR98-056**

Updated to handle the call by SAS4 when the "PARM=CHECK" option (added to the SAS4 control module in MRR98-057) is used. Also, added an option that allows users to specify an X-Y, X-Z, or Y-Z plot and have the code automatically calculate the cosines used for the plot.

SAS4 **MRR98-057**

Added a "PARM=CHECK" option that calls PICTURE from within the SAS4 to plot geometry but not run MORSE. SAS4 prepares or reads MARS geometry input data, reads PICTURE input, and calls PICTURE. Several other changes were made to error messages and formats.

SAS2 **MRR98-058**

Updated to correct an error introduced in SCALE 4.4 that caused the PARM=OLDSAS2 option to fail. Also corrected another problem introduced in SCALE 4.4 that caused spent fuel isotopic data written to file FT72F001 to be incorrect in certain cases where burnable poison rods or other inserts are removed from or inserted into the fuel assembly between fuel cycles.

MORSE **MRR98-059**

Corrected a discrepancy in scoring boundary crossings of surface detectors. A roundoff error caused by comparison of a double precision variable to a single precision constant resulted in boundary crossings not being scored. The epsilon value for the comparison was also increased from 0.0005 to 0.001.

SAS4 **MRR98-060**

Updated to correct the dimensions on two arrays. Also changed a test comparing 2 floating point variable names equivalenced to integer variables to use function ISET. (This test has previously caused floating point underflows on some platforms.)

QADS **MRR98-061**

Added a test on the MIPLIB error flag that terminates execution of the problem if an error occurred.

KENO-VI **MRR98-062**

Updated to allow a particle to cross from one hole directly into an adjacent hole even if the crossing is outside the allowed tolerances. This prevents some cases from entering an infinite loop.

SAS2 **MRR98-063**

Corrected minor discrepancy that resulted in invalid characters being written to title records in ORIGEN-S binary library. Some text editors could not read SAS2 output file when invalid characters were present.

MIPLIB **MRR98-064**

Updated to allow control modules to specify a sensitivity library from NITAWL and to allow number density input for an element that has multiple isotopes.

XSDRNPM **MRR98-065**

The Fortran source for XSDRNPM was converted to Fortran 90 free format. The input-output units were all moved to the 0$ array. The energy of the average lethargy causing fission was added to the balance tables. The output files from the balance tables and the activities were modified and converted to ASCII files. A new file was created which contains the input and derived data from a problem. The flux file was changed to double precision. The code was modified to not run with fluxes out of core unless explicitly requested in the input. The coarse mesh generation algorithm used in rebalancing the inner iterations was modified to correct a problem that prevented convergence a very small class of problems.

C5TOC6/K5TOK6 **MRR98-066/MRR98-067**

The input file generated for CSAS6/KENO VI incorrectly labeled regions generated to surround HOLEs if there were more than one region in a unit that contained HOLEs. Because of a change in KENO-VI, these regions should no longer need to be generated. Subroutine PUNCH_GEOM was modified to not generate these regions.

QAD-CGGP **MRR98-068**

Updated to correct an error introduced in SCALE 4.4. The dimension on one variable in the geometry was not updated when the input format was changed to match that of MARS input. This caused some jobs to fail. Also, updated to correct misspelled name of unit used for error output.

ARPLIB **MRR99-001**

Updated to accept either lower or upper case input.

PRISM **MRR99-002**
Updated to accept either lower or upper case input.

XSECLIST **MRR99-003**
Updated to accept either lower or upper case input.

SAS2 **MRR99-004**
Updated for compatibility with the newest revisions to XSDRNPM (MRR98-065). The routines that wrote the XSDRNPM input files needed to be changed to account for the changes to XSDRNPM input. Subroutine COPYNX had to be changed to add the 0$ array to the XSDRNPM input file, and to move setting the logical unit number of the flux output file from the 2$ array to the 0$ array.

UNIXLIB **MRR99-006**
Changes to update XSDRNPM required a double precision ERF function. This function is part of the Fortran intrinsic library for the DEC Alpha's and the IBM RS/6000, but is not part of that library for the HP or the SUN workstations. This modification provided an update for the necessary routines to compute the double precision ERF when it is not part of the intrinsic library.

BONAMI **MRR99-007**
Updated to correct a problem that caused cases to fail when zero number density input is used.

SAS4 **MRR99-008**
Updated to change the convergence criteria because the criteria in XSDRNPM were changed. Also added an input variable NDAB to allow the user to specify the number of direct access blocks allocated.

XSDOSE **MRR99-009**
Added option to turn off angular flux print and made the default to be no angular flux print.

MODIFY **MRR99-010**
Updated subroutine LODATA for compatibility with changes in MRR98-064(MIPLIB).

XSDRNPM **MRR99-011**
(1) The code was modified to re-cycle if the final iteration performed after convergence failed the convergence test. For group banding cases, convergence is now reset after initial convergence to an order of magnitude less than overall convergence to prevent looping through iterations and never converting. (2) The default value for flux convergence tolerance, PTC, was reduced from 10^{-4} to 10^{-5}. (3) Errors were corrected in the calculation of activities by interval. This previously undocumented option is now documented in the XSDRNPM input description.

KENO-VI **MRR99-012**
Modified KENO-VI to detect intersecting HOLEs in the global unit. A problem will now terminate if intersecting HOLEs are detected in the global unit. Intersecting HOLEs are illegal in KENO-VI geometry but were not detected in the global unit in SCALE 4.4. Intersecting HOLEs in units other than the global unit are detected during tracking of particles through the intersecting regions.

ORIGEN **MRR99-014**
A new subroutine was added to provide the user the option of more significant digits in the output tables. Unit 71 was set as the default file number for the binary file containing concentrations and spectral data.

MIPLIB **MRR99-015**

The XSDRNPM mesh generation algorithm was modified to address two problems: (a) insufficient number of mesh intervals for thick reflectors of low absorbing material and (b) too many mesh intervals for highly absorbing regions. New input options to override the automatic mesh generation were added too. Consistent with MRR99-011, the default value of PTC was reduced from 10^{-4} to 10^{-5}. Although this enhancement was designed primarily for CSAS1X, it potentially affects all control modules that use XSDRNPM.

KENO-VI **MRR99-016**

The code was corrected to define LCHK as a logical variable in subroutine POSIT. In addition, an IMPLICIT NONE statement has been added to the beginning of the subroutine. All variables have been explicitly typed as appropriate.

MODIFY **MRR99-017**

Program MODIFY was changed for consistency with the change in the direct access file made in MRR99-015(MIPLIB).

KMART **MRR99-018**

An error that resulted in calculated volumes of zero for hemicylinders and arrays (if an array number was skipped) was corrected.

CSAS6 **MRR99-019**

The argument list for the call to subroutine PRTPLT was modified for consistency with changes made to KENO-VI in MRR99-012.

SAS2 **MRR99-020**

Calls to subroutine EPSIG were changed for consistency with MIPLIB modifications in MRR99-015.

MORSE **MRR99-021**

The code was updated to correct a problem in determining the day of the week for dates after December 31, 1999.

KENO-VI **MRR99-022**

The code was updated to fix a roundoff problem that sometimes caused particles to get into an infinite loop when they transferred from one array location to another but in the process missed the unit boundary.

SUBLIB **MRR99-023**

Subroutine YREAD turns off the normal invalid character check done by the free form reading routines, but does not make any checks of its own for invalid characters. This can lead to erroneous results in some cases where a user mistypes a character when entering the array data to KENO. Checks were added to the array reading routine to give warning messages if illegal characters are read. Corrections were also made so YREAD would store correctly a double precision array.

KENO-VI **MRR99-024**

The code was updated to fix a problem where the unit boundary shares surfaces with other geometry regions and the unit is in an array. This problem could result in an infinite loop because the code fails to detect a particle crossing the boundary.

SAS2 **MRR99-025**

The following modifications were made: (1) The calculation of the light element concentrations in ORIGEN-S was corrected when multiple fuel zones (MX=500) are used in the PATH B model. The code previously assumed only one fuel zone was present, and did not sum the zone volumes when multiple zones were present, resulting in erroneous light element concentrations in the ORIGEN-S depletion calculations. (2) The depletion of light element nuclides with mixture numbers 50 through 59 is now permitted. (3) The use of 1$ data for MXT (input level 3) when reading a second working library in NITAWL is now permitted.

HEATING **MRR99-027**

The code was updated, including Fortran 90 dynamic memory allocation, to improve portability on both workstation and PC platforms.

UNIXLIB **MRR99-028**

Subroutine JSTIME was modified to return time to the precision supplied by the system.

SAS4 Sample Problems **DRR99-001**

Updated SAS4 sample problems 1, 3, and 5 to remove references to variables FR1, FR2, FR3, and FR4, which became obsolete in SCALE 4.4.

XSDOSE Sample Problem **DRR99-002**

The XSDOSE section of the SCALE Manual documents the output of the sample problem and includes the printing of the fluxes. The input was modified to turn on the new angular flux print option in XSDOSE (see MRR99-009).

KENO V.a Sample Problems **DRR99-003**

Input data for sample problems 17 and 18 were changed. The number of neutrons started in sample problem 18 was changed to agree with the number per generation. Problem 17 was changed to specify the NBK parameter because the default was not large enough.

238- and 44-Group ENDF/B-V Libraries **DRRs 99-004 and 99-005**

Changes were made because problems were discovered with ^{238}Np, ^{250}Cf, ^{253}Cf, ^{249}Bk, ^{242}Am, and ^{233}Pa. The corrections for ^{250}Cf, ^{233}Pa, and ^{249}Bk were very minor and should have no important effects. However, significant errors were identified for ^{238}Np, ^{253}Cf, and ^{242}Am. In addition, these three nuclides do not have fission cross sections specified in the fast region in ENDF/B-V. This omission is obviously wrong, and because it could lead to very non-conservative answers for k_{eff}, these three nuclides were removed from the library.

Major Enhancements in SCALE 4.4

Many enhancements and corrections were made to SCALE in the three years between the release of SCALE-4.3 and 4.4. SCALE 4.4 is compatible with the year 2000 (see "SCALE 4.4 is Year 2000 Compliant"). User-specified surface detectors have been added to SAS4/MORSE to improve its computational flexibility and efficiency (see "Improvements to SAS4 and MORSE"). The KENO-VI input requirements for HOLEs have been simplified and made more consistent with KENO V.a (see "KENO-VI HOLE Input is Simplified"). Additionally, some significant improvements to the speed and stability of KENO-VI have been made (see "KENO-VI Stability and Speed Improvements"). A large number of changes have been made to the SAS2H depletion module (see "SAS2H Corrections and Enhancements").

Several enhancements have been made to the PC version of SCALE 4.4. A significant effort has been made to minimize the programming differences between the PC and Unix workstation versions. Both versions

will contain the same modules. The heat transfer modules HTAS1, HEATING, and the HEATING auxiliary codes are now available in the PC version for the first time. The PC version can recognize MS-DOS, Windows 95, Windows 98, and Windows NT operating systems and run under any of these systems from a single user command. CSAS can now be run directly from the CSASIN input processor.

ORIGEN-ARP, which was first released in the PC version of SCALE-4.3, has been enhanced and now runs under the SCALE driver, so it can run easily on workstations as well as PCs. ORIGEN-ARP has been improved significantly. ARP now interpolates on moderator density as well as burnup and enrichment for BWR fuel types. Several auxiliary codes have been added that enable users to generate their own ORIGEN-ARP cross-section libraries via SAS2H.

The default number of histories in KENO V.a and KENO-VI have been increased to 200,000 to produce more statistically accurate results. Color plots are now the defaults in both these codes.

PICTURE has been upgraded to generate two-dimensional (2-D) color plots of MORSE/MARS and QADS/QAD-CGGP geometry models like the color plots generated by KENO V.a and KENO-VI in SCALE-4.3. A new utility, LEGEND, has been created that adds a color/material legend and title to the color plots generated by KENO and PICTURE.

KMART is a new module to allow post-processing of a KENO V.a restart file, along with a working format cross-section library, to generate activities and/or broad-group fluxes and to compute the fission production activity if the components are available in the working cross-section library for the requested nuclide.

The group banding procedure in XSDRNPM was modified to significantly improve convergence for many large problems. Two examples of improvement include a fixed-source calculation with an 85% reduction in run-time and a k_{eff} calculation with a 50% reduction in run-time.

A correction was made to MIPLIB to allow the use of moderator in the gap region of a lattice cell calculation. Prior to this correction, if the same mixture number was specified in the moderator and the gap regions, the moderator density was incorrectly increased by a factor of two in the Dancoff factor calculation. In CSAS or CSAS6, this error results in a non-conservative calculated k_{eff} value that is approximately 0.5 to 1% low.

Other additions to SCALE 4.4 include the capability to perform a one-dimensional criticality search in CSAS1X (see "Criticality Search in CSAS1X"); the new KENO biasing weights library for 16-, 27-, 44-, 218-, and 238-group problems (see "New KENO Weights Library and Modules to Generate Weights"); the C5TOC6 and K5TOK6 conversion utilities for KENO-VI, and the Q0RDPN binary to ASCII conversion utility for functional module FIDO input files (see "New SCALE Utility Programs"); and the new zirconium hydride cross section data in the 238- and 44-group ENDF/B-V libraries (see "Zirconium Hydride Cross Sections").

The SCALE manual is distributed in electronic format on CD with the software. The manual is formatted in PDF files that can be read, searched, and printed using Adobe Acrobat Reader with Search. Users who desire a hard copy of the manual may obtain one from RSICC for an additional charge to cover reproduction costs.

Many other minor changes included in SCALE 4.4 are listed under "SCALE 4.4 Minor Modifications."

SCALE 4.4 is Year 2000 Compliant

Current and earlier versions of SCALE should calculate results correctly beyond the year 2000. However, when the year 2000 occurs, the output from some codes in these earlier versions will incorrectly display the year as 1900 instead of 2000. All known instances of this problem have been corrected in SCALE 4.4.

Improvements to SAS4 and MORSE

SAS4 and MORSE have been enhanced to allow users to specify multiple non-overlapping surface detectors on each surface (previously defaulted to 4 locations). These surface detectors can be divided into "sub-detectors" that enable the user to obtain detailed dose rate profiles. The flexibility in the use of these surface detectors makes them suitable for the substitution of point detectors, which are much less computationally efficient. Another enhancement to SAS4 was the addition of two options to pass data to PICTURE for plotting. One option generates geometry data only for the purpose of running PICTURE to view 2-D slices of the geometry. The other option provides "PARM=CHECK" option that calls PICTURE from within the SAS4 to plot geometry but not run MORSE. SAS4 prepares or reads MARS geometry input data, reads PICTURE input, and calls PICTURE.

Improvements to MORSE include orderly termination of a problem when errors in tracking to detector exceed a limit, an option to print/not print flux output after each batch, user capability to specify the number of direct-access blocks allocated on scratch units, compatibility with the year 2000, and reduction of the amount of error output in some cases.

KENO-VI HOLE Input Is Simplified

HOLE input in KENO-VI has been simplified. These changes are significant improvements requested by many users. The HOLE boundary no longer needs to be specified in the unit containing the HOLE. The HOLE boundary is automatically added by the program based on the unit specified in the HOLE record and its ORIGIN and ROTATE data. HOLEs cannot intersect. An example of the original and the new methods for adding HOLEs to a unit is given below. The input data no longer required are highlighted in the old input.

```
********** Old KENO-VI input *************
unit 1
hexprism  10  1.0  10.0 -10.0
media  1  10
boundary  10
unit 2
cuboid    10  6p20.0
hexprism  20  1.0  10.0  -10.0  origin x=5.0 y=3.0  rotate a2=90
media 2  10  -20
hole  1  20 origin x=5.0 y=3.0 rotate a2=90
boundary  10
******** New KENO-VI input ***************
unit 1
hexprism  10  1.0  10.0 -10.0
media  1  10
boundary  10
unit 2
cuboid    10  6p20.0
media  2  10
hole   1  origin x=5.0 y=3.0 rotate a2=90
boundary  10
```

Note that in addition to the lack of a geometry record which defines the HOLE boundary, the HOLE record no longer has a vector definition array. The new version of KENO-VI should be able to read most old input files correctly, but they will take longer to run.

KENO-VI Stability and Speed Improvements

Improvements have been made to KENO-VI since the last Web update to increase the stability and the speed of KENO-VI. To improve the code's stability, logic has been added to KENO-VI to check if a particle is still in the boundary region of a unit when it is no longer in any region. If this occurs, an error message is printed and the program terminates. This situation is often caused by an undefined volume in a unit and could previously lead to the program entering an infinite loop.

To improve the execution speed of KENO-VI, the following modification has been made: When a particle is in an array, the particle is tracked both in the unit where it is currently within the array and in the unit containing the array. It needs to be tracked in the unit containing the array so it knows when it crosses out of the array. Previously, the crossing distance to every surface in that unit was calculated. The code has been changed to calculate only the crossing distance to the surfaces related to the array boundary. This change will significantly reduce the running time of problems where particles spend most of the time in an array or where the array is in a complex unit containing many additional regions unrelated to the array boundary. Running times have been reduced by as much as 15% for arrays contained in complex units.

SAS2H Corrections and Enhancements

A large number of corrections and enhancements have been completed in SAS2H for the release of SCALE 4.4. They are listed below.

- Two errors were corrected for cases where there were more than three zones prior to the mixture 500 zone in the Path B model: (1) The atomic densities were not updated with depleted values in the cross-section processing/spectrum calculations when fuel was input to more than one zone (including the cell-weighted mixture 500 zone). (2) Nuclides that only appear in the moderator were depleted. An example of a model that would be affected is a BWR Path B model with Gd-poisoned fuel pin, gap, clad, moderator, and mixture 500. Usually these discrepancies cause only slight errors in the neutronics part of such BWR cases, but could significantly impact the results for some unique fuel models.

- Input checks and error messages were improved.

- A programming error that caused problems with "MXREPEATS=0" cases to fail on PCs was corrected. These cases are typically used to remove or insert burnable poison rods from one cycle to the next in a depletion.

- A modification was made to correctly calculate the fuel bundle area printed in the shipping cask geometry for the triangular-pitch lattice type of fuel.

- The FUELBNDL input parameter was changed from integer to floating point to allow fractions of fuel assemblies.

- The temperatures of the zones (except the gap) in the Path A model may now be changed for each cycle, similar to the BFRAC and H2OFRAC variables.

- The limit on the total number of libraries (NCYC*NLIB/CYC) was increased to 9,999. However, because the number of unique output file names in SCALE is currently limited to 10,000 and there are typically 11 output files per pass in SAS2H, the practical limit for users is approximately 900 total libraries.

- A significant change was implemented to enable fixed sources (volumetric source or angular flux at a boundary) to be used with INPUTLEVEL=3 cases. This change gives users the capability to model cases such as the irradiation of target materials without explicitly including the irradiation facility in the SAS2H model. Previously the driver geometry and its specific power were required as input to govern the depletion calculation. This fixed-source option is specified in the INPUTLEVEL=3 data as either a volumetric or boundary source. SAS2H then determines the flux based on this fixed source and passes it to ORIGEN-S for use in a flux-driven depletion calculation.

- SAS2H was modified to allow two zones in the Path A model to contain the same nuclide, one at a density of 10^{-20} and the other at a density of greater than 10^{-10}.

- The fixed dimension of 1000 for the Path B mixing table arrays was removed where possible and increased otherwise. The size needed for these arrays can be as large as five times the Path A mixing table size (currently a maximum of about 300 in the 44-group library) plus the number of nuclides outside the zone of mixture 500. The dimension of the arrays that remain fixed was increased to 5000. The remaining arrays were variably dimensioned to the maximum of 2000 or the sum of the Path B mixing table size plus 100 (to allow increases of at least 100 nuclides for INPUTLEVEL=3).

Criticality Search in CSAS1X

MIPLIB has been updated to add input options to MORE DATA that allow specifying an XSDRN adjoint solution, a zone width search, a unit number for the balance table file, and suppressing the cross section weighting. The addition of the zone width search option now gives CSAS1X the capability to perform one-dimensional criticality searches on the size of a geometry zone in XSDRNPM.

New KENO Weights Library and Modules to Generate Weights

Because there was a need to be able to automatically generate a set of weights for use in KENO for arbitrary group structure and material, a new control module GWAS and a new functional module GENWGTS have been added. GWAS sets up an adjoint XSDRNPM case and generates weights automatically from the fluxes. GENWGTS is called by GWAS to read the adjoint fluxes, automatically generate the KENO weighting functions from them, and write an output file for use by program WGT. The biasing weights library for KENO V.a and KENO-VI was updated using the new modules GWAS and GENWGTS. The library contains weights for paraffin, water, concrete, and graphite in 16, 27, 44, 218, and 238 energy groups. The new library was created because there were no biasing data for use with the new ENDF/B-V 44- and 238-group libraries that were released in SCALE-4.3. The old library only contained data for 16, 27, and 123 groups. Note that the 123-group library was removed in SCALE-4.3. Results using this new weights library with the 16- and 27-group cross-section libraries will be different but should agree within statistical uncertainty.

New SCALE Utility Programs

Several new utility programs have been developed for SCALE. A new utility LEGEND has been created that adds a title and legend to the color GIF files generated by KENO V.a or KENO-VI. LEGEND was released last summer with the updated version of KENO-VI (see the June 1996 issue of the Newsletter). The versions of KENO V.a and PICTURE in the next release of SCALE will use LEGEND as well.

K5TOK6 and C5TOC6 are new utilities that convert KENO V.a and CSAS input files to KENO-VI and CSAS6 input files by translating the KENO V.a geometry input to KENO-VI format. Since the converted input files are based on the KENO V.a geometry input, they are generally not the most effective in terms of the

KENO-VI geometry features. They do provide the user with a working KENO-VI input file that can be modified for improvements.

Another new utility is Q0RDPN. It converts a binary input file generated by a CSAS or SAS control sequence for one of the functional modules that use FIDO input such as BONAMI, NITAWL-II, ICE, and XSDRNPM, to an ASCII input file. The user can easily edit the ASCII input file to run a modified version of a problem. This capability allows the user to specify input parameters that are not available in the standard control sequences.

Zirconium Hydride Cross Sections

The ENDF/B-V cross-section libraries in SCALE 4.4 have been updated with thermal scattering data for zirconium hydride. New standard compositions have been added to the Standard Composition Library to allow access to these new cross sections. The new standard compositions are the following:

ZRH2 - density 5.61 g/cc, 1 zirconium to 2 hydrogen atoms
ZR5H8 - density 5.61 g/cc, 5 zirconium to 8 hydrogen atoms
H-ZRH2 - density 1.0 g/cc, the hydrogen in zirconium hydride
ZR-ZRH2 - density 1.0 g/cc, the zirconium in zirconium hydride

SCALE 4.4 Minor Modifications

In addition to the major enhancements noted above, SCALE 4.4 contains many minor modifications, including corrections to errors in SCALE-4.3 and changes to improve portability to different computing platforms. Note that some of these modifications may be duplicate listings of items mentioned in the previous sections.

18-Group Gamma Library: (1) Processed through CORECTOL to mark it as NITAWL-II compatible. Could not be processed by NITAWL-II prior to this correction. (2) Updated to replace the Henderson and Claiborne-Trubey dose factors because the data overestimated the doses by about 25%. The replacement data were taken from the 22n-18g group coupled library.

27-Group Burnup Library: Updated data on rhodium-103 so that Bondarenko factors are generated in the unresolved resonance range. A test case based on 4.5 wt % UO_2 burned to 54,585 MWD/MTU, cooled for 5 years, was run. The calculated k_{eff} increased by 0.06% with the new Rh-103 cross sections.

44-Group ENDF/B-V Library: The 44-group neutron cross-section library was recollapsed from the 238-group library using the corrected version of MALOCS. The impact of the MALOCS corrections should be negligible. See MALOCS corrections below for more information.

238-Group and 44-Group ENDF/B-V Libraries: (1) Corrected negative scattering and total cross sections for minor actinides, fission products, and beryllium metal. Also corrected thermal Bondarenko factors for potassium. Only significant impact should be on cases where potassium is important in the thermal range. (2) Updated to remove resonance parameters from specially weighted stainless steel nuclides because they were being doubly applied. Also, zirconium and hydrogen cross sections for zirconium hydride were added to both libraries.

AJAX: Corrected a portability problem in subroutine ANN caused by the array D being typed real by default, and then printing variables from it using an integer format.

ARP: Updated for optional interpolation on moderator density and made more general to handle user-created basic cross-section libraries. ARP now runs under SCALE driver on PCs and workstations.

ARPLIB: This is a new utility program that creates binary ORIGEN libraries for ARP. It extracts libraries at the desired burnups from large multi-burnup library files generated by SAS2H.

AWL: Added AWL to SCALE to convert AMPX working format libraries between ASCII and binary formats. It is required for the SCALE Criticality V&V package.

BONAMI: (1) Updated to improve error handling procedure and messages. (2) Corrected a problem that caused cases to fail when zero number density input was used.

C5TOC6/K5TOK6: The input file generated for CSAS6/KENO VI incorrectly labeled regions generated to surround HOLEs if there were more than one region in a unit that contained HOLEs. Because of a change in KENO-VI, these regions should no longer need to be generated. Subroutine PUNCH_GEOM was modified to no longer generate these regions.

COUPLE: Updated for year 2000 compatibility, PC version compatibility, uppercase or lowercase input files, and for printing the banner page only when COUPLE is first called.

COUPLE Sample Problem: Updated to change the inner radii in the 3$$ array to zero for consistency with the NITAWL-II input requirements.

CSAS/KENO V.a /KENO-VI/SAS2H Sample Problems: Updated to use the 44-group library.

CSAS and MODIFY: CSAS was updated to add additional required data to the direct access file written for a search problem. MODIFY was updated to read this file. A check for valid parameter constraints and the printing of an error message if they are invalid were also added.

H7MAP: For 1-D problems, if the number of nodes is large enough that the output exceeds one page in length, only part of the output is displayed. The output from the first page is repeated, and the rest of the output is never printed. Correcting this problem involved simply moving one statement from within a DO loop to a point before the DO loop.

H7TECPLOT and H7MONITOR: Outdated comment lines in the BLOCK DATA subroutine that are used to activate or deactivate computer-system-dependent blocks of code resulted in memory not being allocated for variably-dimensioned arrays. An additional correction was made in H7TECPLOT, where the x and y axes were reversed when a translation was done from spherical to Cartesian coordinates.

HEATING Sample Problems: The input file for the second HEATING sample problem was modified to first compile and run a simple Fortran program to convert an ASCII node connector file to binary format for use by HEATING. This modification improves installation portability on different Unix workstation platforms.

KENO V.a: (1) Updated subroutine RDPLOT to correct the format used to print the error message for incomplete input data. (2) Corrected variable type in format statements for debug prints. This discrepancy causes problems on some systems, including PCs when debug print is turned on (DBG=YES). (3) Changed default plot type to color. (4) Updated to correct an error in the k_{eff} calculation that caused a doubling of k_{eff}

when using an ICE mixed AMPX format working library. This error was introduced in SCALE-4.3. (5) Updated to allow printing the frequency distributions for 1-group problems. (6) Updated to match KENO-VI with respect to matrix calculations. The calculation of lifetime was corrected because it was not based on a fair game. These changes can cause the lifetime to be substantially different. The error in the lifetime calculation has probably been in KENO V.a since its initial release in SCALE-3.

KENO-VI: (1) Updated to correctly number error messages, replace the word PICTURE with the word PLOT throughout the program, and print plot symbol data only for character plots. (2) Updated subroutine TRACK to correctly sum fluxes. The fluxes didn't sum properly for units that were crossed by an array boundary. (3) Enhanced to allow HOLEs to be used without explicitly defining a geometry region where the HOLE was to be inserted. The code automatically adds to the unit containing the HOLE the equations that define the boundary of the unit contained within the HOLE, properly rotated and translated as specified on the HOLE record. (4) Fixed problem writing restart file on Sun workstation. (5) Modified the subroutine GEOMIN to correct an infinite loop problem. A pointer to the array that contained the unit boundary x, y, and z position was improperly specified. The pointer LBOXGM has been respecified. (6) Corrected a problem where a particle's inability to cross an array boundary due to round-off problems caused an infinite loop. (7) The code was updated to correct a problem that could cause cases containing arrays with complex boundaries to incorrectly calculate k_{eff}. (8) Corrected a discrepancy that caused the code to go into an infinite loop when boundaries consisted of a body with multiple sets of paired planes. (9) Corrected an error that prevented a restart problem from producing a readable file if it stored data in the generation before the code entered the infinite loop. (10) Corrected a problem involving nested arrays and hexprisms that sometimes caused the code to go into an infinite loop if a collision occurred very near a boundary. (11) Corrected a problem that occurred when a particle crossed a boundary and immediately had a collision that reversed its direction without traveling any distance. The particle sometimes got lost and entered an infinite loop. (12) Modified subroutine TRACK to correct a problem that occurred when an array shared a boundary with a hole that contained the array. If the distance to cross out of the array is less than EPS, the particle now exits the array instead of crossing from one unit to another within the array. (13) Corrected an error in placement of starting points for start type 6. (14) Corrected an error in the flux calculation for regions containing holes or arrays. (15) Corrected a roundoff problem with arrays offset a long distance from the origin. This problem could sometimes cause an infinite loop. (16) Corrected a variable that was misnamed and, as a result, was used without being initialized. (17) Set a lower limit for the calculated crossing tolerance to prevent the code from entering an infinite loop. Also made minor changes to the particle-tracking output when parameter TRK=YES. (18) Updated to allow starting points in a volume larger than the global unit. (19) Updated to terminate a problem if a particle in subroutine TRACK gets lost. Also, updated to allow problems that contain array data but do not reference the arrays in the GEOMETRY data block to run. (20) Updated to change the logic in calculating the array boundary crossing distance (decreases running time for some problems) and to change the default plot type to color. (21) Updated to correct a problem with non-cuboidal albedo boundaries and to add additional space for matrix data. The standard deviations for average k-effective by generation skipped are now accumulated in batches. Because of these changes, any matrix information and the table of average k-effective by generation skipped in the sample problem output will be different. (22) Corrected tracking to allow simultaneous crossing of multiple shared boundaries and to correctly sum fluxes after a collision. Also corrected error related to calculating the x-offset of an array. Changed input logic for ORIGIN and ROTATE data to sum values for an auxiliary keyword for a given geometry record rather than use the last value. This last change was made for compatibility with C5TOC6. (23) Updated to allow a particle to cross from one hole directly into an adjacent hole even if the crossing is outside the allowed tolerances. This prevents some cases from entering an infinite loop. (24) Modified to detect intersecting HOLEs in the global unit. A problem will now terminate if intersecting HOLEs are detected in the global unit. Intersecting HOLEs are illegal in KENO-VI geometry but were not detected in the global unit. Intersecting HOLEs in units other than the global unit are detected during tracking of particles through the intersecting regions.

KENO-VI Sample Problems: Sample problem 22 has been altered in the KENO-VI input file. The geometry data were changed to take advantage of the simplified method of adding HOLEs.

KMART: This new module was added to allow post processing of a KENO V.a restart file, along with a working format cross-section library, to generate activities and/or broad group fluxes and compute the fission production activity if the components are available in the working cross-section library for the requested nuclide. A resonance self-shielded value is used for the fission cross section.

MALOCS: (1) An error was corrected in weighting a coupled master library using a neutron spectrum from a neutron library combined with an explicitly specified gamma-ray spectrum. Also introduced several options for truncating upscattering terms. Changes were made to properly weight the delayed and prompt values of v. (2) A discrepancy was corrected that caused the storage of invalid data in the temperature array. In the 44-group library this caused the data for the third temperature to be overwritten and to be used for a temperature that is effectively zero degrees Kelvin.

MARSLIB: (1) Updated to change the value of epsilon used to check for round-off errors in the geometry and, thereby, reduce the number of such errors. This modification eliminated the errors previously experienced with several of the SCALE Shielding V&V problems. (2) Variables IR in subroutine AZIP and IRET in subroutine UNIS are now initialized to 0 before they are used as arguments to function IREAD. In AZIP and in UNIS a 'CALL EXIT' was changed to a 'STOP'. In subroutine ALBERT, the nH was removed from two formats and replaced with quotes.

MIPLIB: (1) Updated to allow moderator mixture in a lattice cell to be used in the gap and to add the ability to specify the inner radius to the resonance data. (2) Updated to allow a control program to suppress certain output by setting flags. Added input options to MORE DATA to allow specifying an XSDRNPM adjoint solution, a criticality search in XSDRNPM using the zone width search option, a unit number for the balance table file, and suppressing the cross section weighting. (3) Corrected an error allowing the input of a number density for a compound or alloy. This error was introduced in SCALE-4.3. (4) Updated to allow number density input for an element that has multiple isotopes.

MIPLIB, SUBLIB, UNIXLIB, COMPOZ, MODIFY: Updated to use new direct access routines for character data and replaced references to specific intrinsic FORTRAN functions with their generic names for Fortran 90 compatibility. Also corrected an error in the Dancoff factor calculation that occurs for cylinders in a MULTIREGION problem. This error results in an error in the calculated k_{eff} value of approximately 0.1% for a cylinder the size of a typical fuel rod. Note that this error did not occur in the LATTICECELL geometry option.

MORSE: (1) Updated the limit on number of tracking errors, the unit number for surface detector results, and increased dimensions on surface detector arrays. (2) Updated to include changes to surface detectors for SAS4 cases, to correct a problem in DIREC for NDSG=17 case, to allow orderly termination of a problem when errors in tracking to detector exceed a limit, to add an option to print/not print flux output after each batch, to input the number of direct-access blocks allocated on scratch units, to change the way date is output (to handle the year 2000 and beyond) and to reduce the amount of error output in some cases.

MORSE Sample Problem 8: The 10** array was modified by adding a 22r0.0 at the end.

NITAWL: Corrected the potential cross section used for higher order resonances (L>0). The impact should be negligible in most cases.

ORIGEN-S: (1) Updated cross-section edit of binary libraries to add option to change cross-section values to quantities derived from total flux (as in ORIGEN2) instead of thermal flux. (2) Corrected calculation of printed average power. (3) Added error message if number of time steps is less than 4 for reactor startup case. (4) Updated to correct the loop index for re-normalizing the R8 array. (5) Updated for year 2000 compatibility and to correct calculation of He-3 and H-3 for long time steps and high flux. (6) Updated to allow saving concentrations and then continuing with a subcase using a new library. (7) Updated to allow the flux input value for the last time step to be zero.

ORIGEN-S Master Photon Library: The library was updated to correct the photon yield data for Ra-222 and Th-226, and the photon yields for gammas accompanying (α,n) and spontaneous fission reactions were updated to reflect small changes that occurred during the last decay data update.

OSBICO/OSBIRE: Updated for compatibility with lastest version of ORIGEN-S.

PERFUME: Improved the selection of new moments when a moment is found to be invalid and converted coding to a more standard Fortran 90.

PERFUME Sample Problem: The special cross-section data file required for the PERFUME sample problem has been added to SCALE, and the sample problem input data have been updated to use it. This problem has not been included in SCALE since SCALE was moved from the mainframe to the workstation several years ago.

PICTURE: (1) The module was updated to add option of generating 2-D color GIF plot files of the geometry model input for the SCALE shielding modules MORSE or QAD-CGGP. This capability already exists in the SCALE criticality modules KENO V.a and KENO-VI. (2) The module was also updated to handle the call by SAS4 when the "PARM=CHECK" option is used. (3) An option was added that allows users to specify an X-Y, X-Z, or Y-Z plot and have the code automatically calculate the cosines used for the plot.

PRISM: This is a new utility program for ARP that can read a single SAS2H or other type of input file and generate multiple copies by replacing generic symbols with specified values.

QADS/QAD-CGGP: (1) Updated to make the combinatorial geometry input data have the same format as the combinatorial portion of the MARS geometry input which is used in other SCALE modules. Old input files will no longer run. (2) Updated to add error checks for limits on number of compositions and elements and to fix the code to handle upper- or lower-case input. (3) Added a test on the MIPLIB error flag that terminates execution of the problem if an error occurred.

QADS and QAD-CGGP Sample Problems: Updated to change the geometry input format to agree with the changes made to QADS and QAD-CGGP.

RADE: Corrected an error in subroutine MCHEK that caused RADE to fail on a Sun workstation. A constant was passed as an argument to subroutine MCHEK to be used for dimensioning, but MCHEK later used the same variable for other purposes. The argument was renamed and used in the dimension statement.

SAS1: Scratch unit N16 was not opened when SCALE driver returned to SAS1 after cross-section processing and prior to XSDRNPM shielding calculation. This problem caused SAS1 to fail on the PC. The OPEN statement was moved to the beginning of main program so it would always be opened.

SAS2H: (1) Updated to fix a problem where the reload feature failed to reload correctly for the final cycle type. (2) Modified subroutine SZNSEG so that it would not cause the ORIGEN library creation to fail by not recognizing the cross-section library specified. The problem was an uninitialized variable ERSET. The change was to initialize the variable as "FALSE" before calling subroutine GETLIB. A change was also made so that the library name was passed to GETLIB instead of only the first 4 characters. (3) Updated to correct an error in the mass of the clad when the clad was input as an isotope and the mass was not input as a light element in Data Block 15. (4) A problem was corrected where the atomic densities were not updated with depleted values in the cross-section processing/spectrum calculations when fuel was input to more than one zone (including the cell-weighted mixture 500 zone) and there were more than three zones prior to the mixture 500 zone. For example, consider a BWR Path B model with Gd-poisoned fuel pin, gap, clad, moderator, and mixture 500, where there are four zones prior to the mixture 500 zone. Usually this discrepancy causes only slight errors in the neutronics part of such BWR cases, but could significantly impact the results for some unique fuel models. (5) The module was updated for compatibility with the newest revisions to XSDRNPM. The routines that wrote the XSDRNPM input files needed to be changed to account for the changes to XSDRNPM input. Subroutine COPYNX had to be changed to add the 0$ array to the XSDRNPM input file, and to move setting the logical unit number of the flux output file from the 2$ array to the 0$ array.

SAS3: (1) Variable IR in subroutine OAKTRE is now initialized to 0 before it is used as an argument to function AREAD. Subroutine RINPUP was updated to initialize the variables JMK and IML in COMMON JOMK because they are used when SAS3 calls MARSLIB routines and they were not being defined prior to the calls to JOMIN. (2) Updated to be compatible with the new MORSE input options and to implement the PARM=SIZE parameter which was not being passed to MORSE.

SAS4: (1) Subroutine MORINP was updated to add common JOMK and to initialize the variables JMK and IML in common JOMK because they are used when SAS4 calls MARSLIB routines and they were not being defined prior to the calls to JOMIN. (2) The code was modified to translate the user input to lowercase. This change was necessary to make SAS4 capable of handling input files in either upper or lowercase, as the other SCALE neutronic codes already do. (3) The code was updated to correct the dimensions on two arrays. Also changed a test comparing 2 floating point variable names equivalenced to integer variables to use function ISET. (This test has previously caused floating point underflows on some platforms.) (4) Added a "PARM=CHECK" option that calls PICTURE from within the SAS4 to plot geometry but not run MORSE. SAS4 prepares or reads MARS geometry input data, reads PICTURE input, and calls PICTURE. Several other changes were made to error messages and formats. (5) The convergence criteria was updated because the criteria in XSDRNPM were changed. (6) The input variable NDAB was added to allow the user to specify the number of direct access blocks allocated.

SAS4 Sample Problems: (1) A ninth sample problem was added to illustrate the new enhanced surface detector option. (2) SAS4 sample problems 1, 3, and 5 were updated to remove references to variables FR1, FR2, FR3, and FR4, which became obsolete in SCALE 4.4.

SCALE Driver: (1) Updated to allow processing the rest of the input data after invalid input data are detected. (2) The driver has been updated to obtain and act on error codes from the modules. The driver now prints error codes and stops further sequence execution.

Standard Composition Library: (1) The default density of B4C was corrected from 2.54 to 2.52 g/cc. This error was introduced in SCALE-4.3. For an LWR fuel problem with B_4C pins between fuel assemblies, the calculated k_{eff} value increased less than 0.2%. (2) Updated to reference the nuclides used for zirconium

hydride which have been added to ENDF/B-V libraries and to add four new standard composition names related to zirconium hydride. (3) The densities for SS304 nuclides were made identical to the standard versions of the same nuclides. (4) Updated the standard composition ZIRC2 for consistency with current technical standard and updated densities for SS304 and SS316. (5) Mass of copper was corrected (it was in atomic mass units instead of C-12 mass units). Density of C-GRAPHITE was changed from 1.0 to 2.3 g/cc. The following compositions were added: GRAPHITE, KEROSENE, KERO(H2O), NORPAR13, NORPAR(H2O), POLYVINYLCL, PVC, PVC(H2O), TBP, TBP(H2O).

SUBLIB/UNIXLIB: (1) Updated to remove year 2000 problems. These changes basically changed the year format for the QA verification table to 4 digits. Additionally, the date format was changed to use a 3-character month abbreviation so that the date would be unambiguous. A new line was added to the QA verification table printout to identify the machine on which the program was run. (2) Updated to remove an artificial limit of 8-character-length filenames for non-standard files in subroutine OPNFIL. (3) Modified subroutines LISTQA and VERGET for consistency of the length of the string containing the executable name, the creation date, and the directory path to the executable. The directory path was increased to 256 characters. (4) Updated subroutine FINDQA to place underscores in place of the blanks in the date to simplify the automatic updating of the QA verification table. (5) Replaced the CHARACTER*8 type of variable CAT with a variable length CHARACTER type in subroutine NOTE. This corrected a problem in WAX on the Sun workstation. (6) Added comments to subroutine OPENDA indicating how to replace the Fortran 90 specific INQUIRE statement with a Fortran 77 compatible statement. (7) Replaced all STOP statements with calls to EXIT with the appropriate error return code for proper detection by the driver. (8) Modified subroutine DREAD to correctly process data following the second digit of an exponent when called by the array reading subroutine YREAD. Previously, exponents of 10 or greater sometimes caused errors in the reading of FIDO-type input arrays. This discrepancy was discovered in an ORIGEN-S case. (9) Changes to update XSDRNPM required a double precision ERF function. The necessary routines were added to compute the double precision ERF when it is not part of the intrinsic library.

XSDOSE: An option was added to turn off angular flux print and no angular flux print was made the default.

XSDOSE Sample Problem: The input was modified to turn on the new angular flux print option in XSDOSE.

XSDRNPM: (1) The special activity file and balance table file were not written correctly, and the correct file structure is not what was documented. Subroutine SETUP was changed such that it would not read or write dummy records after the files were opened. These read/writes were the only way to open the files before Fortran 77, but when the code was converted to Fortran 77 and OPEN statements were added to explicitly open the files, the extra statements were not removed. (2) Updated to correct the accumulation of zone fluxes when inner-cell weighting is selected. (3) Updated to correct the value of productions/absorptions when a direct buckling search is done. (4) The code was also modified to collapse prompt υ and delayed υ using the same procedure as used to collapse the total υ. (5) Corrected calculation of broad group balance tables to be consistent with fine group tables. Broad group cross sections were not in balance when upscatters were collapsed. (6) Updated to print clearer messages when allocated memory is insufficient. Also, in these cases if an output file could not be written, any previously existing file was deleted to prevent subsequent calculations from reading it. (7) The Fortran source for XSDRNPM was converted to Fortran 90 free format. (8) The input/output units were all moved to the 0$ array. The energy of the average lethargy causing fission was added to the balance tables. (9) The output files from the balance tables and the activities were modified and converted to ASCII files. A new file was created which contains the input and derived data from a problem. The flux file was changed to double precision. (10) The code was modified to not run with fluxes out of core unless explicitly requested in the input. (11) The coarse mesh generation algorithm used in rebalancing the

inner iterations was modified to correct a problem that prevented convergence of a very small class of problems.

XSECLIST: This is a new utility program for ARP which prints lists of absorption and fission cross sections vs burnup for nuclides from ORIGEN-S multi-burnup binary libraries.

Portability

Version 4.4a 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, a version for personal computers (PCs) is included in the package. The PC version runs on Windows 95, 98, and NT4.0 and platforms. The system also has been installed and tested by ORNL on SUN and HP workstations. Information needed to install and run SCALE on each of these systems is included in README files with the software package distributed by the code center.

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.

The ORIGNARP input processor is a MS-DOS PC program designed to assist a user in creating an ORIGEN-S input file. It is coupled with the ARP code, which interpolates on standard LWR ORIGEN-S binary libraries, in the ORIGEN-ARP system (Section D1).

CSPAN (Criticality Safety Input Processor for Analysis) is the Windows GUI replacement for the CSASIN input processor for the CSAS criticality sequences in SCALE. CSASIN was an MS-DOS program developed in 1990–91 to assist new and occasional SCALE users. Because CSASIN is incompatible with Pentium II and later PCs, a new easier to use and more powerful Windows program has been developed. CSPAN can be used to read and modify an existing SCALE input file or to create a new input file. CSPAN can call SCALE to execute CSAS using the input file it creates. The SCALE Standard Composition library and the selected SCALE cross-section library are read by CSPAN and the user is only allowed access to those compositions available on the selected cross-section library. The program handles the entry of basic standard compositions, solutions, and arbitrary materials, unit cell data, optional parameter data, and KENO V.a input data. CSPAN can call SCALE to execute any CSAS case. CSPAN runs under Windows 95, 98, or NT. Checks for errors are included throughout the program to verify that the input is valid. The initial version distributed with SCALE 4.4a is considered a beta test version. Help files have not been developed yet, but will be made available soon.

The initial version of a Windows-based GUI for HEATING named Visual Heating is also included in the SCALE 4.4a release. Visual Heating assists the user in preparing a HEATING input file and includes a 3-D graphics display of HEATING geometry models using OpenGL. Visual HEATING can execute the HEATING case in SCALE and display the output file in a text editor. It includes an HTML Help system similar to many commercial Windows programs. The help system is accessible both from the main menu bar and by pressing the F1 key. Most of the information in the HEATING User's Manual (Sect. F10 of the SCALE Manual) is included in the help system along with explanations of Visual HEATING input screens.

Availability

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

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E-mail: rsic@ornl.gov
Internet: http://www-rsicc.ornl.gov

Acknowledgments

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. Lichtenwalter, 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 (ret.) and W. C. Carter, who prepared the entire manuscript. Special acknowledgement is also due to R. M. Westfall and G. E. Whitesides (ret.) who, together with R. H. Odegaarden 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 served as the SCALE Project Leader for the first 15 years, and L. M. Petrie, who for 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
December 1999

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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
ORIGEN-ARP	Point depletion/decay of nuclear fuel and radioactive material	ARP ORIGEN-S	D1
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: • 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

NUREG/CR-0200
Revision 6
Volume 1, Section C4
ORNL/NUREG/CSD-2/V2/R6

Computational Physics and Engineering Division

CSAS: CONTROL MODULE FOR ENHANCED CRITICALITY SAFETY ANALYSIS SEQUENCES

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Date Published: March 2000

Prepared for the
Office of Nuclear Material Safety and Safeguards
U. S. Nuclear Regulatory Commission
Washington, DC 20555
Under Interagency Agreement DOE 1886-C000-9B
NRC JCN No. B0009

Prepared by the
OAK RIDGE NATIONAL LABORATORY
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

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ABSTRACT

The Criticality Safety Analysis Sequences (CSAS) were developed within the SCALE code system to provide automated, problem-dependent, cross-section processing followed by calculation of the neutron multiplication factor for the system being modeled. This document describes the program that contains the available sequences.

These control sequences activate the cross-section processing codes BONAMI and NITAWL-II to provide resonance-corrected cross sections. Control sequences ending with "X" utilize XSDRNPM to provide a cell-weighted mixture cross section and/or the neutron multiplication factor (k-effective) for a one-dimensional system model. ICE is used by CSASI and CSASIX to provide a Monte Carlo-formatted mixed cross-section library. KENO V.a uses the processed cross sections and calculates the k-effective of three-dimensional system models. The geometric modeling capabilities available in KENO V.a coupled with the automated cross-section processing within the control sequences allow complex, three-dimensional systems to be easily analyzed. A search capability is achieved by repeatedly activating the control module MODIFY to alter the pitch or other dimensions and the functional module KENO V.a to calculate the k-effective for the new pitch or dimensions.

The control sequences (sometimes referred to as modules) described within this document were developed simultaneously and are closely related. These sequences are listed in the following table with the modules they invoke:

Control module	Search function	Functional modules executed by the control module				
CSASI	No search	BONAMI	NITAWL-II		ICE	
CSASIX	No search	BONAMI	NITAWL-II	XSDRNPM	ICE	
CSASN	No search	BONAMI	NITAWL-II			
CSAS1X	No search	BONAMI	NITAWL-II	XSDRNPM		
CSAS25	No search	BONAMI	NITAWL-II		KENO V.a	
CSAS2X	No search	BONAMI	NITAWL-II	XSDRNPM	KENO V.a	
CSAS4	Search	BONAMI	NITAWL-II		KENO V.a	MODIFY[a]
CSAS4X	Search	BONAMI	NITAWL-II	XSDRNPM	KENO V.a	MODIFY[a]

[a]MODIFY is a control module.

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ACKNOWLEDGMENTS

CSAS and its related Criticality Safety Analysis Sequences are based on the old CSAS2 control module, which was not written in VS FORTRAN and, therefore, is not included in this version of SCALE, and the KENO V.a functional module described in Sect. F11. Therefore, special acknowledgment is made to J. A. Bucholz, R. M. Westfall, and J. R. Knight who developed CSAS2. G. E. Whitesides is acknowledged for his contributions through early versions of KENO. Appreciation is expressed to C. V. Parks for his guidance in developing CSAS.

C4.1 INTRODUCTION

Within the life cycle of the SCALE system, the CSAS program has superseded earlier programs that contained criticality safety analysis sequences. Embedded within the CSAS program are numerous sequences that enable automated cross-section processing and criticality analyses with and without the search option. All the criticality analysis sequences (sometimes referred to as modules) within SCALE are contained within the CSAS program.

Criticality Safety Analysis Sequence No. 4 (CSAS4) was developed to provide a search capability for three-dimensional (3-D) configurations in the SCALE system. Because it encompassed all the options and functional modules available in earlier SCALE criticality sequences, the program was initially called by the same name, CSAS4. In order to distinguish the program from the numerous sequences that it contained (including CSAS4), the program name was later changed to CSAS. The reader should be aware that the documentation has not been completely revised, and the program is still referred to as CSAS4 in much of the documentation that follows.

The standardized automated procedures process SCALE cross sections using the Bondarenko method (via BONAMI) and the Nordheim integral method (via NITAWL-II) to provide a resonance-corrected cross-section library based on the physical characteristics of the problem being analyzed. This cross-section library can be utilized by KENO V.a, a 3-D multigroup Monte Carlo criticality program, or XSDRNPM, a one-dimensional (1-D) discrete-ordinates code for transport analysis. The search capability utilizes KENO V.a and is performed by activating CSAS4 or CSAS4X. The type of search is defined by the input data, and a parameter search is performed on k-effective as a function of pitch or other dimensions. The two basic search options offered are (1) an optimum search seeking a maximum or minimum and (2) a critical search seeking a fixed value of k-effective.

The user may select the CSAS4 or the CSAS4X sequence to perform a search sequence. An X in the module name specifies that XSDRNPM will be used to provide cell-weighted cross sections. CSAS4 should be used for 3-D searches when the fuel pins are modeled individually in the KENO V.a geometry. CSAS4X should be used for 3-D searches when cell-weighted cross sections are used to provide a homogeneous representation of the fuel pins in the KENO V.a geometry. Cell-weighting is accomplished by describing a unit cell, as in a fuel assembly, for which a 1-D eigenvalue calculation of the unit cell is made to determine the spatially dependent flux spectrum. This flux spectrum is used to cell-weight the microscopic cross-section data. The nuclide number densities in the unit cell are homogenized, and the resultant homogenized cell-weighted cross sections are identified as mixture 500 and utilized in the KENO V.a geometry. Note that only one mixture 500 can be created per problem.

The codes utilized in Criticality Safety Analysis Sequence No. 4 start with an AMPX master format cross-section library and generate a self-shielded, group-averaged library applicable to the specific problem configuration. These cross sections are then used in the Monte Carlo determination of the effective neutron multiplication factor. The codes and their functions are given below.

1. BONAMI — performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections.

2. NITAWL-II — applies a Nordheim resonance self-shielding correction to nuclides having resonance parameters.

3. XSDRNPM — provides cell-weighted cross sections based on the specified unit cell and, in addition, can calculate the effective neutron multiplication (k-effective) for a 1-D system.

4. ICE — creates a Monte Carlo formatted mixed cross-section library for use by KENO V.a.

5. KENO V.a — calculates k-effective of a 3-D system.

6. MODIFY — alters the pitch and redefines the geometry data used by KENO V.a. The optimum pitch search is achieved by repeatedly changing the geometry data and executing KENO V.a until the optimum pitch is determined or the calculation is terminated for other reasons.

All the control sequences in the CSAS program are listed in the following table with the modules they invoke. The first seven sequences are subsets of the CSAS4X sequence. This section of the SCALE manual describes all eight sequences.

Control module	Search function	Functional modules executed by the control module				
CSASI	No search	BONAMI	NITAWL-II		ICE	
CSASIX	No search	BONAMI	NITAWL-II	XSDRNPM	ICE	
CSASN	No search	BONAMI	NITAWL-II			
CSAS1X	No search	BONAMI	NITAWL-II	XSDRNPM		
CSAS25	No search	BONAMI	NITAWL-II		KENO V.a	
CSAS2X	No search	BONAMI	NITAWL-II	XSDRNPM	KENO V.a	
CSAS4	Search	BONAMI	NITAWL-II		KENO V.a	MODIFY*
CSAS4X	Search	BONAMI	NITAWL-II	XSDRNPM	KENO V.a	MODIFY*

*MODIFY is a control module.

C4.2 TECHNIQUES

Criticality Safety Analysis Sequence No. 4 (CSAS) is designed to perform a search utilizing the Monte Carlo Criticality code KENO V.a. Related sequences (see Table C4.2.1) can bypass the search and provide k-effective for the system being analyzed or simply prepare a cross-section library for subsequent use. In order to minimize human error, the SCALE data handling is automated as much as possible. CSAS and many other SCALE sequences apply a standardized procedure to provide appropriate cross sections for the calculation. This procedure is carried out by the Material Information Processor that generates number densities and related information, prepares geometry data for resonance self-shielding and flux-weighting cell calculations, and creates data input files for the cross-section processing codes. Sequences that execute KENO V.a include a KENO V.a Data Processor to read and check the KENO V.a data. Sequences that execute a search use a Search Data Processor to read and check the search data. When the data checking has been completed, the control sequence executes BONAMI and NITAWL-II to prepare a resonance-corrected microscopic cross-section library in the AMPX working library format. If cell-weighted cross sections are requested, XSDRNPM performs the necessary calculations and produces a cell-weighted microscopic cross-section library in the AMPX working library format. ICE may be executed to produce mixture libraries (macroscopic cross-section libraries) in the ICE Monte Carlo format and the AMPX working library format. KENO V.a may be executed to calculate the k-effective or neutron multiplication factor using the cross-section library that was prepared by the control sequence. MODIFY may be invoked to perform a search* by repeatedly altering the KENO V.a data and executing KENO V.a.

Table C4.2.1 CSAS and related criticality sequences

Control module	Search function	Functional modules executed by the control module				
CSASI	No search	BONAMI	NITAWL-II		ICE	
CSASIX	No search	BONAMI	NITAWL-II	XSDRNPM	ICE	
CSASN	No search	BONAMI	NITAWL-II			
CSAS1X	No search	BONAMI	NITAWL-II	XSDRNPM		
CSAS25	No search	BONAMI	NITAWL-II		KENO V.a	
CSAS2X	No search	BONAMI	NITAWL-II	XSDRNPM	KENO V.a	
CSAS4	Search	BONAMI	NITAWL-II		KENO V.a	MODIFY[a]
CSAS4X	Search	BONAMI	NITAWL-II	XSDRNPM	KENO V.a	MODIFY

[a]MODIFY is a control module.

*This search technique is discussed in detail in the report by M. J. Lorek, *Improved Criticality Search Techniques for Low- and High-Enriched Systems*, NUREG/CR-2122, ORNL/NUREG/CSD/TM-13, NUREG/CR-2122, 1981.

The Material Information Processor is described in Sect. M7. It is responsible for reading the standard composition data and other engineering-type specifications, including volume fraction or percent theoretical density, temperature, and isotopic distribution. The techniques used in the Material Information Processor and their applications and limitations are discussed in Sect. M7.2. The input data for the Material Information Processor is the same for all eight analytical sequences available through CSAS. For convenience, the Material Information Processor input data guide is included in Sect. C4.4.

The Material Information Processor checks the input data pertaining to cross-section preparation and prepares binary input files for the applicable functional modules. Depending on the specified sequence, data is prepared for BONAMI, NITAWL-II, XSDRNPM, and ICE as appropriate.

The Bondarenko method is discussed in the Material Information Processor document, Sect. M7.2.5.1, and BONAMI is described in Sect. F1. The Nordheim method and NITAWL-II are described in Sects. M7.2.5.2 and F2 respectively. The Dancoff treatment is discussed in Sect. M7.2.5.3. The automatic mesh generator, the automatic quadrature generator, and the convergence criteria for control sequences that execute XSDRNPM are described in Sects. M7.2.5.6, M7.2.5.7, and M7.2.5.8 respectively. XSDRNPM is described in Sect. F3. ICE is described in Sect. F8, and KENO V.a is described in Sect. F11. See Sect. M7A for an explanation of many of the techniques used in processing the cross sections.

The search capability is implemented by the control module MODIFY. It performs operations according to the specified search data to determine (1) the maximum (or minimum) value of k-effective as a function of pitch or dimensions or (2) the pitch or dimensions corresponding to a specified value of k-effective. An iterative procedure is used, making use of all previous information to modify the pitch or dimensions to achieve the desired result. The procedures for conducting optimum searches and critical searches are summarized below.

C4.2.1 OPTIMUM SEARCH

Because only an initial value of k-effective and a set of boundary constraints are available, four initial points are generated spanning the range defined by the constraints. The search package identifies the type of cubic equation [i.e., a cubic with no local extrema (type A) or a cubic with two local extrema (type B)] and utilizes this knowledge in determining the pitch or dimensions corresponding to the maximum (or minimum) value of k-effective. The optimum search procedure is summarized as follows:

1. Calculate k-effective for the specified problem.

2. Calculate k-effective for the minimum constraint.

3. Calculate k-effective for the maximum constraint.

4. Calculate k-effective for a fourth point that lies approximately equidistant between the initial guess and the constraint that is farthest from it.

5. Utilize a weighted least-squares fit to a cubic polynomial on the data points.

6. Determine the type of cubic. For a type A cubic, go to step 11.

7. Take the first derivative of the least-squares cubic.

8. Solve the quadratic for its roots.

9. Take the second derivative of the least-squares cubic to determine which root is the maximum (or minimum), and if it falls within the constraints, use this root as the next guess. Otherwise, convergence has been defined as occurring at the constraint with the maximum (or minimum) k-effective.

10. Calculate the k-effective corresponding to the next guess. Go to step 5. Repeat this procedure until convergence is achieved.

11. If the cubic equation is a type A cubic, the optimum lies on one of the boundaries. If the fit shows that the cubic is actually a type B cubic, go to step 7 and continue.

Convergence is defined as occurring when a k-effective has been calculated for a point on the curve where the value of the curve is within epsilon of the maximum (or minimum) of the curve. Additionally, the calculated k-effective must be within two standard deviations of the value of the curve at that point. The search is terminated when convergence is achieved or when the code determines there is no local maximum within the constraints.

NOTE: The entire search is performed using the problem-dependent cross sections that were created using data derived from the initial cell description. Therefore, if the search converges with a configuration that is significantly different from the initial cell, the search should be rerun using the converged cell configuration to ensure that the cross-section treatment was adequate.

C4.2.2 CRITICAL SEARCH

The critical search option searches for the pitch or dimensions corresponding to a specified value of k-effective. If the calculated value of k-effective is within the specified search tolerance (EPS) of the desired k-effective, the search is considered to be complete. The critical search procedure is summarized as follows:

1. Calculate k-effective for the specified problem. If it is within EPS of the specified k-effective, convergence has been achieved.

2. Calculate k-effective for one of the constraints. If the specified problem coincided with one of the constraints, calculate k-effective at a point halfway to the other constraint. If the calculated k-effective is within EPS of the specified k-effective, convergence has been achieved.

3. Calculate k-effective for a point chosen from a linear fit of the two existing points closest to the specified k-effective. If the calculated k-effective is within EPS of the specified k-effective, convergence has been achieved.

4. Repeat step 3.

5. Calculate k-effective for a point determined from fitting the previous points to a cubic and solving the cubic for the point closest to the desired k-effective. If all roots lie outside the constraints, the problem is terminated and an appropriate message is written. If the calculated k-effective is within EPS of the specified k-effective, convergence has been achieved. Repeat step 5 until the problem converges, exceeds the specified number of passes, or determines that a feasible solution does not exist.

It should be noted that the entire search is performed using the problem-dependent cross sections that were created using data derived from the initial cell description. Therefore, if the search converges with a configuration that is significantly different from the initial cell, the search should be rerun using the converged cell configuration to ensure that the cross-section treatment was adequate.

C4.2.3 CSAS LIMITATIONS

The CSAS control module was developed to use simple input data and prepare problem-dependent cross sections for use in calculating the effective neutron multiplication factor of a 1-D or 3-D system using XSDRNPM or KENO V.a. An attempt was made to make the system as general as possible within the constraints of the standardized methods chosen to be used in SCALE. Standardized methods of data input were adopted to allow easy data entry and for quality assurance purposes. Some of the limitations of the CSAS sequences are due to assumptions in the Nordheim integral treatment[1] as implemented in CSAS. Inherent limitations in the NITAWL-II Nordheim integral treatment of resonance nuclides are as follows:

1. The treatment assumes no resonance overlap from other resonances or other material regions.

2. The treatment of an external moderator assumes an asymptotic flux present at the absorber-moderator interface.

3. The treatment of spatial transport uses the first-flight escape probability for the absorber, the two-region reciprocity theorem, and Dancoff[2] factors.

In many cases, the Nordheim integral treatment is an excellent method for processing resonance cross sections for use in the analysis of light-water reactor (LWR) fuel pin cells and for many other applications commonly used in neutronics analysis. However, caution should be used in applications involving several isotopes with large resonances or complicated absorber-moderator geometries. Another area of probable inadequacy involves the analysis of machinery for dissolving spent fuel elements. Such a system usually requires the simultaneous consideration of resonance absorbers located in both the solid fuel pellets and the acid solution, thereby resulting in an inadequate treatment by NITAWL-II.

The major limitations of the analytical model used by the Nordheim integral treatment in CSAS are as follows:

1. A lattice system whose fuel or moderator contains an absorber that has rapidly varying cross sections across the resonance region may be inadequately treated. Examples include gadolinium, silver, indium, and hafnium.

2. The presence of more than one resonance isotope in a material can lead to an effect called resonance overlap, which can result in enhanced or reduced group-averaged cross sections, depending on the predominance of resonance scattering or absorption and the relative locations of the resonances within the energy groups. The resonance overlap effect is discussed in more detail in Sect. M7.A.7.

3. Resonance interference between two different media is not correctly treated.

4. Fissile lumps in fissile solutions are not correctly treated.

5. The determination of parameters used in processing the cross sections are derived from the geometry of the cell description. CSAS does not allow multiple cell descriptions.

6. It is strongly recommended that CSAS calculations be made of benchmark experiments similar to the problem being calculated in order to demonstrate the validity of the code/cross-section combination for that type of problem.

CSAS uses cross sections created using data derived from the cell description specified in the Material Information Processor data. The cell description is not updated, and the cross sections are not reprocessed even when convergence is achieved. Therefore, it is strongly recommended that once convergence is achieved, the materials information processor cell be updated to use the converged configuration and the search be rerun to ensure that the cross sections were adequate. The new search should converge immediately if the initial cell was adequate for the cross-section treatment. Otherwise, the search will continue until convergence is achieved.

C4.2.4 REFERENCES

1. L. W. Nordheim, "The Theory of Resonance Absorption," *Proceedings of Symposia in Applied Mathematics*, Vol XI, p. 58, G. Birkhoff and E. P. Wigner, Eds., Am. Math. Soc. (1961).

2. S. M. Dancoff and M. Ginsburg, *Surface Resonance Absorption in a Close-Packed Lattice*, CP-2157, Clinton Plant, U.S. Atomic Energy Commission (September 1944).

C4.3 LOGICAL PROGRAM FLOW

The general flow of Criticality Safety Analysis Sequence No. 4 is given in this section. The program flow is divided into several sections. An abbreviated representation, rather than a formal flowchart, is used to outline the program flow of each section. A flowchart may show a subroutine or library routine only once, even though it may be called multiple times in that portion of the program. The corresponding text usually states when multiple calls are made to a routine. Accompanying each abbreviated flowchart is an explanation of the purpose of that segment of the program and text describing each of the referenced subroutines.

Criticality Safety Analysis Sequence No. 4 has been written in a general form to allow maximum flexibility. Data are transferred from one module to another via sequential data files and direct-access data files. Table C4.3.1 lists the data files utilized by this program. CSAS is used to represent the control module defining the available sequences. Data files utilized by the individual functional modules are included in Table C4.3.2.

The flowchart representation for Criticality Safety Analysis Sequence No. 4 is defined as follows:

The SCALE DRIVER is contained in a diamond, subroutines initiating control modules are contained in circles, functional modules are contained in hexagons, major program segments are contained in rectangularized ovals, subroutine names are contained in boxes, and library routines are represented as bare names. An arrow in the flowchart indicates that the subroutine or module associated with the arrow will be discussed later in the section.

C4.3.1 INITIATION OF CSAS (CRITICALITY SAFETY ANALYSIS SEQUENCE NO. 4)

This portion of the program is the initiation of the criticality safety analysis sequence. The SCALE DRIVER, described in Sect. M1, obtains the name of the module to be accessed from the first card (module specification card) in the user input data file. The control modules available in Criticality Safety Analysis Sequence No. 4 are shown in Fig. C4.3.1. These control modules, with the exception of MODIFY, use the Material Information Processor data as described in Sect. M7.3.

SCALE DRIVER allows implementation of a modular code system which includes Criticality Safety Analysis Sequence No. 4. See Sect. M1 for additional information about the driver.

CSAS4 performs a search for three-dimensional (3-D) problems that do not need a cell-weighted mixture cross section. The search is conducted by sequentially activating the functional modules BONAMI, NITAWL-II, and KENO V.a to process the required cross sections and calculate the k-effective. The control module MODIFY then performs operations to alter the pitch or other geometric dimensions repeatedly and to activate KENO V.a until the search requirements are met or the job is terminated for other reasons.

Table C4.3.1 Description of units utilized by the Criticality Safety Analysis Sequence No. 4 control module

Unit No.	Type of data	Creating module	User module	Type of file
5	Input	DRIVER	CSAS	Sequential
8	Scratch file	CSAS	CSAS	Direct or random-access data
11	Short master cross-section library	CSAS	BONAMI	Sequential
16	Scratch file	CSAS	CSAS	Sequential
17	Scratch file	CSAS	CSAS	Sequential
18	Scratch file	CSAS	CSAS	Sequential
19	Scratch file	CSAS	CSAS	Sequential
70	User-supplied cross sections		CSAS	AMPX master format library
81	16-group cross sections		CSAS	AMPX master format library
82	27-group cross sections		CSAS	AMPX master format library
83	44-group cross sections		CSAS	AMPX master format library
84	238-group cross sections		CSAS	AMPX master format library
85	22 neutron-18 gamma cross sections		CSAS	AMPX master format library
86	18-gamma cross sections		CSAS	AMPX master format library
87	27-group cross sections for burnup		CSAS	AMPX master format library
88	27 neutron-18 gamma cross sections		CSAS	AMPX master format library
89	Standard Composition Library		CSAS	Direct or random-access data file
90	Search data	CSAS	MODIFY	Direct or random-access data
92	ICE input data	CSAS	ICE	Sequential
95	KENO V.a restart data	CSAS	KENO V.a	Sequential
		MODIFY	MODIFY	
		KENO V.a		
96	BONAMI input data	CSAS	BONAMI	
97	NITAWL-II input data	CSAS	NITAWL-II	Sequential
98	XSDRN input data	CSAS	XSDRNPM	Sequential
99	Printed output	CSAS	CSAS	Sequential
		MODIFY	MODIFY	Sequential

Table C4.3.2 Description of units used by the functional modules of CSAS

Unit No.	Module	Action	Type of file
1	BONAMI	WRITE	Microscopic master working format cross sections
	NITAWL-II	READ	Microscopic master working format cross sections
2	ICE	WRITE	Macroscopic working format cross sections
3	XSDRNPM	WRITE	Microscopic cell-weighted working format cross sections
	ICE	READ	Microscopic cell-weighted working format cross sections
	KENO V.a	READ	Microscopic cell-weighted working format cross sections
4	NITAWL-II	WRITE	Microscopic working format cross sections
	ICE	READ	Microscopic working format cross sections
	KENO V.a	READ	Microscopic working format cross sections
	XSDRNPM	READ	Microscopic working format cross sections
6	BONAMI	WRITE	Printed output
	ICE	WRITE	Printed output
	KENO V.a	WRITE	Printed output
	NITAWL-II	WRITE	Printed output
	XSDRNPM	WRITE	Printed output
8	BONAMI	WRITE/READ	Direct or random-access scratch files
	ICE	WRITE/READ	Direct or random-access scratch files
	KENO V.a	WRITE/READ	Direct or random-access scratch files
	XSDRNPM	WRITE/READ	Direct or random-access scratch files
9	BONAMI	WRITE/READ	Direct or random-access scratch files
	ICE	WRITE/READ	Direct or random-access scratch files
	KENO V.a	WRITE/READ	Direct or random-access scratch files
	NITAWL-II	WRITE/READ	Direct or random-access scratch files
	XSDRNPM	WRITE/READ	Direct or random-access scratch files
10	ICE	WRITE/READ	Direct or random-access scratch files
	KENO V.a	WRITE/READ	Direct or random-access scratch files
	XSDRNPM	WRITE/READ	Direct or random-access scratch files
11	BONAMI	READ	Short AMPX master format cross sections
14	ICE	WRITE	Monte Carlo-formatted macroscopic cross sections
	KENO V.a	READ/WRITE	Monte Carlo-formatted macroscopic cross sections
16	KENO V.a	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Angular flux file
17	XSDRNPM	WRITE/READ	Sequential scratch file
18	BONAMI	WRITE/READ	Sequential scratch file
	NITAWL-II	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Sequential scratch file
19	BONAMI	WRITE/READ	Sequential scratch file
	NITAWL-II	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Sequential scratch file
79	KENO V.a	READ	KENO V.a albedo file
80	KENO V.a	READ	KENO V.a weighting file
92	ICE	READ	Binary input file
95	KENO V.a	READ	Binary input file
96	BONAMI	READ	Binary input file
97	NITAWL-II	READ	Binary input file
98	XSDRNPM	READ	Binary input file

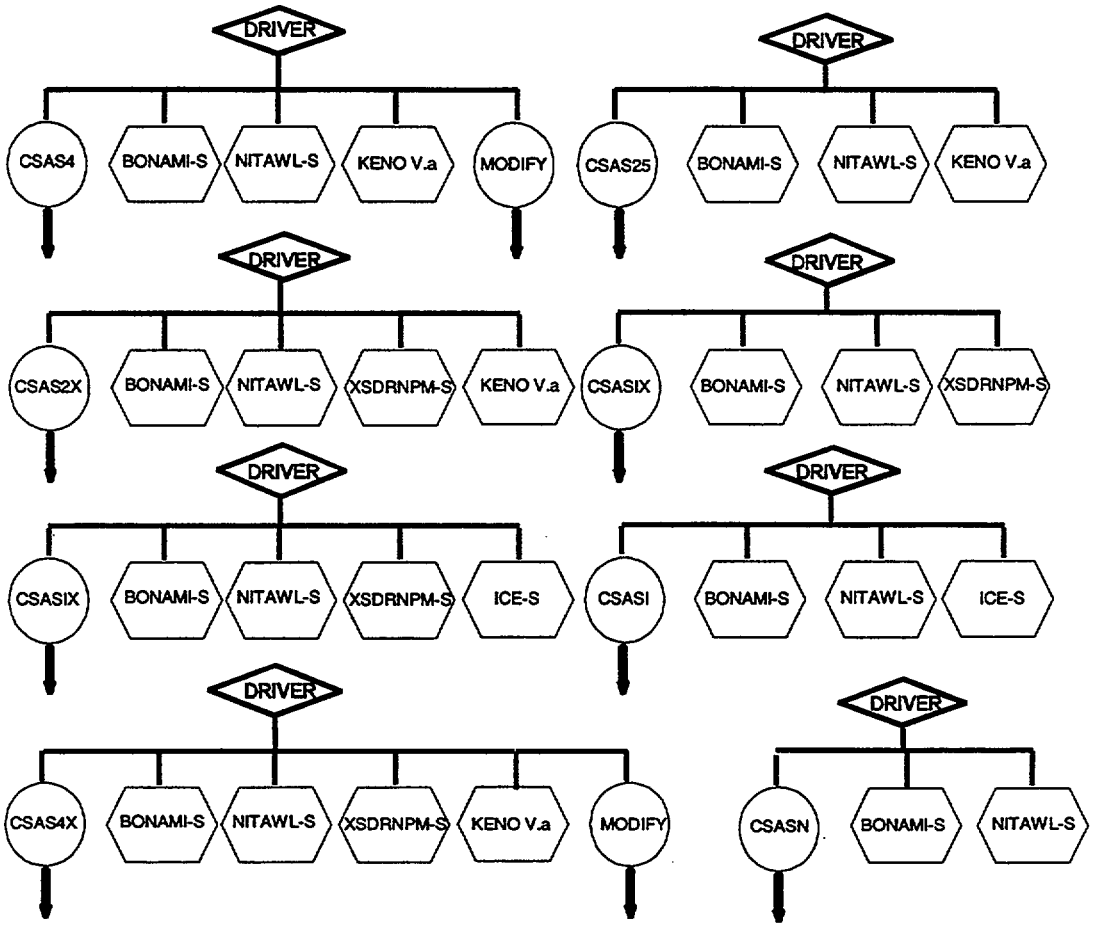


Figure C4.3.1 Control modules available in Criticality Safety Analysis Sequence No. 4

CSAS25 calculates the k-effective for 3-D problems. This module sequentially activates the functional modules BONAMI, NITAWL-II, and KENO V.a to process the required cross sections and calculate the k-effective. Note that a cell-weighted mixture cross section cannot be used.

CSAS2X calculates the k-effective for 3-D problems that require a cell-weighted mixture. It is the same as CSAS25 except a cell-weighted mixture cross section is always created. This control module sequentially activates the functional modules BONAMI, NITAWL-II, XSDRNPM-S, and KENO V.a to process the required cross sections and calculate the k-effective.

CSAS1X creates a microscopic cell-weighted library in the AMPX working library format. This control module sequentially activates the functional modules BONAMI and NITAWL-II to process the necessary cross sections and calculates the k-effective of the one-dimensional (1-D) problem using the discrete-ordinates code XSDRNPM-S.

CSASIX provides a resonance-corrected, cell-weighted, macroscopic mixture cross-section library in the MORSE/KENO (ICE Monte Carlo-processed) format by sequentially activating the functional modules BONAMI, NITAWL-II, XSDRNPM-S, and ICE. The discrete ordinates code XSDRNPM-S also computes the k-effective for the 1-D problem.

CSASI provides a resonance-corrected macroscopic mixture cross-section library in the MORSE/KENO (ICE Monte Carlo-processed) format by sequentially activating the functional modules BONAMI, NITAWL-II, and ICE.

CSAS4X performs a search for 3-D problems that require a cell-weighted mixture cross section. The search is achieved by sequentially activating the functional modules BONAMI, NITAWL-II, XSDRNPM-S, and KENO V.a to process the required cross sections and calculate the k-effective. The control module MODIFY then performs operations to alter the pitch or other geometric dimensions repeatedly and to activate KENO V.a until the search requirements are met or the job is terminated for other reasons.

CSASN creates a resonance-corrected microscopic cross-section library in the AMPX working library format by sequentially activating the functional modules BONAMI and NITAWL-II.

BONAMI is a functional module in the SCALE system that performs resonance self-shielding calculations for nuclides that contain Bondarenko data in their cross sections. See Sect. F1 for detailed information concerning BONAMI.

NITAWL-II is a functional module in the SCALE system. It applies a Nordheim resonance self-shielding correction to nuclides having resonance parameters associated with the cross-section data. See Sect. F2 for detailed information.

KENO V.a is a functional module in the SCALE system. It calculates the effective neutron multiplication of a 3-D problem. See Sect. F11 for a detailed description of KENO V.a.

MODIFY is a control module in the SCALE system. It is responsible for conducting a search by repeatedly altering the geometry specifications and executing KENO V.a. Section C4.3.6 contains more detail about MODIFY.

XSDRNPM-S is a functional module in the SCALE system. It provides cell-weighted cross sections based on the specified unit cell. It can also calculate the k-effective for 1-D problems. See Sect. F3 for additional information.

ICE is a functional module in the SCALE system. It creates a Monte Carlo-formatted mixed cross-section library for use by KENO V.a or MORSE. See Sect. F8 for additional details.

C4.3.2 OVERALL FLOW DIAGRAM

Figure C4.3.2 illustrates the overall flow of Criticality Safety Analysis Sequence No. 4. The control modules CSAS4, CSAS4X, CSAS25, CSAS2X, and CSAS1X communicate with the driver and dictate the order in which other modules are to be executed.

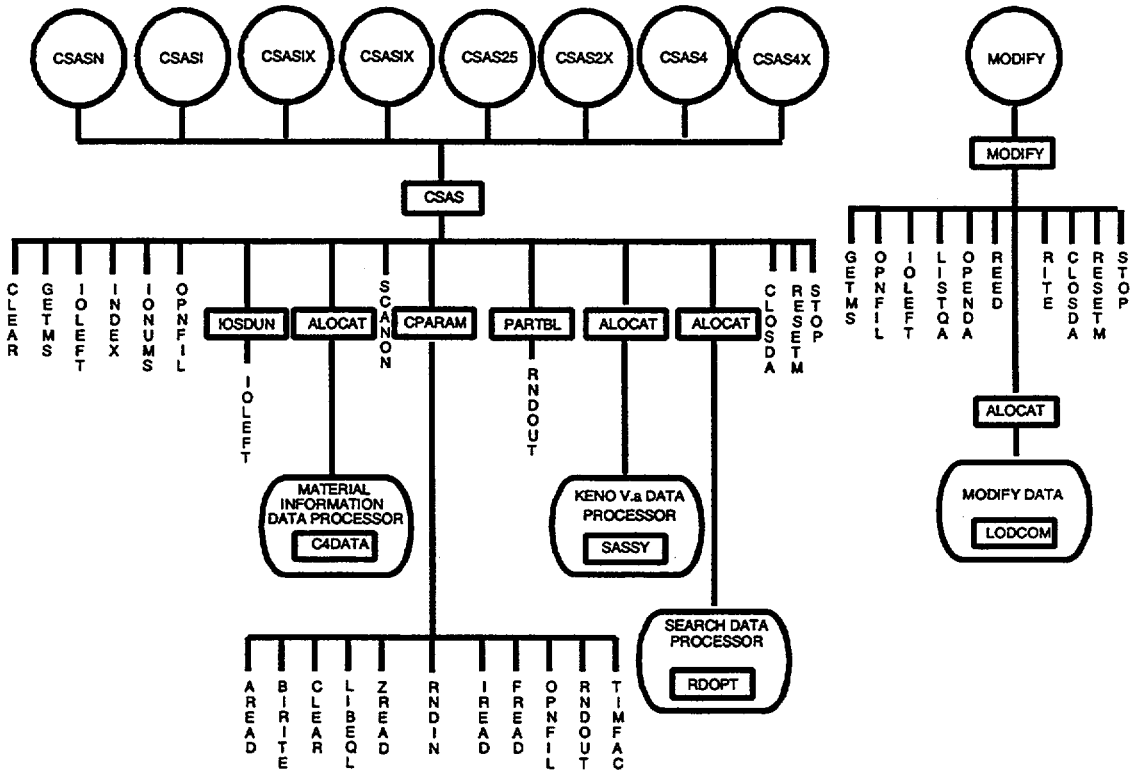


Figure C4.3.2 Overall flow of Criticality Safety Analysis Sequence No. 4

CSASN - This control module generates a resonance-corrected, microscopic cross-section library in the AMPX working library format. This is accomplished by sequentially activating the functional modules BONAMI and NITAWL-II.

CSASI - This control module generates both a resonance-corrected, microscopic, cross-section library in the AMPX working library format and a resonance-corrected, macroscopic mixture cross-section library in the MORSE/KENO (ICE Monte Carlo-processed) format by sequentially activating the functional modules BONAMI, NITAWL-II, and ICE.

CSAS1X - This control module is responsible for performing a 1-D criticality calculation and providing a resonance-corrected, cell-weighted, microscopic cross-section library in the AMPX working library format.

CSASIX - This control module generates both a resonance-corrected, cell-weighted, microscopic cross-section library in the AMPX working library format and a resonance-corrected, cell-weighted, macroscopic mixture cross-section library in the MORSE/KENO (ICE Monte Carlo-processed) format by sequentially activating the functional modules BONAMI, NITAWL-II, XSDRNPM-S, and ICE. The discrete-ordinates code XSDRNPM-S also provides the k-effective for the 1-D problem.

CSAS25 - This control module calculates k-effective for a 3-D system, using KENO V.a, when a cell-weighted mixture cross section is not needed.

CSAS2X - This control module calculates k-effective for a 3-D system, using KENO V.a, when a cell-weighted mixture cross section is required.

CSAS4 - This control module is responsible for conducting a search for 3-D problems that do not need a cell-weighted cross section.

CSAS4X - This control module is responsible for conducting a search for 3-D problems that require a cell-weighted cross section.

CSAS - This is the main program for CSAS and its associated control modules. GETMS is called to read the analytical sequence specification and the parameters associated with it. The sequence specification is used to set flags to cause the desired functional modules to be executed in the proper order. IOLEFT is called to initialize the counter that keeps track of the number of I/Os that are done. INDEX is a FORTRAN-supplied intrinsic function used to determine if a variable matches a specified character string. IONUMS is called to set the input and output units for the free-form reading routines. OPNFIL is called to open the input and output units that are used by the control module. IOSDUN is called several times to determine the number of I/Os that have been used in various operations. C4DATA is called from ALOCAT with the requested storage allocation. This accesses the MATERIAL INFORMATION PROCESSOR. SCANON is called to activate the feature that allows scanning the input data for the word END. If KENO V.a is to be executed, CPARAM is called to read the KENO V.a title and to read and initialize the KENO V.a parameter data. SASSY is called from ALOCAT to read the KENO V.a data and write the information in a form that can be utilized by the CSAS module. If a search is to be made, RDOPT is called from ALOCAT to read and check the search data and transmit it to the CSAS module. If errors are encountered during reading, preparing, and checking the data, execution is terminated without activating any of the functional modules. The direct-access files are closed out when the problem is completed or terminated. This program makes use of error flags in an effort to continue reading and checking input data even after errors are found. However, some errors are severe enough to cause immediate termination.

CLEAR - This library routine is called to initialize an array to zero.

GETMS - This assembly language library routine is called to read the analytical sequence specification and any associated parameter data. It establishes communication with the SCALE driver and enters data obtained from the SCALE driver into common. An example of an analytical sequence specification is given on the following page. This particular example specifies that the control module CSAS is to be executed. The associated parameters are entered following the word "PARM=," starting beyond column 10. In this example the parameters specify that the data are to be checked without executing the problem, and a maximum of 200,000 words is requested to complete this task.

```
=CSAS4    PARM= (CHECK,SIZE=200000).
```

IOLEFT - This library routine is called to store the initial I/O count in common for determining the number of I/Os used in certain parts of the program.

INDEX - A FORTRAN-supplied intrinsic function used to determine if a variable matches a specified character string.

IONUMS - This library routine sets the I/O units or devices for the free-form data reading routines.

OPNFIL - This library routine opens the I/O units or devices that will be utilized in the problem.

IOSDUN - This subroutine is called several times to indicate the number of I/Os used in various operations.

ALOCAT - This assembly language library routine is called with three arguments. The first argument is a subroutine name, the second argument is the maximum number of words of core storage to be allocated, and the third argument is the statement number to return to if the available core storage is less than that requested by the second argument.

MATERIAL INFORMATION PROCESSOR (C4DATA) - This segment of the program is accessed by calling subroutine C4DATA via ALOCAT. It is responsible for reading the standard compositions specification data and associated engineering-type specifications used to generate the mixing table and in performing the cell-weighting calculations. It checks the data for obvious errors and generates information necessary for processing the cross sections. It continues checking and preparing data for use in the functional modules activated by the sequence. The MATERIAL INFORMATION PROCESSOR is described in more detail in Sect. M7.3.

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

CPARAM - This subroutine is called only if KENO V.a is to be executed. It is responsible for reading the KENO V.a title, initializing certain default values for the KENO V.a parameter data, reading the KENO V.a parameter data, and writing the parameter data on the restart data file to communicate it to the KENO V.a functional module. AREAD, IREAD, FREAD and ZREAD are used to read the parameter data. BIRITE is used to write the parameter data on the restart

data file, which is used by the functional module KENO V.a to define the problem. CLEAR is called to zero a common. LIBEQL determines the unit from which cross sections are to be read. RNDIN is called to load the random number if it is entered as parameter data. OPNFIL opens the I/O units that will be used, RNDOUT stores the current random number, and TIMFAC adjusts the time estimate.

AREAD - This library routine may be called many times from subroutine PARAM. It is used to read parameter names and alphanumeric parameter data.

BIRITE - This library routine is used to write the binary data used by the functional modules.

LIBEQL - This subroutine is called to determine which unit or device will be used to read the resonance-corrected microscopic library.

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 is entered as 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 parameter data.

RNDOUT - This library routine is used to preserve the current random number so it can be written on the restart data file.

TIMFAC - This library routine provides the proper adjustment factor by which the allotted time is multiplied to adjust the execution time for execution for different computers.

PARTBL - This subroutine is called only if KENO V.a is to be executed. It is responsible for printing the KENO V.a numeric and logical parameter tables. RNDOUT is called to preserve the current random number so that it can be printed in the numeric parameter table.

KENO V.a DATA PROCESSOR (SASSY) - This segment of the program is accessed by calling subroutine SASSY via ALOCAT. It reads and checks the remainder of the KENO V.a data used by CSAS. It writes the data on the restart data file to be used by the functional module KENO V.a. This segment of the program is described in detail in Sect. C4.3.4.

SEARCH DATA PROCESSOR (RDOPT) - This segment of the program is accessed by calling subroutine RDOPT via ALOCAT. It reads the search data and writes it on a data set for use by the CSAS control module. It is described in more detail in Sect. C4.3.5.

CLOSDA - This library routine is called to close out each direct-access file when the problem is completed in a normal manner.

RESETM - This library routine is an entry point in the assembly language library routine GETMS. It transmits control data back to the SCALE driver.

STOP - This library routine is called several times to write error messages. It can be instructed to provide a traceback and can terminate execution or allow execution to continue, depending on the arguments provided to it.

MODIFY - This is the MAIN program for the search control module. GETMS establishes communication between the SCALE driver and the search control module, MODIFY. OPNFIL opens the input and output units for the search. IOLEFT is used to monitor the I/Os used by the code. LISTQA is called to print a program verification information table for quality assurance purposes. OPENDA opens the direct-access units; REED is used to load data from direct access. LODCOM is called via ALOCAT to process the search data and alter the appropriate data accordingly. RITE writes data on the direct-access unit. CLOSDA is called to close out the direct-access file. RESETM transmits control data back to the SCALE driver. STOP is called if additional core storage is required. If the problem has converged or become unsolvable, an appropriate message is written, and flags are set to terminate execution. Otherwise, a flag is set so that the driver will execute KENO V.a using the modified data.

LISTQA - This subroutine is called to print a program verification information table for quality assurance purposes.

OPENDA - This subroutine opens the direct-access units.

REED - This subroutine is used to read data from a direct-access file.

RITE - This subroutine writes data on the direct-access unit.

MODIFY DATA (LODCOM) - This segment of the program alters the data for the optimum pitch search. It is accessed by calling subroutine LODCOM. Section C4.3.6 contains a detailed description of this segment of the program.

C4.3.3 THE MATERIAL INFORMATION PROCESSOR

The Material Information Processor is responsible for reading data that specifies the cross-section library, defines the materials to be used in the problem, and provides data used to apply geometric and resonance corrections to the cross sections. After the data are read and checked, calculations are performed to create a mixing table and provide data to the functional modules that are invoked by the control module to perform cross-section processing to prepare a problem-dependent cross-section library. Section M7.3 contains the program flow for the Material Information Processor.

C4.3.4 KENO V.a DATA PROCESSOR

This portion of the program, as shown in Fig. C4.3.3, is responsible for processing the KENO V.a input data. All the KENO V.a data, except the title and parameters, are read in this portion of the program. The data are carefully checked for errors and are written on the restart data file to be used by the functional module KENO V.a.

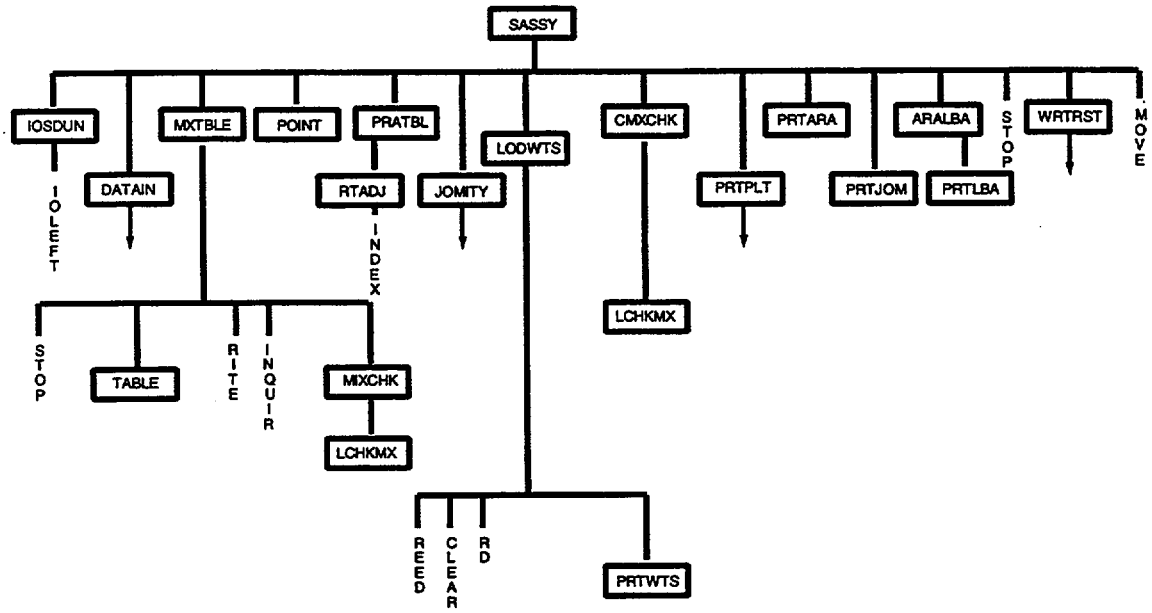


Figure C4.3.3 Flowchart of KENO V.a data processor

SASSY - This subroutine controls the processing of the KENO V.a data. It calls CLEAR to zero the direct-access pointer and length arrays. IOSDUN is called to indicate the number of I/Os used in the different operations involved in processing the KENO V.a data. Then RITE is used to load the direct-access pointer and length arrays on the direct-access data file. Various subroutines are called to read and check the KENO V.a data. If an error is recognized in the data, STOP is called to write a message, and control is returned to the MAIN program. If the data are found to be error free, a restart data file is written by subroutine WRTRST before returning to MAIN.

IOSDUN - This subroutine is called several times to indicate the number of I/Os used for various operations.

IOLEFT - This library routine stores the I/O count in common.

DATAIN - This subroutine controls the reading of all the KENO V.a input data except the title card and parameters. It is explained in more detail in Sect. C4.3.4.1.

MXTBLE - This subroutine initializes the threshold for printing cross-section processing error messages for invalid moments if it was not entered as data, sets up pointers for mixing table data for KENO V.a, calls STOP if more storage is required, and calls TABLE to read the mixing table data. RITE is used to write the mixing table data to a random-access file, and INQUIR is called to set the next block for a direct or random-access device. MIXCHK is called to ensure that the mixtures used in the geometry data were also specified in the Material Information Processor data.

STOP - This library routine is called to print an error message and terminate if errors were found in the CSAS or KENO V.a data.

TABLE - This subroutine is responsible for reading the mixing table data created by the Material Information Processor and storing it in the proper arrays for KENO V.a.

RITE - This subroutine writes data on the direct-access unit.

INQUIR - This subroutine sets direct-access pointer.

MIXCHK - This subroutine reads the KENO V.a mixing table data and writes an error message if a mixture utilized in the geometry data was not created by the Material Information Processor.

LCHKMX - This logical function is called by MIXCHK to return a value of true if a mixture specified on a KENO V.a geometry card is not specified in the mixing table and a value of false if it is.

POINT - This subroutine calculates pointers for storing and accessing KENO V.a data in memory.

PRATBL - This subroutine prints the KENO V.a table of additional data.

RTADJ - This subroutine right-adjusts the albedo boundary condition names that are read in as left-adjusted data. RTADJ utilizes the FORTRAN-supplied intrinsic function INDEX to locate the first blank character.

INDEX - A FORTRAN-supplied intrinsic function used to determine if a variable matches a specified character string.

MITY - 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. See Sect. C4.3.4.9 for additional information.

ODWTS - This subroutine is called only if PWT=YES is specified in the KENO V.a parameter data. LODWTS prints the bias IDs versus the material I/Os used in the problem. It also loads and prints the biasing or weighting data. The library routine REED is used to load the bias IDs from the direct-access device. CLEAR is used to zero the weighting arrays. RD is used to load the biasing data, and subroutine PRTWTS is called to print it.

REED - This subroutine is used to read data from a direct-access file.

CLEAR - This library routine is called to initialize an array to zero.

RD - Load data from direct-access.

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

CMXCHK - This subroutine is used to ensure that a component of the cell-weighted mixture is not used in the KENO V.a geometry data. If it is, an error message is written, and an error flag is set.

LCHKMX - This logical function is called by CMXCHK to return a value of true if a mixture specified on a KENO V.a geometry card is not a component of the cell-weighted mixture and a value of false if it is.

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. C4.3.4.14 for details.

PRTARA - This subroutine prints a table listing the array number, the number of units in the x, y, and z directions, and the nesting level for each array utilized in the problem.

PRTJOM - If a geometry error is recognized, this subroutine is called to print the KENO V.a geometry data that is used in the problem.

ARALBA - This subroutine calls PRTLBA for each unit orientation array used in the problem. Subroutine PRTLBA checks each array for geometrical consistency and prints the array data.

PRTLBA - If a geometry error is recognized, and more than one unit or box type is entered in the geometry data, this subroutine is called to print the KENO V.a unit orientation array data. STOP is called to write an error message if too many units are used in the KENO V.a geometry description.

WRTRST - This subroutine controls the writing of all the KENO V.a data on the restart data file for use by the KENO V.a functional module. MOVE is called to load the required common information into COMMON/REC1/, a common that is used by the analytical sequence. The array that contains the IDs of the 1-D cross sections is written on the restart data file. REED and IO are then used to write the geometry data, unit orientation data, biasing data, and start data on the restart data file.

MOVE - This library routine is called to load data into common.

C4.3.4.1 Control of the Data Input for KENO V.a

This section of the program, shown in Fig. C4.3.4, is responsible for reading the input data that will be used by KENO V.a, with the exception of the title and parameter data.

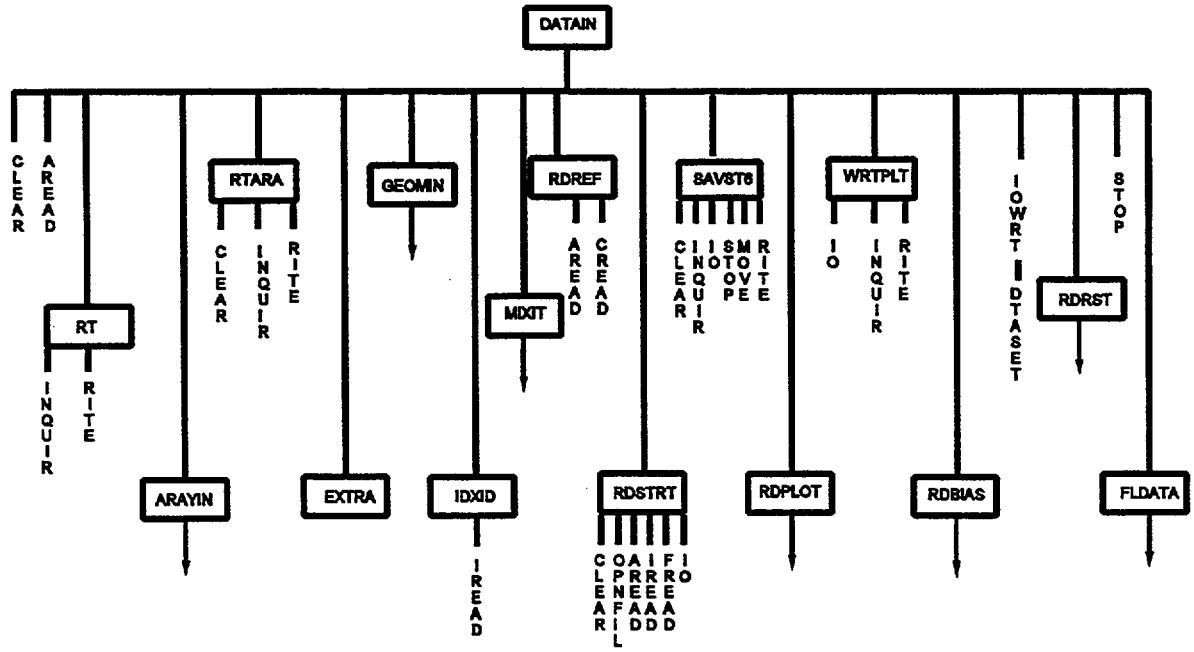


Figure C4.3.4 Flowchart of KENO V.a data reading routines

DATAIN - This subroutine controls the reading of all the KENO V.a data except the title card and parameter data. It initializes COMMON/STDATA/, the common that contains the start data, and initializes the 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. Each block of data is preceded by a keyword that indicates the type of data being entered. After reading the keyword, the appropriate subroutine is called to read the accompanying data. After the data 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 V.a, 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 also 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 and the keyword defining the type of associated data as well as the END flag and the associated keyword. It can be called many times from DATAIN.

RT - This subroutine may be called many times 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 the direct-access device.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

INQUIR - This subroutine sets direct-access pointer.

ARAYIN - This subroutine is called to read data defining the array size. It also reads the unit orientation data if it is entered. ARAYIN is not called for a single unit problem. See Sect. C4.3.4.2 for a more complete description.

RTARA - This subroutine is called only if ARAYIN 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 is not normally processed by KENO V.a. 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. C4.3.4.3 for additional information. The geometry region data are described in detail in Sect. F11.4.4.

IDX1D - This subroutine is called if the number of extra 1-D cross sections is greater than zero and extra 1-D data are 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.

IREAD - This library routine can be called many times from subroutine PARAM. It is used to read integer parameter data.

MIXIT - This subroutine is called to read the mixing table data block that defines the mixtures that are to be created. Section C4.3.4.4 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 KENO V.a geometry data and unit orientation data. The boundary condition data are 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 F11.4.6 describes the input data for defining the KENO V.a boundary conditions.

CREAD - This subroutine is used to read character data.

RDSTRT - This subroutine is called to read start data for KENO V.a. This data are 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. F11.4.8.

OPNFIL - This library routine is called to open I/O units or devices used by the specified CSAS control module and all of the functional modules it involves.

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

IO - This subroutine is used to read/write data from/to a file.

SAVST6 - This subroutine is called to save the data associated with start type 6. SAVST6 is called only if start type 6 is specified in the start type data. See Sect. F11.5.8 for information concerning the specification of start data. The library routine CLEAR is called to initialize the arrays that will contain the start data. 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.

STOP - This library routine is called to print an error message and terminate if errors were found in the CSAS or KENO V.a data.

MOVE - This library routine is called to load data into common.

RDPLOT - This subroutine is called to read the plot data block that is used to generate printer plots. Section C4.3.4.5 explains the processing of the plot data in more detail. Section F11.4.11 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 it 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. C4.3.4.6 for more information. The biasing input data block is described in detail in Sect. F11.4.7.

IOWRT - This subroutine is called with five arguments. In sequence they are (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. C4.3.4.7.

FLDATA - This subroutine is called to supply default data for arrays that were not entered as input. Section C4.3.4.8 contains a more detailed account of the exact procedure.

C4.3.4.2 Read KENO V.a Array Data

This section explains the procedure involved in reading the KENO V.a array data utilized by the analytical sequence, as shown in Fig. C4.3.5.

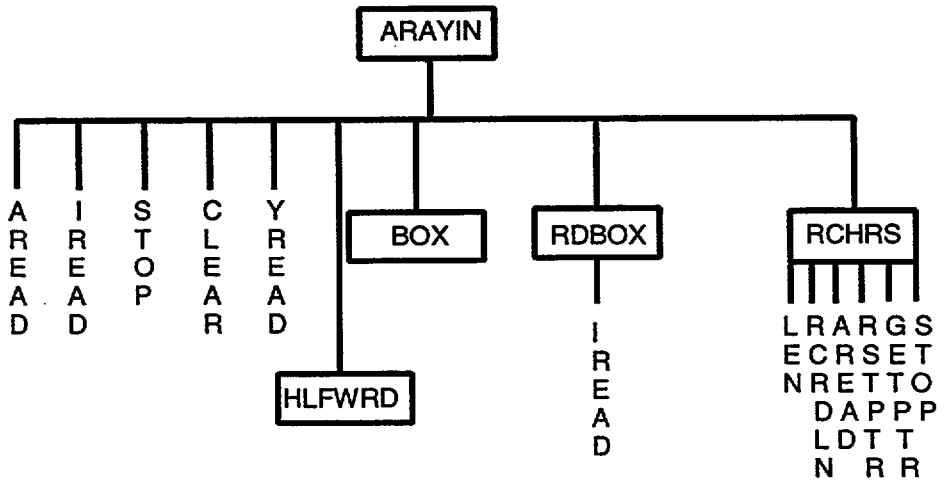


Figure C4.3.5 Flowchart for reading KENO V.a array data

ARAYIN - This subroutine is called from DATAIN when the words READ ARRA are encountered. It is responsible for reading the data that define the size of each unit orientation array. It reads the unit orientation data for each array using subroutine HLFWRD for the FILL option and

subroutine 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. The data are read using the library routines AREAD, IREAD, and YREAD. The data read by this subroutine is described in Sect. F11.4.5.

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 used to zero arrays.

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

HLFWRD - This subroutine is called only if the FILL option is used for entering the unit orientation data. The purpose of HLFWRD is to convert the unit orientation array data from full-word integers to half-word integers.

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. LEN is a FORTRAN-supplied function that sets the length of the data string. 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).

LEN - A FORTRAN-supplied function that sets the length of the data string.

RCRDLN - Sets the length of the input buffer.

RSTPTR - Resets the pointer.

GETPTR - Used to return the current pointer in the input buffer.

C4.3.4.3 Read KENO V.a Geometry Data

This section of the program reads the KENO V.a geometry data required for the problem as shown in Fig. C4.3.6.

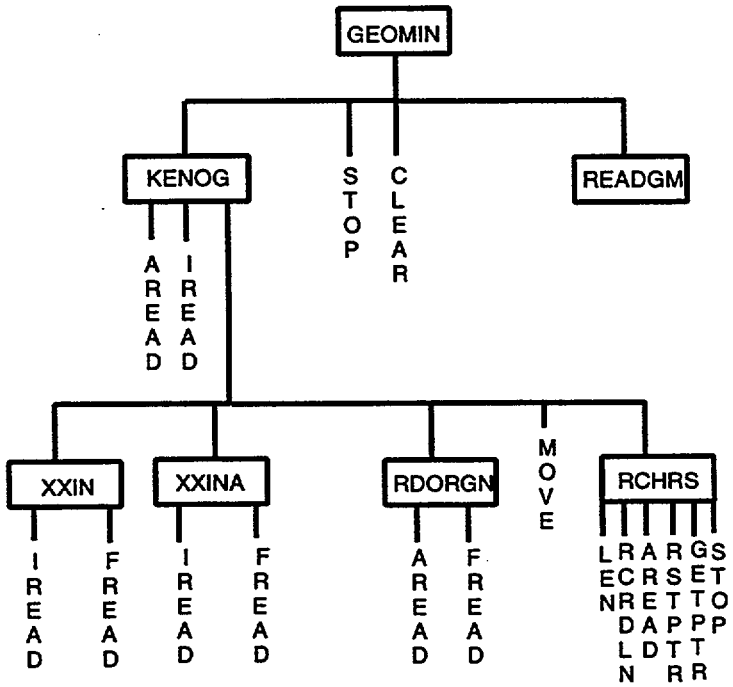


Figure C4.3.6 Flowchart of routines to read the KENO V.a geometry data

GEOMIN - This subroutine controls the reading of the KENO V.a geometry data. KENOG is called to read the data and write it on the scratch data file. Pointers are then calculated. STOP is called to print a message and terminate if more computer storage is required. CLEAR is called to zero the arrays that hold the geometry data. READGM is called to read the data from the scratch data file and load it into the appropriate arrays. STOP is called to write an error message if more storage is needed. Section F11.4.4 describes the KENO V.a geometry input data in detail.

KENOG - This subroutine uses AREAD to read the geometry word. IREAD is called to read the unit number for a unit or box type. It is also used to read the number of reflector regions on a reflector card. XXIN is called to read the mixture number, the bias ID number, and the geometry dimensions. XXINA is an entry point in XXIN. It reads the mixture number and geometry dimensions. The origin specification, if any, associated with a sphere, hemisphere, cylinder, or hemicylinder is read by RDORGN. The chord specification, if any, associated with a hemisphere or hemicylinder is also read by RDORGN. 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.

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.

XXIN - This subroutine is called to read the mixture number, the bias ID number, and the geometry dimensions. IREAD is used to read the mixture number and bias ID number. FREAD is used to read the geometry region dimensions.

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

XXINA - XXINA is an entry point in XXIN. It is called when the geometry word ARRA or ARRAY is encountered. It reads the mixture number and the geometry dimensions. IREAD is used to read the mixture number. FREAD is used to read the geometry region dimensions.

RDORGN - This subroutine uses AREAD to read a word. If the word is ORIGIN, it uses FREAD to read the points defining the origin. If the word is CHORD, it uses FREAD to read the offset of the plane with respect to the origin. If the word is not ORIGIN or CHORD, a flag is set to prevent KENOG from attempting to read another geometry word.

MOVE - This library routine is called to load data into common.

RCHRS - This subroutine is used to read the comment associated with a unit in the geometry region data. LEN is a FORTRAN-supplied function that sets the length of the data string. 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 a message and terminate the problem if the comment is too long.

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

C4.3.4.4 Read KENO V.a Mixing Table Data

This section deals with reading the mixing table data, as shown in Fig. C4.3.7.

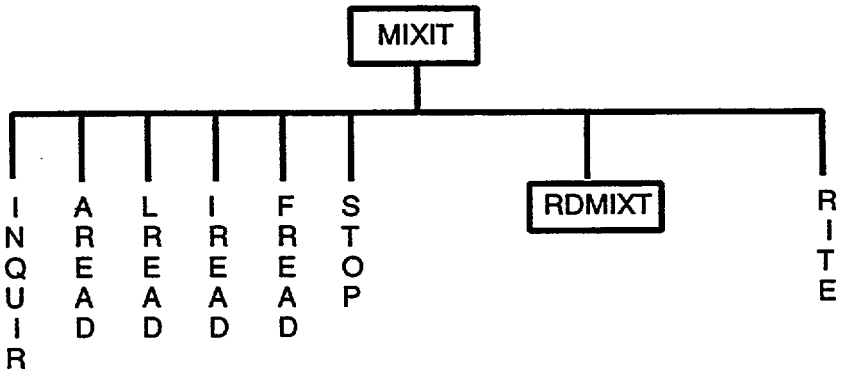


Figure C4.3.7 Flowchart for reading KENO V.a mixing table data

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. FREAD reads the number densities. LREAD is used to determine if the next item is a keyword rather than a number. 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.

The library routine 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.

INQUIR - This subroutine sets direct-access pointer.

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

LREAD - This library routine returns a value of "true" if the next character is a numeric digit. Otherwise, a value of "false" is returned.

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

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

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.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

C4.3.4.5 Read KENO V.a Plot Data

This section of the program, shown in Fig. C4.3.8, reads the plot or picture data used to generate printer plot maps of the mixtures, units, and/or bias IDs used in the problem. The plot input data block is described in Sect. F11.4.11.

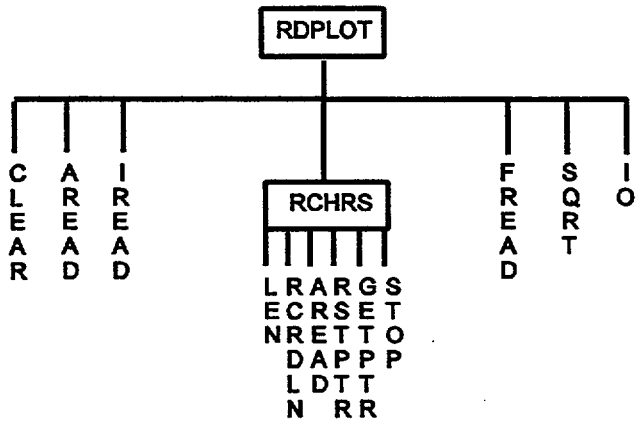


Figure C4.3.8 Flowchart for reading KENO V.a plot data

RDPLOT - 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.

CLEAR - This library routine is used to zero arrays.

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.

RCHRS - This subroutine is used to read the plot title and the character string that defines the symbols to be used in the plot. LEN is a FORTRAN-supplied routine that sets the length of the data string. 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.

LEN - A FORTRAN-supplied function that sets the length of the data string.

RCRDLN - Sets the length of the input buffer.

RSTPTR - Resets the pointer.

GETPTR - Used to return the current pointer in the input buffer.

STOP - This library routine is called from MIXIT if the storage space is insufficient to hold the mixing table arrays.

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

SQRT - This system function returns the square root of a number.

IO - This subroutine is used to read/write data from/to a file.

C4.3.4.6 Read KENO V.a Biasing Data

This section of the program reads the biasing data used in the problem. The biasing input data block is described in Sect. F11.4.7 and illustrated in Fig. C4.3.9.

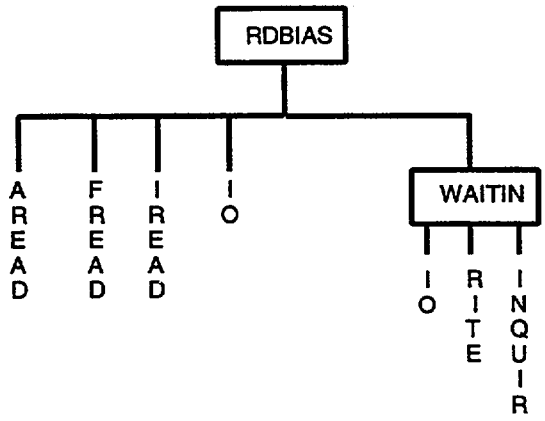


Figure C4.3.9 Flowchart for reading KENO V.a biasing data

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 from cards. 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.

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

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

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

IO - This subroutine is used to read/write data from/to a 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. The library routine INQUIR is called to set the next block on a direct- or random-access device.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

INQUIR - This subroutine sets direct-access pointer.

C4.3.4.7 Read KENO V.a Restart Data

This section of the program reads restart information from the restart data file. The flowchart for this procedure is given in Fig. C4.3.10.

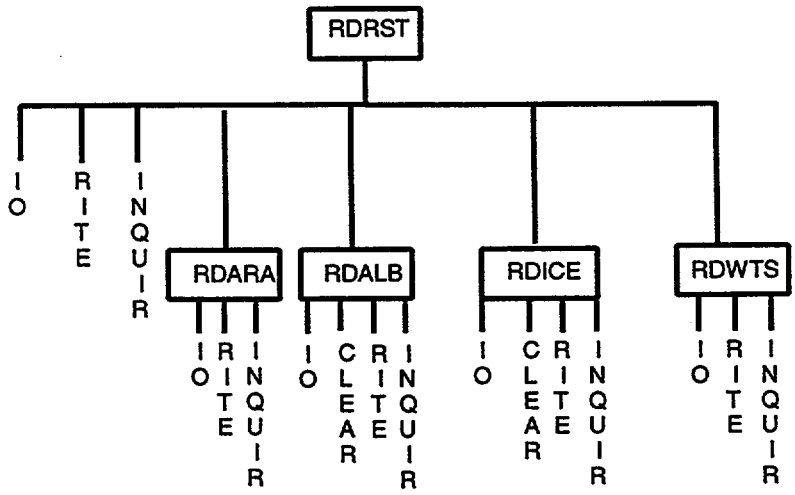


Figure C4.3.10 Flowchart for reading KENO V.a restart data

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.

IO - This subroutine is used to read/write data from/to a file.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

INQUIR - This subroutine sets direct-access pointer.

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 stores the next direct-access block number.

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. INQUIR stores the next direct-access block number. 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.

CLEAR - This library routine is used to zero arrays.

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. INQUIR stores the next direct-access block number. 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.

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 stores the next direct-access block number.

C4.3.4.8 Generate Remaining KENO V.a Data

This section of the program, shown in Fig. C4.3.11, is responsible for generating data that are required for a KENO V.a problem but are not entered directly as data.

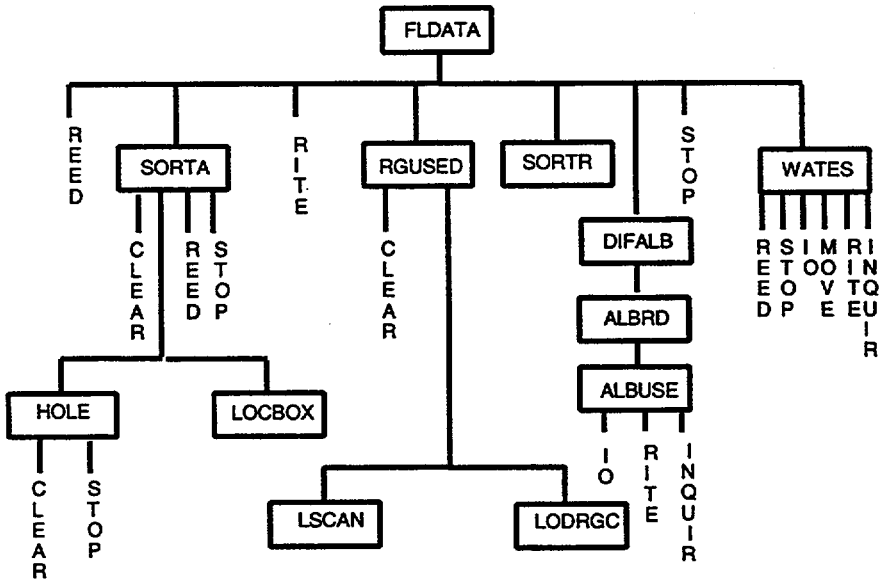


Figure C4.3.11 Flowchart for generating remaining KENO V.a data

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 are 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-dependent biasing function (*wtavg* array) on the direct-access data file.

CLEAR - This library routine is used to zero arrays.

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.

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 ensure holes are not recursively nested.

LOCBOX - This function subprogram is called from SORTA to determine the unit or box type at a given position in the unit orientation array.

STOP - This library routine is called from MIXIT if the storage space is insufficient to hold the mixing table arrays.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

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 or box type 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 or box type is used in the unit orientation array. A value of false is returned if the unit or box type 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 are 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 albedo 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. INQUIR stores the next direct-access block number.

IO - This subroutine is used to read/write data from/to a file.

INQUIR - This subroutine sets direct-access pointer.

WATES - This subroutine reads the biasing input data block from the direct-access data file and reads the KENO V.a 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 from cards, 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 is used to store the next direct-access block number.

MOVE - This library routine is called to load data into common.

C4.3.4.9 Process the KENO V.a Geometry Data

This portion of the program, shown in Fig. C4.3.12, 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.

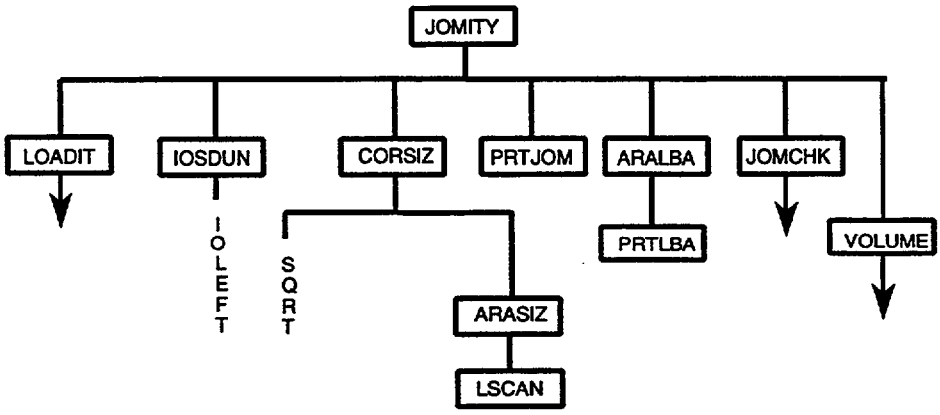


Figure C4.3.12 Flowchart for processing KENO V.a geometry data

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 C4.3.4.10 contains a more detailed description of the procedure.

IOSDUN - This subroutine returns the numbers of I/Os used. The library routine IOLEFT returns the numbers of I/O requests remaining before the system cancels the job.

IOLEFT - This library routine stores the I/O count in common.

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.

SQRT - This system function returns the square root of a number.

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 or box type 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 or box type is used in the unit orientation array. A value of false is returned if the unit or box type 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.

JOMCHK - The purpose of this subroutine is to perform consistency checks on the geometry data and write the appropriate error messages. See Sect. C4.3.4.11 for additional details.

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. C4.3.4.12 for additional details.

C4.3.4.10 Load KENO V.a Data from the Direct-Access File

This portion of the program loads data from the direct-access data file into permanent memory as shown in Fig. C4.3.13.

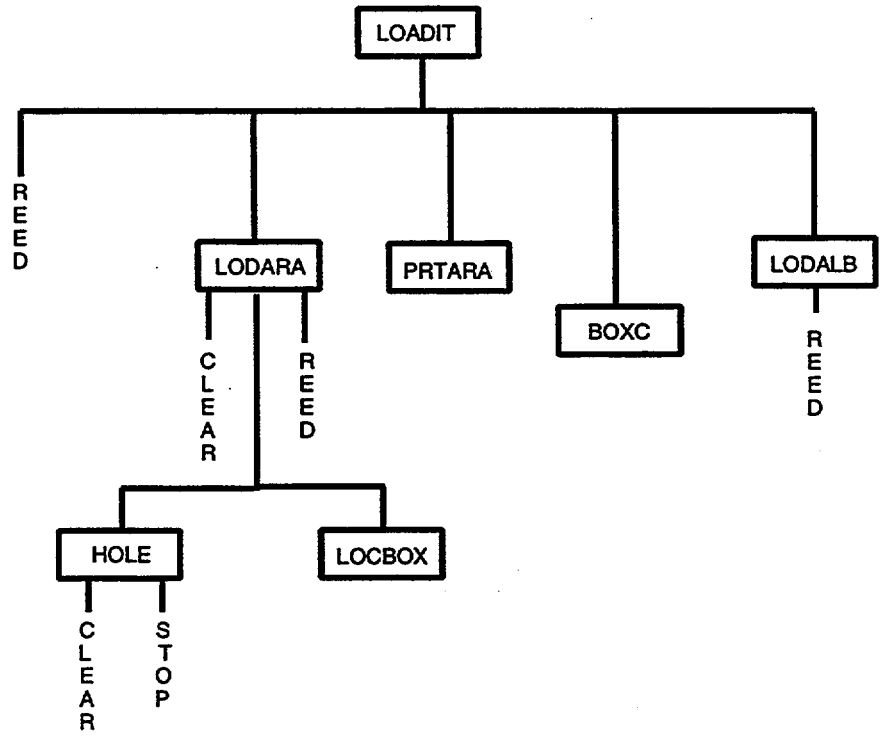


Figure C4.3.13 Flowchart for loading data from direct access

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 array. If multiple boxes 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 box correspondence array, and LODALB is called to load the nonsupergrouped portion of the albedo data.

REED - This subroutine is used to read data from a direct-access file.

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.

CLEAR - This library routine is used to zero arrays.

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 or box type at a given position in the unit orientation array.

STOP - This library routine is called from MIXIT if the storage space is insufficient to hold the mixing table arrays.

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 are printed for each array.

BOXC - This subroutine uses the number of units or box types and the geometry region number corresponding to the first and last geometry region of each unit to generate the box correspondence array that contains the unit or box type number for each geometry region. This 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.

C4.3.4.11 Check the KENO V.a Geometry Data

This portion of the program checks the KENO V.a geometry for inconsistencies, surface intersections, and other errors. The flowchart is shown in Fig. C4.3.14.

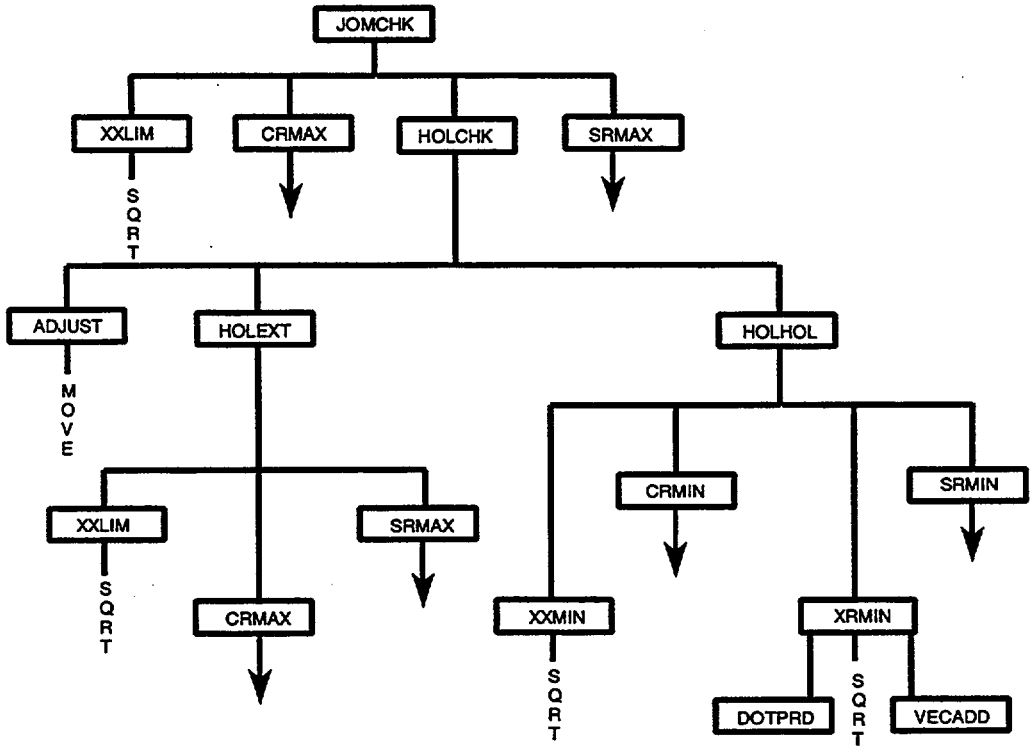


Figure C4.3.14 Flowchart of geometry-checking procedure

JOMCHK - This subroutine checks each geometry region to ensure that it does not intersect the next outer region. If an intersection occurs, an error flag is set and an error message is written. JOMCHK checks each surface of the outer region for an intersection. If the surface is a planar surface, XXLIM is used to return the farthermost point of the inner region in the direction of the plane specified in the call (i.e., for the -x face, XXLIM returns the most negative x value of the inner region). For a spherical surface, SRMAX is used to return the length of the maximum radius vector of the inner region with respect to the origin of the outer region. For a cylindrical surface, CRMAX is used to return the length of the maximum radius vector of the inner region with respect to the axis of the outer region. Subroutine HOLCHK is called to check for intersections between holes and other geometry regions and for holes with other holes.

XXLIM - This routine returns the maximum coordinate of an interior region corresponding to a particular face direction (for negative face directions, maximum means most negative).

SQRT - This system function returns the square root of a number.

CRMAX - This function determines the maximum cylindrical radius vector of a geometry region with respect to a given axis and then returns the magnitude of that vector. See Sect. C4.3.4.12 for additional details.

HOLCHK - This subroutine is responsible for ensuring that a hole does not intersect any other geometry region. ADJUST is called to adjust the dimensions of the hole with respect to the origin of the unit that contains the hole. HOLEXT is called to check for a hole intersecting the region external to it. HOLHOL is used to check for a hole intersecting the region internal to the region that contains the hole. It is also used for checking for the intersection of two holes.

SRMAX - This function determines the maximum radius vector of a geometry region with respect to a given origin and then returns the magnitude of that vector. See Sect. C4.3.4.12 for additional details.

ADJUST - This subroutine corrects the dimensions of a region represented as a hole with respect to the origin of the unit that contains the hole.

MOVE - This library routine is called to load data into common.

HOLEXT - This subroutine checks for a hole intersecting the region external to it. XXLIM is used to return the farthermost point of the hole in the direction of the plane specified in the call. CRMAX is used for a cylindrical surface to return the length of the maximum radius vector of the hole with respect to the axis of the outer region. SRMAX is used for a spherical surface to return the length of the maximum radius vector of the hole with respect to the outer region.

HOLHOL - This subroutine is responsible for ensuring that a hole does not intersect the geometry region internal to the region that contains the hole. It also checks for holes intersecting each other. XXMIN is used to return the nearest point of the hole in the direction of the plane specified in the call. CRMIN is used for a cylindrical surface to return the length of the minimum radius vector of the hole with respect to the axis of the surface. XRMIN determines the minimum coordinate of a hole with respect to a flat circular face. SRMIN is used for a spherical surface to return the length of the minimum radius vector of the hole with respect to the origin of the surface.

XXMIN - This function returns the minimum coordinate of the hole with respect to the fact of the cuboid specified in the call. SQRT is utilized in determining the minimum coordinate of spherical or cylindrical holes.

CRMIN - This function returns the magnitude of the minimum cylindrical radius vector of a hole with respect to a given axis. See Sect. C4.3.4.12 for additional details.

XRMIN - This function determines the minimum coordinate of a hole with respect to a flat circular face. SQRT is used in processing spherical and cylindrical holes. The functions DOTPRD and VECADD are called to perform vector arithmetic.

DOTPRD - This function returns the dot product of two vectors.

VECADD - This function returns the vector sum of two vectors.

SRMIN - This function returns the magnitude of the minimum radius vector from the center of a sphere to another geometry region. See Sect. C4.3.4.12 for additional details.

C4.3.4.12 Determine Distances

This section of the KENO V.a geometry checking procedure is utilized in checking for geometry surface intersections. The flowcharts of the routines utilized in this procedure are given in Fig. C4.3.15.

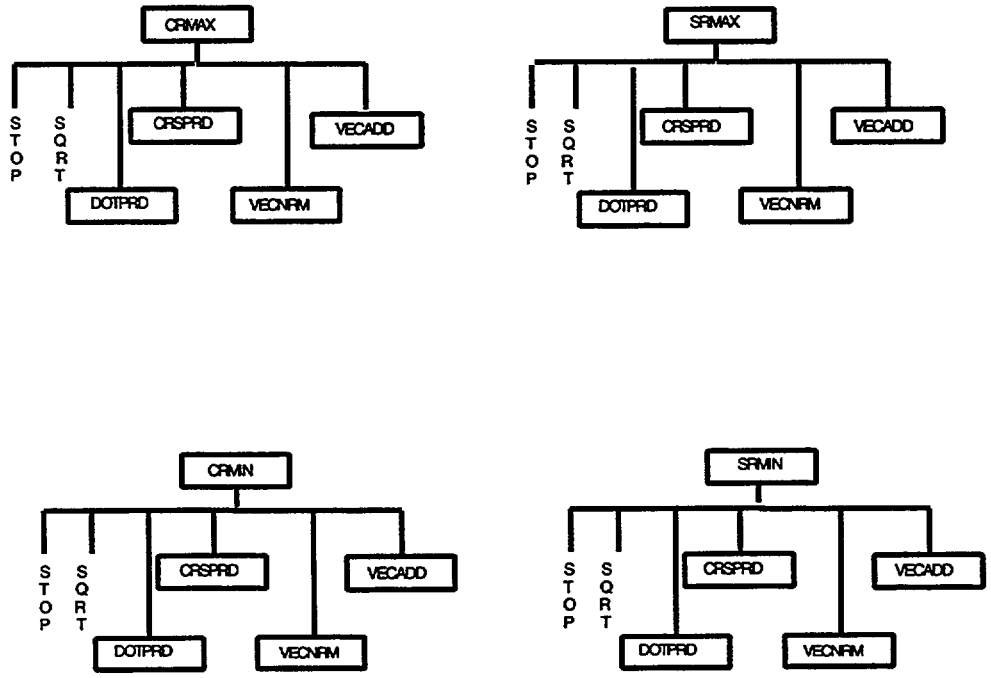


Figure C4.3.15 Flowchart for distance to intersection

CRMAX - This function determines the maximum cylindrical radius vector of a geometry region with respect to a given axis and then returns the magnitude of that vector. Depending on the geometry type, CRMAX may call CRSPRD to generate the cross production of two vectors, DOTPRD to generate the dot product of two vectors, VECADD to add two vectors together, and VECNRM to multiply a vector by a scalar. STOP is called if geometry inconsistencies are encountered.

SRMAX - This function determines the maximum radius vector of a geometry region with respect to a given origin and then returns the magnitude of that vector. Depending on the geometry type, SRMAX may call CRSPRD to take the cross production of two vectors, DOTPRD to take the dot product of two vectors, VECADD to add two vectors together, and VECNRM to multiply a vector by a scalar. STOP is called if geometry inconsistencies are encountered.

CRMIN - This function determines the minimum cylindrical radius vector of a geometry region with respect to a given axis and returns the magnitude of that vector. The geometry type determines which functions will be used to calculate the minimum radius vector. DOTPRD is used to generate the dot product of two vectors, CRSPRD generates the cross product of two vectors, VECNRM multiplies a vector by a scalar, and VECADD adds two vectors together. STOP is called if geometry inconsistencies are encountered.

SRMIN - This function determines the minimum radius vector of a geometry region with respect to a given origin (center of a sphere) and returns the magnitude of that vector. Depending on the geometry type, SRMIN may call DOTPRD to take the dot product of two vectors, CRSPRD to take the cross production of two vectors, VECNRM to multiply a vector by a scalar, and VECADD to add two vectors. STOP is called if geometry inconsistencies are encountered.

STOP - This library routine is called from MIXIT if the storage space is insufficient to hold the mixing table arrays.

SQRT - This system function returns the square root of a number.

DOTPRD - This function returns the dot product of two vectors.

CRSPRD - This is a utility routine to generate the cross product of two vectors.

VECNRM - This routine scales a vector by a constant.

VECADD - This subroutine returns the result of adding two vectors.

C4.3.4.13 Calculate KENO V.a Geometry Volumes

This portion of the program, illustrated in Fig. C4.3.16, is responsible for calculating the volume of each KENO V.a geometry 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.

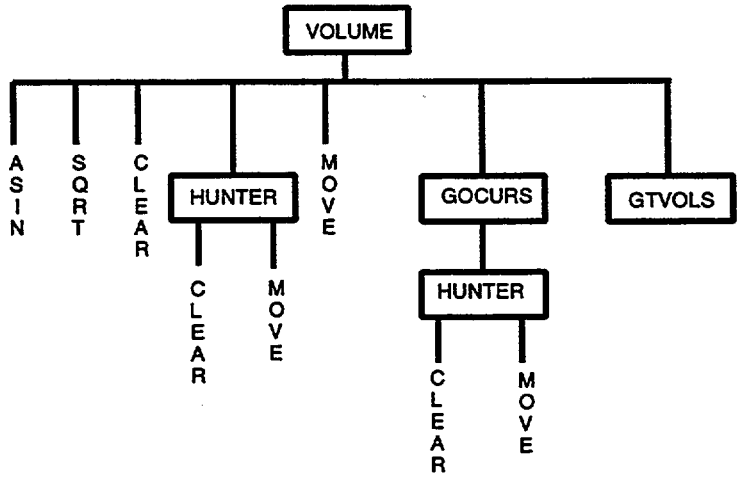


Figure C4.3.16 Flowchart for calculating KENO V.a geometry volumes

VOLUME - This subroutine calculates the volume of each region for every unit that is used in the problem. It then calculates the cumulative volumes for each unit. The intrinsic functions ASIN, which returns the arc sign of a variable, and SQRT, which returns the square root of an expression, are used when calculating the volume of a hemicylinder. 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.

ASIN - This function converts an AMPX working format library to an ANISN format library.

SQRT - This system function returns the square root of a number.

CLEAR - This library routine is used to zero arrays.

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.

MOVE - This library routine is called to load data into common.

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.

C4.3.4.14 Generate Printer Plot

This portion of the program, illustrated in Fig. C4.3.17, generates printer plots of a 2-D slice through the KENO V.a geometry. As many plots as are desired can be printed.

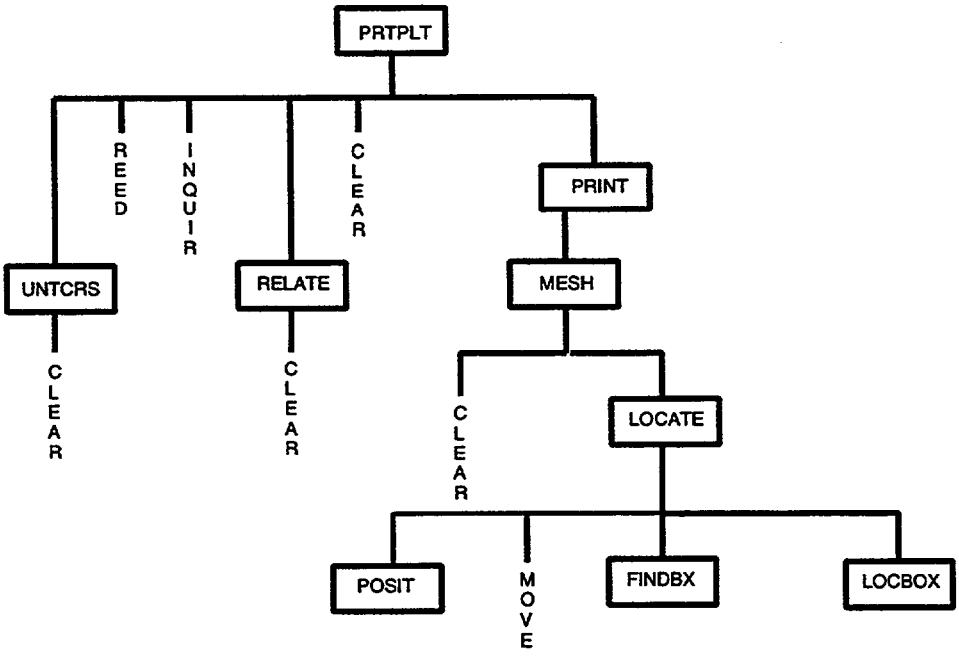


Figure C4.3.17 Flowchart for printer plots

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 data block. 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.

CLEAR - This library routine is used to zero arrays.

REED - This subroutine is used to read data from a direct-access file.

INQUIR - This subroutine sets direct-access pointer.

RELATE - This subroutine calls CLEAR to zero the reverse correspondence array. It then prints the plot header and loads the array that correlates the symbols.

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 or box type 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 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 or box type 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 coordinate of the mesh point is translated to the hole and POSIT is called again.

POSIT - This subroutine determines the region within a unit that contains a specified point.

MOVE - This library routine is called to load data into common.

FINDBX - This subroutine locates the position in an array that contains a specified point.

LOCBOX - This function returns the unit or box type at a given position in an array.

C4.3.4.15 Write KENO V.a Input Data on Restart File

This portion of the program, illustrated in Fig. C4.3.18, is responsible for writing all data except the calculated results on the restart data file. 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. F11.5.3. The calculated results are written on the restart data file later in the program. The restart data file is used for restarting a problem.

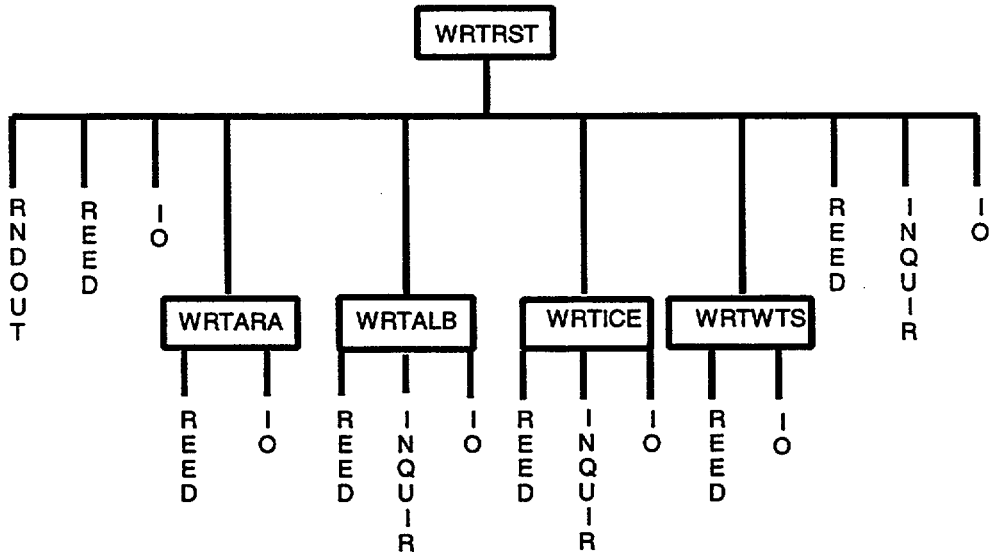


Figure C4.3.18 Flowchart for writing data on the restart data file

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 out the user-supplied weighting or biasing data.

RNDOUT - This library routine is used to preserve the current random number so it can be written on the restart data file.

REED - This subroutine is used to read data from a direct-access file.

IO - This subroutine is used to read/write data from/to a 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 block. 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 it 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.

INQUIR - This subroutine sets direct-access pointer.

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.

C4.3.5 THE SEARCH DATA PROCESSOR

This portion of the program, shown in Fig. C4.3.19, is responsible for processing search data to be used by module MODIFY.

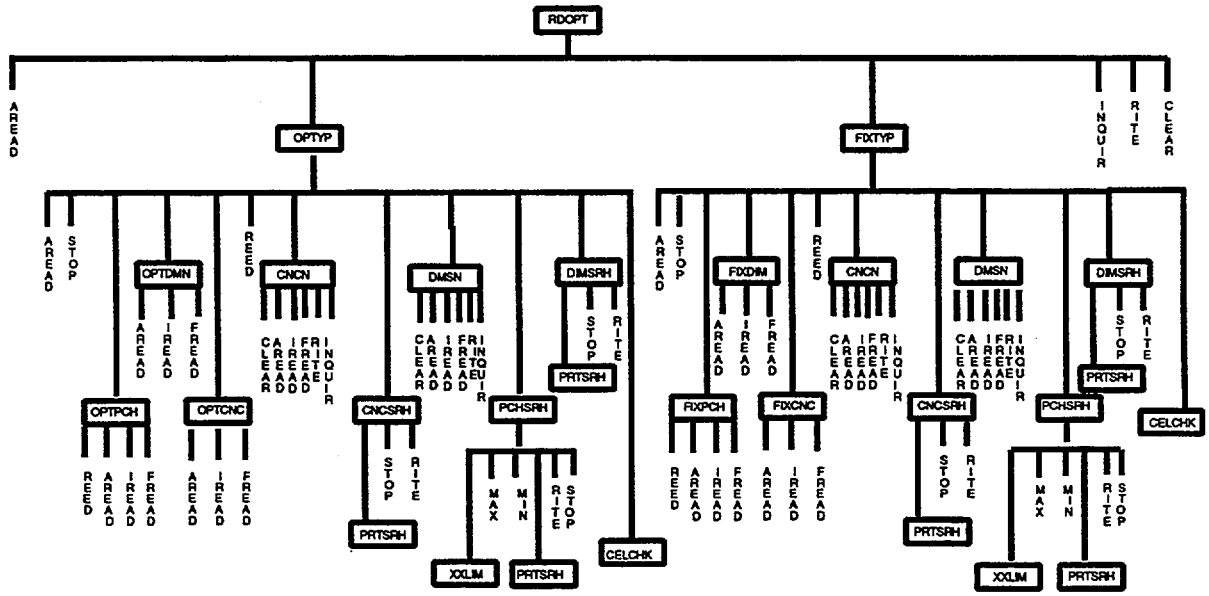


Figure C4.3.19 Flowchart of the Search Data Processor

RDOPT - This subroutine is responsible for reading and processing the search data. AREAD is used to read the keywords READ, SEARCH, and the search type. Two calls are made to subroutine OPTYP to read and process data for an optimum value search and to read and process data for a minimum value search. Subroutine FIXTYP reads and processes data for a fixed value search. The library routine INQUIR is called twice to set the next direct-access block number. The library routine RITE is called to write common information for the control module MODIFY on the direct-access data file. The library routine CLEAR is called to clear space for data that is saved from pass to pass, such as the k-effective and search parameters. RITE is called twice more to rewrite the direct-access pointer and length arrays for the KENO V.a and CSAS data.

The KENO V.a pointers and their associated data are:

LPOINT(1) is the pointer for the current geometry region data
LPOINT(2) is the pointer for the unit orientation data
LPOINT(3) is the pointer for the mixing table information
LPOINT(4) is the pointer for the extra data
LPOINT(5) is the pointer for the weighting importance region data

LPOINT(6) is the pointer for the data defining start type 6
LPOINT(7) is the pointer for the albedo data
LPOINT(8) is the pointer for the mixed cross sections
LPOINT(9) is the pointer for the energy and inverse velocities
LPOINT(10) is the pointer for the plot or picture data
LPOINT(11) is the pointer for the biasing data
LPOINT(12) is the pointer for the albedo cross-section energy correspondence data

The CSAS pointers and their associated data are:

LPOINT(1) is the pointer for COMMON/REC1/
LPOINT(2) is the pointer for the original geometry region data
LPOINT(3) is the pointer for the original mixing table
LPOINT(4) is the pointer for the search data arrays
LPOINT(5) is the pointer for the calculated data that are saved from pass to pass

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

OPTYP - This subroutine is responsible for providing data for both optimum value searches and minimum value searches. AREAD is used to read the search type (pitch, dimension, or concentration). Pointers are created for the data arrays required for the search, and STOP is called to write a message if more computer storage is required. OPTPCH, OPTDMN, OPTCNC, CNCN, CNCSRH, DMSN, PCHSRH, and DIMSRH are used to read and process the search data. REED is called to load data from the direct-access device.

STOP - This library routine is called from MIXIT if the storage space is insufficient to hold the mixing table arrays.

OPTPCH - This subroutine uses REED to reload the geometry data from the direct-access data file. The library routines AREAD, IREAD, and FREAD are used to read the optional search parameters for an optimum pitch search. The processed data are written on the scratch unit.

REED - This subroutine is used to read data from a direct-access file.

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

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

OPTDMN - This subroutine uses the library routines AREAD, IREAD, and FREAD to read the optional search parameters for an optimum dimension search.

OPTCNC - This subroutine uses the library routines AREAD, IREAD, and FREAD to read the optional search parameters for an optimum concentration search.

CNCN - This subroutine calls CLEAR to zero arrays that hold concentration search data. AREAD, IREAD, and FREAD are used to read the concentration search data that are then written on the scratch unit. RITE is called to load the mixing table data on the direct-access data file. INQUIR is called to set the next direct-access block number.

CLEAR - This library routine is used to zero arrays.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

INQUIR - This subroutine sets direct-access pointer.

CNCSRH - This subroutine reads concentration search data from the scratch unit, checks data, sets the maximum and minimum constraints, calls PRTSRH to print the search data table, calls STOP to write an error message if no valid search commands are found, and uses RITE to write the search data on the direct-access data file.

PRTSRH - This subroutine prints the search data table that includes the search parameters and the search commands.

DMSN - This subroutine reads the search commands for a search that alters the geometry dimensions. CLEAR is used to zero data arrays. AREAD, IREAD, and FREAD are used to read the data. After reading the data, some of it is written on the scratch unit. The geometry data are written to a direct-access data file using RITE. INQUIR is used to set the next direct-access data block.

PCHSRH - This subroutine reads optimum pitch search data from the scratch unit and fills the search data arrays for an optimum pitch search. XXLIM, MIN, and MAX are used to determine the maximum and minimum search constraints. PRTSRH is called to print the search data table.

STOP is called to write an error message if no valid search commands are found. The library routine RITE is used to write the search data arrays to a direct-access data file.

XXLIM - This function is used to determine the maximum coordinate of the geometry region interior to the specified face of the unit.

MAX - This system function returns the maximum value of the listed variables.

MIN - This system function returns the minimum value of the listed variables.

DIMSRH - This subroutine reads dimension search data from the scratch unit, sets the maximum and minimum constraints, calls PRTSRH to print the search data table, calls STOP to write an error message if no valid search commands are found, and uses RITE to write the search data arrays to a direct-access data file.

CELCHK - This subroutine checks the input mixtures used in a concentration search to ensure mixtures used to create cell-weighted mixtures are not modified during the search.

FIXTYP - This subroutine is responsible for providing data for a "critical" or "fixed k" search. AREAD is used to read the search type (pitch, dimension, or concentration). Pointers are created for the data arrays required for the search, and STOP is called to write a message if additional computer storage is required. FIXPCH, FIXDIM, FIXCNC, CNCN, CNCSRH, DMSN, PCHSRH, and DIMSRH are used to read and process the search data. REED is called to read data from the direct-access device.

FIXPCH - This subroutine uses REED to reload the geometry data from the direct-access data file. The library routines AREAD, IREAD, and FREAD are used to read the optional search parameters for a critical pitch search. The processed search data arrays are written on the scratch unit.

FIXDIM - This subroutine uses the library routines AREAD, IREAD, and FREAD to read the optional search parameters for a critical dimension search.

FIXCNC - This subroutine uses the library routines AREAD, IREAD, and FREAD to read the optional search parameters for a critical concentration search.

C4.3.6 MODIFY, THE SEARCH MODULE

This segment of the program, shown in Fig. C4.3.20, is part of a control module that is responsible for altering data for a search. CSAS4 and CSAS4X activate both MODIFY and KENO V.a to achieve a search. MODIFY provides new geometry data that are used by KENO V.a to calculate the corresponding k-effective. This procedure is repeated numerous times, and the data resulting from the calculations are analyzed until convergence is achieved, the specified number of search passes have been completed, or the problem uses up the allotted time. See Figs. C4.3.1 and C4.3.2 for the flowcharts that illustrate this procedure. LODCOM is called via ALOCAT from SEARCH, the main program of the control module, MODIFY. SEARCH is activated by the control module MODIFY. Figure C4.3.20 shows the subroutines that are part of the control module MODIFY and are responsible for actually altering the data.

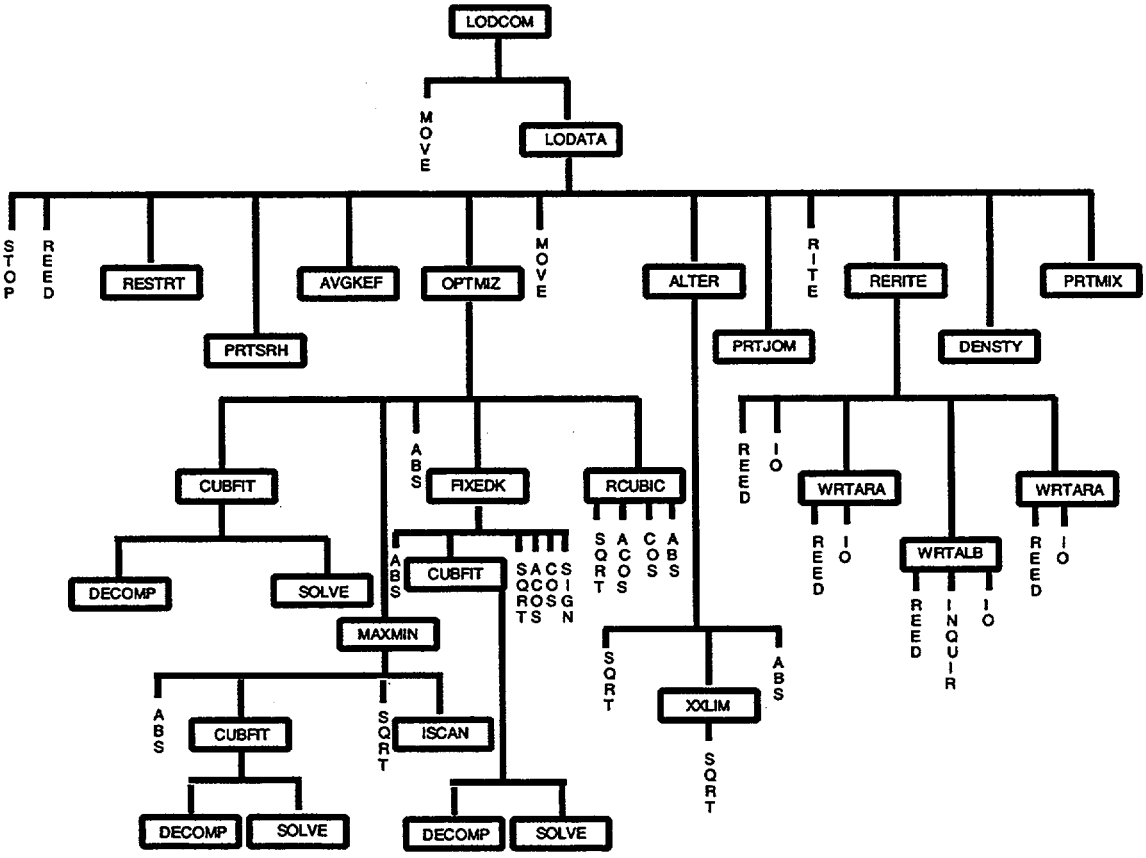


Figure C4.3.20 Flowchart of the search module, MODIFY

LODCOM - This subroutine initiates the data modification procedure of module MODIFY. It strips the individual commons out of COMMON/REC1/ using the library routine MOVE, sets up storage for the required data arrays, and calls subroutine LODATA to load the data into arrays.

MOVE - This library routine is called to load data into common.

LODATA - This subroutine calls the library routine STOP to write an error message if incorrect search data are entered. LODATA uses REED to load the pass-to-pass data into storage from the direct-access data file. RESTRT is called to load data from the restart data file. PRTSRH is called to print the table of search data. AVGKEF is called to load the data that are saved from pass to pass. REED is used to load the search command arrays before calling OPTMIZ to evaluate the parameter values corresponding to values of k-effective. If a pitch or dimension search is to be made, REED is called to load the geometry data and temporary pointers are created for the geometry data. MOVE is called to load the new dimensions into the old dimensions array. ALTER is called to alter the geometry data based on the parameter values returned by OPTMIZ. If convergence has been achieved, a message is written and PRTJOM is called to print the corresponding KENO V.a geometry information. After convergence is achieved, ALTER is called to calculate the best estimate of the dimensions and PRTJOM is called to print them. RITE is used to write the new geometry data on the direct-access data file. REWRITE is called to rewrite the restart data file for KENO V.a, and RITE is used to rewrite the pass-to-pass search data on unit 90. If a concentration search is to be made, REED is called to load the permanent pointers and temporary pointers are created for the mixing table data. MOVE is used to load the new densities into the old density array. DENSTY is called to modify the concentrations, and if convergence is achieved, PRTMIX is called to print the converged mixing table data. After convergence is achieved, DENSTY is called to calculate the best estimate for the mixing table and PRTMIX is called to print it. RITE is used to rewrite the pass-to-pass data on unit 90.

STOP - This library routine is called from MIXIT if the storage space is insufficient to hold the mixing table arrays.

REED - This subroutine is used to read data from a direct-access file.

RESTRT - This subroutine reads the restart data file from unit 95 and loads the k-effective by generation array for processing by subroutine AVGKEF.

PRTSRH - This subroutine prints the search data table that includes the search parameters and the search commands.

AVGKEF - This subroutine loops over the number of generations. It determines the average k-effective and corresponding deviation, skipping an additional generation each time but never skipping more than half the generations. SQRT is used in determining the deviations. The minimum deviation and its corresponding k-effective are stored for use by subroutine OPTMIZ.

OPTMIZ - This subroutine includes methods for an optimization search and a fixed value search. The optimization search[1] is capable of determining a maximum or a minimum. For an optimum pitch search, it searches for the value of a parameter that corresponds to the maximum k-effective. The fixed value search finds the value of a parameter that corresponds to a fixed value of k-effective. Both searches rely on least squares curve fitting to obtain the information

needed to make an estimate. The data points are least squares fitted to a cubic polynomial, which is solved analytically for parameter values. CUBFIT is called to determine the coefficients of the cubic polynomial. MAXMIN is called to provide the parameter value corresponding to the optimum k-effective, using a cubic fit. If a fixed k calculation is to be made, FIXEDK is called to solve the cubic equation. RCUBIC provides the analytic solution of the cubic equation. The FORTRAN-supplied function ABS provides the absolute value of a variable, and DSQRT returns the square root of a double-precision variable.

CUBFIT - This subroutine fits the input data to a cubic equation by determining the coefficients of the cubic polynomial. DECOMP decomposes the matrix, and SOLVE provides the solution for a linear system.

DECOMP - This subroutine decomposes a real matrix by Gaussian elimination and estimates the condition of the matrix.

SOLVE - This subroutine uses the triangularized matrix and pivot vector provided from DECOMP to determine the solution of the linear system.

MAXMIN - This subroutine uses a least-squares fit to a cubic polynomial to determine the parameter value corresponding to the maximum value of k-effective. It is also capable of determining the parameter value corresponding to the minimum k-effective. One portion of the subroutine is devoted to determining the optimum for a cubic having a maximum and a minimum; another portion of the subroutine determines the optimum for a cubic with only a point of inflection. CUBFIT is utilized in both portions to fit the input data to a cubic equation. SQRT is used in the first portion to evaluate the discriminate. The library routine ABS is used to provide the absolute value of a variable. ISCAN is called to ensure that calculations are not duplicated.

ABS - This system function returns the absolute value of a variable.

SQRT - This system function returns the square root of a number.

ISCAN - This function scans a vector for a specific value and returns the index if the value is found.

ACOS - This system function returns the arccosine of a variable.

COS - This system function returns the cosine of a variable.

SIGN - This system returns a value of +1.0 or −1.0 with the sign corresponding to the sign of the variable.

FIXEDK - This subroutine performs a fixed value search. It utilizes an extended mean value theorem method to determine the value of the parameter corresponding to the desired value of k-effective. CUBFIT supplies a least squares fit to a cubic polynomial. The library routines ABS, SQRT, ACOS, COS, and SIGN are used in providing the analytical solution of the cubic.

RCUBIC - This subroutine is responsible for determining the analytical solution to a cubic. It utilizes the library routines SQRT, ACOS, COS, and ABS.

ALTER - This subroutine translates changes in the search parameters into changes in the geometric dimensions. CLEAR is used to zero the region correspondence array. The search command array is used to determine which geometry regions will be altered. For pitch or dimension search, the geometry region data are altered. For a pitch search, the function XXLIM is used to provide the maximum coordinate of the interior region corresponding to the specified face of the unit. This capability ensures that the pitch does not decrease beyond the point of tangency. The new dimensions are calculated from the original dimensions and the parameters provided by OPTMIZ.

XXLIM - This function provides the maximum coordinate of the interior region corresponding to the specified face of the unit. SQRT is used to return the square root of a variable.

PRTJOM - When convergence has been achieved, this subroutine is called to print the geometry data. The corresponding parameter, pass number, and k-effective are printed by LODATA.

RERITE - This subroutine is called to rewrite the restart data file used by KENO V.a. It contains the new geometry data for which a k-effective will be calculated. REED is used to read the data from the direct-access data file, and IO is used to write it on the restart data file. WRTARA, WRTALB, and WRTWTS are used to write the KENO V.a array, albedo, and weighting data on the restart data file.

IO - This subroutine is used to read/write data from/to a 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 used to read the data from the direct-access data file, and IO is used to write it 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, INQUIR is called to return the value of the next direct-access record, and IO is used to write the albedo data on the restart data file.

INQUIR - This subroutine sets direct-access pointer.

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.

DENSTY - This subroutine modifies the number densities of the mixture components according to search commands for a concentration search.

PRTMIX - This subroutine prints the new mixing table resulting from the concentration search.

C4.3.7 REFERENCE

1. M. J. Lorek, *Improved Criticality Search Techniques for Low- and High-Enriched Systems*, ORNL/NUREG/CSD/TM-13, Union Carbide Corp., Nucl. Div., Oak Ridge Natl. Lab., 1981.

C4.4 INPUT DATA GUIDE

This section describes the input data required for Criticality Safety Analysis Sequence No. 4 (CSAS4X). Several subsets of the CSAS4X sequence are available to achieve several different levels of processing. These are listed in Table C4.4.1 with the functional modules they invoke. Note that modules with an "X" in their names create cell-weighted libraries by using XSDRNPM-S.

Table C4.4.1 Functional modules executed by CSAS control modules

Control module	Search function	Functional modules executed by the control module				
CSASI	No search	BONAMI	NITAWL-II		ICE	
CSASIX	No search	BONAMI	NITAWL-II	XSDRNPM	ICE	
CSASN	No search	BONAMI	NITAWL-II			
CSAS1X	No search	BONAMI	NITAWL-II	XSDRNPM		
CSAS25	No search	BONAMI	NITAWL-II		KENO V.a	
CSAS2X	No search	BONAMI	NITAWL-II	XSDRNPM	KENO V.a	
CSAS4	Search	BONAMI	NITAWL-II		KENO V.a	MODIFY[a]
CSAS4X	Search	BONAMI	NITAWL-II	XSDRNPM	KENO V.a	MODIFY

[a]MODIFY is a control module.

Each sequence generates various libraries that may be saved for future use. Table C4.4.2 lists the various I/O units that may be saved and their definitions. Table C4.4.3 lists those I/O units containing cross-section libraries that are generated by each sequence. See Table C4.5.1 in Sect. C4.5 for a complete list of I/O units utilized by Criticality Safety Analysis Sequence No. 4 and Table C4.5.2 for the I/O units utilized by the associated functional modules.

The input data for these CSAS modules are composed of three broad categories of data. The first (Material Information Processor, including Standard Composition Specification Data and Unit Cell Geometry Specification) specifies the cross-section library and defines the composition of each mixture and the unit cell geometry that is used to process the cross sections. This data block is necessary for CSASN, CSAS1X, CSASI, and CSASIX. The second category of data, the KENO V.a input data, are used to specify the geometric and boundary conditions that represent the physical 3-D configuration of the problem. Both data blocks are necessary for CSAS25 and CSAS2X. The last category of data is the search data. All three data blocks are required for CSAS4 and CSAS4X.

All data are entered in free form, allowing alphanumeric data, floating-point data, and integer data to be entered in an unstructured manner. Eighty columns of data entry are allowed, simulating a card of data. Data can usually start or end in any column. Each data entry must be followed by one or more blanks to terminate the data entry. For numeric data, either a comma or a blank can be used to terminate each data entry. Integers may be entered for floating values. For example, 10 will be interpreted as 10.0. Imbedded

blanks are not allowed within a data entry unless an E precedes a single blank as in an unsigned exponent in a floating-point number. For example, 1.0E 4 would be correctly interpreted as 1.0×10^4.

Table C4.4.2 I/O units on which cross-section libraries are written

Unit	Type of data	Creating module
2	Resonance-corrected mixed working library	ICE
3	Resonance-corrected, cell-weighted working library	XSDRNPM
4	Resonance-corrected working library	NITAWL-II
14	Resonance-corrected, mixed cross-section, MORSE/KENO library. If the invoked sequence contains an X in its name, this library contains a cell-weighted mixture identified as mixture 500	ICE, KENO V.a

Table C4.4.3 I/O units generated by CSAS and associated modules

Module name	Primary product	Unit numbers of generated cross-section libraries			
		2	3	4	14
CSASN	Resonance-corrected working library			X	
CSAS1X	XSDRNPM eigenvalue calculation		X	X	
CSASI	Resonance-corrected, mixed cross-section MORSE/KENO library	X		X	X
CSASIX	Resonance-corrected, cell-weighted, mixed cross-section, MORSE/KENO library	X	X	X	X
CSAS25	KENO V.a k-effective			X	X
CSAS2X	KENO V.a k-effective using homogenized cell		X	X	X
CSAS4	Dimension alterations			X	X
CSAS4X	Dimension alterations using homogenized cell		X	X	X

The word "END" is a special data item. An "END" may have a name or label associated with it. The name or label associated with an "END" is separated from the "END" by a single blank and is a maximum of 12 characters long. *At least 2 blanks MUST follow every labeled and unlabeled "END." It is the user's responsibility to ensure compliance with this restriction. Failure to observe this restriction can result in the use of incorrect or incomplete data without the benefit of warning or error messages.*

Multiple entries of the same data value can be achieved by specifying the number of times the data value is to be entered, followed by either R, *, or $, followed by the data value to be repeated. Imbedded blanks

are not allowed between the number of repeats and the repeat flag. For example, 5R12, 5*12, 5$12, or 5R 12, etc., will enter five successive 12s in the input data. Multiple zeros can be specified as nZ where n is the number of zeroes to be entered. The SCALE free-form reading routines are described in more detail in Sect. M3.

The purpose of this section is to define the input data in discrete subsections relating to a particular type of data. Tables of the input data are included in each subsection, and the entries are described in more detail after the tables illustrated in Fig. C4.4.1. Section C4.4.1 is provided for experienced users and contains all the tables that are used to describe the input data. Section C4.4.2 describes input data requirements and the data-checking capability. Sections C4.4.3 through C4.4.8 describe the Material Information Processor data, Sect. C4.4.9 summarizes the KENO V.a data that are explained in detail in Sect. F11.4, and Sect. C4.4.10 describes the search data.

Resonance-corrected cross sections utilize Dancoff corrections based on the unit cell specification. Because only one unit cell can be specified in the data, resonance corrections can only be applied to one mixture via conventional methods. However, if multiple resonance-corrected mixtures are required, the necessary data can be entered via the OPTIONAL PARAMETER DATA described in Sect. C4.4.8 and Tables C4.4.4 and C4.4.13.

To check the input data without actually processing the cross sections, the words "PARM=CHECK" or "PARM=CHK" should be entered, starting in column 11 of the analytical sequence specification for IBM versions as shown below.

```
=CSAS4   PARM=CHK
           or
#CSAS4   PARM=CHK
```

This would cause the input data for CSAS to be checked and appropriate error messages to be printed. If plots are specified in the data, they will be printed. This feature allows the user to debug and verify the input data while using a minimum of computer time. Many problems can be checked in 10 s or less. The number of words of storage requested by CSAS and its associated sequences is defaulted to 100,000 words of storage. This can be respecified through the use of the PARM command on the analytical sequence specification. For example, if 150,000 words of storage are required for the problem, "PARM=SIZE=150,000" should be entered, starting in column 11 of the analytical sequence specification as shown below.

```
=CSAS4   PARM=SIZE=150000
```

To combine checking and size specification, specify "PARM=(CHECK,SIZE=nnn)" or "PARM=(CHK,SIZE=nnn)" starting in column 11 or beyond on the analytical sequence specification. The value of nnn is given in words of storage. The minimum value of nnn is the amount of storage required by the problem, and the maximum value of nnn is the available computer storage.

C4.4.1 INPUT DATA SUMMARY FOR EXPERIENCED USERS

Section C4.4.1 is provided for the convenience of experienced users. Other users should skip to Sect. C4.4.2, page C4.4.26. All of the input data for Criticality Safety Analysis Sequence No. 4 are illustrated in Fig. C4.4.1, and are summarized in Table C4.4.4. This table is provided as an input data guide for users who are familiar with CSAS data requirements. Each component table of Table C4.4.4 is repeated and discussed in detail in Sects. C4.4.4 through C4.4.12. The KENO V.a data are included in this table in very general terms. Table C4.4.5 contains a summary of the KENO V.a input data. They are described in detail in Sect. F11.4 with additional information contained in Sect. F11.5. Table C4.4.6 contains a summary of the SEARCH data for CSAS4 and CSAS4X.

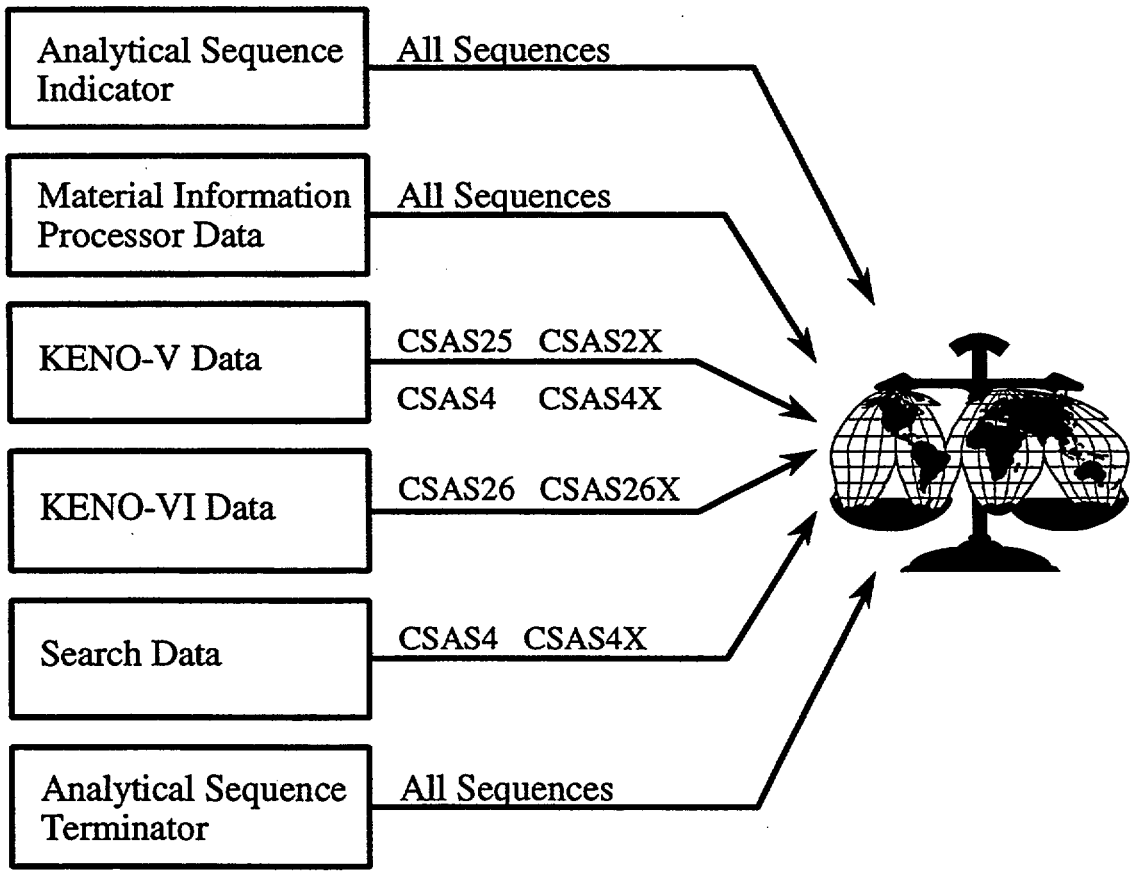


Figure C4.4.1 Outline of CSAS input data

Table C4.4.4 Input data requirements

Summary of data input requirements (see Sect. C4.4.2 for details)

	Type of data	Analytical sequence							
1	Analytical sequence specification	=CSASN	=CSAS1X	=CSASI	=CSASIX	=CSAS25	=CSAS2X	=CSAS4	=CSAS4X
2	Material Information Processor data	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	KENO V.a data	No	No	No	No	Yes	Yes	Yes	Yes
4	Search data	No	No	No	No	No	No	Yes	Yes
5	END for the analytical sequence	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Outline of Material Information Processor data (see Sect. C4.4.3 for details)

Data position	Type of data	Data entry	Comments
1	TITLE	Enter a title	80 characters
2	Cross-section library name	HANSEN-ROACH 27GROUPNDF4 44GROUPNDF5 238GROUPNDF5 27BURNUPLIB etc.	The currently available libraries are listed in Sect. M4.
3	Type of calculation	INFHOMMEDIUM LATTICECELL MULTIREGION	These are the available options. See the explanation in Sect. C4.4.3.
4	Standard Composition specification data	Enter the appropriate data	Terminate this data block with END COMP. See Sect. C4.4.4.
5	Unit cell geometry specification	Enter the appropriate data (optional for INFHOMMEDIUM)	Optional for INFHOMMEDIUM. See Sect. C4.4.5 for INFHOMMEDIUM. See Sect. C4.4.6 for LATTICECELL. See Section C4.4.7 for MULTIREGION.
6	Optional parameter data	Enter the desired data	Precede this data block by MORE DATA if more parameter data are to be entered. Otherwise, omit these data entirely. See Sect. C4.4.8.

Table C4.4.4 (continued)

Outline of standard compositions specification data (see Sect. C4.4.4 for details)

Entry number	Variable name	Type of data	Entry requirement	Comments
1	SC	Standard composition component name	Always	Enter once for each standard composition. Enter the alphanumeric description from Sect. M8.2. Additional allowed names include those beginning with ARBM for arbitrary materials and SOLN for solutions
A1	ROTH	Theoretical density of material (g/cc)	ARBM	Enter once for each standard composition component that is an arbitrary material
A2	NEL	Number of elements in the material	ARBM	Enter once for each standard composition component that is an arbitrary material
A3	IVIS	No longer used but must still be entered	ARBM	Enter once for each standard composition component that is an arbitrary material. Enter 0 or 1
A4	ICP	Compound indicator	ARBM	Enter once for each standard composition component that is an arbitrary material. Enter 1 for a compound, 0 for alloys, mixtures, etc.
A5	IRS	No longer used but must still be entered	ARBM	Enter once for each standard composition component that is an arbitrary material. Enter 0 or 1
A6	NCZA	ID number (from far right column of Table M8.2.1 or M8.2.2)	ARBM	Repeat the sequences A6 and A7 for each element or isotope in the arbitrary material before entering entry number 2. Enter the number from the far right column of Table M8.2.1 or M8.2.2. (Premixed standard compositions cannot be used in an arbitrary material definition)
A7	ATPM	Number of atoms of this element per molecule of arbitrary material	ARBM & ICP=1	Repeat the sequence A6 and A7 for each element in the arbitrary material before entering entry number 2. Do not enter a value unless ICP=1
		or	or	or
		Weight percent of this element in this arbitrary material	ARBM & ICP=0	Repeat the sequence A6 and A7 for each element in the arbitrary material before entering entry number 2. Do not enter a value unless ICP=0

Table C4.4.4 (continued)

Outline of standard compositions specification data (continued)

Entry number	Variable name	Type of data	Entry requirement	Comments
2	MX	Mixture ID number	Always	Enter once for each standard composition component
S1	FD	Fuel density (grams of U or Pu per liter of solution)	SOLN	Enter once for a solution
S2	AML	Acid molarity of the solution	SOLN	Enter once for a solution. AML=0 if there is no acid in the solution
O1	SPGR	Specific gravity of the solution	Optional	If the specific gravity (SPGR) of the solution is known, it should be entered as SPG=SPGR
	or ROTH	or Density of the basic standard composition		or if the density of a basic standard composition (ROTH) is to be entered, use DEN=ROTH
3	VF	Density multiplier	See comment column	Enter the density multiplier (density fraction, volume fraction, or a combination). Default value is 1. This item can be omitted if entries 4, 5, 6a, and 6b are also omitted. VF=0 is not allowed for SOLN or ARBM
4	ADEN	Number density (atoms/b-cm) for the nuclide	VF=0	Enter only if VF=0.0
5	TEMP	Temperature, in K	See comment column	Default value is 293 K. This entry can be omitted if entries 6a and 6b are also omitted
6a	IZA	Isotope's ZA number	VF≠0	Enter for each isotope in the standard composition component. Omit if VF=0. Entries 6a and 6b are entered in pairs until each isotope in the component is defined
6b	WTP	Weight percent of the isotope	VF≠0	Enter for each isotope in the standard composition component. Omit if VF=0.0. Entries 6a and 6b are entered in pairs until each isotope in the component is defined
7[a]	END	Terminate a standard composition	Always	Enter once for each standard composition component. This terminates the data for a standard composition component. Enter END to terminate the component. Repeat entries 1 through 7 until all the mixtures have been defined. At least two blanks must separate entry 7 from the next entry
	END COMP	Terminate the data block	Terminus	Enter once for a problem. Enter the words END COMP when all the standard composition components have been described. At least two blanks must follow the END COMP

[a]NOTE: Entry 7 should not begin in column 1 unless a name is associated with it. At least two blanks should separate the last entry 7 from the END COMP.

Table C4.4.4 (continued)

Optional unit cell specifications for INFHOMMEDIUM problems (see Sect. C4.4.5 for details)

Entry number	Variable name	Type of data	Data entry	Comments
1	NAME	Keyword	CELLMIX	Initiate reading cell data for INFHOMMEDIUM
2	MFUEL	Mixture number in the cell	Mixture number	Specifies the mixture number to be used in the cell. Defaults to the smallest mixture number entered in the standard composition data

NOTE: Unit cell data are necessary for INFHOMMEDIUM only if a mixture number other than the smallest mixture number is to be used in the cell and if a control sequence that executes XSDRNPM has been specified. If mixtures 1, 2, and 3 are specified and if mixture 3 is to be used in the cell, enter CELLMIX 3.

Table C4.4.4 (continued)

Unit cell specification for LATTICECELL problems (see Sect. C4.4.6 for details)

Entry number	Variable name	Type of data	Entry requirement	Data entry	Comments
1	CTP	Type of lattice	Always		Describes the type of lattice or array configuration
				SQUAREPITCH	Use for cylindrical rods in a square pitch
				ASQUAREPITCH	Use for annular cylindrical rods in a square pitch
				TRIANGPITCH	Use for cylindrical rods in a triangular pitch
				ATRIANGPITCH	Use for annular cylindrical rods in a triangular pitch
				SPHSQUAREP	Use for spherical pellets in a cubic lattice
				ASPHSQUAREP	Use for annular spherical pellets in a cubic lattice
				SPHTRIANGP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				ASPHTRIANGP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				SYMMSLABCELL	Use for a symmetric array of slabs
				ASYMSLABCELL	Use for a periodic but asymmetric array of slabs
2	PITCH	Array pitch (cm)	Always	Appropriate dimension	The center-to-center spacing (cm) between fuel lumps. For asymmetric slab cell, enter the distance from the center of one moderator to the center of the other moderator (cm)
3	FUELOD	Outside dimension of fuel (cm)	Always	Appropriate dimension	Outside diameter of fuel (cm), or the thickness of the fuel in a slab
4	MFUEL	Fuel mixture number	Always	Mixture number	Mixture number representing the fuel
5	MMOD	Moderator mixture number	Always	Mixture number	Mixture number representing the moderator
6	MMOD2	2nd moderator mixture number	Annular cell	Mixture number	Mixture number representing the second moderator
7	TKMOD2	2nd moderator thickness	ASYMSLABCELL	Thickness	Thickness of the second moderator (cm) for ASYMSLABCELL
		or	or	or	or
		2nd moderator diameter (cm)	annular cell	diameter	diameter of inner moderator (cm) for other annular cells
8	CLADOD	Outside diameter of clad (cm)	If clad	Clad OD	OMIT IF NO CLAD. For a slab, CLADOD is the sum of thickness of the fuel, gap, and clad
9	MCLAD	Clad mixture number	If clad	Mixture number	OMIT IF NO CLAD. Mixture number representing the clad
10	CLADID	Inside diameter of clad (cm)	If gap	Clad ID	OMIT IF NO GAP between the fuel and clad
11	MGAP	Gap mixture number	If gap	Mixture number	OMIT IF NO GAP between the fuel and clad. A mixture number of zero is often used
12	END	Terminate LATTICECELL data	Always	END	Terminate the LATTICECELL input data by entering the word END. Do not start in column 1. At least two blanks must follow entry number 12

Table C4.4.4 (continued)

Unit cell specification for MULTIREGION problems (see Sect. C4.4.7 for details)

Entry number	Variable name	Type of data	Entry requirement	Data entry	Comments
1	CS	Type of geometry	Always		Describes the type of geometry. The options are:
				SLAB	Use for slab geometry
				CYLINDRICAL	Use for cylindrical geometry
				SPHERICAL	Use for spherical geometry
				BUCKLEDSLAB	Use for slab geometry with a buckling correction for the two transverse directions
				BUCKLEDCYL	Use for cylindrical geometry with a buckling correction in the axial direction
2	BR	Right boundary condition	Required for BUCKLEDSLAB and BUCKLEDCYL optional for other geometries		Default is VACUUM. Describes the right/outside boundary condition
				VACUUM	This provides a non-return condition at the boundary
				REFLECTED	Do not use for cylindrical or spherical
				PERIODIC	Do not use for cylindrical or spherical
				WHITE	This provides isotopic return at the boundary
3	BL	Left boundary condition	Required for BUCKLEDSLAB and BUCKLEDCYL optional for other geometries		Default is REFLECTED. Describes the left boundary condition
				VACUUM	This provides a non-return condition at the boundary
				REFLECTED	Recommended for cylindrical or spherical
				PERIODIC	Do not use for cylindrical or spherical
				WHITE	This provides isotropic return at the boundary
4	ORGN	Location of left boundary on the x-axis (cm)	BUCKLEDSLAB and BUCKLEDCYL optional for other geometries	Appropriate dimension	Default is 0.0. Should not be changed for cylindrical or spherical geometry. A value must be entered if subsequent data are to be entered
5	DY	Buckling height (cm)	BUCKLEDSLAB and BUCKLEDCYL	Appropriate dimension	Omit for SLAB, CYLINDRICAL, and SPHERICAL. This corresponds to one of the transverse dimensions of an actual 3-D slab assembly or to the length of a finite cylinder
6	DZ	Buckling depth (cm)	BUCKLEDSLAB	Appropriate dimension	Omit unless BUCKLEDSLAB was specified. This is thebuckling depth corresponding to the second transverse dimension of a 3-D slab assembly
7	END	End geometry parameters	Always	END	Enter the word END. Do not start in column 1. At least two blanks must separate entry 7 from the first entry 8
8	MXZ	Mixture number in the zone	Always	Mixture number	Repeat entry numbers 8–10 until all zones are defined. Enter the mixture number for this zone
9	RZ	Outside radius of the zone (cm)	Always	Appropriate dimension	Repeat entry numbers 8–10 until all zones are defined. Enter the outside dimension of the zone (cm)

Table C4.4.4 (continued)

Unit cell specification for MULTIREGION problems (see Sect. C4.4.7 for details)

Entry number	Variable name	Type of data	Entry requirement	Data entry	Comments
10	XMOD	External moderator index	Optional		Repeat entry numbers 8–10 until all zones are defined. Entry 10 is optional and can be omitted. If it is omitted, repeat entry numbers 8 and 9 until all zones are defined
				NOEXTERMOD	No moderating materials in the adjacent zones
				ONEEXTERMOD	A moderating material is present in one adjacent zone
				TWOEXTERMOD	Moderating materials are present in two adjacent zones
	END ZONE	Terminate zone data		END ZONE	Enter when all zones have been defined by repeating entry numbers 8 through 10 for each zone. At least two blanks must follow this entry

Table C4.4.4 (continued)

Summary of available optional parameter data (see Sect. C4.4.8)

Entry number	Keyword name	Type of data	Applicable module	Comments
1	MORE DATA	Input flag		This signals that optional parameter data will be entered. Enter only those parameters you wish to change
2	ISN=	Order of angular quadrature	XSDRNPM	The default value is 8. This allows using another value
3	SZF=	Spatial mesh size factor	XSDRNPM	The default value is 1.0. 0<SZF<1.0 gives a finer mesh. SZF>1.0 gives a coarser mesh
4	IIM=	Max. number of inner iterations	XSDRNPM	The default value is 20. This allows using another value
5	ICM=	Max. number of outer iterations	XSDRNPM	The default value is 25. This allows using another value
6	EPS=	Overall convergence criteria	XSDRNPM	The default value is 0.0001. This allows using another value
7	PTC=	Point convergence criteria	XSDRNPM	The default value is 0.0001. This allows using another value
8	BKL=	Buckling factor	XSDRNPM	The default value is 1.420892. Use ONLY for a multiregion problem that specifies BUCKLEDSLAB or BUCKLEDCYL
9	IUS=	Upscatter scaling factor	XSDRNPM	The default value is zero. IUS=0 doesn't utilize upscatter scaling. IUS=1 uses upscatter scaling to accelerate the solution and/or speed convergence
10	RES=	Resonance data	BONAMI NITAWL	Enter the mixture number, geometry type (SLAB, CYLINDER, SPHERE), and the thickness of the slab or radius of the sphere or cylinder in cm. Optionally enter the inner radius (cm) to specify an annular cylinder or sphere
11	DAN(mm)=	Dancoff factor for the specified mixture	BONAMI NITAWL	Enter the mixture number, mm, to which the Dancoff factor applies inside the parentheses; enter the Dancoff factor after the equal sign **Repeat entry numbers 10 and 11 for all resonance mixtures used in the problem that are not treated in the LATTICECELL or MULTIREGION description**
12	BAL=	Key to print balance tables	XSDRNPM	The default value is FINE. BAL=NONE suppresses printing the balance table. BAL=ALL prints all balance tables. BAL=FINE prints only the fine-group balance tables
13	DY=	First transverse dimension	XSDRNPM	The first transverse dimension, in cm, used in a buckling correction to calculate leakage normal to the principal calculation direction (i.e., the height of a slab or a cylinder)
14	DZ=	Second transverse dimension	XSDRNPM	The second transverse dimension, in cm, used for a buckling correction (i.e., the width of a slab)

Table C4.4.4 (continued)

Summary of available optional parameter data (see Sect. C4.4.8)

Entry number	Keyword name	Type of data	Applicable module	Comments
15	COF=	Diffusion coefficient option for transverse leakage correction	XSDRNPM	The default is 0. See Sect. F3.5, 3$ array, variable IPN
16	FRD=	Unit from which fluxes will be read	XSDRNPM	Enter the unit number from which the flux guess for XSDRNPM will be read
17	FWR=	Unit on which fluxes will be written	XSDRNPM	Enter the unit number where the binary fluxes from XSDRNPM will be written
18	ADJ=	Adjoint mode flag	XSDRNPM	Enter a 1 to cause XSDRNPM to solve the problem in adjoint mode
19	NBU=	Unit on which balance tables will be written	XSDRNPM	Enter the unit number where the balance tables from XSDRNPM will be written
20	WGT=	Cross-section weighting flag	XSDRNPM	Enter a 0 to suppress doing the cross-section weighting in XSDRNPM
21	ZMD(iz)=	Zone width modifier for the specified zone	XSDRNPM	Enter the zone number for which the modifier applies inside the parentheses; enter the zone width modifier after the equal sign. **Repeat number 20 to specify all zones to be modified in a search**
22	INT(iz)=	Number of intervals for the specified zone	XSDRNPM	Enter the zone number inside the parentheses; enter the number of intervals after the equal sign. Repeat number 22 to specify all needed zones.
23	KEF=	Value of k_{eff} to be searched for	XSDRNPM	Enter the value of k_{eff} that it is desired to search for. The default is 1.0.
24	KFM=	Value of the eigenvalue modifier	XSDRNPM	Enter the value of the eigenvalue modifier (i.e., the relative change for the first guess of a search). The default is −0.1.
25	DAB=	Number of direct access data blocks	MIP[a]	The default is 200. Number of blocks allocated for direct access unit 90
26	AXS=	Unit on which a mixed ANISN library will be written	ICE	Enter the unit number where ICE is to write a mixed ANISN library
27	MSH=	Maximum number of mesh points/resonance	NITAWL	The default value is 2001. This allows using another value.
28	MLV=	Highest resonance ℓ-value for self-shielding	NITAWL	The default value is 2. This allows using another value.
29	ID1=	Print control for scalar fluxes	XSDRNPM	The default value is −1. See Sect. F3.5, 2$ array, variable ID1.
30	COLL	Key to activate collapse of thermal groups	MIP[a]	Enter COLL to collapse all thermal groups into one group for the shielding sequences
31	END	Terminus		Terminate the optional parameter data. Do not start in column 1. At least two blanks must follow this entry.

[a]MIP is the Material Information Processor.

Table C4.4.4 (continued)

Outline of KENO data (see Table C4.4.5 and Sects. C4.4.9 and F11.4 for details)

Type of data	Starting flag	Comments	Termination flag
Title	None	80 columns, must be entered first	None
Parameters	READ PARM	Enter desired parameter data	END PARM
Biasing or weighting	READ BIAS	Enter desired biasing data	END BIAS
Geometry	READ GEOM	Enter desired geometry data	END GEOM
Array data or unit orientation	READ ARRAY	Enter desired array data	END ARRAY
Boundary conditions or albedos	READ BNDS	Enter desired albedo data	END BNDS
Start data or initial source	READ START	Enter desired start data	END START
Mixing table data	READ MIXT	The Material Information Processor allows only NSCT= and PBXS=	END MIXT
Plot data	READ PLOT	Enter desired plot data	END PLOT
KENO V.a data terminus	END DATA	Enter to signal the end of all KENO V.a data	

Outline of SEARCH[a] data (see Table C4.4.6 and Sect. C4.4.10 for details)

READ SEARCH	Enter desired search data	END SEARCH

[a]Search data are required for CSAS4 and CSAS4X.

Table C4.4.5 Summary of KENO V.a input data

Summary of parameter data

TITLE: The title must be entered first (80 columns) See Sect. F11.4.3

PARAMETERS: Format: READ PARAM enter parameter data here END PARAM
If parameters are entered, they must follow the title. See Sects. F11.4.3, F11.5.2, and F11.5.3.

KEY	STD.	DEFINITION	KEY	STD.	DEFINITION	KEY	STD.	DEFINITION	KEY	STD.	DEFINITION
RND=	Given	Random number	FLX=	NO	Fluxes	MKH=	NO	Matrix by hole	XSC=	14	Mixed xsecs
TME=	120 min	Execution time (min)	FDN=	NO	Fission densities	CKH=	NO	Cofactor k by hole	ALB=	79	Albedo
TBA=	0.5 min	Batch time (min)	ADJ=	NO	Adjoint calculation	FMH=	NO	Fiss. prod. by hole	WTS=	80	Weights
WTA=	0.5	Average weight	AMX=	NO	All mixture xsecs	HHL=	NO	MKH at highest level	LIB=	4	Working xsecs from NITAWL or XSDRN
WTH=	3.0	Wt. for splitting	XAP=	NO	Xsec angles & probs.	MKA=	NO	Matrix by array			
WTL=	1/WTH	Russian Roulette wt.	XS1=	NO	1-D xsecs	CKA=	NO	Cofactor k by array	SKT=	16	Scratch
GEN=	203	No. of generations	XS2=	NO	2-D xsecs	FMA=	NO	Fiss. prod. by array	RST=	95	Read restart
NPG=	1000	No. per generation	PKI=	NO	Fission spectrum	HAL=	NO	MKA at highest level	WRS=	95	Write restart
NSK=	3	Generations skipped	P1D=	NO	Extra 1-D xsecs	BUG=	NO	Debug print	XSC=	14	Mixed xsecs
RES=	0	Gens. between restart	FAR=	NO	Fiss. & abs.	TRK=	NO	Print neutron tracks			
NBK=	NPG+25	Neutron bank positions	MKP=	NO	Matrix by location	PWT=	NO	Print avg. weight			
XNB=	0	Extra bank entries	CKP=	NO	Cofactor k by loc.	PGM=	NO	Unprocessed geometry			
NFB=	NPG	Fission bank positions	FMP=	NO	Fiss. prod. by loc.	SMU=	NO	Self-multiplication			
XFB=	0	Extra bank entries	MKU=	NO	Matrix by unit	NUB=	YES	Neutrons per fission			
X1D=	0	No. of extra 1-Ds	CKU=	NO	Cofactor k by unit	PAX=	NO	Albedo-xsec array			
LNG=	1000000	Words of storage[a]	FMU=	NO	Fiss. prod. by unit	RUN=	YES	Execute problem			
BEG=	1	Restart at this gen.	GAS=	FAR	FAR by energy group	PLT=	YES	Printer plots			
NB8=	200	Blocks for d.a. unit									
NL8=	512	Length of d.a. block									

[a]The words of storage in CSAS are defaulted to 100,000 and can be overridden by using the size= parameter on the analytical sequence specification which then becomes the default value of LNG in KENO V.a.

For example: =CSAS25 PARM=SIZE=200000
or =CSAS25 PARM=(CHECK,SIZE=200000)

Table C4.4.5 (continued)

Summary of array data

ARRAY Format: READ ARRAY array parameters data type orientation data END ARRAY See Sects. F11.4.5, F11.5.6, and F11.5.7.

Repeat the sequence ARRAY PARAMETERS DATA TYPE ORIENTATION DATA for each array used in the problem.

ARRAY PARAMETERS			DATA TYPE FILL LOOP
KEYWORD	DEFAULT	DEFINITION	
ARA=	1	No. defining the array	
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=	Maxara	Global, universe, or overall array number[a]	
COM=	None	Delim comment delim Optional comment is a maximum of 132 characters	

[a]Can be defaulted by the code. 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.

COUNT FIELD	OPTION FIELD	OPERAND FIELD	COMMENTS
		j	Stores j at the current position in the array
i	R	j	Stores j in the next i positions in the array
i	0	j	Stores j in the next i positions in the array
i	$	j	Stores j in the next i positions in the array
i	F	j	Fills remainder of the array with unit no. j starting with the current array position
	A	j	Sets the current position in the array to j increments;
i	S		current position in the array by i allows skipping i positions. The value of 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	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
i	P	j	Alternately stores j and -j in the next i positions of the array
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 oneblank 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.

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:

DATA ENTRY	COMMENTS
LTYPE	The unit or box type. LTYPE must be greater than 1
IX1	Starting position in the X direction. IX1 must be at least 1 and no larger than the value entered for NUX
IX2	Ending position in the X direction. IX2 must be at least 1 and no larger than the value of NUX
INCX	The number of units by which increments are made in the X direction
IY1	The starting position in the Y direction. IY1 must be at least 1 and less than the value entered for NUY
IY2	Ending position int he Y direction. IY2 must be at least 1 and no larger than the value of NUY
INCY	The number of units by which increments are madein the positive Y direction
IZ1	Starting position in the Z direction. IZ1 must be at least 1 and no larger than NUZ
IZ2	Ending position in the Z direction. IZ2 must be at least 1 and no larger than NUZ
INCZ	The number of units by which increments are made in the positive Z direction

Table C4.4.5 (continued)

Summary of biasing data

BIAS (weighting)

Format: READ BIAS keyword correlation data auxiliary END BIAS
See Sects. F11.4.7 and F11.5.8

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	16,27,44,218,238	5 cm
			Paraffin	400	16,27,44,218,238	3 cm
	ibgn	Beginning bias ID	Water	500	16,27,44,218,238	3 cm
	iend	Ending bias ID	Graphite	6100	16,27,44,218,238	20 cm
WT=	AUXILIARY DATA will be read next.					
WTS=	AUXILIARY DATA will be read next.					
	wttitl	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 wtavg's from the first interval of material ID.

Table C4.4.5 (continued)

Summary of boundary condition data

BNDS (albedo or boundary conditions)

Format: READ BNDS face code albedo name END BNDS
See Sect. F11.4.7

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

ALBEDO NAMES AVAILABLE ON THE KENO V ALBEDO LIBRARY, FOR USE WITH THE FACE CODES

ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION
DPOH20 DPOH20 DPO DPO	12-in. double PO 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
H20 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	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	SPEC SPE MIR	
CARBON GRAPHITE C	200-cm carbon differential albedo with 4 incident angles	CONC-16 CON16 CONC16	16-in. concrete differential albedo with 4 incident angles	PERIODIC PERI PER	Periodic 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 C4.4.5 (continued)
Summary of geometry data

GEOMETRY (region)

Format: READ GEOM enter geometry region data here END GEOM
See Sects. F11.4.4, F11.5.1.2, F11.5.6, and F11.5.7.
GEOMETRY REGION DATA consists of SIMPLE GEOMETRY REGION DATA and EXTENDED GEOMETRY REGION DATA.
ENTER GEOMETRY REGION DATA IN THE FOLLOWING FORM:
OPTIONAL GLOBAL SPECIFICATION
UNIT n
OPTIONAL GEOMETRY COMMENT
SIMPLE GEOMETRY REGION DATA
and/or
EXTENDED GEOMETRY REGION DATA
* *
ENTER SIMPLE GEOMETRY REGION DATA IN THE FOLLOWING FORM:

GLOBAL Enter only 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.
fgeom mix no. bias ID dimensions optional origin data (ORIGN coordinates) optional chord dat CHOD)
Enter as many geometry description specifications as necessary to describe the unit and as many units as necessary to describe the system.

SIMPLE GEOMETRY REGION INPUT DATA REQUIREMENTS

TYPE OF DATA	TYPE 1 DATA	TYPE 2 DATA	TYPE 3 DATA	TYPE 4 DATA	TYPE 5 DATA	TYPE 6 DATA
fgeom	SPHERE HEMISPHERE HEMISPHE+X HEMISPHE-X HEMISPHE+Y HEMISPHE-Y HEMISPHE+Z HEMISPHE-Z	XCYLINDER XHEMICYL+Y XHEMICYL-Y XHEMICYL+Z XHEMICYL-Z	YCYLINDER YHEMICYL+X YHEMICYL-X YHEMICYL+Z YHEMICYL-Z	CYLINDER ZCYLINDER ZHEMICYL+X ZHEMICYL-X ZHEMICYL+Y ZHEMICYL-Y	CUBE	CUBOID
Dimensions	R (radius)	R +H -H	R +H -H	R +H -H	+X -X	+X -X +Y -Y +Z -Z
Optional origin coord.[a]	Enter the X Y Z coord. of origin	Enter the Y Z coord. of centerline	Enter the X Z coord. of centerline	Enter the X Y coord. of centerline	Omit	Omit
Optional chord data[b]	Enter the dist. to plane	Enter the dist. to plane	Enter the dist. to plane	Enter the dist. to plane	Omit	Omit

[a]Enter ORIG or ORIGIN for fgeom.
[b]Enter CHORD for fgeom.
Note: Chord data are not applicable for SPHERE, XCYLINDER, YCYLINDER, CYLINDER, ZCYLINDER, CUBE, or CUBOID.
Origin data are not applicable for a CUBE or CUBOID.

Table C4.4.5 (continued)

Summary of geometry data (cont.)

GEOMETRY (region) (cont.)

ENTER EXTENDED GEOMETRY DATA IN THE FOLLOWING FORM:

fgeom ref. ID bias ID thickness per region origin coordinates nreg

EXTENDED GEOMETRY REGION INPUT DATA REQUIREMENTS

TYPE OF DATA	TYPE 1 DATA	TYPE 2 DATA	TYPE 3 DATA
fgeom	ARRAY	HOLE	REPLICATE
	CORE		REFLECTOR
	COREBDY		
	COREBNDS		
	COREBOUN		
Ref. ID	Array no.	Emplaced unit No.	Mixture No. in generated regions
Bias ID	Omit for ARRAY	Omit	First bias ID
Thick./reg.	Omit	Omit	Variable*
Origin coord.	Enter the X Y Z coord. of most neg. pt. of array	Enter the X Y Z coord. of origin	Omit
nreg	Omit	Omit	No. of regions to be generated

*The number of dimensions to be entered is the same as the region preceding the replicate or reflector specification because the generated regions have that shape. The value of the dimensions is the thickness of each generated region of material on that surface.

Table C4.4.5 (continued)

Summary of mixing table data

MIXTURES — Format: READ MIXT xsec parameters END MIXT

Note: In CSAS, only xsec parameters should be entered.
KENO V.a mixing table data consists of "xsec parameters" and a "mixing table."
The "mixing table" is used to define the materials used in the KENO V.a problem.
This data is automatically created by CSAS and provided to KENO V.a. It cannot be overridden.

See Sects. F11.4.10 and F11.5.5.

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

Table C4.4.5 (continued)

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. F11.4.11 and F11.5.9

KEYWORD	DEFAULT	DEFINITION
TTL=	Prob.	delim ptitl delim delim is a one-character delimiter that signals the beginning and end of the title.
	title	ptitl is the plot title (max. 132 char.)
PIC=	MAT	Type of picture: MIXTURE, UNIT NO. or BIAS ID NO.
		MIXTURE ----- MAT
		MIX
		MIXT
		MIXTURE
		MEDI
		MEDIA
		UNIT NO. ------ BOX
		BOXT
		BOXTYPE
		UNT
		UNIT
		UNITTYPE
		BIAS ID NO. --- IMP
		BIAS
		BIASID
		WTS
		WEIG
		WEIGHTS
		WGT
		WGTS
XUL=	Prev. plot	X coord. of upper left corner of 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
YLR=	Prev. plot	Y coord. of lower right corner of plot
ZLR=	Prev. plot	Z coord. of lower right corner of plot

KEYWORD	DEFAULT	DEFINITION
UAX=	Prev. plot 0 IF VAX OR WAX is read	X component of direction cosine for the AX axis of the plot (across)
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[a]	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
SCR=	NO	NO specifies a printer plot. If YES, a .gif file is generated for each plot
CLR=		Use only with SCR=YES to change colors. Input 4 integers: 1st is index into color table, next 3 are red, green, and blue color values

PLOT ORIGIN:

(1) SINGLE UNIT - coincides with origin of geometry description.

(2) BASE ARRAY - at the most negative point of the array (lower left-hand back corner of the global array).

(3) REFLECTED ARRAY - coincides with the origin of the CORE or ARRAY description of the global array.

[a]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 C4.4.5 (continued)
Summary of starting data

START Format: READ START enter start data here END START
The default value of start type is zero. See Sect. F11.4.8.

START TYPE	REQUIRED DATA	OPTIONAL DATA	STARTING DISTRIBUTION
0	None	NST XSM XSP YSM YSP ZSM ZSP RFL PSP	Uniform
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
3	NST TFX TFY TFZ NXS NYS NZS	KFS PSP	Spike
4	NST TFX TFY TFZ NBX	KFS PSP	Multiple spikes
5	NST NBX	PSP	In specified units
6	NST TFX TFY TFZ LNU[a]	NXS NYS NZS KFS PS6 PSP	Arbitrary points

KEYWORD	DEFAULT	DEFINITION
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=		Fission spectra
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

[a]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.

The Material Information Processor now allows terse data input for all data except the standard composition names and the keyword entries in the optional parameter data (MORE DATA). Terse data entry requires the user to enter only as many characters as is necessary to uniquely define the data entry. However, as many characters as are specified by the user must match the name allowed by the code.

For example, refer to Table C4.4.4, **Outline of Material Information Processor data,** data position 3. The available choices for the type of calculation are: INFHOMMEDIUM, LATTICECELL, and MULTIREGION. Therefore, I would be sufficient to specify an infinite homogeneous medium, L would be sufficient for lattice cell, and M would specify multiregion. If it is desirable to use more characters, the user is free to do so. However, as many characters as are entered must match the name allowed by the code. For example, if INFHOMMEDIUM is to be specified, INFH is correct, but INFI is not.

WARNING: If several choices begin with the same letters, sufficient characters should be entered to uniquely define the name. For example, ASPHSQUAREP and ASPHTRIANGP are identical through the first four characters. If only ASPH is entered, the code will accept the first name whose first four characters are ASPH. This may not be the one the user intended to use.

C4.4.2 INPUT DATA REQUIREMENTS AND DATA CHECKING

Table C4.4.7 summarizes the input data required by Criticality Safety Analysis Sequence No. 4. The types of data needed are:

1. Analytical sequence specification. Enter the desired sequence name, starting in column 1. The available options are =CSAS4, =CSAS4X, =CSAS25, =CSAS2X, =CSAS1X, =CSASI, =CSASIX, and =CSASN. Enter PARM=CHK in column 11 to check the data.

2. Material Information Processor data. These data are required for processing the cross sections for use in the problem. These data are described in detail in Sects. M7.4 and C4.4.3 through C4.4.8.

3. KENO V.a data. These data are described briefly in Sect. C4.4.9. A detailed description is found in Sect. F11.4 with additional information in Sect. F11.5.

4. Search data. These data are required for CSAS4 and CSAS4X. A detailed description is given in Sect. C4.4.10. The data required for a simple optimum pitch search are

   READ SEARCH OPTIMUM PITCH END SEARCH

5. END for analytical sequence—Enter END, starting in column 1.

To check the input data, specify the desired analytical sequence and specify PARM=CHECK or PARM=CHK starting beyond column 10. For example, to check CSAS data, the analytical sequence specification would be:

=CSAS4 PARM=CHECK

Table C4.4.6 Summary of SEARCH input data

Outline of search type specification (see Sect. C4.4.10.1 for details)

Entry number	Type of data	Data entry	Comments
1	Search descriptor	OPTIMUM	Initiates a search for the maximum value of k-effective
		CRITICAL	Initiates a search for a specified value of k-effective.
		MINIMUM	Initiates a search for the minimum value of k-effective
2	Search type	PITCH	Vary the pitch
		DIMENSION	Vary one or more dimensions in one or more regions
		CONCENTRATION	Vary the concentration of one or more standard compositions in one or more mixtures
3	Optional search parameters		Optional search parameters allow changing default values. Any or all may be entered in any order
3a	No. of search passes	PAS=	Enter the keyword PAS= followed by the desired number of search passes. Default =10
3b	No. of search parameters	NPM=	Enter the keyword NPM= followed by the number of search parameters. Present capability is limited to 1. Default =1
3c	Search convergence tolerance	EPS=	Enter the keyword EPS= followed by the desired convergence tolerance. Default=0.005
3d	Desired value of k-effective	KEF=	Enter the keyword KEF= followed by the desired value of k-effective. The default value is 1.000. DO NOT ENTER FOR OPTIMUM OR MINIMUM SEARCHES
3e	Maximum allowed pitch	MAXPITCH=	Enter the keyword MAXPITCH= followed by the maximum allowed pitch for a search whose search type, entry 2 above, is PITCH. The default value is the pitch corresponding to -5.0 times the parameter at the minimum possible pitch
3f	Minimum allowed pitch	MINPITCH=	Enter the keyword MINPITCH= followed by the minimum allowed pitch for a search whose search type, entry 2 above, is PITCH. The default value is the minimum possible pitch (i.e., the pitch at which the shapes in the array touch)
4	Additional search data	MORE	Enter the delimiter MORE. This delimiter ends the optional search commands and initiates the auxiliary search commands found in Table C4.4.17.

Table C4.4.6 (continued)

Outline of auxiliary search commands and constraints

Entry number	Keyword name	Type of Data	Comments
GENERIC SEARCH DATA - May be used with all Search Types -			
1a	ALTER CHANGE MODIFY	Begin a new search command	These words are used to specify that modifications will be made to the geometry or concentration according to subsequent commands (entries 3 through 6 as required to specify the desired changes)
1b	MAINTAIN	Begin a new search command	The spacing (thickness) of the specified geometry regions will be maintained when the interior regions grow or shrink
1c	KEEP HOLD	Begin a new search command	This command resets the specified geometry to the original input specifications
2	PAR=	Parameter number	Enter the parameter number that the current command (ALTER, MAINTAIN, KEEP) applies to. The present capability is limited. Default=1 and should not be changed.
3	+CON=	Maximum constraint	Enter the maximum constraint for the current parameter. Default=+10E10
4	-CON=	Minimum constraint	Enter the minimum constraint for the current parameter. Default=-10E10
PITCH & DIMENSION SEARCH DATA - Defines Geometric Changes -			
5	UNIT=	Unit the current command applies to	Enter the unit in which regions are to be altered
6	REGION=	First region to be altered in the unit	Enter the first or only region in the unit that the search constants (entry 8a, b, c and/or d) apply to. Default is the first region
7	TO	Last region to be altered in the unit	Enter the last region in the unit that the search constants (entry 8a, b, c and/or d) apply to. Default is the first region NOTE: Entry 6 must be entered in order to alter a single region in a unit. Entries 6 and 7 must both be entered in order to alter more than one region in a unit
8	ALL=	Search constant for all surfaces (faces) of the region(s)	Enter a value for the search constants for the specified regions. This value will be applied to all surfaces of the region(s)
8a	+X=	Search constant for +X face of cuboid	Enter a value for the search constant for the +X face of a cuboid
	-X=	Search constant for -X face of cuboid	Enter a value for the search constant for the -X face of a cuboid
	+Y=	Search constant for +Y face of cuboid	Enter a value for the search constant for the +Y face of a cuboid
	-Y=	Search constant for -Y face of cuboid	Enter a value for the search constant for the -Y face of a cuboid
	+Z=	Search constant for +Z face of cuboid	Enter a value for the search constant for the +Z face of a cuboid
	-Z=	Search constant for -Z face of cuboid	Enter a value for the search constant for the -Z face of a cuboid
8b	RADIUS=	Search constant for radius	Enter a value for the search constant for the radius of a sphere or a cylinder
8c	+HEIGHT=	Search constant for + height	Enter a value for the search constant for the + height of a cylinder
	-HEIGHT=	Search constant for -height	Enter a value for the search constant for the - height of a cylinder
8d	CHORD=	Search constant for chord	Enter a value for the search constant for the chord face of a hemisphere or hemicylinder
CONCENTRATION SEARCH DATA - Defines Concentration Changes -			
9	MIX=	Search constant for mixture	Enter the mixture number containing the standard composition to be changed.
10	SCNAME=	Search constant for Standard Composition	Enter the standard composition name whose density is to be changed.
11	FACTOR=	Search proportionality constant	Enter the value of the search constant for the concentration search.

Table C4.4.7 Summary of data input requirements

Type of data	Analytical sequence							
1 Analytical sequence specification	=CSASN	=CSAS1X	=CSASI	=CSASIX	=CSAS25	=CSAS2X	=CSAS4	=CSAS4X
2 Material Information Processor data	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3 KENO V.a data	No	No	No	No	Yes	Yes	Yes	Yes
4 Search data	No	No	No	No	No	No	Yes	Yes
5 END for the analytical sequence	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note that =CSAS4 starts in column 1 and PARM=CHECK starts beyond column 10. This causes the input data to be checked, the problem description to be printed, appropriate warning and error messages to be printed, and if KENO V.a data are entered, the data and printer plots are printed.

This feature allows checking the input data without executing any of the functional modules. Simply remove the PARM=CHECK to actually execute the problems.

C4.4.3 MATERIAL INFORMATION PROCESSOR DATA

The Material Information Processor reads the standard compositions specification data and the unit cell geometry specifications. It then produces the mixing table and unit cell information necessary for processing the cross sections. Table C4.4.8 outlines the input data for the Material Information Processor.

The Material Information Processor allows terse data input for all data except the standard composition names and the keyword entries in the optional parameter data (MORE DATA). Terse data entry requires the user to enter only as many characters as are necessary to uniquely define the data entry. However, as many characters as are specified by the user must match the name allowed by the code. For example, refer to Table C4.4.8, **Outline of Material Information Processor data**, data position 3. The available choices for the type of calculation are INFHOMMEDIUM, LATTICECELL, and MULTIREGION. Therefore, it would be sufficient to specify I for an infinite homogeneous medium, L for lattice cell, and M for multiregion. If it is desirable to use more characters, the user is free to do so. However, as many characters as are entered must match the name allowed by the code. For example, if INFHOMMEDIUM is to be specified, INFH is correct, but INFI is not.

WARNING: If several choices begin with the same letters, sufficient characters should be entered to uniquely define the name. For example, ASPHSQUAREP and ASPHTRIANGP are identical through the first four characters. If only ASPH is entered, the code will accept the first name whose first four characters are ASPH. This may not be the one the user intended to use.

Table C4.4.8 Outline of Material Information Processor data

Data position	Type of data	Data entry	Comments
1	Title	Enter a title	80 characters
2	Cross-Section Library Name	HANSEN-ROACH 27GROUPNDF4 44GROUPNDF5 238GROUPNDF5 27BURNUPLIB etc.	The currently available libraries are listed in Sect. M4.
3	Type of Calculation	INFHOMMEDIUM LATTICECELL MULTIREGION	These are the available options. See the explanation in Sect. C4.4.3
4	Standard Composition Specification Data	Enter the appropriate data	Terminate this data block with END COMP. See Sect. C4.4.4
5	Unit Cell Geometry Specification	Enter the appropriate data (optional for INFHOMMEDIUM)	Optional for INFHOMMEDIUM See Sect. C4.4.5 for INFHOMMEDIUM See Sect. C4.4.6 for LATTICECELL See Sect. C4.4.7 for MULTIREGION
6	Optional Parameter Data	Enter the desired data	Precede this data block by MORE DATA if more parameter data are to be entered. Otherwise, omit these data entirely. See Sect. C4.4.8

The types of data required for the Material Information Processor are given in Table C4.4.8. The individual entries are explained in detail in the text following the table.

1. Title. An 80-character title is required. The title is the first 80 characters of the Material Information Processor data.

2. Cross-Section Library Name. This item specifies the cross-section library that is to be used in the calculation. See Table C4.4.8 or Sect. M4 for a list of the available libraries.

3. Type of Calculation. The options are INFHOMMEDIUM, LATTICECELL, and MULTIREGION.

   INFHOMMEDIUM is used for an infinite homogeneous medium. It provides cross sections to represent large homogeneous pieces. The cross sections are treated as if each mixture is infinite. Thus, the self-shielding calculations will not account for any geometrical effects. By default, the smallest mixture number will be used in the cell. A different mixture can be used as described in Sect. C4.4.5 and Table C4.4.10.

   LATTICECELL is used when the geometry can be described as a lattice. It is especially suited for arrays of cylindrical rods or spherical pellets. The use of LATTICECELL requires the entry of additional geometry information (unit cell specification), which is described in Sect. C4.4.6 and

Table C4.4.11. When the problem consists of an array of fuel bundles or similar geometry, the cross sections are corrected for resonance self-shielding, including geometry effects. If cell-weighted cross sections are desired, CSAS2X, CSAS1X, CSASIX, or CSAS4X must be used. A flux disadvantage factor is then applied to the cross sections of the materials that are used in the unit cell. The KENO V.a geometry description may represent a fuel bundle discretely or as a homogeneous region. By using CSAS2X or CSAS4X, a fuel bundle can be represented as a single homogeneous region by specifying a mixture number of 500 on the KENO V.a geometry card that defines the overall size and shape of the bundle. This utilizes the cell-weighted cross sections that represent the spatial behavior of the unit cell. The use of CSAS2X or CSAS4X precludes using individual mixtures from the unit cell in the KENO V.a geometry.

MULTIREGION may be used to define a geometric configuration that is more complicated than that allowed by LATTICECELL. It can also be used for a system involving large geometric regions where geometry effects may be minimal. The cross sections utilized in the unit cell are corrected for resonance self-shielding, and an appropriate Dancoff factor is applied (see Sect. M7.2.4.3). If a cell-weighted mixture is generated, it is derived from homogenizing the entire MULTIREGION unit cell. The additional geometry information (unit cell specification) required for a MULTIREGION problem is described in Sect. C4.4.7 and Table C4.4.12.

4. Standard Compositions. These data are used to define the mixtures that will be used in the problem. See Sect. C4.4.4, and Table C4.4.9, for a description of the standard compositions specification data. These data are required for every problem.

5. Cell Geometry Specificaiton. See Sect. C4.4.5 and Table C4.4.10 for an explanation of the optional unit cell data associated with an INFHOMMEDIUM problem. See Sect. C4.4.6 and Table C4.4.11 for an explanation of the data associated with LATTICECELL problems. Section C4.4.7 and Table C4.4.12 explain the data required for a MULTIREGION problem.

6. Optional Parameter Data. This option allows certain defaulted parameters to be respecified by the user. Omit these data unless they are needed. If data are to be entered, see Sect. C4.4.8 and Table C4.4.13 for assistance.

Table C4.4.9 Outline of standard composition specification data

Entry No.	Variable name	Type of data	Entry requirement	Comments
1	SC	Standard composition component name	Always	Enter once for each standard composition. Enter the alphanumeric description from Sect. M8.2. Additional allowed names include those beginning with **ARBM** for arbitrary materials and **SOLN** for solutions
A1	ROTH	Theoretical density of material (g/cc)	ARBM	Enter once for each arbitrary material
A2	NEL	Number of elements in the material	ARBM	Enter once for each arbitrary material
A3	IVIS	No longer used but must still be entered	ARBM	Enter once for each arbitrary material. Enter 0 or 1
A4	ICP	Compound indicator	ARBM	Enter once for each arbitrary material. Enter 1 for a chemical compound, 0 for alloys, mixtures, etc.
A5	IRS	No longer used but must still be entered	ARBM	Enter once for each arbitrary material. Enter 0 or 1
A6	NCZA	ID number (from far right column of Table M8.2.1)	ARBM	Repeat the sequence A6 and A7 for each element or isotope in the arbitrary material before entering entry 2. Enter the number from the far right column of Table M8.2.1 or M8.2.2. (Premixed standard compositions cannot be used in an arbitrary material definition)
A7	ATPM	Number of atoms of this element per molecule of arbitrary material	ARBM and ICP=1	Repeat the sequence A6 and A7 for each element in the arbitrary material before entering entry 2. Do not enter a value unless ICP=1
		or	or	or
		weight percent of this element in this arbitrary material	ARBM and ICP=0	Repeat the sequence A6 and A7 for each element in the arbitrary material before entering entry 2. Do not enter a value unless ICP=0

Table C4.4.9 (continued)

Entry number	Variable name	Type of data	Entry requirement	Comments
2	MX	Mixture ID number	Always	Enter once for each standard composition component
S1	FD	Fuel density (grams of U or Pu per liter of solution)	SOLN	Enter once for a solution
S2	AML	Acid molarity of the solution	SOLN	Enter once for a solution. AML=0 if there is no acid in the solution
O1	SPGR	Specific gravity of the solution	Optional	If the specific gravity (SPGR) of the solution is known, it should be entered as SPG=SPGR
	or ROTH	or density of the basic standard composition		or if the density of a basic standard composition (ROTH) is to be entered, use DEN=ROTH
3	VF	Density multiplier	See comment column	Enter the density multiplier (density fraction, volume fraction, or a combination). Default value is 1. This item can be omitted if entries 4, 5, 6a, and 6b are also omitted. VF=0 is not allowed for SOLN or ARBM
4	ADEN	Number density (atoms/b-cm) for the nuclide	VF=0	Enter only if VF=0.0
5	TEMP	Temperature, in K	See comment column	Default value is 293 K. This entry can be omitted if entries 6a and 6b are also omitted
6a	IZA	Isotope's ZA number	VF≠0	Enter for each isotope in a multiple isotope nuclide. Omit if VF=0. Entries 6a and 6b are entered in pairs until each isotope in the nuclide is defined
6b	WTP	Weight percent of the isotope	VF≠0	Enter for each isotope in a multiple isotope nuclide. Omit if VF=0. Entries 6a and 6b are entered in pairs until each isotope in the nuclide is defined
7[a]	END	Terminate a standard composition	Always	Enter once for each standard composition component. This terminates the data for a standard composition component. Enter END to terminate the component. Repeat entries 1 through 7 until all the mixtures have been defined. At least two blanks must separate entry 7 from the next entry

Table C4.4.9 (continued)

Entry number	Variable name	Type of data	Entry requirement	Comments
	END COMP	Terminate the data block	Terminus	Enter once for a problem. Enter the words END COMP when all the standard composition components have been described. At least two blanks must follow the END COMP

[a]NOTE: Entry 7 should not begin in column 1 unless a name is associated with it. At least two blanks should separate the last entry 7 from the END COMP.

C4.4.4 STANDARD COMPOSITIONS SPECIFICATION DATA

The standard compositions specification data are used to define mixtures that are to be utilized in the problem. These data can be considered to be a mixing table that defines mixtures in terms of standard compositions specification data (available from Sect. M8.2). The required input for the standard compositions specification data varies, depending on the standard composition component name. However, every standard composition specification must include the following:

1. a standard composition component name (SC),

2. the mixture that contains this component (MX),

3. a terminator for the standard compositions specification data (enter the word END).

Enter as many standard composition specifications as necessary to define all the mixtures needed for the problem. When all the necessary mixtures have been described, enter the words END COMP to signal the completion of this type of data.

The data required to define a standard composition specification are contained in Table C4.4.9. In the column entitled "Entry requirement," "ARBM" is used to denote entries required only for arbitrary materials, and "SOLN" is used for entries required only for solutions.

The input data for standard composition specifications are arranged with entry numbers 1 through 7 that apply to all standard composition data. Entries A1 through A7 apply only to arbitrary materials. Entries S1 and S2 apply only to solutions. Entry O1 is optional data that applies to both basic standard compositions and solutions. The individual entries specified in Table C4.4.9 are explained in detail in the text accompanying the table.

1. SC Standard Composition Component Name. The names of the standard composition components (the alphanumeric identifiers) may be (1) chosen from Sect. M8.2, which contains the lists of elements, compounds, and alloys found in the Standard Composition Library, (2) chosen from the table of available solutions, Sect. M8.3, or (3) designated as an arbitrary material (ARBM). An error message will be printed if the user enters an invalid standard composition component name.

For standard compositions taken from Sect. M8.2 of the Standard Composition Library (basic standard compositions), certain data such as the volume fraction or theoretical density and other engineering type data may need to be entered. For standard compositions containing more than one isotope of an element (such as UO_2), the user is free to specify the weight percent for each isotope such that they total 100%. See Sect. M7.5.5.1 for examples of basic standard compositions.

Solutions require the specification of the density of the heavy metal in the solution and the acid molarity of the solution. The alphanumeric specification of a solution starts with the four characters "SOLN." Some common fissile solutions are SOLNUO2(NO3)2, SOLNPU(NO3)4, and SOLNUO2F2. See Sect. M8.3 for a complete listing of the available solutions. Sections M7.5.5.3 and M7.5.9 contain examples of the input data for solutions.

Arbitrary materials require the user to provide all the information normally found in the Standard Composition Library. The arbitrary material option allows specifying a compound or alloy not available in the Standard Composition Library by utilizing the standard compositions available in the library.

An arbitrary material name must start with the four characters "ARBM." A maximum of twelve characters is allowed for the standard composition component name. Imbedded blanks are not allowed in a standard composition component name. Section M7.5.5.2 contains examples of input data for arbitrary materials.

An additional example of an arbitrary material specification is as follows:

Consider a mixture of boral having 35 wt % B_4C, 65 wt % aluminum and an overall density of 2.64 g/cc. If B4C were not available in the Standard Composition Library, the components BORON, C, and AL could be used as basic standard compositions to describe the boral. The necessary volume fractions would have to be determined as shown in Sect. M7.5.5.4, examples 3 and 4. By utilizing the arbitrary material option, both B_4C and aluminum can be described as a component of the same mixture (assume it is desired to be mixture 3), both have a density of 2.64 g/cc, and the volume fractions are 0.35 for the B_4C and 0.65 for the aluminum. The resulting standard compositions specification data do not require any calculations (see example 1, Sect. M7.5.5.5 for a similar situation) and could be entered as

```
ARBMTL-B4C  2.64 2 1 1 0 5000 4 6012 1 3 0.35 END
ARBMTL-AL   2.64 1 0 0 0 13027 100.0 3 0.65 END
```

A1. ROTH Theoretical density of material. Enter ONLY for arbitrary materials. The density of the arbitrary material is entered in units of grams per cubic centimeter.
NOTE: ROTH can be entered for a basic standard composition as shown by entry O1.

A2. NEL Number of elements in the material. Enter ONLY for arbitrary materials. Enter the number of components from the Standard Composition Library that are to be used to define this arbitrary material. In the above example, the ARBMTL-B4C contains two components, the B and the C. Therefore, NEL is 2 for the B_4C arbitrary material. The ARBMTL-AL contains only one component; so NEL is 1 for it.

A3. IVIS NO LONGER USED BUT MUST STILL BE ENTERED...Enter ONLY for an arbitrary material. Enter 0 or 1.

A4. ICP Compound indicator. Enter ONLY for arbitrary materials. A compound is a substance containing more than one constituent element and having properties different from those which their constituents had as elementary substances. The composition of a pure compound is perfectly definite and is always the same, regardless of the method of formation. Examples of compounds are H_2O, B_4C, CO_2, $Ca(OH)_2$, C_2H_6, Fe_2S_3, Cr_2O_3, etc. ICP is 1 for a compound. ICP is 0 for alloys (stainless steel, monel, etc.) and conglomerates or mixtures such as concrete.

In the B_4C arbitrary material example, ICP is 1; in the aluminum arbitrary material example, ICP is 0. These examples are given in the explanation of entry number 1, SC.

A5. IRS UNUSED VARIABLE...Enter ONLY for arbitrary materials. Enter 0 or 1.

A6. NCZA ID number. Enter ONLY for arbitrary materials. This is the "ZA" ID number for the element or isotope. Usually, NCZA=A+1000*Z, where A is the atomic mass or weight of the nuclide, and Z is the atomic number. For example, NCZA is 1001 for hydrogen, 8016 for oxygen, and 92235 for ^{235}U. For elements for which the natural abundance is acceptable, NCZA can be entered as 1000*Z. For example, 92000 is used for uranium and 5000 is used for boron.

If the arbitrary material contains an element that has multiple isotopes, that element MUST be listed in Table M8.2.3. Uranium (92000), plutonium (94000), and boron (5000) are examples of isotope elements.

REPEAT THE SEQUENCE NCZA and ATPM (A6 and A7) FOR EVERY ELEMENT IN THE ARBITRARY MATERIAL.

A7. ATPM Enter ONLY for arbitrary materials. Repeat the sequence A6 and A7 for every element in the arbitrary material before going on to entry 2.

If ICP is 1 (entry A4), enter the NUMBER OF ATOMS PER MOLECULE.
If the arbitrary material is a compound (entry A4, ICP is 1), enter the number of atoms of this element per molecule of arbitrary material.

If ICP is 0 (entry A4), enter the WEIGHT PERCENT OF THIS ELEMENT IN THE ARBITRARY MATERIAL. If the arbitrary material is a mixture, alloy, or conglomerate rather than a compound (entry A4, ICP is 0), enter the weight percent of this element in the arbitrary material. If ICP is 0, the sum of all the weight percents for the arbitrary material MUST be 100.0.

2. MX Mixture ID number. A mixture number is required on every standard composition specification. It defines the mixture that contains the material defined by the standard composition specifications data. The mixture numbers are utilized in the unit cell specification for INFHOMMEDIUM, LATTICECELL, or MULTIREGION problems and the KENO V.a geometry data.

S1. FD — Fuel density. Enter ONLY for a solution. The standard composition component name for a solution starts with the four characters "SOLN." The available solution names are listed in Sect. M8.3. Enter the fuel density in units of grams of heavy metal (fissile material) per liter of solution.

S2. AML — Acid molarity. Enter ONLY for a solution. If there is no acid in the solution, enter zero. If acid is present in the solution, enter the molarity of the solution.

O1. SPGR or ROTH — Optional data. Does NOT apply to ARBITRARY MATERIALS. These optional data can be entered for a solution or for a basic standard composition using a keyword in the form SPG=SPGR, DEN=SPGR, DEN=ROTH, or SPG=ROTH. The keywords SPG= and DEN= are interchangeable. SPGR is the specific gravity of the fuel solution. If the standard composition name begins with SOLN and if the specific gravity of the solution is known, it should be entered. Otherwise the code has to interpolate in a table to obtain a specific gravity to use in the calculation. ROTH is the specified density of the standard composition in grams per cubic centimeter and can be entered if desired. The interaction between ROTH, the density of the standard composition, and VF (entry 3) is demonstrated in Sect. M7.5.5.

3. VF — Volume fraction. The default value of the volume fraction is 1.0. It can be omitted if items 4, 5, 6a, and 6b are also omitted. The volume fraction can be interpreted as:

a. the volume fraction of this standard composition component in the mixture,

b. the density of the standard composition component in this application divided by the theoretical density listed in the Standard Composition Library (Sect. M8.2), or a product of (a) and (b).

Section M7.5.5 discusses the interaction between ROTH and VF. For example, assume a homogenized mixture representing the water moderator and zircalloy cladding around a fuel pin is to be described. If the volume of the clad is 5.32 cc and if the volume of the water moderator is 44.68 cc, the mixture can be described using H_2O with a volume fraction of 0.8936 [i.e., 44.68/(44.68+5.32)] and ZIRCALLOY with a volume fraction of 0.1064 [i.e., 5.32/(44.68+5.32)].

For UO_2 fuel at 95% theoretical density, the volume fraction is 0.95. For the coolant water in an operating pressurized water reactor, the volume fraction might typically be 0.71.

To describe a mixed-oxide fuel pin with a density of 10.5 g/cc, that is 17.8 wt % PuO_2 and 82.2 wt % UO_2, two standard compositions specifications must be entered: one for the PuO_2 component and one for the UO_2 component. From the Standard Composition Library, the theoretical density of the PuO_2 is 11.46 g/cc, and that of the UO_2 is 10.96 g/cc. Therefore, the volume fraction for the PuO_2 is 0.1631 (i.e., 0.178*10.50/11.46), and the volume fraction for the UO_2 is 0.7875 (i.e., 0.822*10.50/10.96).

Occasionally, a special mixture will be desired for which the determination of the component volume fractions will not be so straightforward. Consider a mixture of boral having 35 wt %

B_4C, 65 wt % aluminum, and an overall density of 2.64 g/cc. Assume that neither boral nor B_4C are in the Standard Composition Library. The volume fractions corresponding to boron, carbon, and aluminum may be computed as illustrated in Sect. M7.5.5.4, examples 3 and 4. Note that the calculation is complicated by the fact that B_4C is a compound and boron has two isotopes. It might be simpler to enter B_4C and aluminum as arbitrary materials as illustrated in example 1 of Sect. M7.5.5.5. Examples 1 and 2 of Sect. M7.5.5.4 illustrate the use of B_4C and aluminum to describe a boral mixture. **If the volume fraction is set to 0.0, the user can enter the number density for the nuclide (in atoms per barn-cm) for item 4. Number densities cannot be entered for standard compositions that represent multiple nuclides.**

4. ADEN Number density. Enter a value for the number density ONLY if the volume fraction (VF, entry 3) was entered as zero. The number density is entered in units of atoms per barn-cm.

5. TEMP Temperature. The default value of the temperature is 293 K. The temperature can be omitted if items 6a and 6b are also omitted.

The temperature is used for Doppler broadening and/or the processing of thermal scattering data.

The resonance self-shielding calculation performed by NITAWL-II uses the Nordheim integral method and can account for Doppler broadening of the resonances at any specified temperature. If this material is known to contain a resonance nuclide, the user should enter an estimate of the temperature of the material.

For each of the light nuclides ($A \leq 20$ a.m.u.), the master cross-section library may contain one or more sets of thermal scattering data, each set corresponding to a different temperature. Scattering matrices for nuclides in media at elevated temperatures are generally fuller than those at lower temperatures. Section M4 indicates which multiple sets of thermal scattering data are currently available. If multiple sets of thermal scattering data are available, the user should enter a rough estimate of the temperature of the material. The code will then use the set of cross-section data that is most appropriate.

6a. IZA Isotope ZA number. Enter a value for each isotope in the standard composition component, item 1. Do not enter a value if the volume fraction, VF, is zero (entry 3).

The ZA number of the isotope is entered if the user wishes to specify the isotopic distribution. This is done by entering 6a and 6b for each isotope until all the desired isotopes have been described. The "ZA" ID number is (A+1000*Z), where A is the atomic mass or weight of the isotope, and Z is the atomic number.

Entries 6a and 6b can be skipped if the default values listed in the isotopic distribution, Sect. M8.2, are acceptable.

6b. WTP Weight percent of the isotope. Do not enter a value if the volume fraction, VF, item 3 is zero. If entry 6a is entered, a value must also be entered for 6b. The weight percent of the isotope is the percent of this isotope in the element.

The user need not enter entries 6a and 6b for each isotope listed for the element in Sect. M8.2. The only requirement is that the sum of entries 6b for the element must sum to 100.0. Thus, uranium could be specified as 92235 3.2 92238 96.8 to represent 3.2% enriched uranium and ignore the 234 and 236 isotopes. However, 92235 3.0 and 92238 96.8 would not be correct because the 3.0 and 96.8 do not sum to 100.0. But 92235 3.0, 92234 0.2, and 92238 96.8 would be correct.

REPEAT THE SEQUENCE 6a and 6b until all the isotopes of the element have been defined as desired.

7. END The word END is entered to terminate the input data for a standard composition component. This END can have a label associated with it that can be as long as 12 characters. The label is optional and, if entered, is separated from the END by a single blank. At least two blanks must separate item 7 from the next data entry.

END COMP The words END COMP are entered only once for a problem. Their purpose is to signal the end of all the standard composition specification data that will be used in the problem. At least two blanks should separate entry 7 from the END COMP. Note that COMP is a label associated with this END. This label can be as long as 12 characters, but the first four characters must be COMP.

C4.4.5 OPTIONAL UNIT CELL SPECIFICATION FOR INFINITE HOMOGENEOUS PROBLEMS

This section describes the unit cell data that can be entered for an INFHOMMEDIUM problem (data position 3 of Table C4.4.8). By default, the smallest mixture number is the mixture that will be used for the cell in XSDRNPM. In order to calculate the eigenvalue of the system, the mixture should contain fissionable material. Unit cell data are required for an infinite homogeneous medium problem ONLY if XSDRNPM is utilized by the control sequence and a mixture number other than the smallest mixture number is to be used in the cell. Control sequences that end in X (CSAS1X, etc.) utilize XSDRNPM. Additional information is available in Sect. M7.5.12 (see also Sect. M7.5.4.1 and M7.5.6.1).

The data required to specify the unit cell for an INFHOMMEDIUM problem are given in Table C4.4.10. The individual entries are explained in the text following the table.

Table C4.4.10 Optional unit cell specification for INFHOMMEDIUM problems

Entry number	Variable name	Type of data	Data entry	Comments
1	NAME	Keyword	CELLMIX	Initiates reading cell data for INFHOMMEDIUM
2	MFUEL	Mixture number in the cell	Mixture number	Specifies the mixture number to be used in the cell. Defaults to the smallest mixture number entered in the standard composition data

NOTE: Unit cell data are necessary for INFHOMMEDIUM only if a mixture number other than the smallest mixture number is to be used in the cell and if a control sequence that executes XSDRN has been specified. If mixtures 1, 2, and 3 are specified and if mixture 3 is to be used in the cell, enter CELLMIX 3.

1. NAME Keyword. The keyword CELLMIX is entered to indicate that unit cell data will be entered. If this entry is entered, entry 2 must also be entered. These data can be entered ONLY if item 3, the "type of calculation" from Table C4.4.8, is entered as INFHOMMEDIUM.

2. MFUEL Mixture number. The mixture number that defines the mixture to be used in the cell. The default value is the smallest mixture number specified in the standard compositions specification data. If either entry 1 or 2 is entered, the other must also be entered.

   To enter the above data, enter the keyword CELLMIX, one or more blanks, and the desired mixture number, MFUEL, as shown below:

   CELLMIX MFUEL

   To specify mixture 5 to be used in the cell, enter the following data:

   CELLMIX 5

WARNING: If unit cell data are to be entered, the word CELLMIX must be spelled correctly. If it is misspelled, the code will not give an error message and will attempt to use the smallest mixture number. The input data will get out of phase for CSAS and SAS sequences that expect to read data after the unit cell specification. For example, CSAS25 expects to read KENO V.a data after the unit cell specification. If CELLMIX is misspelled, the code assumes that it is reading the KENO V.a title card and the data reading gets out of phase.

C4.4.6 UNIT CELL SPECIFICATION FOR LATTICECELL PROBLEMS

This section describes the unit cell data that must be entered for a LATTICECELL problem (data position 3 of Table C4.4.8). Additional information is available in Sects. M7.5.4, M7.5.4.2, M7.5.6.2, and M7.5.8.2. The lattice cell description is especially suited to large arrays of identical cells. The code is limited to a single unit cell description for each problem. The unit cell data are used to provide the lump shape and dimensions for resonance cross-section processing, to provide lattice corrections for cross-section processing, and to provide data used by XSDRNPM to create cell-weighted cross sections. Thus the unit cell specification plays a major role in providing problem-dependent cross sections. The configuration of the unit cell is determined by the specified "type of lattice." The unit cells are limited to infinitely long cylindrical rods in a square or triangular lattice, spheres in a cubic or triangular lattice, a symmetric array of slabs, or an asymmetric array of slabs. Two distinct types of cells ("Regular" and "Annular") are available to be used in a lattice cell problem. "Regular" cells allow a concentric spherical, cylindrical, or symmetric slab configuration constrained to a central fuel region surrounded by an optional gap, an optional clad, and an external moderator. The outer boundary of the cell is limited to provide an array having a square or triangular pitch. "Annular" cells allow a concentric spherical, cylindrical, or asymmetric slab configuration constrained to a central (second) moderator region surrounded by a fuel region having an optional gap and optional clad on each side of the fuel. The gap, if present, is identical on both sides of the fuel. The clad, if present, is identical in dimension and composition on both sides of the fuel. The outer region of the cell is filled with an external (first) moderator. The outer boundary of the cell is limited to provide an array having a square or triangular pitch.

Regular cells are: SQUAREPITCH, TRIANGPITCH, SPHSQUAREP, SPHTRIANGP, and SYMMSLABCELL.

Annular cells are: ASQUAREPITCH, ASQP, ATRIANGPITCH, ATRP, ASPHSQUAREP, ASSP, ASPHTRIANGP, ASTP, and ASYMSLABCELL.

The unit cell data are utilized by the code to define the geometric and resonance self-shielding corrections that will be applied to the cross sections. Cell-weighted cross sections are created only if XSDRNPM is invoked by executing a control sequence ending in X, (CSAS1X, CSAS2X, etc.). The cell-weighted cross sections have a flux disadvantage factor applied to them. Because this weighting is applied to each mixture used in the cell, these cell-weighted mixtures should not be used in the geometry description of a subsequent code. However, the cell-weighted mixture that is created is always assigned a mixture number of 500 and can be used in a subsequent code. KENO V.a is the subsequent code in CSAS2X and CSAS4X. Note that cell-weighted cross sections are not generated if CSAS25 or CSAS4 are used.

The unit cell geometry data required to specify a LATTICECELL problem are given in Table C4.4.11. The individual entries are explained in the text accompanying the table.

Table C4.4.11 Unit cell specification for LATTICECELL problems

Entry No.	Variable name	Type of data	Entry requirement	Data entry	Comments
1	CTP	Type of lattice	Always		Describes the type of lattice or array configuration
				SQUAREPITCH	Use for cylindrical rods in a square pitch
				ASQUAREPITCH	Use for annular cylindrical rods in a square pitch
				ASQP	Use for annular cylindrical rods in a square pitch
				TRIANGPITCH	Use for cylindrical rods in a triangular pitch
				ATRIANGPITCH	Use for annular cylindrical rods in a triangular pitch
				ATRP	Use for annular cylindrical rods in a triangular pitch
				SPHSQUAREP	Use for spherical pellets in a cubic lattice
				ASPHSQUAREP	Use for annular spherical pellets in a cubic lattice
				ASSP	Use for annular spherical pellets in a cubic lattice
				SPHTRIANGP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				ASPHTRIANGP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				ASTP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				SYMMSLABCELL	Use for a symmetric array of slabs
				ASYMSLABCEL	Use for a periodic, but asymmetric array of slabs
2	PITCH	Array pitch (cm)	Always	Appropriate dimension	The center-to-center spacing (cm) between fuel lumps For asymmetric slab cell, enter the distance from the center of one moderator to the center of the other moderator (cm)
3	FUELOD	Outside dimension of fuel (cm)	Always	Appropriate dimension	Outside diameter of fuel (cm), or the thickness of the fuel in a slab
4	MFUEL	Fuel mixture number	Always	Mixture number	Mixture number representing the fuel

Table C4.4.11 (continued)

Entry No.	Variable name	Type of data	Entry requirement	Data entry	Comments
5	MMOD	Moderator mixture number	Always	Mixture number	Mixture number representing the moderator
6	MMOD2	2nd moderator mixture number	ASYMSLABCELL annular cells	Mixture number	Mixture number representing the second moderator
7	TKMOD2	2nd moderator thickness	ASYMSLABCELL	Thickness	Thickness of the second moderator (cm) for ASYMSLABCELL
		or 2nd moderator diameter (cm)	or annular cells	or diameter	or diameter of inner moderator (cm) for other annular cells
8	CLADOD	Outside diameter of clad (cm)	If clad	Clad OD	OMIT IF NO CLAD. For a slab, CLADOD is the sum of thicknesses of the fuel, gap, and clad
9	MCLAD	Clad mixture number	If clad	Mixture number	OMIT IF NO CLAD. Mixture number representing the clad
10	CLADID	Inside diameter of clad (cm)	If gap	Clad ID	OMIT IF NO GAP between the fuel and clad
11	MGAP	Gap mixture number	If gap	Mixture number	OMIT IF NO GAP between the fuel and clad. A mixture number of zero is often used
12	END	Terminate LATTICECELL data	Always	END	Terminate the LATTICECELL input data by entering the word END. Do not start in column 1. At least two blanks must follow entry 12

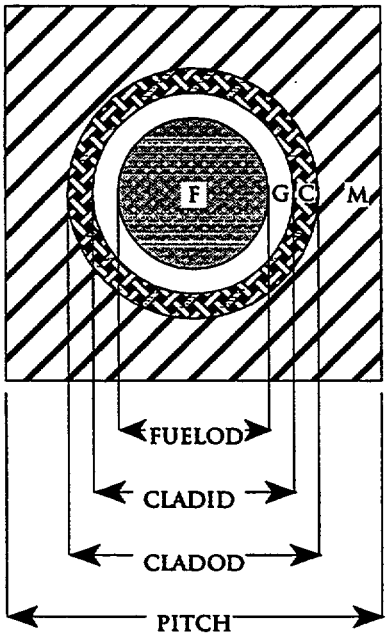


Figure C4.4.2 Arrangement of materials in a SQUAREPITCH and SPHSQUAREP unit cell

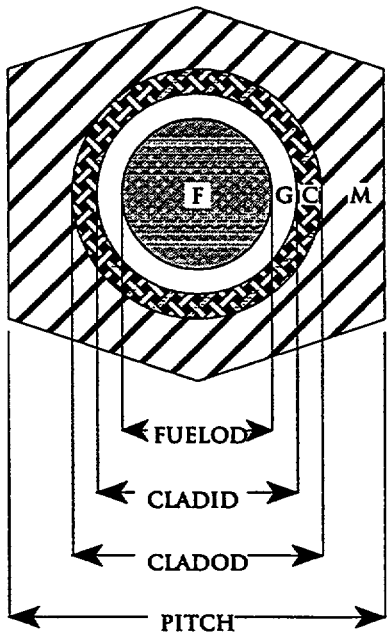


Figure C4.4.3 Arrangement of materials in a TRIANGPITCH and SPHTRIANGP unit cell

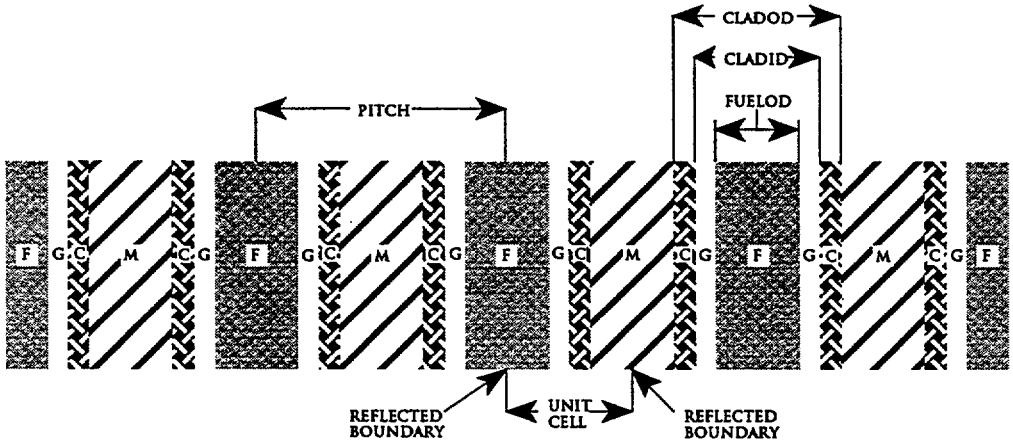


Figure C4.4.4 Arrangement of materials in a SYMMSLABCELL unit cell having reflected left and right boundary conditions

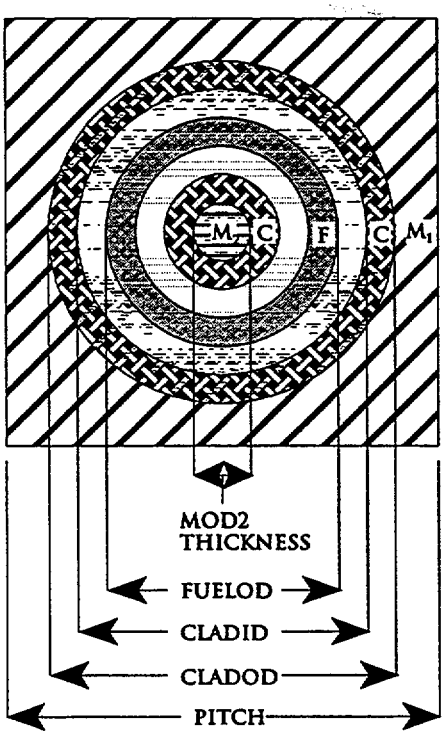


Figure C4.4.5 Arrangement of materials in an ASQUAREPITCH or ASPHSQUAREP unit cell

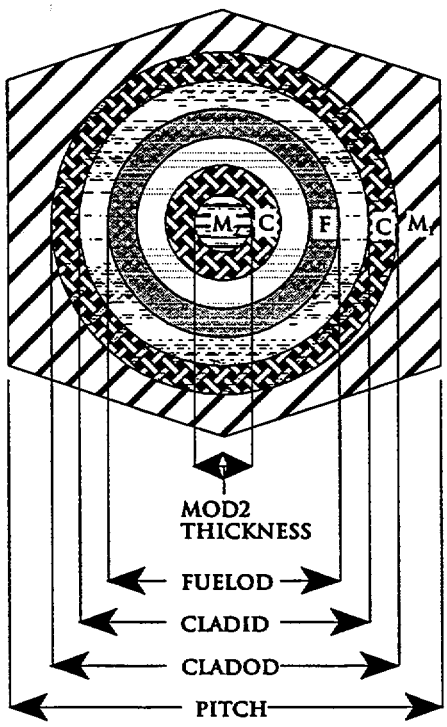


Figure C4.4.6 Arrangement of materials in an ATRIANGPITCH or ASPHTRIANGP unit cell

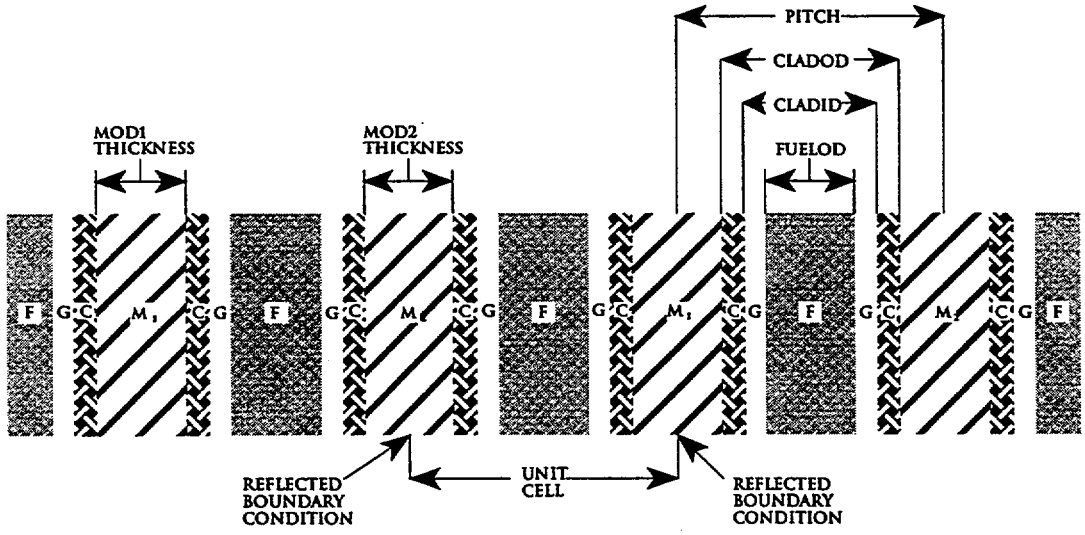


Figure C4.4.7 Arrangement of materials in an ASYMSLABCELL unit cell

1. CTP Type of lattice. This defines the type of lattice or array configuration. Any one of the following alphanumeric descriptions may be used. Note that the alphanumeric description must be separated from subsequent data entries by one or more blanks. Figures C4.4.2 through C4.4.7 are used to illustrate the type of lattice configurations available in a LATTICECELL problem. The fuel region is labeled F; the gap, G; the clad, C; and the moderator, M. If two moderators are present, M1 is the first moderator, and M2 is the second moderator. Both "regular" and "annular" unit cells are available. The arrangement of the materials in the unit cell is strictly constrained. Regular cells are limited to a minimum of two regions and a maximum of four regions. The innermost regions must be fuel, which is surrounded by an optional gap and/or optional clad. The outer region is moderator.

Annular cells are limited to a minimum of three regions. The innermost region must be the second moderator. The annular fuel region is outside the second moderator. If a clad is present, it must be identical in thickness and composition on both sides of the fuel. If a gap is present, it is the same thickness on both sides of the fuel. If the first and second moderators are the same material at the same density and temperature and do not contain resonance nuclides, the same mixture number can be used for both moderators. Otherwise, different mixture numbers must be used for the two moderators.

Regular and annular cell configurations are specified as shown below.

Regular Cells

SQUAREPITCH	is used for an array of cylinders arranged in a square lattice as shown in Fig. C4.4.2. The clad and/or gap can be omitted.
TRIANGPITCH	is used for an array of cylinders arranged in a triangular pitch lattice as shown in Fig. C4.4.3. The clad and/or gap can be omitted.
SPHSQUAREP	is used for an array of spheres arranged in a square pitch lattice. A cross-section view through a cell is represented by Fig. C4.4.2. The clad and/or gap can be omitted.
SPHTRIANGP	is used for an array of spheres arranged in a triangular pitch (dodecahedral) lattice. A cross-section view through a cell is represented by Fig. C4.4.3. The clad and/or gap can be omitted.
SYMMSLABCELL	is used for an infinite array of symmetric slab cells as shown in Fig. C4.4.4. The clad and/or gap can be omitted.

Annular Cells

ASQUAREPITCH or ASQP is used for annular cylindrical rods in a square pitch lattice as shown in Fig. C4.4.5. The gap on both sides of the fuel must be identical, as must the clad. The clad and/or gap can be omitted.

ASPHTRIANGP or ASTP is used for spherical shells in a triangular pitch (dodecahedral) lattice as shown in Fig. C4.4.6. The gap on both sides of the fuel must be identical, as must the clad. The clad and/or gap can be omitted.

ASYMSLABCELL is used for a periodic, but asymmetric, array of slabs as shown in Fig. C4.4.7. The gap on both sides of the fuel must be identical, as must the clad. The clad and/or gap can be omitted.

2. PITCH Array pitch. This is the center-to-center spacing between the fuel lumps (rods, pellets, or slabs) in centimeters shown in Figs. C4.4.2 through C4.4.7. For an ASYMSLABCELL, enter the distance from the center of one moderator to the center of the other moderator. See Fig. C4.4.7.

3. FUELOD Outside dimension of fuel. This is the outside diameter of the fuel in centimeters as shown in Figs. C4.4.2 through C4.4.7. In slab geometry, enter the thickness of the fuel (see Figs. C4.4.2 through C4.4.7).

4. MFUEL Fuel mixture number. This is the mixture number representing the fuel (F in Figs. C4.4.2 through C4.4.7).

5. MMOD Moderator mixture number. This is the mixture number representing the moderator (M or M1 in Figs. C4.4.2 through C4.4.7).

6. MMOD2 Second moderator mixture number. Enter ONLY for annular cells. This is the mixture number representing the second moderator (M2 in Figs. C4.4.5 through C4.4.7).

7. TKMOD2 Second moderator thickness. Enter ONLY for annular cells. This is the thickness or diameter of the second moderator in centimeters. See Figs. C4.4.5 through C4.4.7.

8. CLADOD Outside diameter of clad. Enter ONLY if a clad is present. Enter the thickness of the clad in centimeters. For a slab, CLADOD is the sum of the fuel thickness, twice the gap thickness, and twice the clad thickness. See Figs. C4.4.2 through C4.4.7.

9. MCLAD Clad mixture number. Enter ONLY if a clad is present. Enter the mixture number that represents the clad (C in Figs. C4.4.2 through C4.4.7).

10. CLADID Inside diameter of clad. Enter ONLY if a gap is present between the fuel and the clad. Omit if there is no gap. If a gap is present, enter the inside diameter of the clad in centimeters. This corresponds to the outside diameter of the gap. In slab geometry, CLADID is the sum of the fuel thickness and twice the gap thickness. See Figs. C4.4.2 through C4.4.7.

11. MGAP Gap mixture number. Enter ONLY if a gap is present between the fuel and the clad. Omit if there is no gap. Enter the mixture number representing the gap (G in Figs. C4.4.2 through C4.4.7). Zero is often used to represent a void.

12. END The word END is entered to terminate the LATTICECELL data. An optional label can be associated with this END. The label can be as many as 12 characters long and is separated from the END by a single blank. At least two blanks must follow entry 12.

C4.4.7 UNIT CELL SPECIFICATION FOR MULTIREGION PROBLEMS

These data are entered only if the problem is defined as a MULTIREGION problem. They describe the additional geometry data that are required for a MULTIREGION problem (data position 3 of Table C4.4.8). A MULTIREGION problem can be used to define a geometric arrangement that is more complicated than is allowed by a lattice cell. It can also be used for large geometric regions where the geometry effects for the cross sections are minimal. Additional information is available in Sects. M7.5.4, M7.5.4.3, M7.5.6.3, and M7.5.8.3. BE FULLY AWARE THAT CROSS SECTIONS GENERATED USING MULTIREGION IGNORE THE LATTICE GEOMETRY EFFECTS IN DOING THE RESONANCE CORRECTIONS.

The additional data required for a MULTIREGION problem are given in Table C4.4.12; individual entries are explained in the text accompanying the table.

1. CS Type of geometry. The type of geometry must always be specified for a MULTIREGION problem. The cross-section corrections do not account for lattice effects. The available geometry options are listed below.

   SLAB This is used to describe a slab geometry.

   CYLINDRICAL This is used to describe cylindrical geometry.

   SPHERICAL This is used to describe spherical geometry.

   BUCKLEDSLAB This is used for slab geometry with a buckling correction for the two transverse directions.

   BUCKLEDCYL This is used for cylindrical geometry with a buckling correction in the axial direction.

Table C4.4.12 Geometry specification for MULTIREGION problems

Entry No.	Variable name	Type of data	Entry requirement	Data entry	Comments
1	CS	Type of geometry	Always		Describes the type of geometry. The options are listed below
				SLAB	Use for slab geometry
				CYLINDRICAL	Use for cylindrical geometry
				SPHERICAL	Use for spherical geometry
				BUCKLEDSLAB	Use for slab geometry with a buckling correction for the two transverse directions
				BUCKLEDCYL	Use for cylindrical geometry with a buckling correction in the axial direction
2	BR	Right boundary condition	Required for BUCKLEDSLAB and BUCKLEDCYL; optional for other geometries		Default is VACUUM. Describes the right/outside boundary condition
				VACUUM	This provides a non-return condition at the boundary
				REFLECTED	Do not use for cylindrical or spherical
				PERIODIC	Do not use for cylindrical or spherical
				WHITE	This provides isotopic return at the boundary
3	BL	Left boundary condition	Required for BUCKLEDSLAB and BUCKLEDCYL; optional for other geometries		Default is REFLECTED. Describes the left boundary condition
				VACUUM	This provides a non-return condition at the boundary
				REFLECTED	Recommended for cylindrical or spherical
				PERIODIC	Do not use for cylindrical or spherical
				WHITE	This provides isotropic return at the boundary
4	ORGN	Location of left boundary on the x-axis (cm)	BUCKLEDSLAB and BUCKLEDCYL; optional for other geometries	Appropriate dimension	Default is 0.0. Should not be changed for cylindrical or spherical geometry. A value must be entered if subsequent data are to be entered
5	DY	Buckling height (cm)	BUCKLEDSLAB and BUCKLEDCYL	Appropriate dimension	Omit for SLAB, CYLINDRICAL, and SPHERICAL. This corresponds to one of the transverse dimensions of an actual 3-D slab assembly or to the length of a finite cylinder

Table C4.4.12 (continued)

Entry No.	Variable name	Type of data	Entry requirement	Data entry	Comments
6	DZ	Buckling depth (cm)	BUCKLEDSLAB	Appropriate dimension	Omit unless BUCKLEDSLAB was specified. This is the buckling depth corresponding to the second transverse dimension of a 3-D slab assembly
7	END	End geometry parameters	Always	END	Enter the word END. Do not start in column 1
8	MXZ	Mixture number in the zone	Always	Mixture number	Repeat entry numbers 8-10 until all zones are defined. Enter the mixture number for this zone
9	RZ	Outside radius of the zone (cm)	Always	Appropriate dimension	Repeat entry numbers 8-10 until all zones are defined. Enter the outside dimension of the zone (cm)
10	XMOD	External moderator index	Optional		Repeat entry numbers 8-10 until all zones are defined. Entry 10 is optional and can be omitted. If it is omitted, repeat entries 8 and 9 until all zones are defined.
				NOEXTERMOD	No moderating materials in the adjacent zones
				ONEEXTERMOD	A moderating material is present in one adjacent zone
				TWOEXTERMOD	Moderating materials are present in two adjacent zones
	END ZONE	Terminate zone data		END ZONE	Enter when all zones have been defined by repeating entries 8 through 10 for each zone

2. BR Right boundary condition. This is defaulted to vacuum. A value for BR **MUST** be entered for BUCKLEDSLAB and BUCKLEDCYL but is optional for SLAB, CYLINDRICAL, or SPHERICAL. The available options and their qualifications are listed below:

VACUUM	This imposes a vacuum at the boundary of the system.
REFLECTED	This imposes mirror image reflection at the boundary. Do not use for CYLINDRICAL or SPHERICAL.
PERIODIC	This imposes periodic reflection at the boundary. Do not use for CYLINDRICAL or SPHERICAL.
WHITE	This imposes isotropic return at the boundary.

3. BL Left boundary condition. This is defaulted to reflected. A value for BL **MUST** be entered for BUCKLEDSLAB but is optional for SLAB, CYLINDRICAL, or SPHERICAL. The available options and their qualifications are listed below:

VACUUM	This imposes a vacuum at the boundary of the system.
REFLECTED	This imposes mirror image reflection at the boundary. For CYLINDRICAL or SPHERICAL, this is the only valid boundary condition because the left boundary corresponds to the centerline.
PERIODIC	This imposes periodic reflection at the boundary.
WHITE	This causes isotropic return at the boundary.

4. ORGN Location of left boundary on the origin. The default value of ORGN is 0.0. This is the only value allowed for CYLINDRICAL or SPHERICAL geometry. Enter the location of the left boundary on the axis perpendicular to the slab (in cm).

5. DY Buckling height. Enter *ONLY* for BUCKLEDSLAB or BUCKLEDCYL. This is the buckling height in centimeters. It corresponds to one of the transverse dimensions of an actual 3-D slab assembly or the length of a finite cylinder.

6. DZ Buckling depth. Enter *ONLY* for BUCKLEDSLAB. This is the buckling depth in centimeters. It corresponds to the second transverse dimension of an actual 3-D slab assembly.

7. END The word END is entered to terminate these data before entering the zone description data. It must not be entered in columns 1 through 3. At least two blanks are required between items 1 and 7 if they are the only entries. A label can be associated with this END. The label can be a maximum of 12 characters and is separated from the END by a single blank. At least two blanks must follow entry 7.

The zone description data are entered at this point. Entries 8, 9, and 10 are entered for each zone, and the sequence is repeated until all the desired zones have been described. To terminate the data, enter the words END ZONE.

8. MXZ Mixture number in the zone. Enter the mixture number of the material that is present in the zone. Enter a zero for a void. Repeat the sequence of entries 8 through 10 for each zone.

9. RZ Outside radius of the zone. Enter the outside dimension of the zone in centimeters. In slab geometry, RZ is the location of the zone's right boundary on the x-axis. Repeat the sequence of entries 8 through 10 for each zone.

10. XMOD Optional external moderator index. This optional entry describes the conditions existing in the zones adjacent to the present zone. Appropriate conditions are provided by default. The available options are listed below.

NOEXTERMOD This means there are no moderating materials between this zone and either boundary.

ONEEXTERMOD This means one of the zones between this zone and one of the boundaries contains a material.

TWOEXTERMOD. This indicates that at least one zone on either side of this zone contains a material.

CAUTION: User-provided entries do not always supersede the default values: (1) For SLAB geometry, user-supplied values will be used everywhere except zone 1. If the left boundary is reflected, the default value of ONEEXTERMOD will be used unless NOEXTERMOD is specified. (2) For SPHERICAL and CYLINDRICAL geometry, default values will be used for all zones unless NOEXTERMOD is specified. NOEXTERMOD allows the user to "turn off" geometric corrections.

Repeat the sequence of entries 8 and 9 or 8 through 10 for each zone. When all the zones have been described, enter the words END ZONE.

END ZONE This is used to terminate the MULTIREGION zone data. Enter the words END ZONE when all the zones have been described. Note that ZONE is a label associated with this END. This label can be as long as 12 characters, but the first four characters **must** be ZONE. At least two blanks must follow this entry.

C4.4.8 OPTIONAL PARAMETER DATA

Most of the parameter data for Criticality Safety Analysis Sequence No. 4 are determined by the control module and cannot be adjusted. However, certain parameters can be altered. If the default parameters are acceptable, this section of input data should be omitted in its entirety. Nondefault values for one or more of the parameters can be specified by entering the words MORE DATA followed by the desired keyworded

parameters and their associated values. One or more of the parameters can be entered in any order. Default values are used for parameters that are not entered. Each parameter is entered by spelling its name, followed immediately by an equal sign and the value to be entered. There should not be a blank between the parameter name and the equal sign. Each parameter specification must be separated from the rest by at least one blank. For example

MORE DATA ISN=16 EPS=0.00008 END

would result in using an S16 angular quadrature set and tightening the convergence criteria to 0.00008 in the XSDRNPM calculation. Note that the END is not the end for the analytical sequence, entry 5 of Table C4.4.7.

Table C4.4.13 describes the optional parameters that can be entered as data and the code or codes the parameters apply to. A description of each entry is contained in the text accompanying the table.

1. MORE DATA...These words, followed by one or more blanks, are entered ONLY if optional parameter data are to be entered. They must precede all other optional parameter data. Entries 2 through 28 can be entered in any order.

2. ISN — Order of angular quadrature for XSDRNPM. Quadrature sets are geometry-dependent quantities that are defaulted to order 8 by the Material Information Processor. See Sects. M7.2.5.7 and M7.5.7 for a more detailed explanation.

3. SZF — Spatial mesh size factor for XSDRNPM. The size of the largest mesh interval can be adjusted by entering a value for SZF. The default value is 1.0. A value between zero and 1.0 yields a finer mesh; a value greater than 1.0 yields a coarser mesh. See Sects. M7.2.5.6 and M7.5.7 for more details.

4. IIM — Maximum number of inner iterations for XSDRNPM. This is the maximum number of inner iterations to be used in the XSDRNPM calculation. The default value is 20. See Sect. M7.5.7 for a more detailed explanation.

5. ICM — Maximum number of outer iterations for XSDRNPM. This is the maximum number of outer iterations to be used in the XSDRNPM calculation. The default value is 25. If the calculation reaches the outer iteration limit, a larger value should be used. See Sect. M7.5.7 for a more detailed explanation.

6. EPS — Overall convergence criteria for XSDRNPM. This is used by XSDRNPM after each outer iteration to determine if the problem has converged. The default value of EPS is 0.0001. A value less than 0.0001 tightens the convergence criteria; a larger value loosens the convergence criteria. See Sects. M7.2.5.8 and M7.5.7 for additional information.

Table C4.4.13 Optional parameter data

Entry number	Keyword name	Type of data	Applicable module	Comments
1	MORE DATA	Input flag	XSDRNPM	This signals that optional parameter data will be entered. Enter only those parameters you wish to change
2	ISN=	Order of angular quadrature	XSDRNPM	The default value is 8. This allows using another value
3	SZF=	Spatial mesh size factor	XSDRNPM	The default value is 1.0. 0<SZF<1.0 gives a finer mesh. SZF>1.0 gives a coarser mesh
4	IIM=	Max. number of inner iterations	XSDRNPM	The default value is 20. This allows using another value
5	ICM=	Max. number of outer iterations	XSDRNPM	The default value is 25. This allows using another value
6	EPS=	Overall convergence criteria	XSDRNPM	The default value is 0.0001. This allows using another value
7	PTC=	Point convergence criteria	XSDRNPM	The default value is 0.00001. This allows using another value
8	BKL=	Buckling factor	XSDRNPM	The default value is 1.420892. Use ONLY for a multiregion problem that specifies BUCKLEDSLAB or BUCKLEDCYL
9	IUS=	Upscatter scaling factor	XSDRNPM	The default value is zero. IUS=0 doesn't utilize upscatter scaling. IUS=1 uses upscatter scaling to accelerate the solution and/or speed convergence
10	RES=	Resonance data	BONAMI NITAWL-II	Enter the mixture number, geometry type (SLAB, CYLINDER, SPHERE), and the thickness of the slab or radius of the sphere or cylinder, in cm. Optionally enter the inner radius (cm) to specify an annular cylinder or sphere
11	DAN(mm)=	Dancoff factor for the specified mixture	BONAMI NITAWL-II	Enter the mixture number, mm, to which the Dancoff factor applies inside the parentheses; enter the Dancoff factor after the equal sign **Repeat entries 10 and 11 for all resonance mixtures used in the problem that are not treated in the LATTICECELL or MULTIREGION description.**
12	BAL=	Key to print balance tables	XSDRNPM	The default value is FINE. BAL=NONE suppresses printing the balance table. BAL=ALL prints all balance tables. BAL=FINE prints only the fine-group balance tables

Table C4.4.13 (continued)

Entry number	Keyword name	Type of data	Applicable module	Comments
13	DY=	First transverse dimension	XSDRNPM	The first transverse dimension, in centimeters, used in a buckling correction to calculate leakage normal to the principal calculation direction (i.e., the height of a slab or a cylinder)
14	DZ=	Second transverse dimension	XSDRNPM	The second transverse dimension, in centimeters, used for a buckling correction (i.e., the width of a slab)
15	COF=	Diffusion coefficient option for transverse leakage correction	XSDRNPM	The default is 0. See Sect. F3.5, 3$ array, variable IPN
16	FRD=	Unit from which fluxes will be read	XSDRNPM	Enter the unit number from which the flux guess for XSDRNPM will be read
17	FWR=	Unit on which fluxes will be written	XSDRNPM	Enter the unit number where the binary fluxes from XSDRNPM will be written
18	ADJ=	Adjoint mode flag	XSDRNPM	Enter a 1 to cause XSDRNPM to solve the problem in adjoint mode
19	NBU=	Unit on which balance tables will be written	XSDRNPM	Enter the unit number where the balance tables from XSDRNPM will be written
20	WGT=	Cross-section weighting flag	XSDRNPM	Enter a 0 to suppress doing the cross-section weighting in XSDRNPM
21	ZMD(iz)=	Zone width modifier for the specified zone	XSDRNPM	Enter the zone number for which the modifier applies inside the parentheses; enter the zone width modifier after the equal sign. **Repeat number 20 to specify all zones to be modified in a search**
22	INT(iz)	Number of intervals for the specified zone	XSDRNPM	Enter the zone number inside the parentheses; enter the number of intervals after the equal sign. Repeat number 22 to specify all needed zones.
23	KEF=	Value of k_{eff} to be searched for	XSDRNPM	Enter the value of k_{eff} that it is desired to search for. The default is 1.0.
24	KFM=	Value of the eigenvalue modifier	XSDRNPM	Enter the value of the eigenvalue modifier (i.e., the relative change for the first guess of a search). The default is -0.1.
25	DAB=	Number of direct access data blocks	MIP[a]	The default is 200. Number of blocks allocated for direct access unit 90.
26	AXS=	Unit on which a mixed ANISN library will be written	ICE	Enter the unit number where ICE is to write a mixed ANISN library

Table C4.4.13 (continued)

Entry number	Keyword name	Type of data	Applicable module	Comments
27	MSH=	Maximum number of mesh points/ resonance	NITAWL	The default value is 2001. This allows using another value.
28	MLV=	Highest resonance ℓ-value for self-shielding	NITAWL	The default value is 2. This allows using another value.
29	ID1	Print control for scalar fluxes	XSDRNPM	The default value is -1. See Sect. F3.5, 2$ array, variable ID1.
30	COLL	Key to activate collapse of thermal groups	MIP[a]	Enter COLL to collapse all thermal groups into one group for the shielding sequences
31	END	Terminus		Terminate the optional parameter data. Do not start in column 1. At least two blanks must follow this entry.

[a]MIP is the Material Information Processor.

7. PTC — Pointwise convergence criteria for XSDRNPM. This is the point flux convergence criteria used by XSDRNPM to determine if convergence has been achieved after an inner iteration. The default value is 0.00001. A smaller value tightens convergence; a larger value loosens it. See Sects. M7.2.5.8 and M7.5.7 for more details.

8. BKL — Buckling factor for XSDRNPM. A buckling factor should be used ONLY for a MULTIREGION BUCKLEDSLAB or BUCKLEDCYL problem. Because cylinders are assumed to be infinitely long and slabs are assumed to be infinite in both transverse directions, the analytic sequence may tend to overestimate the total flux for a finite system. A buckling correction can be used to approximate the leakage from the system in the transverse direction(s). The extrapolation distance factor, BKL, is defaulted to 1.420892. See Sects. M7.2.5.4 and M7.5.7 for additional details.

9. IUS — Upscatter scaling flag for XSDRNPM. This option allows the use of upscatter scaling to accelerate the solution or force convergence. The default value is zero, in which case upscatter scaling is not used. IUS=1 facilitates upscatter scaling. Guidelines are not available to indicate when upscatter scaling is needed. Some problems will not converge with it, and some will not converge without it. See Sect. M7.5.7 for a more detailed explanation.

10. RES — RESONANCE DATA FOR BONAMI AND NITAWL...This parameter allows overriding the default resonance data for materials that are not used in the unit cell. The default resonance data are infinite homogeneous media, which may not accurately represent the geometry (for example, an additional fuel mixture, a thin clad, or a container region). The resonance data are entered in the form:

    RES= mixture number geometry type thickness [inner radius]

    The mixture number is the material for which the resonance data apply. The geometry type can be a sphere, slab, or cylinder, and defines the third entry of the 3* array in NITAWL. The thickness is the thickness of a slab or the radius of a sphere or cylinder in cm and defines the fourth entry of the 3* array in NITAWL. An inner radius, in cm, may optionally be entered to treat a cylinder or sphere as an annular geometry. It defines the sixth entry in the 3* array in NITAWL. This entire data sequence should be entered for each material for which the default data are inadequate. See Sect. M7.5.7 for additional details. WARNING: If this parameter is used to enter resonance data for a mixture that is used in the unit cell specification, it will NOT be used. Information provided in the unit cell data will be used instead.

11. DAN(mm)= Dancoff factor for the specified mixtures. This allows entering a Dancoff factor to be used in the resonance correction for the specified mixture. The Dancoff data are entered in the form:

    DAN(mm) = Dancoff factor.

Note that the parentheses must be entered as part of the data. The mixture number, mm, to which the Dancoff factor applies, must be enclosed in the parentheses. The Dancoff factor to be used is entered after the equal sign. See Sect. M7.5.7 for additional details.

Items 10 and 11 should be entered for each resonance mixture that is not specified in the LATTICECELL or MULTIREGION unit cell specification data. See Sects. M7.5.10 and C4.5.1 for additional information.

12. BAL — Balance table print flag for XSDRNPM. This allows control of the balance table print from XSDRNPM. The default value is FINE. BAL=NONE suppresses the balance table print. BAL=ALL prints all of the balance tables. BAL=FINE prints only the fine-group balance tables. See Sect. M7.5.7 for additional details.

13. DY= — First transverse dimension for XSDRNPM. This is the first transverse dimension, in centimeters, used in a buckling correction to calculate the leakage normal to the principal calculation direction (the height of a slab or cylinder). It should only be entered if XSDRNPM is to create cell-weighted cross sections and/or calculate the eigenvalue of a cylinder or slab system of finite height for a LATTICECELL problem. DY= is defaulted to an infinite height, or is set to DY for a buckled MULTIREGION cell description. See Sects. M7.2.5.4 and M7.5.7 for additional details.

14. DZ= — Second transverse dimension for XSDRNPM. This is the second transverse dimension, in centimeters, used for a buckling correction for a slab of finite width. It should only be entered if XSDRNPM is to create cell-weighted cross sections and/or calculate the eigenvalue of a LATTICECELL slab of finite width. DZ= is defaulted to an infinite width, or is set to DZ for a buckled MULTIREGION slab cell of finite width. See Sects. M7.2.5.4 and M7.5.7 for additional details.

15. COF= — Diffusion coefficient for transverse leakage corrections in XSDRNPM. The default value is 0. The available options are

COF=0 sets a transport-corrected cross section for each zone.

COF=1 use a spatially averaged diffusion coefficient for each zone.

COF=2 use a diffusion coefficient for all zones that is one-third the diffusion coefficient determined from the spatially averaged transport cross section for all zones.

COF=3 use a flux and volume weighting across all zones.

See Sect. M7.5.7 or Sect. F3.5, 3$ array, variable IPN for more details.

16. FRD= Unit from which fluxes are read for XSDRNPM. If fluxes are to be used for the initial flux guess, enter the unit number from which they are to be read. The user is responsible for supplying job control language data that is necessary for reading the flux dataset. See Sect. M7.5.7 for more details.

17. FWR= Unit on which fluxes will be written for XSDRNPM. If binary fluxes are to be saved from this XSDRNPM calculation, enter the unit number where they will be written. The user is responsible for supplying job control language data that is necessary for creating and saving the flux dataset. See Sect. M7.5.7 for more details.

18. ADJ= Adjoint mode flag for XSDRNPM. Set to 1 to cause XSDRNPM to solve the adjoint problem.

19. NBU= Unit on which the balance tables will be written from XSDRNPM. If the balance tables file is to be saved, enter the unit number where they are to be written. The user is responsible for supplying job control data necessary to create and save the balance table dataset.

20. WGT= Cross-section weighting flag for XSDRNPM. The default is to do cross-section weighting. If a user needs to not do cross-section weighting, then a value of 0 should be entered.

21. ZMD(iz)= Zone width modifiers for an XSDRNPM search problem. This allows entering a zone width modifier for zone iz in the XSDRNPM problem description. The zone width data are entered in the form:
ZMD(iz)=modifier
Note that the parentheses must be entered as part of the data. The zone number iz, to which the modifier is applied must be enclosed in the parentheses. The modifier is entered after the equal sign. See Sect. F3.2.8 for more information.

22. INT(iz)= Number of mesh intervals for zone iz in XSDRNPM. The default is 0, which causes the number to be calculated. The data are entered in the form:
INT(iz)=number
Note that the parentheses must be entered as part of the keyword. The zone number iz, for which the number of intervals is specified, must be enclosed in the parentheses. The number of intervals is entered after the equal sign.

23. KEF= The desired value of k_{eff} for an XSDRNPM zone width search. The default value is 1.0. If it is desired to search for some other value, such as 0.9, then input it here.

24. KFM= The first eigenvalue modifier used in an XSDRNPM search. This value is used to make the first change in the XSDRNPM search. The default value is -0.1. A user may sometimes need to change this to make the search converge.

25. DAB= Number of direct-access data blocks for the Material Information Processor. This is the number of blocks allocated for direct access on unit 90. The default is 200. See Sect. M7.5.7 for additional details. If the job fails in the Material Information Processor with an LMP005

DA ERROR, then DAB must be used to enter a larger value. See Sect. C4.7.4 for additional details.

26. AXS= Logical unit number for ICE. Write a mixed ANISN library on this unit. The default is zero (no library). If the unit number is input as 7, the ANISN library will be in free-form card image. For any other unit number, the library will be binary. The user is responsible for supplying job control language data that is necessary for creating and saving the ANISN cross-section library. An ANISN cross section can only be created by the control sequences CSASI, CSASIX, and SAS3. See Sect. M7.5.7 for additional details.

27. MSH= THE MAXIMUM NUMBER OF MESH POINTS PER RESONANCE...The default value is 2001. This is the maximum number of mesh points allowed for the Simpson's rule integration in NITAWL. This should be an odd number. See Section M7.5.7 for additional details.

28. MLV= HIGHEST RESONANCE ℓ-VALUE FOR SELF-SHIELDING...The default value is 2. This is the highest resonance ℓ-value for which a self-shielding calculation will be performed in NITAWL. See Sect. M7.5.7 for additional details.

29. ID1= SCALAR FLUX PRINT CONTROL...The default value is - 1, which suppresses printing the scalar fluxes in XSDRNPM. See Sect. F3.5, 2$ array, variable ID1, for allowed values and corresponding actions.

30. COLL Activate collapse of thermal groups. This parameter should only be used with the shielding analysis sequences (SAS1, etc.). It causes the Material Information Processor to instruct XSDRN to collapse all thermal groups into one group.

31. END The word END is entered to terminate the optional parameter data. A label can be associated with this END. The label can be as long by a single blank. If this END is entered without a label, it must not begin in column 1. At least two blanks must follow this entry.

C4.4.9 SUMMARY OF KENO V.a DATA

KENO V.a data are required for CSAS25, CSAS2X, CSAS4, and CSAS4X. A brief outline of the KENO V.a data is given in Table C4.4.14. The input data are summarized in Table C4.4.15. The input data for KENO V.a are discussed in detail in Sects. F11.4 and F11.5. Data need not be supplied for entries whose default value is acceptable. KENO V.a mixing table data cannot be entered or used in CSAS because they are automatically supplied by the control module.

Table C4.4.14 Outline of KENO V.a data

Type of data	Starting flag	Comments	Termination flag
Title	None	80 columns, must be entered first	None
Parameters	READ PARM	Enter desired parameter data	END PARM
Biasing or weighting	READ BIAS	Enter desired biasing data	END BIAS
Geometry	READ GEOM	Enter desired geometry data	END GEOM
Array data or unit orientation	READ ARRAY	Enter desired array data	END ARRAY
Boundary conditions or albedoes	READ BNDS	Enter desired albedo data	END BNDS
Start data or initial source	READ START	Enter desired start data	END START
Mixing table data	READ MIXT	The CSAS4 modules allow only SCT= and EPS=	END MIXT
Plot data	READ PLOT	Enter desired plot data	END PLOT
KENO V.a data terminus	END DATA	Enter to signal the end of all KENO V.a data	

Table C4.4.15 Summary of KENO V.a data

Summary of parameter data

TITLE: The title must be entered first (80 columns) See Sect. F11.4.3

PARAMETERS: Format: READ PARAM enter parameter data here END PARAM
If parameters are entered, they must follow the title. See Sects. F11.4.3, F11.5.2, and F11.5.3.

KEY	STD.	DEFINITION	KEY	STD.	DEFINITION	KEY	STD.	DEFINITION	KEY	STD.	DEFINITION
RND=	given	Random number	FLX=	NO	Fluxes	MKH=	NO	Matrix by hole	XSC=	14	Mixed xsecs
TME=	120 min	Execution time (min)	FDN=	NO	Fission densities	CKH=	NO	Cofactor k by hole	ALB=	79	Albedo
TBA=	0.5 min	Batch time (min)	ADJ=	NO	Adjoint calculation	FMH=	NO	Fiss. prod. by hole	WTS=	80	Weights
WTA=	0.5	Average weight	AMX=	NO	All mixture xsecs	HHL=	NO	MKH at highest level	LIB=	4	Working xsecs from NITAWL or XSDRN
WTH=	3.0	Wt. for splitting	XAP=	NO	Xsec angles and probs.	MKA=	NO	Matrix by array			
WTL=	1/WTH	Russian Roulette wt.	XS1=	NO	1-D xsecs	CKA=	NO	Cofactor k by array			
GEN=	203	No. of generations	XS2=	NO	2-D xsecs	FMA=	NO	Fiss. prod. by array	SKT=	16	Scratch
NPG=	1000	No. per generation	PKI=	NO	Fission spectrum	HAL=	NO	MKA at highest level	RST=	95	Read restart
NSK=	3	Generations skipped	P1D=	NO	Extra 1-D xsecs	PLT=	YES	Printer plots	WRS=	95	Write restart
RES=	0	Gens. between restart	FAR=	NO	Fiss. and abs.	BUG=	NO	Debug print	XSC=	14	Mixed xsecs
NBK=	NPG+25	Neutron bank positions	MKP=	NO	Matrix by location	TRK=	NO	Print neutron tracks			
XNB=	0	Extra bank entries	CKP=	NO	Cofactor k by loc.	PWT=	NO	Print avg. weight			
NFB=	NPG	Fission bank positions	FMP=	NO	Fiss. prod. by loc.	PGM=	NO	Unprocessed geometry			
XFB=	0	Extra bank entries	MKU=	NO	Matrix by unit	SMU=	NO	Self-multiplication			
X1D=	0	No. of extra 1-D's	CKU=	NO	Cofactor k by unit	NUB=	YES	Neutrons per fission			
LNG=	1000000	Words of storage*	FMU=	NO	Fiss. prod. by unit	PAX=	NO	Albedo-xsec array			
BEG=	1	Restart at this gen.	GAS=	FAR	FAR by energy group	RUN=	YES	Execute problem			
NB8=	200	Blocks for d.a. unit				PLT=	YES	Printer plots			
NL8=	512	Length of d.a. block									

*The words of storage in CSAS are defaulted to 100,000 and can be overridden by using the size= parameter on the analytical sequence specification which then becomes the default value of LNG in KENO V.a.
For example: =CSAS25 PARM=SIZE=200000
or =CSAS25 PARM=(CHECK,SIZE=200000)

Table C4.4.15 (continued)
Summary of array data

ARRAY Format: READ ARRAY array parameters data type orientation data END ARRAY See Sects. F11.5.5, F11.5.6, and F11.5.7.

Repeat the sequence ARRAY PARAMETERS DATA TYPE ORIENTATION DATA for each array used in the problem.

ARRAY PARAMETERS			DATA TYPE FILL LOOP
KEYWORD	DEFAULT	DEFINITION	
ARA=	1	No. defining the array	
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=	Maxara	Global, universe, or overall array number**	
		Delim comment delim	
COM=	None	Optional comment is a maximum of 132 characters	

**Can be defaulted by the code. 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.

COUNT FIELD	OPTION FIELD	OPERAND FIELD	COMMENTS
		j	Stores j at the current position in the array
i	R	j	Stores j in the next i positions in the array
i	0	j	Stores j in the next i positions in the array
i	$	j	Stores j in the next i positions in the array
	F	j	Fills remainder of the array with unit no. j starting with the current array position
	A	j	Sets the current position in the array to j increments; current position in
i	S		the array by i allows skipping i positions. The value of 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	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
i	P	j	Alternately stores j and -j in the next i positions of the array
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

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:

DATA ENTRY	COMMENTS
LTYPE	The unit or box type. LTYPE must be greater than 1
IX1	Starting position in the X direction. IX1 must be at least 1 and no larger than the value entered for NUX
IX2	Ending position in the X direction. IX2 must be at least 1 and no larger than the value of NUX
INCX	The number of units by which increments are made in the X direction
IY1	The starting position in the Y direction. IY1 must be at least 1 and less than the value entered for NUY
IY2	Ending position int he Y direction. IY2 must be at least 1 and no larger than the value of NUY
INCY	The number of units by which increments are made in the positive Y direction
IZ1	Starting position in the Z direction. IZ1 must be at least 1 and no larger than NUZ
IZ2	Ending position in the Z direction. IZ2 must be at least 1 and no larger than NUZ
INCZ	The number of units by which increments are made in the positive Z direction

Table C4.4.15 (continued)

Summary of biasing data

BIAS (weighting)

Format: READ BIAS keyword correlation data auxiliary END BIAS
See Sects. F11.4.7 and F11.5.8

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	16,27,44,218,238	5 cm
	ibgn	Beginning bias ID	Paraffin	400	16,27,44,218,238	3 cm
	iend	Ending bias ID	Water	500	16,27,44,218,238	3 cm
			Graphite	6100	16,27,44,218,238	20 cm
WT=	AUXILIARY DATA will be read next.					
WTS=	AUXILIARY DATA will be read next.					
	wttitl	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 wtavg's from the first interval of material ID.

Table C4.4.15 (continued)

Summary of boundary condition data

BNDS (albedo or boundary conditions)

Format: READ BNDS face code albedo name END BNDS
See Sect. F11.4.7

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

ALBEDO NAMES AVAILABLE ON THE KENO V ALBEDO LIBRARY, FOR USE WITH THE FACE CODES

ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION
DPOH20 DPOH20 DPO DPO	12-in. double PO 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
H20 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	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	SPEC SPE MIR	
CARBON GRAPHITE C	200-cm carbon differential albedo with 4 incident angles	CONC-16 CON16 CONC16	16-in. concrete differential albedo with 4 incident angles	PERIODIC PERI PER	Periodic 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 C4.4.15 (continued)

Summary of geometry data

GEOMETRY (region)

Format: READ GEOM enter geometry region data here END GEOM
See Sects. F11.4.4, F11.5.1.2, F11.5.6, and F11.5.7.

GEOMETRY REGION DATA consists of SIMPLE GEOMETRY REGION DATA and EXTENDED GEOMETRY REGION DATA.

ENTER GEOMETRY REGION DATA IN THE FOLLOWING FORM:

OPTIONAL GLOBAL SPECIFICATION
UNIT n
OPTIONAL GEOMETRY COMMENT
SIMPLE GEOMETRY REGION DATA
and/or
EXTENDED GEOMETRY REGION DATA
* *

ENTER SIMPLE GEOMETRY REGION DATA IN THE FOLLOWING FORM:

GLOBAL	Enter only 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.
fgeom mix no. bias ID	dimensions optional origin data (ORIGN coordinates) optional chord dat CHOD)

Enter as many geometry description specifications as necessary to describe the unit and as many units as necessary to describe the system.

SIMPLE GEOMETRY REGION INPUT DATA REQUIREMENTS

TYPE OF DATA	TYPE 1 DATA	TYPE 2 DATA	TYPE 3 DATA	TYPE 4 DATA	TYPE 5 DATA	TYPE 6 DATA
fgeom	SPHERE HEMISPHERE HEMISPHE+X HEMISPHE-X HEMISPHE+Y HEMISPHE-Y HEMISPHE+Z HEMISPHE-Z	XCYLINDER XHEMICYL+Y XHEMICYL-Y XHEMICYL+Z XHEMICYL-Z	YCYLINDER YHEMICYL+X YHEMICYL-X YHEMICYL+Z YHEMICYL-Z	CYLINDER ZCYLINDER ZHEMICYL+X ZHEMICYL-X ZHEMICYL+Y ZHEMICYL-Y	CUBE	CUBOID
dimensions	R (radius)	R +H -H	R +H -H	R +H -H	+X -X	+X -X +Y -Y +Z -Z
optional origin coord.*	Enter the X Y Z coord. of origin	Enter the Y Z coord. of centerline	Enter the X Z coord. of centerline	Enter the X Y coord. of centerline	Omit	Omit
optional chord data**	Enter the dist. to plane	Enter the dist. to plane	Enter the dist. to plane	Enter the dist. to plane	Omit	Omit

*Enter ORIG or ORIGIN for fgeom.
**Enter CHORD for fgeom.
NOTE: Chord data is not applicable for SPHERE, XCYLINDER, YCYLINDER, CYLINDER, ZCYLINDER, CUBE, or CUBOID. Origin data is not applicable for a CUBE or CUBOID.

Table C4.4.15 (continued)

Summary of geometry data (continued)

GEOMETRY (region) (cont.)

ENTER EXTENDED GEOMETRY DATA IN THE FOLLOWING FORM:

fgeom ref. ID bias ID thickness per region origin coordinates nreg

EXTENDED GEOMETRY REGION INPUT DATA REQUIREMENTS

TYPE OF DATA	TYPE 1 DATA	TYPE 2 DATA	TYPE 3 DATA
fgeom	ARRAY CORE COREBDY COREBNDS COREBOUN	HOLE	REPLICATE REFLECTOR
Ref. ID	Array no.	Emplaced unit number	Mixture no. in generated regions
Bias ID	Omit for ARRAY	Omit	First bias ID
Thick./reg.	Omit	Omit	Variable*
Origin coord.	Enter the X Y Z coord. of most neg. pt. of array	Enter the X Y Z coord.of origin	Omit
nreg	Omit	Omit	No. of regions to be generated

*The number of dimensions to be entered is the same as the region preceding the replicate or reflector specification because the generated regions have that shape. The value of the dimensions is the thickness of each generated region of material on that surface.

Table C4.4.15 (continued)

Summary of mixing table data

MIXTURES Format: READ MIXT xsec parameters END MIXT

Note: In CSAS, only xsec parameters should be entered. KENO V.a mixing table data consists of "xsec parameters" and a "mixing table." The "mixing" table" is used to define the materials used in the KENO V.a problem. This data is automatically created by CSAS and provided to KENO V.a. It cannot be overridden.

See Sects. F11.4.10 and F11.5.5.

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

Table C4.4.15 (continued)

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. F11.4.11 and F11.5.9

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.)
PIC=	MAT	Type of picture: MIXTURE, UNIT NO. or BIAS ID NO.
		MIXTURE ---------- MAT
		MIX
		MIXT
		MIXTURE
		MEDI
		MEDIA
		UNIT NO. ----------BOX
		BOXT
		BOXTYPE
		UNT
		UNIT
		UNITTYPE
		BIAS ID NO. ------- IMP
		BIAS
		BIASID
		WTS
		WEIG
		WEIGHTS
		WGT
		WGTS
XUL=	Prev. plot	X coord. of upper left corner of 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
YLR=	Prev. plot	Y coord. of lower right corner of plot
ZLR=	Prev. plot	Z coord. of lower right corner of plot

KEYWORD	DEFAULT	DEFINITION
UAX=	Prev. plot 0 IF VAX OR WAX is read	X component of direction cosine for the AX axis of the plot (across)
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
SCR=	NO	NO specifies a printer plot. If YES, a .gif file is generated for each plot
CLR=		Use only with SCR=YES to change colors. Input 4integers: 1st is index into color table, next 3 are the red, green, and blue color values

PLOT ORIGIN:

(1) SINGLE UNIT - coincides with origin of geometry description.

(2) BASE ARRAY - at the most negative point of the array (lower left-hand back corner of the global array).

(3) REFLECTED ARRAY - coincides with the origin of the CORE or ARRAY description of the global array.

**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 C4.4.15 (continued)
Summary of starting data

START Format: READ START enter start data here END START
The default value of start type is zero. See Sect. F11.4.8.

START TYPE	REQUIRED DATA	OPTIONAL DATA	STARTING DISTRIBUTION
0	None	NST	Uniform
		XSM	
		XSP	
		YSM	
		YSP	
		ZSM	
		ZSP	
		RFL	
		PSP	
1	NST	XSM	Cosine
		XSP	
		YSM	
		YSPO	
		ZSM	
		ZSP	
		RFL	
		PSP	
2	NST	XSM	Cosine with fraction in specified unit
	NXS	XSP	
	NYS	YSM	
	NZS	YSP	
	FCT	ZSM	
		ZSP	
		RFL	
		PSP	

START TYPE	REQUIRED DATA	OPTIONAL DATA	STARTING DISTRIBUTION
3	NST	KFS	Spike
	TFX	PSP	
	TFY		
	TFZ		
	NXS		
	NYS		
	NZS		
4	NST	KFS	Multiple spikes
	TFX	PSP	
	TFY		
	TFZ		
	NBX		
5	NST	PSP	In specified units
	NBX		
6	NST	NXS	Arbitrary points
	TFX	NYS	
	TFY	NZS	
	TFZ	KFS	
	LNU*	PS6	
		PSP	

KEYWORD	DEFAULT	DEFINITION
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=		Fission spectra
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.

C4.4.10 SEARCH DATA

Search data are required only for CSAS4 and CSAS4X. They are omitted for all other sequences. Search data are entered in the form:

READ SEARCH search data END SEARCH

The words READ SEARCH inform the code that search data are to be read, and the words END SEARCH terminate the search data. The search data options are described in Sects. C4.4.10.1 and C4.4.10.2. Additional information and examples are contained in Sects. C4.5.6 through C4.5.11.

C4.4.10.1 Search Type Specification

The basic search data to define the type of search and various search parameters that set limits for the search are described in this section. These data are listed in Table C4.4.16.

The desired search type must be specified in the search data before the individual search commands can be entered. The desired search type is specified only once in a problem. The data specifications are listed below.

1. Search descriptor

   Enter a word (OPTIMUM, CRITICAL, MINIMUM) to define the basic search mode. A default value is not supplied. The three basic search modes are:

   OPTIMUM initiates a search for the maximum value of k-effective.

   CRITICAL initiates a search for a specified value of k-effective.

   MINIMUM initiates a search for the minimum value of k-effective.

2. Search type

   Enter a word (PITCH, DIMENSION, CONCENTRATION) to specify the variable that is changed during the search. A default value is not supplied. The variables are:

   PITCH causes the pitch (center-to-center spacing in the x and y directions) to vary according to the search parameters.

   DIMENSION causes the dimensions in one or more geometry regions to vary according to the search parameters.

   CONCENTRATION causes the concentration of one or more standard composition materials to vary in one or more mixtures.

Table C4.4.16 Outline of search type specification

Entry number	Type of data	Data entry	Comments
1	Search descriptor	OPTIMUM	Initiates a search for the maximum value of k-effective
		CRITICAL	Initiates a search for a specified value of k-effective.
		MINIMUM	Initiates a search for the minimum value of k-effective
2	Search type	PITCH	Vary the pitch
		DIMENSION	Vary one or more dimensions in one or more regions
		CONCENTRATION	Vary the concentration of one or more standard compositions in one or more mixtures
3	Optional search parameters		Optional search parameters allow changing default values. Any or all may be entered in any order
3a	No. of search passes	PAS=	Enter the keyword PAS= followed by the desired number of search passes. Default=10
3b	No. of search parameters	NPM=	Enter the keyword NPM= followed by the number of search parameters. Present capability is limited to 1. Default=1
3c	Search convergence tolerance	EPS=	Enter the keyword EPS= followed by the desired convergence tolerance. Default=0.005
3d	Desired value of k-effective	KEF=	Enter the keyword KEF= followed by the desired value of k-effective. The default value is 1.000. DO NOT ENTER FOR OPTIMUM OR MINIMUM SEARCHES
3e	Maximum allowed pitch	MAXPITCH=	Enter the keyword MAXPITCH= followed by the maximum allowed pitch for a search whose search type, entry 2 above, is PITCH. The default value is the pitch corresponding to -5.0 times the parameter at the minimum possible pitch
3f	Minimum allowed pitch	MINPITCH=	Enter the keyword MINPITCH= followed by the minimum allowed pitch for a search whose search type, entry 2 above, is PITCH. The default value is the minimum possible pitch (i.e., the pitch at which the shapes in the array touch)
4	Additional search data	MORE	Enter the delimiter MORE. This delimiter ends the optional search commands and initiates the auxiliary search commands found in Table C4.4.17.

3. Optional search parameters

Optional search parameters are available for changing default values. They are specified by entering a keyword followed by the desired value. The optional search parameters are listed below.

3a. PAS= Number of search passes

The number of search passes is the maximum number of times the search will change data and calculate the corresponding k-effective. The default is 10.

3b. NPM= Number of search parameters

The number of search parameters is not fully implemented. The default value is 1 and should not be overridden.

3c. EPS= Search convergence tolerance

The search convergence tolerance is the search convergence criteria. OPTIMUM and MINIMUM searches are terminated when a k-effective is calculated that is within EPS of the optimum or minimum respectively. A CRITICAL search is terminated when a calculated k-effective is within EPS of the target or desired k-effective. The default value is 0.005.

3d. KEF= Desired value of k-effective

This information is entered ONLY for a CRITICAL search. The default value is 1.000.

3e. MAXPITCH= Maximum allowed pitch

The maximum allowed pitch (center-to-center spacing in the x and y directions) is specified using this keyword. It applies to a pitch search type and causes the search to terminate if the specified pitch is exceeded. The default value is the pitch corresponding to -5 times the parameter at the minimum pitch.

3f. MINPITCH= Minimum allowed pitch

The minimum allowed pitch (center-to-center spacing in the x and y directions) is specified using this keyword. It applies to a PITCH search type and causes the search to terminate if the pitch needs to be smaller than MINPITCH. The default value is the pitch at which the pins in the array are touching.

4. More additional search data will follow.

   The word MORE terminates the optional search parameters and initiates the individual search commands. Do not enter MORE unless individual search commands are to be entered.

C4.4.10.2 Auxiliary Search Commands and Constraints

Auxiliary search commands are entered ONLY if MORE, item 4, of the search type specification data were entered (see Table C4.4.16). Individual search commands are used to specify search constraints and to communicate to the search program. Searches can alter geometric dimensions (PITCH or DIMENSION Search) or alter concentrations (CONCENTRATION Search). A PITCH or DIMENSION search may require the user to specify the units that will be altered, the regions that will be altered within those units, and the faces or surfaces of those regions that will be altered. A CONCENTRATION search requires the user to specify the mixture, standard composition name, and the search constant for the component being altered.

The data comprising the auxiliary search commands are listed in Table C4.4.17. All data except items 1a, 1b, and 1c are keyworded (i.e., the data are entered by specifying a keyword, followed by a value). An explanation of each individual search command follows the table.

1. Command definition. A command definition tells the code what action is to be taken. A new search command is initiated whenever an item 1a through 1c is encountered. The code will vary the geometry according to subsequent commands.

1a. ALTER, CHANGE, MODIFY — Alter geometry regions. These words specify that modifications will be made to the geometry according to subsequent commands.

1b. MAINTAIN — Maintain the thickness. The thickness of the specified geometry region(s) will be maintained when the interior regions grow or shrink (i.e., the specified region will grow or shrink in conjunction with the interior region in such a way as to maintain the original distance between the two regions). This means that the original thickness of the region is preserved. For instance, the inner radius of a pipe can be altered and the wall thickness can be preserved by applying the MAINTAIN command to the region defining the outer radius of the pipe.

1c. KEEP HOLD — Keep the original specification. This command causes the specified geometry region(s) to be reset to their original input value for every search pass. Therefore they go through the entire search process unchanged.

2. PAR= — Parameter number. The search parameter number is not fully implemented. The default number is 1 and should not be overridden.

Table C4.4.17 Outline of auxiliary search commands and constraints

Entry number	Keyword name	Type of Data	Comments
GENERIC SEARCH DATA - May be used with all Search Types -			
1a	ALTER CHANGE MODIFY	Begin a new search command	These words are used to specify that modifications will be made to the geometry or concentration according to subsequent commands (entries 3 through 6 as required to specify the desired changes)
1b	MAINTAIN	Begin a new search command	The spacing (thickness) of the specified geometry regions will be maintained when the interior regions grow or shrink
1c	KEEP HOLD	Begin a new search command	This command resets the specified geometry to the original input specifications
2	PAR=	Parameter number	Enter the parameter number that the current command (ALTER, MAINTAIN, KEEP) applies to. The present capability is limited. Default=1 and should not be changed.
3	+CON=	Maximum constraint	Enter the maximum constraint for the current parameter. Default=+10E10
4	-CON=	Minimum constraint	Enter the minimum constraint for the current parameter. Default= -10E10
PITCH & DIMENSION SEARCH DATA - Defines Geometric Changes -			
5	UNIT=	Unit the current command applies to	Enter the unit in which regions are to be altered
6	REGION=	First region to be altered in the unit	Enter the first or only region in the unit that the search constants (entry 8a, b, c and/or d) apply to. Default is the first region
7	TO	Last region to be altered in the unit	Enter the last region in the unit that the search constants (entry 8a, b, c and/or d) apply to. Default is the first region NOTE: Entry 6 must be entered in order to alter a single region in a unit. Entries 6 and 7 must both be entered in order to alter more than one region in a unit
8	ALL=	Search constant for all surfaces (faces) of the region(s)	Enter a value for the search constants for the specified regions. This value will be applied to all surfaces of the region(s)
8a	+X=	Search constant for +X face of cuboid	Enter a value for the search constant for the +X face of a cuboid
	-X=	Search constant for -X face of cuboid	Enter a value for the search constant for the -X face of a cuboid
	+Y=	Search constant for +Y face of cuboid	Enter a value for the search constant for the +Y face of a cuboid
	-Y=	Search constant for -Y face of cuboid	Enter a value for the search constant for the -Y face of a cuboid
	+Z=	Search constant for +Z face of cuboid	Enter a value for the search constant for the +Z face of a cuboid
	-Z=	Search constant for -Z face of cuboid	Enter a value for the search constant for the -Z face of a cuboid
8b	RADIUS=	Search constant for radius	Enter a value for the search constant for the radius of a sphere or a cylinder
8c	+HEIGHT=	Search constant for + height	Enter a value for the search constant for the + height of a cylinder

Table C4.4.17 (continued)

CONCENTRATION SEARCH DATA			-Define concentration changes-
	-HEIGHT=	Search constant for -height	Enter a value for the search constant for the -height of a cylinder
8d	CHORD=	Search constant for chord	Enter a value for the search constant for the chord face of a hemisphere or hemicylinder
9	MIX=	Search constant for mixture	Enter the mixture number containing the standard composition to be changed.
10	SCNAME=	Search constant for Standard Composition	Enter the standard composition name whose density is to be changed.
11	FACTOR=	Search proportionality constant	Enter the value of the search constant for the concentration search.

3. +CON= Maximum constraint. Enter the maximum value you wish to allow the search parameter to obtain. The maximum constraint must be larger than the minimum constraint. See Sect. C4.5.6.2b for additional information on how to determine constraints. For a DIMENSION or PITCH search the default value of the maximum constraint is 10^{11}. For a CONCENTRATION search the default value of the maximum constraint is as follows:

+CON = min(-1/FACTOR), if any FACTOR < 0
+CON = -5*(-CON), if all FACTOR > 0

NOTE: For a PITCH search, the maximum constraint is redefined and is calculated from the data entered for MAXPITCH. +CON should not be entered if a value was entered for MAXPITCH. If constraints, +CON= and/or -CON= are not entered as data, the code computes the minimum constraint corresponding to the pins touching, and the maximum constraint is then negative five times the magnitude of the minimum constraint.

4. -CON= Minimum constraint. Enter the minimum value you wish to allow the search parameter to obtain. The minimum constraint must be smaller than the maximum constraint but need not be a negative number. See Sect. C4.5.6.2b for additional information on how to determine constraints. The default value of the minimum constraint for a dimension search is -10^{11}. The default value of the minimum constraint for a pitch search is redefined to correspond to the pins in the lattice touching. For a CONCENTRATION search the default value of the minimum constraint is as follows:

-CON = -5(+CON), if all FACTOR < 0
-CON = max(-1/FACTOR), if any FACTOR > 0

5. UNIT= Geometry unit number. This is the geometry unit to which the previously entered command definition (item 1a, 1b, or 1c) is applied. Items 5, 6, and 7 specify the region(s) within the unit and the surfaces of the region(s) to be altered.

6. REGION= First region to be altered. This is used to specify the first or only region in the unit (specified by item 5) that is to be altered according to the search command (item 1a, 1b, or 1c). The region(s) are altered according to the search constants (items 8a, 8b, 8c, and/or 8d).

7. TO Last region to be altered. This item is entered to specify the last region to be altered, starting with the region specified by REG=. For example, assume unit 3 contains 8 regions and you wish to make changes to regions 4, 5, 6, 7, and 8. These regions are identified by entering the following data. UNIT=3 REG=4 TO 8

Geometric search constants. A search constant is the proportionality factor utilized to alter a geometry region. A search constant must be entered for each surface of a region that is to be altered. A nonzero search constant will cause the region dimension for that surface to be changed. A search constant of 0.0 will cause the region dimension to remain unchanged. The default value of the search constant is 0.0.

8. ALL= Search constant for all surfaces. All of the surfaces in a region are altered simultaneously by using this search command.

8a. +X= Search constant for +X face. This parameter is used to specify the value of the search constant for the +X face of a cuboid.

-X= Search constant for -X face. This parameter is used to specify the value of the search constant for the -X face of a cuboid.

+Y= Search constant for +Y face. This parameter is used to specify the value of the search constant for the +Y face of a cuboid.

-Y= Search constant for -Y face. This parameter is used to specify the value of the search constant for the -Y face of a cuboid.

+Z= Search constant for +Z face. This parameter is used to specify the value of the search constant for the +Z face of a cuboid.

-Z= Search constant for -Z face. This parameter is used to specify the value of the search constant for the -Z face of a cuboid.

NOTE: If it is desirable to change all the faces of a cuboid except the -z face by some amount (search constant of 1.0), items 8a and 8b can be used together as follows: ALL=1.0 -Z=0.0. This is the same as entering +X=1.0 -X=1.0 +Y=1.0 -Y=1.0 +Z=1.0. If both z faces are to remain unchanged, items 8a and 8b can be entered as: ALL=1.0 +Z=0.0 -Z=0.0 or as +X=1.0 -X=1.0 +Y=1.0 -Y=1.0.

8b. RADIUS= Search constant for radius. This parameter is used to specify the value of the search constant for the radius of a sphere, hemisphere, cylinder, or hemicylinder.

8c. +HEIGHT= Search constant for +height. This parameter is used to specify the value of the search constant for the +height of a cylinder or hemicylinder.

-HEIGHT= Search constant for -height. This parameter is used to specify the value of the search constant for the -height of a cylinder or hemicylinder.

8d. CHORD= Search constant for chord. This parameter is used to specify the value of the search constant for the chord of a hemisphere or hemicylinder.

9. MIX= Search constant for mixture. This parameter is the mixture number containing the standard composition that is to be changed during the search.

10. SCNAME= Search constant for the standard composition name. This parameter is the standard composition name associated of the material that is to be changed during the search. Only compositions listed in Sect. M8.2 are allowed. Standard compositions beginning with SOLN and ARBM cannot be altered directly.

NOTE: If the standard composition name specified in the Material Information Data begins with SOLN and the Concentration Search Data specifies SCNAME=UO2(NO3)2, the amount of UO2(NO3)2 in the solution is altered but the amount of H2O and nitric acid is not altered during the search. The resulting mixture, when the search is finished, may no longer meet the criteria associated with the SOLN specification.

11. FACTOR= Concentration search factor used to specify the value of the search constant used in the concentration search. It is a proportionality factor used to alter the specified mixture standard composition. A search constant must be entered for each standard composition that is altered. A non-zero search constant will cause the concentration of the associated standard composition to be altered. The default value of the search constant is 1.0. A set of concentration search data consists of the mixture to be altered, the standard composition to be altered in the mixture, and the search factor. Keywords are used to enter the data. Each set of data consists of items 9, 10 and 11. The keywords used in this data may be entered using terse notation.

C4.5 NOTES FOR CSAS USERS

This section provides tips concerning the use of CSAS and its associated sequences. Section M7.5 provides information about the use of the Material Information Processor, and Sect. F11.7 provides assistance about the use of the KENO V.a data required by CSAS.

C4.5.1 CSAS MODULES

Several CSAS modules are contained in the CSAS family. These modules enable the user to generate and save working format cross sections for use with KENO IV, XSDRNPM, or KENO V.a, or a MORSE/KENO cross-section library for use with MORSE or KENO V.a. Therefore, the user can run different codes using the same cross-section library for comparison purposes. A list of the available modules is given below. Table C4.5.1 lists the I/O devices utilized by CSAS, and Table C4.5.2 lists the type of I/O files utilized by the functional modules invoked by CSAS.

The CSAS input data allow the user to define optional I/O files. The CSAS optional parameter data, Sect. C4.4.8, allow the user to define the following optional files: (1) the unit from which XSDRNPM may read fluxes, (2) the unit on which XSDRNPM may write fluxes, and (3) the unit on which ICE may write an ANISN library. The KENO V.a input data used by CSAS allow the user to define optional logical units used by KENO V.a. See "Logical Unit Numbers" in Sect. F11.4.3. The unit on which a KENO V.a restart data file is written should not be set to 95.

CSASN — Runs BONAMI and NITAWL-II and generates a working format cross-section library on unit 4. The user may save that library for future use or stack a KENO V.a or XSDRNPM problem after it with the input library specified as unit 4. If the user wishes to exercise XSDRNPM options that are not available in CSAS (such as a search or adjoint calculation), an XSDRNPM problem can be stacked immediately after the CSASN problem. When a KENO V.a problem is stacked after a CSASN problem, the parameter LIB=4 should be entered in the KENO V.a parameter data and a mixing table must be entered in order to utilize the working format library from CSASN.

CSAS1X — Runs BONAMI, NITAWL-II, and XSDRNPM. A cell-weighted working format cross-section library is written on unit 3. Note that any mixture utilized in the cell cannot be used in a subsequent KENO V.a calculation because the weighting applied to those mixtures is for the purpose of generating the cell-weighted cross section. This difficulty is circumvented by adding the same mixtures to the CSAS data with different mixture numbers. To utilize the cell-weighted library in a KENO V.a problem following a CSAS1X problem, LIB=3 should be entered in the KENO V.a parameter data, a mixing table must be entered, and the cell-weighted mixture can be used in the geometry.

Table C4.5.1 Description of units utilized by the Criticality Safety Analysis Sequence No. 4 control module

Unit number	Type of data	Creating module	User module	Type of file
5	Input	DRIVER	CSAS	Sequential
8	Scratch file	CSAS	CSAS	Direct or random access data
11	Short master cross-section library	CSAS	BONAMI	Sequential
16	Scratch file	CSAS	CSAS	Sequential
17	Scratch file	CSAS	CSAS	Sequential
18	Scratch file	CSAS	CSAS	Sequential
19	Scratch file	CSAS	CSAS	Sequential
70	User-supplied cross sections		CSAS	AMPX master format library
81	16-group cross sections		CSAS	AMPX master format library
82	27-group cross sections		CSAS	AMPX master format library
83	123-group cross sections		CSAS	AMPX master format library
84	218-group cross sections		CSAS	AMPX master format library
85	22 neutron-18 gamma cross sections		CSAS	AMPX master format library
86	18-gamma cross sections		CSAS	AMPX master format library
87	27-group cross sections for burnup		CSAS	AMPX master format library
88	27 neutron-18 gamma cross sections		CSAS	AMPX master format library
89	Standard Composition Library		CSAS	Direct- or random-access data file
90	Search data	CSAS	MODIFY	Direct or random access data
92	ICE input data	CSAS	ICE	Sequential
95	KENO V.a restart data	CSAS	KENO V.a	Sequential
		MODIFY	MODIFY	
		KENO V.a		
96	BONAMI input data	CSAS	BONAMI	Sequential
97	NITAWL-II input data	CSAS	NITAWL-II	Sequential
98	XSDRNPM input data	CSAS	XSDRNPM	Sequential
99	Printed output	CSAS MODIFY	CSAS MODIFY	Sequential

Table C4.5.2 Description of units used by the functional modules of CSAS

Unit No.	Module	Action	Type of file
1	BONAMI	WRITE	Microscopic master working format cross sections
	NITAWL-II	READ	Microscopic master working format cross sections
2	ICE	WRITE	Macroscopic working format cross sections
3	XSDRNPM	WRITE	Microscopic cell-weighted working format cross sections
	ICE	READ	Microscopic cell-weighted working format cross sections
	KENO V.a	READ	Microscopic cell-weighted working format cross sections
4	NITAWL-II	WRITE	Microscopic working format cross sections
	ICE	READ	Microscopic working format cross sections
	KENO V.a	READ	Microscopic working format cross sections
	XSDRNPM	READ	Microscopic working format cross sections
6	BONAMI	WRITE	Printed output
	ICE	WRITE	Printed output
	KENO V.a	WRITE	Printed output
	NITAWL-II	WRITE	Printed output
	XSDRNPM	WRITE	Printed output
8	BONAMI	WRITE/READ	Direct- or random-access scratch files
	ICE	WRITE/READ	Direct- or random-access scratch files
	KENO V.a	WRITE/READ	Direct- or random-access scratch files
	XSDRNPM	WRITE/READ	Direct- or random-access scratch files
9	BONAMI	WRITE/READ	Direct- or random-access scratch files
	ICE	WRITE/READ	Direct- or random-access scratch files
	KENO V.a	WRITE/READ	Direct- or random-access scratch files
	NITAWL-II	WRITE/READ	Direct- or random-access scratch files
	XSDRNPM	WRITE/READ	Direct- or random-access scratch files
10	ICE	WRITE/READ	Direct- or random-access scratch files
	KENO V.a	WRITE/READ	Direct- or random-access scratch files
	XSDRNPM	WRITE/READ	Direct- or random-access scratch files
11	BONAMI	READ	Short AMPX master format cross sections
14	ICE	WRITE	Monte Carlo-formatted macroscopic cross sections
	KENO V.a*	READ/WRITE	Monte Carlo-formatted macroscopic cross sections
16	KENO V.a	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Angular flux file

Table C4.5.2 (continued)

Unit No.	Module	Action	Type of file
17	XSDRNPM	WRITE/READ	Sequential scratch file
18	BONAMI	WRITE/READ	Sequential scratch file
	NITAWL-II	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Sequential scratch file
19	BONAMI	WRITE/READ	Sequential scratch file
	NITAWL-II	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Sequential scratch file
79	KENO V.a	READ	KENO V.a albedo file
80	KENO V.a	READ	KENO V.a weighting file
92	ICE	READ	Binary input file
95	KENO V.a	READ	Binary input file
96	BONAMI	READ	Binary input file
97	NITAWL-II	READ	Binary input file
98	XSDRNPM	READ	Binary input file

*KENO V.a always reads from unit 14. If microscopic input cross sections are used, KENO V.a prepares macroscopic cross sections and writes them on unit 14 to be read later.

CSASI — Runs BONAMI, NITAWL-II, and ICE. A working format library is written on unit 2, and a MORSE/KENO mixture cross-section library is written on unit 14. To utilize the MORSE/KENO library in a subsequent KENO V.a problem, the parameter XSC=14 must be entered in the KENO V.a parameter data, and the LIB= parameter should be omitted. The mixing table must be omitted, and the mixtures utilized in the geometry must match the mixtures specified in the CSASI data.

CSASIX — Runs BONAMI, NITAWL-II, XSDRNPM, and ICE. A working format library is written on unit 2, and a MORSE/KENO mixture cross-section library, including the cell-weighted mixture 500, is written on unit 14. To utilize the MORSE/KENO library in KENO V.a, the parameter XSC=14 must be entered in the KENO V.a parameter data, and the LIB= parameter should be omitted. The mixing table must be omitted, and the mixtures utilized in the geometry must match the mixtures specified in the CSASIX data.

CSAS25 — Runs BONAMI, NITAWL-II, and KENO V.a. A working format library is written on unit 4, and a MORSE/KENO mixture cross-section library is written on unit 14. Either or both of these libraries can be saved for future use. Because KENO V.a data are entered as part of the CSAS25 data, LIB= and XSC= should not be specified in the KENO V.a parameter data, and the mixing table should be omitted from the KENO V.a data. All KENO V.a options are available through CSAS25.

CSAS2X — Runs BONAMI, NITAWL-II, XSDRNPM, and KENO V.a. A working format library is written on unit 3, and a MORSE/KENO mixture cross-section library is written on unit 14. The cell-weighted mixture 500 is included on unit 14. Either or both of these libraries can be saved for future use. Because KENO V.a data are entered as part of the CSAS25 data, LIB= and XSC= should not be specified in the KENO V.a parameter data, and the mixing table should be omitted from the KENO V.a data. All KENO V.a options are available through CSAS2X. To process cross sections and run KENO V.a, CSAS25 should be used unless use of a cell-weighted mixture in KENO V.a is planned.

CSAS4 — Runs BONAMI, NITAWL-II, KENO V.a, and MODIFY. Use CSAS to perform an automatic search on dimensions or pitch. CSAS is an iterative procedure in which the KENO V.a geometry data is modified and KENO V.a is run until the convergence criteria is met or the problem runs out of time. A working format library is written on unit 4, and a MORSE/KENO mixture cross-section library is written on unit 14. Either or both of these libraries can be saved for future use. Because KENO V.a data are entered as part of the CSAS data, LIB= and XSC= should not be specified in the KENO V.a parameter data, and the mixing table should be omitted from the KENO V.a data. All KENO V.a options are available through CSAS. The search data follow the KENO V.a data.

CSAS4X — Runs BONAMI, NITAWL-II, XSDRNPM, KENO V.a, and MODIFY. Use CSAS4X for search problems where the geometry utilizes a cell-weighted cross section and an automatic search on the KENO V.a geometry dimensions or pitch is desired. The cell-weighted mixture or geometries cannot be modified as part of the search problem. CSAS4X is an iterative procedure in which KENO V.a geometry data are modified and KENO V.a is run until the

convergence criteria is met or the problem runs out of time. A working format library is written on unit 3, and a MORSE/KENO mixture cross-section library is written on unit 14. The cell-weighted mixture 500 is included on unit 14. Either or both of these libraries can be saved for future use. Because the KENO V.a data is entered as part of the CSAS data, LIB= and XSC= should not be specified in the KENO V.a parameter data, and the mixing table should be omitted from the KENO V.a data. All KENO V.a options are available through CSAS4X. The search data follows the KENO V.a data.

C4.5.2 AUTOMATIC CROSS-SECTION PROCESSING FOR CRITICALITY CALCULATIONS

The CSAS family of control modules can prepare an AMPX working format problem-dependent cross-section library for use by KENO V.a. CSAS25, CSAS2X, CSAS4, and CSAS4X can be used to prepare an AMPX working format cross-section library and run KENO V.a without the necessity of having to enter the mixing table data in KENO V.a. Examples are given in Sects. C4.5.2.1 through C4.5.2.4.

C4.5.2.1 Run KENO V.a Using CSAS25 or CSAS4

CSAS25 and CSAS4 create a microscopic working format library and a mixing table that is passed to KENO V.a. CSAS25 executes KENO V.a and calculates k-effective for the problem. CSAS4 executes KENO V.a repeatedly to perform a search as specified in the search data.

EXAMPLE 1. CSAS25 - Determine the k-effective of a system.

Consider a problem consisting of four uranium metal cylinders that are 93.2% wt enriched, having a density of 18.76 g/cc. The cylinders are arranged in a 2 × 2 × 2 array. Each has a radius of 5.748 cm and a height of 10.765 cm. The center-to-center spacing in the horizontal plane (X-Y) is 13.74 cm and the vertical center-to-center spacing is 13.01 cm. The input data for this problem follow. The calculated k-effective for this critical experiment was 0.9934 ± 0.0045.

```
=CSAS25
SET UP 2C8 IN CSAS25
HANSEN-ROACH    INFHOMMEDIUM
URANIUM  1 DEN=18.76 1 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2
END
END COMP
KENO V.a SAMPLE PROBLEM 1  CASE 2C8 BARE
READ PARAMETERS  TME=1.0 FLX=YES FDN=YES FAR=YES
END PARAMETERS
READ GEOMETRY
CYLINDER 1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.87 -6.87 6.87 -6.87 6.505 -6.505
END GEOMETRY
READ ARRAY  NUX=2 NUY=2 NUZ=2  END ARRAY
```

```
END DATA
END
```

EXAMPLE 2. CSAS - Determine the unit size for k-eff = 0.95.

Consider the problem of example 1 above. Determine the size of the uranium metal pieces that will yield a k-effective of 0.95 ± 0.005. Maintain the H/D ratio of the cylinders and the original center-to-center spacings. The input data are

```
=CSAS4
SET UP 2C8 IN CSAS25
HANSEN-ROACH   INFHOMMEDIUM
URANIUM  1 DEN=18.76 1 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
END COMP
CRITICAL DIMENSION SEARCH FOR CASE 2C8 BARE
READ PARAMETERS  TME=1.0 FLX=YES FDN=YES FAR=YES
END PARAMETERS
READ GEOMETRY
CYLINDER 1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.87 -6.87 6.87 -6.87 6.505 -6.505
END GEOMETRY
READ ARRAY  NUX=2 NUY=2 NUZ=2  END ARRAY
END DATA
READ SEARCH   CRITICAL DIMENSION KEF=0.95 EPS=0.005
MORE
ALTER  UNIT=1 REG=1  ALL=1.0
+CON=0.0  -CON= -0.25
END SEARCH
END
```

The calculated results for this search are the following:

```
SEARCH PASS1  KEFF=9.95561E-01  + OR -4.36660E-03  PARAMETER=  0.00000E+00
SEARCH PASS2  KEFF=6.69976E-01  + OR -3.95561E-03  PARAMETER= -2.50000E-01
SEARCH PASS3  KEFF=9.46110E-01  + OR -4.09973E-03  PARAMETER= -3.49840E-02
```

The final configuration for region 1 is:

```
CYLINDER  1 1  5.5469  5.1942  -5.1942
```

EXAMPLE 3. CSAS25 - Determine the k-effective of an array of fuel assemblies.

Consider a 4 × 4 × 1 array of fuel assemblies in a square aluminum cask. Each assembly consists of a 17 × 17 × 1 array of zirconium-clad, 2.35%-enriched UO_2 fuel pins in a square pitched array. The UO_2 has a density of 9.21 g/cc. The pin diameter is 0.8 cm and is 366 cm long. The clad is 0.07 cm thick, and the pitch is 1.3 cm. Each fuel bundle is contained in a 0.65-cm-thick boral sheath. The bundles are separated by an edge-to-edge spacing of 1 cm. The array of bundles is centered in a 10-cm-thick aluminum cask whose inside dimensions are 0.5 cm beyond the outer edges of the fuel bundles. Determine the k-effective of a dry cask. Input data for this cask follow. The calculated k-effective for this system is 0.7940 ± 0.0035.

```
=CSAS25
SQUARE FUEL CASK EXAMPLE
HANSEN-ROACH LATTICECELL
UO2  1 DEN=9.21 1.0 293. 92235 2.35 92238 97.65 END
ZR  2 1 END
H2O  3 1 END
B4C  4 0.367 END
AL  4 0.636 END
H2O  6 1 END
AL  5 1 END
END COMP
SQUAREPITCH  1.3 .8 1 3 .94 2 END
SQUARE FUEL CASK EXAMPLE USING DETAILED MOCKUP
READ PARAM  TME=12.0  NUB=YES FAR=YES GEN=153
END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN'
CYLINDER 1 1 0.4  2P183.0
CYLINDER 2 1 0.47 2P183.07
CUBOID   3 1 4P0.65 2P183.07
UNIT  2
COM='FUEL ASSEMBLY'
ARRAY  1 2R-11.05 -183.07
REPLICATE  4 1 6*0.65 1
REPLICATE  3 1 6*0.5 1
GLOBAL
UNIT 3
COM='FUEL CASK CONTAINING 4X4 ARRAY OF ASSEMBLIES'
ARRAY  2 2R-48.8 -184.22
REPLICATE 5 1 6R10.0 1
END GEOM
READ ARRAY ARA=1 NUX=17 NUY=17 NUZ=1 FILL F1 END FILL
ARA=2 NUX=4 NUY=4 NUZ=1 FILL F2 END FILL
END ARRAY
END DATA
END
```

EXAMPLE 4. CSAS - Determine the optimum pitch for an array of fuel assemblies

Consider the 4 × 4 × 1 array of fuel assemblies in a square aluminum cask described in example 3 above. Search for the assembly spacing that yields the maximum value of k-effective. Because the spacing between the assemblies is to be altered, the last region of unit 2 will be altered. In order to do this, the fuel assembly shroud cannot be defined as a replicate, because the code does not know the size of the array until later. In order to perform a pitch or dimension search, the code calculates the distance between the outermost region of the unit and the region interior to it. Therefore, the fuel assembly gap must be defined as a cuboid, and the water gap between assemblies can be entered as either a cuboid or a replicate. This search has been defined as an optimum dimension search. The calculated k-effectives for this system are listed after the following input data:

```
=CSAS4
SAMPLE FUEL CASK EXAMPLE
HANSEN-ROACH LATTICECELL
UO2  1 DEN=9.21 1.0 293. 92235 2.35 92238 97.65 END
ZR  2 1 END
H2O  3 1 END
B4C  4 0.367 END
AL  4 0.636 END
AL  5 1 END
END COMP
SQUAREPITCH  1.3 .8 1 3 .94 2 END
SQUARE FUEL CASK EXAMPLE WITH DETAILED MOCKUP
READ PARAM  TME=6.0  NUB=YES FAR=YES GEN=103
END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN'
CYLINDER 1 1 0.4  2P183.0
CYLINDER 2 1 0.47 2P183.07
CUBOID   3 1 4P0.65 2P183.07
NIT  2
COM='FUEL ASSEMBLY'
ARRAY  1 2R-11.05 -183.07
CUBOID  4 1 4P11.7 2P183.72
REPLICATE  3 1 6*0.5 1
GLOBAL
UNIT 3
COM='FUEL CASK CONTAINING 4X4 ARRAY OF ASSEMBLIES'
ARRAY  2 2R-48.8 -184.22
REPLICATE 5 1 6R10.0 1
END GEOM
READ ARRAY ARA=1 NUX=17 NUY=17 NUZ=1 FILL F1 END FILL
UARA=2 NUX=4 NUY=4 NUZ=1 FILL F2 END FILL
END ARRAY
END DATA
READ SEARCH  OPTIMUM DIMENSION MORE
ALTER UNIT=2 REG=3 +X=1 -X=1 +Y=1 -Y=1
+CON=0.204918      -CON= -0.0409836
END SEARCH
END
```

The calculated results for this search are:

```
SEARCH PASS 1 KEFF=7.9334-01 + OR - 4.0541-03  PARAMETER=  0.00000E+00
SEARCH PASS 2 KEFF=8.4564-01 + OR - 4.0814-03  PARAMETER= -4.09836E-02
SEARCH PASS 3 KEFF=6.6002-01 + OR - 4.0889-03  PARAMETER=  2.04918E-01
SEARCH PASS 4 KEFF=6.9373-01 + OR - 3.9071-03  PARAMETER=  1.02459E-01
SEARCH PASS 5 KEFF=8.1896-01 + OR - 3.8378-03  PARAMETER= -2.04918E-02
CONVERGENCE WAS ACHIEVED ON PASS 2
```

The corresponding geometry for unit 2 was:

```
ARRAY NUMBER 1 1 11.05 -11.05 11.05 -11.05 183.07 -183.07
CUBOID       4 1 11.70 -11.70 11.70 -11.70 183.72 -183.72
CUBOID       3 1 11.70 -11.70 11.70 -11.70 183.72 -183.72
```

The highest k-effective is achieved on PASS number two, when the fuel assemblies are touching.

An alternative method of entering the search data for this problem is to define the search as an optimum pitch search and require that the spacing of the fuel pin cells remain unchanged. Because a pitch search is always conducted at the lowest array level, in this case the spacing between the pins in the fuel assembly (the outer region of unit 1), it is necessary to countermand the automatic alteration of the outer region of unit 1 by entering the KEEP command. Search constants must be entered for the X and Y faces to instruct the code to KEEP those dimensions unchanged. It is easier to use the keyword ALL, which applies the KEEP command to all of the faces since the optimum pitch search would have changed only the X and Y faces leaving the Z faces unchanged. The ALTER command must then be entered to instruct the search to alter the spacing between the fuel assemblies (region 3 of unit 2). Only the X and Y dimensions are to be altered; so the search constants are entered individually for those dimensions. It is acceptable to enter ALL=1 +Z=0 -Z=0 rather than +X=1 -X=1 +Y=1 -Y=1. It is not necessary to enter the constraints for an optimum pitch search (+CON= and -CON=). They were entered in this case to ensure that the alternative data more nearly duplicate the optimum dimension search data of example 4. These alternative search data are:

```
READ SEARCH  OPTIMUM PITCH MORE
KEEP UNIT=1 REG=3 ALL=1
ALTER UNIT=2 REG=3 +X=1 -X=1 +Y=1 -Y=1
END SEARCH
```

C4.5.2.2 Run KENO V.a Using CSAS2X or CSAS4X

CSAS2X and CSAS4X create a microscopic working format library and a mixing table that is passed to KENO V.a. The microscopic cross sections of the nuclides used in the unit cell geometry description are cell- weighted for use in mixture 500. Mixture 500 utilizes the cell-weighted cross sections that represent the heterogeneous system. CSAS2X executes KENO V.a and calculates k-effective for the problem. CSAS4X executes KENO V.a repeatedly to perform a search as specified in the search data. Cell-weighted mixtures cannot be modified during the search problem.

EXAMPLE 1. CSAS2X - Calculate the k-effective of an array of fuel assemblies using cell-weighted cross sections.

Consider the 4 × 4 × 1 array of fuel assemblies in a square aluminum cask described in Sect. C4.5.2.1, example 3. Calculate the k-effective of the system by using the cell-weighted mixture 500 to represent the fuel pins in the fuel assembly. Note that mixtures 1, 2, and 3, representing UO_2, zirconium, and water, respectively, are used in the unit cell description. Cell-weighting is applied to the microscopic cross sections that are used in the cell, making them incorrect for use elsewhere. Because water is used both inside the cell and between the fuel assemblies, an additional mixture, mixture 6, has been added to represent the water between the fuel assemblies. The input data for this problem follow. The calculated k-effective is 0.79400 ± 0.0030.

```
=CSAS2X
SQUARE FUEL CASK EXAMPLE
HANSEN-ROACH LATTICECELL
UO2  1 DEN=9.21 1.0 293. 92235 2.35 92238 97.65 END
ZR  2 1 END
H2O  3 1 END
B4C  4 0.367 END
AL  4 0.636 END
AL  5 1 END
H2O  6 1 END
END COMP
SQUAREPITCH  1.3 .8 1 3 .94 2 END
SAMPLE SQUARE FUEL CASK USING HOMOGENEOUS MOCKUP
READ PARAM  TME=12.0  NUB=YES FAR=YES GEN=153
END PARAM
READ GEOM
UNIT  2
COM='FUEL ASSEMBLY'
CUBOID  500 1 4P11.05 2P183.07
REPLICATE  4 1 6*0.65 1
REPLICATE  6 1 6*0.5 1
GLOBAL
UNIT 3
COM='FUEL CASK CONTAINING 4X4 ARRAY OF ASSEMBLIES'
ARRAY  1 2R-48.8 -184.22
REPLICATE 5 1 6R10.0 1
END GEOM
READ ARRAY ARA=1 NUX=4 NUY=4 NUZ=1 FILL F2 END FILL
END ARRAY
END DATA
END
```

EXAMPLE 2. CSAS4X - Determine the optimum pitch for an array of fuel assemblies using cell-weighted cross sections.

Consider the 4 × 4 × 1 array of fuel assemblies in a square aluminum cask described using cell-weighted cross sections in example 3 above. Search for the assembly spacing that yields the maximum value of k-effective. The calculated k-effectives for this system are listed after the following input data.

```
=CSAS4X
SQUARE FUEL CASK EXAMPLE
HANSEN-ROACH LATTICECELL
UO2  1 DEN=9.21 1.0 293. 92235 2.35 92238 97.65 END
ZR  2 1 END
H2O  3 1 END
B4C  4 0.367 END
AL  4 0.636 END
AL  5 1 END
H2O  6 1 END
END COMP
SQUAREPITCH  1.3 .8 1 3 .94 2 END
SAMPLE SQUARE FUEL CASK USING HOMOGENIZED MOCKUP
READ PARAM  TME=5.0  NUB=YES FAR=YES GEN=103
END PARAM
READ GEOM
UNIT  2
COM='FUEL ASSEMBLY'
CUBOID  500 1 4P11.05 2P183.07
REPLICATE  4 1 6*0.65 1
REPLICATE  6 1 6*0.5 1
GLOBAL
UNIT 3
COM='FUEL CASK CONTAINING 4X4 ARRAY OF ASSEMBLIES'
ARRAY  1 2R-48.8 -184.22
REPLICATE 5 1 6R10.0 1
END GEOM
READ ARRAY ARA=1 NUX=4 NUY=4 NUZ=1 FILL F2 END FILL
END ARRAY
END DATA
READ SEARCH  OPTIMUM PITCH  END SEARCH
END
```

The calculated results for this search are:

```
SEARCH PASS 1 KEFF=7.9303-01 + OR - 3.6699-03  PARAMETER=  0.00000E+00
SEARCH PASS 2 KEFF=8.4365-01 + OR - 3.9363-03  PARAMETER= -4.09836E-02
SEARCH PASS 3 KEFF=6.5431-01 + OR - 3.9188-03  PARAMETER=  2.04918E-01
SEARCH PASS 4 KEFF=7.0925-01 + OR - 3.6657-03  PARAMETER=  1.02459E-01
CONVERGENCE WAS ACHIEVED ON PASS 2
```

The corresponding geometry for unit 2 was:

```
CUBOID 500 1 11.05 -11.05 11.05 -11.05 183.07 -183.07
CUBOID   4 1 11.70 -11.70 11.70 -11.70 183.72 -183.72
CUBOID   6 1 11.70 -11.70 11.70 -11.70 184.22 -184.22
```

Thus, the highest k-effective is achieved when the fuel assemblies are touching.

C4.5.2.3 Run XSDRNPM Using CSAS1X

XSDRNPM can be utilized to calculate the eigenvalue of a system without the necessity of manually preparing the cross sections and mixing table data by executing CSAS1X as shown in example 1 below.

EXAMPLE 1. CSAS1X - Calculate the eigenvalue of a system.

This example is a critical experiment of plutonium nitrate solution in a spherical stainless steel tank reflected by water. The plutonium is 95.4% wt ^{239}Pu, the remainder being ^{240}Pu. The fuel is a 0.52-M nitric acid solution of plutonium-nitrate, containing 24.4 g of heavy metal per liter of solution. Optional parameters were entered to decrease the number of mesh intervals and to use an S_4 calculation rather than S_8. The input data for this problem follow. The eigenvalue calculated by XSDRNPM is 1.00946.

```
=CSAS1X
CRITICAL PU(NO3)4 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER
HANSEN-ROACH  MULTIREGION
SOLNPU(NO3)4   1 24.4 .52 1 295 94239 95.4 94240 4.6 END
SS304  2 1.0  END
H2O  3 1  END
END COMP
SPHERICAL   VACUUM   REFLECTED   0   END
1 19.304 ONEEXTERMOD   2 19.426 ONEEXTERMOD   3 39.746 NOEXTERMOD
END ZONE
MORE DATA  ISN=4 SZF=1.5 END
END
```

C4.5.3 AUTOMATED CROSS-SECTION PREPARATION FOR USE BY SUBSEQUENT CODES

Many of the control modules available through the CSAS family of codes are used primarily to process cross sections for use by other codes. Some of these applications are described in the following subsections.

C4.5.3.1 Create a Microscopic AMPX Working Format Cross-Section Library for Use by KENO V.a

This example demonstrates the use of CSASN to create a microscopic, AMPX working format library on unit 4. KENO V.a can be executed as part of the same job and use the created cross sections, or the cross-section data set on unit 4 can be saved for later use. It should be noted that the cross-section library created by CSASN is a problem-dependent cross-section library containing only those nuclides specified in the problem. The resonance corrections applied to these cross sections are appropriate only for the specified problem. A simple demonstration of the use of CSASN to create the library and its use by KENO V.a is given in example 1.

EXAMPLE 1

Consider a problem consisting of four uranium metal cylinders that are 93.2% wt enriched, having a density of 18.76 g/cc. The cylinders are arranged in a 2 × 2 × 2 array. Each has a radius of 5.748 cm and a height of 10.765 cm. The center-to-center spacing in the horizontal plane (X-Y) is 13.74 cm, and the vertical center-to-center spacing is 13.01 cm. Use CSASN to create the microscopic, AMPX working format library for use by KENO V.a. The input data for this problem are:

```
=CSASN
CREATE A MICROSCOPIC AMPX WORKING FMT LIBRARY FOR 2C8
HANSEN-ROACH    INFHOMMEDIUM
URANIUM  1 DEN=18.76 1 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
END COMP
END
=KENOV
KENO V.A SAMPLE PROBLEM 1    CASE 2C8 BARE
READ PARAMETERS  TME=1.0 FLX=YES FDN=YES FAR=YES LIB=4
END PARAMETERS
READ MIXT MIX=1 92235 4.48006-2 92238 2.6578-3 92234 4.827-4
92236 9.57-5 END MIXT
READ GEOMETRY
CYLINDER 1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.87 -6.87 6.87 -6.87 6.505 -6.505
END GEOMETRY
READ ARRAY  NUX=2 NUY=2 NUZ=2  END ARRAY
END DATA
END
```

Note that the KENO V.a data given above are the same as those given in Sect. C4.5.2.1 except (1) the parameter data specify LIB=4 to instruct KENO V.a where to obtain the cross-section library and (2) the mixing table data must be supplied to KENO V.a. The number densities in the above data were hand-calculated. An easy method of obtaining the mixing table is to run the CSASN problem with PARM=CHECK, capture the output, and delete everything except the mixing table, which is shown in Fig. C4.5.1. This mixing table can then be edited into the correct format for the KENO V.a mixing table as shown in Figs. C4.5.2 and C4.5.3. Either of these mixing tables can be used in the place of the mixing table shown in example 1.

MIXTURE NO.	NUCLIDE NO.	ATOM DENSITY	N.I.T. POINTER
1	1092235	4.48072E-02	274
1	1092238	2.65827E-03	276
1	1092234	4.82825E-04	273
1	1092236	9.57448E-05	275

Figure C4.5.1 Mixing table from CSASN with PARM=CHECK

```
READ MIXT
MIX=1 1092235  4.48072E-02
      1092238  2.65827E-03
      1092234  4.82825E-04
      1092236  9.57448E-05
END MIXT
```

Figure C4.5.2 Mixing table from CSASN edited to KENO V.a format

```
READ MIXT
  MIX=1      1092235  4.48072E-02
  MIX=1      1092238  2.65827E-03
  MIX=1      1092234  4.82825E-04
  MIX=1      1092236  9.57448E-05
END MIXT
```

Figure C4.5.3 Mixing table from CSASN edited to KENO V.a format

C4.5.3.2 Create a Microscopic Cell-Weighted AMPX Working Format Cross-Section Library

EXAMPLE 1. Use CSAS1X to create a microscopic cell-weighted library.

This example demonstrates the use of CSAS1X to create a microscopic, cell-weighted, AMPX working format, cross-section library for use with KENO V.a. CSAS1X produces the microscopic, cell-weighted AMPX working format library on unit 3. All nuclides that are used in the mixtures specified in the unit cell are flux- weighted according to the characteristics of the unit cell and therefore should not be used in any mixtures utilized in KENO V.a other than the cell-weighted mixture. To utilize this cross-section library in KENO V.a, LIB=3 must be specified in the parameter data and an appropriate mixing table must be supplied. The input data for a CSAS1X problem follow:

```
=CSAS1X
PWR 15x15 LATTICECELL CALCULATION AT OPER. T&P
HANSEN-ROACH  LATTICECELL
UO2  1 0.95 1000.0 92235 3.3 92238 96.7 END
ZIRCALLOY  2 1.0 605.0 END
H2O  3 0.719 581.0 END
END COMP
SQUAREPITCH  1.430 0.92964 1 3 1.07188 2 0.94844 0 END
END
```

Because the printed mixing tables from CSASN and CSAS1X with PARM=CHECK do not contain mixing table data for the cell-weighted mixture, the number densities can be calculated by hand or another sequence (CSASIX or CSAS2X with PARM=CHECK) can be used to obtain the mixing table.

EXAMPLE 2. Use CSASIX to create a microscopic cell-weighted library.

A microscopic, cell-weighted, AMPX format library is created on unit 3 when CSASIX is run. The number densities of the cell-weighted mixture are volume averaged. To obtain the mixing table, CSASIX can be run with PARM=CHECK. The second mixing table (labeled COMPLETE MIXING TABLE) will contain the data for the cell-weighted mixture, but the mixture number will not be designated as mixture 500. Instead, it will be one larger than the largest mixture specified in the standard compositions data for the problem. In example 2, the cell-weighted mixture will be designated as mixture 4 in the complete mixing table.

The CSASIX data are the following:

```
=CSASIX
PWR 15x15 LATTICECELL CALCULATION AT OPER. T&P
HANSEN-ROACH  LATTICECELL
UO2  1 0.95 1000.0 92235 3.3 92238 96.7 END
ZIRCALLOY  2 1.0 605.0 END
H2O  3 0.719 581.0 END
END COMP
SQUAREPITCH  1.430 0.92964 1 3 1.07188 2 0.94844 0 END
END
```

The second mixing table from CSASIX is shown in Fig. C4.5.4. In this problem, mixtures 1, 2, and 3 are the only mixtures defined in the input data, and all of them are used in the unit cell description. The cell-weighted mixture is always one larger than the largest defined mixture number; in this case the cell-weighted mixture is mixture 4. All of the mixtures defined in the standard compositions data are used in the unit cell description. Therefore, all of the nuclides used in this problem are cell-weighted, and it is not valid to use them in any mixture other than the cell-weighted mixture. In Fig. C4.5.5, the cell-weighted mixture is mixture 4. In KENO V.a, LIB=3 must be specified in the parameter data in order to access the cell-weighted cross sections. The cell-weighted mixture is usually defined as mixture 500 in KENO V.a.

The mixing table shown in Fig. C4.5.4 can be edited for use in KENO V.a as shown in Fig. C4.5.5. Because mixtures 1, 2, and 3 were used in the unit cell description, they should not be used in KENO V.a. The mixing table shown in Fig. C4.5.4 can be edited by eliminating the ENTRY column and inserting MIX= in front of each mixture number, and inserting a READ MIXT at the beginning of the data and an END MIXT at the end of the data. Since mixtures 1, 2, and 3 should not be used in KENO V.a, they can be edited out as shown in Fig. C4.5.5, or they can be left in the mixing table and not used in the KENO V.a geometry. It should be noted that the easiest way to use a cell-weighted mixture in KENO V.a is to run CSAS2X and utilize mixture number 500 to designate the cell-weighted mixture in the KENO V.a geometry data so the user does not need to create a mixing table.

COMPLETE MIXING TABLE

MIXTURE NO.	NUCLIDE NO.	ATOM DENSITY
1	1092235	7.76007E-04
4	1092235	2.57581E-04
1	1092238	2.24522E-02
4	1092238	7.45257E-03
1	1008016	4.64564E-02
4	1008016	1.54203E-02
3	3008016	2.39971E-02
4	3008016	1.34078E-02
2	2040302	4.25156E-02
4	2040302	4.07230E-03
3	3001001	4.79943E-02
4	3001001	2.68156E-02

Figure C4.5.4 Second mixing table from CSASIX

```
READ MIXT     MIX=500
1092235       2.57581E-04
1092238       7.45257E-03
1008016       1.54203E-02
3008016       1.34078E-02
2040302       4.07230E-03
3001001       2.68156E-02
END MIXT
```

Figure C4.5.5 Mixing table from CSASIX edited to KENO V.a format

EXAMPLE 3. Use CSASIX to create a microscopic cell-weighted library with extra mixtures.

This example is identical to example 2 except water and Zircaloy are to be used in the KENO V.a geometry description in addition to the cell-weighted mixture. The temperature of this water and Zircaloy is 450 K. Note that even if the temperatures of the water and Zircaloy were identical to the temperatures specified for the mixtures that are used in the LATTICECELL description, they would have to be specified again with a different mixture number in order to use them in the KENO V.a geometry data. The input data for this example are the following:

```
=CSASIX
PWR 15X15 LATTICECELL CALCULATION AT OPER. T&P
HANSEN-ROACH  LATTICECELL
UO2  1 0.95 1000.0 92235 3.3 92238 96.7 END
ZIRCALLOY  2 1.0 605.0 END
H2O  3 0.719 581.0 END
```

```
ZIRCALLOY  4 1.0 450.0 END
H2O  5 0.847 450.0 END
END COMP
SQUAREPITCH  1.430 0.92964 1 3 1.07188 2 0.94844 0 END
END
```

In this example, the cell-weighted mixture will be identified as mixture 7. The mixing tables from CSASIX are shown in Fig. C4.5.6. In order to use the microscopic, cell-weighted, cross-section library in KENO V.a, LIB=3 must be specified in the KENO V.a parameter data because the CSAS sequences whose names contain an X write the microscopic, cell-weighted, cross-section library on unit 3. The appropriate mixing table for KENO V.a can be created by capturing and editing the COMPLETE MIXING TABLE. The order of scatter should be specified in the KENO V.a mixing table. KENO V.a always defaults to P1 scattering, but CSAS sets the order of scattering based on the cross-section library (presently P1 for the Hansen-Roach 16-group library and P3 for all other libraries). In KENO V.a the order of scattering is set using the parameter SCT= in the mixing table data. The resultant mixing table is shown in Figs. C4.5.7 through C4.5.9 below. In Fig. C4.5.7 all of the entries from the CSASIX COMPLETE MIXING TABLE have been edited to conform to the KENO V.a format. In the CSASIX output, mixture 6 is the cell-weighted mixture. Its mixture number has been changed to 500, but it is not necessary to do so. CSASIX, CSAS2X, and CSAS4X automatically label the cell-weighted mixture cross section as mixture 500 on the macroscopic, cross-section library. This example arbitrarily redefined mixture 6 to be mixture 500 so a user would recognize that cell-weighted cross sections were used in the geometry. MIXTURES 1, 2, AND 3 SHOULD NOT BE USED IN THE KENO V.a GEOMETRY DATA BECAUSE THEY HAVE BEEN FLUX-WEIGHTED OVER THE CELL TO CREATE A CELL-WEIGHTED CROSS SECTION THAT ALLOWS THE HETEROGENEOUS SYSTEM TO BE REPRESENTED AS A HOMOGENEOUS MATERIAL.

In Fig C4.5.8, mixtures 1, 2, and 3 have been removed because they should not be used in the KENO V.a geometry description.

MIXING TABLE FROM STANDARD COMPOSITIONS DATA

MIXTURE NO.	NUCLIDE NO.	ATOM DENSITY	N.I.T. POINTER
1	1092235	7.76007E-04	274
1	1092238	2.24522E-02	276
1	1008016	4.64564E-02	21
3	3008016	2.39971E-02	21
5	5008016	2.39971E-02	21
2	2040302	4.25156E-02	95
4	4040302	4.25156E-02	95
3	3001001	4.79943E-02	4
5	5001001	4.79943E-02	4

COMPLETE MIXING TABLE

MIXTURE NO.	NUCLIDE NO.	ATOM DENSITY
1	1092235	7.76007E-04
6	1092235	2.57581E-04
1	1092238	2.24522E-02
6	1092238	7.45257E-03
1	1008016	4.64564E-02
6	1008016	1.54203E-02
3	3008016	2.39971E-02
6	3008016	1.34078E-02
5	5008016	2.82692E-02
2	2040302	4.25156E-02
6	2040302	4.07230E-03
4	4040302	4.25156E-02
3	3001001	4.79943E-02
6	3001001	2.68156E-02
5	5001001	5.65385E-02

Figure C4.5.6 Mixing tables from CSASIX

```
READ MIXT       SCT=1
  MIX=1         1092235         7.76007E-04
  MIX=500       1092235         2.57581E-04
  MIX=1         1092238         2.24522E-02
  MIX=500       1092238         7.45257E-03
  MIX=1         1008016         4.64564E-02
  MIX=500       1008016         1.54203E-02
  MIX=3         3008016         2.39971E-02
  MIX=500       3008016         1.34078E-02
  MIX=5         5008016         2.82692E-02
  MIX=2         2040302         4.25156E-02
  MIX=500       2040302         4.07230E-03
  MIX=4         4040302         4.25156E-02
  MIX=3         3001001         4.79943E-02
  MIX=500       3001001         2.68156E-02
  MIX=5         5001001         5.65385E-02
END MIXT
```

Figure C4.5.7 KENO V.a mixing table using all CSASIX entries

```
READ MIXT       SCT=1
  MIX=500       1092235         2.57581E-04
  MIX=500       1092238         7.45257E-03
  MIX=500       1008016         1.54203E-02
  MIX=500       3008016         1.34078E-02
  MIX=5         5008016         2.82692E-02
  MIX=500       2040302         4.07230E-03
  MIX=4         4040302         4.25156E-02
  MIX=500       3001001         2.68156E-02
  MIX=5         5001001         5.65385E-02
END MIXT
```

Figure C4.5.8 KENO V.a mixing table using only mixtures 4, 5, and 6 from CSASIX

```
READ MIXT       SCT=1
 MIX=4          4040302         4.25156E-02
 MIX=5          5008016         2.82692E-02
                5001001         5.65385E-02
 MIX=500        1092235         2.57581E-04
                1092238         7.45257E-03
                1008016         1.54203E-02
                3008016         1.34078E-02
                2040302         4.07230E-03
                3001001         2.68156E-02
END MIXT
```

Figure C4.5.9 Condensed KENO V.a mixing table using only mixtures 4, 5, and 6 from CSASIX

The mixing table shown in Fig. C4.5.9 has been abbreviated by reordering the data to group all of the components of a mixture together and specifying the mixture number only once for each mixture.

C4.5.3.3 Create a Macroscopic, AMPX Working Format, Cross-Section Library and a Macroscopic, MORSE/KENO, Cross-Section Library

Example 1 illustrates the use of CSASI to produce a macroscopic, AMPX working format, cross-section library on unit 2 for use by KENO V.a. The ID numbers in this library are the mixtures specified in the standard composition data. To utilize this library in KENO V.a, LIB=2 must be entered in the parameter data, and a mixing table must be provided. The mixing table nuclide ID numbers are the mixture numbers used in the CSASI problem. The number density is a multiplication factor applied to the macroscopic cross sections. Entering a number density of 1.0 causes the cross sections to remain unchanged. Consider a CSASI problem that defines three mixtures and mixture 2 is full-density water. If KENO V.a is to use these cross sections and needs to use half-density water in addition to all of the other defined mixtures, mixture 4 can be defined as half-density water, and the mixing table for KENO V.a would be:

```
READ MIXT MIX=1 1 1.0 MIX=2 2 1.0 MIX=3 3 1.0 MIX=4 2 0.5 END MIXT
```

LIB=2 would be entered in the parameter data.

EXAMPLE 1

Consider a problem that consists of four 20.96-kg, 93.2% enriched uranium metal cylinders, density 18.76 g/cc, and four 5-l Plexiglas bottles filled with highly enriched uranyl nitrate solution at 415 g/l, a specific gravity of 1.555, and 0.39 mg of excess nitrate per gram of solution. The isotopic content of the uranium metal is 93.2% wt ^{235}U, 5.6% wt ^{238}U, 1.0% wt ^{234}U, and 0.2% wt ^{236}U. The uranium isotopic content of the nitrate solution is 92.6% wt ^{235}U, 5.9% wt ^{238}U, 1.0% wt ^{234}U, and 0.5% wt ^{236}U. Each metal unit has a diameter of 11.496 cm, a height of 10.765 cm, and an edge-to-edge spacing of 1.684 cm horizontally and 1.685 cm vertically. The uranyl nitrate solution is contained in a Plexiglas cylinder having an ID of 19.05 cm and an inside height of 17.78 cm. The Plexiglas walls are 0.635 cm thick. The solution units have an edge-to-edge

spacing of 1.43 cm horizontally and vertically. The center-to-center spacing between the metal and solution units is 17.465 cm.

CSASI creates a macroscopic, AMPX working format library on unit 2 and a macroscopic, MORSE/KENO library on unit 14. To use the macroscopic, AMPX working format library in KENO V.a, enter LIB=2 in the parameter data, and enter the following mixing table:

READ MIXT MIX=1 1 1.0 MIX=2 2 1.0 MIX=3 3 1.0 END MIXT

The total input data to run CSASI, followed by KENO V.a are given below:

```
=CSASI
SET UP 4AQUEOUS 4 METAL IN CSAS25
HANSEN-ROACH    INFHOMMEDIUM
URANIUM         1 0.985 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
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
PLEXIGLAS       3 END
END COMP
END
=KENOV
KENO VA    4 AQUEOUS 4 METAL MIXED UNITS USING CSASI MACRO WORKING LIBR
READ PARAM  FLX=YES FDN=YES  TME=2.0 LIB=2
END PARAM
READ MIXT MIX=1 1 1.0 MIX=2 2 1.0 MIX=3 3 1.0 END MIXT
READ GEOM
BOX TYPE 1
CYLINDER  2 1 9.525 8.89 -8.89
CYLINDER  3 1 10.16 9.525 -9.525
CUBOID  0 1 10.875 -10.875 10.875 -10.875 10.24 -10.24
BOX TYPE  2
CYLINDER  1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.59 -15.16 6.59 -15.16 6.225 -14.255
BOX TYPE  3
CYLINDER  1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.59 -15.16 15.16 -6.59 6.225 -14.255
BOX TYPE  4
CYLINDER  1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.59 -15.16 6.59 -15.16 14.255 -6.225
BOX TYPE  5
CYLINDER  1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.59 -15.16 15.16 -6.59 14.255 -6.225
END GEOM  READ ARRAY  NUX=2 NUY=2 NUZ=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
END DATA
END
```

Example 2 illustrates the use of CSASI to produce a macroscopic, MORSE/KENO format, cross-section library on unit 14 for use by KENO V.a. The ID numbers in this library are the mixtures specified in the standard composition data. To utilize this library in KENO V.a, XSC=14 must be entered in the parameter data, and a mixing table is not provided. The mixtures used in the KENO V.a geometry must correspond to the mixtures defined in the CSASI data.

EXAMPLE 2

Consider the problem described in example 1. Produce a macroscopic, MORSE/KENO format, cross-section library on unit 14 for use by KENO V.a. To utilize this library in KENO V.a, XSC=14 must be entered in the parameter data, and a mixing table is not provided. The mixture numbers used in the KENO V.a geometry must correspond to the mixtures defined in the standard composition data of CSASI. The input data required to run this problem are the following:

```
=CSASI
SET UP 4AQUEOUS 4 METAL IN CSAS25
HANSEN-ROACH    INFHOMMEDIUM
URANIUM         1 0.985 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
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
PLEXIGLAS       3 END
END COMP
END
=KENOV
KENO VA    4 AQUEOUS 4 METAL MIXED UNITS USING CSASI MACRO WORKING LIBR
READ PARAM  FLX=YES FDN=YES  TME=2.0 XSC=14
END PARAM
READ GEOM
BOX TYPE 1
CYLINDER  2 1 9.525 8.89 -8.89
CYLINDER  3 1 10.16 9.525 -9.525
CUBOID  0 1 10.875 -10.875 10.875 -10.875 10.24 -10.24
BOX TYPE  2
CYLINDER  1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.59 -15.16 6.59 -15.16 6.225 -14.255
BOX TYPE  3
CYLINDER  1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.59 -15.16 15.16 -6.59 6.225 -14.255
BOX TYPE  4
CYLINDER  1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.59 -15.16 6.59 -15.16 14.255 -6.225
BOX TYPE  5
CYLINDER  1 1 5.748 5.3825 -5.3825
CUBOID  0 1 6.59 -15.16 15.16 -6.59 14.255 -6.225
END GEOM  READ ARRAY  NUX=2 NUY=2 NUZ=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
END DATA
END
```

The cross-section libraries created by CSASI are

1. a macroscopic AMPX working format library on unit 2,
2. a macroscopic MORSE/KENO format library on unit 14, and
3. a microscopic AMPX working format library on unit 4.

C4.5.3.4 Create a Macroscopic, Cell-Weighted, AMPX Working Format Library and a Macroscopic, Cell-Weighted, MORSE/KENO Library

This section illustrates the use of CSASIX to produce cell-weighted, macroscopic libraries for use with a subsequent code. The problem-dependent cross-section libraries created by CSASIX are:

1. A macroscopic, cell-weighted, AMPX working format library on unit 2.
   To use this library in KENO V.a, set LIB=2 in the parameter data and enter a mixing table using the mixture numbers as the nuclide ID's and number densities of 1.0.

2. A microscopic, cell-weighted, AMPX working format library on unit 3.
   To use this library in KENO V.a, set LIB=3 in the parameter data and enter a mixing table using the appropriate nuclide IDs and number densities. If the cell-weighted mixture is to be used, its component nuclides and correct number densities must be included in the mixing table.

3. A microscopic, AMPX working format library on unit 4.
   To use this library in KENO V.a, set LIB=4 in the parameter data and enter the mixing table data. None of the cross sections in this library are cell weighted.

4. A macroscopic cell-weighted MORSE/KENO format library on unit 14.
   To use this library in KENO V.a, set XSC=14 in the parameter data and omit LIB. Do not provide a mixing table. The cell-weighted cross section is mixture 500.

Example 1 shows the use of the macroscopic, cell-weighted, AMPX working format library. Example 2 shows the use of the macroscopic, cell-weighted, MORSE/KENO library.

EXAMPLE 1

This example illustrates the use of CSASIX to create a cell-weighted macroscopic library for use in KENO V.a. The CSASIX data define the materials used to describe a flooded 3 × 3 array of PWR fuel assemblies. The center-to-center spacing between the assemblies is 12 cm. Each fuel assembly is a 17 × 17 array of fuel pins contained in a 0.29-cm-thick boral sheath. The fuel is 3.2% enriched UO_2, density = 10.41 g/cc. The fuel OD is 0.819 cm, the gap OD is 0.836 cm, and the clad OD is 9.50 cm. The fuel pin pitch is 1.26 cm. The fuel pin length is 375 cm.

Note that the cell-weighted macroscopic library is specified in KENO V.a by entering LIB=2 in the parameter data and entering mixing table data. The KENO V.a geometry uses mixture 500 to represent the homogenized pin cells inside each fuel assembly. Unit 1 in the geometry describes the fuel assembly and the spacing cuboid

that define the center-to-center spacing between assemblies. Unit 2 defines the water-reflected array of fuel assemblies. Because mixture 3 was used in the unit cell definition in CSASIX, another water, mixture 5, was defined to be used in the KENO V.a geometry because mixtures 1, 2, and 3 have been cell-weighted and cannot be used in the geometry. The input data are the following:

```
=CSASIX
FLOODED PWR FUEL ASSEMBLY (17x17) AT ROOM TEMP
27GROUPNDF4  LATTICECELL
UO2  1  DEN=10.41 1.0 293. 92235 3.2 92238 96.8 END
ZIRCALLOY  2  1.0  END
H2O  3  1.0  END
ARBMTL-B4C  2.64  2  1  1  0  5000  4  6012  1  4  0.015  END
ARBMTL-AL  2.64  1  0  0  0  13027  100.0  4  0.985  END
H2O    5  1.0  END
END COMP
SQUAREPITCH  1.26 0.819 1 3 0.950 2 0.836 0 END
END
=KENOV
3 X 3 ARRAY OF FLOODED FUEL ASSEMBLIES
READ PARAM LIB=2  TME=5.0  END PARAM
READ MIXT MIX=1 1 1.0 MIX=2 2 1.0 MIX=3 3 1.0 MIX=4 4 1.0 MIX=5 5 1.0
END MIXT
READ GEOM
UNIT 1
COM='HOMOGENIZED FUEL ASSEMBLY'
CUBOID  500 1 4P10.71 375.0 0.0
CUBOID    4 1 4P11.0  375.29 -0.29
CUBOID    5 1 4P12.0  375.29 -0.29
GLOBAL UNIT 2
COM='WATER REFLECTED 3X3 ARRAY OF FUEL ASSEMBLIES'
ARRAY 1 3*0.0
REPLICATE 5 2 6P3.0 10
END GEOM
READ ARRAY  ARA=1 NUX=3 NUY=3 NUZ=1 FILL F1 END FILL END ARRAY
READ BIAS ID=500 2 11 END BIAS
END
```

EXAMPLE 2

This example is the same as example 1 except the KENO V.a problem will use the macroscopic, MORSE/KENO library. The input data for CSASIX and KENO V.a are given below. Note that XSC=14 is specified in the KENO V.a data, and a mixing table is not entered. However, the mixture numbers used in the geometry correspond to the mixture numbers defined in the standard composition library. Because water, mixture 3, was used in the unit cell definition in CSASIX, another water, mixture 5, has to be defined to be used in the KENO V.a geometry because mixture 3 has been cell-weighted along with mixtures 1 and 2. The input data follow:

```
=CSASIX
FLOODED PWR FUEL ASSEMBLY (17x17) AT ROOM TEMP
27GROUPNDF4  LATTICECELL
UO2  1  DEN=10.41 1.0 293. 92235 3.2 92238 96.8 END
```

```
ZIRCALLOY  2  1.0  END
H2O  3  1.0  END
ARBMTL-B4C  2.64  2  1  1  0  5000  4  6012  1  4  0.015  END
ARBMTL-AL  2.64  1  0  0  0  13027  100.0  4  0.985  END
H2O    5  1.0  END
END COMP
SQUAREPITCH  1.26 0.819 1 3 0.950 2 0.836 0 END
END
=KENOV
3 X 3 ARRAY OF FLOODED FUEL ASSEMBLIES USING MORSE/KENO LIBRARY
READ PARAM XSC=14 TME=5.0  END PARAM
READ GEOM
UNIT 1
COM='HOMOGENIZED FUEL ASSEMBLY'
CUBOID  500 1 4P10.71 375.0 0.0
CUBOID    4 1 4P11.0  375.29 -0.29
CUBOID    5 1 4P12.0  375.29 -0.29
GLOBAL UNIT 2
COM='WATER REFLECTED 3X3 ARRAY OF FUEL ASSEMBLIES'
ARRAY 1 3*0.0
REPLICATE 5 2 6R3.0 10
END GEOM
READ ARRAY  ARA=1 NUX=3 NUY=3 NUZ=1 FILL F1 END FILL END ARRAY
READ BIAS ID=500 2 11 END BIAS
END
```

C4.5.4 CREATE AND USE TWO CELL-WEIGHTED MIXTURES IN A PROBLEM

Consider a problem in which a stainless steel cylinder with an ID of 56 cm and an inside height of 91 cm is filled with pellets of UO_2 in borated water. The steel is 0.125 cm thick. The spherical 2.57%-enriched UO_2 pellets have a diameter of 1.07 cm and are arranged in a triangular pitch array with a pitch of 1.13 cm. The spherical 2.96%-enriched UO_2 pellets have a diameter of 1.07 cm and are arranged in a triangular pitch array with a pitch of 1.12 cm. The cylindrical tank is filled half full of the 2.96% pellets in borated water, and the remainder is filled with the 2.57%-enriched pellets in borated water.

Example 1 demonstrates how this problem can be calculated by running a CSASIX case for each of the pellet arrays, combining the macroscopic, AMPX working format, cell-weighted libraries using the AMPX module WAX to combine the two libraries. The combined AMPX working format library can then be used to run the KENO V.a problem. It should be noted that this procedure cannot be stacked together to run in a single SCALE execution because the second CSASIX would destroy the library created by the first CSASIX. Example 2 demonstrates how to add an additional WAX step to move the library created by the first CSASIX so that the steps can be stacked together to run in a single SCALE execution.

EXAMPLE 1

STEP 1. Run CSASIX to obtain a macroscopic, cell-weighted, AMPX working format library on unit 2. The mixture 500 on this library represents the 2.57%- enriched pellets in borated water. The input data for this step are given below. The user must save the library that is created on unit 2. The input data are

```
=CSASIX
2.57% ENR UO2 PELLETS IN 3500 PPM BORATED WATER
27GROUPNDF4  LATTICECELL
UO2    1  .925  283 92235 2.57 92238 97.43 END
H2O  2 1.0 283 END
ARBMBACID  2.0017-2 3 1 1 0 5000 1 1001 3 8016 3  2  1.0
         283 5010 18.32 5011 81.68 END
END COMP
SPHTRIANGP 1.13 1.07  1  2 END
END
```

STEP 2. Run CSASIX to obtain a macroscopic, cell-weighted, AMPX working format library on unit 2. The mixture 500 on this library represents the 2.96%-enriched pellets in borated water. The input data for this step are given below. The user must save the library that is created on unit 2. Note that the problem that is to be run by KENO V.a must have stainless steel available to define the cylindrical container. Therefore, stainless steel must be defined in one of the CSASIX problems. The input data are the following:

```
=CSASIX
2.96% ENR UO2 PELLETS IN 3500 PPM BORATED WATER
27GROUPNDF4  LATTICECELL
UO2    1  .925  283 92235 2.96 92238 97.04 END
H2O  2 1.0 283 END
ARBMBACID  2.0017-2 3 1 1 0 5000 1 1001 3 8016 3  2  1.0
         283 5010 18.32 5011 81.68 END
SS304 3 1.0 283 END
END COMP
SPHTRIANGP 1.12   1.07  1  2 END
END
```

STEP 3. Run WAX to combine the macroscopic, cell-weighted, AMPX working format libraries and rename the mixture 500s to distinguish between them. In this case, mixture 500 for the 2.57%-enriched pellets has been renamed to 501 and mixture 500 for the 2.96%-enriched pellets has been renamed to 502. The 2.57% library is mounted on unit 33, the 2.96% library is mounted on unit 34, and the combined library is written out on unit 4. It is not necessary to rename both of the mixture 500s. One of them can be carried through as 500; the other one, as some other number. WAX can be used to rename all of the mixtures on the library. The cell-weighted mixture created by the CSAS modules is always mixture 500, but WAX can be used to rename it to any desired number. The mixture numbers on the WAX library are the nuclide ID numbers that must be used in the KENO V.a mixing table when multiple cell-weighted mixtures are used.
The user must save the library that is created on unit 4 so that it will be available for use in KENO V.a. The input data follow:

```
=WAX
0$$ 4 34
1$$ 2   1T
2$$ 33 1  2T
3$$ 500
4$$ 501     3T
2$$ 34 2  2T
3$$ 3 500
```

```
4$$ 3 502   3T
END
```

STEP 4. Use the combined macroscopic, AMPX working format library to run KENO V.a. Use mixture 501 for the homogenized, cell-weighted, 2.57%-enriched pellets, and use mixture 502 for the homogenized, cell-weighted, 2.96%-enriched pellets. The KENO V.a data are:

```
=KENOV
PROBLEM USING TWO CELL_WEIGHTED MIXTURES (502 IS 2.96% & 501 IS 2.57%)
READ PARAM  FLX=YES LIB=4    END PARAM
READ MIXT  MIX=3 3 1.0 MIX=501 501 1.0  MIX=502 502 1.0 END MIXT
READ GEOM
CYLINDER 502 1 38.0 45.5 0.0
CYLINDER 501 1 38.0 91.0 0.0
CYLINDER   3 1 38.125 91.0 -0.125
END GEOM
END DATA
END
```

Alternatively, KENO V.a could have been set up to define mixtures 1 and 2 as the cell-weighted mixtures as follows:

```
=KENOV
PROBLEM USING TWO CELL_WEIGHTED MIXTURES (502 IS 2.96% & 501 IS 2.57%)
READ PARAM  FLX=YES LIB=4    END PARAM
READ MIXT  MIX=3 3 1.0 MIX=1 501 1.0  MIX=2 502 1.0 END MIXT
READ GEOM
CYLINDER   2 1 38.0 45.5 0.0
CYLINDER   1 1 38.0 91.0 0.0
CYLINDER   3 1 38.125 91.0 -0.125
END GEOM
END DATA
END
```

EXAMPLE 2

This example is the same as example 1 except a WAX step has been added to move the library created by the first CSASIX from unit 2 to unit 12 so that the steps can be stacked together and run in a single SCALE execution. Because all of the steps are stacked together, unit 12 is used instead of unit 33 because unit 12 is defined in the SCALE procedure and will be automatically passed to the next step. The SCALE input data are:

```
=CSASIX
2.57% ENR UO2 PELLETS IN 3500 PPM BORATED WATER
27GROUPNDF4  LATTICECELL
UO2    1  .925  283 92235 2.57 92238 97.43 END
H2O  2 1.0 283 END
ARBMBACID  2.0017-2 3 1 1 0 5000 1 1001 3 8016 3  2  1.0
         283 5010 18.32 5011 81.68 END
END COMP
SPHTRIANGP 1.13 1.07  1  2 END
END
=WAX
```

```
0$$ 12 2
1$$ 1   1T
2$$ 2  1  2T
3$$ 500
4$$ 500     3T
END
=CSASIX
2.96% ENR UO2 PELLETS IN 3500 PPM BORATED WATER
27GROUPNDF4  LATTICECELL
UO2    1  .925  283 92235 2.96 92238 97.04 END
H2O  2 1.0 283 END
ARBMBACID  2.0017-2 3 1 1 0 5000 1 1001 3 8016 3  2  1.0
         283 5010 18.32 5011 81.68 END
SS304 3 1.0 283 END
END COMP
SPHTRIANGP 1.12   1.07  1  2 END
END
=WAX
0$$ 4  2
1$$ 2   1T
'RENAME MIXTURE 500 TO MIXTURE 501
2$$ 12 1  2T
3$$ 500
4$$ 501     3T
'RENAME MIXTURE 500 TO MIXTURE 502.  MIXTURE 3 REMAINS MIXTURE 3
2$$ 2  2  2T
3$$ 3 500
4$$ 3 502   3T
END
=KENOV
PROBLEM USING TWO CELL-WEIGHTED MIXTURES (502 IS 2.96% & 501 IS 2.57%)
READ PARAM  FLX=YES LIB=4    END PARAM
READ MIXT  MIX=3 3 1.0 MIX=501 501 1.0  MIX=502 502 1.0 END MIXT
READ GEOM
CYLINDER 502 1 38.0 45.5 0.0
CYLINDER 501 1 38.0 91.0 0.0
CYLINDER   3 1 38.125 91.0 -0.125
END GEOM
END DATA
END
```

C4.5.5 CREATE A CELL-WEIGHTED MIXTURE REPRESENTING A NONHOMOGENEOUS FUEL ASSEMBLY

Calculate the k-effective of a 3 × 3 × 3 array of the fuel assembly shown in Fig. C4.5.10. The spacing between the assemblies is 2 cm and is filled with water. The array is reflected by 31 cm of water on all faces. Each assembly is a 15 × 15 array of fuel pins with 16 water holes and a central instrumentation hole. The fuel pins are 1.98%-enriched UO_2 at 10.138 g/cc and are 0.94 cm in diameter. The active fuel length is 365.76 cm. The zircaloy-4 clad is 0.545 cm OR × 0.4875 cm IR. The fuel rod pitch is 1.44 cm.

The fuel assembly shrouds are 0.16-cm-thick 304 stainless steel. The IDs are 21.6 cm in cross section. The interstices between the rods are filled with water.

To obtain the correct cell-weighted cross sections for this assembly, run CSASIX to define the cell-weighted fuel pin cell. Then run XSDRNPM to account for the water holes.

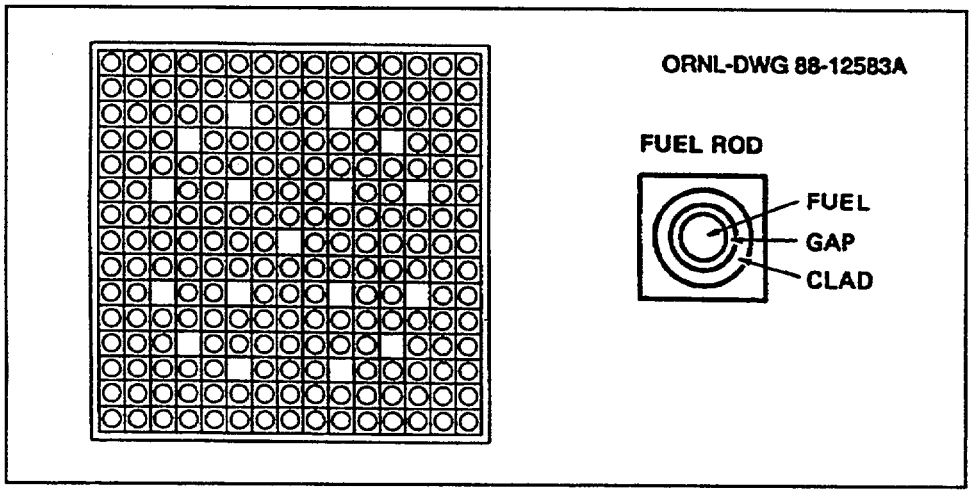


Figure C4.5.10 1.98% enriched UO_2 fuel assembly

The input data for CSASIX are given below. Mixtures 1, 2, and 3 are used in the unit cell description, causing them to be cell-weighted and therefore unacceptable for use by a subsequent code. The cross sections for the stainless steel shroud and water holes must be defined so they will be available for use by a subsequent code, XSDRNPM in this case. Mixture 4 is the stainless steel for the fuel assembly shroud, and mixture 5 is the water for the instrumentation hole and water holes. XSDRNPM will create a cell-weighted cross section representing the interior of the fuel assembly. This procedure will use the cell-weighted cross section from CSASIX and the mixture 5 water. Therefore mixture 5 will be cell-weighted and cannot be used in a subsequent code. Since water is to be used in the KENO V.a calculation that uses the cell-weighted cross sections from XSDRNPM, a mixture 6 that is identical to mixtures 3 and 5 must be added to the CSASIX data. The input data follow:

```
=CSASIX
CREATE CELL WEIGHTED CROSS SECTION FOR FUEL PIN CELL
27GROUPNDF4  LATTICECELL
UO2         1 .925     293 92235 1.98 92238 98.02 END
ZIRCALLOY   2 1.0      293 END
```

```
H2O          3 1.0      293 END
SS304        4 1.0      293 END
H2O          5 1.0      293 END
H2O          6 1.0      293 END
END COMP
SQUAREPITCH  1.44 .94 1 3 1.09 2 .975 0 END
END
```

The input data for XSDRNPM are given below. Each assembly contains 225 units, 17 of which are water holes (the instrumentation hole is treated as a water hole). The geometry for XSDRNPM is an infinite cylinder of water having an area equal to the area of the central instrumentation hole. The ratio of fuel to water in the assembly is (225-17)/17; so the area of the fuel region surrounding the water is (225-17)/17 times the area of the water region. The OR of the water hole is 0.81243 cm, and the OR of the fuel region is 2.95566 cm. XSDRNPM will use the macroscopic, cell-weighted, cross-section library that was created by CSASIX on unit 2 and will create a new macroscopic cell-weighted cross-section library on unit 3 as specified in the 0$$ array. Note that XSDRNPM will process only those mixtures that are used in the problem. All mixtures that are to be passed through XSDRNPM for use by a subsequent code must be included in every mixture used in XSDRNPM and should have a very small number density (1.0-20). Therefore, mixtures 4 and 6 must be added to both the water (mixture 5 from CSASIX) and the cell-weighted pin cell mixture (mixture 500 from CSASIX) with a negligible number density. The macroscopic, cell-weighted, cross-section library from CSASIX is read from unit 2, and the resultant cell-weighted cross-section library is written on unit 3. The 3$$ array must specify that a weighting calculation is to be done.

```
=XSDRNPM
USE CELL WTD PIN CELL XSECS AND CREATE CELL WTD FUEL ASSMBLY XSECS
0$$ A3 2 E
1$$  2 2 20 1 3 4 6 8 3 1 E
2$$  A7 -1 E
3$$  1 E
4$$  -1 27 E  1T
13$$   1   2  1 2 1 2
14$$   5 500  4 4 6 6
15** 1.0 1.0  4R1.-20   2T
33## F1.0 4T
35** 9I0 9I0.812433 2.95566
36$$ 10R1 10R2
51$$ 25I1 27 5T
END
```

The input data for KENO V.a are given below. The cell-weighted cross-section library is read from unit 3. This library contains mixtures 5, 500, 4, and 6. Mixtures 5 and 500 have been cell-weighted to represent the heterogeneous fuel assembly. To create a cell-weighted mixture that represents the fuel assembly, the number densities associated with mixtures 5 and 500 are their respective volume fractions in the fuel assembly. In this problem, mixture 1 is the homogenized fuel assembly mixture. Mixture 4 is the stainless steel shroud, and mixture 6 is water. The number density is 1.0 for mixtures 4 and 6.

```
=KENOVA
WATER REFLECTED 3X3X3 ARRAY OF HOMOGENIZED FUEL ASSEMBLIES
READ PARAM LIB=3 TME=10 END PARAM
READ MIXT MIX=1 5 0.075556 500 0.924444  MIX=4 4 1.0 MIX=6 6 1.0 END MIXT
READ GEOM
UNIT 1
COM='CELL-WEIGHTED HOMOGENIZED FUEL ASSEMBLY WITH ZIRCALLOY SHROUD
AND H2O'
CUBOID 1 1 4P10.8 365.76 0.0
REPLICATE 4 1 6R0.16 1
REPLICATE 6 1 6R1.0 1
GLOBAL UNIT 2
ARRAY 1 3*0.0
REPLICATE 6 2 6R3.0 10
END GEOM
READ ARRAY NUX=3 NUY=3 NUZ=3 FILL F1 END FILL END ARRAY
READ BIAS ID=500 2 11 END BIAS
END DATA
END
```

C4.5.6 SEARCH DATA

Search data must be entered for CSAS4 and CSAS4X. The search data enable the code to perform a search according to the instructions specified by the user. The code begins reading search data when it encounters the words READ SEARCH and continues reading search data until it encounters the words END SEARCH. Search data consist of the search type specification and auxiliary search commands.

C4.5.6.1 Search Type Specification

These data are used to define the type of search and to set the parameters that provide limits for the search. The search type specification data consist of (a) a search descriptor, (b) the search type, and (c) optional search parameters as described below.

C4.5.6.1a SEARCH DESCRIPTOR is used to define the search mode.
Use OPTIMUM if the maximum value of k-effective is to be determined.
Use CRITICAL if a specified value of k-effective is to be obtained.
Use MINIMUM if the minimum value of k-effective is to be determined.

C4.5.6.1b SEARCH TYPE is used to specify the variable that is to be changed during the search procedure.
Use PITCH to alter the center-to-center spacing between the units at the lowest array level. By default only the spacing in the X and Y directions will be altered.
Use DIMENSION to alter the dimensions of one or more geometry regions.
Use CONCENTRATION to alter the concentration of one or more standard compositions in one or more mixtures.

The combination of the search descriptor and the search type defines the search method. An OPTIMUM PITCH search will search for the pitch that gives the maximum value of k-effective. By default only the X and Y spacing will be altered. Auxiliary search commands can be used to instruct the code to also vary the z spacing. An OPTIMUM DIMENSION search will alter the dimensions of one or more

geometry regions in accordance with the specified auxiliary search commands and determine the maximum value of k-effective. An OPTIMUM CONCENTRATION search alters the concentration of standard compositions in mixtures in accordance with specified search commands to determine the maximum value of k-effective. A CRITICAL PITCH search alters the spacing between units in the same manner as an optimum pitch search to achieve the specified value of k-effective. A CRITICAL DIMENSION search alters the dimensions of one or more geometry regions in accordance with the specified auxiliary search commands to achieve the specified value of k-effective. A CRITICAL CONCENTRATION search alters the concentration of standard compositions in mixtures in accordance with the specified auxiliary search commands to achieve the specified value of k-effective. A MINIMUM PITCH search will search for the pitch that gives the minimum value of k-effective. A MINIMUM DIMENSION search alters the dimensions of one or more geometry regions in accordance with the specified auxiliary search commands to achieve the minimum value of k-effective. A MINIMUM CONCENTRATION search alters the concentration of standard compositions in mixtures according to the specified auxiliary search commands to determine the miniimum value of k-effective. Only one combination of SEARCH DESCRIPTOR and SEARCH TYPE is allowed in a problem.

C4.5.6.1c OPTIONAL SEARCH PARAMETERS are entered after the SEARCH DESCRIPTOR AND SEARCH TYPE and are used to alter the default values of the optional search parameters. Only one set of optional search parameters can be entered for a problem. The optional search parameters are listed below.

PAS=nn is used to set the maximum number of times the search will calculate k-effective. The first pass calculates the k-effective corresponding to the initial geometry dimensions. The second pass calculates the k-effective corresponding to one of the constraints, and the third pass often corresponds to the other constraint. The default value of nn is 10.

NPM=nn is used to set the number of search parameters. The default value is 1 and should not be overridden.

EPS=ff is used to set the search convergence tolerance (the amount by which k-effective is allowed to vary from the desired k-effective). An optimum or minimum search is terminated when the calculated k-effective is within EPS of the optimum or minimum value as indicated by the mathematical fit to the calculated points. A critical search is terminated when the calculated k-effective is within EPS of the specified k-effective. The default value of ff is 0.005.

KEF=ff is used only for a critical search and is used to specify the desired value of k-effective. The default value of ff is 1.000.

MAXPITCH=ff is allowed ONLY for a PITCH search. It is used to specify the maximum allowed pitch (center-to-center spacing in the x and y directions) between units in an array. The search will terminate if the specified pitch is exceeded. The default value of ff is the pitch corresponding to -5 times the parameter that corresponds to the minimum pitch. It is much easier to specify a maximum allowed pitch than to calculate the appropriate value of the maximum constraint.

MINPITCH=ff is allowed ONLY for a PITCH search. It is used to specify the minimum allowed pitch (center-to-center spacing in the x and y directions) between the units in an array. The search will terminate if the pitch becomes smaller than the specified minimum pitch. The default value of ff is the pitch at which the region immediately inside the spacing region touches the spacing region. It is much easier to specify the minimum allowed pitch than to calculate the appropriate value of the minimum constraint.

MORE is used to terminate the optional search parameters and initiate the auxiliary search commands. Do not enter MORE unless auxiliary search commands are to be entered.

C4.5.6.2 Auxiliary Search Commands

Auxiliary search commands are entered ONLY if the word MORE was entered in the search type specification data. These data are used to define the method the search will use to alter the geometry data and to set the constraints for the parameter search. The auxiliary search commands consist of (1) INDIVIDUAL SEARCH COMMANDS and (2) SEARCH PARAMETER CONSTRAINTS.

C4.5.6.2a An INDIVIDUAL SEARCH COMMAND consists of (1) a command definition, (2) the geometry unit number, (3) the region(s) to be altered, and (4) search constants for each dimension that is to be altered in the specified region(s). A series of individual search commands can be entered for a problem to govern the search process. A new search command is initiated whenever a command definition, item (1) above, is encountered.

The COMMAND DEFINITION tells the code what action is to be taken for a specified geometry region or range of regions. ALTER, CHANGE, or MODIFY are used to cause the specified geometry region(s) to be modified. MAINTAIN is used to maintain the thickness of the specified geometry region(s). KEEP or HOLD are used to cause the specified geometry region(s) to be reset to its original value. Terse input allows the user to truncate words (ALTER, KEEP, MODIFY, MAINTAIN, KEEP, HOLD) as desired. However, sufficient characters must be specified to uniquely define it. For example, an M is not sufficient to distinguish between MODIFY and MAINTAIN. The available command definitions are listed below.

ALTER
CHANGE
MODIFY The list of commands to the left are command definitions, item (1) above. These commands are used to instruct the code to make changes to the specified geometry region(s). The regions that are to be changed are specified using items (2) and (3) above. The amount of change is governed by the search constants, item (4) above.

MAINTAIN The list of commands to the left are command definitions, item (1) above. These commands are used to instruct the code to maintain the thickness of the specified region(s) noted in items (2) and (3) above. The search constants, item (4) above, must be nonzero to cause the thickness of the region(s) to be preserved. It should be noted that the thickness of a region can be maintained using this command ONLY when the interior boundary of the region is being altered. If the exterior boundary is being altered, the code is unable to maintain the thickness between it and the boundary interior to it. For example, consider a spherical stainless steel tank with a wall thickness of 1/4 in., filled with a fissile solution. Region 1 is a sphere of solution, and region 2 is the stainless steel. If the search data specifies that region 1 is to be altered and region 2 is to be maintained, the search will maintain a tight-fitting, 1/4-in.-thick, stainless steel region around the fissile solution sphere as it changes sizes. However, if the search data specify only that region 2 is to be altered, the size of the solution sphere will be unchanged and the thickness of the stainless steel spherical shell will vary. If the search data specify that region 1 is to be maintained and region 2 is to be altered, the size of the solution sphere will remain unchanged and the thickness of the stainless-steel container will vary. If the search data specify only that region 2 is to be maintained, no changes will be made and neither region will be changed.

KEEP
HOLD The list of commands to the left are command definitions, item (1) above. These commands are used to instruct the code to preserve the **original** dimensions of the specified region(s) noted in items (2) and (3) above. The search constants, item (4) above, must be nonzero in order to preserve the original dimensions of the region(s).

THE GEOMETRY UNIT NUMBER, item (2) above, is used to define the unit or box type that contains the geometry region(s) to which the command definition pertains. The geometry unit number is specified by entering the keyword UNIT= followed by the desired unit number.

UNIT=nn is used to define the geometry unit to which the previously entered command definition is to be applied. The keyword **UNIT=** is entered, followed by the unit number, nn. There is no default value of nn.

THE REGION(S) TO BE ALTERED, item (3) above, defines the region(s) in unit nn to which the command definition pertains. A single geometry region is specified by entering the keyword REG=, followed by the desired region number, nn. A range of regions is specified by entering the keyword REG=, followed by the first region to which the search commands pertain. The last region in the range is specified by entering the keyword TO and the last region of the range.

REG=nn is used to define the first geometry region to which the previously entered command definition is to be applied. The keyword REG= is entered, followed by the region number, nn. There is no default value of nn.

TO mm is used to define the final geometry region of the range to which the previously entered command definition applies. The keyword TO is entered, followed by the last region number of the range, mm. There is no default value of mm.

For example, if region 3 of unit 2 is to be altered, items 1, 2, and 3 would be entered as:

```
ALTER UNIT=2 REG=3
```

If regions 3, 4, 5, and 6 of unit 2 are to be altered, items 1, 2, and 3 would be entered as:

```
ALTER UNIT=2 REG=3 TO 6
```

THE SEARCH CONSTANTS, item (4) above, are proportionality factors that are applied to the specified dimensions of the specified region(s) to which the command definition applies. The search constants define both the dimension to which the search command pertains and the value of the corresponding search constant. Search constants are entered by using a keyword to define the appropriate dimension, followed by a proportionality constant, pc. The default value of pc is 0.0. A nonzero value of pc causes the dimension(s) specified by the keyword to have the search command applied to it. A list of search constant keywords follows.

ALL= is used to define the search constant for all of the dimensions of the region or range of regions defined by items (2) and (3) above. ALL= changes the +X, -X, +Y, -Y, +Z, and -Z dimensions of a cuboid; the radius and +Height and -Height of a cylinder; and the radius of a sphere.

+X= is used to define the search constant for the positive X dimension of a cuboid.

-X= is used to define the search constant for the negative X dimension of a cuboid.

+Y= is used to define the search constant for the positive Y dimension of a cuboid.

-Y= is used to define the search constant for the negative Y dimension of a cuboid.

+Z= is used to define the search constant for the positive Z dimension of a cuboid.

-Z= is used to define the search constant for the negative Z dimension of a cuboid.

R= is used to define the search constant for the radius of a sphere or a cylinder.

+H= is used to define the search constant for the positive height of a cylinder.

-H= is used to define the search constant for the negative height of a cylinder.

CH= is used to define the search constant for the chord of a hemisphere or hemicylinder.

ENTERING AUXILIARY SEARCH COMMANDS IN THE SEARCH DATA

EXAMPLE 1

Consider an example in which region 2 of unit 1 is a cuboid and all of the dimensions of the cuboid are to be altered. The search data could be entered as:

```
    ALTER  UNIT=1  REG=2  ALL=1.0
or
    ALTER  UNIT=1  REG=2  +X=1.0  -X=1.0  +Y=1.0  -Y=1.0  +Z=1.0  -Z=1.0
```

Because all of the search constants are nonzero, all of the dimensions will be changed. Because the search constants are identical, the original relationship between the dimensions will be preserved as they are altered.

For example, if region 2 of unit 1 is a cylinder and if all the dimensions of the cylinder are to be altered, the search data could be entered as:

```
    ALTER  UNIT=1  REG=2  ALL=1.0
or
    ALTER  UNIT=1  REG=2  R=1.0  +H=1.0  -H=1.0
```

Because all of the search constants are nonzero, all of the dimensions will be changed. Because the search constants are identical, the original relationship between the dimensions will be preserved as they are altered. If the original height-to-diameter ratio is 1.5, that ratio will be preserved throughout the search only if the search constants for the radius and + and - height are identical.

Search constants can be entered sequentially with each new entry overriding only identical previous entries. For example, if region 2 of unit 1 is a cuboid and if all of the dimensions except the -Z dimension are to be altered, the search data could be entered as:

```
    ALTER  UNIT=1  REG=2  +X=1.0  -X=1.0  +Y=1.0  -Y=1.0  +Z=1.0
or
    ALTER  UNIT=1  REG=2  ALL=1.0 -Z=0.0
```

In the second example, all of the search constants corresponding to the cuboid's dimensions are set to 1.0 by using the ALL= command. This includes the -Z dimension. To reset the search constant for the -Z dimension to zero, -Z=0.0 is added following the ALL=1.0 command. If the search commands are reversed, -Z=0.0 ALL=1.0, the -Z dimension will also be altered because the -Z portion of the ALL= command will override the previously entered -Z=0.0 command.

EXAMPLE 2

A search command must be entered for each unit and region specification. Consider a problem having units 1, 2, and 3. Unit 1 consists of 3 concentric spheres in a cuboid. Unit 2 consists of a single sphere in a cuboid, and unit 3 contains 3 concentric cuboids. A search is to be made that changes the exterior dimensions of the 3 units, the inner sphere of unit 1, and the sphere of unit 2. The thicknesses of the outer spheres of unit 1 are to be maintained, and the two inner cuboids of unit 3 are to remain unchanged. The search data for this problem can be entered as follows:

```
ALTER UNIT=1 REG=1 ALL=1.0
ALTER UNIT=1 REG=4 ALL=1.0
ALTER UNIT=2 REG=1 TO 2 ALL=1.0
```

```
ALTER UNIT=3 REG=3 ALL=1.0
MAINTAIN UNIT=1 REG=2 TO 3 ALL=1.0
```

C4.5.6.2b SEARCH PARAMETER CONSTRAINTS set the parameter limits for the search. The minimum constraint is the minimum value of the parameter allowed in the search. The maximum constraint is the maximum value of the parameter allowed in the search. The initial geometry configuration corresponds to a parameter value of 0.0. A physical limit occurs when the value of the parameter causes geometry intersections. Constraints should be entered for a DIMENSION search.

For a DIMENSION search, the constraints are given by Eqs. (C4.5.1) and (C4.5.2):

$$C_{min} = ((D_{min}/D_i) - 1.0)/SC \qquad \text{(C4.5.1)}$$

$$C_{max} = ((D_{max}/D_i) - 1.0)/SC\,, \qquad \text{(C4.5.2)}$$

where

C_{min} is the minimum constraint for the search

C_{max} is the maximum constraint for the search

D_{min} is the minimum allowed dimension for the search [For a chord, $D_{min} = (Radius_{min} + Chord_{min})/2\ Radius_{min}$]

D_{max} is the maximum allowed dimension for the search [For a chord, $D_{max} = (Radius_{max} + Chord_{max})/2\ Radius_{max}$]

D_i is the initial dimension [For a chord, $D_i = (Radius_{initial} + Chord_{initial})/2\ Radius_{initial}$]

SC is the search constant for that dimension

For example, the initial radius of a sphere is 6 cm, and a search is to be conducted to determine the radius at which the sphere is critical. The minimum radius the user wishes to allow is 3 cm, and the maximum radius to be allowed is 9 cm. A nonzero search constant must be entered to cause the radius to be changed. A search constant of 1.0 will be used for the radius. The constraints calculated from Eqs. (C4.5.1) and (C4.5.2) are:

$C_{min} = ((3.0/6.0)-1.0)/1.0 = -0.5$

$C_{max} = ((9.0/6.0)-1.0)/1.0 = 0.5$

The constraints would be entered in the problem by entering the following data:

```
-CON=-0.5   +CON=0.5
```

For a PITCH search, the minimum constraint defines the limit for shrinking the system, and the maximum constraint defines the limit for expanding the system:

$$C_{min} = \underset{i=1}{\overset{i=\text{number of faces}}{MAX}} \left[D_+, D_- \right] \text{ for shrinking}$$

$$C_{max} = \underset{i=1}{\overset{i=\text{number of faces}}{MIN}} \left[D_+, D_- \right] \text{ for expanding}$$

where

C_{min} is the minimum constraint,
C_{max} is the maximum constraint,
D_+ are face constraints for the positive dimensions,
D– are face constraints for the negative dimensions.

Face constraints must be calculated for each face using Eqs. (C4.5.3) and (C4.5.4):

$$D_+ = \frac{(X_{d+} - X_{i+})(SC_+ \times del_+ + SC_- \times del_-)}{(X_{i+} - X_{i-})(SC_+ **2 \times del_+)}, \qquad \text{(C4.5.3)}$$

$$D_- = \frac{-(X_{d-} - X_{i-})(SC_+ \times del_+ + SC_- \times del_-)}{(X_{i+} - X_{i-})(SC_- **2 \times del_-)}, \qquad \text{(C4.5.4)}$$

where

X_{d+} is the desired limit of the positive dimension of the spacing cuboid in that direction (positive dimension of X, Y, or Z, whichever dimension is under consideration)

X_{i+} is the initial positive dimension of the spacing cuboid in that direction (positive dimension of X, Y, or Z, whichever dimension is under consideration)

X_{d-} is the desired limit of the negative dimension of the spacing cuboid in that direction (negative dimension of X, Y, or Z, whichever dimension is under consideration)

X_{i-} is the initial negative dimension of the spacing cuboid in that direction (negative dimension of X, Y, or Z, whichever dimension is under consideration)

SC_+ is the search constant for the positive dimension of the spacing cuboid in that direction (positive dimension of X, Y, or Z, whichever dimension is under consideration)

SC_- is the search constant for the negative dimension of the spacing cuboid in that direction (negative dimension of X, Y, or Z, whichever dimension is under consideration)

NOTE: Using a search constant of 1.0 simplifies the determination of C_{max} and C_{min} when the dimensions are to change proportionately.

del_+ is the initial distance from the spacing cuboid to the closest interior region in the positive direction (positive dimension of X, Y, or Z, whichever dimension is under consideration)

del_- is the initial distance from the spacing cuboid to the closest interior region in the negative direction (negative dimension of X, Y, or Z, whichever dimension is under consideration)

The search parameter constraints are entered using the following keywords:

-CON=pp is used to set the minimum constraint for the current parameter. The value of pp is defaulted to -10E10 for a dimension search. The value of pp is defaulted to a value that allows geometry regions to touch for a pitch search unless a value was entered for MINPITCH, in which case the parameter corresponding to that pitch is calculated and used.

+CON=rr is used to set the maximum constraint for the current parameter. The value of rr is defaulted to +10E10 for a dimension search and to -5 x pp for a pitch search.

NOTE: A search will reset a constraint (entered using the keyword +CON= or -CON=) that falls outside the default range to the default value. If a PITCH search is specified and if a value has been entered for MAXPITCH and/or MINPITCH, values should not be entered for the constraints. If values are entered for +CON= and/or -CON= for a PITCH search and if MAXPITCH and/or MINPITCH were specified in the optional search parameters, the maximum and minimum constraints will be set to the values corresponding to MAXPITCH and MINPITCH, even though the value of MINPITCH may result in an intersection.

C4.5.6.2.c INDIVIDUAL SEARCH COMMANDS for CONCENTRATION SEARCHES

An individual search command for a concentration search consists of (1) a command definition, (2) the mixture number of the mixture to be altered, (3) the name of the standard composition to be altered, and (4) a factor. A series of individual search commands can be entered to govern the search process. A new search command is initiated whenever a command definition, item (1) above, is encountered.

The COMMAND DEFINITION defines the action to be taken for the specified mixture and standard composition component. ALTER, CHANGE, or MODIFY are used to cause the concentration (number densities) of the specified standard composition in the specified mixture to be modified. MAINTAIN, HOLD, and KEEP have not been implemented for a concentration search.

ALTER
CHANGE The commands to the left are command definitions, item (1) above. These commands instruct the code to modify the specified concentration data.

MAINTAIN This command definition is not implemented for a concentration search.

KEEP
HOLD These command definitions are not implemented for a concentration search.

The MIXTURE NUMBER, item (2) above, defines the mixture that contains the standard composition whose concentration is to be varied during the search. The keyword **MIX=** is entered, followed by the mixture number, nn.

MIX=nn is used to define the mixture number associated with the component that is to be changed. The keyword MIX= is entered, followed by the mixture number, nn. There is no default value of nn.

The STANDARD COMPOSITION NAME, item (3) above, defines the standard composition whose concentration will be changed in the defined mixture. Only standard compositions listed in Sect. M8.2 can be entered. Standard compositions beginning with SOLN and ARB cannot be altered directly, but their components can be altered.

SCNAME=mm is used to specify the standard composition name of the component that is to be altered. The keyword SCNAME= is entered, followed by the mixture number, mm. There is no default value for mm.

NOTE: If the standard composition component name specified in the Material Information Data (item 1 of the Standard Composition Specification Data) is a solution, for example, SOLN UO2(NO3)2, and the Concentration Search Data specifies SCNAME=UO2(NO3)2, the amount of UO2(NO3)2 in the solution will be altered, but the amount of water and nitric acid will not be changed. Thus, the resultant mixture may no longer meet the criteria associated with the SOLN specification.

The SEARCH CONSTANT for a concentration search, item (4) above, is a proportional factor that applies to the standard composition being altered. The keyword FACTOR= followed by a proportionality factor is used to specify the search constant for a concentration search.

FACTOR=pc is used to specify the search constant. The keyword FACTOR= is entered, followed by the value of the search constant or proportionality factor, pc.

ENTERING AUXILIARY SEARCH COMMANDS IN THE CONCENTRATION SEARCH DATA

EXAMPLE 1

Consider an example in which the density of water is to be varied. Full density water, mixture 1, was specified in the standard composition specification data as: H2O 1 END The auxiliary search data could be entered as follows:

```
ALTER  MIX=1  SCNAME=H2O  FACTOR=1.0
              or
ALTER  MIX=1  SCNA=H2O    FAC=1.0
              or
ALTER  M=1    S=H2O       F=1.0
```

Note that terse input allows truncation of the keywords.

EXAMPLE 2

Consider an example in which the density of UO_2F_2, is to be varied in mixture 2, a uranyl fluoride solution. The uranyl fluoride solution was specified as:

```
SOLNUO2F2   2   300   0   1   293   92235   5   92238   95   END
```

The auxiliary search data could be entered as follows:

```
ALTER  MIX=2  SCNAME=UO2F2  FACTOR=1
              or
ALTER  M=2    S=UO2F2       F=1
```

The terse input option allows truncation of the keywords.

C4.5.6.2.d SEARCH PARAMETER CONSTRAINTS for CONCENTRATION SEARCHES

The search parameter constraints for concentration searches set the parameter limits for the search. The minimum constraint is the minimum value of the parameter allowed in the search. The maximum constraint is the maximum value of the parameter allowed in the search. The initial concentration corresponds to a parameter value of 0.0. A physical limit occurs when the value of the parameter causes the density of the specified standard composition to become negative. The search can produce an unrealistically high density. Users should manually eliminate those results or set constraints to avoid them.

For a CONCENTRATION search, the constraints are given by Eqs. (C4.5.5) and (C4.5.6). The maximum constraint must be larger than the minimum constraint.

$$C_{min} = \left(\left(\frac{D_{min}}{D_i} \right) - 1 \right) \Big/ \text{FACTOR} \qquad \text{(C4.5.5)}$$

$$C_{max} = \left(\left(\frac{D_{max}}{D_i} \right) - 1 \right) \Big/ \text{FACTOR} \qquad \text{(C4.5.6)}$$

where

C_{min}	is the minimum constraint for the search,
C_{max}	is the maximum constraint for the search,
D_{min}	is the minimum allowed density for the specified standard composition,
D_{max}	is the maximum allowed density for the specified standard composition,
D_i	is the initial density of the specified standard composition,
FACTOR	is the search constant for the standard composition that is being varied.

Default search constraints are calculated if +CON and -CON are not entered. The default concentration search constraints are calculated as follows:

$$+CON = \begin{Bmatrix} \min(-1/FACTOR), \text{ if any } FACTOR < 0 \\ -S \times (-CON), \text{ if all } FACTOR > 0 \end{Bmatrix}$$

$$-CON = \begin{Bmatrix} -S \times (+CON), \text{ if all } FACTOR < 0 \\ \max(-1/FACTOR), \text{ if any } FACTOR > 0 \end{Bmatrix}$$

C4.5.7 SEARCH CONSIDERATIONS

Both DIMENSION searches and PITCH searches can be performed using CSAS4 and CSAS4X. A DIMENSION search alters only those regions specified in the search data. A PITCH search alters the center-to-center spacing of units in an array.

By default, a pitch search is performed at the lowest array level, and only the spacing in the x and y directions will be changed. For example, if an array of fuel assemblies is described in the geometry, the lowest array level is the array of fuel pins comprising an assembly. Therefore, an optimum pitch search would alter the spacing between the fuel pins within the assembly. The spacing can be expanded until the array intersects the first region external to it. The exterior size of the fuel pin array would grow or shrink within the confines of the exterior region (fuel assembly shroud). If the external regions are described using replicate regions, the array can grow or shrink within the confines of the maximum and minimum constraints.

If replicate regions are used outside an altered region or an array whose spacing units are altered, the dimensions of the replicate regions are recalculated (maintaining the thickness) at each search pass without having to enter search data for those regions. However, geometry regions specified by a geometry shape (sphere, cuboid, cylinder, etc.) that exist outside an altered region or an array whose spacing units are being altered will remain unchanged unless search data are provided for them. In other words, REPLICATE regions will grow and shrink in response to changes in the dimensions of the interior region, but other geometry shapes will not.

Some of the limitations applicable to a search are:

1. A pitch search is performed only at the lowest array level unless search commands are entered to keep the lowest array level unit unchanged and other commands are entered to cause other units to be altered.

2. A pitch search alters the +X, -X, +Y, and -Y dimensions by default. Appropriate search commands can be entered to alter the +Z and -Z dimensions if it is desirable to do so. Entering a search constant of zero for +X, -X, +Y, and/or -Y will keep the corresponding dimension from being altered.

3. A pitch search alters only the outer region of the unit(s) used in the array at the lowest array level unless the search data specifying otherwise is input.

4. A search cannot alter a region whose boundaries are set by the code (i.e., an ARRAY, CORE BOUNDARY, or REPLICATE following an ARRAY). If the dimensions of a replicate region are to be altered, the dimensions of the region interior to it must be explicitly defined. For example, the interior region can be a standard geometry shape (sphere, cylinder, cuboid, etc.), but cannot be a replicate following an array or core boundary.

5. All searches allow auxiliary search data as described in Sect. C4.4.10.2.

C4.5.8 OPTIMUM PITCH SEARCH

An optimum pitch search searches for the pitch that yields the highest value of k-effective. An optimum pitch search is activated by entering "OPTIMUM PITCH" in the search data. By default, the search is performed at the lowest array level, and only the spacing in the x and y directions (the x and y dimensions of the outermost region of the unit(s) used in the array at the lowest array level) will be changed. The search constants are defaulted to 1.0 for the +X, -X, +Y, and -Y dimensions of the region. The dimensions of other geometry regions will not be changed (their search constants are defaulted to 0.0) unless additional search data containing appropriate instructions are supplied.

The limits for an optimum pitch search can be set using either the MAXPITCH=/MINPITCH= option in the optional search parameters (Sect. C4.5.6.1c) or the +CON=/-CON= in the search parameter constraints of the auxiliary search commands (Sect. C4.5.6.2b). MAXPITCH=/MINPITCH= are used to enter a value of the maximum allowed pitch and minimum allowed pitch respectively. +CON=/-CON= are used to enter values for the parameter constraints (i.e., the maximum and minimum allowed value of the search parameter). Typically, it is easier to set the maximum allowed pitch and minimum allowed pitch using MAXPITCH=/MINPITCH= than it is to calculate the value of the parameter corresponding to those pitches.

The default minimum constraint corresponds to MINPITCH, the pitch at which the largest interior region of a unit used in the array is in contact with the spacing cuboid of that unit. The maximum constraint is defaulted to -5 times the minimum constraint. The code calculates k-effective for the initial geometry first. Then the dimensions corresponding to the minimum constraint and maximum constraint are calculated.

A simple optimum pitch search is demonstrated in example 1:

EXAMPLE 1

Consider a 10 × 10 × 10 array of uranium spheres arranged in an array having a "square" pitch. The uranium spheres are 2 cm in radius, and the center-to-center spacing is 8 cm. The uranium spheres and their associated spacing are defined to be unit 1, and the 10 × 10 × 10 array is defined to be array 1. Search data and results for some optimum pitch searches using this example are given in methods 1 through 6 below.

DEFAULT OPTIMUM PITCH SEARCH

The search data for a default optimum pitch search are as follows:

```
READ SEARCH OPTIMUM PITCH END SEARCH
```

These data will cause the code to alter the +X, –X, +Y, and –Y dimensions of the outer region of unit 1 and search for the dimensions that give the maximum k-effective. The +Z and –Z dimensions will remain unchanged, thereby preserving the original spacing between the z layers. The original relationship between the dimensions is preserved (i.e., the original ratio of the X to Y dimensions of the cuboid is preserved throughout the search). Because this is an optimum pitch search, the sphere dimensions will not be changed. For this particular example, results for only three passes are given.

METHOD 1

Define unit 1 so the sphere is centered in the unit. The geometry region data and search data for this example are:

```
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0
READ SEARCH  OPTIMUM PITCH  END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.4990 ± 0.0033  Parameter=0.000
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0
SECOND PASS..k-effective=0.9127 ± 0.0045  Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0

THIRD PASS...k-effective=0.2861 ± 0.0025  Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P14.0 2P4.0
```

METHOD 2

Define unit 1 so that the sphere is offset in the unit in the X direction but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case follow:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0
READ SEARCH  OPTIMUM PITCH  END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5017 ± 0.0036   Parameter=0.000
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 6.0 -2.0 4P4.0

SECOND PASS..k-effective=0.9127 ± 0.0045   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0

THIRD PASS...k-effective=0.2837 ± 0.0028   Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 2P14.0 2P4.0
```

METHOD 3

Define unit 1 so that the sphere is offset in the unit in X, Y, and Z but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0
READ SEARCH  OPTIMUM PITCH  END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5054 ± 0.0036   Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0

SECOND PASS..k-effective=0.9094 ± 0.0044   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0

THIRD PASS...k-effective=0.2825 ± 0.0031   Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 26.0 -2.0 6.0 -2.0
```

OPTIMUM PITCH SEARCH IN ALL THREE DIMENSIONS

Search data for an optimum pitch search that alters the Z dimensions as well as the X and Y dimensions are given below.

```
READ SEARCH
OPTIMUM PITCH MORE ALTER UNIT=1 REG=2 +Z=1.0 -Z=1.0
END SEARCH
```

These data will cause the code to alter the +X, -X, +Y, -Y, +Z, and -Z dimensions of the outer region of unit 1 and search for the dimensions that give the maximum k-effective. The original relationship between the dimensions is preserved (i.e., original ratio of the X to Y to Z dimensions of the cuboid is preserved throughout the search). Because this is an optimum pitch search, the sphere dimensions will not be changed. For this particular example, results for only three passes are given.

METHOD 4

Define unit 1 so the sphere is centered in the unit. The geometry region data and search data for this example are:

```
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0
READ SEARCH
OPTIMUM PITCH MORE ALTER UNIT=1 REG=2 +Z=1.0 -Z=1.0
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.4990 ± 0.0033   Parameter=0.000
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0

SECOND PASS..k-effective=1.2771 ± 0.0048   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

THIRD PASS...k-effective=0.2609 ± 0.0020   Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P14.0
```

METHOD 5

Define unit 1 so that the sphere is offset in the unit in the X direction but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0
READ SEARCH
OPTIMUM PITCH MORE ALTER UNIT=1 REG=2 +Z=1.0 -Z=1.0
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5017 ± 0.0036   Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0

SECOND PASS..k-effective=1.2771 ± 0.0048   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

THIRD PASS...k-effective=0.2570 ± 0.0024   Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 4P14.0
```

METHOD 6

Define unit 1 so that the sphere is offset in the unit in X, Y, and Z but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are the following:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 2.0
READ SEARCH
OPTIMUM PITCH MORE ALTER UNIT=1 REG=2 +Z=1.0 -Z=1.0
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5054 ± 0.0036   Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0

SECOND PASS..k-effective=1.2771 ± 0.0048   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

THIRD PASS...k-effective=0.2596 ± 0.0021   Parameter=2.500
UNIT 1
```

```
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 26.0 -2.0 26.0 -2.0
```

C4.5.9 OPTIMUM DIMENSION SEARCH

An optimum dimension search searches for the geometry dimensions that yield the highest value of k-effective. An optimum dimension search is activated by entering "OPTIMUM DIMENSION" in the search data. There are no defaulted search data in a dimension search. The user must specify the dimensions to be changed and the manner in which they will be changed as described in the auxiliary search commands (Sect. C4.5.6.2).

A dimension search is performed by altering the regions having nonzero search constants specified in the auxiliary search commands portion of the search data. By default, the search constants for every dimension in the problem is zero. Only those dimensions having a nonzero search constant are altered by the code.

By default, a dimension search sets the minimum constraint to -10E10 and the maximum constraint to +10E10. The relationship between the constraints and the search constants are given in Eqs. (C4.5.1) and (C4.5.2). If the default values of the constraints are used, appropriate search constants must be calculated using these equations. It may be simpler to set the search constants to 1.0 and calculate the corresponding maximum and minimum constraints.

A simple optimum dimension search is demonstrated in example 1.

EXAMPLE 1

Consider a $10 \times 10 \times 10$ array of uranium spheres arranged in an array having a "square" pitch. The uranium spheres are 2 cm in radius, and the center-to-center spacing is 8 cm. The uranium spheres and their associated spacing are defined to be unit 1, and the $10 \times 10 \times 10$ array is defined to be array 1. Search data and results for some optimum dimension searches using this example are given in methods 1 through 6 below.

OPTIMUM DIMENSION SEARCH IN X AND Y

The search data for an optimum dimension search that alters only the x and y dimensions of region 2 of unit 1 are given as follows. The constraints are set to be consistent with those of the optimum pitch search above.

```
READ SEARCH  OPTIMUM DIMENSION
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

These data will cause the code to alter the +X, -X, +Y, and -Y dimensions of the outer region of unit 1 and search for the dimensions that give the maximum k-effective. The +Z and -Z dimensions will remain unchanged, thereby preserving the original spacing between the z layers. The original relationship between the dimensions is preserved (i.e., the original ratio of the X to Y dimensions of the cuboid is preserved throughout the search). Because this is an optimum pitch search, the sphere dimensions will not be changed. For this particular example, results for only three passes are given.

METHOD 1

Define unit 1 so that the sphere is centered in the unit. The geometry region data and search data for this example are:

```
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0
READ SEARCH  OPTIMUM DIMENSION
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.4990 ± 0.0033   Parameter=0.000
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0

SECOND PASS..k-effective=0.9027 ± 0.0043   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0

THIRD PASS...k-effective=0.2861 ± 0.0025   Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P14.0 2P4.0
```

METHOD 2

Define unit 1 so that the sphere is offset in the unit in the X direction but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are the following:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0
READ SEARCH  OPTIMUM DIMENSION
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5017 ± 0.0036   Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0

SECOND PASS..k-effective=0.9032 ± 0.0042   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0
```

```
THIRD PASS...k-effective=0.2837 ± 0.0028    Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 2P14.0 2P4.0
```

METHOD 3

Define unit 1 so that the sphere is offset in the unit in X, Y, and Z but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are the following:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0
READ SEARCH  OPTIMUM DIMENSION
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5054 ± 0.0036  Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0

SECOND PASS...k-effective=0.9009 ± 0.0044  Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0

THIRD PASS...k-effective=0.2596 ± 0.0021  Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 2P14.0 2P4.0
```

OPTIMUM DIMENSION SEARCH IN ALL THREE DIMENSIONS

Search data for an optimum dimension search that alters the X, Y, and Z dimensions follow. The constraints are set to be consistent with the optimum pitch search above.

```
REACH SEARCH  OPTIMUM DIMENSION
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0 +Z=1.0 -Z=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

These data will cause the code to alter the +X, -X, +Y, -Y, +Z, and -Z dimensions of the outer region of unit 1 and search for the dimensions that give the maximum k-effective. The original relationship between the dimensions is preserved (i.e., the original ratio of the X to Y to Z dimensions of the cuboid is preserved throughout the search). Because this is an optimum dimension search, the sphere dimensions will not be altered unless search data are entered for region 1 of unit 1. For this particular example, results for only three passes are given.

METHOD 4

Define unit 1 so that the sphere is centered in the unit. The geometry region data and search data for this example are:

```
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0
READ SEARCH  OPTIMUM DIMENSION
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0 +Z=1.0 -Z=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.4990 ± 0.0033   Parameter=0.000
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0

SECOND PASS...k-effective=1.2743 ± 0.0053  Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

THIRD PASS...k-effective=0.2609 ± 0.0020  Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P14.0
```

METHOD 5

Define unit 1 so that the sphere is offset in the unit in the X direction but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0
READ SEARCH  OPTIMUM DIMENSION
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0 +Z=1.0 -Z=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5017 ± 0.0036  Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0

SECOND PASS...k-effective=1.2854 ± 0.0047  Parameter= -0.500
UNIT 1
```

```
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

THIRD PASS...k-effective=0.2570 ± 0.0024  Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 4P14.0
```

METHOD 6

Define unit 1 so that the sphere is offset in the unit in X, Y, and Z but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are given below:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0
READ SEARCH  OPTIMUM DIMENSION
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0 +Z=1.0 -Z=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5054 ± 0.0036   Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0

SECOND PASS..k-effective=1.2778 ± 0.0045   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

THIRD PASS...k-effective=0.2596 ± 0.0021   Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 26.0 -2.0 26.0 -2.0
```

C4.5.10 CRITICAL PITCH SEARCH

A critical pitch search alters the outer region of the unit or units at the lowest array level in search of a specified value of k-effective. A critical pitch search is activated by entering "CRITICAL PITCH" in the search data. By default, the search is performed at the lowest array level, and only the spacing in the x and y directions (the x and y dimensions of the outermost region of the unit(s) used in the array at the lowest array level) will be changed. The search constants are defaulted to 1.0 for the +X, -X, +Y, and -Y dimensions of the region. The dimensions of other geometry regions will not be changed (their search constants are defaulted to 0.0) unless additional search data containing appropriate instructions are supplied.

The limits for a critical pitch search can be set using either the MAXPITCH=/MINPITCH= option in the optional search parameters (Sect. C4.5.6.1c) or the +CON=/-CON= in the search parameter constraints of the auxiliary search commands (Sect. C4.5.6.2b). MAXPITCH+/MINPITCH= are used to enter a value of the maximum allowed pitch and minimum allowed pitch respectively. +CON=/-CON= are used to enter values for the parameter constraints (i.e., the maximum and minimum allowed value of the search parameter).

Typically, it is easier to set the maximum allowed pitch and minimum allowed pitch using MAXPITCH=/MINPITCH= than it is to calculate the value of the parameter corresponding to those pitches.

The default minimum constraint corresponds to MINPITCH, the pitch at which the largest interior region of a unit used in the array is in contact with the spacing cuboid of that unit. The maximum constraint is defaulted to -5 times the minimum constraint. The code calculates k-effective for the initial geometry first. Then the dimensions corresponding to the minimum constraint and maximum constraint are calculated.

A simple critical pitch search is demonstrated in example 1.

EXAMPLE 1

Consider a 10 × 10 × 10 array of uranium spheres arranged in an array having a "square" pitch. The uranium spheres are 2 cm in radius, and the center-to-center spacing is 8 cm. The uranium spheres and their associated spacing are defined to be unit 1, and the 10 × 10 × 10 array is defined to be array 1. Search data and results for some critical pitch searches using this example are given in methods 1 through 6.

DEFAULT CRITICAL PITCH SEARCH

The search data for a critical pitch search that alters the +X, -X, +Y, and -Y dimensions in search of a k-effective of 0.93 are:

```
READ SEARCH  CRITICAL PITCH KEF=0.93  END SEARCH
```

These data will cause the code to alter the +X, -X, +Y, and -Y dimensions of the outer region of unit 1 and search for the dimensions that give the maximum k-effective. The +Z and -Z dimensions will remain unchanged, thereby preserving the original spacing between the z layers. The original relationship between the dimensions is preserved (i.e., the original ratio of the X to Y dimensions of the cuboid is preserved throughout the search). Because this is a critical pitch search, the sphere dimensions will not be changed. For this particular example, results for only three passes are given.

METHOD 1

Define unit 1 so that the sphere is centered in the unit. The geometry region data and search data for this example follow:

```
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0
READ SEARCH  CRITICAL PITCH KEF=0.93  END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.4990 ± 0.0033   Parameter=0.000
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0

SECOND PASS..k-effective=0.2861 ± 0.0025   Parameter=2.500
UNIT 1
```

```
SPHERE 1 1 2.0
CUBOID 0 1 4P14.0 2P4.0

THIRD PASS...k-effective=0.9127 ± 0.0045   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0
```

After the third pass, the code recognizes that the desired k-effective of 0.93 lies outside the range of the parameter constraints. Messages CS-85 and CS-83 are printed and execution is terminated.

METHOD 2

Define unit 1 so that the sphere is offset in the unit in the X direction but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0
READ SEARCH  CRITICAL PITCH KEF=0.93  END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5017 ± 0.0036   Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0

SECOND PASS..k-effective=0.2837 ± 0.0028   Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 2P14.0 2P4.0

THIRD PASS..k-effective=0.9127 ± 0.0045   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0
```

After the third pass, the code recognizes that the desired k-effective of 0.93 lies outside the range of the parameter constraints. Messages CS-85 and CS-83 are printed and execution is terminated.

METHOD 3

Define unit 1 so that the sphere is offset in the unit in X, Y, and Z but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0 READ SEARCH
CRITICAL PITCH KEF=0.93  END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5054 ± 0.0036   Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0

SECOND PASS..k-effective=0.2825 ± 0.0031   Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 26.0 -2.0 6.0 -2.0

THIRD PASS...k-effective=0.9094 ± 0.0044   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 6.0 -2.0
```

After the third pass, the code recognizes that the desired k-effective of 0.93 lies outside the range of the parameter constraints. Messages CS-85 and CS-83 are printed and execution is terminated.

CRITICAL PITCH SEARCH IN ALL THREE DIMENSIONS

Search data for a critical pitch search that alters the Z dimensions as well as the X and Y dimensions follow:

```
READ SEARCH
CRITICAL PITCH MORE KEF=0.93 ALTER UNIT=1 REG=2 +Z=1.0 -Z=1.0
END SEARCH
```

These data will cause the code to alter the +X, -X, +Y, -Y, +Z, and -Z dimensions of the outer region of unit 1 and search for the dimensions that give a k-effective of 0.93. The original relationship between the dimensions is preserved (i.e., original ratio of the X to Y to Z dimensions of the cuboid is preserved throughout the search). Because this is an optimum pitch search, the sphere dimensions will not be changed. For this particular example, results for only three passes are given.

METHOD 4

Define unit 1 so that the sphere is centered in the unit. The geometry region data and search data for this example are given below:

```
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0
READ SEARCH
CRITICAL PITCH MORE KEF=0.93 ALTER UNIT=1 REG=2 +Z=1.0 -Z=1.0
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.4990 ± 0.0033   Parameter=0.000
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0

SECOND PASS..k-effective=0.2609 ± 0.0020   Parameter=2.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P14.0

THIRD PASS...k-effective=1.2771 ± 0.0048   Parameter= -0.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

FOURTH PASS..k-effective=0.7643 ± 0.0047   Parameter= -0.2769
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.8922

FIFTH PASS...k-effective=0.9226 ± 0.0041   Parameter= -0.3643
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.5426
```

METHOD 5

Define unit 1 so that the sphere is offset in the unit in the X direction but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are given below:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0
READ SEARCH
CRITICAL PITCH MORE KEF=0.93 ALTER UNIT=1 REG=2 +Z=1.0 -Z=1.0
END SEARCH
```

The code results are summarized below.

```
FIRST PASS...k-effective=0.5017 ± 0.0036   Parameter=0.0000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0

SECOND PASS..k-effective=0.2570 ± 0.0024   Parameter=2.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 4P14.0
```

```
THIRD PASS...k-effective=1.2771 ± 0.0048   Parameter= -0.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

FOURTH PASS..k-effective=0.7616 ± 0.0040   Parameter= -0.2762
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 3.7906 -2.0 4P2.8953

FIFTH PASS...k-effective=0.9221 ± 0.0042  Parameter= -0.3650
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 3.0801 -2.0 4P2.54
```

METHOD 6

Define unit 1 so that the sphere is offset in the unit in X, Y, and Z but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case follow:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0
CRITICAL PITCH MORE KEF=0.93 ALTER UNIT=1 REG=2 +Z=1.0 -Z=1.0
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5054 ± 0.0036  Parameter=0.0000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0

SECOND PASS...k-effective=0.2596 ± 0.0021  Parameter=2.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 26.0 -2.0 26.0 -2.0

THIRD PASS...k-effective=1.2771 ± 0.0048  Parameter= -0.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

FOURTH PASS...k-effective=0.7598 ± 0.0042  Parameter= -0.2751
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 3.7992 -2.0 3.7992 -2.0 3.7992 -2.0

FIFTH PASS...k-effective=0.9183 ± 0.0047  Parameter= -0.3652
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 3.0783 -2.0 3.0783 -2.0 3.0783 -2.0
```

C4.5.11 CRITICAL DIMENSION SEARCH

A critical dimension search searches for the geometry dimensions that yield a specified value of k-effective. A critical dimension search is activated by entering "CRITICAL DIMENSION" in the search data. No defaulted search data are in a dimension search. The user must specify the dimensions to be changed and the manner in which they will be changed.

A dimension search is performed by altering the regions having nonzero search constants specified in the individual search commands portion of the search data. By default, the search constants for every dimension in the problem is zero. Only those dimensions having a nonzero search constant are altered by the code.

By default, a dimension search sets the minimum constraint to -10E10 and the maximum constraint to +10E10. The relationship between the constraints and the search constants is given in Eqs. (C4.5.1) and (C4.5.2). If the default values of the constraints are used, appropriate search constants must be calculated using these equations. It may be simpler to set the search constants to 1.0 and calculate the corresponding maximum and minimum constraints.

A simple critical dimension search is demonstrated using example 1 with methods 1 through 6. A more complicated critical dimension search is given in example 2.

EXAMPLE 1

Consider a $10 \times 10 \times 10$ array of uranium spheres arranged in an array having a "square" pitch. The uranium spheres are 2 cm in radius, and the center-to-center spacing is 8 cm. The uranium spheres and their associated spacing are defined to be unit 1, and the $10 \times 10 \times 10$ array is defined to be array 1. Search data and results for some optimum dimension searches using this example are given in methods 1 through 6.

CRITICAL DIMENSION SEARCH IN X AND Y

The search data for a critical dimension search that alter only the x and y dimensions of region 2 of unit 1 follow. The constraints are set to be consistent with those of the optimum pitch search above.

```
READ SEARCH  CRITICAL DIMENSION  KEF=0.93
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

These data will cause the code to alter the +X, −X, +Y, and −Y dimensions of the outer region of unit 1 and search for the dimensions that give the maximum k-effective. The +Z and −Z dimensions will remain unchanged, thereby preserving the original spacing between the z layers. The original relationship between the dimensions is preserved (i.e., the original ratio of the X to Y dimensions of the cuboid is preserved throughout the search). Because this is an optimum pitch search, the sphere dimensions will not be changed. For this particular example, results for only three passes are given.

METHOD 1

Define unit 1 so that the sphere is centered in the unit. The geometry region data and search data for this example are:

```
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0
READ SEARCH  CRITICAL DIMENSION  KEF=0.93
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.4990 ± 0.0033   Parameter=0.000
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0

SECOND PASS..k-effective=0.2861 ± 0.0025   Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P14.0 2P4.0

THIRD PASS...k-effective=0.9028 ± 0.0043   Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0
```

After the third pass, the code recognizes that the desired k-effective of 0.93 lies outside the range of the parameter constraints. Messages CS-85 and CS-83 are printed and execution is terminated.

METHOD 2

Define unit 1 so that the sphere is offset in the unit in the X direction but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are the following:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0
READ SEARCH  CRITICAL DIMENSION  KEF=0.93
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5017 ± 0.0036   Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0
```

```
SECOND PASS..k-effective=0.2837 ± 0.0028    Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 2P14.0 2P4.0

THIRD PASS...k-effective=0.9032 ± 0.0042    Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 2P4.0
```

After the third pass, the code recognizes that the desired k-effective of 0.93 lies outside the range of the parameter constraints. Messages CS-85 and CS-83 are printed and execution is terminated.

METHOD 3

Define unit 1 so that the sphere is offset in the unit in X, Y, and Z but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case are given below.

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0
READ SEARCH  CRITICAL DIMENSION  KEF=0.93
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5054 ± 0.0036    Parameter=0.000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0

SECOND PASS..k-effective=0.2825 ± 0.0031    Parameter=2.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 26.0 -2.0 6.0 -2.0

THIRD PASS...k-effective=0.9009 ± 0.0044    Parameter= -0.500
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 4P2.0 6.0 -2.0
```

CRITICAL DIMENSION SEARCH IN ALL THREE DIMENSIONS

Search data for a critical dimension search that alters the X, Y, and Z dimensions follow. The constraints are set to be consistent with the critical pitch search above.

```
READ SEARCH  CRITICAL DIMENSION  KEF=0.93
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0 +Z=1.0 -Z=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

These data will cause the code to alter the +X, -X, +Y, -Y, +Z, and -Z dimensions of the outer region of unit 1 and search for the dimensions that give the maximum k-effective. The original relationship between the dimensions is preserved (i.e., the original ratio of the X to Y to Z dimensions of the cuboid is preserved throughout the search). Because this is a critical dimension search, the sphere dimensions will not be altered unless search data are entered for region 1 of unit 1. For this particular example results for only three passes are given.

METHOD 4

Define unit 1 so that the sphere is centered in the unit. The geometry region data and search data for this sample follow:

```
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0
READ SEARCH  CRITICAL DIMENSION  KEF=0.93
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0 +Z=1.0 -Z=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.4990 ± 0.0033   Parameter=0.0000
UNIT 1
SPHERE 1 1 2.0
CUBE   0 1 2P4.0

SECOND PASS..k-effective=0.2609 ± 0.0020   Parameter=2.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P14.0

THIRD PASS...k-effective=1.2742 ± 0.0054   Parameter= -0.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

FOURTH PASS..k-effective=0.7687 ± 0.0043   Parameter= -0.2780
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.8881

FIFTH PASS...k-effective=0.9211 ± 0.0039   Parameter= -0.3637
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.5454
```

METHOD 5

Define unit 1 so that the sphere is offset in the unit in the X direction but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case follow:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0
READ SEARCH  CRITICAL DIMENSION  KEF=0.93
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0 +Z=1.0 -Z=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5017 ± 0.0036   Parameter=0.0000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 4P4.0

SECOND PASS..k-effective=0.2569 ± 0.0024   Parameter=2.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 4P14.0

THIRD PASS...k-effective=0.7557 ± 0.0042   Parameter= -0.2733
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 3.8139 -2.0 4P2.9069

FOURTH PASS..k-effective=0.9142 ± 0.0042   Parameter= -0.3644
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 3.0851 -2.0 4P2.54

FIFTH PASS...k-effective=0.9228 ± 0.0041   Parameter= -0.3665
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0
```

METHOD 6

Define unit 1 so that the sphere is offset in the unit in X, Y, and Z but the center-to-center spacing is retained at 8.0 cm. The geometry region data for this case follow:

```
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0
READ SEARCH  CRITICAL DIMENSION  KEF=0.93
MORE ALTER UNIT=1 REG=2 +X=1.0 -X=1.0 +Y=1.0 -Y=1.0 +Z=1.0 -Z=1.0
-CON= -0.5 +CON=2.5
END SEARCH
```

A summary of the code results follows:

```
FIRST PASS...k-effective=0.5054 ± 0.0036   Parameter=0.0000
SPHERE 1 1 2.0
CUBOID 0 1 6.0 -2.0 6.0 -2.0 6.0 -2.0

SECOND PASS..k-effective=0.2596 ± 0.0021   Parameter=2.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 26.0 -2.0 26.0 -2.0 26.0 -2.0

THIRD PASS...k-effective=1.2778 ± 0.0045   Parameter= -0.5000
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 6P2.0

FOURTH PASS..k-effective=0.7556 ± 0.0042   Parameter= -0.2748
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 3.8012 -2.0 3.8012 -2.0 3.8012 -2.0

FIFTH PASS...k-effective=0.9228 ± 0.0041   Parameter= -0.3665
UNIT 1
SPHERE 1 1 2.0
CUBOID 0 1 3.0678 -2.0 3.0678 -2.0 3.0678 -2.0
```

EXAMPLE 2

Consider a problem having units 1, 2, and 3. Unit 1 consists of three concentric spheres in a cuboid. Unit 2 consists of a single sphere in a cuboid, and Unit 3 contains three concentric cuboids. A search is to be made that changes the exterior dimensions of the three units, the inner sphere of unit 1, and the sphere of unit 2. The thicknesses of the outer spheres of unit 1 are to be maintained, and the two inner cuboids of unit 3 are to remain unchanged. The search data for this problem are the following:

```
READ SEARCH CRITICAL DIMENSION
KEF=1.000 EPS=0.005
MORE
ALTER UNIT=1 REG=1 ALL=1.0
ALTER UNIT=1 REG=4 ALL=1.0
ALTER UNIT=2 REG=1 TO 2 ALL=1.0
ALTER UNIT=3 REG=3 ALL=1.0
MAINTAIN UNIT=1 REG=2 TO 3 ALL=1.0
+CON=2.0   -CON= -0.5
END SEARCH
```

The complete input data for this problem are:

```
=CSAS4                                                              SEARCH
DEMONSTRATION OF CRITICAL DIMENSION SEARCH
HANSEN-ROACH   INFHOMMEDIUM
URANIUM  1 0.985 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
PLEXIGLASS  2 END
SS304    3 END
```

```
END COMP
SEARCH DEMONSTRATION OF CRITICAL DIMENSION SEARCH
READ PARAMETERS  TME=1.0 GEN=53
END PARAMETERS
READ GEOMETRY
UNIT 1
SPHERE 1 1 3.0
SPHERE 0 1 3.25
SPHERE 2 1 3.5
CUBE   0 1 2P5.0
UNIT 2
SPHERE 1 1 3.0
CUBE   0 1 2P5.0
UNIT 3
CUBE   0 1 2P4.9
CUBE   3 1 2P5.0
CUBE   0 1 2P5.0
END GEOMETRY
READ ARRAY ARA=1 NUX=3 NUY=3 NUZ=3 FILL
1 3 2 3 2 3 2 3 1
3 2 3 1 3 2 3 1 3
2 3 1 3 1 3 1 3 2
END FILL END ARRAY
END DATA
READ SEARCH   CRITICAL DIMENSION
KEF=1.000  EPS=0.005
MORE
ALTER UNIT=1 REG=1 ALL=1.0
ALTER UNIT=1 REG=4 ALL=1.0
ALTER UNIT=2 REG=1 TO 2 ALL=1.0
ALTER UNIT=3 REG=3 ALL=1.0
MAINTAIN UNIT=1 REG=2 TO 3 ALL=1.0
+CON=2.0  -CON= -0.5
END SEARCH
END
```

The results of this search are

```
FIRST PASS...k-effective=0.4075    Parameter=0.000
UNIT 1
SPHERE 1 1 3.0
SPHERE 0 1 3.25
SPHERE 2 1 3.5
CUBE   0 1 2P5.0
UNIT 2
SPHERE 1 1 3.0
CUBE   0 1 2P5.0
UNIT 3
CUBE   0 1 2P4.9
CUBE   3 1 2P5.0
CUBE   0 1 2P5.0
```

```
SECOND PASS..k-effective=1.0744    Parameter=2.000
UNIT 1
SPHERE 1 1 9.0
SPHERE 0 1 9.25
SPHERE 2 1 9.5
CUBE   0 1 2P15.0
UNIT 2
SPHERE 1 1 9.0
CUBE   0 1 2P15.0
UNIT 3
CUBE   0 1 2P4.9
CUBE   3 1 2P5.0
CUBE   0 1 2P15.0

THIRD PASS...k-effective=1.0159    Parameter=1.777
UNIT 1
SPHERE 1 1 8.3307
SPHERE 0 1 8.5807
SPHERE 2 1 3.8307
CUBE   0 1 2P13.885
UNIT 2
SPHERE 1 1 8.33017
CUBE   0 1 2P13.8856
UNIT 3
CUBE   0 1 2P4.9
CUBE   3 1 2P5.0
CUBE   0 1 2P13.885

FOURTH PASS..k-effective=0.9952    Parameter=1.716
UNIT 1
SPHERE 1 1 8.1490
SPHERE 0 1 8.3990
SPHERE 2 1 8.6490
CUBE   0 1 2P13.583
UNIT 2
SPHERE 1 1 8.1490
CUBE   0 1 2P13.582
UNIT 3
CUBE   0 1 2P4.9
CUBE   3 1 2P5.0
CUBE   0 1 2P13.582
```

Convergence was achieved on the fourth pass. Based on the preceding data, the best estimate of the parameter is 1.730 with the following corresponding geometry:

```
UNIT 1
SPHERE 1 1 8.1901
SPHERE 0 1 8.4401
SPHERE 2 1 8.6901
CUBE   0 1 2P13.650
UNIT 2
SPHERE 1 1 8.1901
CUBE   0 1 2P13.650
UNIT 3
CUBE   0 1 2P4.9
CUBE   3 1 2P5.0
CUBE   0 1 2P13.650
```

In the search data of the above example, note that the search command, ALTER, must be entered each time. If it were entered only once regions 1 and 2 of unit 3 would be altered; no changes would be made to unit 1 or unit 2:

```
ALTER UNIT=1 REG=1 ALL=1.0
      UNIT=1 REG=4 ALL=1.0
      UNIT=2 REG=1 TO 2 ALL=1.0
      UNIT=3 REG=1 TO 2 ALL=1.0
MAINTAIN UNIT=1 REG=2 TO 3 ALL=1.0
```

The following data are equivalent to the above data:

```
ALTER UNIT=3 REG=1 TO 2 ALL=1.0
```

C4.5.12 CONCENTRATION SEARCH CONSIDERATIONS

Concentration searches can be performed using CSAS4 or CSAS4X. A concentration search alters only those standard compositions specified in the search data. Standard compositions beginning with SOLN and ARB cannot be altered directly. However, one or more of their components can be altered. For example, if the standard composition component name specified in the material information data is SOLN (SOLNUO2F2) and the concentration search data specifies SCNAME=UO2F2, the amount of uranyl fluoride salt, UO2F2, in the solution will be altered, but the amount of water and hydrofluoric acid in the solution will remain unchanged. Therefore, the resultant mixture may no longer meet the criteria for a solution (SOLN) specification.

Physically, the concentration can vary from zero to some upper limit. The code will prevent the concentration from falling below zero but the user is responsible for setting constraints that prevent the concentration from exceeding reasonable values. The theoretical density is a reasonable upper limit.

WARNING: Cell-weighted mixtures cannot be modified during search problems.

C4.5.13 OPTIMUM CONCENTRATION SEARCH

An optimum concentration search alters the concentration of the specified standard composition in the specified mixture to determine the highest value of k-effective. The limits for an optimum concentration search are governed by the values entered for the parameter constraints (see Sect. C4.5.6.2.4).

EXAMPLE 1

Consider a 10 × 10 × 10 array of uranium spheres arranged in an array having a square pitch. The uranium spheres are 2 cm in radius and the center-to-center spacing is 8 cm. The spheres are moderated by ½ density water. Determine the water concentration yielding the maximum value of k-effective. The maximum allowed density is full density water. The minimum allowed density is 0.05 density water.

The input data for this problem specifies mixture 2 to be H2O with a density multiplier of 0.5 (H2O 2 0.5 END). The maximum constraint is calculated according to:

$$+CON = \left(\frac{D_{max}}{D_{initial}} - 1 \right) / FACTOR \quad +CON = \left(\frac{1.0}{0.5} - 1 \right) /1 = 1.0.$$

The minimum constraint is calculated according to:

$$-CON = \left(\frac{D_{min}}{D_{initial}} - 1 \right) / FACTOR \quad -CON = \left(\frac{0.05}{0.5} - 1 \right) /1 = -0.9.$$

The search data with constraints to limit the water density range from 5% density to full density follows.

```
READ SEARCH    OPTIMUM CONCENTRATION    MORE
ALTER    MIX=2    SCNAME=H2O    FACTOR=1
+CON=1.0    -CON= -0.9    END SEARCH
```

The code results follow:

FIRST PASS...k-effective = 1.22307±0.0049 Parameter=0.000

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	3.33757-2
	2	2008016	1.66879-2

SECOND PASS...k-effective=0.576665±0.0039 Parameter= –0.900

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	3.33757-3
	2	2008016	1:66879-3

THIRD PASS...k-effective=1.16362±0.0044 Parameter=1.000

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	6.67514-2
	2	2008016	3.33757-2

FOURTH PASS...k-effective=1.16362±0.0044 Parameter=0.500

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	5.00636-2
	2	2008016	2.50318-2

FIFTH PASS...k-effective=1.23497±0.0048 Parameter=0.080

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	3.60458-2
	2	2008016	1.80229-2

For this particular problem, convergence was achieved on search pass number five. Since the initial pass was set up for half density water and the converged results occurred for 0.54 density water, it is not necessary to resubmit the problem using the converged water concentration.

C4.5.14 CRITICAL CONCENTRATION SEARCH

A critical concentration search alters the concentration of the specified standard composition in the specified mixture to obtain a specified value of k-effective. The limits for a critical concentration search are governed by the values entered for the parameter constraints (see Sect. C4.5.6.2.4).

EXAMPLE 1

Consider a 10 × 10 × 10 array of uranium spheres arranged in an array having a square pitch. The uranium spheres are 2 cm in radius and the center-to-center spacing is 8 cm. The spheres are moderated by ½ density water. Determine the water concentration yielding a k-effective of 0.90. The maximum allowed density is full density water. The minimum allowed density is 0.05% density water.

The input data for this problem specifies mixture 2 to be H2O with a density multiplier of 0.5 (H2O 2 0.5 END). The maximum constraint is calculated according to

$$+\text{CON} = \left(\frac{D_{max}}{D_{initial}} - 1 \right) / \text{FACTOR} \quad +\text{CON} = \left(\frac{1.0}{0.5} - 1 \right) /1 = 1.0.$$

The minimum constraint is calculated according to:

$$-\text{CON} = \left(\frac{D_{min}}{D_{initial}} - 1 \right) / \text{FACTOR} \quad -\text{CON} = \left(\frac{0.0005}{0.5} - 1 \right) /1 = -0.999.$$

The search data with constraints to limit the water density range from 0.05% density to full density follows.

```
READ SEARCH   CRITICAL CONCENTRATION   KEF=0.90   MORE
ALTER   MIX=2   SCNAME=H2O   FACTOR=1
+CON=1.0   -CON= -0.999   END SEARCH
```

The code results follow:

FIRST PASS...k-effective=1.2344±0.0032 Parameter=0.000

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	3.33757-2
	2	2008016	1.66872-2

SECOND PASS...k-effective=0.5063±0.0024 Parameter= -0.999

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	3.33749-5
	2	2008016	1.66874-5

THIRD PASS...k-effective=1.0628±0.0037 Parameter= -0.459

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	1.80613-2
	2	2008016	9.03063-3

FOURTH PASS...k-effective=0.5804±0.0027 Parameter= -0.894

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	3.52600-3
	2	2008016	1.76300-3

FIFTH PASS...k-effective=0.9255±0.0036 Parameter= -0.601

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	1.33055-2
	2	2008016	6.65275-3

SIXTH PASS...k-effective=0.8988±0.0035 Parameter= -0.625

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	2	2001001	1.25267-2
	2	2008016	6.26336-3

Convergence was achieved on the sixth pass. Based on the data, the best estimate of the parameter is -0.624 and the corresponding mixing table for water is:

MIXTURE	NUCLIDE	DENSITY
2	2001001	1.25630-2
2	2008016	6.28149-3

The averaged results and the best estimate correspond to a converged density multiplier of 0.188 for the parameter = −0.625. Since the code does resonance processing through BONAMI and NITAWL prior to each run, this is a good result.

EXAMPLE 2

Consider the 10×10×10 array of uranium spheres described in Example 1. The spheres are moderated by water having a density of 0.25 g/cc. The search limits are specified to allow the minimum water density to be 0.15 g/cc and the maximum water density to be 0.33 g/cc. Determine the water density corresponding to a k-effective of 0.90.

The input data for this problem specifies mixture 1 as water with a density of 0.25 g/cc (H2O 1 DEN=0.25 END). The search data is:

```
READ SEARCH   CRIT CONC   KEF=0.90   MORE   ALTER  MIX=1
SC=H2O   FACTOR=1   +CON=0.32   -CON= -0.40   END SEARCH
```

The code results follow:

FIRST PASS...k-effective=1.02415±0.0036 Parameter=0.000

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	1	1001001	1.67179-2
	1	1008016	8.35897-3

SECOND PASS...k-effective= −.8072±0.0034 Parameter= −0.400

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	1	1001001	1.00308-2
	1	1008016	5.01538-3

THIRD PASS...k-effective=0.9175±0.0037 Parameter= −0.229

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	1	1001001	1.28920-2
	1	1008016	6.44598-3

FOURTH PASS...k-effective= −.8956±0.0036 Parameter= −0.256

mixing table entries for water:	MIXTURE	NUCLIDE	DENSITY
	1	1001001	1.24389-2
	1	1008016	6.21943-3

Convergence was achieved on the fourth pass. Based on the data, the best estimate of the parameter is -0.250 and the corresponding mixing table for water is:

MIXTURE	NUCLIDE	DENSITY
1	1001001	1.25303-2
1	1008016	6.26514-3

This parameter corresponds to a water density of 0.1875 g/cc (H2O 1 DEN=0.1875 END).

EXAMPLE 3

Consider a spherical tank of 304 stainless steel filled with 5% enriched uranyl fluoride with a density of 300 gU/ℓ and no excess acid. The inside radius of the tank is 30 cm and the wall is 0.25 cm thick. Determine the concentration of uranyl fluoride yielding a k-effective of 1.0

The input data for this problem specifies mixture 1 to be a uranyl fluoride solution as shown below.

```
SOLNUO2F2  1  300  0  1  293  92235  5  92238  95  END
```

The search data, including constraints to limit the density from 75 gU/ℓ to 750 gU/ℓ follows:

```
READ SEARCH    CRITICAL CONCEN    KEF=1    MORE
ALTER MIX=1    SCNA=UO2F2    FAC=1    -CON= -0.75    +CON=1.5
END  SEARCH
```

The code results for the first search attempt follow:

FIRST PASS...k-effective= -.8009±0.0030 Parameter=0.000

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	3.84319-5
1	1092238	7.20984-4
1	1008016	3.33408-2
1	1009019	1.51883-3
1	1001001	6.36440-2

SECOND PASS...k-effective=1.0306±0.0039 Parameter=1.500

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	9.60799-5
1	1092238	1.80246-3
1	1008016	3.56191-2
1	1009019	3.79708-3
1	1001001	6.36440-2

THIRD PASS...k-effective=1.0230±0.0034 Parameter=1.300

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	8.84014-5
1	1092238	1.65841-3
1	1008016	3.53156-2
1	1009019	3.49363-3
1	1001001	6.36440-2

FOURTH PASS...k-effective=0.9536±0.0038 Parameter=0.695

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	6.51516-5
1	1092238	1.22225-3
1	1008016	3.43968-2
1	1009019	2.57479-3
1	1001001	6.36440-2

FIFTH PASS...k-effective=1.0019±0.0041 Parameter=1.028

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	7.79365-5
1	1092238	1.46209-3
1	1008016	3.49020-2
1	1009019	3.08005-3
1	1001001	6.36440-2

Convergence was achieved on the fifth pass. Based on the preceding data, the best estimate of the parameter is 1.0108. The corresponding mixing table for mixture 1 follows.

MIXTURE	NUCLIDE	DENSITY
1	1092235	7.72789-5
1	1092238	1.44975-3
1	1008016	3.48761-2
1	1009019	3.05406-3
1	1001001	6.36440-2

The best estimate of the parameter, 1.0108, corresponds to 603 gU/ℓ. Because the current implementation of the concentration search varies only the UO2F2 portion of the solution and does not alter the acid and water, the converted results do not accurately represent the true solution. To test the best-estimate results, the problem was rerun with the uranyl fluoride solution specified as

```
SOLNUO2F2  1  603  0  1  293  92235  5  92238  95  END
```

The search data were specified to limit the range of the search to vary from 500 gU/ℓ to 700 gU/ℓ as shown below.

```
READ SEARCH  CRITICAL CONCEN  KEF=1  MORE
ALTER  MIX=1  SCNA=UO2F2  FAC=1  -CON= -0.17  +CON=0.16  END SEARCH
```

The code results for the second search attempt follow.

FIRST PASS...k-effective=1.0111±0.0035 Parameter=0.000

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	7.72482-5
1	1092238	1.44918-3
1	1008016	3.31955-2
1	1009019	3.05285-3
1	1001001	6.02853-2

SECOND PASS...k-effective=0.96817±0.0034 Parameter= -0.17

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	6.41160-5
1	1092238	1.20282-3
1	1008016	3.26765-2
1	1009019	2.53387-3
1	1001001	6.02853-2

+THIRD PASS...k-effective=1.0017±0.0040 Parameter= -0.044

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	7.38460-5
1	1092238	1.38535-3
1	1008016	3.30611-2
1	1009019	2.98140-3
1	1001001	6.02853-2

Convergence was achieved on the third pass, and the best estimate of the parameter was nearly identical to the parameter from the third pass. A parameter of -0.044 corresponds to a density of 576 gU/ℓ. Respecify the problem to run using this density and limiting the density range from 500 gU/ℓ (-CON= -0.132) to 625 gU/ℓ (+CON=0.085).

The code results for the third search attempt follow.

FIRST PASS...k-effective=0.9879±0.0041 Parameter=0.000

mixing table entries for mixture 1:	MIXTURE	NUCLIDE	DENSITY
	1	1092235	7.3789-5
	1	1092238	1.38429-3
	1	1008016	3.32085-2
	1	1009019	2.91616-3
	1	1001001	6.05846-2

SECOND PASS...convergence achieved, k-effective=1.0011±0.0039 Parameter=0.085

mixing table entries for mixture 1:	MIXTURE	NUCLIDE	DENSITY
	1	1092235	8.00614-5
	1	1092238	1.50195-3
	1	1008016	3.34563-2
	1	1009019	3.16403-3
	1	1001001	6.05846-2

A parameter of 0.085 corresponds to a density of 625 gU/ℓ. Respecify the problem to run using a density of 625 gU/ℓ, and limiting the range from 550 gU/ℓ (-CON= -0.12) to 700 gU/ℓ (+CON=0.12).

The code results for the fourth search attempt follow.

FIRST PASS...k-effective=1.0168±0.0043 Parameter=0.000

mixing table entries for mixture 1:	MIXTURE	NUCLIDE	DENSITY
	1	1092235	8.00666-5
	1	1092238	1.50205-3
	1	1008016	3.31850-2
	1	1009019	3.16423-3
	1	1001001	6.00415-2

SECOND PASS...k-effective=0.9818±0.0040 Parameter= -0.12

mixing table entries for mixture 1:	MIXTURE	NUCLIDE	DENSITY
	1	1092235	7.04586-5
	1	1092238	1.32180-3
	1	1008016	3.28053-2
	1	1009019	2.78452-3
	1	1001001	6.00415-2

THIRD PASS...convergence achieved, k-effective=1.0032±0.0037 Parameter= -0.0575

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	7.54619-5
1	1092238	1.41567-3
1	1008016	3.30030-2
1	1009019	2.98226-3
1	1001001	6.00415-2

A parameter of −0.0575 corresponds to a density of 589 gU/ℓ.

Respecify the problem to use a density of 589 gU/ℓ and limiting the search range from 550 gU/ℓ (−CON= −0.066) to 625 gU/ℓ (+CON=0.061), the following results were obtained for the fifth search pass.

FIRST PASS...convergence achieved k-effective=1.0078±0.0039 Parameter=0.000

mixing table entries for mixture 1:

MIXTURE	NUCLIDE	DENSITY
1	1092235	7.54547-5
1	1092238	1.41553-3
1	1008016	3.32022-2
1	1009019	2.98197-3
1	1001001	6.04405-2

This type of concentration search did not function as well as desired because only the UO2F2 portion of the solution was altered. Therefore, the H/X for a converged search was not the true H/X for a solution having the density determined by the search. A summary of the search results for example 3 follows.

EXAMPLE 3 SEARCH RESULTS

Search number	Initial density (gU/ℓ)	Initial H/U-235	Converged parameter	Converged density (gU/ℓ)	Converged H/U-235
1	300	1,656	1.0108	603	824
2	603	780	−0.044	576	818
3	576	821	0.085	625	757
4	625	750	−0.0575	589	796
5	589	801	0.000	589	801

C4.6 DESCRIPTION OF OUTPUT

This section describes the output from the CSAS control sequences. The output files that are created when the CSAS control sequences are executed consist of (1) output from the control module, (2) output from the functional modules invoked by the control module, and (3) a listing of the input data. The order in which these output files appear is system dependent. If PARM=CHECK is specified on the analytical sequence indicator, there will be no output from the functional modules. The output files from the functional modules are described in the section pertaining to the module (see Table C4.6.1).

Table C4.6.1 Location of functional module output

Functional module	Section
BONAMI	F1.6
NITAWL-II	F2.8.2
XSDRN	F3.7
ICE	F8.5
KENO V.a	F11.6

C4.6.1 CONTROL MODULE HEADER PAGE

The control module header page, shown in Fig. C4.6.1, prints the name of the control module in block letters. The job name from the job control language, the date (month/day/year), and the time at execution (hour:minute:second) are also printed. This time is given in terms of a 24-h clock, with midnight being 2400 h.

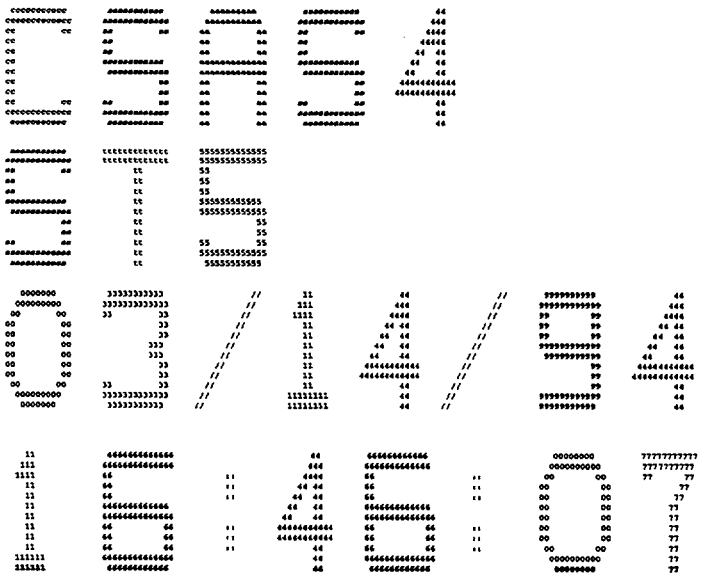


Figure C4.6.1 Sample control module header page

C4.6.2 CONTROL MODULE PROGRAM VERIFICATION TABLE

The control module program verification information table, shown in Fig. C4.6.2, is printed after the header page. It lists the name of the control module that is being executed, 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. Some computers do not store load modules in a library, in which case the library entry is left blank. The job name, date, and time of execution are also printed. This information may be useful for quality assurance purposes.

```
 ssssssssss     cccccccccc      aaaaaaaaa     ll              eeeeeeeeeeee
ssssssssssss   cccccccccccc    aaaaaaaaaaa    ll              eeeeeeeeeeee
ss          ss cc          cc  aa          aa ll              ee
ss             cc              aa          aa ll              ee
ss             cc              aa          aa ll              ee
ssssssssssss   cc              aaaaaaaaaaaaa ll              eeeeeeeee
 ssssssssssss  cc              aaaaaaaaaaaaa ll              eeeeeeeee
          ss   cc              aa          aa ll              ee
          ss   cc              aa          aa ll              ee
ss        ss   cc          cc  aa          aa ll              ee
ssssssssssss   cccccccccccc    aa          aa llllllllllll    eeeeeeeeeeee
 ssssssssss     cccccccccc     aa          aa llllllllllll    eeeeeeeeeeee

*********************************************************************************
*********************************************************************************
*********************************************************************************
*****                                                                       *****
*****                  program verification information                  *****
*****                                                                       *****
*****                 code system:    scale  version:    4.2             *****
*****                                                                       *****
*********************************************************************************
*********************************************************************************
*****                                                                       *****
*****                                                                       *****
*****              program:  csas                                           *****
*****                                                                       *****
*****        creation date:  12/01/93                                       *****
*****                                                                       *****
*****              library:  /scale4.2p/exe                                 *****
*****                                                                       *****
*****                                                                       *****
*****      production code:  csas                                           *****
*****                                                                       *****
*****              version:  2.2                                            *****
*****                                                                       *****
*****              jobname:  st5                                            *****
*****                                                                       *****
*****    date of execution:  03/14/94                                       *****
*****                                                                       *****
*****    time of execution:  16:46:07                                       *****
*****                                                                       *****
*********************************************************************************
*********************************************************************************
*********************************************************************************
```

Figure C4.6.2 Sample control module program verification table

C4.6.3 MATERIAL INFORMATION PROCESSOR OUTPUT

The Material Information Processor output is printed immediately after the program verification table. This output is discussed in detail in Sects. M7.6.1 through M7.6.6. An example of this output is given in Figs. C4.6.3 and C4.6.4.

```
sample problem 4  set up 2c8 in csas25

**** problem parameters ****

lib hansen-roach library
mxx             1 mixtures
msc             1 composition specifications
izm             1 material zones
ge  infhommedium geometry
more            0 0/1 do not read/read optional parameter data
msln            0 fuel solutions

**** problem composition description ****

sc  uranium      standard composition
mx              1 mixture no.
vf         .9850 volume fraction
roth     19.0500 theoretical density
temp       293.0 deg kelvin
           92235  93.20%
           92238   5.60%
           92234   1.00%
           92236    .20%
end

**** problem geometry ****

**** infinite homogeneous medium ****
mfuel           1 mixture no. of the infinite homogeneous medium
```

Figure C4.6.3 Part 1 of Material Information Processor printout

```
*** sample problem 4  set up 2c8 in csas25 ***

*** ********** data library information ********** ***

***   unit                                          volume                                ***
***  number          data set name                   name        unit function          ***
***  ------          -------------                   ----        -------------          ***
***    89    /scale4.2p/datalib/scale.rev05.sclib                standard composition library ***
***    81    /scale4.2p/datalib/scale.rev02.xn16                 cross section library        ***
***    11    ft11f001                                            short cross section library  ***

*** standard composition library data ***
***  ---------------------------------  ***

***    unit number  :  89                                                                  ***
***    dataset name :  /scale4.2p/datalib/scale.rev05.sclib                                ***
***    library title:  scale-4 standard composition library                                ***
***                    386 standard compositions, 332 nuclides                             ***
***                    10 elements with variable isotopic distrbutions.                    ***
***    creation date:   1/25/94                                                            ***

*** cross section library data ***
***  --------------------------  ***

***    unit number  :  81                                                                  ***
***    dataset name :  /scale4.2p/datalib/scale.rev02.xn16                                 ***
***    library title:  scale 4 - 16 neutron group criticality safety library               ***
***                      hansen-roach data with knight modifications and some endf/b 4 data ***
***                        compiled for nrc       1/27/89                                  ***
***                          last updated        10/12/89                                  ***
***                            l.m.petrie       ornl                                      ***
```

Figure C4.6.4 Part 2 of Material Information Processor printout

C4.6.4 KENO V.a OUTPUT

Output from KENO V.a is printed if the control sequence expects to execute KENO V.a and PARM=CHECK is specified on the analytical sequence indicator. See Sects. F11.6.3 through F11.6.20 for an explanation of the KENO V.a output.

If the control sequence expects to execute KENO V.a and if PARM=CHECK is not specified on the analytical sequence indicator, the KENO V.a output consists of a set of cryptic statements indicating the number of I/Os used to process the KENO V.a data as shown in Fig. C4.6.5.

```
........    0 io's were used before reading keno v data    ........
........    0 io's were used reading the keno v parameter data    ........
*************** data reading completed ***************
........    0 io's were used preparing the keno v input data    ........
........    0 io's were used loading the keno v data    ........
........    0 io's were used loading the data    ........
........    0 io's were used checking the keno v geometry data    ........
*****  restart data has been written on unit 95  *****
........    0 io's were used writing the keno v - csas data    ........
........    0 io's were used before reading search data    ........
........    0 io's were used processing csas input data    ........
```

Figure C4.6.5 Summary of KENO V.a I/O usage by CSAS control module

The first line of Fig. C4.6.5, the number of I/Os used before reading KENO V.a data, is always printed for the analytical sequences contained in the CSAS family of control modules. It is the only line of Fig. C4.6.5 that is printed for CSASN, CSAS1X, CSASI, and CSASIX. The next to the last line of Fig. C4.6.5 is printed only for control modules that expect to perform a search by executing the control module MODIFY (i.e., CSAS4 and CSAS4X). All other lines of Fig. C4.6.5 are printed by control modules that expect to execute KENO V.a (i.e., CSAS25, CSAS2X, CSAS4, and CSAS4X).

C4.6.5 PROGRAM VERIFICATION TABLE FOR THE CONTROL MODULE MODIFY

If a search is to be performed, the control module MODIFY is invoked to alter the KENO V.a geometry data and execute KENO V.a using the new data. This procedure is repeated until the problem achieves convergence, runs out of time or I/Os, or completes the specified number of search passes.

The program verification information table for MODIFY is shown in Fig. C4.6.6. It lists the name of the control module, 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. Some computers do not store load modules in a library, in which case the library entry is left blank. The job name, date, and time of execution are also printed. This information may be useful for quality assurance purposes.

```
 ssssssssss     ccccccccccc      aaaaaaaaa     ll              eeeeeeeeeeee
ssssssssssss   ccccccccccccc    aaaaaaaaaaa    ll              eeeeeeeeeeee
ss          ss cc           cc  aa          aa  ll              ee
ss             cc               aa          aa  ll              ee
ss             cc               aa          aa  ll              ee
ssssssssssss   cc               aaaaaaaaaaaaa  ll              eeeeeeeee
 ssssssssssss  cc               aaaaaaaaaaaaa  ll              eeeeeeeee
          ss   cc               aa          aa  ll              ee
          ss   cc               aa          aa  ll              ee
ss        ss   cc           cc  aa          aa  ll              ee
ssssssssssss   ccccccccccccc   aa          aa  llllllllllll    eeeeeeeeeeee
 ssssssssss     ccccccccccc    aa          aa  llllllllllll    eeeeeeeeeeee

**********************************************************************************
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                  program verification information                   *****
*****                                                                        *****
*****                 code system:    scale  version:    4.2              *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                                                                        *****
*****              program:  modify                                          *****
*****                                                                        *****
*****        creation date:  10/25/93                                        *****
*****                                                                        *****
*****              library:  /scale4.2p/exe                                  *****
*****                                                                        *****
*****                                                                        *****
*****      production code:  modify                                          *****
*****                                                                        *****
*****              version:  2.1                                             *****
*****                                                                        *****
*****              jobname:  st5                                             *****
*****                                                                        *****
*****    date of execution:  03/14/94                                        *****
*****                                                                        *****
*****    time of execution:  16:46:26                                        *****
*****                                                                        *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
**********************************************************************************
```

Figure C4.6.6 Program verification table for MODIFY

C4.6.6 TABLE OF SEARCH DATA

The table of search data, shown in Fig. C4.6.7, lists the search data for the problem. The KENO V.a title is printed at the top of the table. The search parameters are printed in the top portion of the table after the KENO V.a title and below the heading "SEARCH DATA." The search type is the first entry in the search parameters and defines the type of search to be performed. In this example, a critical pitch search is to be performed. PAS is the number of search passes to be performed. The default value is 10. NPM, the number of search parameters, is defaulted to 1 and should not be changed. EPS is the search convergence tolerance and is defaulted to 0.005. If a critical pitch or critical dimension search is to be performed, KEF, the desired value of k-effective, is printed. It is omitted for "optimum" and "minimum" searches. -CON is the value of the minimum constraint and +CON is the value of the maximum constraint. If a "pitch" search is performed and if values are entered for the minimum allowed pitch, MINPITCH, and the maximum allowed pitch, MAXPITCH, they are printed following +CON.

The bottom portion of the table of search data lists the search command, the unit number, the range of regions in the unit the search command is applicable to, and the search constants for each dimension of those regions. A search constant of 0.0 means the search command should be ignored for that particular dimension. In Fig. C4.6.7, all six dimensions (+X, -X, +Y, -Y, +Z, -Z) of region 2 of unit 1 will be altered.

```
*** critical pitch search for case 2c8 bare ***

*** ****** search data ****** ***
*** search type critical pitch ***
*** pas number of search passes 10 ***
*** npm number of search parameters 1 ***
*** eps search convergence tolerance .0050 ***
*** kef desired k-effective 1.0000 ***
*** -con minimum constraint -.2070 ***
*** +con maximum constraint .0693 ***

*** command unit number | first region | last region | search constants (+x or r | -x or +h | +y or -h | -y | +z | -z) ***

*** alter/change/modify  1  2  2  1.00  1.00  1.00  1.00  .00  .00 ***
*** alter/change/modify  1  2  2  .00  .00  .00  .00  1.00  1.00 ***
```

Figure C4.6.7 Table of search data

C4.6.7 SEARCH PASS ITERATION DATA

This portion of the search output is created as the search progresses. At the end of each KENO V.a calculation, the pass number, k-effective, and deviation are printed, followed by the value of the search parameter. The third line is a statement that modified KENO V.a data have been written on unit 95 to provide data for the next pass to KENO V.a. These three lines are printed for every completed search pass. However, the third line is not printed when convergence is achieved. This output is illustrated in Fig. C4.6.8.

```
**********   search pass  1     keff=  9.62581E-01 + or -  4.66186E-03   **********
                          the parameter was  0.00000E+00
                *****  modified keno v data has been rewritten on unit 95  *****

**********   search pass  2     keff=  9.26968E-01 + or -  4.76267E-03   **********
                          the parameter was  6.92605E-02
                *****  modified keno v data has been rewritten on unit 95  *****

**********   search pass  3     keff=  1.01030E+00 + or -  4.65530E-03   **********
                          the parameter was -7.27719E-02
                *****  modified keno v data has been rewritten on unit 95  *****

**********   search pass  4     keff=  1.00968E+00 + or -  4.18861E-03   **********
                          the parameter was -5.70604E-02
                *****  modified keno v data has been rewritten on unit 95  *****

**********   search pass  5     keff=  9.80129E-01 + or -  5.04216E-03   **********
                          the parameter was -3.87869E-02
                *****  modified keno v data has been rewritten on unit 95  *****

**********   search pass  6     keff=  9.98210E-01 + or -  4.21917E-03   **********
                          the parameter was -5.09593E-02
```

Figure C4.6.8 Search pass iteration data

C4.6.8 SEARCH CONVERGENCE INFORMATION

If a search achieves convergence, the search convergence information table is printed as shown in Fig. C4.6.9. The KENO V.a title is the first line printed. The pass at which convergence was achieved is printed followed by the equation used in the search to determine k-effective in terms of the parameter, P. The k-effective and deviation from the converged pass are printed, followed by the geometry description from the converged pass.

```
                                critical pitch search for case 2c8 bare
*****************************************************************************************************************************
*****************************************************************************************************************************

                          convergence was achieved on pass  6  the parameter was  -5.09593E-02

                          the equation used in the search was:

                          k-eff = +9.39989E-01 -9.76969E-01*p +7.86001E+00*p**2 +8.33712E+01*p**3

                          k-effective=  9.98210E-01 + or -  4.21917E-03   the corresponding geometry follows;

              media bias      geometry description for those units utilized in this problem
region         num   id

                                                    -----   unit     1   -----

1 cylinder    1  1  radius =  5.7480   +z =  5.3825   -z = -5.3825   centerline is at  x = 0.00000E+00  y = 0.00000E+00

2 cuboid      0  1      +x =  6.8786   -x = -6.8786   +y =  6.8786   -y = -6.8786     +z =  6.5318     -z = -6.5318

*****************************************************************************************************************************
*****************************************************************************************************************************
```

Figure C4.6.9 Search pass iteration data

C4.6.9 EXTRAPOLATION OF CONVERGED DATA

If a search achieves convergence and has run four or more passes, the data from the search are used to provide an estimate of the parameter that is used to determine the geometry corresponding to the best estimate of the parameter. This last information printed for a search is shown in Fig. C4.6.10.

```
                              critical pitch search for case 2c8 bare

                        based on the preceding data, the best estimate of the parameter is    -5.17118E-02

                        the geometry corresponding to this parameter follows:

            media bias      geometry description for those units utilized in this problem
region       num   id

                                                        -----   unit     1   -----

1 cylinder  1   1   radius = 5.7480  +z = 5.3825  -z = -5.3825  centerline is at  x = 0.00000E+00  y = 0.00000E+00

2 cuboid    0   1       +x = 6.8732  -x = -6.8732 +y =  6.8732  -y = -6.8732     +z =  6.5266     -z = -6.5266

*****************************************************************************************************************
*****************************************************************************************************************
                           *****  modified keno v data has been rewritten on unit 95  *****

*****  convergence has been achieved in the search package.  *****

 control module modify   is complete.
```

Figure C4.6.10 Best estimate of the parameter and geometry

C4.7 WARNING AND ERROR MESSAGES

CSAS4 contains two types of warning and error messages. The first type of message is from the Material Information Processor which is common to many of the SCALE analytical sequences. These messages are prefixed by MP- followed by a number. The Material Information Processor messages are listed in numerical order in Sect. C4.7.1. The second type of message pertaining to CSAS4 is identified by CS- followed by a number. These messages are listed in numerical order in Sect. C4.7.2. For additional information concerning a message, simply look up the number in this section.

Warning messages appear when a possible error is encountered. It is the responsibility of the user to verify whether or not the data are correct when a warning message is encountered. The functional modules activated by CSAS4 and related sequences will be executed even though a warning message has been generated.

When an error is recognized, an error message is written and an error flag is set so the functional modules will not be activated. The code stops immediately if the error is too severe to allow continuation of input. However, it will continue to read and check the data if it is able. When the data reading is completed, execution is terminated if an error flag was set when the data were being processed. If the error flag has not been set, execution continues. The STOP codes associated with the severe error messages are listed in Sect. C4.7.3.

C4.7.1 MATERIAL INFORMATION PROCESSOR MESSAGES

The following messages originate in the Material Information Processor, that portion of the analytical sequence that reads the parameter data, standard compositions specification data, and geometry data necessary for preparing the required information for the cross-section processing codes:

MP-1 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine KNIGHT indicates that the allocated computer storage will not hold the directories and isotope information tables. The first number printed is the amount of storage, in words, needed to hold this data. The second number is the amount of computer storage that was allocated, and the third number is the minimum additional words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 300 is executed when this message is printed.

MP-2 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine KNIGHT indicates that the allocated computer storage will not hold the directories and isotope information tables. The first number printed is the amount of storage, in words, needed to hold this data. The second number is the amount of computer storage that was allocated, and the third number is the minimum additional words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 310 is executed when this message is printed.

MP-3 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine KNIGHT indicates that the allocated computer storage will not hold the directories and isotope information tables. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 320 is executed when this message is printed.

MP-4 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine SETUPA indicates that the allocated computer storage will not hold the directories and isotope information tables. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 330 is executed when this message is printed.

MP-5 ***ERROR***SYSTEM GEOMETRY NAME INCORRECT. INSTEAD OF (____), THE USER SHOULD HAVE ENTERED LATTICECELL, MULTIREGION, OR INFHOMMEDIUM AS THE SECOND ITEM ON THE PARAMETER CARD. CHECK SPELLING.

This self-explanatory message is from subroutine SETUPB. The user has misspelled the word defining the type of calculation to be performed, or the parameter data preceding it were entered incorrectly. See Sect. C4.4.3 for assistance in correctly specifying the parameter data.

MP-6 ***ERROR*** ____ NOT FOUND IN STANDARD COMPOSITION LIBRARY. MAKE SURE THE COMPOSITION NAME USED IS IN THE STANDARD COMPOSITION LIBRARY.

This self-explanatory message from subroutine STDCMP indicates that a standard composition name is misspelled, the standard composition specification data were out of order, or the "END" has been omitted from the preceding standard composition specification. Check the standard composition specification data carefully. See Sect. C4.4.4 for assistance with standard composition specification cards. See Sect. M8 for the materials available in the Standard Composition Library.

MP-7 ***ERROR*** THE USER ENTERED A VOLUME FRACTION (VF) OF 0.0 FOR ONE OF THE STANDARD COMPOSITIONS (_____). THIS INDICATES THAT HE INTENDS TO ENTER A NUMBER DENSITY FOR THE STANDARD COMPOSITION. THAT, HOWEVER, CAN ONLY BE DONE WHEN THE STANDARD COMPOSITION NAME REPRESENTS A SINGLE NUCLIDE (LIKE H, O, PB, B-10, U-238, ETC.). CHECK THE STANDARD COMPOSITION LIBRARY.

This self-explanatory message is from subroutine STDCMP. Check the Standard Composition Library, Sect. M8, for the available standard composition names. See Sect. C4.4.4 for the correct method of specifying standard composition specification data.

MP-8 ***ERROR*** CELL TYPE NAME (_____) IS INCORRECT. CHECK THE SPELLING. THE ALLOWED NAMES ARE: SQUAREPITCH, TRIANGPITCH, SPHSQUAREP, SPHTRIANGP, SYMMSLABCELL, ASYMSLABCELL, ASQUAREPITCH, ATRIANGPITCH, ASPHSQUAREP, ASPHTRIANGP, ASQP, ATRP, ASSP, ASTP.

This self-explanatory message is from subroutine LATCEL. The data are misspelled or out of order. Some data items may be missing, or extra ones may have been entered. Errors in the standard composition specification data can cause this message to be printed. See Sect. C4.4.6 for additional assistance.

MP-9 ***ERROR*** THE NUMBER OF ZONES (IZM=_____) IS INCORRECT FOR ASYMSLABCELL GEOMETRY. FOR AN ASYMMETRIC LATTICECELL CALCULATION, ONE SHOULD HAVE IZM=3, 5, OR 7, DEPENDING ON THE MATERIALS PRESENT.

This self-explanatory message is from subroutine LATCEL. See Sect. C4.4.6 for an explanation of the ASYMSLABCELL geometry data. A code error is responsible for this message.

MP-10 ***ERROR*** INSUFFICIENT DATA SUPPLIED ON THE GEOMETRY DESCRIPTION CARD.

This message from subroutine LATCEL can be caused by having an error in the standard composition specification data, thereby causing the reading routines to get out of phase. If no error messages precede this message, it may indicate that a code error exists. The number of material zones (IZM) has been destroyed or altered in some manner.

MP-11 ***ERROR*** MIXTURE _____ IN THE CSAS GEOMETRY DESCRIPTION WAS NOT SPECIFIED IN THE STANDARD COMPOSITION DATA.

This message from subroutine LATCEL indicates that a mixture number used in the geometry description was not defined in the standard composition specification data. Check the input data for consistency. If the specified mixture number is zero and if the problem is a LATTICELL problem using mixture zero for the clad or moderator, it will be necessary to specify a low-density mixture in the standard composition data and use it in the cell specification.

MP-12 ***ERROR*** THE GAP WAS SPECIFIED AS MIXTURE ____ ON THE LATTICECELL. IT SHOULD BE ZERO OR A VALID MIXTURE NUMBER.

This message from subroutine LATCEL indicates that the mixture number used for the GAP was not defined in the standard composition specification data. Check the input data for consistency.

MP-13 **WARNING** NUMBER OF ENTRIES ON THE GEOMETRY DESCRIPTION CARD EXCEEDS THE NUMBER EXPECTED. THIS MESSAGE MAY BE GENERATED IF THE USER FORGOT TO ENTER THE END ON THE GEOMETRY DESCRIPTION CARD.

This message from subroutine LATCEL may result from a code error or from omitting the word "END" from the geometry description card.

MP-14 ***ERROR*** THE COORDINATE SYSTEM NAME (_____) IS INCORRECT. FOR THIS MULTIREGION CALCULATION, THE USER SHOULD HAVE ENTERED SLAB, CYLINDRICAL, SPHERICAL, BUCKLEDSLAB OR BUCKLEDCYL ON THE GEOMETRY DESCRIPTION CARD. CHECK SPELLING.

This self-explanatory message is from subroutine MULTRG.

MP-15 ***ERROR*** ALPHANUMERIC DESCRIPTION OF THE RIGHT-HAND BOUNDARY CONDITION (_____) IS INCORRECT. ONLY VACUUM, REFLECTED, PERIODIC, AND WHITE BOUNDARY CONDITIONS ARE ALLOWED. CHECK SPELLING. CHECK GEOMETRY DESCRIPTION CARD INPUT INSTRUCTIONS FOR ADDITIONAL ASSISTANCE.

This self-explanatory message is from subroutine MULTRG. See Sect. C4.4.6 for additional assistance.

MP-16 ***ERROR*** ALPHANUMERIC DESCRIPTION OF THE LEFT-HAND BOUNDARY CONDITION (_____) IS INCORRECT. ONLY VACUUM, REFLECTED, PERIODIC, AND WHITE BOUNDARY CONDITIONS ARE ALLOWED IN SLAB GEOMETRY. IN THE CASE OF CYLINDRICAL OR SPHERICAL GEOMETRY, ONLY THE REFLECTED BOUNDARY CONDITION IS ALLOWED ON THE LEFT. CHECK SPELLING. CHECK GEOMETRY DESCRIPTION CARD INPUT INSTRUCTIONS FOR ADDITIONAL INSTRUCTIONS.

This self-explanatory message is from subroutine MULTRG. See Sect. C4.4.6 for additional assistance.

MP-17 ***ERROR*** MIXTURE _____ FROM THE MULTIREGION DATA WAS NOT SPECIFIED IN THE STANDARD COMPOSITION DATA.

This message is from subroutine MULTRG. It indicates that a mixture number specified in the multiregion data was not defined in the standard composition specification data. Check the input data for consistency.

MP-18 ***ERROR*** USER MADE AT LEAST _____ DATA ERRORS. PROBLEM WILL NOT BE RUN. HOPEFULLY, EACH OF THESE ERRORS WILL HAVE GENERATED ITS OWN SELF-EXPLANATORY ERROR MESSAGE. IF NOT, CHECK DATA CAREFULLY BEFORE RESUBMITTING.

This self-explanatory message is from subroutine SETUPB. Check through the problem printout and correct all errors that have occurred.

MP-19 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message is from subroutine SETUPB. It indicates that the allocated computer storage will not hold the data that must be loaded to calculate the information that must be passed to BONAMI. The first number is the amount of storage, in words, needed to hold these data. The second number is the amount of computer storage that is required to hold these data. The third number is the minimum additional words of storage required to hold these data. Subsequent portions of the program may require even more storage. Increase the region size in the "go step" of the job control language and resubmit the problem. A STOP 390 is executed when this message is printed.

MP-20 ***ERROR*** MIXTURE NUMBER ____ ON A STANDARD COMPOSITION CARD IS LESS THAN 1.

This message is from subroutine SETUPB. A mixture number specified on a standard composition specification card must always be greater than zero. This message is triggered if a MP-6 message is printed. Fixing the MP-6 error should eliminate this message. If the printed mixture number is a positive number, a code error is responsible for the message.

MP-21 ***WARNING*** STANDARD COMPOSITION CARD NUMBER _____ IMPLIES THAT MIXTURE NUMBER _____ HAS A TEMPERATURE OF _____ DEGREES KELVIN, WHEREAS STANDARD COMPOSITION SPECIFICATION CARD _____ IMPLIES THAT MIXTURE NUMBER _____ HAS A TEMPERATURE OF _____ DEGREES KELVIN. (ONE OF THESE MAY HAVE BEEN THE VALUE SPECIFIED BY DEFAULT.) THE CODE WILL ASSUME THE HIGHER OF THE TWO AND PROCEED. IF THIS IS NOT SATISFACTORY, THE USER SHOULD ENTER THE CORRECT TEMPERATURE ON EACH OF THE STANDARD COMPOSITION SPECIFICATION CARDS INDICATED.

This self-explanatory message is from subroutine SETUPB.

MP-22 **WARNING** STANDARD COMPOSITION SPECIFICATION CARD(S) MISSING FOR MIXTURE NUMBER _____.

This message from SETUPB is printed to remind the user that the mixture numbers specified in the standard composition specification data are not contiguous. This may result in wasted storage space, but is not necessarily indicative of an error.

MP-23 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine MTABLE indicates that the allocated computer storage will not hold the nuclide ID numbers that will be processed by subroutine IDENTS. 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 words of storage needed to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 340 is executed when this message is printed.

MP-24 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine MIXTAB indicates that the allocated computer storage will not hold the three mixing table arrays that will be processed by subroutine ARRAY3. 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 words of storage needed to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 350 is executed when this message is printed.

MP-25 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine MIXTAB indicates that the allocated computer storage will not hold the three mixing table arrays that will be processed by subroutine ARRAY3. 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 words of storage needed to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 360 is executed when this message is printed.

MP-26 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine MIXTAB indicates that the allocated computer storage will not hold the three mixing table arrays that will be processed by subroutine ARRAY3. 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 words of storage needed to hold the data

to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 370 is executed when this message is printed.

MP-27 ***ERROR*** THE NUMBER OF MIXTURES FOUND IN THE MIXING TABLE IS INCONSISTENT WITH THE INPUT DATA. THE NUMBER FOUND IS _____, BUT THE INPUT DATA INDICATED _____.

This message from subroutine REORDR indicates that an error was found in the mixing table during operations to reorder and load it in permanent storage. The number of mixtures found in the mixing table should be the same as the number indicated by the input data. A code error is the likely cause of this message. A STOP 380 is executed when this message is printed.

MP-28 ***ERROR*** NUCLIDE ID _____ SPECIFIED IN THE INPUT DATA WAS NOT FOUND IN THE STANDARD COMPOSITION LIBRARY.

This message is from subroutine IDENTS or subroutine SLNS. A STOP 395 is printed with this message. Check the standard compositions specification data, Sect. C4.4.4, and ensure that the "ZA" ID numbers were entered correctly. This message is also printed if an arbitrary material specifies a value other than 0 or 1 for the MULTIPLE ISOTOPE INDICATOR (IVIS in Sect. C4.4.4).

MP-29 ***ERROR*** AN ARGUMENT OF _____ IS INVALID FOR AN ARCSIN OR ARCCOS.

This message from subroutine ARCHK is indicative of a code error. ARCHK is called from subroutine DAN to ensure that proper arguments are supplied to the ARCSIN and ARCCOS functions in determining cylinder Dancoff factors. This error can be caused by specifying a center-to-center spacing that is smaller than is physically possible.

MP-30 ***ERROR*** THE MATRIX WAS SINGULAR WHEN THE NUMBER FRACTION OF AN ISOTOPE IN AN ELEMENT WAS BEING DETERMINED. MAKE SURE THE SPECIFIED ISOTOPE DISTRIBUTION (WEIGHT PERCENT) SUMS TO 100.0.

This message from subroutine NOFRAC is caused by an isotope distribution that does not sum to 100% for an element. Entry A7 of Sects. C4.4.4 or M7.4.4 illustrates the correct procedure for specifying the weight percent of the various isotopes in an element.

MP-31 ***ERROR*** THE CALCULATED NUMBER FRACTIONS DO NOT REPRODUCE THE WEIGHT PERCENTS ENTERED AS INPUT DATA OR OBTAINED FROM THE STANDARD COMPOSITION LIBRARY.

WTFRAC=nnnnnnnnnn NOFRAC=mmmmmmmmmm MASS=ℓℓℓℓℓℓℓℓℓℓ

This message is printed from subroutine NOFRAC. WTFRAC, NOFRAC, and MASS are printed for each isotope in the standard composition. WTFRAC is the specified input weight percent for the isotope converted to weight fraction instead of weight percent. NOFRAC is the adjusted atom percent converted to atom fraction for the isotope corresponding to a total weight percent of 100% for the isotopes in the standard

composition. MASS is the atomic weight of the isotope. The adjusted isotopic weight percents are not printed in MP-31 but can be calculated according to:

$$ADJ_i = \frac{NOFRAC_i \times MASS_i}{\sum_i NOFRAC_i \times MASS_i} \times 100, \qquad \text{(C4.7.1)}$$

where

ADJ_i is the adjusted weight percent of isotope i,

$NOFRAC_i$ is the number fraction of isotope i printed in MP-31,

$MASS_i$ is the atomic weight of isotope i printed in MP-31.

Message MP-31 is printed if the adjusted weight percent of an isotope differs by 0.4% or more from the isotopic weight percent specified for that particular isotope in the standard composition data. An error flag is set, and the problem will not execute. If the isotopic weight percents specified in the input data do not sum to 100%, the weight percent of the first isotope whose specified weight percent is greater than 0.1% is adjusted to force the total weight percent to sum to 100%. If this adjustment results in a calculated weight percent for that isotope that is less than 0.4% different from that specified in the input data, the problem is run using the adjusted data. If message MP-31 is printed, correct the isotopic weight percents specified in the standard composition input data to sum to 100 or specify the isotope with the largest weight percent first, and resubmit the problem.

MP-32 ***ERROR*** END COMP WAS EXPECTED, BUT _____ WAS READ INSTEAD.

This message from subroutine SETUPA is printed if the data is out of order or the keywords END COMP or END COMPOSITIONS are omitted after the last standard composition specification. An END followed by blanks is also allowed. Check the data and the spelling of the END COMP. See Sect. C4.4.4.

MP-33 ***ERROR*** END OF FILE WAS ENCOUNTERED WHILE READING MULTIREGION ZONE DESCRIPTION. VERIFY THAT THE END ZONE CARD WAS ENTERED.

This self-explanatory message from subroutine SETUPA is printed if the END ZONE is omitted following the MULTIREGION zone description data. See Sect. C4.4.7.

MP-34 ***ERROR*** END ZONE WAS EXPECTED, BUT _____ WAS READ INSTEAD.

This message from subroutine SETUPA is printed if data is out of order or the keywords END ZONE are omitted at the end of the MULTIREGION zone description data. Check the data and the spelling of the END ZONE. See Sect. C4.4.7.

MP-35 ***ERROR*** END OF FILE WAS ENCOUNTERED WHEN THE GEOMETRY DESCRIPTION CARD WAS EXPECTED.

This self-explanatory message from subroutine SETUPA is printed if data are omitted or out of order. See Sect. C4.4.

MP-36 ***ERROR*** ILLEGAL SOLUTION NAME _____. ALLOWED NAMES INCLUDE SOLNUO2F2, SOLNUO2(NO3)2 AND SOLNPU(NO3)4.

This self-explanatory message from subroutines SLNS and SLNAME is printed if a solution name is misspelled or data are out of order. See Sect. C4.4.4 for assistance in specifying solution names correctly.

MP-37 ***ERROR*** ____ IS AN INVALID NAME WHEN READING MORE DATA.

This message is printed from subroutine MOREDT when extra parameter data is to be entered as explained in Sect. C4.4.8. The data are out of order, or a parameter name is misspelled.

MP-38 ***ERROR*** INVALID GEOMETRY WORD _____. ONLY INFHOMMEDIUM, MULTIREGION, OR LATTICECELL ARE ALLOWED.

This self-explanatory message is from subroutine SETUPA. Correct the input data and resubmit the problem. Check the spelling of the geometry word, ensure that the data are in order, and resubmit the problem.

MP-39 ***WARNING*** AN END DATA WAS READ BEFORE IT WAS EXPECTED. AN END WAS PROBABLY OMITTED FROM A STANDARD COMPOSITION.

This message from subroutine SETUPA indicates that an "END" was omitted from a standard composition specification or that the END for a standard composition specification was followed by COMP. The first four characters following the END on a standard composition specification card cannot be COMP. The words END COMP terminate the standard composition specification data. Check the standard composition specification data carefully.

MP-40 ***ERROR*** NUCLIDE ID _____ IN MIXTURE _____ DOES NOT OCCUR IN THE STANDARD COMPOSITION LIBRARY.

This self-explanatory message is from subroutine REORDR. A STOP 385 is executed in conjunction with this message.

MP-41 ***ERROR*** A NUCLIDE ID OF _____ IS INVALID FOR _____ IN THE FOLLOWING STANDARD COMPOSITION SPECIFICATION.

This message from subroutine STDCMP indicates that a nuclide ID is not compatible with a standard composition name. For example: UO2 3 1 300 94240 50 94238 50 END would cause this error because plutonium is invalid for a uranium standard composition specification. If this message is printed for a solution, the specific gravity of the solution may have been entered without the required keyword SPG=.

MP-42 ***ERROR*** AN END WAS ENCOUNTERED BEFORE MORE DATA WAS COMPLETED.

This message from MOREDT indicates incomplete input for MORE DATA. See Sect. C4.4.8 or M7.4.8 for assistance.

MP-43 ***WARNING*** BAL=_____ IS AN INVALID BALANCE TABLE SPECIFICATION. ALL BALANCE TABLES WILL BE PRINTED.

This message from subroutine MOREDT indicates that the value entered following BAL= is incorrect. Available options are NONE, FINE, and ALL. If any other value is entered, this message will be printed.

MP-44 *** ERROR *** NUCLIDE _____ IS NOT A MULTIPLE ISOTOPE NUCLIDE ***ERROR***.

This message from subroutine STDCMP indicates that a value greater than zero was entered for the multiple isotope indicator (IVIS) in an arbitrary material and that the first ID NUMBER (NCZA) is not a multiple isotope nuclide (see Sect. C4.4.4). When this message is printed, an error flag is set to prevent execution and IVIS is set to zero to allow the code to continue checking the remaining input data. If an arbitrary material was not specified, this message indicates that the Standard Composition Library is in error for the standard composition printed immediately following this message.

MP-45 ***** ERROR ***** ____ IS NOT A VALID CALCULATION TYPE. USE INFHOMMEDIUM, LATTICECELL, OR MULTIREGION. EXECUTION IS TERMINATED.

This message from subroutine CSPARM indicates that the TYPE OF CALCULATION (see item 3 of Sect. C4.4.3) was spelled incorrectly, entered out of order, or was improperly specified.

MP-46 *** ERROR *** THE FUELOD CANNOT BE GREATER THAN THE PITCH.

This self-explanatory message from subroutine LATCEL results from an error in the UNIT CELL SPECIFICATION for a LATTICECELL problem (see Sect. C4.4.6). The value of PITCH must be at least as large as the value of FUELOD.

MP-47 *** ERROR *** THE CLADOD CANNOT BE LESS THAN THE FUELOD, NOR GREATER THAN THE PITCH.

This message from subroutine LATCEL indicates an error in the UNIT CELL SPECIFICATION for a LATTICECELL problem. See Sect. C4.4.5 and verify the values of PITCH, FUELOD, and CLADOD.

MP-48 *** ERROR *** THE GAPOD CANNOT BE LESS THAN THE FUELOD, NOR GREATER THAN THE CLADOD.

This message from subroutine LATCEL indicates an error in the UNIT CELL SPECIFICATION for a LATTICECELL problem. See Sect. C4.4.6 and verify the values of FUELOD, CLADOD, and CLADID (note that CLADID is the GAPOD and is equal to FUELOD + twice the gap thickness).

MP-49 *** ERROR *** THE ABOVE RADIUS MUST BE GREATER THAN THE PREVIOUS RADIUS.

This message from subroutine MULTRG indicates an error in the GEOMETRY SPECIFICATION for a MULTIREGION problem. See Sect. C4.4.7 and check to ensure that each value of RZ is greater than the previous value of RZ.

MP-50 *** WARNING *** IN MORE DATA, RESONANCE INFORMATION (RES=) WAS SUPPLIED FOR MIXTURE _____. IT WILL NOT BE USED BECAUSE THAT MIXTURE OCCURS IN THE CELL DESCRIPTION.

This message from subroutine MOREDT is printed if resonance data (RES=) are entered for a mixture in MORE DATA (Sect. C4.4.8) and are also used in the cell description (Sects. C4.4.6 and C4.4.7).

MP-51 *** ERROR *** IN MORE DATA _____ IS AN INVALID GEOMETRY TYPE FOR USE IN SPECIFYING RESONANCE DATA.
CYLINDER, SPHERE, OR SLAB MUST BE ENTERED.

This message from subroutine MOREDT is printed if resonance data (RES=) are entered in MORE DATA (Sect. C4.4.8) and an incorrect shape is specified. The correct specification for a sphere of mixture 3 having a radius of 1.5 cm is: RES=3 SPHERE 1.5

MP-52 *** WARNING *** IN MORE DATA, DANCOFF INFORMATION (DAN( )=) WAS SUPPLIED FOR MIXTURE _____. THIS VALUE WILL BE USED INSTEAD OF CALCULATING THE DANCOFF FROM THE CELL DESCRIPTION.

This message from subroutine MOREDT is printed to alert the user that the Dancoff information calculated from the unit cell (Sects. C4.4.6 and C4.4.7) specification is being overridden by the value that was entered in MORE DATA (Sect. C4.4.8).

MP-54 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the volume fraction data from subroutine VERIFY. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-55 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the mixing table data required for subroutine BONAMI. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-56 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the mixture number, outer radii, temperature, sigma-H, and zone identifiers for each BONAMI zone. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-57 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the BONAMI control parameters. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-58 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the cross-section data required by subroutines EPSIG and XSMESH. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-59 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the data required by subroutine XSDRN. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-60 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the data required by subroutine ICE. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-61 *** ERROR *** THE CROSS-SECTION LIBRARY NAME ENTERED IN THE MATERIAL INFORMATION PROCESSOR DATA FOR THIS CSAS PROBLEM IS INCORRECT. SEE TABLE M4.1.1 OF THE SCALE MANUAL.

This message from subroutine C4DATA indicates that an invalid CROSS-SECTION LIBRARY NAME (see item 2 of Sect. M7.4.3) was entered. The name was misspelled, out of order, or improperly specified. See Table M4.1.1 for a list of valid library names.

MP-62 ***ERROR*** A MIXTURE NUMBER IS OUT OF RANGE. ENTRY _____ IN THE MIXING TABLE IS _____. IT SHOULD FALL BETWEEN 1 AND _____, THE LARGEST NUMBER USED IN THE STANDARD COMPOSITION DATA.

This message is from subroutine EPSIG. Because the largest mixture number is determined by the code as the input data are read, this message may be the result of a code error introduced when changes were made to the code.

MP-63 ***ERROR*** A POINTER INTO THE NUCLIDE DATA IS OUT OF RANGE. ENTRY ___ IN THE MIXING TABLE IS ____. IT SHOULD FALL BETWEEN 1 AND ____, THE NUMBER OF NUCLIDES IN THE STANDARD COMPOSITION LIBRARY.

This message is from subroutine EPSIG. It may result from a code error introduced when changes were made to the code.

MP-64 TAPE COPY NEEDS _____ WORDS, BUT ONLY HAS _____ WORDS.

This message from subroutine SHORTX indicates that the allocated computer storage is insufficient to create the short cross-section library utilized by the Material Information Processor. Increase the space allocation using the "SIZE" parameter on the analytical sequence indicator (Sect. M7.4.2) and resubmit the problem. A STOP 200 is executed when this message is printed.

MP-65 ***** ERROR ***** THE FOLLOWING NUCLIDES WERE NOT FOUND ON THE MASTER LIBRARY:

This message from subroutine SHORTX indicates that the user specified a standard composition that contains a nuclide that is not available on the specified master library. For example, nuclide ID 25304, which is stainless-steel-weighted manganese, is not available on any of the libraries but is listed in the Standard Composition Library. 25055 could be used instead.

MP-66 ***ERROR*** THE MIX. NO. (MIXZ=____) ASSIGNED TO ZONE IZ=____ WAS OUTSIDE THE RANGE 0 TO MXX=_____.

This message from subroutine VERIFY indicates that the mixture number is out of range. A code error is the likely cause of this error.

MP-67 **WARNING** MIXTURE ____ WAS ASSIGNED TO ZONES ____ AND ____. THIS MAY BE CORRECT IF THE MIXTURE HAS NO RESONANCE NUCLIDES AND HAS THERMAL SCATTERING DATA AT ONLY ONE TEMPERATURE. USUALLY, UNIQUE MIXTURE NUMBERS SHOULD BE USED IN EACH ZONE, EVEN THOUGH THE MIXTURE SPECIFICATIONS MAY BE IDENTICAL. THIS ALLOWS BONAMI AND NITAWL TO PRODUCE SEPARATE CROSS SECTIONS BASED ON THE APPROPRIATE NUMBER OF EXTERNAL MODERATORS AND THE ACTUAL MEAN CHORD LENGTH FOR EACH SPECIFIED ZONE AS WELL AS THE ACTUAL TEMPERATURE FOR THAT ZONE.

This self-explanatory message is from subroutine VERIFY. The user should verify that the multiple use of the stated mixture number was intentional and correct.

MP-68 ERRONEOUS MIXING TABLE LENGTH FOR XSDRN.

This message from subroutine XSDRN is indicative of a code error. The computed mixing table length, MS, passed to subroutine XSDRN, does not match the counted length in subroutine XSDRN.

MP-69 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

This message from subroutine XSMESH indicates that the allocated computer storage will not hold the interval boundaries and zone number for each interval. The first number printed is the amount of storage, in words, needed to hold this data. The second number is the amount of computer storage that was allocated, and the third number is the minimum additional words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. Specification (by the control module) of too many mesh

intervals in a given zone is the most frequent cause of failure. In MULTIREGION calculations where one has a large zone containing a strong absorber (such as a tank of uranyl-fluoride solution), it may be necessary to reduce the number of mesh intervals by increasing the size factor (SZE) in the optional parameter data (Sect. C4.4.8). Making this factor large enough (SZF=10, 15, 20, 30, etc.) will generally allow any problem to run in the space allocated. Once the problem runs, one should check the number density of all strong absorbers to see if they are realistic. Occasionally a user will accidentally specify an unrealistic concentration of a strong absorber in one or more zones. Such a mistake dramatically increases the number of mesh intervals the code thinks it needs.

MP-70 ***ERROR*** MORE THAN ONE ZONE WAS ENCOUNTERED FOR THIS INFINITE HOMOGENEOUS MEDIA PROBLEM.

This self-explanatory message is from subroutine XSMESH. Correct the input data and resubmit the problem.

MP-71 ***WARNING*** THE TEMPERATURE FOR STANDARD COMPOSITION _____ WAS SPECIFIED AS _____ DEGREE CELSIUS.
DENSITY DATA AT 25 DEGREES CELSIUS WILL BE USED FOR THIS SOLUTION.

This message from subroutine SLNS is printed if SOLNUO2F2 or SOLNPU(NO3)4 were specified in the standard composition data with a temperature outside the range of 15 to 30°C. The Standard Composition Library does not contain data for these solutions outside that temperture range.

MP-72 *** ERROR *** KEYWORD SPG= TO SPECIFY THE SPECIFIC GRAVITY OF THE SOLUTION WAS EXPECTED. KEYWORD _____ WAS READ INSTEAD.

This message from subroutine STDCMP indicates an error in the specification of solution data in the standard composition specification. If the specific gravity of a solution is to be entered, it is the fourth entry after the solution name. Check the solution input data carefully.

MP-73 ***ERROR*** EXTERNAL MODERATOR INDEX IS INCORRECT IN ZONE _____ OF THE MULTIREGION DATA. ENTER NOEXTERMOD, ONE EXTERMOD, OR TWOEXTERMOD INSTEAD OF (_____). CHECK SPELLING.

This self-explanatory message is printed from subroutine MULTRG and subroutine RESDA. The user has misspelled the word defining the external moderator index of the specified zone or the MULTIREGION data are out of order. See Sect. M7.4.4.7.

MP-74 *** ERROR *** FIRST MODERATOR HAS NEGATIVE THICKNESS

This message from subroutine DANCOF indicates that the dimensions specified for an ASYMSLABCELL are inconsistent. The array pitch (PITCH) is smaller than the sum of the second moderator thickness (TKMOD2) and *MAX* where *MAX* is the outside diameter of the clad (CLADOD) if entered; otherwise, *MAX* is the outside diameter of the fuel (FUELOD). Correct the data and resubmit the problem. See Sect. M7.4.6 and Fig. M7.5.6.2 for assistance.

MP-75 *** ERROR *** KEYWORD DEN= OR SPG= TO SPECIFY THE DENSITY OF THE BASIC STANDARD COMPOSITION WAS EXPECTED. KEYWORD _____ WAS READ INSTEAD.

This message from subroutine STDCMP indicates an error in the specification of the density in the basic standard composition data. If the density of the material is to be entered, it is the second entry after the standard composition name. The density is optional data. If the density is entered, it is multiplied by the volume fraction to obtain the density actually used for this composition.

MP-76 *** ERROR *** THE LOWER BOUND OF XSDRN INTERVAL _____ IS _____WHICH MUST BE LESS THAN THE UPPER BOUND OF _____.

This message from subroutine XSMESH indicates that the specified XSDRN mesh interval is incorrect. Each mesh interval must have a finite positive thickness. This message can be caused by an error in the unit cell data. Either a zero-thick region was specified or the unit cell dimensions were incorrectly specified. Carefully check the unit cell dimensions. If a LATTICECELL annular cell is specified, verify that the FUELOD is at least as large as TKMOP2+2(CLADOD-FUELOD).

MP-77 A NEGATIVE DIMENSION WAS ENCOUNTERED IN THE UNIT CELL DATA. CHECK AND CORRECT THE GEOMETRY DIMENSION.

This message from subroutine LATCEL is printed if a negative number is read for a cell dimension. Check the printed problem geometry and correct the input data (Sect. M7.4.6).

MP-78 THE FUEL THICKNESS IS NEGATIVE. THE ANNULAR CELL DIMENSIONS FOR TKMOD2, CLADOD, AND FUELOD ARE INCONSISTENT.

This message from subroutine LATCEL indicates an error in the description of a cylindrical or spherical annular cell. The cell description must provide a finite fuel thickness. The ID of the fuel is calculated using the diameter of the second moderator, TKMOD2, and the OD of the clad, CLADOD. If the calculated ID of the fuel is greater than or equal to the specified OD of the fuel, there is no fuel in the cell and this message is printed. The thickness of the gap and clad is ½(CLADOD–FUELOD), so the ID of the fuel is TKMOD2+CLADOD–FUELOD. See Sect. M7.4.6 for data input instructions.

MP-79 *** ERROR *** THE ORIGIN MUST BE 0.0 FOR SPHERICAL OR CYLINDRICAL GEOMETRY.

This message from subroutine MULTRG is printed if the origin, ORGN of Table M7.4.8, Sect. M.4.7, is nonzero for a cylinder or sphere. Either the MULTIREGION unit cell data are out of order or a nonzero number has been entered for ORGN. Correct the data and resubmit the problem.

MP-80 *** ERROR *** NOT ENOUGH STORAGE IN CLAPSE - FIRST NUMBER IS THE AMOUNT NEEDED, SECOND IS THE AMOUNT AVAILABLE.

PERTINENT CONSTANTS

This message from subroutine CLAPSE indicates that the allocated computer storage is insufficient to allow collapsing the thermal cross sections to one group for shielding calculations. 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. A STOP 201 is executed when this message is printed.

MP-81 *** ERROR *** DANCOFF FACTOR MUST BE BETWEEN 0.0 AND 1.0.

This message from subroutine MOREDT is printed if DAN(n)= is specified in MORE DATA with a value greater than 1.0 or less than 0.0. Dancoff factors must lie between 0 and 1. The problem will not be run if message MP-81 is printed. Correct the data and resubmit the problem. See Sect. M7.4.7 for assistance.

MP-82 THE FIRST MODERATOR THICKNESS IS NEGATIVE. THE ASYMMETRIC SLAB CELL DIMENSIONS FOR TKMOD2, CLADOD, AND PITCH ARE INCONSISTENT

This message from subroutine LATCEL indicates an error in the description of an asymmetric slab cell. The thickness of the first moderator is not specified in the input data and is calculated as PITCH–TKMOD2/2–CLADOD. If the thickness of the first moderator is negative, this message is printed.

MP-83 *** ERROR *** AN INPUT DATA ERROR HAS BEEN ENCOUNTERED IN THE MATERIAL INFORMATION PROCESSOR DATA ENTERED FOR THIS PROBLEM.

This message from subroutine C4DATA is printed if the subroutine library routine LRDERR returns a value of "TRUE," indicating that a reading error was encountered in the Material Information Processor input data. Locate the unnumbered message stating "***** ERROR IN INPUT. CARD IMAGE PRINTED ON NEXT LINE *****." Correct the data and resubmit the problem.

MP-84 *** WARNING *** FOR MIXTURE _____ THE DANCOFF FACTOR OF _____ IS OUTSIDE THE RANGE OF 0 TO 1. IT WILL BE RESET TO THE CLOSER BOUND.

This message from subroutine RESDA is printed when the DANCOFF factor is less than 10^{-4} outside the allowed range of 0 to 1. This is usually due to roundoff in calculating the Dancoff factor.

MP-85 *** ERROR *** FOR MIXTURE _____ THE DANCOFF FACTOR OF ____ IS OUTSIDE THE RANGE OF 0 TO 1. IT WILL BE RESET TO THE CLOSER BOUND. THE PROBLEM WILL NOT BE EXECUTED.

This message from subroutine RESDA is printed when the Dancoff factor is more than 10^{-4} outside the allowed range of 0 to 1. Check the input data to be sure that the specified Dancoff factor is between 0 and 1. See Sect. M7.4.8 or C4.4.8 for input specifications for the Dancoff factor. If the Dancoff factor was not specified in the optional parameter data, the message is due to a code error.

MP-86 ***ERROR*** THE FUEL DENSITY FOR SOLUTION ____ IN MIXTURE ____ SPECIFIES A FUEL DENSITY OF ____ G/L, WHICH EXCEEDS THE FUEL DENSITY OF A HYDRATED CRYSTAL, AND WILL LEAD TO ERRONEOUS DENSITIES WHEN USED AS A SOLUTION

This message from subroutine SLNS is printed only for solution standard compositions (those that begin with SOLN) that are incorrectly specified. Each solution standard composition is composed of (1) a fuel-salt, **fs**, (2) water, $\mathbf{H_2O}$, and (3) an acid. A fully hydrated fuel-salt is defined as $fs \cdot nH_2O$ where **n** defines the number of water molecules associated with the fuel-salt crystal (water of hydration). The values of **n** are:

n	Solution	Hydrated Salt
2	UO_2F_2	$UO_2F_2 \cdot 2H_2O$
6	$UO_2(NO_3)_2$	$UO_2(NO_3)_2 \cdot 6H_2O$
5	$Pu(NO_3)_4$	$Pu(NO_3)_4 \cdot 5H_2O$

If the fuel density is so large that there is not enough water in the solution to form fully hydrated crystals of fuel-salt, this message will be printed. The solution name, mixture number, and specified fuel density are printed in the error message. The problem will not run if this message is printed. Correct the input data for this solution standard composition in the specified mixture and resubmit the problem.

MP-87 ***WARNING*** THE FUEL DENSITY FOR SOLUTION ____ IN MIXTURE ___ SPECIFIES A FUEL DENSITY OF ___ G/L. THIS MAY BE GREATER THAN THE SATURATED SOLUTION FUEL DENSITY, AND MAY GIVE INCORRECT DENSITIES AS A SOLUTION. CHECK THE DENSITIES CAREFULLY.

This message from subroutine SLNS is printed because the fuel density for the specified solution standard composition may be high enough to allow precipitation of the fuel-salt. Each solution standard composition is composed of (1) a fuel-salt (**fs**), (2) water (H_2O), and (3) an acid. The water/fuel-salt ratio, **n**, is the ratio of the moles of water to moles of fuel-salt. The minimum threshold values of **n** used to trigger this message are:

n	Solution
8	UO_2F_2
17	$UO_2(NO_3)_2$
17	$Pu(NO_3)_4$

The solution name, mixture number, and specified fuel density are printed in the error message. The problem will run and it is the responsibility of the user to verify that the resulting solution is correct.

MP-88 ***ERROR*** THE LIBRARY SPECIFIED IS A PRE-NITAWL-II LIBRARY

This error message from subroutine SETUPA indicates the specified library was created to be used with a version of NITAWL prior to NITAWL-II. See Table M4.1.1 for a list of acceptable cross-section libraries. If the library is correctly specified, its format is not consistent with the NITAWL-II format.

MP-89 ***ERROR*** THE MATERIAL SPECIFIED IN THE ____TH STANDARD COMPOSITION SPECIFICATION DOES NOT CONTAIN ANY MULTIPLE ISOTOPE NUCLIDES. ISOTOPIC SPECIFICATIONS ARE NOT ALLOWED.

This error message from subroutine SCDATA indicates that the nth standard composition specification does not contain multiple isotopic nuclides but isotopic data (NCZA and ATPM) were included. It could possibly indicate a missing END statement. When determining the nth specification, arbm and basic standard composition specifications count as one each and solution specifications count as three each (fuel salt, water, and an acid).

MP-90 ***ERROR*** TOO MANY ISOTOPES WERE SPECIFIED FOR THE ____TH ELEMENT OF THE _____TH STANDARD COMPOSITION SPECIFICATION.

This error message from subroutine SCDATA indicates the nth element of the mth standard composition specification contains more isotopes than are allowed. Reduce the number of isotopes used to describe the material. When determining the mth standard composition specification, arbitrary materials and basic standard composition specifications count as one each and solution specifications count as three each (fuel salt, water, and an acid).

MP-91 ***ERROR*** THE USER SPECIFIED A NEGATIVE VOLUME FRACTION FOR _____.

This self-explanatory error message from subroutine STDCMP indicates a negative density multiplier or volume fraction (VF). It was entered for the standard composition named in the message.

MP-92 ***ERROR*** THE USER SPECIFIED A NEGATIVE OR 0 MIXTURE NUMBER FOR ___.

This self-explanatory error message from subroutine STDCMP indicates that a negative or zero mixture number (MX) was entered for the standard composition named in the message.

MP-93 ***ERROR*** THE USER SPECIFIED A NEGATIVE OR 0 DENSITY FOR _____.

This self-explanatory error message from subroutine STDCMP indicates that a negative or zero density or specific gravity (SPGR or ROTH) was specified for the standard composition named in the message.

MP-94 ***ERROR*** THE USER SPECIFIED A NEGATIVE OR 0.0 FUEL DENSITY FOR SOLUTION _____.

This self-explanatory error message from subroutine STDCMP indicates that a negative or zero fuel density (FD) was specified for the solution standard composition named in the message.

MP-95 ***ERROR*** THE USER SPECIFIED A NEGATIVE ACID MOLARITY FOR SOLUTION _____.

This self-explanatory error message from subroutine STDCMP indicates that a negative or zero acid molarity (AML) was specified for the solution standard composition named in the message.

MP-96 *** ERROR*** ILLEGAL ENDING KEYWORD FOR DANCOFF.)= SHOULD HAVE BEEN ENTERED, BUT _____ WAS READ INSTEAD.

This message from subroutine MOREDT indicates that DAN(was entered in the input, but after the mixture number something other than a)= occurred.

MP-97 *** ERROR ***A ZONE WIDTH MODIFIER WAS SPECIFIED FOR ZONE _____. IT MUST BE BETWEEN 1 AND _____.

This message from subroutine MOREDT indicates that ZMD(was entered in the input to specify a zone width modifier for an XSDRN search, but the zone number that followed was less than 1, or was greater than the number of zones defined for the problem.

C4.7.2 MESSAGES FROM CRITICALITY SAFETY SEQUENCE NO. 4

The following messages originate in the part of CSAS4 that reads, checks, and prepares data for KENO V.a and the search module MODIFY.

CS-16 ***WARNING*** READ FLAG NOT FOUND. ASSUME KENO V PARAMETER DATA FOLLOWS.

This message from subroutine CPARAM indicates that the word READ is not the first word of KENO V.a data following the KENO V.a title. If parameter data is to be entered, the code expects the words READ PARAMETERS to precede the parameter input data. If the word READ is not the first word, the code assumes the data are parameter input data.

CS-21 A UNIT NUMBER WAS ENTERED FOR THE CROSS-SECTION LIBRARY. (LIB= IN PARAMETER DATA.) THE DEFAULT VALUE SHOULD BE USED IN ORDER TO UTILIZE THE CROSS SECTIONS GENERATED BY CSAS. MAKE CERTAIN THE CORRECT CROSS-SECTION LIBRARY IS BEING USED.

This message is from subroutine CPARAM. It indicates that a value has been entered for the cross-section library in the KENO V.a parameter data. The cross-section library created by the analytical sequence should be used. MAKE CERTAIN THAT THE CORRECT CROSS SECTIONS ARE BEING USED.

CS-50 *** ERROR *** SEARCH COMMAND NUMBER ___ IS UNABLE TO PERFORM A PITCH SEARCH BECAUSE THE DIMENSIONS OF REGION _____ OF UNIT _____ ARE NOT EXPLICITLY DEFINED.

This message from subroutine PCHSRH indicates that the specified search command is not valid for the specified region. An ARRAY or CORE region cannot be altered; nor can a REPLICATE or REFLECTOR region immediately following an ARRAY or CORE region.

CS-55 *** ERRORS WERE ENCOUNTERED IN PROCESSING THE CSAS-KENO5 DATA. EXECUTION IS IMPOSSIBLE. ***

This message from subroutine SASSY is printed if errors were found in the KENO V.a input data for CSAS. If a search is being made, data reading will continue until all the data have been entered or a fatal error terminates the data reading. When the data reading and checking have been completed, the problem will terminate without executing. Check the printout to locate the errors responsible for this message.

CS-62 *** ERROR *** MIXTURE _____ IN THE GEOMETRY WAS NOT CREATED IN THE STANDARD COMPOSITIONS SPECIFICATION DATA.

This message from subroutine MIXCHK indicates that a mixture specified in the KENO V.a geometry was not created in the standard composition data. If mixture 500 (a cell-weighted, homogenized mixture) is to be used in the KENO V.a geometry data, CSAS2X or CSAS4X must be specified to create it.

CS-65 *** ERROR *** INSUFFICIENT SPACE ALLOCATION. C4DATA WAS NOT CALLED.

This message from the main program, CSAS, is printed if the space requested in the job control language is not enough to hold the program. There is not enough space available to load the material input processor and data preprocessor. Increase the amount of space requested in the job control language and resubmit the problem. A STOP 207 is executed when this message is printed.

CS-66 *** ERROR *** INSUFFICIENT SPACE ALLOCATION. SASSY WAS NOT CALLED.

This message from the main program, CSAS, is printed if the space requested in the job control language is not enough to hold the program. There is not enough space available to load the KENO V.a input processor. Increase the amount of space requested in the job control language and resubmit the problem. A STOP 208 is executed when this message is printed.

CS-67 *** ERROR *** INSUFFICIENT SPACE ALLOCATION. RDOPT WAS NOT CALLED.

This message from the main program, CSAS, is printed if the space requested in the job control language is not enough to hold the program. There is not enough space available to load the processor for the search data. Increase the amount of space requested in the job control language and resubmit the problem. A STOP 209 is executed when this message is printed.

CS-68 *** ERROR *** AN INPUT DATA ERROR HAS BEEN ENCOUNTERED IN THE ___DATA ENTERED FOR THIS PROBLEM.

This message from the main program, CSAS, is printed if the subroutine library routine LRDERR returns a value of "TRUE," indicating that a reading error has been encountered in the "KENO PARAMETER" data or the CSAS "SEARCH" data. The appropriate data type is printed in the message.

Locate the unnumbered message stating "***** ERROR IN INPUT. CARD IMAGE PRINTED ON NEXT LINE *****." Correct the data and resubmit the problem.

CS-69 ***ERROR*** MIXTURE _____ IS AN INAPPROPRIATE MIXTURE NUMBER FOR USE IN THE KENO GEOMETRY DATA BECAUSE IT IS A COMPONENT OF THE CELL-WEIGHTED MIXTURE CREATED BY XSDRNPM.

This message from subroutine CMXCHK indicates that a mixture that is a component of a cell-weighted mixture has been used in the KENO V.a geometry data.

CS-70 ***** ERROR ***** SEARCH OR OPTIMIZATION DATA MUST BE ENTERED FOR CSAS4, CSAS4X, AND CSAS3. NO SEARCH DATA WAS ENTERED.

This message from subroutine RDOPT is self-explanatory. If the user does not desire to run a search, another sequence such as CSAS25, CSAS2X, or CSAS1X should be chosen.

CS-71 *** ERROR *** _____ IS NOT A VALID SEARCH TYPE.

This message is from subroutine RDOPT. The allowed search types include OPTIMIZATION, DIMENSION, and CONCENTRATION. The first four characters of the search data after the words READ SEARCH must be OPTI, OPT, OPTM, DIM, DIME, DMSN, CON, or CONC. The data may be misspelled or out of order.

CS-72 *** ERROR *** THE SEARCH TYPE IS INVALID. I=_____.

This message is from subroutine RDOPT. The numerical index, I, should be 1 for an optimum pitch search, 2 for a dimension search, and 3 for a concentration search. If it is none of these, the search type has been incorrectly specified or a code error has been introduced.

CS-73 ***** AN END OF FILE WAS ENCOUNTERED BEFORE ALL THE SEARCH DATA WAS READ.

This self-explanatory message is from subroutine RDOPT. Check the input data to be sure nothing was omitted or misspelled.

CS-74 ***** AN END SEARCH FLAG WAS READ BEFORE ALL THE SEARCH DATA WAS READ.

This self-explanatory message is from subroutine RDOPT. Check the input data for omissions and correct order.

CS-75 *** ERROR *** READ SEARCH FLAG WAS NOT FOUND. _____ WAS READ INSTEAD.

This self-explanatory message is from subroutine RDOPT. READ SEARCH was expected but was not found. Check the input data for omissions and correct order.

CS-76 *** ERROR *** END SEARCH FLAG WAS NOT FOUND. _____ WAS READ INSTEAD.

This self-explanatory message from subroutine RDOPT indicates that an end of file was encountered when looking for READ SEARCH. Check the input data for omissions, correct order, and spelling.

CS-77 *** ERROR *** AN END OF FILE WAS FOUND WHEN THE READ SEARCH FLAG WAS EXPECTED.

This self-explanatory message is from subroutine RDOPT. Check the input data for omissions, correct order, and spelling.

CS-78 *** ERROR *** _____ IS NOT A VALID OPTIMIZATION SEARCH TYPE.

This message is from subroutines FIXTYP and OPTYPE. It indicates that an invalid search type was read. The valid search names include OPTIMUM PITCH, OPTIMUM CONCENTRATION, and OPTIMUM DIMENSION. Either the data was entered improperly or a code error has been introduced. A STOP 215 is executed when this message is printed.

CS-79 *** ERROR *** THE SEARCH TYPE IS INVALID. I=_____.

This message from subroutines FIXTYP and OPTYPE indicates that the search type was misspelled or a code error has been introduced. A STOP 216 is executed when this message is printed.

CS-80 *** ERROR *** SEARCH DATA HAS BEEN DESTROYED. I=___ ICMND=____ IPNUM= ___ II=____ IGEOM=____

This message from subroutines CNCSRH or DIMSRH indicates that the search data cannot be interpreted. This is probably due to a code error.

CS-81 THE SEARCH WAS PREMATURELY TERMINATED BECAUSE ONLY _____ GENERATIONS WERE COMPLETED IN THE LAST KENO PASS. AT LEAST _____ GENERATIONS (NSK=, IN THE KENO PARAMETER DATA) ARE REQUIRED TO SUSTAIN A SEARCH.

This self-explanatory message is from subroutine LODATA. Alter the data and/or the job control language to specify enough time and I/Os to allow completion of a sufficient number of generations in each pass. A STOP 212 is executed when this message is printed.

CS-82 *** AN ERROR WAS ENCOUNTERED IN ONE OF THE FUNCTIONAL MODULES.

This message from MODIFY, the main program of the search package, indicates that an error was encountered during execution of BONAMI, NITAWL, XSDRN, or KENO V.a. Check the printout to locate and correct the error.

CS-83 ***** NO FEASIBLE SOLUTION WAS FOUND IN THE SEARCH PACKAGE. EXECUTION IS TERMINATED. *****

This message from MODIFY, the main program of the search package, is self-explanatory. The code was unable to reach a feasible solution for the requested type of search.

CS-84 **** ERROR **** POINTER INDEX IS OUT OF RANGE. MODIFIED KENO V DATA CANNOT BE WRITTEN. NDX=_____.

This message from subroutine RERITE is probably due to a code error. A STOP 213 is executed when this message is printed.

CS-85 *** ERROR *** ALL OF THE ROOTS FOR K=_____ LIE OUTSIDE THE PARAMETER CONSTRAINTS.

This self-explanatory message from subroutine LODATA indicates that a solution does not exist for the specified desired value of k-effective.

CS-86 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutines FIXTYP and OPTYP indicates that the allocated computer storage will not hold the information required for a search. 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 words of storage necessary to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 211 is executed in conjunction with this message.

CS-87 *** ERROR *** INSUFFICIENT SPACE ALLOCATION. LODATA WAS NOT CALLED.

This message from subroutine MODIFY indicates that the allocated computer storage is not large enough to load the search data. The message is accompanied by a STOP 220. Increase the requested computer storage in the job control language.

CS-88 *** NOT ENOUGH STORAGE TO LOAD THE KENO V.a MIXING TABLE.

This message from subroutine MXTBLE is printed if the allocated computer storage will not accommodate the KENO V.a mixing table data. Increase the requested computer storage in the job control language.

CS-89 *** ERROR *** _____ IS AN INVALID DIMENSION SEARCH COMMAND.

This message from subroutine DMSN indicates that the dimension search data are out of order, a search command is spelled incorrectly, or the search data are specified incorrectly.

CS-90 *** ERROR *** _____ IS AN INVALID SEARCH PARAMETER.

This message printed from subroutines FIXCNC, FIXDIM, FIXPCH, OPTCNC, OPTDMN, or OPTPCH indicates that a parameter entered in the search type specification data is not valid (see Sect. C4.4.9.1 and Table C4.4.15). The data could be misspelled or out of order. Omission of the keyword MORE before entering the individual search commands (Sect. C4.4.9.2) can cause this error.

CS-91 *** ERROR *** _____ IS AN INVALID CONCENTRATION SEARCH COMMAND.

This message from subroutine CNCN is caused by a misspelled or illegal search command when attempting to do a concentration search.

CS-92 *** ERROR *** ITY IS NOT PITCH(1), DIMENSION(2), OR CONCENTRATION(3). ITY IS PRINTED BELOW.

PERTINENT CONSTANTS

This message from subroutine LODATA indicates that the search data was incorrect when it was reloaded. This error is probably due to a code error.

CS-93 *** ERROR *** NOPT IS NOT MINIMUM (-1), CRITICAL(0), OR MAXIMUM(1). NOPT IS PRINTED BELOW.

PERTINENT CONSTANTS

This message from subroutine LODATA indicates that the search data were incorrect when they were reloaded. This error is probably due to a code error.

CS-94 *** ERROR *** REG= _____ IS AN INVALID SEARCH DATA ENTRY. THE REGION NUMBER MUST BE GREATER THAN ZERO AND NO LARGER THAN THE NUMBER OF REGIONS IN THE UNIT.

This message from subroutine DMSN indicates that the region to be altered is incorrectly specified. For example, if the unit being altered contains five geometry regions, the value specified for REG= can be as small as 1 and as large as 5.

CS-95 *** ERROR *** AN ERROR WAS ENCOUNTERED IN THE SEARCH DATA. THE LAST REGION NUMBER MUST BE AT LEAST AS LARGE AS THE FIRST REGION NUMBER. CHECK THE SEARCH DATA PRINTED BELOW.
keyword UNIT ____ REGIONS ____ TO ____ PARAMETER=____
SEARCH CONSTANTS ARE ____ ____ ____ ____ ____ ____

This message from subroutine DMSN indicates that the search data specified an invalid region number for the final region to be altered. Check the printed data and correct as appropriate.

CS-96 *** ERROR *** AN ERROR WAS ENCOUNTERED IN THE SEARCH DATA. THE REGION NUMBERS MUST BE GREATER THAN ZERO AND NO LARGER THAN THE NUMBER OF REGIONS IN THE UNIT. CHECK THE SEARCH DATA PRINTED BELOW.
keyword UNIT _____ REGIONS _____ TO _____ PARAMETER=_____
SEARCH CONSTANTS ARE _____ _____ _____ _____ _____ _____

This message from subroutine DMSN indicates that one of the specified region numbers is incorrect. Check the printed data and correct as appropriate.

CS-97 *** ERROR *** NO VALID SEARCH COMMANDS WERE FOUND IN THE DATA.

This message is accompanied by a STOP 235 and is printed from subroutines PCHSRH, CNCSRH, and DIMSRH. A common cause of this error is the omission of the MORE command before the individual search commands are entered. See Sects. C4.4.10.1 and C4.4.10.2.

CS-99 THIS PROBLEM WILL NOT BE RUN BECAUSE PARM=CHECK WAS ENTERED IN THE ANALYTICAL SEQUENCE SPECIFICATION.

This message from subroutine CSAS indicates that the problem data were read and checked and no errors were found. To execute the problem, remove the PARM=CHECK or PARM=CHK from the analytical sequence indicator data entry.

CS-100 THIS PROBLEM WILL NOT BE RUN BECAUSE ERRORS WERE ENCOUNTERED IN THE INPUT DATA.

This message from subroutine CSAS is self-explanatory. Examine the printout to locate the error or errors in the input data. Correct them and resubmit the problem.

CS-101 THE CONSTRAINTS ARE NOT VALID FOR PARAMETER SET. -CON=_____ +CON=_____

This message is printed from either subroutine CNCN or DMSN if the parameter set is invalid. For a parameter set to be valid, -CON must be less than 0.0 and +CON must be greater than 0.0. They can be explicitly set or calculated using default or provided data.

CS-103 CANNOT MODIFY STANDARD COMPOSITION IN CELL-WEIGHTED MIXTURE. THE FOLLOWING COMPOSITIONS ARE IN THE CELL-WEIGHTED MIXTURE.

This message from subroutine CELCHK indicates that searches cannot be performed on compositions contained in the unit cell data used to make a cell-weighted mixture.

C4.7.3 STOP CODES

The STOP codes that are utilized in CSAS3 and CSAS4 are listed in tabular form, indicating the subroutine where they occur and the associated error message. A STOP is executed when a fatal error is recognized. Locate 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 printed at the completion of the associated message.

Stop No.	Subroutine	Traceback	Associated Message
20			See Sect. C4.7.5
200	SHORTX	No	MP-64
201	CLAPSE	No	MP-80
203	MXTBLE	No	CS-88
207	CSAS	Yes	CS-65
208	CSAS	Yes	CS-66
209	CSAS	Yes	CS-67
211	OPTYP	No	CS-86
	FIXTYP	No	CS-86
212	LODATA	No	CS-81
213	RERITE	No	CS-84
214	CSAS	Yes	CS-68
215	OPTYP	No	CS-78
	FIXTYP	No	CS-78
216	OPTYP	No	CS-79
	FIXTYP	No	CS-79
220	MODIFY	No	CS-87
225	LODATA	Yes	CS-92
230	LODATA	Yes	CS-93
235	DIMSRH	Yes	CS-97
	OPTSRH	Yes	CS-97
	PCHSRH	Yes	CS-97
300	KNIGHT	Yes	MP-1
310	KNIGHT	Yes	MP-2
320	KNIGHT	Yes	MP-3
330	SETUPA	Yes	MP-4
340	MTABLE	Yes	MP-23
350	MIXTAB	Yes	MP-24
360	MIXTAB	Yes	MP-25
370	MIXTAB	Yes	MP-26
380	REORDR	No	MP-27
385	REORDR	No	MP-40
390	SETUPB	Yes	MP-19
395	IDENTS	No	MP-28
	SLNS	No	MP-28
396	CSPARM	No	MP-45

C4.7.4 MESSAGES ASSOCIATED WITH STOP 20 IN CSAS

The following messages from Subroutine Library routines will result in a STOP 20 in the material information processor and CSAS:

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 CSAS 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 CSAS, this error may be caused by entering a direct-access unit number for FRD= or FWR= in MORE DATA.

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 that the data control block was not open. In CSAS 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 MORE DATA by entering the parameter DAB=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. For CSAS25, CSAS2X, CSAS4, and CSAS4X, it may also be necessary to set NB8=nnn in the KENO parameter data.

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. In CSAS 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 I/O error has occurred.

C4.7.5 UNNUMBERED MESSAGES

Occasionally the code may terminate without printing a message that can be located via the message number. Some of these messages are:

***** END OF FILE READ ON UNIT n *****

This message is from subroutine ENFILE in the Subroutine Library. Unit n is the device from which data is being read. This message can be caused by lack of a double blank between the END for the last standard composition and the END COMP. It can also be caused by omitting the END COMP or misspelling COMP in the END COMP entry. Other causes include incomplete or missing data. A traceback accompanies this message. Correct the data and resubmit the problem.

***** ERROR IN INPUT. CARD IMAGE PRINTED ON NEXT LINE *****
card image is printed here
ON THE ABOVE CARD, CHARACTER NUMBER m (IMAGE=c) IS NOT VALID.

This message is from the Subroutine Library free-form reading routine DREAD. The character number, m, and the character image, c, printed in the message are recognized as being invalid for the type of data being read. For example, character data were encountered when numerical data were expected. This message can be caused by missing or incomplete data and by omitting double blanks after a labeled or unlabeled END. A traceback accompanies this message. Correct the data and resubmit the problem.

C4.A ALPHABETICAL INDEX OF SUBROUTINES

This section provides a convenient alphabetical index of the subroutines and functions and common blocks used in CSAS.

Table C4.A.1 provides an alphabetical listing of the subroutines and functions that comprise CSAS.

Table C4.A.2 provides an alphabetical listing of the subroutines and functions in the control module MODIFY. MODIFY allows the user to perform searches using KENO V.a.

Table C4.A.3 provides an alphabetical index of the common blocks used in CSAS.

Table C4.A.4 provides an alphabetical index of the common blocks used in MODIFY.

Table C4.A.1 Alphabetical index of CSAS routines

Subroutine Name	Calling Subroutine	Called Subroutine
birite	cparam	
celchk	fixtyp optyp	
cmxchk	sassy	lchkmx
cncn	fixtyp optyp	aread clear cread fread iread lcompr
cncsrh	fixtyp optyp	inquir prtsrh rite stop
cparam		aread birite clear fread iread libeql opnfil rndin rndout timfac zread
dimsrh	fixtyp optyp	inquir prtsrh rite stop
dmsn	fixtyp optyp	clear cread fread inquir iread lcompr rite
fixcnc	fixtyp	aread cread fread iread lcompr

Table C4.A.1 (continued)

Subroutine Name	Calling Subroutine	Called Subroutine
fixdim	fixtyp	aread
		cread
		fread
		iread
		lcompr
fixpch	fixtyp	aread
		cread
		fread
		iread
		lcompr
		reed
fixtyp	rdopt	celchk
		cncn
		cncsrh
		cread
		creed
		dimsrh
		dmsn
		fixcnc
		fixdim
		fixpch
		inquir
		lcompr
		pchsrh
		reed
		rite
		stop
libeql	cparam	
mixchk	mxtble	lchkmx
mxtble	sassy	clear
		inquir
		mixchk
		rite
		stop
		table
optcnc	optyp	aread
		cread
		fread
		iread
		lcompr
optdmn	optyp	aread
		cread
		fread
		iread
		lcompr

Table C4.A.1 (continued)

Subroutine Name	Calling Subroutine	Called Subroutine
optpch	optyp	aread
		cread
		fread
		iread
		lcompr
		reed
optyp	rdopt	celchk
		cncn
		cncsrh
		cread
		creed
		dimsrh
		dmsn
		inquir
		lcompr
		optcnc
		optdmn
		optpch
		pchsrh
		reed
		rite
		stop
partbl		rndout
pchsrh	fixtyp	inquir
	optyp	prtsrh
		rite
		stop
		xxlim
pratbl	sassy	rtadj
prtsrh	cncsrh	
	dimsrh	
	pchsrh	
rdopt		aread
		clear
		cread
		fixtyp
		inquir
		lcompr
		optyp
		rite

Table C4.A.1 (continued)

Subroutine Name	Calling Subroutine	Called Subroutine
sassy		aralba
		cmxchk
		datain
		iosdun
		jomity
		lodwts
		move
		mxtble
		point
		pratbl
		prtara
		prtjom
		prtplt
		stop
		wrtrst
table	mxtble	

Table C4.A.2 Alphabetical index of MODIFY routines

Subroutine Name	Calling Subroutine	Called Subroutine
alter	lodata	clear
		xxlim
avgkef	lodata	
compct	lodata	
cubfit	fixedk	decomp
	maxmin	solve
	optmiz	
decomp	cubfit	
densty	lodata	stop
fixedk	optmiz	cubfit
gtdata	lodata	corsiz
		rgused
		sorta
		stop
lodata	lodcom	alter
		avgkef
		bonami
		clear
		compct
		densty
		gtdata
		inquir
		mixprt
		move
		nitawl
		openda
		optmiz
		poke
		prtjom
		prtsrh
		readid
		reed
		rerite
		resda
		restrt
		rite
		stop
lodcom		lodata
		move
maxmin	optmiz	cubfit
		mscan

Table C4.A.2 (continued)

Subroutine Name	Calling Subroutine	Called Subroutine
mixprt	lodata	prtmix
mscan	maxmin	
optmiz	lodata	cubfit fixedk maxmin rcubic
prtsrh	lodata	
rcubic	optmiz	
readid	lodata	io opnfil
rerite	lodata	inquir io reed wrtalb wrtara wrtwts
restrt	lodata	move
solve	cubfit	

Table C4.A.3 Commons used in CSAS

Common Name	Referencing Subroutine
albdat	cparam
	partbl
	pratbl
	sassy
albnam	cparam
	partbl
	pratbl
	sassy
blklnc	cparam
	partbl
ccdata	fixtyp
	optyp
	sassy
cdata	fixtyp
	optyp
	sassy
celmix	cmxchk
deal	celchk
dimen	cncn
	cparam
	dmsn
	fixtyp
	mxtble
	optyp
	partbl
	pratbl
	sassy
drtacs	cncn
	cncsrh
	dimsrh
	dmsn
	fixpch
	fixtyp
	mxtble
	optpch
	optyp
	pchsrh
	rdopt
	sassy
errflg	sassy

Table C4.A.3 (continued)

Common Name	Referencing Subroutine
flg	cncsrh
	dimsrh
	fixcnc
	fixdim
	fixpch
	fixtyp
	optcnc
	optdmn
	optpch
	optyp
	pchsrh
	rdopt
ios	sassy
liba	fixtyp
	optyp
libc	fixtyp
	optyp
logic	cparam
	partbl
	sassy
lpnt	rdopt
	sassy
matrx	pratbl
pass	sassy
pointr	sassy
rec1	cncn
	dmsn
	fixpch
	fixtyp
	optpch
	optyp
	prtsrh
	rdopt
	sassy
runtyp	birite
	cparam
	partbl
stdata	sassy

Table C4.A.3 (continued)

Common Name	Referencing Subroutine
titl	cparam
	partbl
	pratbl
	prtsrh
unit	celchk
	cncn
	cncsrh
	cparam
	dimsrh
	dmsn
	fixcnc
	fixdim
	fixpch
	fixtyp
	mxtble
	optcnc
	optdmn
	optpch
	optyp
	partbl
	pchsrh
	prtsrh
	rdopt
	sassy
units	sassy

Table C4.A.4 Commons used in MODIFY

Common Name	Referencing Subroutine
albdat	lodcom rerite restrt
albnam	lodcom rerite restrt
ccdata	lodata
cdata	lodata
cunit	lodata
cycle	lodata lodcom
deal	alter lodata
dimen	gtdata lodata lodcom rerite restrt
drtacs	gtdata lodata lodcom rerite restrt
liba	lodata
libc	lodata
logic	gtdata rerite restrt
lowbnd	gtdata lodata
lpnt	lodata
pass	lodata
pcolor	rerite restrt
pict	rerite restrt

Table C4.A.4 (continued)

Common Name	Referencing Subroutine
picttl	rerite
	restrt
rec1	lodata
	lodcom
	prtsrh
	rerite
stdata	lodcom
	rerite
	restrt
titl	prtsrh
	restrt
unit	alter
	densty
	lodata
	lodcom
	prtsrh
	rerite
units	avgkef
	lodata
xsdrnc	lodata

C4.B SAMPLE PROBLEMS

This section contains sample problems to demonstrate some of the options available in CSAS and its associated sequences. A brief problem description and the associated input data are included for each problem. See Sect. C4.5 for additional examples.

SAMPLE PROBLEM 1 K-EFFECTIVE CALCULATION

The purpose of this problem is to calculate the k-effective of a system. This problem is the same as the KENO V.a sample problem 12 in Sect. F11.D except the cross-section library and KENO V.a mixing table are prepared by CSAS. The problem represents a critical experiment consisting of a composite array[1,2] of four highly enriched (93.2%) uranium metal cylinders having a density of 18.76 g/cc and four 5.0677-L Plexiglas containers filled with uranyl nitrate solution. The uranium metal cylinders have a radius of 5.748 cm and a height of 10.765 cm. The uranyl nitrate solution has a specific gravity of 1.555 and contains 415 g of uranium per liter. The ID of the Plexiglas bottle is 19.05 cm and the inside height is 17.78 cm. The Plexiglas is 0.635 cm thick. The center-to-center spacing between the metal units is 13.18 cm in the "y" direction and 13.45 cm in the "z" direction. The center-to-center spacing between the solution units is 21.75 cm in the "y" direction and 20.48 cm in the "z" direction. The spacing between the y-z plane that passes through the centers of the metal units and the y-z plane that passes through the centers of the solution units is 17.465 cm in the "x" direction.

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. C4.B.1.

```
#csas25
sample problem 1  set up 4aqueous 4 metal in csas25
44group   infhommedium
uranium         1 0.985 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 end
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
plexiglass      3 end
end comp
keno v.a sample problem 19 4 aqueous 4 metal array of arrays (samp prob 12)
read param  flx=yes fdn=yes nub=yes
end param
read geom
unit 1
com='uranyl nitrate solution in a plexiglas container'
cylinder  2 1 9.525 2p8.89
cylinder  3 1 10.16 2p9.525
cuboid  0 1 4p10.875 2p10.24
unit 2
com='uranium metal cylinder'
cylinder  1 1 5.748 2p5.3825
cuboid  0 1 4p6.59 2p6.225
unit 3
com='1x2x2 array of solution units'
array 1 3*0.0
unit 4
com='1x2x2 array of metal units padded to match solution array'
array 2 3*0.0
replicate 0 1 2*0.0 2*8.57 2*8.03 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
```

```
com='composite array of solution and metal units'
fill 4 3 end fill
end array
end data
end
#clec_out
end
```

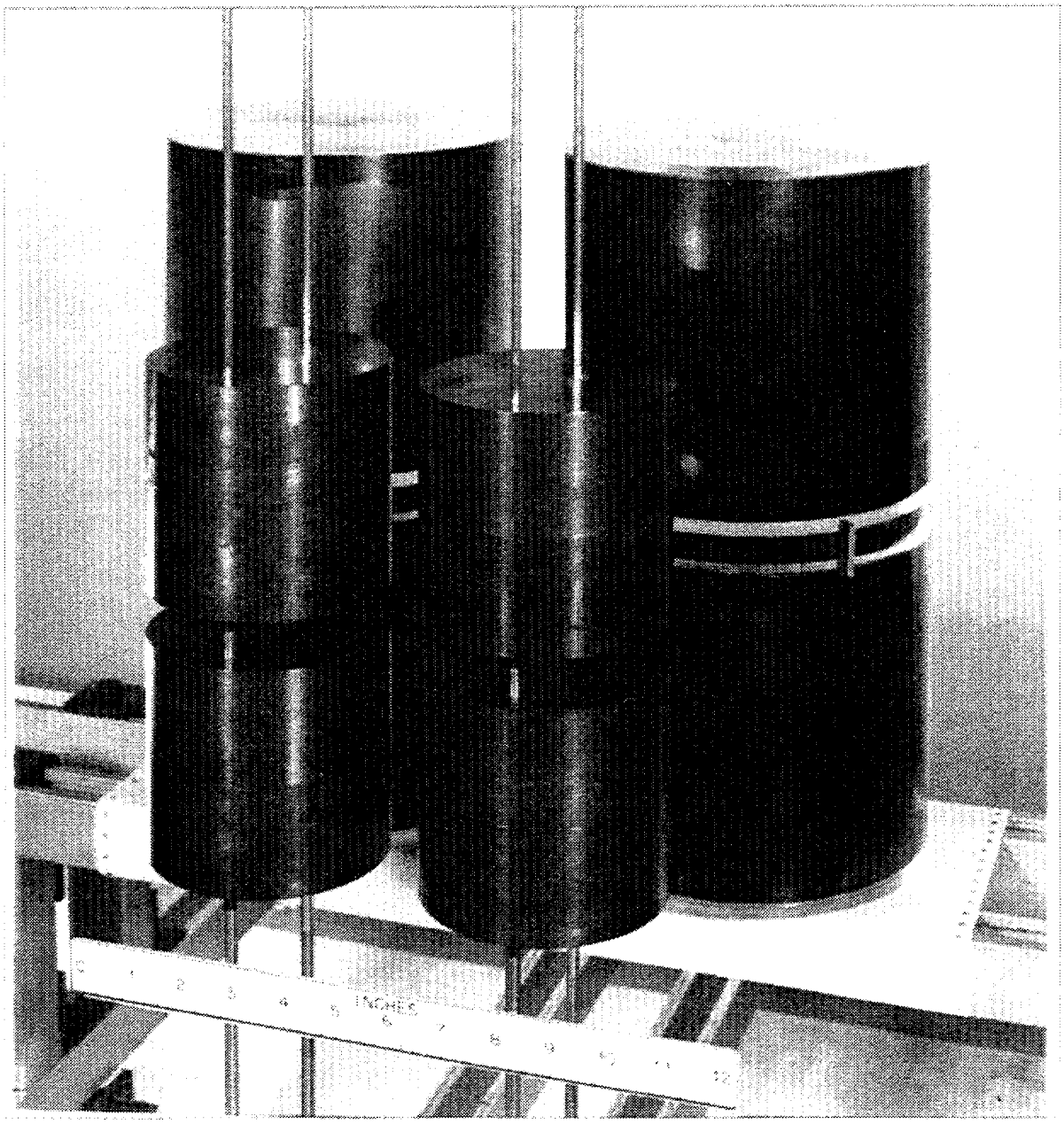


Figure C4.B.1 Critical assembly of four solution units and four metal units

SAMPLE PROBLEM 2 OPTIMUM PITCH SEARCH USING DETAILED GEOMETRY

This problem represents an attempt to optimize the reactivity of PWR-like fuel bundles in a storage pool. The storage array is an infinite planar array of flooded fuel bundles. Each bundle consists of a 17 x 17 x 1 array of 2.35%-enriched UO_2 pins, density 9.21 g/cc, clad with zircaloy-2. The fuel is 0.823 cm in diameter, the clad diameter is 0.9627 cm, and the length of each pin is 366 cm. Each fuel bundle is encased in a boral sheath. There is a 1/4-in. gap flooded with water between the bundle and the sheath. The boral sheath is 3/8 in. thick. One inch of water separates the fuel bundle sheaths in the horizontal plane, and 15 cm of water is present on the top and bottom of the array.

The KENO V.a geometry represents each fuel pin in the bundle discretely. The search should determine the optimum pitch within the fuel bundle. The gap between the bundle and the boral remains fixed, as does the thickness of the sheath and the spacing between sheaths.

```
#csas4
sample problem 2  pwr-like fuel bundle
44group latticecell
uo2    1 .84 293. 92235 2.35 92238 97.65 end
zirc2  2 1 end
h2o    3 1 end
b4c    4 den=2.65 0.3517 end
al     4 den=2.65 0.6483 end
h2o    5 1 end
end comp
squarepitch  1.2751 .823 1 3 .9627 2 end
storage array of pwr-like fuel bundles in poison sheaths
read param  nub=yes far=yes gen=103 npg=500 gas=no fdn=yes
end param
read array nux=17 nuy=17 nuz=1 end array
read bounds  xyf=mirror   end bounds
read geom
cylinder  1 1 .4115 183.0 -183.0
cylinder  2 1 .48135 183.1 -183.1
cuboid  3 1 .63755 -.63755 .63755 -.63755 183.1 -183.1
core  0 1 0 0 0
reflector 5 1 4*.635 2z 1
reflector 4 1 4*.9525 2z 1
reflector 5 1 4*1.27 2z 1
reflector 5 2 4z 2*3.0 5
end geom
read bias id=500 2 6 end bias
end data
read search  optimum pitch  end search
end
#clec_out
end
```

SAMPLE PROBLEM 3 OPTIMUM PITCH SEARCH USING HOMOGENIZED GEOMETRY

This problem illustrates the use of CSAS4X to represent a fuel cask. It utilizes a cell-weighted mixture to represent a PWR-like fuel bundle. The cask contains a 2 x 2 x 1 array of fuel bundles. Each fuel bundle consists of a 17 x 17 x 1 array of zircaloy-2 clad, 2.35%-enriched UO_2 fuel pins with a density of 9.21 g/cc arranged in a square pitch. The pin diameter is 0.823 cm, and its length is 366 cm. The clad is 0.06985 cm thick, and the pitch is 1.275 cm. Each fuel bundle is contained in a 0.6625-cm-thick boral sheath. The bundles are separated by 1 cm of water, representing a flooded cask. The square aluminum cask is 10 cm thick on all faces and is reflected by 15 cm of water.

By using CSAS4X, a cell-weighted cross section is created to represent the fuel bundle. The KENO V.a geometry utilizes the cell-weighted mixture (500) and the overall dimensions of the fuel bundle to represent the entire fuel bundle as a single homogeneous region. The first reflector card represents the fuel cask, and the second reflector card represents the 15-cm reflector.

```
#csas4x
sample problem 3  sample fuel cask
44group latticecell
uo2    1 .84 293. 92235 2.35 92238 97.65 end
zirc2  2 1 end
h2o    3 1 end
b4c    4 den=2.65 0.3517 end
al     4 den=2.65 0.6483 end
h2o    5 1 end
al     6 1 end
end comp
squarepitch  1.275 .823 1 3 .9627 2 end
sample square fuel cask
read param  nub=yes far=yes gen=103 npg=500 gas=no fdn=yes
end param
read array nux=2  nuy=2  nuz=1 end array
read geom
cuboid 500 1 4p10.8375 2p183.0
cuboid   4 1 4p11.5    2p183.0
cuboid   5 1 4p12.0    2p183.0
core     0 1 3*0
reflector 6 1 6*10.0 1
reflector 5 2 6*3 5
end geom
read bias id=500 2 6 end bias
end data
read search  optimum pitch  end search
end
#clec_out
end
```

SAMPLE PROBLEM 4 SEARCH FOR A SPECIFIED VALUE OF K-EFFECTIVE

Find the pitch at which a 2 × 2 × 2 array of cylinders of highly enriched (93.2%) uranium metal with a density of 18.76 g/cc are critical. Each cylinder has a radius of 5.748 cm and a height of 10.765 cm. The surface-to-surface spacing between the units is the same in all directions. The initial guess for the critical surface-to-surface spacing was 3.0 cm. The experimentally critical surface-to-surface separation for this system, shown in Fig. C4.B.2, is 2.248 cm. The input data for this problem are given below.

```
#csas4
sample problem 4  set up 2c8 in csas25
44group   infhommedium
uranium  1 0.985 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 end
end comp
critical pitch search for case 2c8 bare
read parameters  flx=yes fdn=yes far=yes gas=no rnd=656651ed24de
end parameters
read geometry
cylinder 1 1 5.748 5.3825 -5.3825
cuboid  0 1 4p7.248 2p6.8825
end geometry
read array  nux=2 nuy=2 nuz=2  end array
end data
read search   critical pitch   maxpitch=15.5  more
```

```
alter  unit=1 reg=2 +z=1.0531 -z=1.0531
end search
end
```

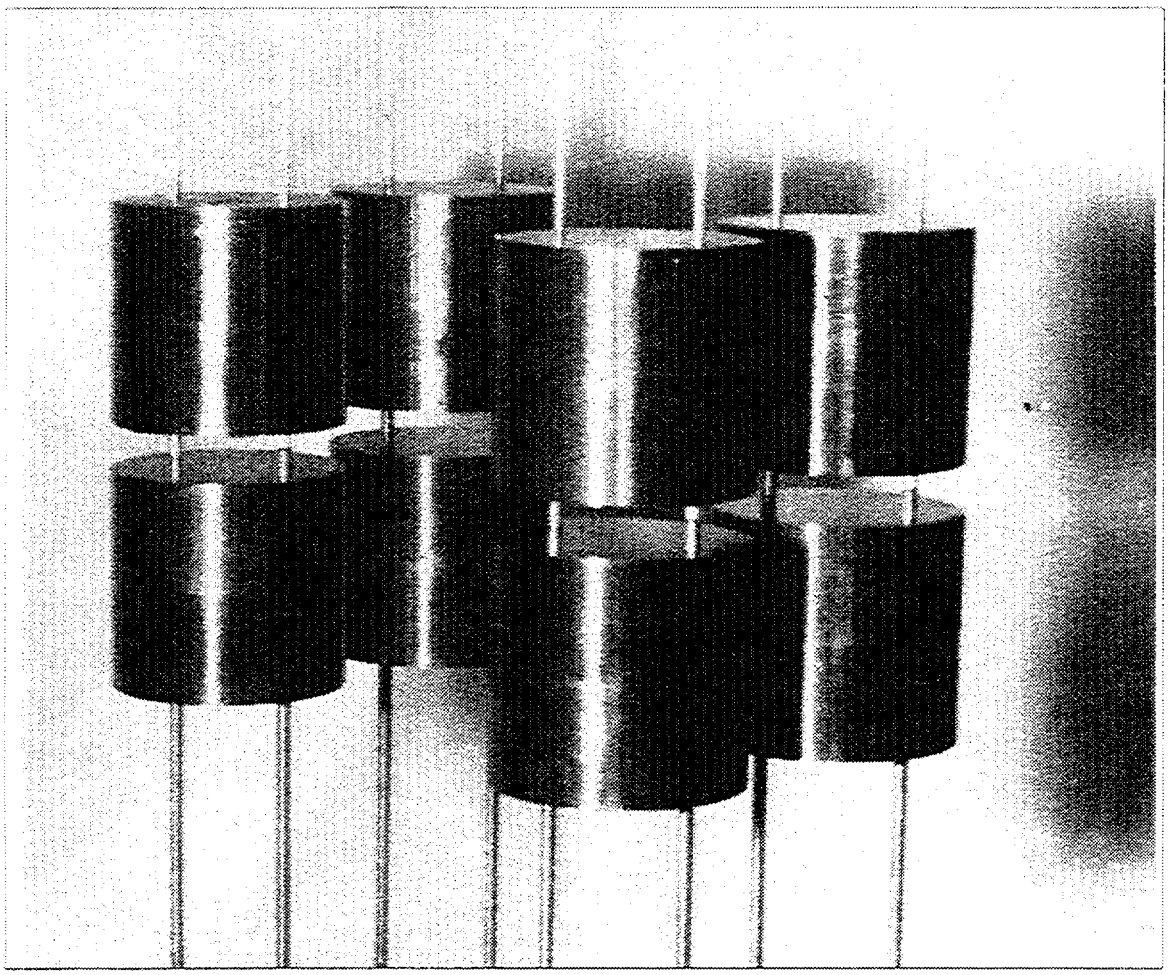


Figure C4.B.2 Critical assembly of eight highly enriched uranium metal cylinders

C4.B.1 REFERENCES

1. J. T. Thomas, "Critical Three-Dimensional Arrays of U(93.2)-Metal Cylinders," *Nucl. Sci. Eng.* **52**, 350 (November 1973).

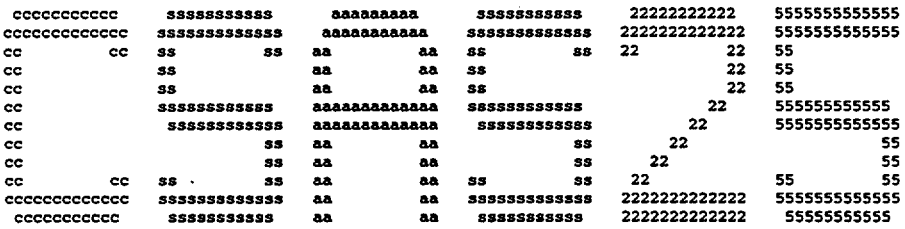
2. J. T. Thomas, *Critical Three-Dimensional Arrays of Neutron-Interacting Units, Part II*, ORNL/TM-868, Union Carbide Corp., Nucl. Div., Oak Ridge Natl. Lab. (July 1964).

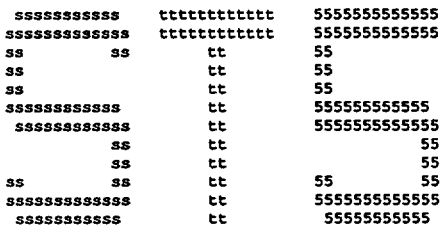
C4.C SAMPLE OUTPUT

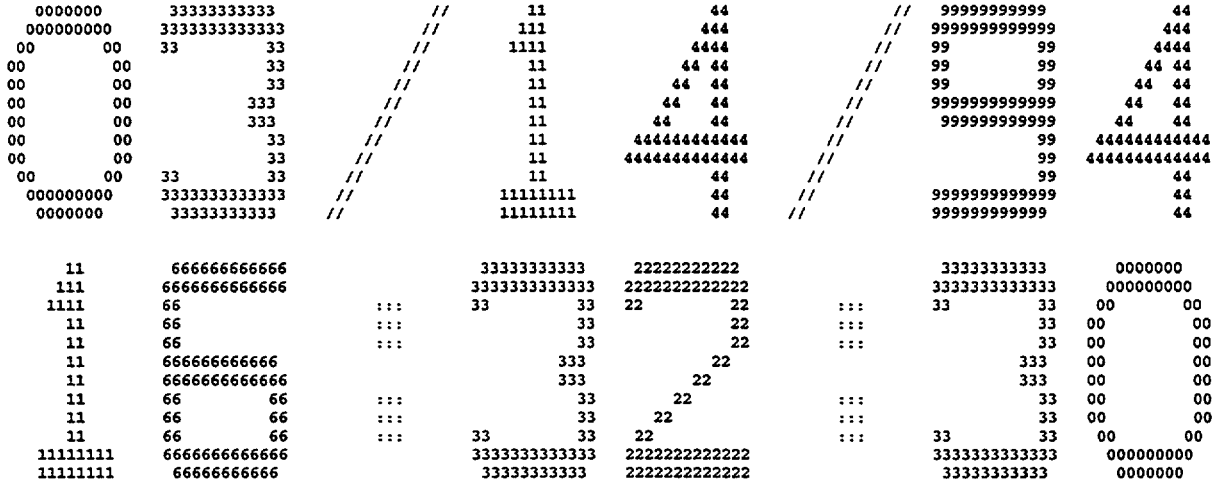
This section contains the computer printout generated by the control module for each sample problem. Output from functional modules is not included in this section. See Sect. C4.6 for a generic explanation of the control module output.

Sample problem 1 does not perform a search, so the k-effective resulting from this calculation does not appear in the control module output. This problem is a description of a critical experiment, so the KENO V.a output should yield a k-effective of 1.0 within statistical accuracy.

Sample problems 2, 3, and 4 perform searches. The search data and search results are printed after the program verification table for MODIFY. The k-effective is printed as each search pass is completed. These k-effectives may vary because of differences in the random number sequences on different computers.







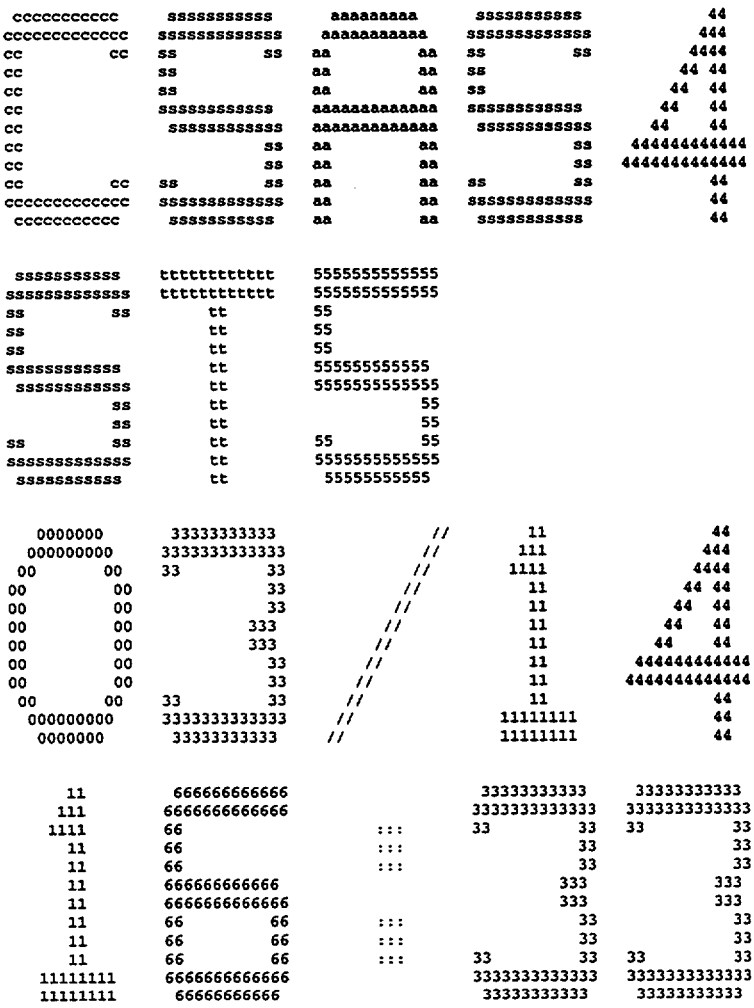
```
 sssssssssss     ccccccccccc      aaaaaaaaa      ll              eeeeeeeeeeee
ssssssssssssss   ccccccccccccc    aaaaaaaaaaa    ll              eeeeeeeeeeee
ss          ss  cc          cc   aa          aa  ll              ee
ss              cc               aa          aa  ll              ee
ss              cc               aa          aa  ll              ee
sssssssssss     cc               aaaaaaaaaaaaa   ll              eeeeeeeee
 sssssssssss    cc               aaaaaaaaaaaaa   ll              eeeeeeeee
          ss    cc               aa          aa  ll              ee
          ss    cc               aa          aa  ll              ee
ss        ss    cc          cc   aa          aa  ll              ee
ssssssssssssss  ccccccccccccc    aa          aa  llllllllllll    eeeeeeeeeeee
 sssssssssss     ccccccccccc     aa          aa  llllllllllll    eeeeeeeeeeee
```

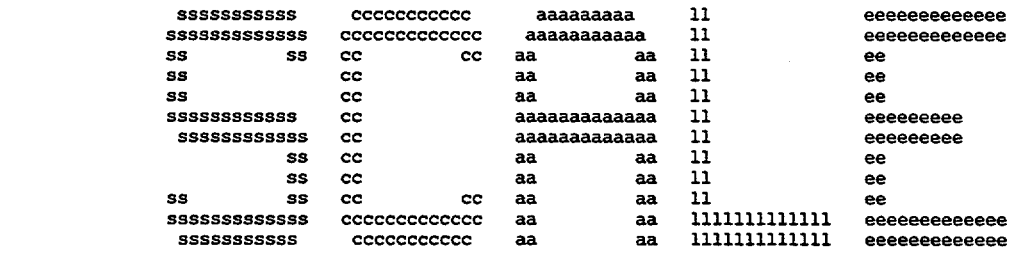
```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                  program verification information                *****
*****                                                                     *****
*****                 code system:    scale  version:    4.2           *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****              program:  csas                                         *****
*****                                                                     *****
*****        creation date:  12/01/93                                     *****
*****                                                                     *****
*****              library:  /scale4.2p/exe                               *****
*****                                                                     *****
*****                                                                     *****
*****      production code:  csas                                         *****
*****                                                                     *****
*****              version:  2.2                                          *****
*****                                                                     *****
*****              jobname:  st5                                          *****
*****                                                                     *****
*****    date of execution:  03/14/94                                     *****
*****                                                                     *****
*****    time of execution:  16:32:30                                     *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

```
sample problem 1  set up 4aqueous 4 metal in csas25


**** problem parameters ****

lib hansen-roach library
mxx             3 mixtures
msc             3 composition specifications
izm             1 material zones
ge  infhommedium geometry
more            0 0/1 do not read/read optional parameter data
msln            1 fuel solutions


**** problem composition description ****

sc  uranium       standard composition
mx              1 mixture no.
vf         .9850 volume fraction
roth     19.0500 theoretical density
temp       293.0 deg kelvin
           92235  93.20%
           92238   5.60%
           92234   1.00%
           92236    .20%
end

sc  solnuo2(no3) standard composition
mx              2 mixture no.
fd       415.0000 solution fuel density
aml         .0098 acid molarity
vf        1.0000 volume fraction
temp       293.0 deg kelvin
spg       1.5550 specified specific gravity
           92235  92.60%
           92238   5.90%
           92234   1.00%
           92236    .50%
end

sc  plexiglass   standard composition
mx              3 mixture no.
vf        1.0000 volume fraction
roth      1.1800 theoretical density
end


**** problem geometry ****


**** infinite homogeneous medium ****
mfuel           1 mixture no. of the infinite homogeneous medium
```

```
*** sample problem 1  set up 4aqueous 4 metal in csas25 ***

********** data library information **********

      unit                                              volume
     number          data set name                      name        unit function
     ------          -------------                      ----        -------------

       89     /scale4.2p/datalib/scale.rev05.sclib                  standard composition library

       81     /scale4.2p/datalib/scale.rev02.xn16                   cross section library

       11     ft11f001                                              short cross section library

                          standard composition library data
                          ---------------------------------

        unit number  :  89

        dataset name :  /scale4.2p/datalib/scale.rev05.sclib

        library title:  scale-4 standard composition library
                        386 standard compositions, 332 nuclides
                        10 elements with variable isotopic distrbutions.

        creation date:   1/25/94

                             cross section library data
                             --------------------------

        unit number  :  81

        dataset name :  /scale4.2p/datalib/scale.rev02.xn16

        library title:  scale 4 - 16 neutron group criticality safety library
                          hansen-roach data with knight modifications and some endf/b 4 data
                            compiled for nrc       1/27/89
                              last updated        10/12/89
                                l.m.petrie       ornl
```

```
        ........    0 io's were used before reading keno v data    ........

        ........    0 io's were used reading the keno v parameter data    ........

       *************** data reading completed ***************

        ........    0 io's were used preparing the keno v input data    ........

        ........    0 io's were used loading the keno v data    ........

        ........    0 io's were used loading the data    ........

        ........    0 io's were used checking the keno v geometry data    ........
        *****  restart data has been written on unit 95  *****

        ........    0 io's were used writing the keno v - csas data    ........

        ........    0 io's were used processing csas input data    ........
control module csas25   is complete.
```






```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                  program verification information                *****
*****                                                                     *****
*****                 code system:    scale  version:    4.2           *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****              program:  csas                                         *****
*****                                                                     *****
*****        creation date:  12/01/93                                     *****
*****                                                                     *****
*****              library:  /scale4.2p/exe                               *****
*****                                                                     *****
*****                                                                     *****
*****      production code:  csas                                         *****
*****                                                                     *****
*****              version:  2.2                                          *****
*****                                                                     *****
*****              jobname:  st5                                          *****
*****                                                                     *****
*****    date of execution:  03/14/94                                     *****
*****                                                                     *****
*****    time of execution:  16:33:08                                     *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

```
sample problem 2  pwr-like fuel bundle


**** problem parameters ****

lib hansen-roach library
mxx            5 mixtures
msc            6 composition specifications
izm            3 material zones
ge  latticecell  geometry
more           0 0/1 do not read/read optional parameter data
msln           0 fuel solutions


**** problem composition description ****

sc  uo2          standard composition
mx             1 mixture no.
vf         .8400 volume fraction
roth     10.9600 theoretical density
temp       293.0 deg kelvin
           92235   2.35%
           92238  97.65%
end

sc  zr           standard composition
mx             2 mixture no.
vf        1.0000 volume fraction
roth      6.4400 theoretical density
end

sc  h2o          standard composition
mx             3 mixture no.
vf        1.0000 volume fraction
roth       .9982 theoretical density
end

sc  b4c          standard composition
mx             4 mixture no.
vf         .3670 volume fraction
roth      2.5200 theoretical density
end

sc  al           standard composition
mx             4 mixture no.
vf         .6360 volume fraction
roth      2.6989 theoretical density
end

sc  h2o          standard composition
mx             5 mixture no.
vf        1.0000 volume fraction
roth       .9982 theoretical density
end


**** problem geometry ****

ctp squarepitch  cell type
pitch     1.2751 cm center to center spacing
fuelod     .8230 cm fuel diameter or slab thickness
mfuel          1 mixture no. of fuel
mmod           3 mixture no. of moderator
cladod     .9627 cm clad outer diameter
mclad          2 mixture no. of clad


zone specifications for latticecell geometry

              zone  1 is fuel
              zone  2 is clad
              zone  3 is mod
```

```
*** sample problem 2  pwr-like fuel bundle ***

*** ********** data library information ********** ***

***  unit                                          volume                                ***
***  number        data set name                   name       unit function              ***
***  ------        -------------                   ----       -------------              ***
***    89    /scale4.2p/datalib/scale.rev05.sclib              standard composition library ***
***    81    /scale4.2p/datalib/scale.rev02.xn16               cross section library        ***
***    11    ft11f001                                          short cross section library  ***

*** standard composition library data ***
***  unit number  :  89                                                                    ***
***  dataset name :  /scale4.2p/datalib/scale.rev05.sclib                                  ***
***  library title:  scale-4 standard composition library                                  ***
***                  386 standard compositions, 332 nuclides                           ***
***                  10 elements with variable isotopic distrbutions.                  ***
***  creation date:   1/25/94                                                              ***

*** cross section library data ***
***  unit number  :  81                                                                    ***
***  dataset name :  /scale4.2p/datalib/scale.rev02.xn16                                   ***
***  library title:  scale 4 - 16 neutron group criticality safety library                 ***
***                    hansen-roach data with knight modifications and some endf/b 4 data  ***
***                      compiled for nrc       1/27/89                                  ***
***                        last updated        10/12/89                                  ***
***                          l.m.petrie       ornl                                       ***

 ........    0 io's were used before reading keno v data    ........

 ........    0 io's were used reading the keno v parameter data    ........

 *************** data reading completed ***************

 ........    0 io's were used preparing the keno v input data    ........

 ........    0 io's were used loading the keno v data    ........

 ........    0 io's were used loading the data    ........

 ........    0 io's were used checking the keno v geometry data    ........
 *****  restart data has been written on unit 95  *****

 ........    0 io's were used writing the keno v - csas data    ........

 ........    0 io's were used before reading search data    ........

 ........    0 io's were used processing csas input data    ........
```

```
 sssssssssss     ccccccccccc      aaaaaaaaa      ll              eeeeeeeeeeeee
ssssssssssssss   ccccccccccccc    aaaaaaaaaaa    ll              eeeeeeeeeeeee
ss          ss  cc          cc   aa          aa  ll              ee
ss              cc               aa          aa  ll              ee
ss              cc               aa          aa  ll              ee
sssssssssssss   cc               aaaaaaaaaaaaa  ll              eeeeeeeee
 sssssssssssss  cc               aaaaaaaaaaaaa  ll              eeeeeeeee
          ss    cc               aa          aa  ll              ee
          ss    cc               aa          aa  ll              ee
ss        ss    cc          cc   aa          aa  ll              ee
ssssssssssssss  ccccccccccccc    aa          aa  llllllllllll    eeeeeeeeeeeee
 sssssssssss     ccccccccccc     aa          aa  llllllllllll    eeeeeeeeeeeee
```

```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                  program verification information                *****
*****                                                                     *****
*****                 code system:    scale  version:    4.2           *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****              program:  modify                                       *****
*****                                                                     *****
*****        creation date:  10/25/93                                     *****
*****                                                                     *****
*****              library:  /scale4.2p/exe                               *****
*****                                                                     *****
*****                                                                     *****
*****      production code:  modify                                       *****
*****                                                                     *****
*****              version:  2.1                                          *****
*****                                                                     *****
*****              jobname:  st5                                          *****
*****                                                                     *****
*****    date of execution:  03/14/94                                     *****
*****                                                                     *****
*****    time of execution:  16:34:22                                     *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

```
*** storage array of pwr-like fuel bundles in poison sheaths ***

***                          ******          search data          ******                          ***
***                                                                                               ***
***                                                                                               ***
***                          search type                          optimum pitch                   ***
***                                                                                               ***
***          pas             number of search passes                    10                       ***
***                                                                                               ***
***          npm             number of search parameters                 1                       ***
***                                                                                               ***
***          eps             search convergence tolerance             .0050                      ***
***          -con            minimum constraint                      -.2450                     ***
***                                                                                               ***
***          +con            maximum constraint                      1.2250                     ***
***                                                                                               ***
***                                                                                               ***
***                  unit    first   last                                                       ***
***  command         number  region  region  ----------------   search constants   ----------------  ***
***                                                                                               ***
***                  unit    reg=__  to __   +x or r  -x or +h  +y or -h    -y       +z       -z   ***
***                                                                                               ***
***  alter/change/modify  1      3       3       1.00      1.00      1.00      1.00      .00      .00  ***
***                                                                                               ***

 ********************   search pass  1     keff=  7.31988E-01 + or -  6.08683E-03   ********************
                            the parameter was  0.00000E+00
                      *****  modified keno v data has been rewritten on unit 95  *****

 ********************   search pass  2     keff=  3.58234E-01 + or -  4.64021E-03   ********************
                            the parameter was -2.45000E-01
                      *****  modified keno v data has been rewritten on unit 95  *****

 ********************   search pass  3     keff=  7.44512E-01 + or -  3.79809E-03   ********************
                            the parameter was  1.22500E+00
                      *****  modified keno v data has been rewritten on unit 95  *****

 ********************   search pass  4     keff=  8.97264E-01 + or -  4.79952E-03   ********************
                            the parameter was  6.12501E-01
                      *****  modified keno v data has been rewritten on unit 95  *****

 ********************   search pass  5     keff=  9.13226E-01 + or -  4.64053E-03   ********************
                            the parameter was  4.12008E-01
```

storage array of pwr-like fuel bundles in poison sheaths

convergence was achieved on pass 5 the parameter was 4.12008E-01

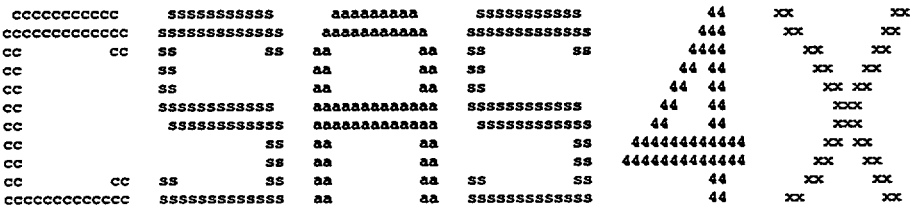
the equation used in the search was:

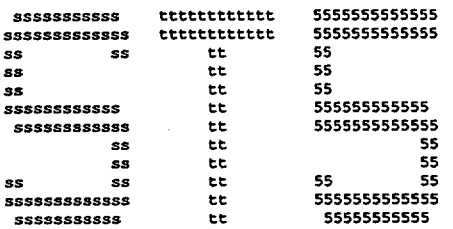
k-eff = +7.18481E-01 +1.00598E+00*p -1.54341E+00*p**2 +6.05700E-01*p**3

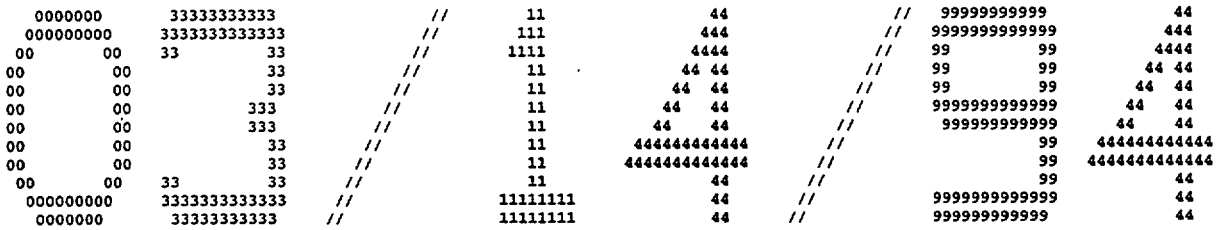
k-effective= 9.13226E-01 + or - 4.64053E-03 the corresponding geometry follows;

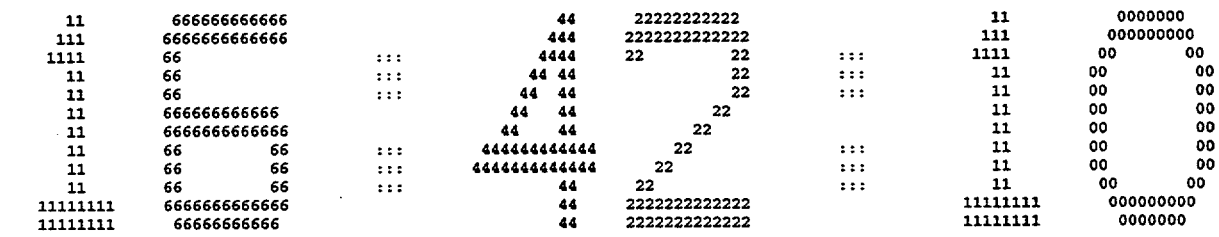
region	media num	bias id	geometry description for those units utilized in this problem
			----- unit 1 -----
1 cylinder	1	1	radius = .41150 +z = 183.00 -z = -183.00 centerline is at x = 0.00000E+00 y = 0.00000E+00
2 cylinder	2	1	radius = .48135 +z = 183.10 -z = -183.10 centerline is at x = 0.00000E+00 y = 0.00000E+00
3 cuboid	3	1	+x = .90023 -x = -.90023 +y = .90023 -y = -.90023 +z = 183.10 -z = -183.10

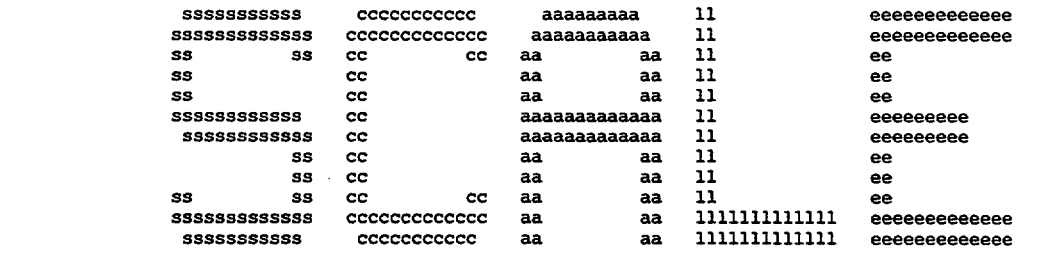
```
                                storage array of pwr-like fuel bundles in poison sheaths

                              based on the preceding data, the best estimate of the parameter is     4.39709E-01

                              the geometry corresponding to this parameter follows:

                    media bias      geometry description for those units utilized in this problem
region              num   id

                                                                  -----   unit     1   -----

  1 cylinder  1  1  radius =  .41150   +z =  183.00   -z = -183.00   centerline is at  x = 0.00000E+00  y = 0.00000E+00

  2 cylinder  2  1  radius =  .48135   +z =  183.10   -z = -183.10   centerline is at  x = 0.00000E+00  y = 0.00000E+00

  3 cuboid    3  1       +x =  .91789   -x = -.91789   +y =  .91789   -y = -.91789     +z =  183.10     -z = -183.10

**********************************************************************************************************************************
**********************************************************************************************************************************
                                  *****  modified keno v data has been rewritten on unit 95  *****

*****  convergence has been achieved in the search package.  *****

 control module modify   is complete.
```









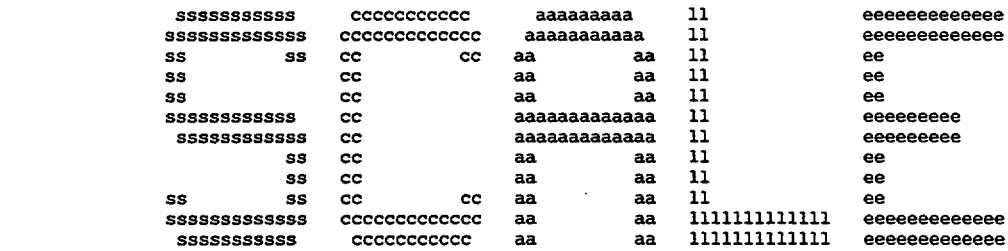



```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                  program verification information                *****
*****                                                                     *****
*****                 code system:    scale  version:    4.2           *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****              program:  csas                                         *****
*****                                                                     *****
*****        creation date:  12/01/93                                     *****
*****                                                                     *****
*****              library:  /scale4.2p/exe                               *****
*****                                                                     *****
*****                                                                     *****
*****      production code:  csas                                         *****
*****                                                                     *****
*****              version:  2.2                                          *****
*****                                                                     *****
*****              jobname:  st5                                          *****
*****                                                                     *****
*****    date of execution:  03/14/94                                     *****
*****                                                                     *****
*****    time of execution:  16:42:11                                     *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

```
sample problem 3  sample fuel cask

**** problem parameters ****

lib hansen-roach library
mxx            6 mixtures
msc            7 composition specifications
izm            3 material zones
ge  latticecell  geometry
more           0 0/1 do not read/read optional parameter data
msln           0 fuel solutions

**** problem composition description ****

sc  uo2          standard composition
mx             1 mixture no.
vf         .8400 volume fraction
roth     10.9600 theoretical density
temp      293.0 deg kelvin
           92235   2.35%
           92238  97.65%
end

sc  zr           standard composition
mx             2 mixture no.
vf        1.0000 volume fraction
roth      6.4400 theoretical density
end

sc  h2o          standard composition
mx             3 mixture no.
vf        1.0000 volume fraction
roth       .9982 theoretical density
end

sc  b4c          standard composition
mx             4 mixture no.
vf         .3670 volume fraction
roth      2.5200 theoretical density
end

sc  al           standard composition
mx             4 mixture no.
vf         .6360 volume fraction
roth      2.6989 theoretical density
end

sc  h2o          standard composition
mx             5 mixture no.
vf        1.0000 volume fraction
roth       .9982 theoretical density
end

sc  al           standard composition
mx             6 mixture no.
vf        1.0000 volume fraction
roth      2.6989 theoretical density
end
```

```
**** problem geometry ****

ctp squarepitch  cell type
pitch     1.2750 cm center to center spacing
fuelod     .8230 cm fuel diameter or slab thickness
mfuel           1 mixture no. of fuel
mmod            3 mixture no. of moderator
cladod     .9627 cm clad outer diameter
mclad           2 mixture no. of clad


zone specifications for latticecell geometry

                zone  1 is fuel
                zone  2 is clad
                zone  3 is mod
```

```
*****************************************************************************************************************
***                                                                                                           ***
***                            sample problem 3  sample fuel cask                                             ***
***                                                                                                           ***
*****************************************************************************************************************
*****************************************************************************************************************
***                                                                                                           ***
***                              ********** data library information **********                              ***
***                                                                                                           ***
***        unit                                                  volume                                       ***
***       number              data set name                      name        unit function                    ***
***       ------              -------------                      ----        -------------                    ***
***                                                                                                           ***
***         89      /scale4.2p/datalib/scale.rev05.sclib                     standard composition library     ***
***                                                                                                           ***
***         81      /scale4.2p/datalib/scale.rev02.xn16                      cross section library            ***
***                                                                                                           ***
***         11      ft11f001                                                 short cross section library      ***
***                                                                                                           ***
*****************************************************************************************************************
*****************************************************************************************************************
***                                                                                                           ***
***                                                                                                           ***
***                                    standard composition library data                                      ***
***                                    ---------------------------------                                      ***
***                                                                                                           ***
***          unit number  :  89                                                                               ***
***                                                                                                           ***
***           dataset name :  /scale4.2p/datalib/scale.rev05.sclib                                            ***
***                                                                                                           ***
***          library title:  scale-4 standard composition library                                             ***
***                          386 standard compositions, 332 nuclides                                          ***
***                          10 elements with variable isotopic distrbutions.                                 ***
***                                                                                                           ***
***          creation date:  1/25/94                                                                          ***
***                                                                                                           ***
***                                       cross section library data                                          ***
***                                      ---------------------------                                          ***
***                                                                                                           ***
***          unit number  :  81                                                                               ***
***                                                                                                           ***
***          dataset name :  /scale4.2p/datalib/scale.rev02.xn16                                              ***
***                                                                                                           ***
***          library title:  scale 4 - 16 neutron group criticality safety library                            ***
***                           hansen-roach data with knight modifications and some endf/b 4 data              ***
***                             compiled for nrc       1/27/89                                               ***
***                               last updated        10/12/89                                               ***
***                                 l.m.petrie       ornl                                                    ***
***                                                                                                           ***
***                                                                                                           ***
*****************************************************************************************************************
*****************************************************************************************************************

**** xsdrn mesh intervals ****

   4 mesh intervals in zone  1
   4 mesh intervals in zone  2
  14 mesh intervals in zone  3

                          ........    0 io's were used before reading keno v data    ........

                          ........    0 io's were used reading the keno v parameter data    ........


                         *************** data reading completed ***************

                          ........    0 io's were used preparing the keno v input data    ........

                          ........    0 io's were used loading the keno v data    ........

                          ........    0 io's were used loading the data    ........

                          ........    0 io's were used checking the keno v geometry data    ........
                         *****  restart data has been written on unit 95  *****

                          ........    0 io's were used writing the keno v - csas data    ........

                          ........    0 io's were used before reading search data    ........

                          ........    0 io's were used processing csas input data    ........
```




```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                  program verification information                *****
*****                                                                     *****
*****                 code system:    scale  version:    4.2           *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****              program:  modify                                       *****
*****                                                                     *****
*****        creation date:  10/25/93                                     *****
*****                                                                     *****
*****              library:  /scale4.2p/exe                               *****
*****                                                                     *****
*****                                                                     *****
*****      production code:  modify                                       *****
*****                                                                     *****
*****              version:  2.1                                          *****
*****                                                                     *****
*****              jobname:  st5                                          *****
*****                                                                     *****
*****    date of execution:  03/14/94                                     *****
*****                                                                     *****
*****    time of execution:  16:43:11                                     *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

```
*****************************************************************************************************************
***                                                                                                           ***
***                              sample square fuel cask                                                      ***
***                                                                                                           ***
*****************************************************************************************************************
*****************************************************************************************************************
***                            ******          search data          ******                                   ***
***                                                                                                           ***
***                                                                                                           ***
***                            search type                          optimum pitch                            ***
***                                                                                                           ***
***                  pas       number of search passes                    10                               ***
***                                                                                                           ***
***                  npm       number of search parameters                 1                               ***
***                                                                                                           ***
***                  eps       search convergence tolerance             .0050                              ***
***                  -con      minimum constraint                      -.0417                              ***
***                                                                                                           ***
***                  +con      maximum constraint                       .2083                              ***
***                                                                                                           ***
***                                                                                                           ***
***                      unit    first   last                                                               ***
***       command        number  region  region   ---------------   search constants  ---------------      ***
***                                                                                                           ***
***                      unit     reg=__  to __   +x or r   -x or +h  +y or -h     -y       +z       -z     ***
***                                                                                                           ***
*** alter/change/modify  1         3       3       1.00       1.00       1.00       1.00      .00      .00    ***
***                                                                                                           ***
*****************************************************************************************************************
*****************************************************************************************************************
```

```
**********************   search pass  1     keff=  7.11079E-01 + or -  5.77865E-03   **********************
                              the parameter was  0.00000E+00
                        *****  modified keno v data has been rewritten on unit 95  *****
 **********************   search pass  2     keff=  7.62379E-01 + or -  4.31515E-03   **********************
                              the parameter was -4.16667E-02
                        *****  modified keno v data has been rewritten on unit 95  *****
 **********************   search pass  3     keff=  6.20806E-01 + or -  5.39177E-03   **********************
                              the parameter was  2.08333E-01
                        *****  modified keno v data has been rewritten on unit 95  *****
 **********************   search pass  4     keff=  6.43165E-01 + or -  4.71612E-03   **********************
                              the parameter was  1.04167E-01
```

sample square fuel cask

****

convergence was achieved on pass 2 the parameter was -4.16667E-02
the equation used in the search was:
k-eff = +7.11079E-01 -1.03319E+00*p +4.44000E+00*p**2 -7.49067E+00*p**3
k-effective= 7.62379E-01 + or - 4.31515E-03 the corresponding geometry follows;

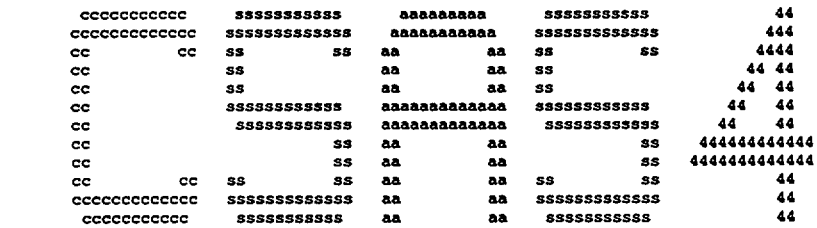
region	media num	bias id	geometry description for those units utilized in this problem									
			----- unit 1 -----									
1 cuboid	500	1	+x = 10.837	-x = -10.837	+y = 10.837	-y = -10.837	+z = 183.00	-z = -183.00				
2 cuboid	4	1	+x = 11.500	-x = -11.500	+y = 11.500	-y = -11.500	+z = 183.00	-z = -183.00				
3 cuboid	5	1	+x = 11.500	-x = -11.500	+y = 11.500	-y = -11.500	+z = 183.00	-z = -183.00				

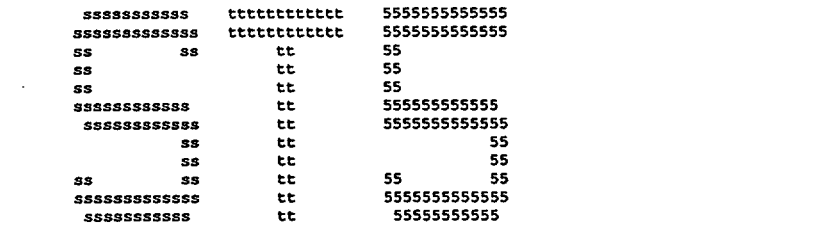
****

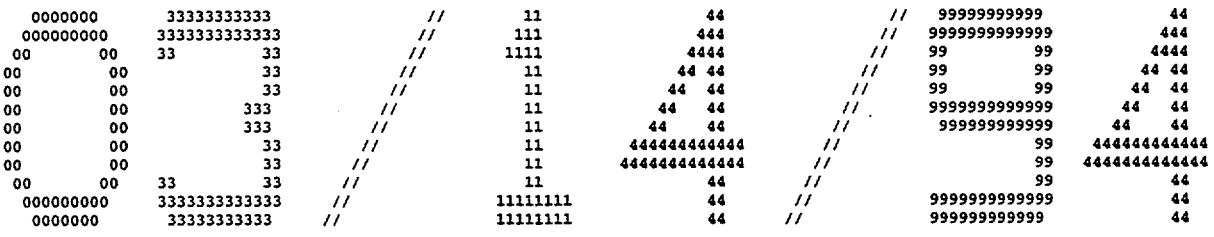
***** modified keno v data has been rewritten on unit 95 *****

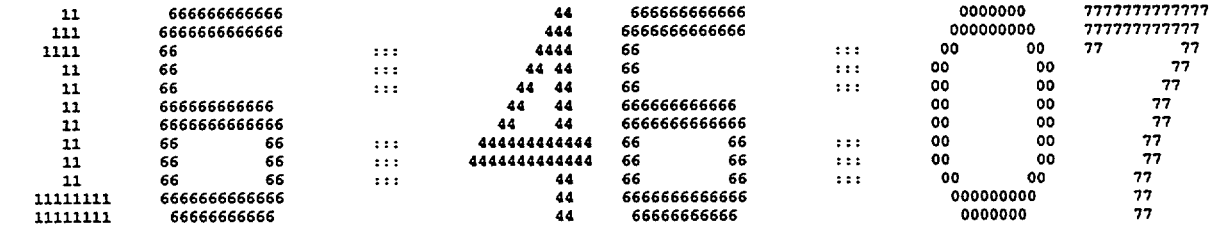
***** convergence has been achieved in the search package. *****

control module modify is complete.









```
 sssssssssss     ccccccccccc      aaaaaaaaa      ll              eeeeeeeeeeee
ssssssssssssss   ccccccccccccc    aaaaaaaaaaa    ll              eeeeeeeeeeee
ss          ss  cc           cc  aa          aa  ll              ee
ss              cc               aa          aa  ll              ee
ss              cc               aa          aa  ll              ee
sssssssssss     cc               aaaaaaaaaaaaa  ll              eeeeeeeee
 sssssssssss    cc               aaaaaaaaaaaaa  ll              eeeeeeeee
          ss    cc               aa          aa  ll              ee
          ss    cc               aa          aa  ll              ee
ss        ss    cc           cc  aa          aa  ll              ee
ssssssssssss    ccccccccccccc    aa          aa  lllllllllllll   eeeeeeeeeeee
 sssssssssss     ccccccccccc     aa          aa  lllllllllllll   eeeeeeeeeeee
```

```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                  program verification information                *****
*****                                                                     *****
*****                 code system:    scale  version:    4.2           *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****              program:  csas                                         *****
*****                                                                     *****
*****        creation date:  12/01/93                                     *****
*****                                                                     *****
*****              library:  /scale4.2p/exe                               *****
*****                                                                     *****
*****                                                                     *****
*****      production code:  csas                                         *****
*****                                                                     *****
*****              version:  2.2                                          *****
*****                                                                     *****
*****              jobname:  st5                                          *****
*****                                                                     *****
*****    date of execution:  03/14/94                                     *****
*****                                                                     *****
*****    time of execution:  16:46:07                                     *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

```
sample problem 4  set up 2c8 in csas25


**** problem parameters ****

lib hansen-roach library
mxx            1 mixtures
msc            1 composition specifications
izm            1 material zones
ge  infhommedium geometry
more           0 0/1 do not read/read optional parameter data
msln           0 fuel solutions


**** problem composition description ****

sc  uranium      standard composition
mx             1 mixture no.
vf         .9850 volume fraction
roth     19.0500 theoretical density
temp       293.0 deg kelvin
           92235  93.20%
           92238   5.60%
           92234   1.00%
           92236    .20%
end


**** problem geometry ****


**** infinite homogeneous medium ****
mfuel          1 mixture no. of the infinite homogeneous medium
```

```
*****************************************************************************************************************
***                                                                                                           ***
***                              sample problem 4  set up 2c8 in csas25                                       ***
***                                                                                                           ***
*****************************************************************************************************************
*****************************************************************************************************************
***                                                                                                           ***
***                            ********** data library information **********                               ***
***                                                                                                           ***
***          unit                                                    volume                                   ***
***         number                 data set name                     name      unit function                 ***
***         ------                 -------------                     ----      -------------                 ***
***                                                                                                           ***
***           89      /scale4.2p/datalib/scale.rev05.sclib                     standard composition library    ***
***                                                                                                           ***
***           81      /scale4.2p/datalib/scale.rev02.xn16                      cross section library           ***
***                                                                                                           ***
***           11      ft11f001                                                 short cross section library     ***
***                                                                                                           ***
*****************************************************************************************************************
*****************************************************************************************************************
***                                                                                                           ***
***                                                                                                           ***
***                                  standard composition library data                                        ***
***                                  ---------------------------------                                        ***
***                                                                                                           ***
***            unit number  :  89                                                                             ***
***                                                                                                           ***
***            dataset name :  /scale4.2p/datalib/scale.rev05.sclib                                           ***
***                                                                                                           ***
***            library title:  scale-4 standard composition library                                           ***
***                            386 standard compositions, 332 nuclides                                        ***
***                            10 elements with variable isotopic distributions.                              ***
***                                                                                                           ***
***            creation date:   1/25/94                                                                       ***
***                                                                                                           ***
***                                                                                                           ***
***                                                                                                           ***
***                                     cross section library data                                            ***
***                                    ---------------------------                                            ***
***                                                                                                           ***
***            unit number  :  81                                                                             ***
***                                                                                                           ***
***            dataset name :  /scale4.2p/datalib/scale.rev02.xn16                                            ***
***                                                                                                           ***
***            library title:  scale 4 - 16 neutron group criticality safety library                          ***
***                              hansen-roach data with knight modifications and some endf/b 4 data           ***
***                                 compiled for nrc       1/27/89                                            ***
***                                   last updated        10/12/89                                            ***
***                                     l.m.petrie        ornl                                                ***
***                                                                                                           ***
***                                                                                                           ***
*****************************************************************************************************************
*****************************************************************************************************************

                    ........    0 io's were used before reading keno v data    ........

                    ........    0 io's were used reading the keno v parameter data    ........

                   *************** data reading completed ***************

                    ........    0 io's were used preparing the keno v input data    ........

                    ........    0 io's were used loading the keno v data    ........

                    ........    0 io's were used loading the data    ........

                    ........    0 io's were used checking the keno v geometry data    ........
                    *****  restart data has been written on unit 95  *****

                    ........    0 io's were used writing the keno v - csas data    ........

                    ........    0 io's were used before reading search data    ........

                    ........    0 io's were used processing csas input data    ........
```

```
 ssssssssss     ccccccccccc      aaaaaaaaa      ll              eeeeeeeeeeee
ssssssssssss   ccccccccccccc    aaaaaaaaaaa     ll              eeeeeeeeeeee
ss          ss cc           cc  aa          aa  ll              ee
ss             cc               aa          aa  ll              ee
ss             cc               aa          aa  ll              ee
ssssssssssss   cc               aaaaaaaaaaaaa   ll              eeeeeeeee
 ssssssssssss  cc               aaaaaaaaaaaaa   ll              eeeeeeeee
          ss   cc               aa          aa  ll              ee
          ss   cc               aa          aa  ll              ee
ss        ss   cc           cc  aa          aa  ll              ee
ssssssssssss   ccccccccccccc    aa          aa  llllllllllll    eeeeeeeeeeee
 ssssssssss     ccccccccccc     aa          aa  llllllllllll    eeeeeeeeeeee
```

```
**********************************************************************************
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                  program verification information                   *****
*****                                                                        *****
*****                 code system:    scale  version:    4.2              *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                                                                        *****
*****              program:  modify                                          *****
*****                                                                        *****
*****        creation date:  10/25/93                                        *****
*****                                                                        *****
*****              library:  /scale4.2p/exe                                  *****
*****                                                                        *****
*****                                                                        *****
*****      production code:  modify                                          *****
*****                                                                        *****
*****              version:  2.1                                             *****
*****                                                                        *****
*****              jobname:  st5                                             *****
*****                                                                        *****
*****    date of execution:  03/14/94                                        *****
*****                                                                        *****
*****    time of execution:  16:46:26                                        *****
*****                                                                        *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
**********************************************************************************
```

```
*** critical pitch search for case 2c8 bare ***

***  ******  search data  ******  ***
***                                ***
***  search type  critical pitch   ***
***                                ***
***  pas  number of search passes  10  ***
***                                ***
***  npm  number of search parameters  1  ***
***                                ***
***  eps  search convergence tolerance  .0050  ***
***                                ***
***  kef  desired k-effective  1.0000  ***
***                                ***
***  -con  minimum constraint  -.2070  ***
***                                ***
***  +con  maximum constraint  .0693  ***
***                                ***
***                  unit  first  last                                                    ***
***  command         number region region  ----------  search constants  ----------      ***
***                                                                                       ***
***                  unit  reg=__ to __  +x or r  -x or +h  +y or -h  -y  +z  -z        ***
***                                                                                       ***
***  alter/change/modify  1  2  2  1.00  1.00  1.00  1.00  .00  .00                      ***
***                                                                                       ***
***                                                                                       ***
***  alter/change/modify  1  2  2  .00  .00  .00  .00  1.00  1.00                        ***

     ********** search pass 1  keff= 9.62581E-01 + or - 4.66186E-03 **********
                      the parameter was 0.00000E+00
               ***** modified keno v data has been rewritten on unit 95 *****

     ********** search pass 2  keff= 9.26968E-01 + or - 4.76267E-03 **********
                      the parameter was 6.92605E-02
               ***** modified keno v data has been rewritten on unit 95 *****

     ********** search pass 3  keff= 1.01030E+00 + or - 4.65530E-03 **********
                      the parameter was -7.27719E-02
               ***** modified keno v data has been rewritten on unit 95 *****

     ********** search pass 4  keff= 1.00968E+00 + or - 4.18861E-03 **********
                      the parameter was -5.70604E-02
               ***** modified keno v data has been rewritten on unit 95 *****

     ********** search pass 5  keff= 9.80129E-01 + or - 5.04216E-03 **********
                      the parameter was -3.87869E-02
               ***** modified keno v data has been rewritten on unit 95 *****

     ********** search pass 6  keff= 9.98210E-01 + or - 4.21917E-03 **********
                      the parameter was -5.09593E-02
                  critical pitch search for case 2c8 bare
```

```
**********************************************************************************************************************************
**********************************************************************************************************************************

                        convergence was achieved on pass  6  the parameter was  -5.09593E-02

                        the equation used in the search was:

                        k-eff = +9.39989E-01 -9.76969E-01*p +7.86001E+00*p**2 +8.33712E+01*p**3

                        k-effective=  9.98210E-01 + or -  4.21917E-03   the corresponding geometry follows;

        media bias      geometry description for those units utilized in this problem
 region  num   id

                                                  -----  unit     1   -----

 1 cylinder  1  1 radius =  5.7480    +z =  5.3825   -z = -5.3825    centerline is at  x = 0.00000E+00  y = 0.00000E+00

 2 cuboid    0  1     +x =  6.8786    -x = -6.8786   +y =  6.8786    -y = -6.8786     +z =  6.5318     -z = -6.5318

**********************************************************************************************************************************
**********************************************************************************************************************************
```

```
                                critical pitch search for case 2c8 bare

                               based on the preceding data, the best estimate of the parameter is   -5.17118E-02

                               the geometry corresponding to this parameter follows:

          media bias           geometry description for those units utilized in this problem
   region   num   id

                                                        -----   unit     1   -----

 1 cylinder  1  1  radius =  5.7480     +z =  5.3825     -z = -5.3825     centerline is at  x = 0.00000E+00  y = 0.00000E+00

 2 cuboid    0  1     +x =  6.8732     -x = -6.8732     +y =  6.8732     -y = -6.8732     +z =  6.5266     -z = -6.5266

********************************************************************************************************************************************
********************************************************************************************************************************************
                                  *****  modified keno v data has been rewritten on unit 95  *****

*****  convergence has been achieved in the search package.  *****

 control module modify   is complete.
```

NUREG/CR-0200
Revision 6
Volume 1, Section C6
ORNL/NUREG/CSD-2/V1/R6

Computational Physics and Engineering Division

CSAS6: CONTROL MODULE FOR ENHANCED CRITICALITY SAFETY ANALYSIS WITH KENO-VI

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Date Published: March 2000

Prepared for the
Office of Nuclear Material Safety and Safeguards
U. S. Nuclear Regulatory Commission
Washington, DC 20555
Under Interagency Agreement DOE 1886-C000-9B
NRC JCN No. B0009

Prepared by the
OAK RIDGE NATIONAL LABORATORY
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

ABSTRACT

The Criticality Safety Analysis Sequences (CSAS) were developed within the SCALE code system to provide automated, problem-dependent, cross-section processing followed by calculation of the neutron multiplication factor for the system being modeled. The current version of CSAS decides which sequence to run based on the first record in the problem description. If the sequence of modules to be run includes KENO V.a, the problem geometry is read and checked in MIPLIB which is part of CSAS. Since KENO-VI has a different geometry package than KENO V.a, the current version of CSAS is not compatible with KENO-VI. This document describes a version of CSAS, named CSAS6, specifically written for KENO-VI.

CSAS6 contains two control sequences, CSAS26 and CSAS26X. CSAS26 activates the cross-section processing codes BONAMI and NITAWL-II to provide resonance-corrected cross sections for use in KENO-VI. CSAS26X, in addition to activating BONAMI and NITAWL-II, calls XSDRNPM to provide cell-weighted cross sections. The enhanced geometric modeling capabilities available in KENO-VI, coupled with the automated cross-section processing within the control sequences, allow complex, three-dimensional systems to be easily analyzed.

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ACKNOWLEDGMENTS

The CSAS6 Criticality Safety Analysis Sequence is based on the CSAS4 control module, described in Sect. C4, and the KENO-VI functional module, described in Sect. F17. Therefore, special acknowledgment is made to J. A. Bucholz, R. M. Westfall, and J. R. Knight who developed CSAS2, which is the precursor to CSAS4. G. E. Whitesides is acknowledged for his contributions through early versions of KENO. Appreciation is expressed to C. V. Parks for his guidance in developing CSAS.

C6.1 INTRODUCTION

Within the life cycle of the SCALE system, the CSAS program has superseded earlier programs that contained criticality safety analysis sequences. Embedded within the CSAS program are numerous sequences that enable automated cross-section processing and criticality analyses. Currently, all the criticality analysis sequences (sometimes referred to as modules) within SCALE are contained within the CSAS program. Unfortunately, due to the conflicting geometry packages in KENO V.a and KENO-VI, the inclusion of a criticality analysis sequence within CSAS that calls KENO-VI is not practical. Instead, a new criticality safety analysis sequence has been developed solely for KENO-VI.

Criticality Safety Analysis Sequence No. 6 (CSAS6) was developed to provide automated cross-section processing for KENO-VI in the SCALE system. Because it includes all the options available in earlier SCALE criticality sequences, except searches, and is designed for use with KENO-VI only, the program is called by the name CSAS6.

The standardized automated procedures process SCALE cross sections using the Bondarenko method (via BONAMI) and the Nordheim integral method (via NITAWL-II) to provide a resonance-corrected cross-section library based on the physical characteristics of the problem being analyzed. This cross-section library is then utilized by KENO-VI, a three-dimensional (3-D) multigroup Monte Carlo criticality program.

The user may select the CSAS26 or the CSAS26X sequence in CSAS6. An X in the module name specifies that XSDRNPM will be used to provide cell-weighted cross sections. CSAS26X should be used when cell-weighted cross sections are used to provide a homogeneous representation of the fuel pins in the KENO-VI geometry. Cell-weighting is accomplished by describing a unit cell, as in a fuel assembly, for which a one-dimensional (1-D) eigenvalue calculation of the unit cell is made to determine the spatially dependent flux spectrum. This flux spectrum is used to cell-weight the microscopic cross-section data. The nuclide number densities in the unit cell are homogenized, and the resultant homogenized cell-weighted cross sections are identified as mixture 500 and utilized in the KENO-VI geometry. Note that only one mixture 500 can be created per problem.

The codes utilized in CSAS6 start with an AMPX master format cross-section library and generate a self-shielded, group-averaged library applicable to the specific problem configuration. These cross sections are then used in the KENO-VI Monte Carlo code to determine the effective neutron multiplication factor. The codes and their functions are given below.

1. BONAMI — performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections.

2. NITAWL-II — applies a Nordheim resonance self-shielding correction to nuclides having resonance parameters and produces a working problem-dependent cross-section library.

3. KENO-VI — calculates k-effective of a 3-D system using the Monte Carlo method.

C6.2 TECHNIQUES

CSAS6 is designed to prepare a resonance-corrected cross-section library for subsequent use in KENO VI. In order to minimize human error, the SCALE data handling is automated as much as possible. CSAS6 applies a standardized procedure to provide appropriate cross sections for the calculation. This procedure is carried out by the Material Information Processor that generates number densities and related information, prepares geometry data for resonance self-shielding and flux-weighting cell calculations, and creates data input files for the cross-section processing codes. After reading the problem input and checking as much as possible, the control sequence executes BONAMI and NITAWL-II to prepare a resonance-corrected microscopic cross-section library in the AMPX working library format. If cell-weighted cross sections are requested, XSDRNPM performs the necessary calculations and produces a cell-weighted microscopic cross-section library in the AMPX working library format. KENO-VI is then executed to calculate the k-effective or neutron multiplication factor using the cross-section library that was prepared by the control sequence.

The Material Information Processor is described in Sect. M7. It is responsible for reading the standard composition data and other engineering-type specifications, including volume fraction or percent theoretical density, temperature, and isotopic distribution. The techniques used in the Material Information Processor and their applications and limitations are discussed in Sect. M7.2. The input data for the Material Information Processor is the same as that used for CSAS4. For convenience, the Material Information Processor input data guide is included in Sect. C6.4.

The Material Information Processor checks the input data pertaining to cross-section preparation and prepares binary input files for the applicable functional modules. Depending on the specified sequence, data are prepared for BONAMI, NITAWL-II, XSDRNPM, and ICE as appropriate.

The Bondarenko method is discussed in the Material Information Processor document, Sect. M7.2.5.1, and BONAMI is described in Sect. F1. The Nordheim method and NITAWL-II are described in Sects. M7.2.5.2 and F2, respectively. The Dancoff treatment is discussed in Sect. M7.2.5.3. The automatic mesh generator, the automatic quadrature generator, and the convergence criteria for control sequences that execute XSDRNPM are described in Sects. M7.2.5.6, M7.2.5.7, and M7.2.5.8, respectively. XSDRNPM is described in Sect. F3, ICE is described in Sect. F8, and KENO-VI is described in Sect. F17. See Sect. M7A for an explanation of many of the techniques used in processing the cross sections.

C6.2.1 CSAS6 LIMITATIONS

The CSAS6 control module was developed to use simple input data and prepare problem-dependent cross sections for use in calculating the effective neutron multiplication factor of a 3-D system using KENO VI and possibly XSDRNPM. An attempt was made to make the system as general as possible within the constraints of the standardized methods chosen to be used in SCALE. Standardized methods of data input were adopted to allow easy data entry and for quality assurance purposes. Some of the limitations of the CSAS6 sequences are due to assumptions in the Nordheim integral treatment[1] as implemented in CSAS6. Inherent limitations in the NITAWL-II Nordheim integral treatment of resonance nuclides are as follows:

1. The treatment assumes no resonance overlap from other resonances or other material regions.

2. The treatment of an external moderator assumes an asymptotic flux present at the absorber-moderator interface.

3. The treatment of spatial transport uses the first-flight escape probability for the absorber, the two-region reciprocity theorem, and Dancoff factors.[2]

In many cases, the Nordheim integral treatment is an excellent method for processing resonance cross sections for use in the analysis of light-water reactor (LWR) fuel pin cells and for many other applications commonly used in neutronics analysis. However, caution should be used in applications involving several isotopes with large resonances or complicated absorber-moderator geometries. Another area of probable inadequacy involves the analysis of machinery for dissolving spent fuel elements. Such a system usually requires the simultaneous consideration of resonance absorbers located in both the solid fuel pellets and the acid solution, thereby resulting in an inadequate treatment by NITAWL-II.

The major limitations of the analytical model used by the Nordheim integral treatment in CSAS6 are as follows:

1. A lattice system whose fuel or moderator contains an absorber that has rapidly varying cross sections across the resonance region may be inadequately treated. Examples include gadolinium, silver, indium, and hafnium.

2. The presence of more than one resonance isotope in a material can lead to an effect called resonance overlap, which can result in enhanced or reduced group-averaged cross sections, depending on the predominance of resonance scattering or absorption and the relative locations of the resonances within the energy groups. The resonance overlap effect is discussed in more detail in Sect. M7.A.7.

3. Resonance interference between two different media is not correctly treated.

4. Fissile lumps in fissile solutions are not correctly treated.

5. The determination of parameters used in processing the cross sections are derived from the geometry of the cell description. CSAS6 does not allow multiple cell descriptions.

6. It is strongly recommended that CSAS calculations be made of benchmark experiments similar to the problem being calculated in order to demonstrate the validity of the code/cross-section combination for that type of problem.

C6.2.2 REFERENCES

1. L. W. Nordheim, "The Theory of Resonance Absorption," *Proceedings of Symposia in Applied Mathematics*, Vol XI, p. 58, G. Birkhoff and E. P. Wigner, Eds., Am. Math. Soc. (1961).

2. S. M. Dancoff and M. Ginsburg, *Surface Resonance Absorption in a Close-Packed Lattice*, CP-2157, Clinton Plant, U.S. Atomic Energy Commission, September 1944.

C6.3 LOGICAL PROGRAM FLOW

The general flow of CSAS6 is given in this section. The program flow is divided into several sections. An abbreviated representation, rather than a formal flowchart, is used to outline the program flow of each section. A flowchart may show a subroutine or library routine only once, even though it may be called multiple times in that portion of the program. The corresponding text usually states when multiple calls are made to a routine. Accompanying each abbreviated flowchart is an explanation of the purpose of that segment of the program and text describing each of the referenced subroutines.

CSAS6 has been written in a general form to allow maximum flexibility. Data are transferred from one module to another via sequential data files and direct-access data files. Table C6.3.1 lists the data files utilized by this program. CSAS6 is used to represent the control module defining the sequence. Data files utilized by the individual functional modules are included in Table C6.3.2.

The flowchart representation for CSAS6 is defined as follows:

> The SCALE DRIVER is contained in a diamond, subroutines initiating control modules are contained in circles, functional modules are contained in hexagons, major program segments are contained in rectangularized ovals, subroutine names are contained in boxes, and library routines are represented as bare names. An arrow in the flowchart indicates that the subroutine or module associated with the arrow will be discussed later in the section.

C6.3.1 INITIATION OF CSAS6

This portion of the program is the initiation of the criticality safety analysis sequence. The SCALE DRIVER, described in Sect. M1, obtains the name of the module to be accessed from the first record (module specification record) in the user input data file. The control modules available in CSAS6 are shown in Fig. C6.3.1. These control modules use the Material Information Processor data as described in Sect. M7.3.

SCALE DRIVER allows implementation of a modular code system which includes Criticality Safety Analysis Sequence No. 6. See Sect. M1 for additional information about the driver.

CSAS26 calculates the system k-effective for 3-D problems. This module sequentially activates the functional modules BONAMI, NITAWL-II, and KENO-VI to process the required cross sections and calculate the k-effective. Note that a cell-weighted mixture cross section cannot be used.

CSAS26X calculates the system k-effective for 3-D problems that require a cell-weighted mixture. It is the same as CSAS26 except a cell-weighted mixture cross section is always created. This control module sequentially activates the functional modules BONAMI, NITAWL-II, XSDRNPM, and KENO-VI to process the required cross sections and calculate the k-effective.

CSAS1X creates a microscopic cell-weighted library in the AMPX working library format. This control module sequentially activates the functional modules BONAMI and NITAWL-II to process the necessary cross sections and calculates the system k-effective of the 1-D problem using the discrete-ordinates code XSDRNPM. This sequence has been disabled in CSAS6.

Table C6.3.1 Description of units utilized by the CSAS6 control module

Unit No.	Type of data	Creating module	User module	Type of file
5	Input	DRIVER	CSAS6	Sequential
8	Scratch file	CSAS6	CSAS6	Direct or random-access data
11	Short master cross-section library	CSAS6	BONAMI	Sequential
16	Scratch file	CSAS6	CSAS6	Sequential
17	Scratch file	CSAS6	CSAS6	Sequential
18	Scratch file	CSAS6	CSAS6	Sequential
19	Scratch file	CSAS6	CSAS6	Sequential
70	User-supplied cross sections		CSAS6	AMPX master format library
81	16-group cross sections		CSAS6	AMPX master format library
82	27-group cross sections		CSAS6	AMPX master format library
83	44-group cross sections		CSAS6	AMPX master format library
84	238-group cross sections		CSAS6	AMPX master format library
85	22 neutron-18 gamma cross sections		CSAS6	AMPX master format library
86	18-gamma cross sections		CSAS6	AMPX master format library
87	27-group cross sections for burnup		CSAS6	AMPX master format library
88	27 neutron-18 gamma cross sections		CSAS6	AMPX master format library
89	Standard Composition Library		CSAS6	Direct or random-access data file
92	ICE input data	CSAS6	ICE	Sequential
95	KENO-VI restart data	CSAS6 KENO-VI	KENO-VI	Sequential
96	BONAMI input data	CSAS6	BONAMI	Sequential
97	NITAWL-II input data	CSAS6	NITAWL-II	Sequential
98	XSDRNPM input data	CSAS6	XSDRNPM	Sequential
99	Printed output	CSAS6	CSAS6	Sequential

Table C6.3.2 Description of units used by the functional modules of CSAS6

Unit No.	Module	Action	Type of file
1	BONAMI	WRITE	Microscopic master working format cross sections
	NITAWL-II	READ	Microscopic master working format cross sections
2	ICE	WRITE	Macroscopic working format cross sections
3	XSDRNPM	WRITE	Microscopic cell-weighted working format cross sections
	ICE	READ	Microscopic cell-weighted working format cross sections
	KENO-VI	READ	Microscopic cell-weighted working format cross sections
4	NITAWL-II	WRITE	Microscopic working format cross sections
	ICE	READ	Microscopic working format cross sections
	KENO-VI	READ	Microscopic working format cross sections
	XSDRNPM	READ	Microscopic working format cross sections
6	BONAMI	WRITE	Printed output
	ICE	WRITE	Printed output
	KENO-VI	WRITE	Printed output
	NITAWL-II	WRITE	Printed output
	XSDRNPM	WRITE	Printed output
8	BONAMI	WRITE/READ	Direct or random-access scratch files
	ICE	WRITE/READ	Direct or random-access scratch files
	KENO-VI	WRITE/READ	Direct or random-access scratch files
	XSDRNPM	WRITE/READ	Direct or random-access scratch files
9	BONAMI	WRITE/READ	Direct or random-access scratch files
	ICE	WRITE/READ	Direct or random-access scratch files
	KENO-VI	WRITE/READ	Direct or random-access scratch files
	NITAWL-II	WRITE/READ	Direct or random-access scratch files
	XSDRNPM	WRITE/READ	Direct or random-access scratch files
10	ICE	WRITE/READ	Direct or random-access scratch files
	KENO-VI	WRITE/READ	Direct or random-access scratch files
	XSDRNPM	WRITE/READ	Direct or random-access scratch files
11	BONAMI	READ	Short AMPX master format cross sections
14	ICE	WRITE	Monte Carlo-formatted macroscopic cross sections
	KENO-VI	READ/WRITE	Monte Carlo-formatted macroscopic cross sections
16	KENO-VI	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Angular flux file
17	XSDRNPM	WRITE/READ	Sequential scratch file
18	BONAMI	WRITE/READ	Sequential scratch file
	NITAWL-II	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Sequential scratch file
19	BONAMI	WRITE/READ	Sequential scratch file
	NITAWL-II	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Sequential scratch file
79	KENO-VI	READ	KENO albedo file
80	KENO-VI	READ	KENO weighting file
92	ICE	READ	Binary input file
95	KENO-VI	READ	Binary input file
96	BONAMI	READ	Binary input file
97	NITAWL-II	READ	Binary input file
98	XSDRNPM	READ	Binary input file

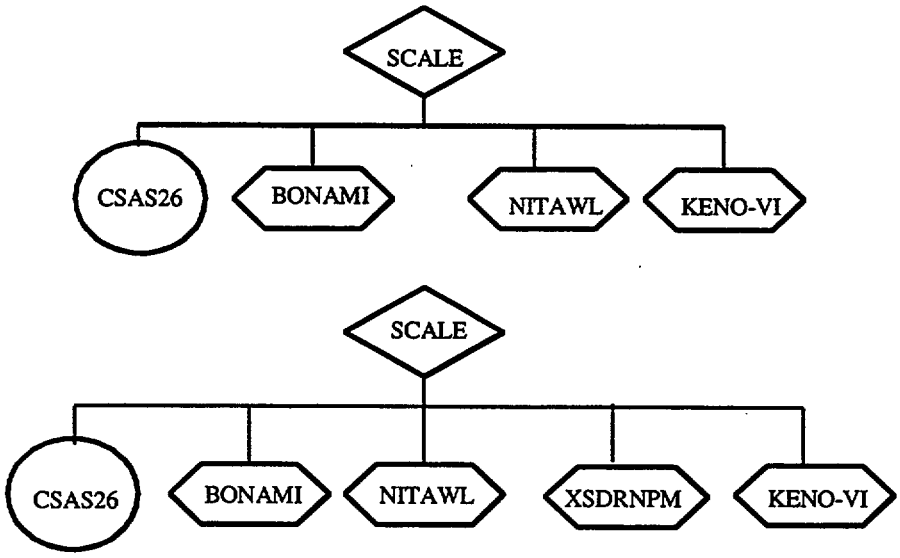


Figure C6.3.1 Control modules available in CSAS6

CSASN creates a resonance-corrected microscopic cross-section library in the AMPX working library format by sequentially activating the functional modules BONAMI and NITAWL-II. This section has been disabled in CSAS6.

CSASI provides a resonance-corrected macroscopic mixture cross-section library in the MORSE/KENO (ICE Monte Carlo-processed) format by sequentially activating the functional modules BONAMI, NITAWL-II, and ICE. This sequence has been disabled in CSAS6.

CSASIX provides a resonance-corrected, cell-weighted, macroscopic mixture cross-section library in the MORSE/KENO (ICE Monte Carlo-processed) format by sequentially activating the functional modules BONAMI, NITAWL-II, XSDRNPM, and ICE. The discrete-ordinates code XSDRNPM also computes the k-effective for the 1-D problem. This sequence has been disabled in CSAS6.

BONAMI is a functional module in the SCALE system that performs resonance self-shielding calculations for nuclides that contain Bondarenko data in their cross sections. See Sect. F1 for detailed information concerning BONAMI.

NITAWL-II is a functional module in the SCALE system. It applies a Nordheim resonance self-shielding correction to nuclides having resonance parameters associated with the cross-section data. See Sect. F2 for detailed information.

XSDRNPM is a functional module in the SCALE system. It provides cell-weighted cross sections based on the specified unit cell. It can also calculate the k-effective for 1-D problems. See Sect. F3 for additional information.

ICE is a functional module in the SCALE system. It creates a Monte Carlo-formatted mixed cross-section library for use by KENO V.a, KENO-VI, or MORSE. See Sect. F8 for additional details.

KENO-VI is a functional module in the SCALE system. It calculates the system k-effective of a 3-D problem. See Sect. F17 for a detailed description of KENO-VI.

C6.3.2 OVERALL FLOW DIAGRAM

Figure C6.3.2 illustrates the overall flow of CSAS6. The control modules CSAS26 and CSAS26X communicate with the driver and dictate the order in which other modules are to be executed.

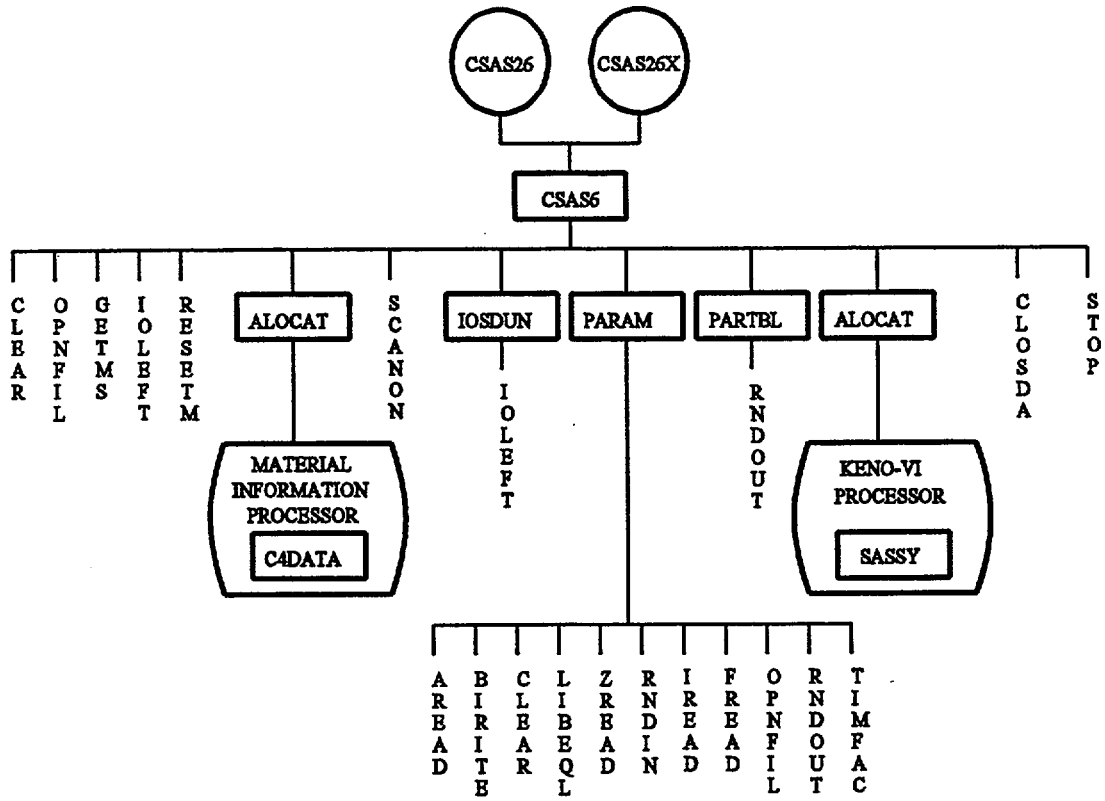


Figure C6.3.2 Overall flow of CSAS6

CSAS26 - This control module calculates k-effective for a 3-D system, using KENO-VI, when a cell-weighted mixture cross section is not needed.

CSAS62X - This control module calculates k-effective for a 3-D system, using KENO-VI, when a cell-weighted mixture cross section is required.

CSAS6 - This is the main program for CSAS6 and its associated control modules. GETMS is called to read the analytical sequence specification and the parameters associated with it. The sequence specification is used to set flags to cause the desired functional modules to be executed in the proper order. IOLEFT is called to initialize the counter that keeps track of the number of I/Os that are done. INDEX is a FORTRAN-supplied intrinsic function used to determine if a variable

matches a specified character string. IONUMS is called to set the input and output units for the free-form reading routines. OPNFIL is called to open the input and output units that are used by the control module. IOSDUN is called several times to determine the number of I/Os that have been used in various operations. C4DATA is called from ALOCAT with the requested storage allocation. This accesses the MATERIAL INFORMATION PROCESSOR. SCANON is called to activate the feature that allows scanning the input data for the word END. CPARAM is called to read the KENO-VI title and to read and initialize the KENO-VI parameter data. SASSY is called from ALOCAT to read the KENO-VI data and write the information in a form that can be utilized by the CSAS6 module. If errors are encountered during reading, preparing, and checking the data, execution is terminated without activating any of the functional modules. The direct-access files are closed out when the problem is completed or terminated. This program makes use of error flags in an effort to continue reading and checking input data even after errors are found. However, some errors are severe enough to cause immediate termination.

CLEAR - This library routine is called to initialize the logical unit numbers used by CSAS.

OPNFIL - This library routine is called to open the I/O units or devices used by the specified CSAS control module and all of the functional modules it invokes.

GETMS - This assembly language library routine is called to read the analytical sequence specification and any associated parameter data. It establishes communication with the SCALE driver and enters data obtained from the SCALE driver into common. An example of an analytical sequence specification is given on the following page. This particular example specifies that the control module CSAS is to be executed. The associated parameters are entered following the word "PARM=," which must start beyond column 10. In this example the parameters specify that the data are to be checked without executing the problem, and a maximum of 200,000 words is requested to complete this task.

```
=CSAS26      PARM= (CHECK,SIZE=200000).
```

IOLEFT - This library routine is called to store the initial I/O count in common for determining the number of I/Os used in certain parts of the program.

RESETM - This library routine is an entry point in the assembly language library routine GETMS. It transmits control data back to the SCALE driver.

ALOCAT - This assembly language library routine is called with three arguments. The first argument is a subroutine name, the second argument is the maximum number of words of core storage to be allocated, and the third argument is the statement number to return to if the available core storage is less than that requested by the second argument. ALOCAT is used to call C4DATA and SASSY. In each call an array name, the length of the array, and a statement number in a nonstandard return are passed to the subroutine.

C4DATA - MATERIAL INFORMATION PROCESSOR - This segment of the program is accessed by calling subroutine C4DATA via ALOCAT. It is responsible for reading the standard compositions specification data and associated engineering-type specifications used to generate the mixing table and in performing the cell-weighting calculations. It checks the data for obvious errors and generates information necessary for processing the cross sections. It continues

checking and preparing data for use in the functional modules activated by the sequence. The MATERIAL INFORMATION PROCESSOR is described in more detail in Sect. M7.3.

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

IOSDUN - This subroutine is called several times to indicate the number of I/Os used in various operations.

PARAM - This subroutine is responsible for initializing certain default values for the KENO-VI parameter data, reading the KENO-VI parameter data, and writing the parameter data on the restart data file to communicate it to the KENO-VI functional module. AREAD, IREAD, FREAD, and ZREAD are used to read the parameter data. BIRITE is used to write the parameter data on the restart data file, which is used by the functional module KENO-VI to define the problem. CLEAR is called to zero a common. LIBEQL determines the unit from which cross sections are to be read. RNDIN is called to load the random number if it is entered as parameter data. OPNFIL opens the I/O units that will be used, RNDOUT stores the current random number, and TIMFAC adjusts the time estimate.

AREAD - This library routine may be called many times from subroutine PARAM. It is used to read parameter names and alphanumeric parameter data.

BIRITE - This library routine is used to write the binary data used by the functional modules.

CLEAR - This library routine is called to zero common DIMEN.

LIBEQL - This subroutine is called to determine which unit or device will be used to read the resonance-corrected microscopic library.

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 is entered as 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 parameter data.

RNDOUT - This library routine is used to preserve the current random number so it can be written on the restart data file.

TIMFAC - This library routine provides the proper adjustment factor by which the allotted time is multiplied to adjust the execution time for execution for different computers.

PARTBL - This subroutine is called only if KENO V.a is to be executed. It is responsible for printing the KENO V.a numeric and logical parameter tables. RNDOUT is called to preserve the current random number so that it can be printed in the numeric parameter table.

SASSY - KENO-VI DATA PROCESSOR - This segment of the program is accessed by calling subroutine SASSY via ALOCAT. It calls SASSY6 which reads and checks the remainder of the KENO-VI data used by CSAS6. It writes the data on the restart data file to be used by the functional module KENO-VI. This segment of the program is described in detail in Sect. C6.3.4.

CLOSDA - This library routine is called to close out each direct-access file when the problem is completed in a normal manner.

STOP - This library routine is called several times to write error messages. It can be instructed to provide a traceback and can terminate execution or allow execution to continue, depending on the arguments provided to it.

C6.3.3 THE MATERIAL INFORMATION PROCESSOR

The Material Information Processor is responsible for reading data that specify the cross-section library, define the materials to be used in the problem, and provide data used to apply geometric and resonance corrections to the cross sections. After the data are read and checked, calculations are performed to create a mixing table and provide data to the functional modules that are invoked by the control module to perform cross-section processing to prepare a problem-dependent cross-section library. Section M7.3 contains the program flow for the Material Information Processor.

C6.3.4 KENO-VI DATA PROCESSOR

This portion of the program, as shown in Fig. C6.3.3, is responsible for processing the KENO-VI input data. All the KENO-VI data, except the title and parameters, are read in this portion of the program. The data are carefully checked for errors and are written on the restart data file to be used by the functional module KENO-VI.

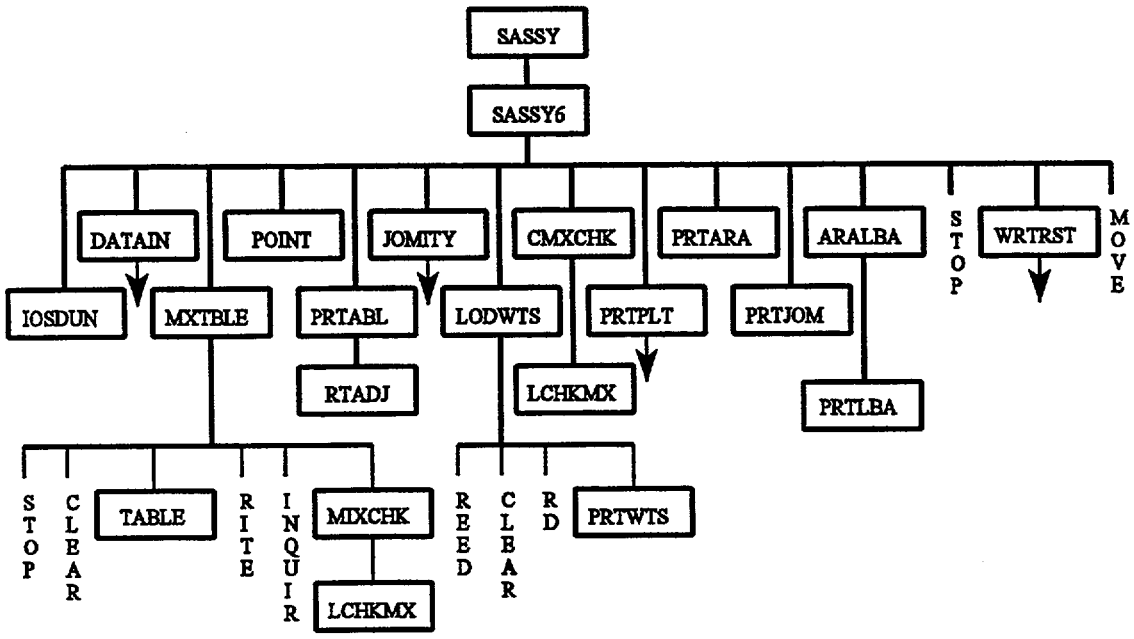


Figure C6.3.3 Flowchart of KENO-VI data processor

SASSY - This subroutine is an interface between CSAS6 and the KENO-VI DATA PROCESSOR controlled by SASS6.

SASSY6 - This subroutine controls the processing of the KENO-VI data. It calls CLEAR to zero the direct-access pointer and length arrays. IOSDUN is called to indicate the number of I/Os used in the different operations involved in processing the KENO-VI data. Then RITE is used to load the direct-access pointer and length arrays on the direct-access data file. Various subroutines are called to read and check the KENO-VI data. If an error is recognized in the data, STOP is called to write a message, and control is returned to the MAIN program. If the data are found to be error free, a restart data file is written by subroutine WRTRST before returning to MAIN.

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 the KENO-VI input data except the title card and parameters. It is explained in more detail in Sect. C6.3.4.1.

MXTBLE - This subroutine initializes the threshold for printing cross-section processing error messages for invalid moments if it was not entered as data, sets up pointers for mixing table data for KENO-VI, calls STOP if more storage is required, and calls TABLE to read the mixing table data. RITE is used to write the mixing table data to a random-access file, and INQUIR is called to set the next block for a direct or random-access device. MIXCHK is called to ensure that the mixtures used in the geometry data were also specified in the Material Information Processor data.

STOP - This library routine is called several times to write error messages. It can be instructed to provide a traceback and can terminate execution or allow execution to continue, depending on the arguments provided to it.

CLEAR - This library routine is called to zero common DIMEN.

TABLE - This subroutine is responsible for reading the mixing table data created by the Material Information Processor and storing it in the proper arrays for KENO-VI.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

INQUIR - Set direct-access pointer.

MIXCHK - This subroutine reads the KENO-VI mixing table data and writes an error message if a mixture utilized in the geometry data was not created by the Material Information Processor.

LCHKMX - This logical function is called by MIXCHK to return a value of true if a mixture specified on a KENO-VI geometry card is not specified in the mixing table and a value of false if it is.

POINT - This subroutine calculates pointers for storing and accessing KENO-VI data in memory.

PRATBL - This subroutine prints the KENO-VI table of additional data.

RTADJ - This subroutine right-adjusts the albedo boundary condition names that are read in as left-adjusted data. RTADJ locates the first blank character.

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. See Sect. C6.3.4.9 for additional information.

LODWTS - This subroutine is called only if PWT=YES is specified in the KENO-VI parameter data. LODWTS prints the bias IDs versus the material I/Os used in the problem. It also loads and prints the biasing or weighting data. The library routine REED is used to load the bias IDs from the direct-access device. CLEAR is used to zero the weighting arrays. RD is used to load the biasing data, and subroutine PRTWTS is called to print it.

REED - Load data from direct-access supergroup data file.

RD - Load data from direct access.

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

CMXCHK - This subroutine is used to ensure that a component of the cell-weighted mixture is not used in the KENO VI geometry data. If it is, an error message is written, and an error flag is set.

LCHKMX - This logical function is called by CMXCHK to return a value of true if a mixture specified on a KENO-VI geometry card is not a component of the cell-weighted mixture and a value of false if it is.

PRTPLT - This subroutine is called to generate and print two-dimensional (2-D) printer plots representing slices through the geometrical representation of the physical problem. See Sect. C6.3.4.14 for details.

PRTARA - This subroutine prints a table listing the array number, the number of units in the x, y, and z directions, and the nesting level for each array utilized in the problem.

PRTJOM - If a geometry error is recognized, this subroutine is called to print the KENO-VI geometry data that is used in the problem.

ARALBA - This subroutine calls PRTLBA for each unit orientation array used in the problem. Subroutine PRTLBA checks each array for geometrical consistency and prints the array data.

PRTLBA - If a geometry error is recognized, and more than one unit is entered in the geometry data, this subroutine is called to print the KENO-VI unit orientation array data. STOP is called to write an error message if too many units are used in the KENO-VI geometry description.

STOP - This library routine is called to print an error message and terminate if errors were found in the CSAS6 or KENO-VI data.

WRTRST - This subroutine controls the writing of all the KENO-VI data on the restart data file for use by the KENO-VI functional module. MOVE is called to load the required common information into COMMON/REC1/, a common that is used by the analytical sequence. The array that contains the IDs of the 1-D cross sections is written on the restart data file. REED and IO are then used to write the geometry data, unit orientation data, biasing data, and start data on the restart data file.

MOVE - This library routine is called to load data into common.

C6.3.4.1 Control of the Data Input for KENO-VI

This section of the program, shown in Fig. C6.3.4, is responsible for reading the input data that will be used by KENO-VI, with the exception of the title and parameter data.

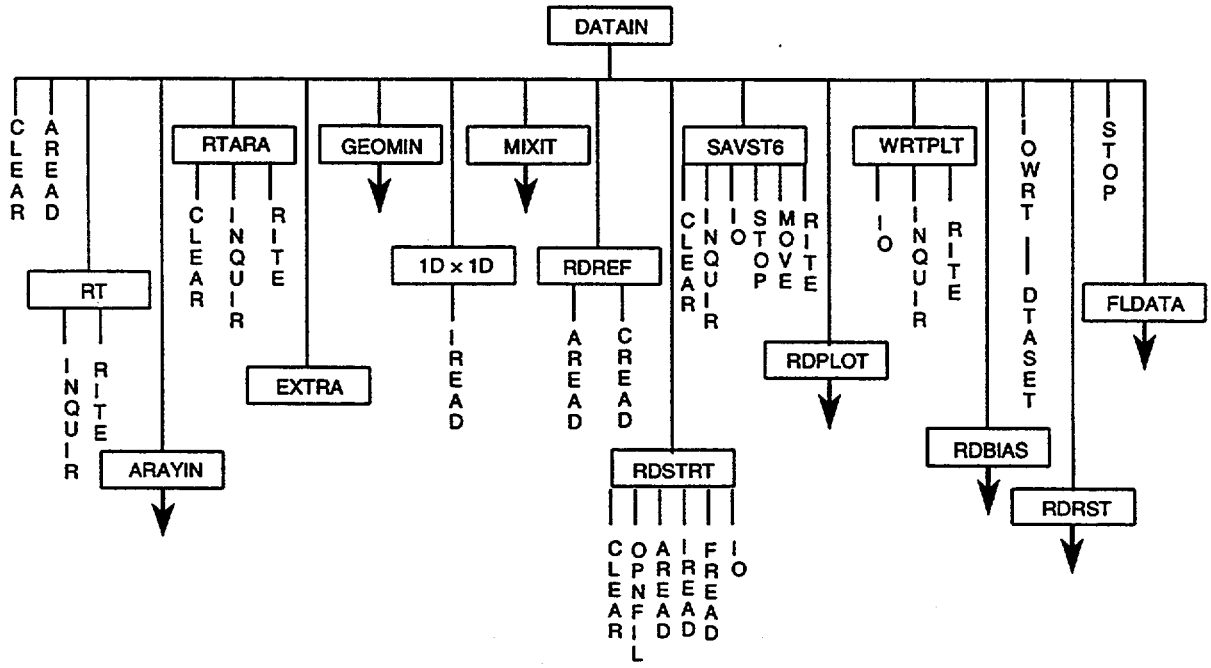


Figure C6.3.4 Flowchart of KENO-VI data reading routines

DATAIN - This subroutine controls the reading of all the KENO-VI data except the title card and parameter data. It initializes COMMON/STDATA/, the common that contains the start data, and initializes the 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. Each block of data is preceded by a keyword that indicates the type of data being entered. After reading the keyword, the appropriate subroutine is called to read the accompanying data. After the data have 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 also 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 and the keyword defining the type of associated data as well as the END flag and the associated keyword. It can be called many times from DATAIN.

RT - This subroutine may be called many times 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 the direct-access device.

INQUIR - Set direct-access pointer.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

ARAYIN - This subroutine is called to read data defining the array size. It also reads the unit orientation data if it is entered. ARAYIN is always called if array data are specified. See Sect. C6.3.4.2 for a more complete description.

RTARA - This subroutine is called only if ARAYIN 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 is not normally 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. C6.3.4.3 for additional information. The geometry region data are 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 extra 1-D data are 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.

IREAD - This library routine can be called many times from subroutine PARAM. It is used to read integer parameter data.

MIXIT - This subroutine is called to read the mixing table data block that defines the mixtures that are to be created. Section C6.3.4.4 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 KENO-VI geometry data and unit orientation data. The boundary condition data are 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 input data for defining the KENO-VI boundary conditions.

CREAD - This subroutine is used to read character data.

RDSTRT - This subroutine is called to read start data for KENO-VI. This data are 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.

OPNFIL - This library routine opens the I/O units or devices that will be utilized in the problem.

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

IO - This subroutine is used to read/write data from/to a file.

SAVST6 - This subroutine is called to save the data associated with start type 6. SAVST6 is called only if start type 6 is specified in the start type data. See Sect. F17.4.8 for information concerning the specification of start data. The library routine CLEAR is called to initialize the arrays that will contain the start data. 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.

STOP - This library routine is called to print an error message and terminate if errors were found in the CSAS6 or KENO-VI data.

MOVE - This library routine is called to load data into common.

RDPLOT - This subroutine is called to read the plot data block that is used to generate printer plots. Section C6.3.4.5 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 it 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. C6.3.4.6 for more information. The biasing input data block is described in detail in Sect. F17.4.7.

IOWRT - This subroutine is called with five arguments. In sequence they are (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. C6.3.4.7.

FLDATA - This subroutine is called to supply default data for arrays that were not entered as input. Section C6.3.4.8 contains a more detailed account of the exact procedure.

C6.3.4.2 Read KENO-VI Array Data

This section explains the procedure involved in reading the KENO-VI array data utilized by the analytical sequence, as shown in Fig. C6.3.5.

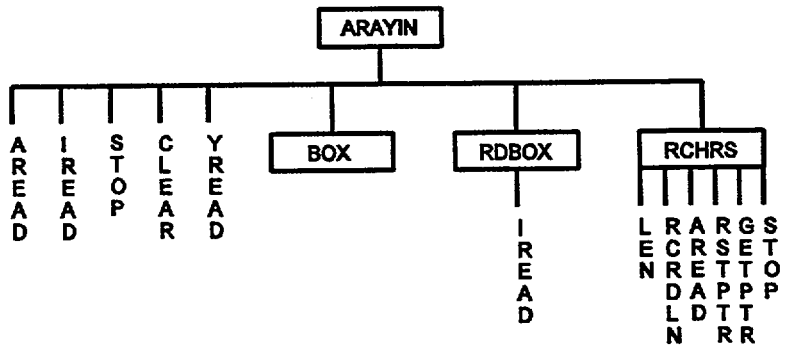


Figure C6.3.5 Flowchart for reading KENO-VI array data

ARAYIN - This subroutine is called from DATAIN when the words READ ARRA are encountered. It is responsible for reading the data that define the size of each unit orientation array. It reads the unit orientation data for each array using YREAD for the FILL option and subroutine 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. The data are read using the library routines AREAD, IREAD, and YREAD. The data read by this subroutine is described in Sect. F11.4.5.

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 used to zero arrays.

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 is 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).

LEN - An intrinsic Fortran function that returns the length of a string.

RCRDLN - This subroutine reads an old record length from common/qrdbuf/ and writes a new record to common/qrdbuf/.

RSTPTR - Stores a character location to common/qrdbuf/.

GETPTR - Gets a character location from common/qrdbuf/.

C6.3.4.3 Read KENO-VI Geometry Data

This section of the program reads the KENO-VI geometry data required for the problem as shown in Fig. C6.3.6 and Fig. C6.3.7.

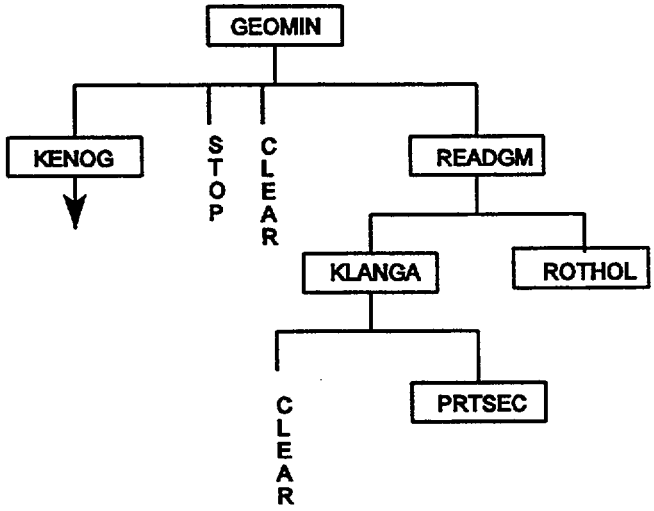


Figure C6.3.6 Flowchart of routines to read the KENO-VI geometry data

This section of the program reads the geometry data.

GEOMIN - This subroutine controls the reading of the KENO-VI geometry data. KENOG is called to read the data and write it on the scratch data file. Pointers are then calculated and CLEAR is called to zero the arrays that hold the geometry data. READGM is called to read the data from the scratch data file and load it into the appropriate arrays. STOP is called to write an error message if more storage is needed. Section F17.4.4 describes the KENO-VI geometry input data in detail.

KENOG - This subroutine uses AREAD to read the geometry work and IREAD to read the unit number. KENOG then calls the appropriate subroutine, based on the geometry work 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.

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 used to zero arrays.

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

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

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

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

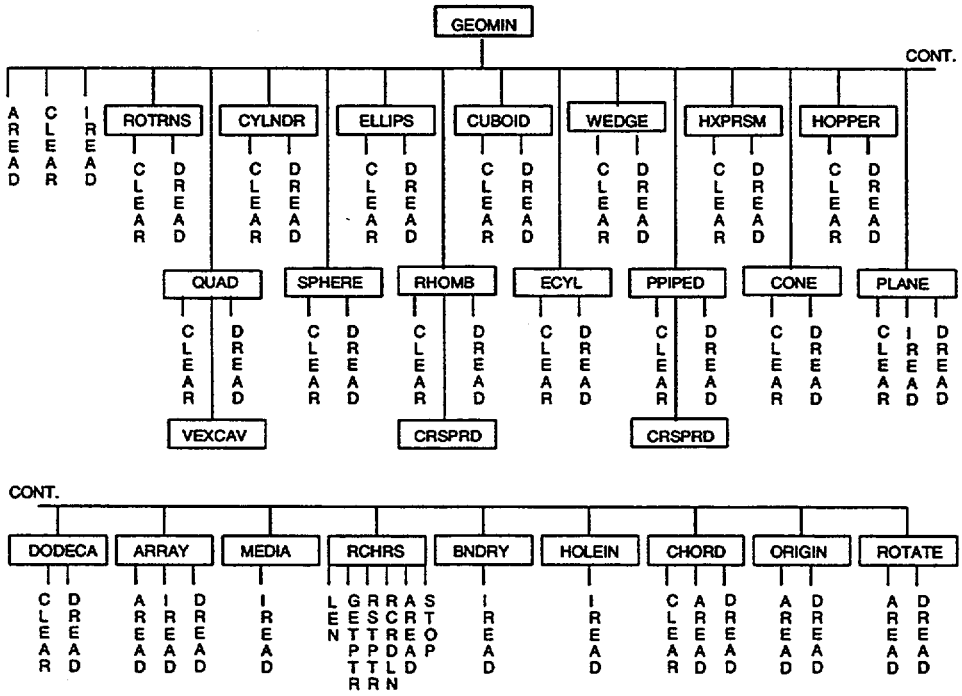


Figure C6.3.7 Flowchart for reading KENO-VI geometric shape data

GEOMIN - This subroutine controls the reading of the KENO-VI geometry data. KENOG is called to read the data and write it on the scratch data file. Pointers are then calculated and CLEAR is called to zero the arrays that hold the geometry data. READGM is called to read the data from the scratch data file and load it into the appropriate arrays. STOP is called to write an error message if more storage is needed. Section F17.4.4 describes the KENO-VI geometry input data in detail.

AREAD - This library routine is used to read the READ flag and the keyword defining the type of associated data as well as the END flag and the associated keyword. It can be called many times from DATAIN.

CLEAR - This library routine is used to zero arrays.

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

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.

DREAD - This library routine is used to read double precision floating point data.

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.

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.

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

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.

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 2 input vector.

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 surfaces of the cuboid.

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.

WEDGE - This subroutine reads the x-coordinate of the triangular base, the x and y coordinates of the intersection of the other 2 sides, and the height of the wedge using DREAD and generates the set of quadratic equations that represent the surface of the wedge.

PPIPED - This subroutine reads the x-distance, y-distance, and 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 parallelpiped.

HXPRSM - 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.

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.

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.

DODECA - This subroutine reads the inscribed radius of the dodecahedron using DREAD and generates the quadratic equations 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.

RCHRS - This subroutine is used to read the plot title and the character string that defines the symbols to be used in the plot. LEN is a FORTRAN-supplied routine that sets the length of the data string. 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.

LEN - An intrinsic Fortran function that returns the length of a string.

GETPTR - Gets a character location from common/qrdbuf/.

RSTPTR - Stores a character location to common/qrdbuf/.

RCRDLN - This subroutine reads an old record length from common/qrdbuf/ and writes a new record to common/qrdbuf/.

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

BNDRY - This subroutine reads the vector definition array of the boundary of each unit using IREAD.

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 which 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/.

C6.3.4.4 Read KENO-VI Mixing Table Data

This section deals with reading the mixing table data, as shown in Fig. C6.3.8.

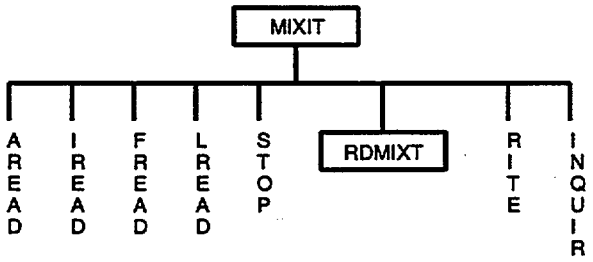


Figure C6.3.8 Flowchart for reading KENO-VI mixing table data

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 item is numeric or character data. 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. The library routine 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.

AREAD - This library routine is used to read the READ flag and the keyword defining the type of associated data as well as the END flag and the associated keyword. It can be called many times from DATAIN.

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

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

LREAD - This library routine returns a value of "true" if the next position contains 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.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

INQUIR - Set direct-access pointer.

C6.3.4.5 Read KENO-VI Plot Data

This section of the program, shown in Fig. C6.3.9, reads the plot or picture data used to generate printer plot maps of the mixtures, units, and/or bias IDs used in the problem. The plot input data block is described in Sect. F17.4.11.

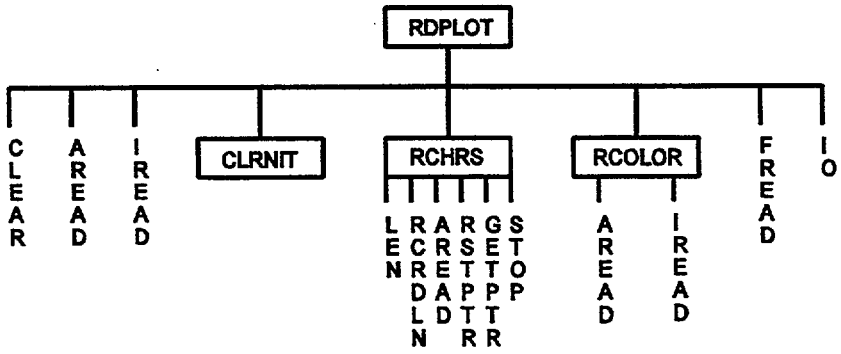


Figure C6.3.9 Flowchart for reading KENO-VI plot data

RDPLOT - 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.

CLEAR - This library routine is used to zero arrays.

AREAD - This library routine is used to read the READ flag and the keyword defining the type of associated data as well as the END flag and the associated keyword. It can be called many times from DATAIN.

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

CLRNIT - This subroutine initializes the 255 default colors used in screen plots.

RCHRS - This subroutine is used to read the plot title and the character string that defines the symbols to be used in the plot. LEN is a FORTRAN-supplied routine that sets the length of the data string. 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.

LEN - An intrinsic Fortran function that returns the length of a string.

RCRDLN - This subroutine reads an old record length from common/qrdbuf/ and writes a new record to common/qrdbuf/.

RSTPTR - Stores a character location to common/qrdbuf/.

GETPTR - Gets a character location from common/qrdbuf/.

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

RCOLOR - This subroutine is used to read new colors that are used in screen plots.

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

IO - This subroutine is used to read/write data from/to a file.

C6.3.4.6 Read KENO-VI Biasing Data

This section of the program reads the biasing data used in the problem. The biasing input data block is described in Sect. F17.4.7 and illustrated in Fig. C6.3.10.

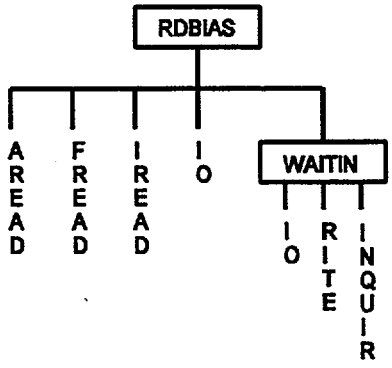


Figure C6.3.10 Flowchart for reading KENO-VI biasing data

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 from cards. 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.

AREAD - This library routine is used to read the READ flag and the keyword defining the type of associated data as well as the END flag and the associated keyword. It can be called many times from DATAIN.

FREAD - This library routine can be called many times from subroutine PARAM. It is used to read floating-point parameter data.

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

IO - This subroutine is used to read/write data from/to a 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. The library routine INQUIR is called to set the next block on a direct- or random-access device.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

INQUIR - Set direct-access pointer.

C6.3.4.7 Read KENO-VI Restart Data

This section of the program reads restart information from the restart data file. The flowchart for this procedure is given in Fig. C6.3.11.

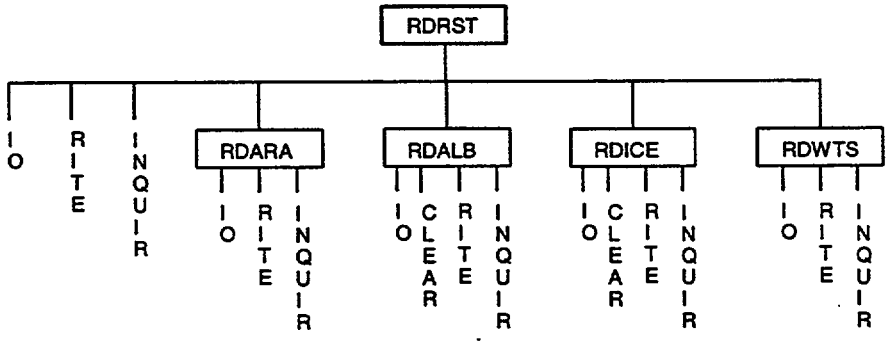


Figure C6.3.11 Flowchart for reading KENO-VI restart data

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.

IO - This subroutine is used to read/write data from/to a file.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

INQUIR - Set direct-access pointer.

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 stores the next direct-access block number.

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. INQUIR stores the next direct-access block number. 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.

CLEAR - This library routine is used to zero arrays.

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. INQUIR stores the next direct-access block number. 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.

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 stores the next direct-access block number.

C6.3.4.8 Generate Remaining KENO-VI Data

This section of the program, shown in Fig. C6.3.12, is responsible for generating data that are required for a KENO-VI problem but are not entered directly as data.

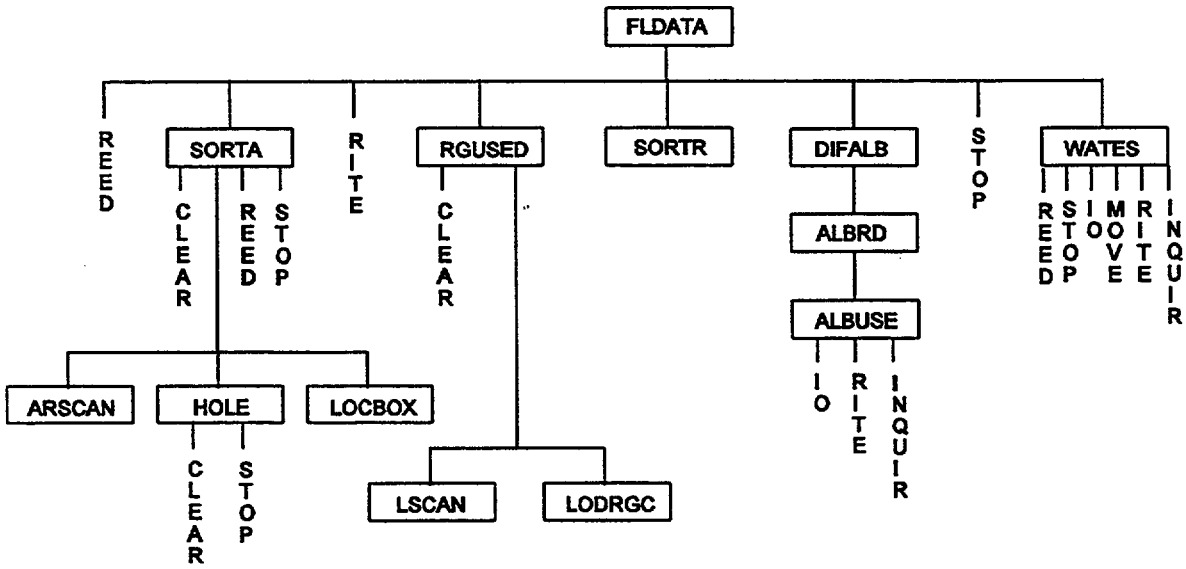


Figure C6.3.12 Flowchart for generating remaining KENO-VI data

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 are 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-dependent biasing function (*wtavg* array) on the direct-access data file.

REED - Load data from direct-access supergroup 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.

CLEAR - This library routine is used to zero arrays.

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

ARSCAN - This function, which is called from sorta, is used to determine if array data is entered when an array is 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 ensure holes are not recursively nested.

LOCBOX - This function subprogram is called from SORTA to determine the unit or box type at a given position in the unit orientation array.

RITE - This library routine is called from RT to write an array of data on the direct-access data file.

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 or box type 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 or box type is used in the unit orientation array. A value of false is returned if the unit or box type 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 are 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 albedo 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. INQUIR stores the next direct-access block number.

IO - This subroutine is used to read/write data from/to a file.

INQUIR - Set direct-access pointer.

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 from cards, 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 is used to store the next direct-access block number.

MOVE - This library routine is called to load data into common.

C6.3.4.9 Process the KENO-VI Geometry Data

This portion of the program, shown in Fig. C6.3.13, 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.

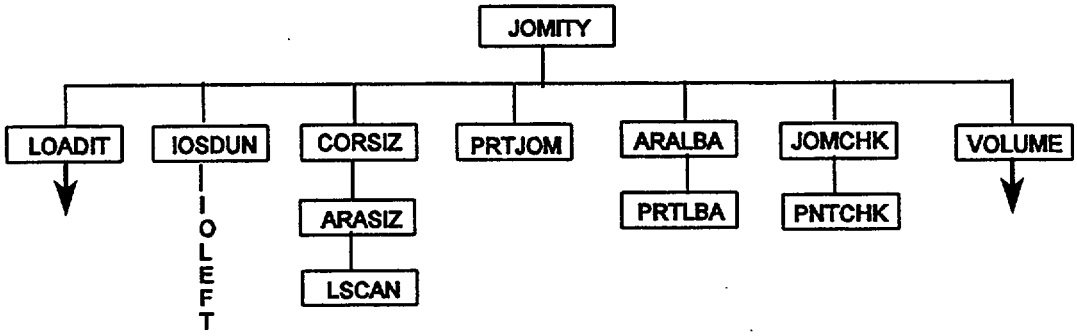


Figure C6.3.13 Flowchart for processing KENO-VI geometry data

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 C6.3.4.10 contains a more detailed description of the procedure.

IOSDUN - This subroutine returns the numbers of I/Os used. The library routine IOLEFT returns the numbers of I/O requests remaining before the system cancels the job.

IOLEFT - This library routine is called to store the initial I/O count in common for determining the number of I/Os used in certain parts of the program.

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 or box type is used in the unit orientation array. A value of false is returned if the unit or box type 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.

JOMCHK - This subroutine checks KENO-VI geometry for illegal conditions such as: holes containing units that do not exist, array boundaries extending outside of arrays, inconsistencies between array types and unit boundaries in the array.

PNTCHK - This subroutine checks points on the exterior of an array to ensure they are outside or on the array boundary.

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. C6.3.4.12 for additional details. Volumes are currently not calculated in KENO-VI.

C6.3.4.10 Load KENO-VI Data from the Direct-Access File

This portion of the program loads data from the direct-access data file into permanent memory as shown in Fig. C6.3.14.

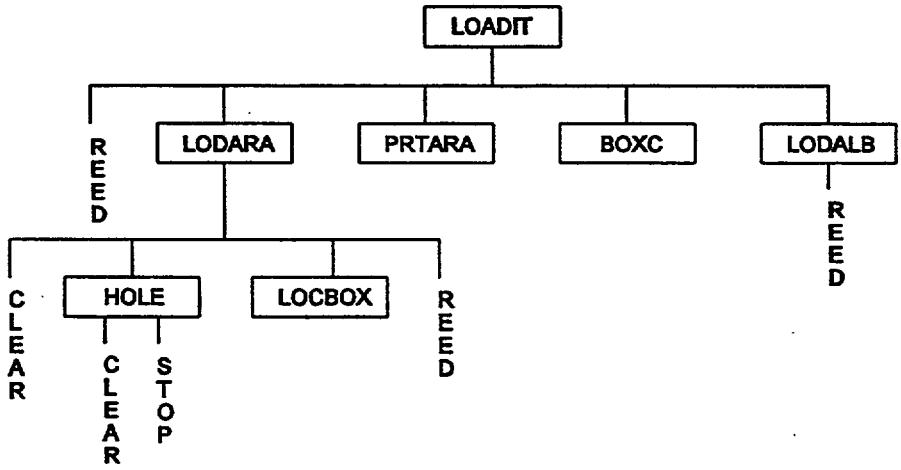


Figure C6.3.14 Flowchart for loading data from direct access

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 array. If multiple boxes 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 box correspondence array, and LODALB is called to load the nonsupergrouped portion of the albedo data.

REED - Load data from direct-access supergroup data file.

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.

CLEAR - This library routine is used to zero arrays.

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.

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

LOCBOX - This function is called from LODARA to return the unit type 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 are printed for each array.

BOXC - This subroutine uses the number of units or box types and the geometry region number corresponding to the first and last geometry region of each unit to generate the box correspondence array that contains the unit or box type number for each geometry region. This 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.

C6.3.4.11 Calculate KENO-VI Geometry Volumes

This portion of the program, illustrated in Fig. C6.3.15, is responsible for calculating the volume of each KENO-VI geometry 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. Currently, volumes are not calculated in KENO-VI.

VOLUME - This subroutine calculates the volume of each region for every unit that is used in the problem. It then calculates the cumulative volumes for each unit. The intrinsic functions ASIN, which returns the arc sign of a variable, and SQRT, which returns the square root of an expression, are used when calculating the volume of a hemicylinder. CLEAR is used to initialize arrays. If an external reflector is present, HUNTER is called to determine the number of times each array

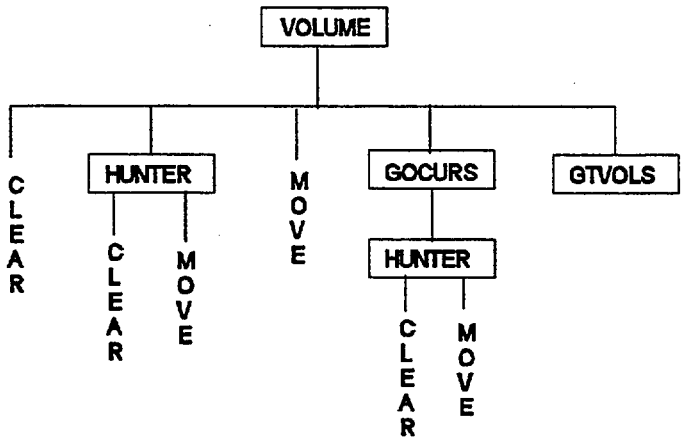


Figure C6.3.15 Flowchart for calculating KENO-VI geometry volumes

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. Currently, volumes are not calculated.

CLEAR - This library routine is used to zero arrays.

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.

MOVE - This library routine is called to load data into common.

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.

C6.3.4.12 Generate Printer Plot

This portion of the program, illustrated in Fig. C6.3.16, generates printer plots of a 2-D slice through the KENO-VI geometry. As many plots as are desired can be printed.

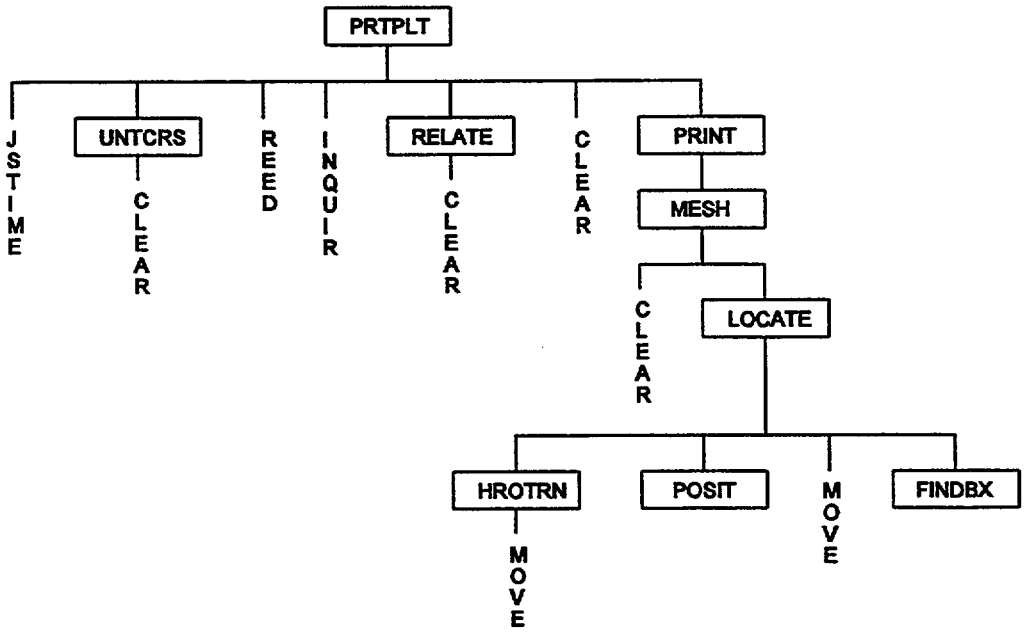


Figure C6.3.16 Flowchart for printer plots

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 data block. 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.

JSTIME - This library routine stores the time for timing purposes.

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.

CLEAR - This library routine is used to zero arrays.

REED - Load data from direct-access supergroup data file.

INQUIR - Set direct-access pointer.

RELATE - This subroutine calls CLEAR to zero the reverse correspondence array. It then prints the plot header and loads the array that correlates the symbols.

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 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 or box type 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 coordinate of the mesh point is translated to the hole and POSIT is called again.

HROTRN - This subroutine rotates and translates a particle entering a hole.

MOVE - This library routine is called to load data into common.

POSIT - This subroutine determines the region within a unit that contains a specified point.

FINDBX - This subroutine locates the position in an array that contains a specified point.

C6.3.4.13 Write KENO-VI Input Data on Restart File

This portion of the program, illustrated in Fig. C6.3.17, is responsible for writing all data except the calculated results on the restart data file. 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. F17.5.3. The calculated results are written on the restart data file later in the program. The restart data file is used for restarting a problem.

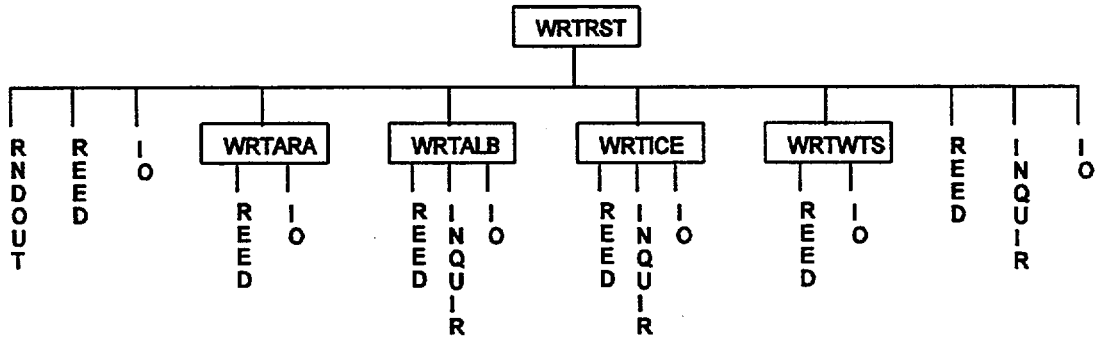


Figure C6.3.17 Flowchart for writing data on the restart data file

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 out the user-supplied weighting or biasing data.

RNDOUT - This library routine is used to preserve the current random number so it can be written on the restart data file.

REED - Load data from direct-access supergroup data file.

IO - This subroutine is used to read/write data from/to a 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 block. 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 it 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.

INQUIR - Set direct-access pointer.

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.

C6.4 INPUT DATA GUIDE

This section describes the input data required for Criticality Safety Analysis Sequence No. 6. This sequence contains two control modules. These are listed in Table C6.4.1 with the functional modules they invoke. Note that modules with an "X" in the name create cell-weighted libraries by using XSDRNPM.

Each sequence generates various libraries that may be saved for future use. Table C6.4.2 lists the various I/O units that may be saved and their definitions. Table C6.4.3 lists those I/O units containing cross-section libraries that are generated by each sequence. See Table C6.5.1 in Section C6.5 for a complete list of I/O units utilized by Criticality Safety Analysis Sequence No. 6 and Table C6.5.2 for the I/O units utilized by the associated functional modules.

The input data for these CSAS6 modules are composed of two broad categories of data. The first (Material Information Processor, including Standard Composition Specification Data and Unit Cell Geometry Specification) specifies the cross-section library and defines the composition of each mixture and the unit cell geometry that is used to process the cross sections. The second category of data, the KENO-VI input data, are used to specify the geometric and boundary conditions that represent the physical 3-D configuration of the problem. Both data blocks are necessary for CSAS26 and CSAS62X.

All data are entered in free form, allowing alphanumeric data, floating-point data, and integer data to be entered in an unstructured manner. Eighty columns of data entry are allowed, simulating a card of data. Data can usually start or end in any column. Each data entry must be followed by one or more blanks to terminate the data entry. For numeric data, either a comma or a blank can be used to terminate each data entry. Integers may be entered for floating values. For example, 10 will be interpreted as 10.0. Imbedded blanks are not allowed within a data entry unless an E precedes a single blank as in an unsigned exponent in a floating-point number. For example, 1.0E 4 would be correctly interpreted as 1.0×10^4.

The word "END" is a special data item. An "END" may have a name or label associated with it. The name or label associated with an "END" is separated from the "END" by a single blank and is a maximum of 12 characters long. *At least 2 blanks MUST follow every labeled and unlabeled "END." It is the user's responsibility to ensure compliance with this restriction. Failure to observe this restriction can result in the use of incorrect or incomplete data without the benefit of warning or error messages.*

Multiple entries of the same data value can be achieved by specifying the number of times the data value is to be entered, followed by either R, *, or $, followed by the data value to be repeated. Imbedded blanks are not allowed between the number of repeats and the repeat flag. For example, 5R12, 5*12, 5$12, or 5R 12, etc., will enter five successive 12s in the input data. Multiple zeros can be specified as nZ where n is the number of zeroes to be entered. The SCALE free-form reading routines are described in more detail in Sect. M3.

The purpose of this section is to define the input data in discrete subsections relating to a particular type of data. Tables of the input data are included in each subsection, and the entries are described in more detail after the tables illustrated in Fig. C6.4.1. Section C6.4.1 is provided for experienced users and contains all the tables that are used to describe the input data. Section C6.4.2 describes input data requirements and the data-checking capability. Sections C6.4.3 through C6.4.8 describe the Material Information Processor data, Sect. C6.4.9 summarizes the KENO-VI data that are explained in detail in Sect. F17.4.

Resonance-corrected cross sections utilize Dancoff corrections based on the unit cell specification. Because only one unit cell can be specified in the data, resonance corrections can only be applied to one mixture via conventional methods. However, if multiple resonance-corrected mixtures are required, the necessary data can be entered via the OPTIONAL PARAMETER DATA described in Section C6.4.8 and Tables C6.4.4 and C6.4.13.

Table C6.4.1 Functional modules executed by CSAS6 control modules

Control module	Search function	Functional modules executed by the control module			
CSAS26	No search	BONAMI	NITAWL-II		KENO-VI
CSAS26X	No search	BONAMI	NITAWL-II	XSDRNPM	KENO-VI

Table C6.4.2 I/O units on which cross-section libraries are written

Unit	Type of data	Creating module
2	Resonance-corrected mixed working library	ICE
3	Resonance-corrected, cell-weighted working library	XSDRNPM
4	Resonance-corrected working library	NITAWL-II
14	Resonance-corrected, mixed cross-section, MORSE/KENO library. If the invoked sequence contains an X in its name, this library contains a cell-weighted mixture identified as mixture 500	ICE

Table C6.4.3 I/O units generated by CSAS6 and associated modules

Module name	Primary product	Unit numbers of generated cross-section libraries			
		2	3	4	14
CSAS26	KENO-VI k-effective	X		X	X
CSAS26X	KENO-VI k-effective using homogenized cell	X	X	X	X

To check the input data without actually processing the cross sections, the words "PARM=CHECK" or "PARM=CHK" should be entered, starting in or after column 11 of the analytical sequence specification.

```
=CSAS26   PARM=CHK
          or
#CSAS26   PARM=CHK
```

This would cause the input data for CSAS26 to be checked and appropriate error messages to be printed. If plots are specified in the data, they will be printed. This feature allows the user to debug and verify the input data while using a minimum of computer time. Many problems can be checked in 10 seconds or less. The number of words of storage requested by CSAS6 and its associated sequences is defaulted to 100,000 words of storage. This can be respecified through the use of the PARM command on the analytical sequence specification. For example, if 150,000 words of storage are required for the problem, "PARM=SIZE=150,000" should be entered, starting in or after column 11 of the analytical sequence specification as shown below.

```
=CSAS26   PARM=SIZE=150000
```

To combine checking and size specification, specify "PARM=(CHECK,SIZE=nnn)" or "PARM=(CHK,SIZE=nnn)" starting in or after column 11 on the analytical sequen ce specification. The value of nnn is given in words of storage. The minimum value of nnn is the amount of storage required by the problem, and the maximum value of nnn is the available computer storage.

C6.4.1 INPUT DATA SUMMARY FOR EXPERIENCED USERS

Section C6.4.1 is provided for the convenience of experienced users. Other users should skip to Section C6.4.2. All of the input data for Criticality Safety Analysis Sequence No. 6 are illustrated in Fig. C6.4.1, and are summarized in Table C6.4.4. This table is provided as an input data guide for users who are familiar with CSAS6 data requirements. Each component table of Table C6.4.4 is repeated and discussed in detail in Sections C6.4.4 through C6.4.12. The KENO-VI data are included in this table in very general terms. Table C6.4.5 contains a summary of the KENO-VI input data. They are described in detail in Section F17.4 with additional information contained in Section F17.5.

The Material Information Processor now allows terse data input for all data except the standard composition names and the keyword entries in the optional parameter data (MORE DATA). Terse data entry requires the user to enter only as many characters as is necessary to uniquely define the data entry. However, as many characters as are specified by the user must match the name allowed by the code.

For example, refer to Table C6.4.4, **Outline of Material Information Processor data,** data position 3. The available choices for the type of calculation are: INFHOMMEDIUM, LATTICECELL, and MULTIREGION. Therefore, I would be sufficient to specify an infinite homogeneous medium, L would be sufficient for lattice cell, and M would specify multiregion. If it is desirable to use more characters, the user is free to do so. However, as many characters as are entered must match the name allowed by the code. For example, if INFHOMMEDIUM is to be specified, INFH is correct, but INFI is not.

WARNING: If several choices begin with the same letters, sufficient characters should be entered to uniquely define the name. For example, ASPHSQUAREP and ASPHTRIANGP are identical through the first four characters. If only ASPH is entered, the code will accept the first name whose first four characters are ASPH. This may not be the one the user intended to use.

Table C6.4.4 Input data requirements

Summary of data input requirements (see Sect. C6.4.2 for details)			
	Type of data	Analytical sequence	
1	Analytical sequence specification	=CSAS26	=CSAS26X
2	Material Information Processor data	Yes	Yes
3	KENO-VI data	Yes	Yes
4	END for the analytical sequence	Yes	Yes

Outline of Material Information Processor data (see Sect. C6.4.3 for details)

Data position	Type of data	Data entry	Comments
1	TITLE	Enter a title	80 characters
2	Cross-section library name	HANSEN-ROACH 27GROUPNDF4 44GROUPNDF5 238GROUPNDF5 27BURNUPLIB etc.	The currently available libraries are listed in Table M8.8.2.
3	Type of calculation	INFHOMMEDIUM LATTICECELL MULTIREGION	These are the available options. See the explanation in Sect. C6.4.3.
4	Standard Composition specification data	Enter the appropriate data	Terminate this data block with END COMP. See Sect. C6.4.4.
5	Unit cell geometry specification	Enter the appropriate data (optional for INFHOMMEDIUM)	Optional for INFHOMMEDIUM. See Sect. C6.4.5 for INFHOMMEDIUM. See Sect. C6.4.6 for LATTICECELL. See Section C6.4.7 for MULTIREGION.
6	Optional parameter data	Enter the desired data	Precede this data block by MORE DATA if more parameter data are to be entered. Otherwise, omit these data entirely. See Sect. C6.4.8.

Table C6.4.4 (continued)

Outline of standard compositions specification data (see Sect. C6.4.4 for details)

Entry number	Variable name	Type of data	Entry requirement	Comments
1	SC	Standard composition component name	Always	Enter once for each standard composition. Enter the alphanumeric description from Table M8.2.1. Additional allowed names include those beginning with ARBM for arbitrary materials and SOLN for solutions
A1	ROTH	Theoretical density of material (g/cc)	ARBM	Enter once for each standard composition component that is an arbitrary material
A2	NEL	Number of elements in the material	ARBM	Enter once for each standard composition component that is an arbitrary material
A3	IVIS	No longer used but still must be entered	ARBM	Enter once for each standard composition component that is an arbitrary material. Enter 0 or 1.
A4	ICP	Compound indicator	ARBM	Enter once for each standard composition component that is an arbitrary material. Enter 1 for a compound, 0 for alloys, mixtures, etc.
A5	IRS	No longer used but still must be entered	ARBM	Enter once for each standard composition component that is an arbitrary material. Enter 0 or 1.
A6	NCZA	ID number (from far right column of Table M8.2.1)	ARBM	Repeat the sequences A6 and A7 for each element in the arbitrary material before entering entry number 2. Enter the number from the far right column of Table M8.2.1. (Premixed standard compositions cannot be used in an arbitrary material definition)
A7	ATPM	Number of atoms of this element per molecule of arbitrary material	ARBM & ICP=1	Repeat the sequence A6 and A7 for each element in the arbitrary material before entering entry number 2. Do not enter a value unless ICP=1
		or	or	or
		Weight percent of this element in this arbitrary material	ARBM & ICP=0	Repeat the sequence A6 and A7 for each element in the arbitrary material before entering entry number 2. Do not enter a value unless ICP=0

Table C6.4.4 (continued)

Outline of standard compositions specification data (continued)

Entry number	Variable name	Type of data	Entry requirement	Comments
2	MX	Mixture ID number	Always	Enter once for each standard composition component
S1	FD	Fuel density (grams of U or Pu per liter of solution)	SOLN	Enter once for a solution
S2	AML	Acid molarity of the solution	SOLN	Enter once for a solution. AML=0 if there is no acid in the solution
O1	SPGR	Specific gravity of the solution	Optional	If the specific gravity (SPGR) of the solution is known, it should be entered as SPG=SPGR
	or ROTH	or Density of the basic standard composition		or if the density of a basic standard composition (ROTH) is to be entered, use DEN=ROTH
3	VF	Density multiplier	See comment column	Enter the density multiplier (density fraction, volume fraction, or a combination). Default value is 1. This item can be omitted if entries 4, 5, 6a, and 6b are also omitted. VF=0 is not allowed for SOLN or ARBM
4	ADEN	Number density (atoms/b-cm) for the nuclide	VF=0	Enter only if VF=0.0
5	TEMP	Temperature, in K	See comment column	Default value is 293 K. This entry can be omitted if entries 6a and 6b are also omitted
6a	IZA	Isotope's ZA number	VF≠0	Enter for each isotope in the standard composition component. Omit if VF=0. Entries 6a and 6b are entered in pairs until each isotope in the component is defined
6b	WTP	Weight percent of the isotope	VF≠0	Enter for each isotope in the standard composition component. Omit if VF=0.0. Entries 6a and 6b are entered in pairs until each isotope in the component is defined
7[a]	END	Terminate a standard composition	Always	Enter once for each standard composition component. This terminates the data for a standard composition component. Enter END to terminate the component. Repeat entries 1 through 7 until all the mixtures have been defined. At least two blanks must separate entry 7 from the next entry
	END COMP	Terminate the data block	Terminus	Enter once for a problem. Enter the words END COMP when all the standard composition components have been described. At least two blanks must follow the END COMP

[a]NOTE: Entry 7 should not begin in column 1 unless a name is associated with it. At least two blanks should separate the last entry 7 from the END COMP.

Table C6.4.4 (continued)

Optional unit cell specifications for INFHOMMEDIUM problems
(see Sect. C6.4.5 for details)

Entry number	Variable name	Type of data	Data entry	Comments
1	NAME	Keyword	CELLMIX	Initiate reading cell data for INFHOMMEDIUM
2	MFUEL	Mixture number in the cell	Mixture number	Specifies the mixture number to be used in the cell. Defaults to the smallest mixture number entered in the standard composition data

NOTE: Unit cell data are necessary for INFHOMMEDIUM only if a mixture number other than the smallest mixture number is to be used in the cell and if a control sequence that executes XSDRNPM has been specified. If mixtures 1, 2, and 3 are specified and if mixture 3 is to be used in the cell, enter CELLMIX 3.

Table C6.4.4 (continued)

Unit cell specification for LATTICECELL problems (see Sect. C6.4.6 for details)

Entry number	Variable name	Type of data	Entry requirement	Data entry	Comments
1	CTP	Type of lattice	Always		Describes the type of lattice or array configuration
				SQUAREPITCH	Use for cylindrical rods in a square pitch
				ASQUAREPITCH	Use for annular cylindrical rods in a square pitch
				ASQP	Use for annular cylindrical rods in a square pitch
				TRIANGPITCH	Use for cylindrical rods in a triangular pitch
				ATRIANGPITCH	Use for annular cylindrical rods in a triangular pitch
				ATRP	Use for annular cylindrical rods in a triangular pitch
				SPHSQUAREP	Use for spherical pellets in a cubic lattice
				ASPHSQUAREP	Use for annular spherical pellets in a cubic lattice
				ASSP	Use for annular spherical pellets in a cubic lattice
				SPHTRIANGP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				ASPHTRIANGP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				ASTP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				SYMMSLABCELL	Use for a symmetric array of slabs
				ASYMSLABCELL	Use for a periodic but asymmetric array of slabs
2	PITCH	Array pitch (cm)	Always	Appropriate dimension	The center-to-center spacing (cm) between fuel lumps. For asymmetric slab cell, enter the distance from the center of one moderator to the center of the other moderator (cm)
3	FUELOD	Outside dimension of fuel (cm)	Always	Appropriate dimension	Outside diameter of fuel (cm), or the thickness of the fuel in a slab
4	MFUEL	Fuel mixture number	Always	Mixture number	Mixture number representing the fuel
5	MMOD	Moderator mixture number	Always	Mixture number	Mixture number representing the moderator
6	MMOD2	2nd moderator mixture number	Annular cell	Mixture number	Mixture number representing the second moderator
7	TKMOD2	2nd moderator thickness	ASYMSLABCELL	Thickness	Thickness of the second moderator (cm) for ASYMSLABCELL
		or	or	or	or
		2nd moderator diameter (cm)	annular cell	diameter	Diameter of inner moderator (cm) for other annular cells
8	CLADOD	Outside diameter of clad (cm)	If clad	Clad OD	OMIT IF NO CLAD. For a slab, CLADOD is the sum of thickness of the fuel, gap, and clad
9	MCLAD	Clad mixture number	If clad	Mixture number	OMIT IF NO CLAD. Mixture number representing the clad
10	CLADID	Inside diameter of clad (cm)	If gap	Clad ID	OMIT IF NO GAP between the fuel and clad
11	MGAP	Gap mixture number	If gap	Mixture number	OMIT IF NO GAP between the fuel and clad. A mixture number of zero is often used
12	END	Terminate LATTICECELL data	Always	END	Terminate the LATTICECELL input data by entering the word END. Do not start in column 1. At least two blanks must follow entry number 12

Table C6.4.4 (continued)

Unit cell specification for MULTIREGION problems (see Sect. C6.4.7 for details)

Entry number	Variable name	Type of data	Entry requirement	Data entry	Comments
1	CS	Type of geometry	Always		Describes the type of geometry. The options are:
				SLAB	Use for slab geometry
				CYLINDRICAL	Use for cylindrical geometry
				SPHERICAL	Use for spherical geometry
				BUCKLEDSLAB	Use for slab geometry with a buckling correction for the two transverse directions
				BUCKLEDCYL	Use for cylindrical geometry with a buckling correction in the axial direction
2	BR	Right boundary condition	Required for BUCKLEDSLAB and BUCKLEDCYL optional for other geometries		Default is VACUUM. Describes the right/outside boundary condition
				VACUUM	This provides a non-return condition at the boundary
				REFLECTED	Do not use for cylindrical or spherical
				PERIODIC	Do not use for cylindrical or spherical
				WHITE	This provides isotopic return at the boundary
3	BL	Left boundary condition	Required for BUCKLEDSLAB and BUCKLEDCYL optional for other geometries		Default is REFLECTED. Describes the left boundary condition
				VACUUM	This provides a non-return condition at the boundary
				REFLECTED	Recommended for cylindrical or spherical
				PERIODIC	Do not use for cylindrical or spherical
				WHITE	This provides isotropic return at the boundary
4	ORGN	Location of left boundary on the x-axis (cm)	BUCKLEDSLAB and BUCKLEDCYL optional for other geometries	Appropriate dimension	Default is 0.0. Should not be changed for cylindrical or spherical geometry. A value must be entered if subsequent data are to be entered
5	DY	Buckling height (cm)	BUCKLEDSLAB and BUCKLEDCYL	Appropriate dimension	Omit for SLAB, CYLINDRICAL, and SPHERICAL. This corresponds to one of the transverse dimensions of an actual 3-D slab assembly or to the length of a finite cylinder
6	DZ	Buckling depth (cm)	BUCKLEDSLAB	Appropriate dimension	Omit unless BUCKLEDSLAB was specified. This is the buckling depth corresponding to the second transverse dimension of a 3-D slab assembly
7	END	End geometry parameters	Always	END	Enter the word END. Do not start in column 1. At least two blanks must separate entry 7 from the first entry 8
8	MXZ	Mixture number in the zone	Always	Mixture number	Repeat entry numbers 8-10 until all zones are defined. Enter the mixture number for this zone
9	RZ	Outside radius of the zone (cm)	Always	Appropriate dimension	Repeat entry numbers 8-10 until all zones are defined. Enter the mixture number for this zone (cm)
10	XMOD	External moderator index	Optional		Repeat entry numbers 8-10 until all zones are defined. Entry 10 is optional and can be omitted. If it is omitted, repeat entry numbers 8 and 9 until all zones are defined
				NOEXTERMOD	No moderating materials in the adjacent zones
				ONEEXTERMOD	A moderating material is present in one adjacent zone
				TWOEXTERMOD	Moderating materials are present in two adjacent zones
	END ZONE	Terminate zone data		END ZONE	Enter when all zones have been defined by repeating entry numbers 8 through 10 for each zone. At least two blanks must follow this entry

Table C6.4.4 (continued)

Summary of available optional parameter data (see Sect. C6.4.8)

Entry number	Keyword name	Type of data	Applicable module	Comments
1	MORE DATA	Input flag		This signals that optional parameter data will be entered. Enter only those parameters you wish to change
2	ISN=	Order of angular quadrature	XSDRNPM	The default value is 8. This allows using another value
3	SZF=	Spatial mesh size factor	XSDRNPM	The default value is 1.0. 0<SZF<1.0 gives a finer mesh. SZF>1.0 gives a coarser mesh
4	IIM=	Max. number of inner iterations	XSDRNPM	The default value is 20. This allows using another value
5	ICM=	Max. number of outer iterations	XSDRNPM	The default value is 25. This allows using another value
6	EPS=	Overall convergence criteria	XSDRNPM	The default value is 0.0001. This allows using another value
7	PTC=	Point convergence criteria	XSDRNPM	The default value is 0.0001. This allows using another value
8	BKL=	Buckling factor	XSDRNPM	The default value is 1.420892. Use ONLY for a multiregion problem that specifies BUCKLEDSLAB or BUCKLEDCYL
9	IUS=	Upscatter scaling factor	XSDRNPM	The default value is zero. IUS=0 doesn't utilize upscatter scaling. IUS=1 uses upscatter scaling to accelerate the solution and/or speed convergence
10	RES=	Resonance data	BONAMI NITAWL	Enter the mixture number, geometry type (SLAB, CYLINDER, SPHERE), and the thickness of the slab or radius of the sphere or cylinder in cm. Optionally enter the inner radius (cm) to specify an annular cylinder or sphere
11	DAN(mm)=	Dancoff factor for the specified mixture	BONAMI NITAWL	Enter the mixture number, mm, to which the Dancoff factor applies inside the parentheses; enter the Dancoff factor after the equal sign **Repeat entry numbers 10 and 11 for all resonance mixtures used in the problem that are not treated in the LATTICECELL or MULTIREGION description**

Table C6.4.4 (continued)

Summary of available optional parameter data (continued)

Entry number	Keyword name	Type of data	Applicable module	Comments
12	BAL=	Key to print balance tables	XSDRNPM	The default value is FINE. BAL=NONE suppresses printing the balance table. BAL=ALL prints all balance tables. BAL=FINE prints only the fine-group balance tables
13	DY=	First transverse dimension	XSDRNPM	The first transverse dimension, in cm, used in a buckling correction to calculate leakage normal to the principal calculation direction (i.e., the height of a slab or a cylinder)
14	DZ=	Second transverse dimension	XSDRNPM	The second transverse dimension, in cm, used for a buckling correction (i.e., the width of a slab)
15	COF=	Diffusion coefficient option for transverse leakage correction	XSDRNPM	The default is 0. See Sect. F3.5, 3$ array, variable IPN
16	FRD=	Unit from which fluxes will be read	XSDRNPM	Enter the unit number from which the flux guess for XSDRNPM will be read
17	FWR=	Unit on which fluxes will be written	XSDRNPM	Enter the unit number where the binary fluxes from XSDRNPM will be written
18	ADJ=	Adjoint mode flag	XSDRNPM	Enter a 1 to cause XSDRNPM to solve the problem in adjoint mode
19	NBU=	Unit on which balance tables will be written	XSDRNPM	Enter the unit number where the balance tables from XSDRNPM will be written
20	WGT=	Cross-section weighting flag	XSDRNPM	Enter a 0 to suppress doing the cross-section weighting in XSDRNPM
21	ZMD(iz)=	Zone width modifier for the specified zone	XSDRNPM	Enter the zone number for which the modifier applies inside the parentheses; enter the zone width modifier after the equal sign. **Repeat number 20 to specify all zones to be modified in a search.**

Table C6.4.4 (continued)

Summary of available optional parameter data (continued)

Entry number	Keyword name	Type of data	Applicable module	Comments
22	INT(iz)=	Number of intervals for the specified zone	XSDRNPM	Enter the zone number inside the parentheses; enter the number of intervals after the equal sign. Repeat number 22 to specify all needed zones.
23	KEF=	Value of k_{eff} to be searched for	XSDRNPM	Enter the value of k_{eff} that it is desired to search for. The default is 1.0.
24	KFM=	Value of the eigenvalue modifier	XSDRNPM	Enter the value of the eigenvalue modifier (i.e., the relative change for the first guess of a search). The default is -0.1.
25	DAB=	Number of direct access data blocks	MIP[a]	The default is 200. Number of blocks allocated for direct access unit 90.
26	AXS=	Unit on which a mixed ANISN library will be written	ICE	Enter the unit number where ICE is to write a mixed ANISN library.
27	MSH=	Maximum number of mesh points/ resonance	NITAWL	The default value is 2001. This allows using another value.
28	MLV=	Highest resonance ℓ-value for self-shielding	NITAWL	The default value is 2. This allows using another value.
29	ID1=	Print control for scalar fluxes	XSDRNPM	The default value is -1. See Sect. F3.5, 2$ array, variable ID1.
30	COLL	Key to activate collapse of thermal groups	MIP[a]	Enter COLL to collapse all thermal groups into one group for the shielding sequences
31	END	Terminus		Terminate the optional parameter data. Do not start in column 1. At least two blanks must follow this entry.

[a]MIP is the Material Information Processor.

Table C6.4.4 (continued)

Outline of KENO-VI data (see Table C6.4.5 and Sects. C6.4.9 and F17.4 for details)

Type of data	Starting flag	Comments	Termination flag
Parameters	READ PARM	Enter desired parameter data	END PARM
Biasing or weighting	READ BIAS	Enter desired biasing data	END BIAS
Geometry	READ GEOM	Enter desired geometry data	END GEOM
Array data or unit orientation	READ ARRAY	Enter desired array data	END ARRAY
Boundary conditions or albedos	READ BNDS	Enter desired albedo data	END BNDS
Start data or initial source	READ START	Enter desired start data	END START
Mixing table data	READ MIXT	The Material Information Processor allows only NSCT= and PBXS=	END MIXT
Plot data	READ PLOT	Enter desired plot data	END PLOT
KENO-VI data terminus	END DATA	Enter to signal the end of all KENO-VI data	

Table C6.4.5 Summary of KENO-VI input data

Summary of parameter data

TITLE: The title must be entered first (80 columns) 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=	4	Working xsecs from NITAWL or XSDRN
WTH=	3.0	Wt. for splitting	AMX=	NO	All mixture xsecs	MKA=	NO	Matrix by array			
WTL=	1/WTH	Russian Roulette wt.	XAP=	NO	Xsec angles & probs.	CKA=	NO	Cofactor k by array			
GEN=	203	No. of generations	XS1=	NO	1-D xsecs	FMA=	NO	Fiss. prod. by array	SKT=	16	Scratch
NPG=	1000	No. per generation	XS2=	NO	2-D xsecs	HAL=	NO	MKA at highest level	RST=	95	Read restart
NSK=	3	Generations skipped	PKI=	NO	Fission spectrum	PLT=	YES	Printer plots	WRS=	95	Write restart
RES=	0	Gens. between restart	P1D=	NO	Extra 1-D xsecs	BUG=	NO	Debug print	XSC=	14	Mixed xsecs
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-Ds	MKU=	NO	Matrix by unit	NUB=	YES	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									

*The words of storage in CSAS are defaulted to 100,000 and can be overridden by using the size= parameter on the analytical sequence specification which then becomes the default value of LNG in KENO-VI.
For example: =CSAS26 PARM=SIZE=200000
or =CSAS26 PARM=(CHECK,SIZE=200000)

Table C6.4.5 (continued)
Summary of array data

ARRAY Format: READ ARRAY array parameters data type orientation data END ARRAY See Sects. F17.4.5, 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.

COUNT FIELD	OPTION FIELD	OPERAND FIELD	COMMENTS
		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
	F	j	Fills remainder of the array with unit no. j starting with the current array position
	A	j	Sets the current position in the array to j. Increments the current position
i	S		in the array by i allows skipping i positions. The value of 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	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
i	P	j	Alternately stores j and -j in the next i positions of the array
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

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:

DATA ENTRY	COMMENTS
LTYPE	The unit or box type. LTYPE must be greater than 1
IX1	Starting position in the X direction. IX1 must be at least 1 and no larger than the value entered for NUX
IX2	Ending position in the X direction. IX2 must be at least 1 and no larger than the value of NUX
INCX	The number of units by which increments are made in the X direction
IY1	The starting position in the Y direction. IY1 must be at least 1 and less than the value entered for NUY
IY2	Ending position int he Y direction. IY2 must be at least 1 and no larger than the value of NUY
INCY	The number of units by which increments are made in the positive Y direction
IZ1	Starting position in the Z direction. IZ1 must be at least 1 and no larger than NUZ
IZ2	Ending position in the Z direction. IZ2 must be at least 1 and no larger than NUZ
INCZ	The number of units by which increments are made in the positive Z direction

Table C6.4.5 (continued)

Summary of biasing data

BIAS (weighting) Format: READ BIAS keyword correlation data auxiliary 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	16,27,44,218,238	5 cm
			Paraffin	400	16,27,44,218,238	3 cm
	ibgn	Beginning bias ID	Water	500	16,27,44,218,238	3 cm
	iend	Ending bias ID	Graphite	6100	16,27,44,218,238	20 cm
WT=	AUXILIARY DATA will be read next.					
WTS=	AUXILIARY DATA will be read next.					
	wttitl	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 wtavg's from the first interval of material ID.

Table C6.4.5 (continued)
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
	Positive X face	YFC=	Both Y faces	&XY=	Positive X and Y faces	-XY=	Negative X and Y faces
	Negative X face	ZFC=	Both Z faces	&YX=	Positive X and Y faces	=XZ=	Negative X and Z faces
	Positive Y face	+FC=	All positive faces	+XZ=	Positive X and Z faces	=YZ=	Negative Y and Z faces
	Positive Y face	&FC=	All positive faces	+ZX=	Positive X and Z faces	YXF=	All X and Y faces
	Negative Y face	-FC=	All negative faces	&XZ=	Positive X and Z faces	ZXF=	All X and Z faces
	Positive Z face	XYF=	All X and Y faces	&ZX=	Positive X and Z faces	ZYF=	All Y and Z faces
	Positive Z face	XZF=	All X and Z faces	+YZ=	Positive Y and Z faces	-YX=	Negative X and Y faces
	Negative Z face	YZF=	All Y and Z faces	+ZY=	Positive Y and Z faces	-ZX=	Negative X and Z faces
	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 that is a cuboid.
Any albedo condition, but the same condition on all faces, is allowed if the global unit boundary record consists of one geometry record that is composed of paired planes.
Only void, mirror, or white boundary conditions, the same condition on all faces, if the global unit boundary record consists of only one geometry record of any shape.
Only void boundary condition is allowed if the global unit boundary record contains multiple geometry records. Default is void on all global unit boundary surfaces.

ALBEDO NAMES AVAILABLE ON THE KENO ALBEDO LIBRARY, FOR USE WITH THE FACE CODES

ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION
DPOH20	12-in. double PO water differential albedo with 4 incident angles	CONC-4	4-in. concrete differential albedo with 4 incident angles	VACUUM	Vacuum condition
DPOH20		CON4		VOID	
DPO		CONC4		VACU	
DPO				VAC	
H20	12-in. water differential albedo with 4 incident angles	CONC-8	8-in. concrete differential albedo with 4 incident angles	SPECULAR	Mirror image reflection
WATER		CON8		MIRROR	
PARAFFIN	12-in. paraffin differential albedo with 4 incident angles	CONC8		MIRR	
PARA				SPEC	
WAX		CONC-12	12-in. concrete differential albedo with 4 incident angles	SPE	
		CON12		MIR	
CARBON	200-cm carbon differential albedo with 4 incident angles	CONC12		PERIODIC	Periodic boundary condition
GRAPHITE		CONC-16	16-in. concrete differential albedo with 4 incident angles	PERI	
C		CON16		PER	
ETHYLENE	12-in. polyethylene differential albedo with 4 incident angles	CONC16		WHITE	White boundary Condition
POLY		CONC-24	24-in. concrete differential albedo with 4 incident angles		
CH2		CON24			
		CONC24			

Table C6.4.5 (continued)

Summary of geometry data

GEOMETRY (region)

Format: READ GEOM enter geometry region data here END GEOM
See Sects. F17.4.4, F17.5.1.2, F17.5.6, and F17.5.7.
GEOMETRY REGION DATA consists of SIMPLE GEOMETRY REGION DATA and MODIFICATION GEOMETRY REGION DATA.
ENTER GEOMETRY REGION DATA IN THE FOLLOWING FORM:
OPTIONAL GLOBAL SPECIFICATION
UNIT n
OPTIONAL GEOMETRY COMMENT
GEOMETRY, MODIFICATION, MEDIA, and BOUNDARY DATA
* *
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 a 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	IPUT PARAMETERS	NOTES
GEOMETRY	CONE	Lbl Rt Zt Rb Zb	Lbl is an integer assigned to a geometry record, unique within the unit, that relates the geometry record to the media region in the Region Definition Vector i1 i2 ...
	CUBOID	Lbl +X -X +Y -Y +Z -Z	
	CYLINDER	Lbl R Zt Zb	
	DODECAHEDRON	Lbl R	
	ECYLINDER	Lbl Rx Ry Zt Zb	
	ELLIPSOID	Lbl Rx Ry Rz	
	HEXPRISM	Lbl R Zt Zb	
	HOPPER	Lbl Lxt Lyt Zt Lxb Lyb Zb	
	PARALLELPIPED	Lbl XDIST YDIST ZDIST PHI THETA PHI	
	PLANE*	XPL=a YPL=b ZPL=c CON=d	Data is entered after the = following the respective subordinate keyword. Only non-zero data is required.
	QUADRATIC*	Lbl AQU=a BQU=b CQU=c DQU=d EQU=e FQU=f GQU=g HQU=h IQU-i JQU=j	Data is entered after the = following the respective subordinate keyword. Only non-zero data is required.
	RHOMBOID	Lbl DX PSI	
	SPHERE	Lbl R	
	WEDGE	Lbl XBASE XPT YPT ZLNG	
MODIFICATION*	CHORD	+X= -X= +Y= -Y= +Z= -Z=	Only non-zero data is required.
	ORIGIN	X= Y= Z=	Only non-zero data is required.
	ROTATE	A1= A2= A3=	The body is rotated about the Origin using the Euler angle x-convention. Only non-zero data is required.
MEDIA**	MEDIA	Mid Bid i1 i2 ...	The region boundary containing the hole must exactly match the boundary of the unit being placed in the hole.
	HOLE	Hid i1 i2 ...	
	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 unit boundary.

*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 C6.4.5 (continued)

Summary of mixing table data

MIXTURES

Format: READ MIXT xsec parameters END MIXT

Note: In CSAS6, only xsec parameters should be entered.
KENO-VI mixing table data consists of "xsec parameters" and a "mixing table." The "mixing table" is used to define the materials used in the KENO-VI problem. This data is automatically created by CSAS6 and provided to KENO-VI. It cannot be overridden.

See 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=	2	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. K6-60

Table C6.4.5 (continued)
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
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.)
PIC=	MAT	Type of picture: MIXTURE, UNIT NO. or BIAS ID NO.
		MIXTURE ---------- MAT
		MIX
		MIXT
		MIXTURE
		MEDI
		MEDIA
		UNIT NO. ---------- BOX
		BOXT
		BOXTYPE
		UNT
		UNIT
		UNITTYPE
		BIAS ID NO. ------- IMP
		BIAS
		BIASID
		WTS
		WEIG
		WEIGHTS
		WGT
		WGTS
XUL=	Prev. plot	X coord. of upper left corner of 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
YLR=	Prev. plot	Y coord. of lower right corner of plot
ZLR=	Prev. plot	Z coord. of lower right corner of plot

KEYWORD	DEFAULT	DEFINITION
UAX=	Prev. plot 0 IF VAX OR WAX is read	X component of direction cosine for the AX axis of the plot (across)
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
SCR=	NO	No specifies a printer plot. If YES, a .gif file is generated for each plot.
CLR=		Used only with SCR=YES to change colors. Input 4 integers: 1st is index into color table. next 3 are the red, green, and blue color values.

PLOT ORIGIN:
(1) SINGLE UNIT - coincides with origin of geometry description.
(2) BASE ARRAY - at the most negative point of the array (lower left-hand back corner of the global array).
(3) REFLECTED ARRAY - coincides with the origin of the CORE or ARRAY description of the global array.

*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 C6.4.5 (continued)

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
0	None	NST	Uniform
		XSM	
		XSP	
		YSM	
		YSP	
		ZSM	
		ZSP	
		RFL	
		PSP	
1	NST	XSM	Cosine
		XSP	
		YSM	
		YSPO	
		ZSM	
		ZSP	
		RFL	
		PSP	
2	NST	XSM	Cosine with fraction in specified unit
	NXS	XSP	
	NYS	YSM	
	NZS	YSP	
	FCT	ZSM	
		ZSP	
		RFL	
		PSP	
3	NST	KFS	Spike
	TFX	PSP	
	TFY		
	TFZ		
	NXS		
	NYS		
	NZS		
4	NST	KFS	Multiple spikes
	TFX	PSP	
	TFY		
	TFZ		
	NBX		
5	NST	PSP	In specified units
	NBX		
6	NST	NXS	Arbitrary points
	TFX	NYS	
	TFY	NZS	
	TFZ	KFS	
	LNU[a]	PS6	
		PSP	

KEYWORD	DEFAULT	DEFINITION
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=		Fission spectra
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

[a]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.
Unless otherwise specified, the starting volume is defined by the first positive geometry label in the global unit boundary region definition vector.

C6.4.2 INPUT DATA REQUIREMENTS AND DATA CHECKING

Table C6.4.7 summarizes the input data required by Criticality Safety Analysis Sequence No. 6. The types of data needed are:

Table C6.4.7 Summary of data input requirements

	Type of Data	Analytical Sequence	
1	Analytical Sequence Specification	=CSAS26	=CSAS26x
2	Material Information Processor Data	Yes	Yes
3	KENO-VI Data	Yes	Yes
5	Search Data	No	No
	END for the Analytical Sequence	Yes	Yes

1. Analytical sequence specification. Enter the desired sequence name, starting in column 1. The available options are =CSAS26, =CSAS26X. Enter PARM=CHK in column 11 to check the data.

2. Material Information Processor data. These data are required for processing the cross sections for use in the problem. These data are described in detail in Sects. M7.4 and C6.4.3 through C6.4.8.

3. KENO-VI data. These data are described briefly in Sect. C6.4.9. A detailed description is found in Sect. F17.4 with additional information in Sect. F17.5.

4. Search data. There is currently no search options available using KENO-VI.

5. END for analytical sequence—Enter END, starting in column 1.

To check the input data, specify the desired analytical sequence and specify PARM=CHECK or PARM=CHK starting beyond column 10. For example, to check CSAS26 data, the analytical sequence specification would be:

```
=CSAS26     PARM=CHECK
```

Note that =CSAS26 starts in column 1 and PARM=CHECK starts in or after column 11. This causes the input data to be checked, the problem description to be printed, appropriate warning and error messages to be printed, and if specified, the KENO-VI data and printer plots are printed.

This feature allows checking the input data without executing any of the functional modules. Simply remove the PARM=CHECK to actually execute the problems.

C6.4.3 MATERIAL INFORMATION PROCESSOR DATA

The Material Information Processor reads the standard compositions specification data and the unit cell geometry specifications. It then produces the mixing table and unit cell information necessary for processing the cross sections. Table C6.4.8 outlines the input data for the Material Information Processor.

The Material Information Processor allows terse data input for all data except the standard composition names and the keyword entries in the optional parameter data (MORE DATA). Terse data entry requires the user to enter only as many characters as are necessary to uniquely define the data entry. However, as many characters as are specified by the user must match the name allowed by the code. For example, refer to Table C6.4.8, **Outline of Material Information Processor data**, data position 3. The available choices for the type of calculation are INFHOMMEDIUM, LATTICECELL, and MULTIREGION. Therefore, it would be sufficient to specify I for an infinite homogeneous medium, L for lattice cell, and M for multiregion. If it is desirable to use more characters, the user is free to do so. However, as many characters as are entered must match the name allowed by the code. For example, if INFHOMMEDIUM is to be specified, INFH is correct, but INFI is not.

WARNING: If several choices begin with the same letters, sufficient characters should be entered to uniquely define the name. For example, ASPHSQUAREP and ASPHTRIANGP are identical through the first four characters. If only ASPH is entered, the code will accept the first name whose first four characters are ASPH. This may not be the one the user intended to use.

The types of data required for the Material Information Processor are given in Table C6.4.8. The individual entries are explained in detail in the text following the table.

1. Title. An 80-character title is required. The title is the first 80 characters of the Material Information Processor data.

2. Cross-Section Library Name. This item specifies the cross-section library that is to be used in the calculation. See Section C6.4, Table C6.4.8, or Section M8, Table M8.2.2, for a list of the available libraries.

3. Type of Calculation. The options are INFHOMMEDIUM, LATTICECELL, and MULTIREGION.

   INFHOMMEDIUM is used for an infinite homogeneous medium. It provides cross sections to represent large homogeneous pieces. The cross sections are treated as if each mixture is infinite. Thus, the self-shielding calculations will not account for any geometrical effects. By default, the smallest mixture number will be used in the cell. A different mixture can be used as described in Section C6.4.5 and Table C6.4.10.

Table C6.4.8 Outline of Material Information Processor data

Data position	Type of data	Data entry	Comments
1	Title	Enter a title	80 characters
2	Cross-Section Library Name	HANSEN-ROACH 27GROUPNDF4 44GROUPNDF5 238GROUPNDF5 27BURNUPLIB etc.	The currently available libraries are listed in Tables C6.4.4 and C6.4.8.
3	Type of Calculation	INFHOMMEDIUM LATTICECELL MULTIREGION	These are the available options. See the explanation in Sect. C6.4.3
4	Standard Composition Specification Data	Enter the appropriate data	Terminate this data block with END COMP. See Sect. C6.4.4
5	Unit Cell Geometry Specification	Enter the appropriate data (optional for INFHOMMEDIUM)	Optional for INFHOMMEDIUM See Sect. C6.4.5 for INFHOMMEDIUM See Sect. C6.4.6 for LATTICECELL See Sect. C6.4.7 for MULTIREGION
6	Optional Parameter Data	Enter the desired data	Precede this data block by MORE DATA if more parameter data are to be entered. Otherwise, omit these data entirely. See Sect. C6.4.8

LATTICECELL is used when the geometry can be described as a lattice. It is especially suited for arrays of cylindrical rods or spherical pellets. The use of LATTICECELL requires the entry of additional geometry information (unit cell specification), which is described in Section C6.4.6 and Table C6.4.11. When the problem consists of an array of fuel bundles or similar geometry, the cross sections are corrected for resonance self-shielding, including geometry effects. If cell-weighted cross sections are desired, CSAS26X must be used. A flux disadvantage factor is then applied to the cross sections of the materials that are used in the unit cell. The KENO-VI geometry description may represent a fuel bundle discretely or as a homogeneous region. By using CSAS26X a fuel bundle can be represented as a single homogeneous region by specifying a mixture number of 500 on the KENO-VI geometry card that defines the overall size and shape of the bundle. This utilizes the cell-weighted cross sections that represent the spatial behavior of the unit cell. The use of CSAS26X precludes using individual mixtures from the unit cell in the KENO-VI geometry.

MULTIREGION may be used to define a geometric configuration that is more complicated than that allowed by LATTICECELL. It can also be used for a system involving large geometric regions where geometry effects may be minimal. The cross sections utilized in the unit cell are corrected for resonance

self-shielding, and an appropriate Dancoff factor is applied (see Sect. M7.2.4.3). If a cell-weighted mixture is generated, it is derived from homogenizing the entire MULTIREGION unit cell. The additional geometry information (unit cell specification) required for a MULTIREGION problem is described in Section C6.4.7 and Table C6.4.12.

4. Standard Compositions. These data are used to define the mixtures that will be used in the problem. See Section C6.4.4, and Table C6.4.9, for a description of the standard compositions specification data. These data are required for every problem.

5. Cell Geometry Specification. See Section C6.4.5 and Table C6.4.10 for an explanation of the optional unit cell data associated with an INFHOMMEDIUM problem. See Section C6.4.6 and Table C6.4.11 for an explanation of the data associated with LATTICECELL problems. Section C6.4.7 and Table C6.4.12 explain the data required for a MULTIREGION problem.

6. Optional Parameter Data. This option allows certain defaulted parameters to be respecified by the user. Omit these data unless they are needed. If data are to be entered, see Section C6.4.8 and Table C6.4.13 for assistance.

C6.4.4 STANDARD COMPOSITIONS SPECIFICATION DATA

The standard compositions specification data are used to define mixtures that are to be utilized in the problem. These data can be considered to be a mixing table that defines mixtures in terms of standard compositions specification data (available from Section M8.2, Table M8.2.1). The required input for the standard compositions specification data varies, depending on the standard composition component name. However, every standard composition specification must include the following:

1. a standard composition component name (SC),

2. the mixture that contains this component (MX),

3. a terminator for the standard compositions specification data (enter the word END).

Enter as many standard composition specifications as necessary to define all the mixtures needed for the problem. When all the necessary mixtures have been described, enter the words END COMP to signal the completion of this type of data.

The data required to define a standard composition specification are contained in Table C6.4.9. In the column entitled "Entry requirement," "ARBM" is used to denote entries required only for arbitrary materials, and "SOLN" is used for entries required only for solutions.

The input data for standard composition specifications are arranged with entry numbers 1 through 7 that apply to all standard composition data. Entries A1 through A7 apply only to arbitrary materials. Entries S1 and S2 apply only to solutions. Entry O1 is optional data that applies to both basic standard compositions and solutions. The individual entries specified in Table C6.4.9 are explained in detail in the text accompanying the table.

Table C6.4.9 Outline of standard composition specification data

Entry number	Variable name	Type of data	Entry requirement	Comments
1	SC	Standard composition component name	Always	Enter once for each standard composition. Enter the alphanumeric description from Table M8.2.1. Additional allowed names include those beginning with **ARBM** for arbitrary materials and **SOLN** for solutions
A1	ROTH	Theoretical density of material (g/cc)	ARBM	Enter once for each standard composition component that is an arbitrary material
A2	NEL	Number of elements in the material	ARBM	Enter once for each standard composition component that is an arbitrary material
A3	IVIS	No longer used but must still be entered.	ARBM	Enter once for each standard composition component that is an arbitrary material. Enter 0 or 1.
A4	ICP	Compound indicator	ARBM	Enter once for each standard composition component that is an arbitrary material. Enter 1 for a compound, 0 for alloys, mixtures, etc.
A5	IRS	No longer used but must still be entered.	ARBM	Enter once for each standard composition component that is an arbitrary material. Enter 0 or 1.
A6	NCZA	ID number (from far right column of Table M8.2.1)	ARBM	Repeat the sequence A6 and A7 for each element in the arbitrary material before entering entry 2. Enter the number from the far right column of Table M8.2.1. (Premixed standard compositions cannot be used in an arbitrary material definition)
A7	ATPM	Number of atoms of this element per molecule of arbitrary material	ARBM and ICP=1	Repeat the sequence A6 and A7 for each element in the arbitrary material before entering entry 2. Do not enter a value unless ICP=1
		or	or	or
		weight percent of this element in this arbitrary material	ARBM and ICP=0	Repeat the sequence A6 and A7 for each element in the arbitrary material before entering entry 2. Do not enter a value unless ICP=0

Table C6.4.9 (continued)

Entry number	Variable name	Type of data	Entry requirement	Comments
2	MX	Mixture ID number	Always	Enter once for each standard composition component
S1	FD	Fuel density (grams of U or Pu per liter of solution)	SOLN	Enter once for a solution
S2	AML	Acid molarity of the solution	SOLN	Enter once for a solution. AML=0 if there is no acid in the solution
O1	SPGR	Specific gravity of the solution	Optional	If the specific gravity (SPGR) of the solution is known, it should be entered as SPG=SPGR
	or ROTH	or density of the basic standard composition		or if the density of a basic standard composition (ROTH) is to be entered, use DEN=ROTH
3	VF	Density multiplier	See comment column	Enter the density multiplier (density fraction, volume fraction, or a combination). Default value is 1. This item can be omitted if entries 4, 5, 6a, and 6b are also omitted. VF=0 is not allowed for SOLN or ARBM
4	ADEN	Number density (atoms/ b-cm) for the nuclide	VF=0	Enter only if VF=0.0
5	TEMP	Temperature, in K	See comment column	Default value is 293 K. This entry can be omitted if entries 6a and 6b are also omitted
6a	IZA	Isotope's ZA number	VF≠0	Enter for each isotope in the standard composition component. Omit if VF=0. Entries 6a and 6b are entered in pairs until each isotope in the component is defined
6b	WTP	Weight percent of the isotope	VF≠0	Enter for each isotope in the standard composition component. Omit if VF=0. Entries 6a and 6b are entered in pairs until each isotope in the component is defined
7[a]	END	Terminate a standard composition	Always	Enter once for each standard composition component. This terminates the data for a standard composition component. Enter END to terminate the component. Repeat entries 1 through 7 until all the mixtures have been defined. At least two blanks must separate entry 7 from the next entry
	END COMP	Terminate the data block	Terminus	Enter once for a problem. Enter the words END COMP when all the standard composition components have been described. At least two blanks must follow the END COM

[a]NOTE: Entry 7 should not begin in column 1 unless a name is associated with it. At least two blanks should separate the last entry 7 from the END COMP.

1. SC Standard Composition Component Name. The names of the standard composition components (the alphanumeric identifiers) may be (1) chosen from Table M8.2.1 of Section M8.2, which contains the list of elements, compounds, and alloys found in the Standard Composition Library, (2) they may be chosen from the table of available solutions, Section M8.3, or (3) they may be designated as an arbitrary material (ARBM). An error message will be printed if the user enters an invalid standard composition component name.

For standard compositions taken from Table M8.2.1 of the Standard Composition Library (basic standard compositions), certain data such as the volume fraction or theoretical density and other engineering type data may need to be entered. For standard compositions containing more than one isotope of an element (such as UO_2), the user is free to specify the weight percent for each isotope such that they total 100%. See Section M7.5.5.1 for examples of basic standard compositions.

Solutions require the specification of the density of the heavy metal in the solution and the acid molarity of the solution. The alphanumeric specification of a solution starts with the four characters "SOLN." Some common fissile solutions are SOLNUO2(NO3)2, SOLNPU(NO3)4, and SOLNUO2F2. See Section M8.3 for a complete listing of the available solutions. Sections M7.5.5.3 and M7.5.9 contain examples of the input data for solutions.

Arbitrary materials require the user to provide all the information normally found in the Standard Composition Library. The arbitrary material option allows specifying a compound or alloy not available in the Standard Composition Library by utilizing the standard compositions available in the library. Table M8.2.1 indicates which nuclides require a resonance self-shielding calculation.

An arbitrary material name must start with the four characters "ARBM." A maximum of twelve characters is allowed for the standard composition component name. Imbedded blanks are not allowed in a standard composition component name. Section M7.5.5.2 contains examples of input data for arbitrary materials.

An additional example of an arbitrary material specification is as follows:

Consider a mixture of boral having 35 wt % B_4C, 65 wt % aluminum and an overall density of 2.64 g/cc. If neither BORAL nor B4C were available in the Standard Composition Library, the components BORON, C, and AL could be used as basic standard compositions to describe the boral. The necessary volume fractions would have to be determined as shown in Section M7.5.5.4, examples 3 and 4. By utilizing the arbitrary material option, both B_4C and aluminum can be described as a component of the same mixture (assume it is desired to be mixture 3), both have a density of 2.64 g/cc, and the volume fractions are 0.35 for the B_4C and 0.65 for the aluminum. The resulting standard compositions specification data do not require any calculations (see example 1, Section M7.5.5.5 for a similar situation) and could be entered as

```
ARBMTL-B4C  2.64 2 1 1 0 5000 4 6012 1 3 0.35 END
ARBMTL-AL   2.64 1 0 0 0 13027 100.0 3 0.65 END
```

A1. ROTH Theoretical density of material. Enter ONLY for arbitrary materials. The density of the arbitrary material is entered in units of grams per cubic centimeter.
NOTE: ROTH can be entered for a basic standard composition as shown by entry O1.

A2. NEL Number of elements in the material. Enter ONLY for arbitrary materials. Enter the number of components from the Standard Composition Library that are to be used to define this arbitrary material. In the above example, the ARBMTL-B4C contains two components, the B and the C. Therefore, NEL is 2 for the B_4C arbitrary material. The ARBMTL-AL contains only one component; so NEL is 1 for it.

A3. IVIS Unused Variable. Enter ONLY for an arbitrary material. Enter 0 or 1.

A4. ICP Compound indicator. Enter ONLY for arbitrary materials. A compound is a substance containing more than one constituent element and having properties different from those which their constituents had as elementary substances. The composition of a pure compound is perfectly definite and is always the same, regardless of the method of formation. Examples of compounds are H_2O, B_4C, CO_2, $Ca(OH)_2$, C_2H_6, Fe_2S_3, Cr_2O_3, etc. ICP is 1 for a compound. ICP is 0 for alloys (stainless steel, monel, etc.) and conglomerates or mixtures such as concrete.

In the B_4C arbitrary material example, ICP is 1; in the aluminum arbitrary material example, ICP is 0. These examples are given in the explanation of entry number 1, SC.

A5. IRS Unused Variable. Enter ONLY for arbitrary materials. Enter 0 or 1.

A6. NCZA ID number. Enter ONLY for arbitrary materials. This is the "ZA" ID number for the element or isotope. Usually, NCZA=A+1000*Z, where A is the atomic mass or weight of the nuclide, and Z is the atomic number. For example, NCZA is 1001 for hydrogen, 8016 for oxygen, and 92235 for ^{235}U. For elements for which the natural abundance is acceptable, NCZA can be entered as 1000*Z. For example, 92000 is used for uranium and 5000 is used for boron.

Arbitrary materials may now contain more than one element that has multiple isotopes. Multiple isotope elements need not be the first element specified in the arbitrary material. The multiple isotope element MUST be listed in the Isotope Distribution Table, Table M8.4.1. Uranium (92000), plutonium (94000), and boron (5000) are multiple isotope elements.

For example:
ARBMTL-B4C 2.64 2 1 1 0 5000 4 6012 1 3 0.35 END is correct;
ARBMTL-B4C 2.64 2 1 1 0 6012 1 5000 4 3 0.35 END is also correct even though the multiple isotope element is not listed first.

REPEAT THE SEQUENCE NCZA and ATPM (A6 and A7) FOR EVERY ELEMENT IN THE ARBITRARY MATERIAL.

A7. ATPM Enter ONLY for arbitrary materials. Repeat the sequence A6 and A7 for every element in the arbitrary material before going on to entry 2.

If ICP is 1 (entry A4), enter the NUMBER OF ATOMS PER MOLECULE.
If the arbitrary material is a compound (entry A4, ICP is 1), enter the number of atoms of this element per molecule of arbitrary material.

If ICP is 0 (entry A4), enter the WEIGHT PERCENT OF THIS ELEMENT IN THE ARBITRARY MATERIAL. If the arbitrary material is a mixture, alloy, or conglomerate rather than a compound (entry A4, ICP is 0), enter the weight percent of this element in the arbitrary material. If ICP is 0, the sum of all the weight percents for the arbitrary material MUST be 100.0.

2. MX Mixture ID number. A mixture number is required on every standard composition specification. It defines the mixture that contains the material defined by the standard composition specifications data. The mixture numbers are utilized in the unit cell specification for INFHOMMEDIUM, LATTICECELL, or MULTIREGION problems and the KENO-VI geometry data.

S1. FD Fuel density. Enter ONLY for a solution. The standard composition component name for a solution starts with the four characters "SOLN." The available solution names are listed in Section M8.3. Enter the fuel density in units of grams of heavy metal (fissile material) per liter of solution.

S2. AML Acid molarity. Enter ONLY for a solution. If there is no acid in the solution, enter zero. If acid is present in the solution, enter the molarity of the solution.

O1. SPGR or ROTH Optional data. Does NOT apply to ARBITRARY MATERIALS. These optional data can be entered for a solution or for a basic standard composition using a keyword in the form SPG=SPGR, DEN=SPGR, DEN=ROTH, or SPG=ROTH. The keywords SPG= and DEN= are interchangeable. SPGR is the specific gravity of the fuel solution. If the standard composition name begins with SOLN and if the specific gravity of the solution is known, it should be entered. Otherwise the code has to interpolate in a table to obtain a specific gravity to use in the calculation. ROTH is the specified density of the standard composition in grams per cubic centimeter and can be entered if desired. The interaction between ROTH, the density of the standard composition, and VF (entry 3) is demonstrated in Section M7.5.5.

3. VF Volume fraction. The default value of the volume fraction is 1.0. It can be omitted if items 4, 5, 6a, and 6b are also omitted. The volume fraction can be interpreted as:

a. the volume fraction of this standard composition component in the mixture,

b. the density of the standard composition component in this application divided by the theoretical density listed in the Standard Composition Library (Section M8.2, Table M8.2.1), or a product of (a) and (b).

Section M7.5.5 discusses the interaction between ROTH and VF. For example, assume a homogenized mixture representing the water moderator and zircalloy cladding around a fuel pin is to be described. If the volume of the clad is 5.32 cc and if the volume of the water moderator is 44.68 cc, the mixture can be described using H_2O with a volume fraction of 0.8936 [i.e., 44.68/(44.68+5.32)] and ZIRCALLOY with a volume fraction of 0.1064 [i.e., 5.32/(44.68+5.32)].

For UO_2 fuel at 95% theoretical density, the volume fraction is 0.95. For the coolant water in an operating pressurized water reactor, the volume fraction might typically be 0.71.

To describe a mixed-oxide fuel pin with a density of 10.5 g/cc, that is 17.8 wt % PuO_2 and 82.2 wt % UO_2, two standard composition specifications must be entered: one for the PuO_2 component and one for the UO_2 component. From the Standard Composition Library, Table M8.2.1, the theoretical density of the PuO_2 is 11.46 g/cc, and that of the UO_2 is 10.96 g/cc. Therefore, the volume fraction for the PuO_2 is 0.1631 (i.e., 0.178*10.50/11.46), and the volume fraction for the UO_2 is 0.7875 (i.e., 0.822*10.50/10.96).

Occasionally, a special mixture will be desired for which the determination of the component volume fractions will not be so straightforward. Consider a mixture of boral having 35 wt % B_4C, 65 wt % aluminum, and an overall density of 2.64 g/cc. Assume that neither boral nor B_4C are in the Standard Composition Library. The volume fractions corresponding to boron, carbon, and aluminum may be computed as illustrated in Section M7.5.5.4, examples 3 and 4. Note that the calculation is complicated by the fact that B_4C is a compound and boron has two isotopes. It might be simpler to enter B_4C and aluminum as arbitrary materials as illustrated in example 1 of Section M7.5.5.5. Examples 1 and 2 of Section M7.5.5.4 illustrate the use of B_4C and aluminum to describe a boral mixture. **If the volume fraction is set to 0.0, the user can enter the number density for the nuclide (in atoms per barn-cm) for item 4. Number densities cannot be entered for standard compositions that represent multiple nuclides.**

4. ADEN Number density. Enter a value for the number density ONLY if the volume fraction (VF, entry 3) was entered as zero. The number density is entered in units of atoms per barn-cm.

5. TEMP Temperature. The default value of the temperature is 293 K. The temperature can be omitted if items 6a and 6b are also omitted.

   The temperature is used for Doppler broadening and/or the selection of the proper set of thermal scattering data.

   The resonance self-shielding calculation performed by NITAWL-II uses the Nordheim integral method and can account for Doppler broadening of the resonances at any specified temperature. If this material is known to contain a resonance nuclide, the user should enter a rough estimate of the temperature of the material. To determine whether resonance data are available for any of the nuclides in a material,

a. check Table M8.2.1 if entry number 1 is not a solution, SOLN;

b. check Table M8.3.1 if entry number 1 denotes a solution, SOLN.

For each of the light nuclides (A ≤ 20 a.m.u.), the master cross-section library may contain one or more sets of thermal scattering data, each set corresponding to a different temperature. Scattering matrices for nuclides in media at elevated temperatures are generally fuller than those at lower temperatures. Tables M8.2.1 and M8.3.1 indicate the isotopes, elements, compounds, solutions, and alloys for which multiple sets of thermal scattering data are currently available. If multiple sets of thermal scattering data are available, the user should enter a rough estimate of the temperature of the material. The code will then interpolate between the appropriate data to produce a set of cross-section data that is most appropriate.

6a. IZA Isotope ZA number. Enter a value for each isotope in the standard composition component, item 1. Do not enter a value if the volume fraction, VF, is zero (entry 3).

The ZA number of the isotope is entered if the user wishes to specify the isotopic distribution. This is done by entering 6a and 6b for each isotope until all the desired isotopes have been described. The "ZA" ID number is (A+1000*Z), where A is the atomic mass or weight of the isotope, and Z is the atomic number.

Entries 6a and 6b can be skipped if the default values listed in the Isotope Distribution Table, Table M8.4.1, are acceptable.

6b. WTP Weight percent of the isotope. Do not enter a value if the volume fraction, VF, item 3 is zero. If entry 6a is entered, a value must also be entered for 6b. The weight percent of the isotope is the percent of this isotope in the element.

The user need not enter entries 6a and 6b for each isotope listed for the element in Table M8.4.1. The only requirement is that the sum of entries 6b for the element must sum to 100.0. Thus, uranium could be specified as 92235 3.2 92238 96.8 to represent 3.2% enriched uranium and ignore the 234 and 236 isotopes. However, 92235 3.0 and 92238 96.8 would not be correct because the 3.0 and 96.8 do not sum to 100.0. But 92235 3.0, 92234 0.2, and 92238 96.8 would be correct.

REPEAT THE SEQUENCE 6a and 6b until all the isotopes of the element have been defined as desired.

7. END The word END is entered to terminate the input data for a standard composition component. This END can have a label associated with it that can be as long as 12 characters. The label is optional and, if entered, is separated from the END by a single blank. At least two blanks must separate item 7 from the next data entry.

END COMP The words END COMP are entered only once for a problem. Their purpose is to signal the end of all the standard composition specification data that will be used in the problem. At least two blanks should separate entry 7 from the END COMP. Note that COMP is a label associated

with this END. This label can be as long as 12 characters, but the first four characters must be COMP.

C6.4.5 OPTIONAL UNIT CELL SPECIFICATION FOR INFINITE HOMOGENEOUS PROBLEMS

This section describes the unit cell data that can be entered for an INFHOMMEDIUM problem (data position 3 of Table C6.4.8). By default, the smallest mixture number is the mixture that will be used for the cell in XSDRNPM. In order to calculate the eigenvalue of the system, the mixture should contain fissionable material. Unit cell data are required for an infinite homogeneous medium problem ONLY if XSDRNPM is utilized by the control sequence and a mixture number other than the smallest mixture number is to be used in the cell. Additional information is available in Section M7.5.12 (see also Sections M7.5.4.1 and M7.5.6.1).

The data required to specify the unit cell for an INFHOMMEDIUM problem are given in Table C6.4.10. The individual entries are explained in the text following the table.

Table C6.4.10 Optional unit cell specification for INFHOMMEDIUM problems

Entry number	Variable name	Type of data	Data entry	Comments
1	NAME	Keyword	CELLMIX	Initiates reading cell data for INFHOMMEDIUM
2	MFUEL	Mixture number in the cell	Mixture number	Specifies the mixture number to be used in the cell. Defaults to the smallest mixture number entered in the standard composition data

NOTE: Unit cell data are necessary for INFHOMMEDIUM only if a mixture number other than the smallest mixture number is to be used in the cell and if a control sequence that executes XSDRN has been specified. If mixtures 1, 2, and 3 are specified and if mixture 3 is to be used in the cell, enter CELLMIX 3.

1. NAME Keyword. The keyword CELLMIX is entered to indicate that unit cell data will be entered. If this entry is entered, entry 2 must also be entered. These data can be entered ONLY if item 3, the "type of calculation" from Table C6.4.8, is entered as INFHOMMEDIUM.

2. MFUEL Mixture number. The mixture number that defines the mixture to be used in the cell. The default value is the smallest mixture number specified in the standard compositions specification data. If either entry 1 or 2 is entered, the other must also be entered.

To enter the above data, enter the keyword CELLMIX, one or more blanks, and the desired mixture number, MFUEL, as shown below:

CELLMIX MFUEL

To specify mixture 5 to be used in the cell, enter the following data:

CELLMIX 5

WARNING: If unit cell data are to be entered, the word CELLMIX must be spelled correctly. If it is misspelled, the code will not give an error message and will attempt to use the smallest mixture number. The input data will get out of phase for CSAS and SAS sequences that expect to read data after the unit cell specification. For example, CSAS26 expects to read KENO-VI data after the unit cell specification. If CELLMIX is misspelled, the code assumes that it is reading KENO-VI data and the data reading gets out of phase.

C6.4.6 UNIT CELL SPECIFICATION FOR LATTICECELL PROBLEMS

This section describes the unit cell data that must be entered for a LATTICECELL problem (data position 3 of Table C6.4.8). Additional information is available in Sections M7.5.4, M7.5.4.2, M7.5.6.2, and M7.5.8.2. The lattice cell description is especially suited to large arrays of identical cells. The code is limited to a single unit cell description for each problem. The unit cell data are used to provide the lump shape and dimensions for resonance cross-section processing, to provide lattice corrections for cross-section processing, and to provide data used by XSDRNPM to create cell-weighted cross sections. Thus the unit cell specification plays a major role in providing problem-dependent cross sections. The configuration of the unit cell is determined by the specified "type of lattice." The unit cells are limited to infinitely long cylindrical rods in a square or triangular lattice, spheres in a cubic or triangular lattice, a symmetric array of slabs, or an asymmetric array of slabs. Two distinct types of cells ("Regular" and "Annular") are available to be used in a lattice cell problem. "Regular" cells allow a concentric spherical, cylindrical, or symmetric slab configuration constrained to a central fuel region surrounded by an optional gap, an optional clad, and an external moderator. The outer boundary of the cell is limited to provide an array having a square or triangular pitch. "Annular" cells allow a concentric spherical, cylindrical, or asymmetric slab configuration constrained to a central (second) moderator region surrounded by a fuel region having an optional gap and optional clad on each side of the fuel. The gap, if present, is identical on both sides of the fuel. The clad, if present, is identical in dimension and composition on both sides of the fuel. The outer region of the cell is filled with an external (first) moderator. The outer boundary of the cell is limited to provide an array having a square or triangular pitch.

Regular cells are: SQUAREPITCH, TRIANGPITCH, SPHSQUAREP, SPHTRIANGP, and SYMMSLABCELL.

Annular cells are: ASQUAREPITCH, ASQP, ATRIANGPITCH, ATRP, ASPHSQUAREP, ASSP, ASPHTRIANGP, ASTP, and ASYMSLABCELL.

The unit cell data are utilized by the code to define the geometric and resonance self-shielding corrections that will be applied to the cross sections. Cell-weighted cross sections are created only if XSDRNPM is invoked by executing a control sequence ending in X, (CSAS26X.). The cell-weighted cross sections have a flux disadvantage factor applied to them. Because this weighting is applied to each mixture used in the cell, these cell-weighted mixtures should not be used in the geometry description of a subsequent code. However, the cell-weighted mixture that is created is always assigned a mixture number of 500 and can be used in a subsequent code. KENO-VI is the subsequent code in CSAS26X. Note that cell-weighted cross sections are not generated if CSAS26 is used.

The unit cell geometry data required to specify a LATTICECELL problem are given in Table C6.4.11. The individual entries are explained in the text accompanying the table.

1. CTP — Type of lattice. This defines the type of lattice or array configuration. Any one of the following alphanumeric descriptions may be used. Note that the alphanumeric description must be separated from subsequent data entries by one or more blanks. Figures C6.4.1 through C6.4.6 are used to illustrate the type of lattice configurations available in a LATTICECELL problem. The fuel region is labeled F; the gap, G; the clad, C; and the moderator, M. If two moderators are present, M1 is the first moderator, and M2 is the second moderator. Both "regular" and "annular" unit cells are available. The arrangement of the materials in the unit cell is strictly constrained. Regular cells are limited to a minimum of two regions and a maximum of four regions. The innermost regions must be fuel, which is surrounded by an optional gap and/or optional clad. The outer region is moderator.

   Annular cells are limited to a minimum of three regions. The innermost region must be the second moderator. The annular fuel region is outside the second moderator. If a clad is present, it must be identical in thickness and composition on both sides of the fuel. If a gap is present, it is the same thickness on both sides of the fuel. If the first and second moderators are the same material at the same density and temperature and do not contain resonance nuclides, the same mixture number can be used for both moderators. Otherwise, different mixture numbers must be used for the two moderators.

Regular and annular cell configurations are specified as shown below.

Regular Cells

SQUAREPITCH — is used for an array of cylinders arranged in a square lattice as shown in Fig. C6.4.1. The clad and/or gap can be omitted.

TRIANGPITCH — is used for an array of cylinders arranged in a triangular pitch lattice as shown in Fig. C6.4.2. The clad and/or gap can be omitted.

SPHSQUAREP — is used for an array of spheres arranged in a square pitch lattice. A cross-section view through a cell is represented by Fig. C6.4.1. The clad and/or gap can be omitted.

SPHTRIANGP — is used for an array of spheres arranged in a triangular pitch (dodecahedral) lattice. A cross-section view through a cell is represented by Fig. C6.4.2. The clad and/or gap can be omitted.

SYMMSLABCELL — is used for an infinite array of symmetric slab cells as shown in Fig. C6.4.3. The clad and/or gap can be omitted.

Table C6.4.11 Unit cell specification for LATTICECELL problems

Entry number	Variable name	Type of data	Entry requirement	Data entry	Comments
1	CTP	Type of lattice	Always		Describes the type of lattice or array configuration
				SQUAREPITCH	Use for cylindrical rods in a square pitch
				ASQUAREPITCH	Use for annular cylindrical rods in a square pitch
				ASQP	Use for annular cylindrical rods in a square pitch
				TRIANGPITCH	Use for cylindrical rods in a triangular pitch
				ATRIANGPITCH	Use for annular cylindrical rods in a triangular pitch
				ATRP	Use for annular cylindrical rods in a triangular pitch
				SPHSQUAREP	Use for spherical pellets in a cubic lattice
				ASPHSQUAREP	Use for annular spherical pellets in a cubic lattice
				ASSP	Use for annular spherical pellets in a cubic lattice
				SPHTRIANGP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				ASPHTRIANGP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				ASTP	Use for spherical pellets in a bi-centered or face centered hexagonal close-packed lattice
				SYMMSLABCELL	Use for a symmetric array of slabs
				ASYMSLABCEL	Use for a periodic, but asymmetric array of slabs
2	PITCH	Array pitch (cm)	Always	Appropriate dimension	The center-to-center spacing (cm) between fuel lumps For asymmetric slab cell, enter the distance from the center of one moderator to the center of the other moderator (cm)
3	FUELOD	Outside dimension of fuel (cm)	Always	Appropriate dimension	Outside diameter of fuel (cm), or the thickness of thefuel in a slab
4	MFUEL	Fuel mixture number	Always	Mixture number	Mixture number representing the fuel
5	MMOD	Moderator mixture number	Always	Mixture number	Mixture number representing the moderator
6	MMOD2	2nd moderator mixture number	ASYMSLABCELL annular cells	Mixture number	Mixture number representing the second moderator
7	TKMOD2	2nd moderator thickness	ASYMSLABCELL	Thickness	Thickness of the second moderator (cm) for ASYMSLABCELL
		or	or	or	or
		2nd moderator diameter (cm)	annular cells	diameter	diameter of inner moderator (cm) for other annular cells
8	CLADOD	Outside diameter of clad (cm)	If clad	Clad OD	OMIT IF NO CLAD. For a slab, CLADOD is the sum of thicknesses of the fuel, gap, and clad
9	MCLAD	Clad mixture number	If clad	Mixture number	OMIT IF NO CLAD. Mixture number representing the clad
10	CLADID	Inside diameter of clad (cm)	If gap	Clad ID	OMIT IF NO GAP between the fuel and clad
11	MGAP	Gap mixture number	If gap	Mixture number	OMIT IF NO GAP between the fuel and clad. A mixture number of zero is often used
12	END	Terminate LATTICECELL data	Always	END	Terminate the LATTICECELL input data by entering the word END. Do not start in column 1. At least two blanks must follow entry 12

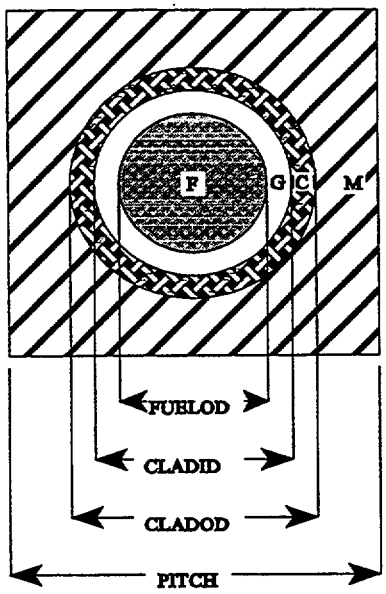


Figure C6.4.1 Arrangement of materials in a SQUAREPITCH and SPHSQUAREP unit cell

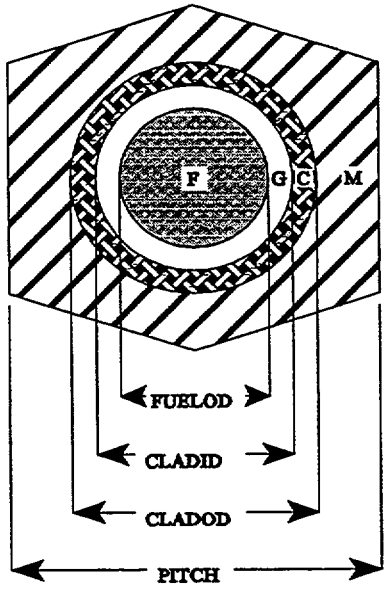


Figure C6.4.2 Arrangement of materials in a TRIANGPITCH and SPHTRIANGP unit cell

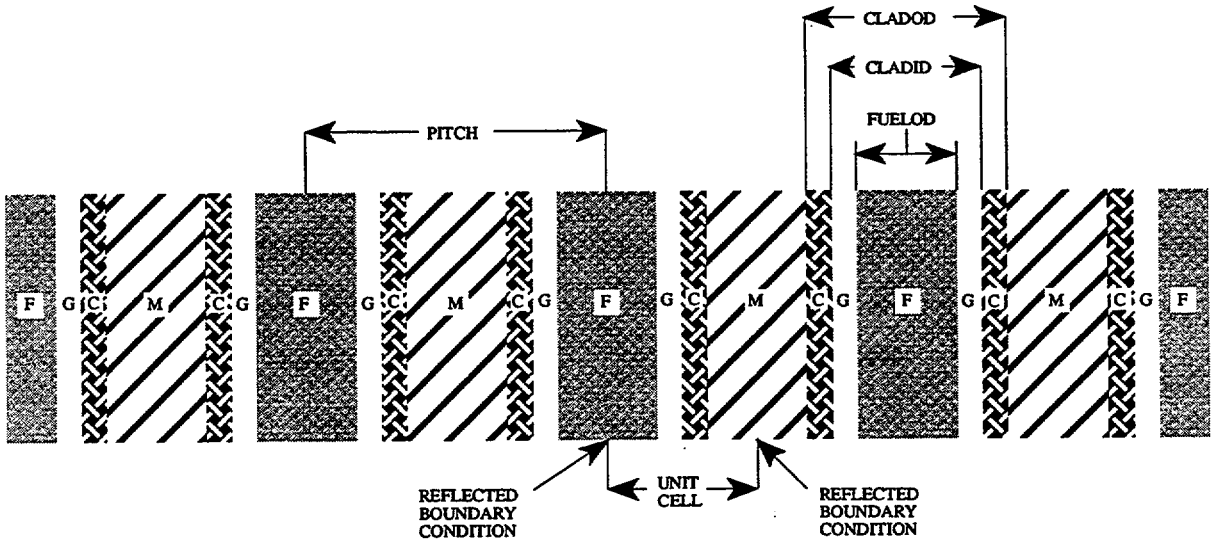


Figure C6.4.3 Arrangement of materials in a SYMMSLABCELL unit cell having reflected left and right boundary conditions

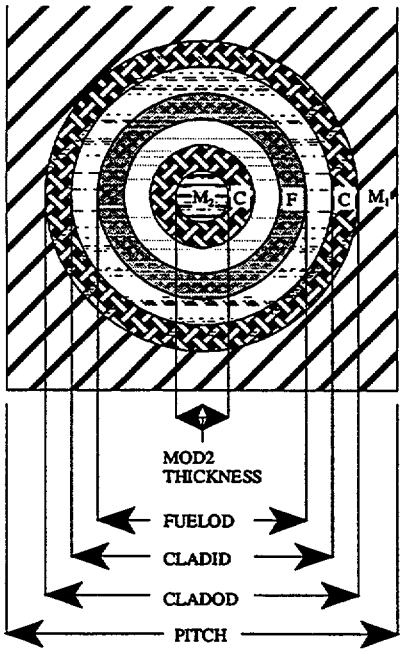


Figure C6.4.4 Arrangement of materials in an ASQUAREPITCH and ASPHSQUAREP unit cell

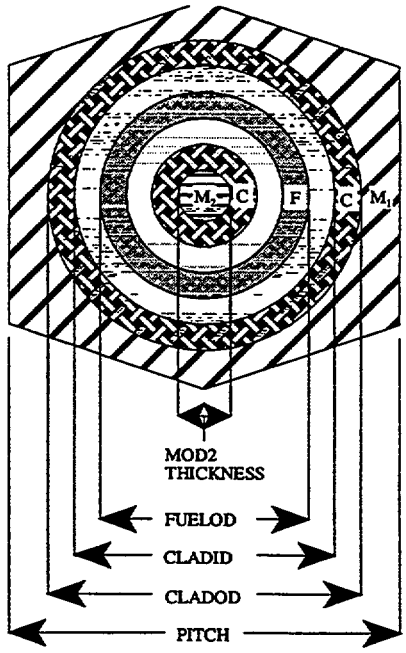


Figure C6.4.5 Arrangement of materials in an ATRIANGPITCH and ASPHTRIANGP unit cell

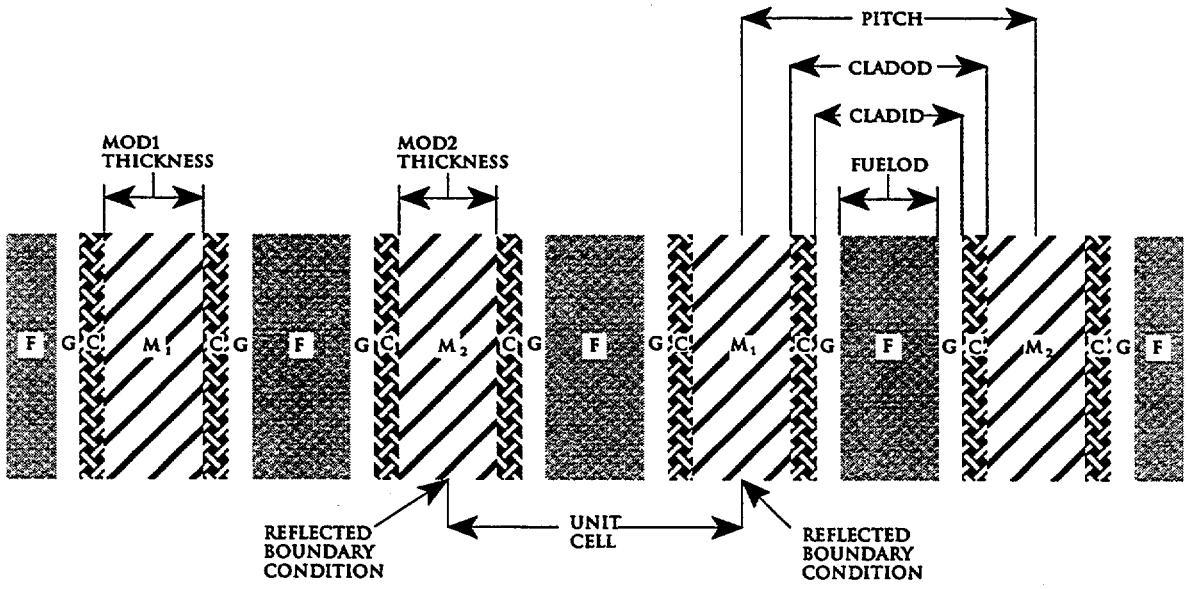


Figure C6.4.6 Arrangement of materials in an ASYMSLABCELL unit cell

Annular Cells

ASQUAREPITCH or ASQP is used for annular cylindrical rods in a square pitch lattice as shown in Fig. C6.4.4. The gap on both sides of the fuel must be identical, as must the clad. The clad and/or gap can be omitted.

ATRIANGPITCH or ATRP is used for annular cylindrical rods in a triangular pitch lattice as shown in Fig. C6.4.5. The gap on both sides of the fuel must be identical, as must the clad. The clad and/or gap can be omitted.

ASPHSQUAREP or ASSP is used for spherical shells in a square pitch lattice as shown in Fig. C6.4.4. The gap on both sides of the fuel must be identical, as must the clad. The clad and/or gap can be omitted.

ASPHTRIANGP or ASTP is used for spherical shells in a triangular pitch (dodecahedral) lattice as shown in Fig. C6.4.5. The gap on both sides of the fuel must be identical, as must the clad. The clad and/or gap can be omitted.

ASYMSLABCELL is used for a periodic, but asymmetric, array of slabs as shown in Fig. C6.4.6. The gap on both sides of the fuel must be identical, as must the clad. The clad and/or gap can be omitted.

2. PITCH Array pitch. This is the center-to-center spacing between the fuel lumps (rods, pellets, or slabs) in centimeters shown in Figs. C6.4.1 through C6.4.6. For an ASYMSLABCELL, enter the distance from the center of one moderator to the center of the other moderator. See Fig. C6.4.6.

3. FUELOD Outside dimension of fuel. This is the outside diameter of the fuel in centimeters as shown in Figs. C6.4.1 through C6.4.6. In slab geometry, enter the thickness of the fuel (see Figs. C6.4.1 through C6.4.6).

4. MFUEL Fuel mixture number. This is the mixture number representing the fuel (F in Figs. C6.4.1 through C6.4.6).

5. MMOD Moderator mixture number. This is the mixture number representing the moderator (M or M1 in Figs. C6.4.1 through C6.4.6).

6. MMOD2 Second moderator mixture number. Enter ONLY for annular cells. This is the mixture number representing the second moderator (M2 in Figs. C6.4.4 through C6.4.6).

7. TKMOD2 Second moderator thickness. Enter ONLY for annular cells. This is the thickness or diameter of the second moderator in centimeters. See Figs. C6.4.4 through C6.4.6.

8. CLADOD Outside diameter of clad. Enter ONLY if a clad is present. Enter the thickness of the clad in centimeters. For a slab, CLADOD is the sum of the fuel thickness, twice the gap thickness, and twice the clad thickness. See Figs. C6.4.1 through C6.4.6.

9. MCLAD Clad mixture number. Enter ONLY if a clad is present. Enter the mixture number that represents the clad (C in Figs. C6.4.1 through C6.4.6).

10. CLADID Inside diameter of clad. Enter ONLY if a gap is present between the fuel and the clad. Omit if there is no gap. If a gap is present, enter the inside diameter of the clad in centimeters. This corresponds to the outside diameter of the gap. In slab geometry, CLADID is the sum of the fuel thickness and twice the gap thickness. See Figs. C6.4.1 through C6.4.6.

11. MGAP Gap mixture number. Enter ONLY if a gap is present between the fuel and the clad. Omit if there is no gap. Enter the mixture number representing the gap (G in Figs. C6.4.1 through C6.4.6). Zero is often used to represent a void.

12. END The word END is entered to terminate the LATTICECELL data. An optional label can be associated with this END. The label can be as many as 12 characters long and is separated from the END by a single blank. At least two blanks must follow entry 12.

C6.4.7 UNIT CELL SPECIFICATION FOR MULTIREGION PROBLEMS

These data are entered only if the problem is defined as a MULTIREGION problem. They describe the additional geometry data that are required for a MULTIREGION problem (data position 3 of Table C6.4.8). A MULTIREGION problem can be used to define a geometric arrangement that is more complicated than is allowed by a lattice cell. It can also be used for large geometric regions where the geometry effects for the cross sections are minimal. Additional information is available in Sections M7.5.4, M7.5.4.3, M7.5.6.3, and M7.5.8.3. BE FULLY AWARE THAT CROSS SECTIONS GENERATED USING MULTIREGION IGNORE THE LATTICE GEOMETRY EFFECTS IN DOING THE RESONANCE CORRECTIONS.

The additional data required for a MULTIREGION problem are given in Table C6.4.12; individual entries are explained in the text accompanying the table.

1. CS Type of geometry. The type of geometry must always be specified for a MULTIREGION problem. The cross-section corrections do not account for lattice effects. The available geometry options are listed below.

SLAB	This is used to describe a slab geometry.
CYLINDRICAL	This is used to describe cylindrical geometry.
SPHERICAL	This is used to describe spherical geometry.
BUCKLEDSLAB	This is used for slab geometry with a buckling correction for the two transverse directions.

BUCKLEDCYL This is used for cylindrical geometry with a buckling correction in the axial direction.

2. BR Right boundary condition. This is defaulted to vacuum. A value for BR **MUST** be entered for BUCKLEDSLAB and BUCKLEDCYL but is optional for SLAB, CYLINDRICAL, or SPHERICAL. The available options and their qualifications are listed below:

   VACUUM This imposes a vacuum at the boundary of the system.

   REFLECTED This imposes mirror image reflection at the boundary. Do not use for CYLINDRICAL or SPHERICAL.

   PERIODIC This imposes periodic reflection at the boundary. Do not use for CYLINDRICAL or SPHERICAL.

   WHITE This imposes isotropic return at the boundary.

3. BL Left boundary condition. This is defaulted to reflected. A value for BL **MUST** be entered for BUCKLEDSLAB but is optional for SLAB, CYLINDRICAL, or SPHERICAL. The available options and their qualifications are listed below:

   VACUUM This imposes a vacuum at the boundary of the system.

   REFLECTED This imposes mirror image reflection at the boundary. For CYLINDRICAL or SPHERICAL, this is the only valid boundary condition because the left boundary corresponds to the centerline.

   PERIODIC This imposes periodic reflection at the boundary.

   WHITE This causes isotropic return at the boundary.

4. ORGN Location of left boundary on the origin. The default value of ORGN is 0.0. This is the only value allowed for CYLINDRICAL or SPHERICAL geometry. Enter the location of the left boundary on the axis perpendicular to the slab (in cm).

5. DY Buckling height. Enter *ONLY* for BUCKLEDSLAB or BUCKLEDCYL. This is the buckling height in centimeters. It corresponds to one of the transverse dimensions of an actual 3-D slab assembly or the length of a finite cylinder.

6. DZ Buckling depth. Enter *ONLY* for BUCKLEDSLAB. This is the buckling depth in centimeters. It corresponds to the second transverse dimension of an actual 3-D slab assembly.

Table C6.4.12 Geometry specification for MULTIREGION problems

Entry number	Variable name	Type of data	Entry requirement	Data entry	Comments
1	CS	Type of geometry	Always		Describes the type of geometry. The options are listed below
				SLAB	Use for slab geometry
				CYLINDRICAL	Use for cylindrical geometry
				SPHERICAL	Use for spherical geometry
				BUCKLEDSLAB	Use for slab geometry with a buckling correction for the two transverse directions
				BUCKLEDCYL	Use for cylindrical geometry with a buckling correction in the axial direction
2	BR	Right boundary condition	Required for BUCKLEDSLAB and BUCKLEDCYL; optional for other geometries		Default is VACUUM. Describes the right/outside boundary condition
				VACUUM	This provides a non-return condition at the boundary
				REFLECTED	Do not use for cylindrical or spherical
				PERIODIC	Do not use for cylindrical or spherical
				WHITE	This provides isotopic return at the boundary
3	BL	Left boundary condition	Required for BUCKLEDSLAB and BUCKLEDCYL; optional for other geometries		Default is REFLECTED. Describes the left boundary condition
				VACUUM	This provides a non-return condition at the boundary
				REFLECTED	Recommended for cylindrical or spherical
				PERIODIC	Do not use for cylindrical or spherical
				WHITE	This provides isotropic return at the boundary
4	ORGN	Location of left boundary on the x-axis (cm)	BUCKLEDSLAB and BUCKLEDCYL; optional for other geometries	Appropriate dimension	Default is 0.0. Should not be changed for cylindrical or spherical geometry. A value must be entered if subsequent data are to be entered
5	DY	Buckling height (cm)	BUCKLEDSLAB and BUCKLEDCYL	Appropriate dimension	Omit for SLAB, CYLINDRICAL, and SPHERICAL. This corresponds to one of the transverse dimensions of an actual 3-D slab assembly or to the length of a finite cylinder
6	DZ	Buckling depth (cm)	BUCKLEDSLAB	BUCKLEDSLAB	Omit unless BUCKLEDSLAB was specified. This is the buckling depth corresponding to the second transverse dimension of a 3-D slab assembly
7	END	End geometry parameters	Always	Appropriate dimension	Enter the word END. Do not start in column 1
8	MXZ	Mixture number in the zone	Always	END	Repeat entry numbers 8-10 until all zones are defined. Enter the mixture number for this zone
9	RZ	Outside radius of the zone (cm)	Always	Mixture number	Repeat entry numbers 8-10 until all zones are defined. Enter the outside dimension of the zone (cm)
10	XMOD	External moderator index	Optional	Appropriate dimension	Repeat entry numbers 8-10 until all zones are defined. Entry 10 is optional and can be omitted. If it is omitted, repeat entries 8 and 9 until all zones are defined
				NOEXTERMOD	No moderating materials in the adjacent zones
				ONEEXTERMOD	A moderating material is present in one adjacent zone
				TWOEXTERMOD	Moderating materials are present in two adjacent zones
	END ZONE	Terminate zone data		END ZONE	Enter when all zones have been defined by repeating entries 8 through 10 for each zone

7. END The word END is entered to terminate these data before entering the zone description data. It must not be entered in columns 1 through 3. At least two blanks are required between items 1 and 7 if they are the only entries. A label can be associated with this END. The label can be a maximum of 12 characters and is separated from the END by a single blank. At least two blanks must follow entry 7.

The zone description data are entered at this point. Entries 8, 9, and 10 are entered for each zone, and the sequence is repeated until all the desired zones have been described. To terminate the data, enter the words END ZONE.

8. MXZ Mixture number in the zone. Enter the mixture number of the material that is present in the zone. Enter a zero for a void. Repeat the sequence of entries 8 through 10 for each zone.

9. RZ Outside radius of the zone. Enter the outside dimension of the zone in centimeters. In slab geometry, RZ is the location of the zone's right boundary on the x-axis. Repeat the sequence of entries 8 through 10 for each zone.

10. XMOD Optional external moderator index. This optional entry describes the conditions existing in the zones adjacent to the present zone. Appropriate conditions are provided by default. The available options are listed below.

NOEXTERMOD This means there are no moderating materials between this zone and either boundary.

ONEEXTERMOD This means one of the zones between this zone and one of the boundaries contains a material.

TWOEXTERMOD This indicates that at least one zone on either side of this zone contains a material.

CAUTION: User-provided entries do not always supersede the default values: (1) For SLAB geometry, user-supplied values will be used everywhere except zone 1. If the left boundary is reflected, the default value of ONEEXTERMOD will be used unless NOEXTERMOD is specified. (2) For SPHERICAL and CYLINDRICAL geometry, default values will be used for all zones unless NOEXTERMOD is specified. NOEXTERMOD allows the user to "turn off" geometric corrections.

Repeat the sequence of entries 8 and 9 or 8 through 10 for each zone. When all the zones have been described, enter the words END ZONE.

END ZONE This is used to terminate the MULTIREGION zone data. Enter the words END ZONE when all the zones have been described. Note that ZONE is a label associated with this END. This label can be as long as 12 characters, but the first four characters **must** be ZONE. At least two blanks must follow this entry.

C6.4.8 OPTIONAL PARAMETER DATA

Most of the parameter data for Criticality Safety Analysis Sequence No. 6 are determined by the control module and cannot be adjusted. However, certain parameters can be altered. If the default parameters are acceptable, this section of input data should be omitted in its entirety. Nondefault values for one or more of the parameters can be specified by entering the words MORE DATA followed by the desired keyworded parameters and their associated values. One or more of the parameters can be entered in any order. Default values are used for parameters that are not entered. Each parameter is entered by spelling its name, followed immediately by an equal sign and the value to be entered. There should not be a blank between the parameter name and the equal sign. Each parameter specification must be separated from the rest by at least one blank. For example

MORE DATA ISN=16 EPS=0.00008 END

would result in using an S16 angular quadrature set and tightening the convergence criteria to 0.00008 in the XSDRNPM calculation. Note that the END is not the end for the analytical sequence, entry 5 of Table C6.4.7.

Table C6.4.13 describes the optional parameters that can be entered as data and the code or codes the parameters apply to. A description of each entry is contained in the text accompanying the table.

1. MORE DATA...These words, followed by one or more blanks, are entered ONLY if optional parameter data are to be entered. They must precede all other optional parameter data. Entries 2 through 19 can be entered in any order.

2. ISN= Order of angular quadrature for XSDRNPM. Quadrature sets are geometry-dependent quantities that are defaulted to order 8 by the Material Information Processor. See Sections M7.2.5.7 and M7.5.7 for a more detailed explanation.

3. SZF= Spatial mesh size factor for XSDRNPM. The size of the largest mesh interval can be adjusted by entering a value for SZF. The default value is 1.0. A value between zero and 1.0 yields a finer mesh; a value greater than 1.0 yields a coarser mesh. See Sections M7.2.5.6 and M7.5.7 for more details.

4. IIM= Maximum number of inner iterations for XSDRNPM. This is the maximum number of inner iterations to be used in the XSDRNPM calculation. The default value is 20. See Section M7.5.7 for a more detailed explanation.

5. ICM= Maximum number of outer iterations for XSDRNPM. This is the maximum number of outer iterations to be used in the XSDRNPM calculation. The default value is 25. If the calculation reaches the outer iteration limit, a larger value should be used. See Section M7.5.7 for a more detailed explanation.

6. EPS= Overall convergence criteria for XSDRNPM. This is used by XSDRNPM after each outer iteration to determine if the problem has converged. The default value of EPS is 0.0001. A value less than 0.0001 tightens the convergence criteria; a larger value loosens the convergence criteria. See Sections M7.2.5.8 and M7.5.7 for additional information.

7. PTC — Pointwise convergence criteria for XSDRNPM. This is the point flux convergence criteria used by XSDRNPM to determine if convergence has been achieved after an inner iteration. The default value is 0.0001. A smaller value tightens convergence; a larger value loosens it. See Sections M7.2.5.8 and M7.5.7 for more details.

8. BKL — Buckling factor for XSDRNPM. A buckling factor should be used ONLY for a MULTIREGION BUCKLEDSLAB or BUCKLEDCYL problem. Because cylinders are assumed to be infinitely long and slabs are assumed to be infinite in both transverse directions, the analytic sequence may tend to overestimate the total flux for a finite system. A buckling correction can be used to approximate the leakage from the system in the transverse direction(s). The extrapolation distance factor, BKL, is defaulted to 1.420892. See Sections M7.2.5.4 and M7.5.7 for additional details.

9. IUS — Upscatter scaling flag for XSDRNPM. This option allows the use of upscatter scaling to accelerate the solution or force convergence. The default value is zero, in which case upscatter scaling is not used. IUS=1 facilitates upscatter scaling. Guidelines are not available to indicate when upscatter scaling is needed. Some problems will not converge with it, and some will not converge without it. See Section M7.5.7 for a more detailed explanation.

10. RES — Resonance data for BONAMI and NITAWL-II. This parameter allows overriding the default resonance data for **materials that are not used in the unit cell**. The default resonance data are infinite homogeneous media that may not accurately represent the geometry (for example, a thin clad or container region). The resonance data are entered in the form:

RES= mixture number geometry type thickness [inner radius]

The mixture number is the material for which the resonance data apply. The geometry type can be a sphere, slab, or cylinder and defines the third entry of the 3* array in NITAWL-II. The thickness is the thickness of a slab or the radius of a sphere or cylinder in centimeters and defines the fourth entry of the 3* array in NITAWL-II. The inner radius is the optionally entered inner radius of an annular cylinder or sphere and defines the sixth entry of the 3* array in NITAWL-II. This entire data sequence should be entered for each material for which the default data are inadequate. See Section M7.5.7 for additional details.

WARNING: If this parameter is used to enter resonance data for a mixture that is used in the unit cell specification, it will NOT be used. Information provided in the unit cell data will be used instead.

Table C6.4.13 Optional parameter data

Entry number	Keyword name	Type of data	Applicable module	Comments
1	MORE DATA	Input flag		This signals that optional parameter data will be entered. Enter only those parameters you wish to change
2	ISN=	Order of angular quadrature	XSDRNPM	The default value is 8. This allows using another value
3	SZF=	Spatial mesh size factor	XSDRNPM	The default value is 1.0. 0<SZF<1.0 gives a finer mesh. SZF>1.0 gives a coarser mesh
4	IIM=	Max. number of inner iterations	XSDRNPM	The default value is 20. This allows using another value
5	ICM=	Max. number of outer iterations	XSDRNPM	The default value is 25. This allows using another value
6	EPS=	Overall convergence criteria	XSDRNPM	The default value is 0.0001. This allows using another value
7	PTC=	Point convergence criteria	XSDRNPM	The default value is 0.0001. This allows using another value
8	BKL=	Buckling factor	XSDRNPM	The default value is 1.420892. Use ONLY for a multiregion problem that specifies BUCKLEDSLAB or BUCKLEDCYL
9	IUS=	Upscatter scaling factor	XSDRNPM	The default value is zero. IUS=0 doesn't utilize upscatter scaling. IUS=1 uses upscatter scaling to accelerate the solution and/or speed convergence
10	RES=	Resonance data	BONAMI NITAWL-II	Enter the mixture number, geometry type (SLAB, CYLINDER, SPHERE), and the thickness of the slab or radius of the sphere or cylinder, in cm. Optionally enter the inner radius (cm) to specify an annular cylinder or sphere
11	DAN(mm)=	Dancoff factor for the specified mixture	BONAMI NITAWL-II	Enter the mixture number, mm, to which the Dancoff factor applies inside the parentheses; enter the Dancoff factor after the equal sign. Repeat entries 10 and 11 for all resonance mixtures used in the problem that are not treated in the LATTICECELL or MULTIREGION description

Table C6.4.13 (continued)

Entry number	Keyword name	Type of data	Applicable module	Comments
12	BAL=	Key to print balance tables	XSDRNPM	The default value is FINE. BAL=NONE suppresses printing the balance table. BAL=ALL prints all balance tables. BAL=FINE prints only the fine-group balance tables
13	DY=	First transverse dimension	XSDRNPM	The first transverse dimension, in centimeters, used in a buckling correction to calculate leakage normal to the principal calculation direction (i.e., the height of a slab or a cylinder)
14	DZ=	Second transverse dimension	XSDRNPM	The second transverse dimension, in centimeters, used for a buckling correction (i.e., the width of a slab)
15	COF=	Diffusion coefficient option for transverse leakage correction	XSDRNPM	The default is 0. See Section F3.5, 3$ array, variable IPN
16	FRD=	Unit from which fluxes will be read	XSDRNPM	Enter the unit number from which the flux guess for XSDRNPM will be read
17	FWR=	Unit on which fluxes will be written	XSDRNPM	Enter the unit number where the binary fluxes from XSDRNPM will be written
18	ADJ=	Adjoint mode flag	XSDRNPM	Enter a 1 to cause XSDRNPM to solve the problem in adjoint mode
19	NBU=	Unit on which balance tables will be written	XSDRNPM	Enter the unit number where the balance tables from XSDRNPM will be written
20	WGT=	Cross-section weighting flag	XSDRNPM	Enter a 0 to suppress doing the cross-section weighting in XSDRNPM
21	ZMD(iz)=	Zone width modifier for the specified zone	XSDRNPM	Enter the zone number for which the modifier applies inside the parentheses; enter the zone width modifier after the equal sign. **Repeat number 20 to specify all zones to be modified in a search.**
22	INT(iz)=	Number of intervals for the specified zone	XSDRNPM	Enter the zone number inside the parentheses; enter the number of intervals after the equal sign. Repeat number 22 to specify all needed zones.
23	KEF=	Value of k_{eff} to be searched for	XSDRNPM	Enter the value of k_{eff} that is desired to search for. The default is 1.0.
24	KFM=	Value of the eigenvalue modifier	XSDRNPM	Enter the value of the eigenvalue modifier (i.e., the relative change for the first guess of a search). The default is -0.1.
25	DAB=	Number of direct access data blocks	MIP[a]	The default is 200. Number of blocks allocated for direct-access unit 90.
26	AXS=	Unit on which a mixed ANISN library will be written	ICE	Enter the unit number where ICE is to write a mixed ANISN library.

Table C6.4.13 (continued)

Entry number	Keyword name	Type of data	Applicable module	Comments
27	MSH=	Maximum number of mesh points/ resonance	NITAWL	The default value is 2001. This allows using another value.
28	MLV=	Highest resonance ℓ-value for self-shielding	NITAWL	The default value is 2. This allows using another value.
29	ID1=	Print control for scalar fluxes	XSDRNPM	The default value is -1. See Section F3.5, 2$ array, variable ID1.
30	COLL	Key to activate collapse of thermal groups	MIP[a]	Enter COLL to collapse all thermal groups into one group for the shielding sequences.
31	END	Terminus		Terminate the optional parameter data. Do not start in column 1. At least two blanks must follow this entry.

[a]MIP is the Material Information Processor.

11. DAN(mm)= Dancoff factor for the specified mixtures. This allows entering a Dancoff factor to be used in the resonance correction for the specified mixture. The Dancoff data are entered in the form:

    DAN(mm) = Dancoff factor.

    Note that the parentheses must be entered as part of the data. The mixture number, mm, to which the Dancoff factor applies, must be enclosed in the parentheses. The Dancoff factor to be used is entered after the equal sign. See Section M7.5.7 for additional details.

    Items 10 and 11 should be entered for each resonance mixture that is not specified in the LATTICECELL or MULTIREGION unit cell specification data. See Sections M7.5.10 and C6.5.1 for additional information.

12. BAL= Balance table print flag for XSDRNPM. This allows control of the balance table print from XSDRNPM. The default value is FINE. BAL=NONE suppresses the balance table print. BAL=ALL prints all of the balance tables. BAL=FINE prints only the fine-group balance tables. See Section M7.5.7 for additional details.

13. DY= First transverse dimension for XSDRNPM. This is the first transverse dimension, in centimeters, used in a buckling correction to calculate the leakage normal to the principal calculation direction (the height of a slab or cylinder). It should only be entered if XSDRNPM is to create cell-weighted cross sections and/or calculate the eigenvalue of a cylinder or slab system of finite height for a LATTICECELL problem. DY= is defaulted to

an infinite height, or is set to DY for a buckled MULTIREGION cell description. See Sects M7.2.5.4 and M7.5.7 for additional details.

14. DZ= Second transverse dimension for XSDRNPM. This is the second transverse dimension, in centimeters, used for a buckling correction for a slab of finite width. It should only be entered if XSDRNPM is to create cell-weighted cross sections and/or calculate the eigenvalue of a LATTICECELL slab of finite width. DZ= is defaulted to an infinite width, or is set to DZ for a buckled MULTIREGION slab cell of finite width. See Sections M7.2.5.4 and M7.5.7 for additional details.

15. COF= Diffusion coefficient for transverse leakage corrections in XSDRNPM. The default value is 0. The available options are

    COF=0 sets a transport-corrected cross section for each zone.

    COF=1 use a spatially averaged diffusion coefficient for each zone.

    COF=2 use a diffusion coefficient for all zones that is one-third the diffusion coefficient determined from the spatially averaged transport cross section for all zones.

    COF=3 use a flux and volume weighting across all zones.

    See Section M7.5.7 or Section F3.5, 3$ array, variable IPN for more details.

16. FRD= Unit from which fluxes are read for XSDRNPM. If fluxes are to be used for the initial flux guess, enter the unit number from which they are to be read. The user is responsible for supplying job control language data that is necessary for reading the flux dataset. See Section M7.5.7 for more details.

17. FWR= Unit on which fluxes will be written for XSDRNPM. If binary fluxes are to be saved from this XSDRNPM calculation, enter the unit number where they will be written. The user is responsible for supplying job control language data that is necessary for creating and saving the flux dataset. See Section M7.5.7 for more details.

18. ADJ= Adjoint mode flag for XSDRNPM. Set to 1 to cause XSDRNPM to solve the adjoint problem.

19. NBU= Unit on which the balance tables will be written from XSDRNPM. If the balance tables file is to be saved, enter the unit number where they are to be written. The user is responsible for supplying job control data necessary to create and save the balance table dataset.

20. WGT= Cross-section weighting flag for XSDRNPM. The default is to do cross-section weighting. If a user needs to not do cross-section weighting, then a value of 0 should be entered.

21. ZMD(iz)= Zone width modifiers for an XSDRNPM search problem. This allows entering a zone width modifier for zone iz in the XSDRNPM problem description. The zone width data are entered in the form:
ZMD(iz)=modifier
Note that the parentheses must be entered as part of the keyword. The zone number iz, to which the modifier is applied must be enclosed in the parentheses. The modifier is entered after the equal sign. See Sect. F3.2.8 for more information.

22. INT(iz)= Number of mesh intervals for zone iz in XSDRNPM. The default is 0, which causes the number to be calculated. The data are entered in the form:
INT(iz)=number
Note that the parentheses must be entered as part of the keyword. The zone number iz, for which the number of intervals is specified, must be enclosed in the parenthesis. The number of intervals is entered after the equal sign.

23. KEF= The desired value of k_{eff} for an XSDRNPM zone width search. The default value is 1.0. If it is desired to search for some other value, such as 0.9, then input it here.

24. KFM= The first eigenvalue modifier used in an XSDRNPM search. This value is used to make the first change in the XSDRNPM search. The default value is -0.1. A user may sometimes need to change this to make the search converge.

25. DAB= Number of direct-access data blocks for the Material Information Processor. These are the number of blocks allocated for direct access on unit 90. The default is 200. See Sect. M7.5.7 for additional details. If the job fails in the Material Information Processor with an LMP005 DA ERROR, then DAB must be used to enter a larger value. See Section M7.7.3 for additional details.

26. AXS= Logical unit number for ICE. Write a mixed ANISN library on this unit. The default is zero (no library). If the unit number is input as 7, the ANISN library will be in free-form card image. For any other unit number, the library will be binary. The user is responsible for supplying job control language data that is necessary for creating and saving the ANISN cross-section library. An ANISN cross section can only be created by the control sequences CSASI, CSASIX, and SAS3. See Sect. M7.5.7 for additional details.

27. MSH= The maximum number of mesh points per resonance. The default value is 2001. This is the maximum number of mesh points allowed for the Simpson's rule integration in NITAWL. This should be an odd number. See Sect. M7.5.7 for additional details.

28. MLV= Highest resonance ℓ-value for self-shielding. The default value is 2. This is the highest resonance ℓ-value for which a self-shielding calculation will be performed in NITAWL. See Sect. M7.5.7 for additional details.

29. ID1= Scalar flux print control. The default value is -1, which suppresses printing the scalar fluxes in XSDRNPM. See Sect. F3.5, 2$ array, variable ID1 for allowed values and corresponding actions.

30. COLL — Activate collapse of thermal groups. This parameter should only be used with the shielding analysis sequences (SAS1, etc.). It causes the Material Information Processor to instruct XSDRNPM to collapse all thermal groups into one group. See Sect. M7.5.7 for additional details.

31. END — The word END is entered to terminate the optional parameter data. A label can be associated with this END. The label can be as long as 12 characters, but must be preceded by a single blank. If this END is entered without a label, it must not begin in column 1. At least two blanks must follow this entry.

C6.4.9 SUMMARY OF KENO-VI DATA

KENO-VI data are required for CSAS26 and CSAS26X. A brief outline of the KENO-VI data is given in Table C6.4.14. The input data are summarized in Table C6.4.15. The input data for KENO-VI are discussed in detail in Sects. F17.4 and F17.5. Data need not be supplied for entries whose default value is acceptable. KENO-VI mixing table data cannot be entered or used in CSAS26 because they are automatically supplied by the control module.

Table C6.4.14 Outline of KENO-VI data

Type of data	Starting flag	Comments	Termination flag
Title	None	80 columns, must be entered first	None
Parameters	READ PARM	Enter desired parameter data	END PARM
Biasing or weighting	READ BIAS	Enter desired biasing data	END BIAS
Geometry	READ GEOM	Enter desired geometry data	END GEOM
Array data or unit orientation	READ ARRAY	Enter desired array data	END ARRAY
Boundary conditions or albedos	READ BNDS	Enter desired albedo data	END BNDS
Start data or initial source	READ START	Enter desired start data	END START
Mixing table data	READ MIXT	The CSAS6 modules allow only SCT= and EPS=	END MIXT
Plot data	READ PLOT	Enter desired plot data	END PLOT
KENO-VI data terminus	END DATA	Enter to signal the end of all KENO-VI data	

Table C6.4.15 Summary of KENO-VI data

Summary of parameter data

TITLE: The title must be entered first (80 columns) 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=	4	Working xsecs from NITAWL or XSDRN
WTH=	3.0	Wt. for splitting	AMX=	NO	All mixture xsecs	MKA=	NO	Matrix by array			
WTL=	1/WTH	Russian Roulette wt.	XAP=	NO	Xsec angles and probs.	CKA=	NO	Cofactor k by array			
GEN=	203	No. of generations	XS1=	NO	1-D xsecs	FMA=	NO	Fiss. prod. by array			Scratch
NPG=	1000	No. per generation	XS2=	NO	2-D xsecs	HAL=	NO	MKA at highest level			Read restart
NSK=	3	Generations skipped	PKI=	NO	Fission spectrum	PLT=	YES	Printer plots	SKT=	16	Write restart
RES=	0	Gens. between restart	P1D=	NO	Extra 1-D xsecs	BUG=	NO	Debug print	RST=	95	Mixed xsecs
NBK=	NPG+25	Neutron bank positions	FAR=	NO	Fiss. and abs.	TRK=	NO	Print neutron tracks	WRS=	95	
XNB=	0	Extra bank entries	MKP=	NO	Matrix by location	PWT=	NO	Print avg. weight	XSC=	14	
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=	YES	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						
NB8=	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									

*The words of storage in CSAS6 are defaulted to 100,000 and can be overridden by using the size= parameter on the analytical sequence specification which then becomes the default value of LNG in KENO-VI.
For example =CSAS26 PARM=SIZE=200000
=CSAS26 PARM=(CHECK,SIZE=200000)

Table C6.4.15 (continued)

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 FILL LOOP
KEYWORD	DEFAULT	DEFINITION	
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.

COUNT FIELD	OPTION FIELD	OPERAND FIELD	COMMENTS
		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
	F	j	Fills remainder of the array with unit no. j starting with the current array position
	A	j	Sets the current position in the array to j
i	S		Increments the current position in the array by i allows skipping i positions. The value of i may be positive or negative
i	Q	j	Repeats the previous j entries i times. Thedefault 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	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
i	P	j	Alternately stores j and -j in the next i positions of the array
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

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:

DATA ENTRY	COMMENTS
LTYPE	The unit or box type. LTYPE must be greater than 1
IX1	Starting position in the X direction. IX1 must be at least 1 and no larger than the value entered for NUX
IX2	Ending position in the X direction. IX2 must be at least 1 and no larger than the value of NUX
INCX	The number of units by which increments are made in the X direction
IY1	The starting position in the Y direction. IY1 must be at least 1 and less than the value entered for NUY
IY2	Ending position int he Y direction. IY2 must be at least 1 and no larger than the value of NUY
INCY	The number of units by which increments are made in the positive Y direction
IZ1	Starting position in the Z direction. IZ1 must be at least 1 and no larger than NUZ
IZ2	Ending position in the Z direction. IZ2 must be at least 1 and no larger than NUZ
INCZ	The number of units by which increments are made in the positive Z direction

Table C6.4.15 (continued)

Summary of biasing data

BIAS (weighting) Format: READ BIAS keyword correlation data auxiliary END BIAS
See Sects. F17.4.7 and F17.5.8

KEYWORD	DESCRIPTION	
ID=	CORRELATION DATA will be read next.	
	id	Material ID. Enter from table at right to use weighting data from the library
	ibgn	Beginning bias ID
	iend	Ending bias ID
WT=	AUXILIARY DATA will be read next.	
WTS=	AUXILIARY DATA will be read next.	
	wttitl	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

MATERIAL	ID	ENERGY GROUPS	THICKNESS/ INCREMENT
Concrete	301	16,27,44,218,238	5 cm
Paraffin	400	16,27,44,218,238	3 cm
Water	500	16,27,44,218,238	3 cm
Graphite	6100	16,27,44,218,238	20 cm

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 ID's 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 C6.4.15 (continued)

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 that is a cuboid.
Any albedo condition, but the same condition on all faces, is allowed if the global unit boundary record consists of one geometry record that is composed of paired planes.
Only void, mirror, or white boundary conditions, the same condition on all faces, if the global unit boundary record consists of only one geometry record of any shape.
Only void boundary condition is allowed if the global unit boundary record contains multiple geometry records. Default is void on all global unit boundary surfaces.

ALBEDO NAMES AVAILABLE ON THE KENO V ALBEDO LIBRARY, FOR USE WITH THE FACE CODES

ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION	ALBEDO NAME	DESCRIPTION
DPOH20 DPOH20 DPO DPO	12-in. double PO 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
H20 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	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	SPE MIR	
CARBON GRAPHITE C	200-cm carbon differential albedo with 4 incident angles	CONC-16 CON16 CONC16	16-in. concrete differential albedo with 4 incident angles	PERIODIC PERI PER	Periodic 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	WHITE	White boundary condition

Table C6.4.15 (continued)

Summary of geometry data

GEOMETRY (region)

Format: READ GEOM enter geometry region data here END GEOM
See Sects. F17.4.4, F17.5.1.2, F17.5.6, and F17.5.7.

GEOMETRY REGION DATA consists of SIMPLE GEOMETRY REGION DATA and MODIFICATION GEOMETRY REGION DATA.

ENTER GEOMETRY REGION DATA IN THE FOLLOWING FORM:
OPTIONAL GLOBAL SPECIFICATION
UNIT n
OPTIONAL GEOMETRY COMMENT
GEOMETRY, MODIFICATION, MEDIA, and BOUNDARY DATA
* *
SIMPLE GEOMETRY REGION DATA IN THE FOLLOWING FORM:

GLOBAL Enter only 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 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 a boundary record.
Enter as many geometry description specifications 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 Zt Rb Zb	Lbl is an integer assigned to a geometry record, unique within the unit, that relates the geometry record to the media region in the Region Definition Vector i1 i2 ...
	CUBOID	Lbl +X -X +Y -Y +Z -Z	
	CYLINDER	Lbl R Zt Zb	
	DODECAHEDRON	Lbl R	
	ECYLINDER	Lbl Rx Ry Zt Zb	
	ELLIPSOID	Lbl Rx Ry Rz	
	HEXPRISM	Lbl R Zt Zb	
	HOPPER	Lbl Lxt Lyt Lzt Lxb Lyb Lzb	
	PARALLELPIPED	Lbl XDIST YDIST ZDIST PHI THETA PHI	
	PLANE*	Lbl XPL=a YPL=b ZPL=c CON=d	Data is entered after the = following the respective subordinate keyword. Only non-zero data is required.
	QUADRATIC*	Lbl AQU=a BQU=b CQU=c DQU=d EQU=e Lbl FQU=f GQU=g HQU=h IQU=i JQU=j	Data is entered after the = following the respective subordinate keyword. Only non-zero data is required.
	RHOMBOID	Lbl DX PSI	
	SPHERE	Lbl R	
	WEDGE	Lbl XBASE XPT YPT ZLNG	
MODIFICATION*	CHORD	+X= -X= +Y= -Y= +Z= -Z=	Only non-zero data is required.
	ORIGIN	X= Y= Z=	Only non-zero data is required.
	ROTATE	A1= A2= A3=	The body is rotated about the Origin using the Euler angle x-convention. Only non-zero data is required.
MEDIA**	MEDIA	Mid Bid i1 i2 ...	The region boundary containing the hole must exactly match the boundary of the unit being placed in the hole.
	HOLE	Hid	
	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 unit boundary.

*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 C6.4.15 (continued)

Summary of mixing table data

MIXTURES Format: READ MIXT xsec parameters END MIXT

Note: In CSAS6, only xsec parameters should be entered.
KENO-VI mixing table data consists of "xsec parameters" and a "mixing table."
The "mixing table" is used to define the materials used in the KENO-VI problem.
These data are automatically created by CSAS6 and provided to KENO-VI.
It cannot be overridden. See 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=	2	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. K6-60

Table C6.4.15 (continued)

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. F17.4.11 and F17.5.9

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.)
PIC=	MAT	Type of picture: MIXTURE, UNIT NO. or BIAS ID NO.
		MIXTURE ---------- MAT
		MIX
		MIXT
		MIXTURE
		MEDI
		MEDIA
		UNIT NO. ---------- BOX
		BOXT
		BOXTYPE
		UNT
		UNIT
		UNITTYPE
		BIAS ID NO. ------- IMP
		BIAS
		BIASID
		WTS
		WEIG
		WEIGHTS
		WGT
		WGTS
XUL=	Prev. plot	X coord. of upper left corner of 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
YLR=	Prev. plot	Y coord. of lower right corner of plot
ZLR=	Prev. plot	Z coord. of lower right corner of plot

KEYWORD	DEFAULT	DEFINITION
UAX=	Prev. plot 0 IF VAX OR WAX is read	X component of direction cosine for the AX axis of the plot (across)
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
SCR=	NO	No specifies a printer plot. If YES, a .gif file is generated for each plot.
CLR=		Used only with SCR=YES to change colors. Input 4 integers: 1st is index into color table, next 3 are the red, green, and blue color values.

PLOT ORIGIN:

(1) SINGLE UNIT - coincides with origin of geometry description.

(2) BASE ARRAY - at the most negative point of the array (lower left-hand back corner of the global array).

(3) REFLECTED ARRAY - coincides with the origin of the CORE or ARRAY description of the global array.

**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 C6.4.15 (continued)

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
0	None	NST	Uniform
		XSM	
		XSP	
		YSM	
		YSP	
		ZSM	
		ZSP	
		RFL	
		PSP	
1	NST	XSM	Cosine
		XSP	
		YSM	
		YSPO	
		ZSM	
		ZSP	
		RFL	
		PSP	
2	NST	XSM	Cosine with fraction in specified unit
	NXS	XSP	
	NYS	YSM	
	NZS	YSP	
	FCT	ZSM	
		ZSP	
		RFL	
		PSP	

START TYPE	REQUIRED DATA	OPTIONAL DATA	STARTING DISTRIBUTION
3	NST	KFS	Spike
	TFX	PSP	
	TFY		
	TFZ		
	NXS		
	NYS		
	NZS		
4	NST	KFS	Multiple spikes
	TFX	PSP	
	TFY		
	TFZ		
	NBX		
5	NST	PSP	In specified units
	NBX		
6	NST	NXS	Arbitrary points
	TFX	NYS	
	TFY	NZS	
	TFZ	KFS	
	LNU*	PS6	
		PSP	

KEYWORD	DEFAULT	DEFINITION
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=		Fission spectra
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.
Unless otherwise specified, the starting volume is defined by the first positive geometry label in the global unit boundary region definition vector.

C6.5 NOTES FOR CSAS6 USERS

This section provides tips concerning the use of CSAS6 and its associated sequences. Section M7.5 provides information about the use of the Material Information Processor, and Section F17.7 provides assistance about the use of the KENO-VI data required by CSAS6.

C6.5.1 CSAS6 MODULES

Several CSAS6 modules are contained in the CSAS6 family. These modules allow the user to generate and save working format cross sections for use with KENO V.a, XSDRNPM, or KENO-VI, or a MORSE/KENO cross-section library for use with MORSE, KENO V.a, or KENO-VI. Therefore, the user can run different codes using the same cross-section library for comparison purposes. A list of the available modules is given below. Table C6.5.1 lists the I/O devices utilized by CSAS6, and Table C6.5.2 lists the type of I/O files utilized by the functional modules invoked by CSAS6.

The CSAS6 input data allow the user to define optional I/O files. The CSAS6 optional parameter data, Section C6.4.8, allow the user to define the following optional files: (1) the unit from which XSDRNPM may read fluxes, (2) the unit on which XSDRNPM may write fluxes, and (3) the unit on which ICE may write an ANISN library. The KENO-VI input data used by CSAS6 allow the user to define optional logical units used by KENO-VI. See "Logical Unit Numbers" in Section F17.4.3. The unit on which a KENO-VI restart data file is written should not be set to 95.

CSAS26 — Runs BONAMI, NITAWL-II, and KENO-VI. A working format library is written on unit 4, and a MORSE/KENO mixture cross-section library is written on unit 14. Either or both of these libraries can be saved for future use. Because KENO-VI data are entered as part of the CSAS26 data, LIB= and XSC= should not be specified in the KENO-VI parameter data, and the mixing table should be omitted from the KENO-VI data. All KENO-VI options are available through CSAS26.

CSAS26X — Runs BONAMI, NITAWL-II, XSDRNPM, and KENO-VI. A working format library is written on unit 3, and a MORSE/KENO mixture cross-section library is written on unit 14. The cell-weighted mixture 500 is included on unit 14. Either or both of these libraries can be saved for future use. Because KENO-VI data are entered as part of the CSAS26 data, LIB= and XSC= should not be specified in the KENO-VI parameter data, and the mixing table should be omitted from the KENO-VI data. All KENO-VI options are available through CSAS26X. To process cross sections and run KENO-VI, CSAS26 should be used unless use of a cell-weighted mixture in KENO-VI is planned.

Table C6.5.1 Description of units utilized by the Criticality Safety Analysis Sequence No. 6 control module

Unit number	Type of data	Creating module	User module	Type of file
5	Input	DRIVER	CSAS6	Sequential
8	Scratch file	CSAS6	CSAS6	Direct or random access data
11	Short master cross-section library	CSAS6	BONAMI	Sequential
16	Scratch file	CSAS6	CSAS6	Sequential
17	Scratch file	CSAS6	CSAS6	Sequential
18	Scratch file	CSAS6	CSAS6	Sequential
19	Scratch file	CSAS6	CSAS6	Sequential
70	User-supplied cross sections		CSAS6	AMPX master format library
81	16-group cross sections		CSAS6	AMPX master format library
82	27-group cross sections		CSAS6	AMPX master format library
83	44-group cross sections		CSAS6	AMPX master format library
84	238-group cross sections		CSAS6	AMPX master format library
85	22 neutron-18 gamma cross sections		CSAS6	AMPX master format library
86	18-gamma cross sections		CSAS6	AMPX master format library
87	27-group cross sections for burnup		CSAS6	AMPX master format library
88	27 neutron-18 gamma cross sections		CSAS6	AMPX master format library
89	Standard Composition Library	CSAS6	CSAS6	Direct- or random-access data file
92	ICE input data	CSAS6	ICE	Sequential
95	KENO-VI restart data	CSAS6 KENO-VI	KENO-VI	Sequential
96	BONAMI input data	CSAS6	BONAMI	Sequential
97	NITAWL-II input data	CSAS6	NITAWL-II	Sequential
98	XSDRNPM input data	CSAS6	XSDRNPM	Sequential
99	Printed output	CSAS6	CSAS6	Sequential

Table C6.5.2 Description of units used by the functional modules of CSAS6

Unit No.	Module	Action	Type of file
1	BONAMI	WRITE	Microscopic master working format cross sections
	NITAWL-II	READ	Microscopic master working format cross sections
2	ICE	WRITE	Macroscopic working format cross sections
3	XSDRNPM	WRITE	Microscopic cell-weighted working format cross sections
	ICE	READ	Microscopic cell-weighted working format cross sections
	KENO-VI	READ	Microscopic cell-weighted working format cross sections
4	NITAWL-II	WRITE	Microscopic working format cross sections
	ICE	READ	Microscopic working format cross sections
	KENO-VI	READ	Microscopic working format cross sections
	XSDRNPM	READ	Microscopic working format cross sections
6	BONAMI	WRITE	Printed output
	ICE	WRITE	Printed output
	KENO-VI	WRITE	Printed output
	NITAWL-II	WRITE	Printed output
	XSDRNPM	WRITE	Printed output
8	BONAMI	WRITE/READ	Direct- or random-access scratch files
	ICE	WRITE/READ	Direct- or random-access scratch files
	KENO-VI	WRITE/READ	Direct- or random-access scratch files
	XSDRNPM	WRITE/READ	Direct- or random-access scratch files
9	BONAMI	WRITE/READ	Direct- or random-access scratch files
	ICE	WRITE/READ	Direct- or random-access scratch files
	KENO-VI	WRITE/READ	Direct- or random-access scratch files
	NITAWL-II	WRITE/READ	Direct- or random-access scratch files
	XSDRNPM	WRITE/READ	Direct- or random-access scratch files
10	ICE	WRITE/READ	Direct- or random-access scratch files
	KENO-VI	WRITE/READ	Direct- or random-access scratch files
	XSDRNPM	WRITE/READ	Direct- or random-access scratch files
11	BONAMI	READ	Short AMPX master format cross sections
14	ICE	WRITE	Monte Carlo-formatted macroscopic cross sections
	KENO-VI*	READ/WRITE	Monte Carlo-formatted macroscopic cross sections
16	KENO-VI	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Angular flux file
17	XSDRNPM	WRITE/READ	Sequential scratch file
18	BONAMI	WRITE/READ	Sequential scratch file
	NITAWL-II	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Sequential scratch file

Table C6.5.2 (continued)

Unit No.	Module	Action	Type of file
19	BONAMI	WRITE/READ	Sequential scratch file
	NITAWL-II	WRITE/READ	Sequential scratch file
	XSDRNPM	WRITE/READ	Sequential scratch file
79	KENO-VI	READ	KENO-VI albedo file
80	KENO-VI	READ	KENO-VI weighting file
92	ICE	READ	Binary input file
95	KENO-VI	READ	Binary input file
96	BONAMI	READ	Binary input file
97	NITAWL-II	READ	Binary input file
98	XSDRNPM	READ	Binary input file

*KENO-VI always reads from unit 14. If microscopic input cross sections are used, KENO-VI prepares macroscopic cross sections and writes them on unit 14 to be read later.

C6.5.2 AUTOMATIC CROSS-SECTION PROCESSING FOR CRITICALITY CALCULATIONS

The CSASI, CSASIX, CSAS1X, and CSASN moduled, used to prepare an AMPX working format problem-dependent cross-section library, have been disabled in CSAS26. These modules, which can be used to prepare cross-section libraries for use in KENOVI, are contained in CSAS4. CSAS26 and CSAS26X can be used to prepare an AMPX working format cross-section library and run KENO-VI without the necessity of having to enter the mixing table data in KENO-VI. Examples are given in Section C6.5.2.1 through C6.5.2.4.

C6.5.2.1 Run KENO-VI Using CSAS26

CSAS26 creates a microscopic working format library and a mixing table that is passed to KENO-VI. CSAS26 executes KENO-VI and calculates k-effective for the problem.

EXAMPLE 1. CSAS26 – Determine the k-effective of a system.

Consider a problem consisting of four uranium metal cylinders that are 93.2% wt enriched, having a density of 18.76 g/cc. The cylinders are arranged in a 2 × 2 × 2 array. Each has a radius of 5.748 cm and a height of 10.765 cm. The center-to-center spacing in the horizontal plane (X-Y) is 13.74 cm and the vertical center-to-center spacing is 13.01 cm. The input data for this problem follow. The calculated k-effective for this critical experiment was 0.9934 ± 0.0045.

```
=CSAS26
SET UP 2C8 IN CSAS26
HANSEN-ROACH    INFHOMMEDIUM
URANIUM  1 DEN=18.76 1 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
END COMP
READ PARAMETERS  TME=1.0 FLX=YES FDN=YES FAR=YES
END PARAMETERS
READ GEOMETRY
UNIT 1
CYLINDER 10  5.748 5.3825 -5.3825
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
GLOBAL UNIT 2
CUBOID 10 4P13.74   2P13.010
ARRAY  1  10  PLACE 1 1 1 -6.87 -6.87 -6.505
BOUNDARY 10
END GEOMETRY
READ ARRAY  GBL=1 ARA=1 NUX=2 NUY=2 NUZ=2  FILL  F1 END FILL
END ARRAY
END DATA
END
```

EXAMPLE 2. CSAS26 – Determine the k-effective of an array of fuel assemblies.

Consider a 4 × 4 × 1 array of fuel assemblies in a square aluminum cask. Each assembly consists of a 17 × 17 × 1 array of zirconium-clad, 2.35%-enriched UO_2 fuel pins in a square pitched array. The UO_2 has a density of 9.21 g/cc. The pin diameter is 0.8 cm and is 366 cm long. The clad is 0.07 cm thick, and the pitch is 1.3 cm. Each fuel bundle is contained in a 0.65-cm-thick boral sheath. The bundles are separated by an edge-to-edge spacing of 1 cm. The array of bundles is centered in a 10-cm-thick aluminum cask whose inside dimensions are 0.5 cm beyond the outer edges of the fuel bundles. Determine the k-effective of a dry cask. Input data for this cask follow. The calculated k-effective for this system is 0.7940 ± 0.0035.

```
=CSAS26
SQUARE FUEL CASK EXAMPLE USING DETAILED MOCKUP
44GROUP LATTICECELL
UO2  1 DEN=9.21 1.0 293. 92235 2.35 92238 97.65 END
ZR  2 1 END
H2O  3 1 END
B4C  4 0.367 END
AL  4 0.636 END
AL  5 1 END
END COMP
SQUAREPITCH  1.3 .8 1 3 .94 2 END
READ PARAM  TME=30.0  NUB=YES FAR=YES GEN=153
END PARAM
READ GEOM
UNIT  1
COM='FUEL PIN'
CYLINDER 10  0.4  2P183.0
CYLINDER 20  0.47 2P183.07
CUBOID     30  4P0.65 2P183.07
MEDIA 1 1 10
MEDIA 2 1 20 -10
MEDIA 3 1 30 -20 -10
BOUNDARY 30
UNIT  2
COM='FUEL ASSEMBLY'
CUBOID  10  4P11.05  2P183.07
CUBOID  20  4P11.7   2P183.72
CUBOID  30  4P12.2   2P184.22
ARRAY  1  10  PLACE 9 9 1 3*0.0
MEDIA  4  1  20 -10
MEDIA  3  1  20 -20 -20
BOUNDARY  30
GLOBAL  UNIT 3
COM='FUEL CASK CONTAINING 4X4 ARRAY OF ASSEMBLIES'
CUBOID  10  4P48.8  2P184.22
CUBOID  20  4P58.8  2P194.22
ARRAY  2 10  PLACE  1 1 1 -36.6  -36.6  0.0
MEDIA  5  1  20  -10
BOUNDARY  20
END GEOM
READ ARRAY ARA=1 NUX=17 NUY=17 NUZ=1 FILL F1 END FILL
GBL= 2 ARA=2 NUX=4 NUY=4 NUZ=1 FILL F2 END FILL
END ARRAY
END DATA
END
```

C6.5.2.2 Run KENO-VI Using CSAS26X

CSAS26X create a microscopic working format library and a mixing table that is passed to KENO-VI. The microscopic cross sections of the nuclides used in the unit cell geometry description are cell-weighted for use in mixture 500. Mixture 500 utilizes the cell-weighted cross sections that represent the heterogeneous system. CSAS26X executes KENO-VI and calculates k-effective for the problem.

EXAMPLE 1. CSAS26X - Calculate the k-effective of an array of fuel assemblies using cell-weighted cross sections.

Consider the 4 × 4 × 1 array of fuel assemblies in a square aluminum cask described in Section C6.5.2.1, example 3. Calculate the k-effective of the system by using the cell-weighted mixture 500 to represent the fuel pins in the fuel assembly. Note that mixtures 1, 2, and 3, representing UO_2, zirconium, and water, respectively, are used in the unit cell description. Cell-weighting is applied to the microscopic cross sections that are used in the cell, making them incorrect for use elsewhere. Because water is used both inside the cell and between the fuel assemblies, an additional mixture, mixture 6, has been added to represent the water between the fuel assemblies. The input data for this problem follow.

```
=CSAS26X
SQUARE FUEL CASK EXAMPLE USING HOMOGENEOUS MOCKUP
44GROUP LATTICECELL
UO2  1 DEN=9.21 1.0 293. 92235 2.35 92238 97.65 END
ZR  2 1 END
H2O  3 1 END
B4C  4 0.367 END
AL  4 0.636 END
AL  5 1 END
H2O  6 1 END
END COMP
SQUAREPITCH  1.3 .8 1 3 .94 2 END
READ PARAM  TME=30.0  NUB=YES FAR=YES GEN=153
END PARAM
READ GEOM
UNIT  2
COM='FUEL ASSEMBLY'
CUBOID  10 4P11.05  2P183.07
CUBOID  20 4P11.70  2P183.72
CUBOID  30 4P12.20  2P184.22
MEDIA  500  1  10
MEDIA  4  1  20  -10
MEDIA  6  1  30  -20  -10
BOUNDARY  30
GLOBAL  UNIT 3
COM='FUEL CASK CONTAINING 4X4 ARRAY OF ASSEMBLIES'
CUBOID  10  4P48.8  2P184.22
CUBOID  20  4P58.8  2P194.22
ARRAY  1 10  PLACE 1 1 1 -36.6 -36.6 0.0
MEDIA  5  1  20 -10
BOUNDARY  20
END GEOM
READ ARRAY ARA=1 NUX=4 NUY=4 NUZ=1 FILL F2 END FILL
END ARRAY
END DATA
END
```

C6.5.2.3 Run XSDRNPM Using CSAS1X

XSDRNPM can be utilized to calculate the eigenvalue of a system without the necessity of manually preparing the cross sections and mixing table data by executing CSAS1X as shown in example 1 below.

EXAMPLE 1. CSAS1X - Calculate the eigenvalue of a system.

This example is a critical experiment of plutonium nitrate solution in a spherical stainless steel tank reflected by water. The plutonium is 95.4% wt ^{239}Pu, the remainder being ^{240}Pu. The fuel is a 0.52-M nitric acid solution of plutonium-nitrate, containing 24.4 g of heavy metal per liter of solution. Optional parameters were entered to decrease the number of mesh intervals and to use an S_4 calculation rather than S_8. The input data for this problem follow. The eigenvalue calculated by XSDRNPM is 1.00946.

```
=CSAS1X
CRITICAL PU(NO3)4 SOLUTION IN A SS SPHERICAL TANK REFLECTED BY WATER
HANSEN-ROACH  MULTIREGION
SOLNPU(NO3)4   1 24.4 .52 1 295 94239 95.4 94240 4.6 END
SS304  2 1.0  END
H2O  3 1  END
END COMP
SPHERICAL   VACUUM   REFLECTED   0   END
1 19.304 ONEEXTERMOD   2 19.426 ONEEXTERMOD   3 39.746 NOEXTERMOD
END ZONE
MORE DATA  ISN=4 SZF=1.5 END
END
```

C6.5.3 AUTOMATED CROSS-SECTION PREPARATION FOR USE BY SUBSEQUENT CODES

Many of the control modules available through the CSAS4 family of codes are used primarily to process cross sections for use by other codes. Although these modules are not part of CSAS6, the cross sections they produce can be used with KENO-VI which is in the CSAS6 family of codes. Some of these applications are described in the following subsections.

C6.5.3.1 Create a Microscopic, AMPX Working Format, Cross-Section Library for Use by KENO-VI

This example demonstrates the use of CSASN to create a microscopic, AMPX working format library on unit 4. KENO-VI can be executed as part of the same job and use the created cross sections, or the cross-section data set on unit 4 can be saved for later use. It should be noted that the cross-section library created by CSASN is a problem-dependent cross-section library containing only those nuclides specified in the problem. The resonance corrections applied to these cross sections are appropriate only for the specified problem. A simple demonstration of the use of CSASN to create the library and its use by KENO-VI is given in example 1.

EXAMPLE 1

Consider a problem consisting of four uranium metal cylinders that are 93.2% wt enriched, having a density of 18.76 g/cc. The cylinders are arranged in a 2 x 2 x 2 array. Each has a radius of 5.748 cm and a height of 10.765 cm. The center-to-center spacing in the horizontal plane (X-Y) is 13.74 cm, and the vertical center-to-center spacing is 13.01 cm. Use CSASN to create the microscopic, AMPX working format library for use by KENO-VI. The input data for this problem are:

```
=CSASN
CREATE A MICROSCOPIC AMPX WORKING FMT LIBRARY FOR 2C8
HANSEN-ROACH    INFHOMMEDIUM
URANIUM  1 DEN=18.76 1 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
END COMP
END
=KENOVI
KENO-VI SAMPLE PROBLEM 1    CASE 2C8 BARE
READ PARAMETERS  TME=1.0 FLX=YES FDN=YES FAR=YES LIB=4
END PARAMETERS
READ MIXT MIX=1 92235 4.48006-2 92238 2.6578-3 92234 4.827-4
92236 9.57-5 END MIXT
READ GEOMETRY
UNIT 1
CYLINDER 10  5.748 5.3825 -5.3825
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
GLOBAL UNIT 2
CUBOID  10  4P13.74  2P13.01
ARRAY  1 10 PLACE 1 1 1 -6.87 -6.87 -6.505
BOUNDARY  10
END GEOMETRY
READ ARRAY ARA=1  NUX=2 NUY=2 NUZ=2 FILL F1 END FILL
END ARRAY
END DATA
END
```

Note that the KENO-VI data given above are the same as those given in Section C6.5.2.1 except (1) the parameter data specify LIB=4 to instruct KENO-VI where to obtain the cross-section library and (2) the mixing table data must be supplied to KENO-VI. The number densities in the above data were hand-calculated. An easy method of obtaining the mixing table is to run the CSASN problem with PARM=CHECK, capture the output, and delete everything except the mixing table, which is shown in Fig. C6.5.1. This mixing table can then be edited into the correct format for the KENO-VI mixing table as shown in Figs. C6.5.2 and C6.5.3. Either of these mixing tables can be used in the place of the mixing table shown in example 1.

MIXTURE NO.	NUCLIDE NO.	ATOM DENSITY	N.I.T. POINTER
1	1092235	4.48072E-02	274
1	1092238	2.65827E-03	276
1	1092234	4.82825E-04	273
1	1092236	9.57448E-05	275

Figure C6.5.1 Mixing table from CSASN with PARM=CHECK

```
READ MIXT
MIX=1          1092235  4.48072E-02
               1092238  2.65827E-03
               1092234  4.82825E-04
               1092236  9.57448E-05
END MIXT
```

Figure C6.5.2 Mixing table from CSASN edited to KENO-VI format

```
READ MIXT
  MIX=1  1092235      4.48072E-02
  MIX=1  1092238      2.65827E-03
  MIX=1  1092234      4.82825E-04
  MIX=1  1092236      9.57448E-05
END MIXT
```

Figure C6.5.3 Mixing table from CSASN edited to KENO-VI format

C6.5.3.2 Create a Microscopic, Cell-Weighted, AMPX Working Format, Cross-Section Library

EXAMPLE 1. Use CSAS1X to create a microscopic cell-weighted library.

This example demonstrates the use of CSAS1X to create a microscopic, cell-weighted, AMPX working format, cross-section library for use with KENO-VI. CSAS1X produces the microscopic, cell-weighted AMPX working format library on unit 3. All nuclides that are used in the mixtures specified in the unit cell are flux- weighted according to the characteristics of the unit cell and therefore should not be used in any mixtures utilized in KENO-VI other than the cell-weighted mixture. To utilize this cross-section library in KENO-VI, LIB=3 must be specified in the parameter data and an appropriate mixing table must be supplied. The input data for a CSAS1X problem follow:

```
=CSAS1X
PWR 15X15 LATTICECELL CALCULATION AT OPER. T&P
HANSEN-ROACH  LATTICECELL
UO2  1 0.95 1000.0 92235 3.3 92238 96.7 END
ZIRCALLOY  2 1.0 605.0 END
H2O  3 0.719 581.0 END
END COMP
SQUAREPITCH  1.430 0.92964 1 3 1.07188 2 0.94844 0 END
END
```

Because the printed mixing tables from CSASN and CSAS1X with PARM=CHECK do not contain mixing table data for the cell-weighted mixture, the number densities can be calculated by hand or another sequence (CSASIX or CSAS26X with PARM=CHECK) can be used to obtain the mixing table.

EXAMPLE 2. Use CSASIX to create a microscopic cell-weighted library.

A microscopic, cell-weighted, AMPX format library is created on unit 3 when CSASIX is run. The number densities of the cell-weighted mixture are volume averaged. To obtain the mixing table, CSASIX can be run with PARM=CHECK. The second mixing table (labeled COMPLETE MIXING TABLE) will contain the data for the cell-weighted mixture, but the mixture number will not be designated as mixture 500. Instead, it will be one larger than the largest mixture specified in the standard compositions data for the problem. In example 2, the cell-weighted mixture will be designated as mixture 4 in the complete mixing table. The CSASIX data are the following:

```
=CSASIX
PWR 15X15 LATTICECELL CALCULATION AT OPER. T&P
HANSEN-ROACH  LATTICECELL
UO2  1 0.95 1000.0 92235 3.3 92238 96.7 END
ZIRCALLOY  2 1.0 605.0 END
H2O  3 0.719 581.0 END
END COMP
SQUAREPITCH  1.430 0.92964 1 3 1.07188 2 0.94844 0 END
END
```

The second mixing table from CSASIX is shown in Fig. C6.5.4. In this problem, mixtures 1, 2, and 3 are the only mixtures defined in the input data, and all of them are used in the unit cell description. The cell-weighted mixture is always one larger than the largest defined mixture number; in this case the cell-weighted mixture is mixture 4. All of the mixtures defined in the standard compositions data are used in the unit cell description. Therefore, all of the nuclides used in this problem are cell-weighted, and it is not valid to use them in any mixture other than the cell-weighted mixture. In Fig. C6.5.5, the cell-weighted mixture is mixture 4. In KENO-VI, LIB=3 must be specified in the parameter data in order to access the cell-weighted cross sections. The cell-weighted mixture is usually defined as mixture 500 in KENO-VI.

The mixing table shown in Fig. C6.5.4 can be edited for use in KENO-VI as shown in Fig. C6.5.5. Because mixtures 1, 2, and 3 were used in the unit cell description, they should not be used in KENO-VI. The mixing table shown in Fig. C6.5.4 can be edited by eliminating the ENTRY column and inserting MIX= in front of each mixture number, and inserting a READ MIXT at the beginning of the data and an END MIXT at the end of the data. Since mixtures 1, 2, and 3 should not be used in KENO-VI, they can be edited out as shown in Fig. C6.5.5, or they can be left in the mixing table and not used in the KENO-VI geometry. It should be noted that the easiest way to use a cell-weighted mixture in KENO-VI is to run CSAS26X and utilize mixture number 500 to designate the cell-weighted mixture in the KENO-VI geometry data so the user does not need to create a mixing table.

COMPLETE MIXING TABLE

MIXTURE NO.	NUCLIDE NO.	ATOM DENSITY
1	1092235	7.76007E-04
4	1092235	2.57581E-04
1	1092238	2.24522E-02
4	1092238	7.45257E-03
1	1008016	4.64564E-02
4	1008016	1.54203E-02
3	3008016	2.39971E-02
4	3008016	1.34078E-02
2	2040302	4.25156E-02
4	2040302	4.07230E-03
3	3001001	4.79943E-02
4	3001001	2.68156E-02

Figure C6.5.4 Second mixing table from CSASIX

READ MIXT	MIX=500
1092235	2.57581E-04
1092238	7.45257E-03
1008016	1.54203E-02
3008016	1.34078E-02
2040302	4.07230E-03
3001001	2.68156E-02
END MIXT	

Figure C6.5.5 Mixing table from CSASIX edited to KENO-VI format

EXAMPLE 3. Use CSASIX to create a microscopic cell-weighted library with extra mixtures.

This example is identical to example 2 except water and Zircaloy are to be used in the KENO-VI geometry description in addition to the cell-weighted mixture. The temperature of this water and Zircaloy is 450 K. Note that even if the temperatures of the water and Zircaloy were identical to the temperatures specified for the mixtures that are used in the LATTICECELL description, they would have to be specified again with a different mixture number in order to use them in the KENO-VI geometry data. The input data for this example are the following:

```
=CSASIX
PWR 15X15 LATTICECELL CALCULATION AT OPER. T&P
HANSEN-ROACH  LATTICECELL
UO2  1 0.95 1000.0 92235 3.3 92238 96.7 END
ZIRCALLOY  2 1.0 605.0 END
H2O  3 0.719 581.0 END
ZIRCALLOY  4 1.0 450.0 END
H2O  5 0.847 450.0 END
END COMP
```

```
SQUAREPITCH  1.430 0.92964 1 3 1.07188 2 0.94844 0 END
END
```

In this example, the cell-weighted mixture will be identified as mixture 7. The mixing tables from CSASIX are shown in Fig. C6.5.6.

MIXING TABLE FROM STANDARD COMPOSITIONS DATA

MIXTURE NO.	NUCLIDE NO.	ATOM DENSITY	N.I.T. POINTER
1	1092235	7.76007E-04	274
1	1092238	2.24522E-02	276
1	1008016	4.64564E-02	21
3	3008016	2.39971E-02	21
5	5008016	2.39971E-02	21
2	2040302	4.25156E-02	95
4	4040302	4.25156E-02	95
3	3001001	4.79943E-02	4
5	5001001	4.79943E-02	4

COMPLETE MIXING TABLE

MIXTURE NO.	NUCLIDE NO.	ATOM DENSITY
1	1092235	7.76007E-04
6	1092235	2.57581E-04
1	1092238	2.24522E-02
6	1092238	7.45257E-03
1	1008016	4.64564E-02
6	1008016	1.54203E-02
3	3008016	2.39971E-02
6	3008016	1.34078E-02
5	5008016	2.82692E-02
2	2040302	4.25156E-02
6	2040302	4.07230E-03
4	4040302	4.25156E-02
3	3001001	4.79943E-02
6	3001001	2.68156E-02
5	5001001	5.65385E-02

Figure C6.5.6 Mixing tables from CSASIX

In order to use the microscopic, cell-weighted, cross-section library in KENO-VI, LIB=3 must be specified in the KENO-VI parameter data because the CSAS6 sequences whose names contain an X write the microscopic, cell-weighted, cross-section library on unit 3. The appropriate mixing table for KENO-VI can be created by capturing and editing the COMPLETE MIXING TABLE. The order of scatter should be specified in the KENO-VI mixing table. KENO-VI always defaults to P1 scattering, but CSAS6 sets the order of scattering based on the cross-section library (presently P1 for the Hansen-Roach 16-group library and P3 for all other libraries). In KENO-VI the order of scattering is set using the parameter SCT= in the mixing table data. The resultant mixing table is shown in Figs. C6.5.7 through C6.5.9 below.

```
READ MIXT       SCT=1
  MIX=1         1092235         7.76007E-04
  MIX=500       1092235         2.57581E-04
  MIX=1         1092238         2.24522E-02
  MIX=500       1092238         7.45257E-03
  MIX=1         1008016         4.64564E-02
  MIX=500       1008016         1.54203E-02
  MIX=3         3008016         2.39971E-02
  MIX=500       3008016         1.34078E-02
  MIX=5         5008016         2.82692E-02
  MIX=2         2040302         4.25156E-02
  MIX=500       2040302         4.07230E-03
  MIX=4         4040302         4.25156E-02
  MIX=3         3001001         4.79943E-02
  MIX=500       3001001         2.68156E-02
  MIX=5         5001001         5.65385E-02
END MIXT
```

Figure C6.5.7 KENO-VI mixing table using all CSASIX entries

In Fig. C6.5.7 all of the entries from the CSASIX COMPLETE MIXING TABLE have been edited to conform to the KENO-VI format. In the CSASIX output, mixture 6 is the cell-weighted mixture. Its mixture number has been changed to 500, but it is not necessary to do so. CSASIX and CSAS26X automatically label the cell-weighted mixture cross section as mixture 500 on the macroscopic, cross-section library. This example arbitrarily redefined mixture 6 to be mixture 500 so a user would recognize that cell-weighted cross sections were used in the geometry. MIXTURES 1, 2, AND 3 SHOULD NOT BE USED IN THE KENO-VI GEOMETRY DATA BECAUSE THEY HAVE BEEN FLUX-WEIGHTED OVER THE CELL TO CREATE A CELL-WEIGHTED CROSS SECTION THAT ALLOWS THE HETEROGENEOUS SYSTEM TO BE REPRESENTED AS A HOMOGENEOUS MATERIAL.

```
READ MIXT       SCT=1
 MIX=500        1092235     2.57581E-04
 MIX=500        1092238     7.45257E-03
 MIX=500        1008016     1.54203E-02
 MIX=500        3008016     1.34078E-02
 MIX=5          5008016     2.82692E-02
 MIX=500        2040302     4.07230E-03
 MIX=4          4040302     4.25156E-02
 MIX=500        3001001     2.68156E-02
 MIX=5          5001001     5.65385E-02
END MIXT
```

Figure C6.5.8 KENO-VI mixing table using only mixtures 4, 5 and 6 from CSASIX

In Fig C6.5.8, mixtures 1, 2, and 3 have been removed because they should not be used in the KENO-VI geometry description.

```
READ MIXT       SCT=1
 MIX=4          4040302     4.25156E-02
 MIX=5          5008016     2.82692E-02
                5001001     5.65385E-02
 MIX=500        1092235     2.57581E-04
                1092238     7.45257E-03
                1008016     1.54203E-02
                3008016     1.34078E-02
                2040302     4.07230E-03
                3001001     2.68156E-02
END MIXT
```

Figure C6.5.9 Condensed KENO-VI mixing table using only mixtures 4, 5, and 6 from CSASIX

The mixing table shown in Fig. C6.5.9 has been abbreviated by reordering the data to group all of the components of a mixture together and specifying the mixture number only once for each mixture.

C6.5.3.3 Create a Macroscopic, AMPX Working Format, Cross-Section Library and a Macroscopic, MORSE/KENO, Cross-Section Library

Example 1 illustrates the use of CSASI to produce a macroscopic, AMPX working format, cross-section library on unit 2 for use by KENO-VI. The ID numbers in this library are the mixtures specified in the standard composition data. To utilize this library in KENO-VI, LIB=2 must be entered in the parameter data, and a mixing table must be provided. The mixing table nuclide ID numbers are the mixture numbers used in the CSASI problem. The number density is a multiplication factor applied to the macroscopic cross sections. Entering a number density of 1.0 causes the cross sections to remain unchanged. Consider a CSASI problem that defines three mixtures and mixture 2 is full-density water. If KENO-VI is to use these cross sections and

needs to use half-density water in addition to all of the other defined mixtures, mixture 4 can be defined as half-density water, and the mixing table for KENO-VI would be:

```
READ MIXT MIX=1 1 1.0 MIX=2 2 1.0 MIX=3 3 1.0 MIX=4 2 0.5 END MIXT
```

LIB=2 would be entered in the parameter data.

EXAMPLE 1

Consider a problem that consists of four 20.96-kg, 93.2% enriched uranium metal cylinders, density 18.76 g/cc, and four 5-liter Plexiglas bottles filled with highly enriched uranyl nitrate solution at 415 g/l, a specific gravity of 1.555, and 0.39 mg of excess nitrate per gram of solution. The isotopic content of the uranium metal is 93.2% wt ^{235}U, 5.6% wt ^{238}U, 1.0% wt ^{234}U, and 0.2% wt ^{236}U. The uranium isotopic content of the nitrate solution is 92.6% wt ^{235}U, 5.9% wt ^{238}U, 1.0% wt ^{234}U, and 0.5% wt ^{236}U. Each metal unit has a diameter of 11.496 cm, a height of 10.765 cm, and an edge-to-edge spacing of 1.684 cm horizontally and 1.685 cm vertically. The uranyl nitrate solution is contained in a Plexiglas cylinder having an ID of 19.05 cm and an inside height of 17.78 cm. The Plexiglas walls are 0.635 cm thick. The solution units have an edge-to-edge spacing of 1.43 cm horizontally and vertically. The center-to-center spacing between the metal and solution units is 17.465 cm.

CSASI creates a macroscopic, AMPX working format library on unit 2 and a macroscopic, MORSE/KENO library on unit 14. To use the macroscopic, AMPX working format library in KENO-VI, enter LIB=2 in the parameter data, and enter the following mixing table:

```
READ MIXT MIX=1 1 1.0 MIX=2 2 1.0 MIX=3 3 1.0 END MIXT
```

The total input data to run CSASI, followed by KENO-VI are given below:

```
=CSASI
SET UP 4AQUEOUS 4 METAL IN CSAS26
HANSEN-ROACH    INFHOMMEDIUM
URANIUM         1 0.985 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
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
PLEXIGLAS       3 END
END COMP
END
=KENOVI
KENO VI    4 AQUEOUS 4 METAL MIXED UNITS USING CSASI MACRO WORKING LIBR
READ PARAM  FLX=YES FDN=YES  TME=2.0 LIB=2
END PARAM
READ MIXT MIX=1 1 1.0 MIX=2 2 1.0 MIX=3 3 1.0 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  20  -10
MEDIA  0  1  30  -20
BOUNDARY  30
UNIT  2
CYLINDER  10  5.748 5.3825 -5.3825
CUBOID      10  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      10  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      10  6.59 -15.16 6.59 -15.16 14.255 -6.225
MEDIA  1  0  10
MEDIA  0  1  20  -10
BOUNDARY  20
UNIT  5
CYLINDER  10  5.748 5.3825 -5.3825
CUBOID      10  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 NUY=2 NUZ=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
END DATA
END
```

Example 2 illustrates the use of CSASI to produce a macroscopic, MORSE/KENO format, cross-section library on unit 14 for use by KENO-VI. The ID numbers in this library are the mixtures specified in the standard composition data. To utilize this library in KENO-VI, XSC=14 must be entered in the parameter data, and a mixing table is not provided. The mixtures used in the KENO-VI geometry must correspond to the mixtures defined in the CSASI data.

EXAMPLE 2

Consider the problem described in example 1. Produce a macroscopic, MORSE/KENO format, cross-section library on unit 14 for use by KENO-VI. To utilize this library in KENO-VI, XSC=14 must be entered in the parameter data, and a mixing table is not provided. The mixture numbers used in the KENO-VI geometry must correspond to the mixtures defined in the standard composition data of CSASI. The input data required to run this problem are the following:

```
=CSASI
SET UP 4AQUEOUS 4 METAL IN CSAS26
HANSEN-ROACH    INFHOMMEDIUM
URANIUM         1 0.985 293  92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
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
PLEXIGLAS       3 END
END COMP
END
=KENOVI
KENO-VI   4 AQUEOUS 4 METAL MIXED UNITS USING CSASI MACRO WORKING LIBR
READ PARAM  FLX=YES FDN=YES  TME=2.0 XSC=14
END PARAM
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  20  -10
MEDIA  0  1  30  -20
BOUNDARY  30
UNIT  2
CYLINDER  10  5.748 5.3825 -5.3825
CUBOID      10  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      10  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      10  6.59 -15.16 6.59 -15.16 14.255 -6.225
MEDIA  1  0  10
MEDIA  0  1  20  -10
BOUNDARY  20
UNIT  5
CYLINDER  10  5.748 5.3825 -5.3825
CUBOID      10  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 NUY=2 NUZ=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
END DATA
END
```

The cross-section libraries created by CSASI are

1. a macroscopic AMPX working format library on unit 2,
2. a macroscopic MORSE/KENO format library on unit 14, and
3. a microscopic AMPX working format library on unit 4.

C6.5.3.4 Create a Macroscopic, Cell-Weighted, AMPX Working Format Library and a Macroscopic, Cell-Weighted, MORSE/KENO Library

This section illustrates the use of CSASIX to produce cell-weighted, macroscopic libraries for use with a subsequent code. The problem-dependent cross-section libraries created by CSASIX are:

1. A macroscopic, cell-weighted, AMPX working format library on unit 2.
   To use this library in KENO-VI, set LIB=2 in the parameter data and enter a mixing table using the mixture numbers as the nuclide ID's and number densities of 1.0.

2. A microscopic, cell-weighted, AMPX working format library on unit 3.
   To use this library in KENO-VI, set LIB=3 in the parameter data and enter a mixing table using the appropriate nuclide IDs and number densities. If the cell-weighted mixture is to be used, its component nuclides and correct number densities must be included in the mixing table.

3. A microscopic, AMPX working format library on unit 4.
   To use this library in KENO-VI, set LIB=4 in the parameter data and enter the mixing table data. None of the cross sections in this library are cell weighted.

4. A macroscopic cell-weighted MORSE/KENO format library on unit 14.
   To use this library in KENO-VI, set XSC=14 in the parameter data and omit LIB. Do not provide a mixing table. The cell-weighted cross section is mixture 500.

Example 1 shows the use of the macroscopic, cell-weighted, AMPX working format library. Example 2 shows the use of the macroscopic, cell-weighted, MORSE/KENO library.

EXAMPLE 1

This example illustrates the use of CSASIX to create a cell-weighted macroscopic library for use in KENO-VI. The CSASIX data define the materials used to describe a flooded 3 × 3 array of PWR fuel assemblies. The center-to-center spacing between the assemblies is 12 cm. Each fuel assembly is a 17 × 17 array of fuel pins contained in a 0.29-cm-thick boral sheath. The fuel is 3.2% enriched UO_2, density = 10.41 g/cc. The fuel OD is 0.819 cm, the gap OD is 0.836 cm, and the clad OD is 9.50 cm. The fuel pin pitch is 1.26 cm. The fuel pin length is 375 cm.

Note that the cell-weighted macroscopic library is specified in KENO-VI by entering LIB=2 in the parameter data and entering mixing table data. The KENO-VI geometry uses mixture 500 to represent the homogenized pin cells inside each fuel assembly. Unit 1 in the geometry describes the fuel assembly and the spacing cuboid that define the center-to-center spacing between assemblies. Unit 2 defines the water-reflected array of fuel assemblies. Because mixture 3 was used in the unit cell definition in CSASIX, another water, mixture 5, was defined to be used in the KENO-VI geometry because mixtures 1, 2, and 3 have been cell-weighted and cannot be used in the geometry. The input data are the following:

```
=CSASIX
FLOODED PWR FUEL ASSEMBLY (17X17) AT ROOM TEMP
27GROUPNDF4  LATTICECELL
UO2  1  DEN=10.41 1.0 293. 92235 3.2 92238 96.8 END
ZIRCALLOY  2  1.0  END
H2O  3  1.0  END
ARBMTL-B4C  2.64  2  1  1  0  5000  4  6012  1  4  0.015  END
ARBMTL-AL  2.64  1  0  0  0  13027  100.0  4  0.985  END
H2O    5  1.0  END
END COMP
SQUAREPITCH  1.26 0.819 1 3 0.950 2 0.836 0 END
```

```
END
=KENOVI
3 X 3 ARRAY OF FLOODED FUEL ASSEMBLIES
READ PARAM LIB=2  TME=5.0  END PARAM
READ MIXT MIX=1 1 1.0 MIX=2 2 1.0 MIX=3 3 1.0 MIX=4 4 1.0 MIX=5 5 1.0
END MIXT
READ GEOM
UNIT 1
COM='HOMOGENIZED FUEL ASSEMBLY'
CUBOID  10  4P10.71 375.0 0.0
CUBOID  20  4P11.0  375.29 -0.29
CUBOID  30  4P12.0  375.29 -0.29
MEDIA  500  1  10
MEDIA  4  1  20  -10
MEDIA  5  1  30  -20  -10
BOUNDARY  30
GLOBAL UNIT 2
COM='WATER REFLECTED 3X3 ARRAY OF FUEL ASSEMBLIES'
CUBOID    10  4P18.0  375.29  -0.29
CUBOID    20  4P21.0  378.29  -3.29
CUBOID    30  4P24.0  381.29  -6.29
CUBOID    40  4P27.0  384.29  -9.29
CUBOID    50  4P30.0  387.29  -12.29
CUBOID    60  4P33.0  390.29  -25.29
CUBOID    70  4P36.0  393.29  -18.29
CUBOID    80  4P39.0  396.29  -21.29
CUBOID    90  4P42.0  399.29  -24.29
CUBOID  100  4P45.0  402.29  -27.29
CUBOID  110  4P48.0  405.29  -30.29
ARRAY  1  10  PLACE 2  2  1  3*0.0
MEDIA  5  2      20    -10
MEDIA  5  3      30    -20
MEDIA  5  4      40    -30
MEDIA  5  5      50    -40
MEDIA  5  6      60    -50
MEDIA  5  7      70    -60
MEDIA  5  8      80    -70
MEDIA  5  9      90    -80
MEDIA  5  10  100    -90
MEDIA  5  11  110  -100
BOUNDARY  110
END GEOM
READ ARRAY  ARA=1 NUX=3 NUY=3 NUZ=1 FILL F1 END FILL END ARRAY
READ BIAS ID=500 2 11 END BIAS
END
```

EXAMPLE 2

This example is the same as example 1 except the KENO-VI problem will use the macroscopic, MORSE/KENO library. The input data for CSASIX and KENO-VI are given below. Note that XSC=14 is specified in the KENO-VI data, and a mixing table is not entered. However, the mixture numbers used in the geometry correspond to the mixture numbers defined in the standard composition library. Because water, mixture 3, was used in the unit cell definition in CSASIX, another water, mixture 5, has to be defined to be used in the KENO-VI geometry because mixture 3 has been cell-weighted along with mixtures 1 and 2. The input data follow:

```
=CSASIX
FLOODED PWR FUEL ASSEMBLY (17X17) AT ROOM TEMP
```

```
27GROUPNDF4  LATTICECELL
UO2  1  DEN=10.41 1.0 293. 92235 3.2 92238 96.8 END
ZIRCALLOY  2  1.0  END
H2O  3  1.0  END
ARBMTL-B4C  2.64  2  1  1  0  5000  4  6012  1  4  0.015  END
ARBMTL-AL  2.64  1  0  0  0  13027  100.0  4  0.985  END
H2O    5  1.0  END
END COMP
SQUAREPITCH  1.26 0.819 1 3 0.950 2 0.836 0 END
END
=KENOVI
3 X 3 ARRAY OF FLOODED FUEL ASSEMBLIES USING MORSE/KENO LIBRARY
READ PARAM XSC=14 TME=5.0  END PARAM
READ GEOM
UNIT 1
COM='HOMOGENIZED FUEL ASSEMBLY'
CUBOID  10  4P10.71 375.0 0.0
CUBOID  20  4P11.0  375.29 -0.29
CUBOID  30  4P12.0  375.29 -0.29
MEDIA  500  1  10
MEDIA  4  1  20  -10
MEDIA  5  1  30  -20  -10
BOUNDARY  30
GLOBAL UNIT 2
COM='WATER REFLECTED 3X3 ARRAY OF FUEL ASSEMBLIES'
CUBOID    10  4P18.0  375.29  -0.29
CUBOID    20  4P21.0  378.29  -3.29
CUBOID    30  4P24.0  381.29  -6.29
CUBOID    40  4P27.0  384.29  -9.29
CUBOID    50  4P30.0  387.29  -12.29
CUBOID    60  4P33.0  390.29  -25.29
CUBOID    70  4P36.0  393.29  -18.29
CUBOID    80  4P39.0  396.29  -21.29
CUBOID    90  4P42.0  399.29  -24.29
CUBOID   100  4P45.0  402.29  -27.29
CUBOID   110  4P48.0  405.29  -30.29
ARRAY  1  10  PLACE 2  2  1  3*0.0
MEDIA  5  2      20    -10
MEDIA  5  3      30    -20
MEDIA  5  4      40    -30
MEDIA  5  5      50    -40
MEDIA  5  6      60    -50
MEDIA  5  7      70    -60
MEDIA  5  8      80    -70
MEDIA  5  9      90    -80
MEDIA  5  10    100    -90
MEDIA  5  11    110   -100
BOUNDARY  110
END GEOM

READ ARRAY  ARA=1 NUX=3 NUY=3 NUZ=1 FILL F1 END FILL END ARRAY
READ BIAS ID=500 2 11 END BIAS
END
```

C6.5.4 CREATE AND USE TWO CELL-WEIGHTED MIXTURES IN A PROBLEM

Consider a problem in which a stainless steel cylinder with an ID of 56 cm and an inside height of 91 cm is filled with pellets of UO_2 in borated water. The steel is 0.125 cm thick. The spherical 2.57%-enriched UO_2 pellets have a diameter of 1.07 cm and are arranged in a triangular pitch array with a pitch of

1.13 cm. The spherical 2.96%-enriched UO_2 pellets have a diameter of 1.07 cm and are arranged in a triangular pitch array with a pitch of 1.12 cm. The cylindrical tank is filled half full of the 2.96% pellets in borated water, and the remainder is filled with the 2.57%-enriched pellets in borated water.

Example 1 demonstrates how this problem can be calculated by running a CSASIX case for each of the pellet arrays, combining the macroscopic, AMPX working format, cell-weighted libraries using the AMPX module WAX to combine the two libraries. The combined AMPX working format library can then be used to run the KENO-VI problem. It should be noted that this procedure cannot be stacked together to run in a single SCALE execution because the second CSASIX would destroy the library created by the first CSASIX. Example 2 demonstrates how to add an additional WAX step to move the library created by the first CSASIX so that the steps can be stacked together to run in a single SCALE execution.

EXAMPLE 1

STEP 1. Run CSASIX to obtain a macroscopic, cell-weighted, AMPX working format library on unit 2. The mixture 500 on this library represents the 2.57%- enriched pellets in borated water. The input data for this step are given below. The user must save the library that is created on unit 2. The input data are

```
=CSASIX
2.57% ENR UO2 PELLETS IN 3500 PPM BORATED WATER
27GROUPNDF4  LATTICECELL
UO2    1  .925  283 92235 2.57 92238 97.43 END
H2O  2 1.0 283 END
ARBMBACID  2.0017-2 3 1 1 0 5000 1 1001 3 8016 3  2  1.0
         283 5010 18.32 5011 81.68 END
END COMP
SPHTRIANGP 1.13 1.07  1  2 END
END
```

STEP 2. Run CSASIX to obtain a macroscopic, cell-weighted, AMPX working format library on unit 2. The mixture 500 on this library represents the 2.96%-enriched pellets in borated water. The input data for this step are given below. The user must save the library that is created on unit 2. Note that the problem that is to be run by KENO-VI must have stainless steel available to define the cylindrical container. Therefore, stainless steel must be defined in one of the CSASIX problems. The input data are the following:

```
=CSASIX
2.96% ENR UO2 PELLETS IN 3500 PPM BORATED WATER
27GROUPNDF4  LATTICECELL
UO2    1  .925  283 92235 2.96 92238 97.04 END
H2O  2 1.0 283 END
ARBMBACID  2.0017-2 3 1 1 0 5000 1 1001 3 8016 3  2  1.0
         283 5010 18.32 5011 81.68 END
SS304 3 1.0 283 END
END COMP
SPHTRIANGP 1.12   1.07  1  2 END
END
```

STEP 3. Run WAX to combine the macroscopic, cell-weighted, AMPX working format libraries and rename the mixture 500s to distinguish between them. In this case, mixture 500 for the 2.57%-enriched pellets has been renamed to 501 and mixture 500 for the 2.96%-enriched pellets has been renamed to 502. The 2.57% library is mounted on unit 33, the 2.96% library is mounted on unit 34, and the combined library is written out on unit 4. It is not necessary to rename both of the mixture 500s. One of them can be carried through as 500; the other one, as some other number. WAX can be used to rename all of the mixtures on the library. The cell-weighted mixture created by the CSAS modules is always mixture 500, but WAX can be used to rename it to any desired number. The mixture numbers on the WAX library are the nuclide ID numbers that must be used in the KENO-VI mixing table when multiple cell-weighted mixtures are used. The user must save the library that is created on unit 4 so that it will be available for use in KENO-VI. The input data follow:

```
=WAX
0$$ 4 34
1$$ 2   1T
2$$ 33 1  2T
3$$ 500
4$$ 501     3T
2$$ 34 2  2T
3$$ 3 500
4$$ 3 502   3T
END
```

STEP 4. Use the combined macroscopic, AMPX working format library to run KENO-VI. Use mixture 501 for the homogenized, cell-weighted, 2.57%-enriched pellets, and use mixture 502 for the homogenized, cell-weighted, 2.96%-enriched pellets. The KENO-VI data are:

```
=KENOV
PROBLEM USING TWO CELL_WEIGHTED MIXTURES (502 IS 2.96% & 501 IS 2.57%)
READ PARAM  FLX=YES LIB=4    END PARAM
READ MIXT  MIX=3 3 1.0 MIX=501 501 1.0  MIX=502 502 1.0 END MIXT
READ GEOM
GLOBAL UNIT 1
CYLINDER   10 38.0 45.5 0.0
CYLINDER   20  38.0 91.0 0.0
CYLINDER   30  38.125 91.0 -0.125
MEDIA  502  1  10
MEDIA  501  1  20  -10
MEDIA      3  1  30  -20  -10
BOUNDARY  30
END GEOM
END DATA
END
```

Alternatively, KENO-VI could have been set up to define mixtures 1 and 2 as the cell-weighted mixtures as follows:

```
=KENOV
PROBLEM USING TWO CELL_WEIGHTED MIXTURES (502 IS 2.96% & 501 IS 2.57%)
READ PARAM  FLX=YES LIB=4    END PARAM
READ MIXT  MIX=3 3 1.0 MIX=1 501 1.0  MIX=2 502 1.0 END MIXT
READ GEOM
```

```
GLOBAL UNIT 1
CYLINDER    10 38.0 45.5 0.0
CYLINDER    20  38.0 91.0 0.0
CYLINDER    30  38.125 91.0 -0.125
MEDIA  2  1  10
MEDIA  1  1  20  -10
MEDIA  3  1  30  -20  -10
END GEOM
END DATA
END
```

EXAMPLE 2

This example is the same as example 1 except a WAX step has been added to move the library created by the first CSASIX from unit 2 to unit 12 so that the steps can be stacked together and run in a single SCALE execution. Because all of the steps are stacked together, unit 12 is used instead of unit 33 because unit 12 is defined in the SCALE procedure and will be automatically passed to the next step. The SCALE input data are:

```
=CSASIX
2.57% ENR UO2 PELLETS IN 3500 PPM BORATED WATER
27GROUPNDF4  LATTICECELL
UO2     1  .925  283 92235 2.57 92238 97.43 END
H2O  2 1.0 283 END
ARBMBACID  2.0017-2 3 1 1 0 5000 1 1001 3 8016 3  2  1.0
          283 5010 18.32 5011 81.68 END
END COMP
SPHTRIANGP 1.13 1.07  1  2 END
END
=WAX
0$$ 12 2
1$$ 1   1T
2$$ 2  1  2T
3$$ 500
4$$ 500     3T
END
=CSASIX
2.96% ENR UO2 PELLETS IN 3500 PPM BORATED WATER
27GROUPNDF4  LATTICECELL
UO2     1  .925  283 92235 2.96 92238 97.04 END
H2O  2 1.0 283 END
ARBMBACID  2.0017-2 3 1 1 0 5000 1 1001 3 8016 3  2  1.0
          283 5010 18.32 5011 81.68 END
SS304 3 1.0 283 END
END COMP
SPHTRIANGP 1.12   1.07  1  2 END
END
=WAX
0$$ 4  2
1$$ 2   1T
'RENAME MIXTURE 500 TO MIXTURE 501
2$$ 12 1  2T
3$$ 500
4$$ 501     3T
'RENAME MIXTURE 500 TO MIXTURE 502.  MIXTURE 3 REMAINS MIXTURE 3
2$$ 2  2  2T
3$$ 3 500
4$$ 3 502   3T
END
=KENOV
```

```
PROBLEM USING TWO CELL-WEIGHTED MIXTURES (502 IS 2.96% & 501 IS 2.57%)
READ PARAM  FLX=YES LIB=4    END PARAM
READ MIXT  MIX=3 3 1.0 MIX=501 501 1.0  MIX=502 502 1.0 END MIXT
READ GEOM
GLOBAL UNIT 1
CYLINDER   10 38.0 45.5 0.0
CYLINDER   20  38.0 91.0 0.0
CYLINDER   30  38.125 91.0 -0.125
MEDIA  502  1  10
MEDIA  501  1  20  -10
MEDIA      3  1  30  -20  -10
END GEOM
END DATA
END
```

C6.5.5 CREATE A CELL-WEIGHTED MIXTURE REPRESENTING A NONHOMOGENEOUS FUEL ASSEMBLY

Calculate the k-effective of a 3 × 3 × 3 array of the fuel assembly shown in Fig. C6.5.10. The spacing between the assemblies is 2 cm and is filled with water. The array is reflected by 31 cm of water on all faces. Each assembly is a 15 × 15 array of fuel pins with 16 water holes and a central instrumentation hole. The fuel pins are 1.98%-enriched UO_2 at 10.138 g/cc and are 0.94 cm in diameter. The active fuel length is 365.76 cm. The zircaloy-4 clad is 0.545 cm OR × 0.4875 cm IR. The fuel rod pitch is 1.44 cm.

The fuel assembly shrouds are 0.16-cm-thick 304 stainless steel. The IDs are 21.6 cm in cross section. The interstices between the rods are filled with water.

To obtain the correct cell-weighted cross sections for this assembly, run CSASIX to define the cell-weighted fuel pin cell. Then run XSDRNPM to account for the water holes.

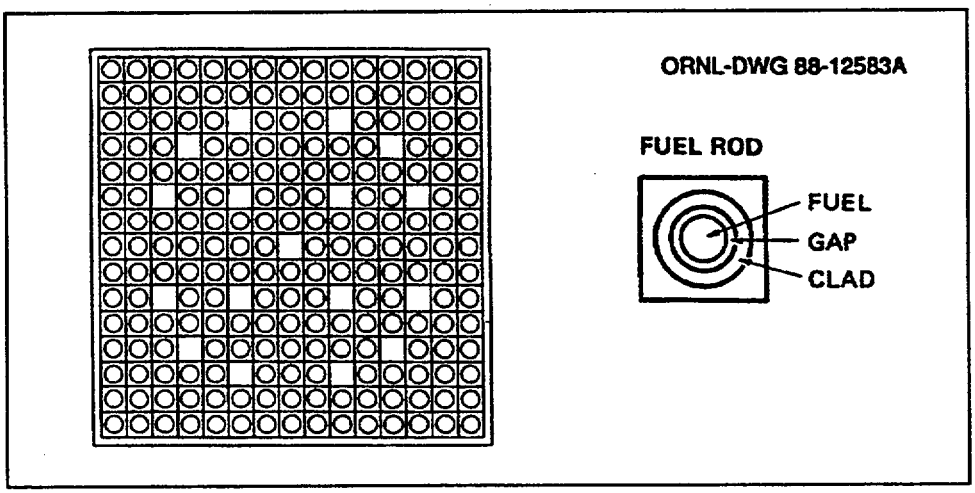


Figure C6.5.10 1.98% enriched UO_2 fuel assembly

The input data for CSASIX are given below. Mixtures 1, 2, and 3 are used in the unit cell description, causing them to be cell-weighted and therefore unacceptable for use by a subsequent code. The cross sections for the

stainless steel shroud and water holes must be defined so they will be available for use by a subsequent code, XSDRNPM in this case. Mixture 4 is the stainless steel for the fuel assembly shroud, and mixture 5 is the water for the instrumentation hole and water holes. XSDRNPM will create a cell-weighted cross section representing the interior of the fuel assembly. This procedure will use the cell-weighted cross section from CSASIX and the mixture 5 water. Therefore mixture 5 will be cell-weighted and cannot be used in a subsequent code. Since water is to be used in the KENO-VI calculation that uses the cell-weighted cross sections from XSDRNPM, a mixture 6 that is identical to mixtures 3 and 5 must be added to the CSASIX data. The input data follow:

```
=CSASIX
CREATE CELL WEIGHTED CROSS SECTION FOR FUEL PIN CELL
27GROUPNDF4  LATTICECELL
UO2         1 .925    293 92235 1.98 92238 98.02 END
ZIRCALLOY   2 1.0     293 END
H2O         3 1.0     293 END
SS304       4 1.0     293 END
H2O         5 1.0     293 END
H2O         6 1.0     293 END
END COMP
SQUAREPITCH  1.44 .94 1 3 1.09 2 .975 0 END
END
```

The input data for XSDRNPM are given below. Each assembly contains 225 units, 17 of which are water holes (the instrumentation hole is treated as a water hole). The geometry for XSDRNPM is an infinite cylinder of water having an area equal to the area of the central instrumentation hole. The ratio of fuel to water in the assembly is (225-17)/17; so the area of the fuel region surrounding the water is (225-17)/17 times the area of the water region. The OR of the water hole is 0.81243 cm, and the OR of the fuel region is 2.95566 cm. XSDRNPM will use the macroscopic, cell-weighted, cross-section library that was created by CSASIX on unit 2 and will create a new macroscopic cell-weighted cross-section library on unit 3 as specified in the 0$$ array. Note that XSDRNPM will process only those mixtures that are used in the problem. All mixtures that are to be passed through XSDRNPM for use by a subsequent code must be included in every mixture used in XSDRNPM and should have a very small number density (1.0-20). Therefore, mixtures 4 and 6 must be added to both the water (mixture 5 from CSASIX) and the cell-weighted pin cell mixture (mixture 500 from CSASIX) with a negligible number density. The macroscopic, cell-weighted, cross-section library from CSASIX is read from unit 2, and the resultant cell-weighted cross-section library is written on unit 3. The 3$$ array must specify that a weighting calculation is to be done.

```
=XSDRNPM
USE CELL WTD PIN CELL XSECS AND CREATE CELL WTD FUEL ASSMBLY XSECS
0$$ A3 2 E
1$$  2 2 20 1 3 4 6 8 3 1 E
2$$  A7 -1 E
3$$  1 E
4$$  -1 27 E  1T
13$$   1   2  1 2 1 2
14$$   5 500  4 4 6 6
15** 1.0 1.0  4R1.-20   2T
33## F1.0 4T
35** 9I0 9I0.812433 2.95566
36$$ 10R1 10R2
51$$ 25I1 27 5T
END
```

The input data for KENO-VI are given below. The cell-weighted cross-section library is read from unit 3. This library contains mixtures 5, 500, 4, and 6. Mixtures 5 and 500 have been cell-weighted to represent the heterogeneous fuel assembly. To create a cell-weighted mixture that represents the fuel assembly, the number densities associated with mixtures 5 and 500 are their respective volume fractions in the fuel assembly. In this problem, mixture 1 is the homogenized fuel assembly mixture. Mixture 4 is the stainless steel shroud, and mixture 6 is water. The number density is 1.0 for mixtures 4 and 6.

```
=KENOVI
WATER REFLECTED 3X3X3 ARRAY OF HOMOGENIZED FUEL ASSEMBLIES
READ PARAM LIB=3 TME=10 END PARAM
READ MIXT MIX=1 5 0.075556 500 0.924444  MIX=4 4 1.0 MIX=6 6 1.0 END MIXT
READ GEOM
UNIT 1
COM='CELL-WEIGHTED HOMOGENIZED FUEL ASSEMBLY WITH ZIRCALLOY SHROUD
AND H2O'
CUBOID  10  4P10.8 365.76 0.0
CUBOID  20  4P10.96  365.92  -0.16
CUBOID  30  4P11.96  366.92  -1.16
MEDIA  1  1  10
MEDIA  4  1  20  -10
MEDIA  6  1  30  -20
BOUNDARY  30
GLOBAL UNIT 2
CUBOID  10  4P32.88  735.5  -369.24
CUBOID  20  4P62.88  765.5  -399.24
ARRAY  1  10  PLACE  2  2  2  3*0.0
MEDIA  6  1  20  -10
BOUNDARY  20
END GEOM
READ ARRAY NUX=3 NUY=3 NUZ=3 FILL F1 END FILL END ARRAY
END DATA
END
```

C6.6 DESCRIPTION OF OUTPUT

This section describes the output from the CSAS6 control sequences. The output files that are created when the CSAS6 control sequences are executed consist of (1) output from the control module, (2) output from the functional modules invoked by the control module, and (3) a listing of the input data. The order in which these output files appear is system dependent. If PARM=CHECK is specified on the analytical sequence indicator, there will be no output from the functional modules. The output files from the functional modules are described in the section pertaining to the module (see Table C6.6.1).

Table C6.6.1 Location of functional module output

Functional module	Section
BONAMI	F1.6
NITAWL-II	F2.8.2
XSDRN	F3.7
ICE	F8.5
KENO-VI	F17.6

C6.6.1 CONTROL MODULE HEADER PAGE

The control module header page, shown in Fig. C6.6.1, prints the name of the control module in block letters. The job name from the job control language, the date (month/day.year), and the time at execution (hour:minute:second) are also printed. This time is given in terms of a 24-h clock, with midnight being 2400 h.

Figure C6.6.1 Sample control module header page

C6.6.2 CONTROL MODULE PROGRAM VERIFICATION TABLE

The control module program verification information table, shown in Fig. C6.6.2, is printed after the header page. It lists the name of the control module that is being executed, 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. Some computers do not store load modules in a library, in which case the library entry is left blank. The job name, date, and time of execution are also printed. This information may be useful for quality assurance purposes.

```
*****                                                                        *****
*****                  PROGRAM VERIFICATION INFORMATION                      *****
*****                CODE SYSTEM:    SCALE  VERSION:    4.2                 *****
*****                                                                        *****

                PROGRAM:  CSAS6
          CREATION DATE:  06/27/95
                LIBRARY:  /SCALE/EXE

        PRODUCTION CODE:  CSAS6
                VERSION:  2.0
                JOBNAME:  DFZ
      DATE OF EXECUTION:  06/28/95
      TIME OF EXECUTION:  08:53:12
```

Figure C6.6.2 Sample control module program verification table

C6.6.3 MATERIAL INFORMATION PROCESSOR OUTPUT

The Material Information Processor output is printed immediately after the program verification table. This output is discussed in detail in Sections M7.6.1 through M7.6.6. An example of this output is given in Figs. C6.6.3 and C6.6.4.

```
 SAMPLE PROBLEM 1  CASE 2C8 BARE

**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX             1 MIXTURES
MSC             1 COMPOSITION SPECIFICATIONS
IZM             1 MATERIAL ZONES
GE  INFHOMMEDIUM GEOMETRY
MORE            0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
MSLN            0 FUEL SOLUTIONS

**** PROBLEM COMPOSITION DESCRIPTION ****

SC  URANIUM      STANDARD COMPOSITION
MX              1 MIXTURE NO.
VF         1.0000 VOLUME FRACTION
ROTH      18.7600 SPECIFIED DENSITY
NEL             1 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
TEMP        293.0 DEG KELVIN
            92000       1.00 ATOM/MOLECULE
                                92235     93.200 WT%
                                92238      5.600 WT%
                                92234      1.000 WT%
                                92236       .200 WT%
END

**** PROBLEM GEOMETRY ****

**** INFINITE HOMOGENEOUS MEDIUM ****
MFUEL           1 MIXTURE NO. OF THE INFINITE HOMOGENEOUS MEDIUM
```

Figure C6.6.3 Part 1 of Material Information Processor printout

```
                                    SAMPLE PROBLEM 1  CASE 2C8 BARE

                          ********** DATA LIBRARY INFORMATION **********

  UNIT                                          VOLUME
 NUMBER              DATA SET NAME               NAME            UNIT FUNCTION
 ------              -------------               ----            -------------

   89       /SCALE/DATALIB/SCALE.REV10.SCLIB                 STANDARD COMPOSITION LIBRARY

   82       /SCALE/DATALIB/SCALE.REV04.XN27                  CROSS SECTION LIBRARY

   11       FT11F001                                         SHORT CROSS SECTION LIBRARY

   90       FT90F001                                         INPUT DATA DIRECT ACCESS


                                  STANDARD COMPOSITION LIBRARY DATA
                                  ---------------------------------

          UNIT NUMBER  :  89

          DATASET NAME :  /SCALE/DATALIB/SCALE.REV10.SCLIB

          LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY
                          637 STANDARD COMPOSITIONS, 490 NUCLIDES
                          90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.

          CREATION DATE:   5/ 3/95


                                    CROSS SECTION LIBRARY DATA
                                    --------------------------

          UNIT NUMBER  :  82

          DATASET NAME :  /SCALE/DATALIB/SCALE.REV04.XN27

          LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
                             BASED ON ENDF-B VERSION 4 DATA
                                COMPILED FOR NRC     1/27/89
                                   LAST UPDATED                          08/12/94
                                      L.M.PETRIE   -   ORNL
```

Figure C6.6.4 Part 2 of Material Information Processor printout

C6.6.4 KENO-VI OUTPUT

Output from KENO-VI is printed if the control sequence expects to execute KENO-VI and PARM=CHECK is specified on the analytical sequence indicator. See Sects. F17.6.3 through F17.6.20 for an explanation of the KENO-VI output.

If the control sequence expects to execute KENO-VI and if PARM=CHECK is not specified on the analytical sequence indicator, the KENO-VI output consists of a set of cryptic statements indicating the number of I/Os used to process the KENO-VI data as shown in Fig. C6.6.5. On some platforms the number of I/Os used is not summed so the number of I/Os used is reported as zero.

```
........    0 IO'S WERE USED BEFORE READING KENO V DATA     ........
........    0 IO'S WERE USED READING THE KENO-VI PARAMETER DATA     ........

*************** DATA READING COMPLETED ***************
........    0 IO'S WERE USED PREPARING THE KENO-VI INPUT DATA     ........
........    0 IO'S WERE USED LOADING THE KENO-VI DATA     ........
........    0 IO'S WERE USED LOADING THE DATA     ........
........    0 IO'S WERE USED CHECKING THE KENO-VI GEOMETRY DATA     ........
*****  RESTART DATA HAS BEEN WRITTEN ON UNIT 95  *****
........    0 IO'S WERE USED WRITING THE KENO-VI - CSAS DATA     ........
........    0 IO'S WERE USED PROCESSING CSAS INPUT DATA     ........
```

Figure C6.6.5 Summary of KENO-VI I/O usage by CSAS control module

The first line of Fig. C6.6.5, the number of I/Os used before reading KENO-VI data, is always printed for the analytical sequences contained in the CSAS family of control modules. It is the only line of Fig. C6.6.5 that is printed for CSASN, CSAS1X, CSASI, and CSASIX. All other lines of Fig. C6.6.5 are printed by control modules that expect to execute KENO-VI (i.e., CSAS26 and CSAS26X).

C6.7 WARNING AND ERROR MESSAGES

CSAS6 contains two types of warning and error messages. The first type of message is from the Material Information Processor which is common to many of the SCALE analytical sequences. These messages are prefixed by MP- followed by a number. The Material Information Processor messages are listed in numerical order in Sect. C6.7.1. The second type of message pertaining to both CSAS4 and CSAS6 is identified by CS- followed by a number. These messages are listed in numerical order in Sect. C6.7.2. For additional information concerning a message, simply look up the number in this section.

Warning messages appear when a possible error is encountered. It is the responsibility of the user to verify whether or not the data are correct when a warning message is encountered. The functional modules activated by CSAS6 and related sequences will be executed even though a warning message has been generated.

When an error is recognized, an error message is written and an error flag is set so the functional modules will not be activated. The code stops immediately if the error is too severe to allow continuation of input. However, it will continue to read and check the data if it is able. When the data reading is completed, execution is terminated if an error flag was set when the data were being processed. If the error flag has not been set, execution continues. The STOP codes associated with the severe error messages are listed in Sect. C6.7.3.

C6.7.1 MATERIAL INFORMATION PROCESSOR MESSAGES

The following messages originate in the Material Information Processor, that portion of the analytical sequence that reads the parameter data, standard compositions specification data, and geometry data necessary for preparing the required information for the cross-section processing codes:

MP-1 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine KNIGHT indicates that the allocated computer storage will not hold the directories and isotope information tables. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 300 is executed when this message is printed.

MP-2 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine KNIGHT indicates that the allocated computer storage will not hold the directories and isotope information tables. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 310 is executed when this message is printed.

MP-3 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine KNIGHT indicates that the allocated computer storage will not hold the directories and isotope information tables. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 320 is executed when this message is printed.

MP-4 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine SETUPA indicates that the allocated computer storage will not hold the directories and isotope information tables. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 330 is executed when this message is printed.

MP-5 ***ERROR***SYSTEM GEOMETRY NAME INCORRECT. INSTEAD OF (____), THE USER SHOULD HAVE ENTERED LATTICECELL, MULTIREGION, OR INFHOMMEDIUM AS THE SECOND ITEM ON THE PARAMETER CARD. CHECK SPELLING.

This self-explanatory message is from subroutine SETUPB. The user has misspelled the word defining the type of calculation to be performed, or the parameter data preceding it were entered incorrectly. See Sect. C6.4.3 for assistance in correctly specifying the parameter data.

MP-6 ***ERROR*** ____ NOT FOUND IN STANDARD COMPOSITION LIBRARY. MAKE SURE THE COMPOSITION NAME USED IS IN THE STANDARD COMPOSITION LIBRARY.

This self-explanatory message from subroutine STDCMP indicates that a standard composition name is misspelled, the standard composition specification data were out of order, or the "END" has been omitted from the preceding standard composition specification. Check the standard composition specification data carefully. See Sect. C6.4.4 for assistance with standard composition specification cards. See Sect. M8 for the materials available in the Standard Composition Library.

MP-7 ***ERROR*** THE USER ENTERED A VOLUME FRACTION (VF) OF 0.0 FOR ONE OF THE STANDARD COMPOSITIONS (_____). THIS INDICATES THAT HE INTENDS TO ENTER A NUMBER DENSITY FOR THE STANDARD COMPOSITION. THAT, HOWEVER, CAN ONLY BE DONE WHEN THE STANDARD COMPOSITION NAME REPRESENTS A SINGLE NUCLIDE (LIKE H, O, PB, B-10, U-238, ETC.). CHECK THE STANDARD COMPOSITION LIBRARY.

This self-explanatory message is from subroutine STDCMP. Check the Standard Composition Library, Sect. M8, for the available standard composition names. See Sect. C6.4.4 for the correct method of specifying standard composition specification data.

MP-8 ***ERROR*** CELL TYPE NAME (_____) IS INCORRECT. CHECK THE SPELLING. THE ALLOWED NAMES ARE: SQUAREPITCH, TRIANGPITCH, SPHSQUAREP, SPHTRIANGP, SYMMSLABCELL, ASYMSLABCELL, ASQUAREPITCH, ATRIANGPITCH, ASPHSQUAREP, ASPHTRIANGP, ASQP, ATRP, ASSP, ASTP.

This self-explanatory message is from subroutine LATCEL. The data are misspelled or out of order. Some data items may be missing, or extra ones may have been entered. Errors in the standard composition specification data can cause this message to be printed. See Sect. C6.4.6 for additional assistance.

MP-9 ***ERROR*** THE NUMBER OF ZONES (IZM=_____) IS INCORRECT FOR ASYMSLABCELL GEOMETRY. FOR AN ASYMMETRIC LATTICECELL CALCULATION, ONE SHOULD HAVE IZM=3, 5, OR 7, DEPENDING ON THE MATERIALS PRESENT.

This self-explanatory message is from subroutine LATCEL. See Sect. C6.4.6 for an explanation of the ASYMSLABCELL geometry data. A code error is responsible for this message.

MP-10 ***ERROR*** INSUFFICIENT DATA SUPPLIED ON THE GEOMETRY DESCRIPTION CARD.

This message from subroutine LATCEL can be caused by having an error in the standard composition specification data, thereby causing the reading routines to get out of phase. If no error messages precede this message, it may indicate that a code error exists. The number of material zones (IZM) has been destroyed or altered in some manner.

MP-11 ***ERROR*** MIXTURE _____ IN THE CSAS GEOMETRY DESCRIPTION WAS NOT SPECIFIED IN THE STANDARD COMPOSITION DATA.

This message from subroutine LATCEL indicates that a mixture number used in the geometry description was not defined in the standard composition specification data. Check the input data for consistency. If the specified mixture number is zero and if the problem is a LATTICECELL problem using mixture zero for the clad or moderator, it will be necessary to specify a low-density mixture in the standard composition data and use it in the cell specification.

MP-12 ***ERROR*** THE GAP WAS SPECIFIED AS MIXTURE _____ ON THE LATTICECELL. IT SHOULD BE ZERO OR A VALID MIXTURE NUMBER.

This message from subroutine LATCEL indicates that the mixture number used for the GAP was not defined in the standard composition specification data. Check the input data for consistency.

MP-13 **WARNING** NUMBER OF ENTRIES ON THE GEOMETRY DESCRIPTION CARD EXCEEDS THE NUMBER EXPECTED. THIS MESSAGE MAY BE GENERATED IF THE USER FORGOT TO ENTER THE END ON THE GEOMETRY DESCRIPTION CARD.

This message from subroutine LATCEL may result from a code error or from omitting the word "END" from the geometry description card.

MP-14 ***ERROR*** THE COORDINATE SYSTEM NAME (_____) IS INCORRECT. FOR THIS MULTIREGION CALCULATION, THE USER SHOULD HAVE ENTERED SLAB, CYLINDRICAL, SPHERICAL, BUCKLEDSLAB OR BUCKLEDCYL ON THE GEOMETRY DESCRIPTION CARD. CHECK SPELLING.

This self-explanatory message is from subroutine MULTRG.

MP-15 ***ERROR*** ALPHANUMERIC DESCRIPTION OF THE RIGHT-HAND BOUNDARY CONDITION (_____) IS INCORRECT. ONLY VACUUM, REFLECTED, PERIODIC, AND WHITE BOUNDARY CONDITIONS ARE ALLOWED. CHECK SPELLING. CHECK GEOMETRY DESCRIPTION CARD INPUT INSTRUCTIONS FOR ADDITIONAL ASSISTANCE.

This self-explanatory message is from subroutine MULTRG. See Sect. C6.4.6 for additional assistance.

MP-16 ***ERROR*** ALPHANUMERIC DESCRIPTION OF THE LEFT-HAND BOUNDARY CONDITION (_____) IS INCORRECT. ONLY VACUUM, REFLECTED, PERIODIC, AND WHITE BOUNDARY CONDITIONS ARE ALLOWED IN SLAB GEOMETRY. IN THE CASE OF CYLINDRICAL OR SPHERICAL GEOMETRY, ONLY THE REFLECTED BOUNDARY CONDITION IS ALLOWED ON THE LEFT. CHECK SPELLING. CHECK GEOMETRY DESCRIPTION CARD INPUT INSTRUCTIONS FOR ADDITIONAL INSTRUCTIONS.

This self-explanatory message is from subroutine MULTRG. See Sect. C6.4.6 for additional assistance.

MP-17 ***ERROR*** MIXTURE _____ FROM THE MULTIREGION DATA WAS NOT SPECIFIED IN THE STANDARD COMPOSITION DATA.

This message is from subroutine MULTRG. It indicates that a mixture number specified in the multiregion data was not defined in the standard composition specification data. Check the input data for consistency.

MP-18 ***ERROR*** USER MADE AT LEAST _____ DATA ERRORS. PROBLEM WILL NOT BE RUN. HOPEFULLY, EACH OF THESE ERRORS WILL HAVE GENERATED ITS OWN SELF-EXPLANATORY ERROR MESSAGE. IF NOT, CHECK DATA CAREFULLY BEFORE RESUBMITTING.

This self-explanatory message is from subroutine SETUPB. Check through the problem printout and correct all errors that have occurred.

MP-19 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message is from subroutine SETUPB. It indicates that the allocated computer storage will not hold the data that must be loaded to calculate the information that must be passed to BONAMI. The first number is the amount of storage, in words, needed to hold these data. The second number is the amount of computer storage that is required to hold these data. The third number is the minimum additional words of storage required to hold these data. Subsequent portions of the program may require even more storage. Increase the region size in the "go step" of the job control language and resubmit the problem. A STOP 390 is executed when this message is printed.

MP-20 ***ERROR*** MIXTURE NUMBER ____ ON A STANDARD COMPOSITION CARD IS LESS THAN 1.

This message is from subroutine SETUPB. A mixture number specified on a standard composition specification card must always be greater than zero. This message is triggered if a MP-6 message is printed. Fixing the MP-6 error should eliminate this message. If the printed mixture number is a positive number, a code error is responsible for the message.

MP-21 ***WARNING*** STANDARD COMPOSITION CARD NUMBER _____ IMPLIES THAT MIXTURE NUMBER _____ HAS A TEMPERATURE OF _____ DEGREES KELVIN, WHEREAS STANDARD COMPOSITION SPECIFICATION CARD _____ IMPLIES THAT MIXTURE NUMBER _____ HAS A TEMPERATURE OF _____ DEGREES KELVIN. (ONE OF THESE MAY HAVE BEEN THE VALUE SPECIFIED BY DEFAULT.) THE CODE WILL ASSUME THE HIGHER OF THE TWO AND PROCEED. IF THIS IS NOT SATISFACTORY, THE USER SHOULD ENTER THE CORRECT TEMPERATURE ON EACH OF THE STANDARD COMPOSITION SPECIFICATION CARDS INDICATED.

This self-explanatory message is from subroutine SETUPB.

MP-22 **WARNING** STANDARD COMPOSITION SPECIFICATION CARD(S) MISSING FOR MIXTURE NUMBER _____.

This message from SETUPB is printed to remind the user that the mixture numbers specified in the standard composition specification data are not contiguous. This may result in wasted storage space, but is not necessarily indicative of an error.

MP-23 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine MTABLE indicates that the allocated computer storage will not hold the nuclide ID numbers that will be processed by subroutine IDENTS. 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 words of storage needed to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 340 is executed when this message is printed.

MP-24 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine MIXTAB indicates that the allocated computer storage will not hold the three mixing table arrays that will be processed by subroutine ARRAY3. 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 words of storage needed to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 350 is executed when this message is printed.

MP-25 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine MIXTAB indicates that the allocated computer storage will not hold the three mixing table arrays that will be processed by subroutine ARRAY3. 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 words of storage needed to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 360 is executed when this message is printed.

MP-26 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine MIXTAB indicates that the allocated computer storage will not hold the three mixing table arrays that will be processed by subroutine ARRAY3. 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 words of storage needed to hold the data

to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 370 is executed when this message is printed.

MP-27 ***ERROR*** THE NUMBER OF MIXTURES FOUND IN THE MIXING TABLE IS INCONSISTENT WITH THE INPUT DATA. THE NUMBER FOUND IS _____, BUT THE INPUT DATA INDICATED _____.

This message from subroutine REORDR indicates that an error was found in the mixing table during operations to reorder and load it in permanent storage. The number of mixtures found in the mixing table should be the same as the number indicated by the input data. A code error is the likely cause of this message. A STOP 380 is executed when this message is printed.

MP-28 ***ERROR*** NUCLIDE ID _____ SPECIFIED IN THE INPUT DATA WAS NOT FOUND IN THE STANDARD COMPOSITION LIBRARY.

This message is from subroutine IDENTS or subroutine SLNS. A STOP 395 is printed with this message. Check the standard compositions specification data, Sect. C6.4.4, and ensure that the "ZA" ID numbers were entered correctly. This message is also printed if an arbitrary material specifies a value other than 0 or 1 for the MULTIPLE ISOTOPE INDICATOR (IVIS in Sect. C6.4.4).

MP-29 ***ERROR*** AN ARGUMENT OF _____ IS INVALID FOR AN ARCSIN OR ARCCOS.

This message from subroutine ARCHK is indicative of a code error. ARCHK is called from subroutine DAN to ensure that proper arguments are supplied to the ARCSIN and ARCCOS functions in determining cylinder Dancoff factors. This error can be caused by specifying a center-to-center spacing that is smaller than is physically possible.

MP-30 ***ERROR*** THE MATRIX WAS SINGULAR WHEN THE NUMBER FRACTION OF AN ISOTOPE IN AN ELEMENT WAS BEING DETERMINED. MAKE SURE THE SPECIFIED ISOTOPE DISTRIBUTION (WEIGHT PERCENT) SUMS TO 100.0.

This message from subroutine NOFRAC is caused by an isotope distribution that does not sum to 100% for an element. Entry A7 of Sects. C6.4.4 or M7.4.4 illustrates the correct procedure for specifying the weight percent of the various isotopes in an element.

MP-31 ***ERROR*** THE CALCULATED NUMBER FRACTIONS DO NOT REPRODUCE THE WEIGHT PERCENTS ENTERED AS INPUT DATA OR OBTAINED FROM THE STANDARD COMPOSITION LIBRARY.

WTFRAC=nnnnnnnnnn NOFRAC=mmmmmmmmmm MASS=ℓℓℓℓℓℓℓℓℓℓ

This message is printed from subroutine NOFRAC. WTFRAC, NOFRAC, and MASS are printed for each isotope in the standard composition. WTFRAC is the specified input weight percent for the isotope converted to weight fraction instead of weight percent. NOFRAC is the adjusted atom percent converted to atom fraction for the isotope corresponding to a total weight percent of 100% for the isotopes in the standard

composition. MASS is the atomic weight of the isotope. The adjusted isotopic weight percents are not printed in MP-31 but can be calculated according to:

$$ADJ_i = \frac{NOFRAC_i \times MASS_i}{\sum_i NOFRAC_i \times MASS_i} \times 100, \qquad \text{(C6.7.1)}$$

where

ADJ_i is the adjusted weight percent of isotope i,

$NOFRAC_i$ is the number fraction of isotope i printed in MP-31,

$MASS_i$ is the atomic weight of isotope i printed in MP-31.

Message MP-31 is printed if the adjusted weight percent of an isotope differs by 0.4% or more from the isotopic weight percent specified for that particular isotope in the standard composition data. An error flag is set, and the problem will not execute. If the isotopic weight percents specified in the input data do not sum to 100%, the weight percent of the first isotope whose specified weight percent is greater than 0.1% is adjusted to force the total weight percent to sum to 100%. If this adjustment results in a calculated weight percent for that isotope that is less than 0.4% different from that specified in the input data, the problem is run using the adjusted data. If message MP-31 is printed, correct the isotopic weight percents specified in the standard composition input data to sum to 100 or specify the isotope with the largest weight percent first, and resubmit the problem.

MP-32 ***ERROR*** END COMP WAS EXPECTED, BUT _____ WAS READ INSTEAD.

This message from subroutine SETUPA is printed if the data are out of order or the keywords END COMP or END COMPOSITIONS are omitted after the last standard composition specification. An END followed by blanks is also allowed. Check the data and the spelling of the END COMP. See Sect. C6.4.4.

MP-33 ***ERROR*** END OF FILE WAS ENCOUNTERED WHILE READING MULTIREGION ZONE DESCRIPTION. VERIFY THAT THE END ZONE CARD WAS ENTERED.

This self-explanatory message from subroutine SETUPA is printed if the END ZONE is omitted following the MULTIREGION zone description data. See Sect. C6.4.7.

MP-34 ***ERROR*** END ZONE WAS EXPECTED, BUT _____ WAS READ INSTEAD.

This message from subroutine SETUPA is printed if data is out of order or the keywords END ZONE are omitted at the end of the MULTIREGION zone description data. Check the data and the spelling of the END ZONE. See Sect. C6.4.7.

MP-35 ***ERROR*** END OF FILE WAS ENCOUNTERED WHEN THE GEOMETRY DESCRIPTION CARD WAS EXPECTED.

This self-explanatory message from subroutine SETUPA is printed if data are omitted or out of order. See Sect. C6.4.

MP-36 ***ERROR*** ILLEGAL SOLUTION NAME _____. ALLOWED NAMES INCLUDE SOLNUO2F2, SOLNUO2(NO3)2 AND SOLNPU(NO3)4.

This self-explanatory message from subroutines SLNS and SLNAME is printed if a solution name is misspelled or data are out of order. See Sect. C6.4.4 for assistance in specifying solution names correctly.

MP-37 ***ERROR*** ____ IS AN INVALID NAME WHEN READING MORE DATA.

This message is printed from subroutine MOREDT when extra parameter data is to be entered as explained in Sect. C6.4.8. The data are out of order, or a parameter name is misspelled.

MP-38 ***ERROR*** INVALID GEOMETRY WORD _____. ONLY INFHOMMEDIUM, MULTIREGION, OR LATTICECELL ARE ALLOWED.

This self-explanatory message is from subroutine SETUPA. Correct the input data and resubmit the problem. Check the spelling of the geometry word, ensure that the data are in order, and resubmit the problem.

MP-39 ***WARNING*** AN END DATA WAS READ BEFORE IT WAS EXPECTED. AN END WAS PROBABLY OMITTED FROM A STANDARD COMPOSITION.

This message from subroutine SETUPA indicates that an "END" was omitted from a standard composition specification or that the END for a standard composition specification was followed by COMP. The first four characters following the END on a standard composition specification card cannot be COMP. The words END COMP terminate the standard composition specification data. Check the standard composition specification data carefully.

MP-40 ***ERROR*** NUCLIDE ID _____ IN MIXTURE _____ DOES NOT OCCUR IN THE STANDARD COMPOSITION LIBRARY.

This self-explanatory message is from subroutine REORDR. A STOP 385 is executed in conjunction with this message.

MP-41 ***ERROR*** A NUCLIDE ID OF _____ IS INVALID FOR _____ IN THE FOLLOWING STANDARD COMPOSITION SPECIFICATION.

This message from subroutine STDCMP indicates that a nuclide ID is not compatible with a standard composition name. For example: UO2 3 1 300 94240 50 94238 50 END would cause this error because plutonium is invalid for a uranium standard composition specification. If this message is printed for a solution, the specific gravity of the solution may have been entered without the required keyword SPG=.

MP-42 ***ERROR*** AN END WAS ENCOUNTERED BEFORE MORE DATA WAS COMPLETED.

This message from MOREDT indicates incomplete input for MORE DATA. See Sect. C6.4.8 or M7.4.8 for assistance.

MP-43 ***WARNING*** BAL=_____ IS AN INVALID BALANCE TABLE SPECIFICATION. ALL BALANCE TABLES WILL BE PRINTED.

This message from subroutine MOREDT indicates that the value entered following BAL= is incorrect. Available options are NONE, FINE, and ALL. If any other value is entered, this message will be printed.

MP-44 *** ERROR *** NUCLIDE _____ IS NOT A MULTIPLE ISOTOPE NUCLIDE ***ERROR***.

This message from subroutine STDCMP indicates that a value greater than zero was entered for the multiple isotope indicator (IVIS) in an arbitrary material and that the first ID NUMBER (NCZA) is not a multiple isotope nuclide (see Sect. C6.4.4). When this message is printed, an error flag is set to prevent execution and IVIS is set to zero to allow the code to continue checking the remaining input data. If an arbitrary material was not specified, this message indicates that the Standard Composition Library is in error for the standard composition printed immediately following this message.

MP-45 ***** ERROR ***** ____ IS NOT A VALID CALCULATION TYPE. USE INFHOMMEDIUM, LATTICECELL, OR MULTIREGION. EXECUTION IS TERMINATED.

This message from subroutine CSPARM indicates that the TYPE OF CALCULATION (see item 3 of Sect. C6.4.3) was spelled incorrectly, entered out of order, or was improperly specified.

MP-46 *** ERROR *** THE FUELOD CANNOT BE GREATER THAN THE PITCH.

This self-explanatory message from subroutine LATCEL results from an error in the UNIT CELL SPECIFICATION for a LATTICECELL problem (see Sect. C6.4.6). The value of PITCH must be at least as large as the value of FUELOD.

MP-47 *** ERROR *** THE CLADOD CANNOT BE LESS THAN THE FUELOD, NOR GREATER THAN THE PITCH.

This message from subroutine LATCEL indicates an error in the UNIT CELL SPECIFICATION for a LATTICECELL problem. See Sect. C6.4.5 and verify the values of PITCH, FUELOD, and CLADOD.

MP-48 *** ERROR *** THE GAPOD CANNOT BE LESS THAN THE FUELOD, NOR GREATER THAN THE CLADOD.

This message from subroutine LATCEL indicates an error in the UNIT CELL SPECIFICATION for a LATTICECELL problem. See Sect. C6.4.6 and verify the values of FUELOD, CLADOD, and CLADID (note that CLADID is the GAPOD and is equal to FUELOD + twice the gap thickness).

MP-49 ***ERROR *** THE ABOVE RADIUS MUST BE GREATER THAN THE PREVIOUS RADIUS.

This message from subroutine MULTRG indicates an error in the GEOMETRY SPECIFICATION for a MULTIREGION problem. See Sect. C6.4.7 and check to ensure that each value of RZ is greater than the previous value of RZ.

MP-50 *** WARNING *** IN MORE DATA, RESONANCE INFORMATION (RES=) WAS SUPPLIED FOR MIXTURE _____. IT WILL NOT BE USED BECAUSE THAT MIXTURE OCCURS IN THE CELL DESCRIPTION.

This message from subroutine MOREDT is printed if resonance data (RES=) are entered for a mixture in MORE DATA (Sect. C6.4.8) and are also used in the cell description (Sects. C6.4.6 and C6.4.7).

MP-51 *** ERROR *** IN MORE DATA _____ IS AN INVALID GEOMETRY TYPE FOR USE IN SPECIFYING RESONANCE DATA.
CYLINDER, SPHERE, OR SLAB MUST BE ENTERED.

This message from subroutine MOREDT is printed if resonance data (RES=) are entered in MORE DATA (Sect. C6.4.8) and an incorrect shape is specified. The correct specification for a sphere of mixture 3 having a radius of 1.5 cm is: RES=3 SPHERE 1.5

MP-52 *** WARNING *** IN MORE DATA, DANCOFF INFORMATION (DAN( )=) WAS SUPPLIED FOR MIXTURE _____. THIS VALUE WILL BE USED INSTEAD OF CALCULATING THE DANCOFF FROM THE CELL DESCRIPTION.

This message from subroutine MOREDT is printed to alert the user that the Dancoff information calculated from the unit cell (Sects. C6.4.6 and C6.4.7) specification is being overridden by the value that was entered in MORE DATA (Sect. C6.4.8).

MP-54 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the volume fraction data from subroutine VERIFY. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-55 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the mixing table data required for subroutine BONAMI. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-56 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the mixture number, outer radii, temperature, sigma-H, and zone identifiers for each BONAMI zone. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-57 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the BONAMI control parameters. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-58 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the cross-section data required by subroutines EPSIG and XSMESH. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-59 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the data required by subroutine XSDRN. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-60 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutine C4DATA indicates that the allocated computer storage will not hold the data required by subroutine ICE. 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 words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem.

MP-61 *** ERROR *** THE CROSS-SECTION LIBRARY NAME ENTERED IN THE MATERIAL INFORMATION PROCESSOR DATA FOR THIS CSAS PROBLEM IS INCORRECT. SEE TABLE M8.2.2 OF THE SCALE MANUAL.

This message from subroutine C4DATA indicates that an invalid CROSS-SECTION LIBRARY NAME (see item 2 of Sect. M7.4.3) was entered. The name was misspelled, out of order, or improperly specified.

MP-62 ***ERROR*** A MIXTURE NUMBER IS OUT OF RANGE. ENTRY _____ IN THE MIXING TABLE IS _____. IT SHOULD FALL BETWEEN 1 AND _____, THE LARGEST NUMBER USED IN THE STANDARD COMPOSITION DATA.

This message is from subroutine EPSIG. Because the largest mixture number is determined by the code as the input data are read, this message may be the result of a code error introduced when changes were made to the code.

MP-63 ***ERROR*** A POINTER INTO THE NUCLIDE DATA IS OUT OF RANGE. ENTRY ___ IN THE MIXING TABLE IS ____. IT SHOULD FALL BETWEEN 1 AND ____, THE NUMBER OF NUCLIDES IN THE STANDARD COMPOSITION LIBRARY.

This message is from subroutine EPSIG. It may result from a code error introduced when changes were made to the code.

MP-64 TAPE COPY NEEDS _____ WORDS, BUT ONLY HAS _____ WORDS.

This message from subroutine SHORTX indicates that the allocated computer storage is insufficient to create the short cross-section library utilized by the Material Information Processor. Increase the space allocation using the "SIZE" parameter on the analytical sequence indicator (Sect. M7.4.2) and resubmit the problem. A STOP 200 is executed when this message is printed.

MP-65 ***** ERROR ***** THE FOLLOWING NUCLIDES WERE NOT FOUND ON THE MASTER LIBRARY:

This message from subroutine SHORTX indicates that the user specified a standard composition that contains a nuclide that is not available on the specified master library. For example, nuclide ID 25304, which is stainless-steel-weighted manganese, is not available on any of the libraries but is listed in the Standard Composition Library. 25055 could be used instead.

MP-66 ***ERROR*** THE MIX. NO. (MIXZ=____) ASSIGNED TO ZONE IZ=____ WAS OUTSIDE THE RANGE 0 TO MXX=_____.

This message from subroutine VERIFY indicates that the mixture number is out of range. A code error is the likely cause of this error.

MP-67 **WARNING** MIXTURE ____ WAS ASSIGNED TO ZONES _____ AND ____. THIS MAY BE CORRECT IF THE MIXTURE HAS NO RESONANCE NUCLIDES AND HAS THERMAL SCATTERING DATA AT ONLY ONE TEMPERATURE. USUALLY, UNIQUE MIXTURE NUMBERS SHOULD BE USED IN EACH ZONE, EVEN THOUGH THE MIXTURE SPECIFICATIONS MAY BE IDENTICAL. THIS ALLOWS BONAMI AND NITAWL TO PRODUCE SEPARATE CROSS SECTIONS BASED ON THE APPROPRIATE NUMBER OF EXTERNAL MODERATORS AND THE ACTUAL MEAN CHORD LENGTH FOR EACH SPECIFIED ZONE AS WELL AS THE ACTUAL TEMPERATURE FOR THAT ZONE.

This self-explanatory message is from subroutine VERIFY. The user should verify that the multiple use of the stated mixture number was intentional and correct.

MP-68 ERRONEOUS MIXING TABLE LENGTH FOR XSDRN.

This message from subroutine XSDRN is indicative of a code error. The computed mixing table length, MS, passed to subroutine XSDRN, does not match the counted length in subroutine XSDRN.

MP-69 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

This message from subroutine XSMESH indicates that the allocated computer storage will not hold the interval boundaries and zone number for each interval. The first number printed is the amount of storage, in words, needed to hold this data. The second number is the amount of computer storage that was allocated, and the third number is the minimum additional words of storage required to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step"

in the job control language and resubmit the problem. Specification (by the control module) of too many mesh intervals in a given zone is the most frequent cause of failure. In MULTIREGION calculations where one has a large zone containing a strong absorber (such as a tank of uranyl-fluoride solution), it may be necessary to reduce the number of mesh intervals by increasing the size factor (SZE) in the optional parameter data (Sect. C6.4.8). Making this factor large enough (SZF=10, 15, 20, 30, etc.) will generally allow any problem to run in the space allocated. Once the problem runs, one should check the number density of all strong absorbers to see if they are realistic. Occasionally a user will accidentally specify an unrealistic concentration of a strong absorber in one or more zones. Such a mistake dramatically increases the number of mesh intervals the code thinks it needs.

MP-70 ***ERROR*** MORE THAN ONE ZONE WAS ENCOUNTERED FOR THIS INFINITE HOMOGENEOUS MEDIA PROBLEM.

This self-explanatory message is from subroutine XSMESH. Correct the input data and resubmit the problem.

MP-71 ***WARNING*** THE TEMPERATURE FOR STANDARD COMPOSITION _____ WAS SPECIFIED AS _____ DEGREE CELSIUS.
DENSITY DATA AT 25 DEGREES CELSIUS WILL BE USED FOR THIS SOLUTION.

This message from subroutine SLNS is printed if SOLNUO2F2 or SOLNPU(NO3)4 were specified in the standard composition data with a temperature outside the range of 15 to 30°C. The Standard Composition Library does not contain data for these solutions outside that temperature range.

MP-72 *** ERROR *** KEYWORD SPG= TO SPECIFY THE SPECIFIC GRAVITY OF THE SOLUTION WAS EXPECTED. KEYWORD _____ WAS READ INSTEAD.

This message from subroutine STDCMP indicates an error in the specification of solution data in the standard composition specification. If the specific gravity of a solution is to be entered, it is the fourth entry after the solution name. Check the solution input data carefully.

MP-73 ***ERROR*** EXTERNAL MODERATOR INDEX IS INCORRECT IN ZONE _____ OF THE MULTIREGION DATA. ENTER NOEXTERMOD, ONE EXTERMOD, OR TWOEXTERMOD INSTEAD OF (_____). CHECK SPELLING.

This self-explanatory message is printed from subroutine MULTRG and subroutine RESDA. The user has misspelled the word defining the external moderator index of the specified zone or the MULTIREGION data are out of order. See Sect. M7.4.4.7.

MP-74 *** ERROR *** FIRST MODERATOR HAS NEGATIVE THICKNESS

This message from subroutine DANCOF indicates that the dimensions specified for an ASYMSLABCELL are inconsistent. The array pitch (PITCH) is smaller than the sum of the second moderator thickness (TKMOD2) and *MAX* where *MAX* is the outside diameter of the clad (CLADOD) if entered; otherwise, *MAX* is the outside diameter of the fuel (FUELOD). Correct the data and resubmit the problem. See Sect. M7.4.6 and Fig. M7.5.6.2 for assistance.

MP-75 *** ERROR *** KEYWORD DEN= OR SPG= TO SPECIFY THE DENSITY OF THE BASIC STANDARD COMPOSITION WAS EXPECTED. KEYWORD _____ WAS READ INSTEAD.

This message from subroutine STDCMP indicates an error in the specification of the density in the basic standard composition data. If the density of the material is to be entered, it is the second entry after the standard composition name. The density is optional data. If the density is entered, it is multiplied by the volume fraction to obtain the density actually used for this composition.

MP-76 *** ERROR *** THE LOWER BOUND OF XSDRN INTERVAL _____ IS _____WHICH MUST BE LESS THAN THE UPPER BOUND OF _____.

This message from subroutine XSMESH indicates that the specified XSDRN mesh interval is incorrect. Each mesh interval must have a finite positive thickness. This message can be caused by an error in the unit cell data. Either a zero-thick region was specified or the unit cell dimensions were incorrectly specified. Carefully check the unit cell dimensions. If a LATTICECELL annular cell is specified, verify that the FUELOD is at least as large as TKMOP2+2(CLADOD-FUELOD).

MP-77 A NEGATIVE DIMENSION WAS ENCOUNTERED IN THE UNIT CELL DATA. CHECK AND CORRECT THE GEOMETRY DIMENSION.

This message from subroutine LATCEL is printed if a negative number is read for a cell dimension. Check the printed problem geometry and correct the input data (Sect. M7.4.6).

MP-78 THE FUEL THICKNESS IS NEGATIVE. THE ANNULAR CELL DIMENSIONS FOR TKMOD2, CLADOD, AND FUELOD ARE INCONSISTENT.

This message from subroutine LATCEL indicates an error in the description of a cylindrical or spherical annular cell. The cell description must provide a finite fuel thickness. The ID of the fuel is calculated using the diameter of the second moderator, TKMOD2, and the OD of the clad, CLADOD. If the calculated ID of the fuel is greater than or equal to the specified OD of the fuel, there is no fuel in the cell and this message is printed. The thickness of the gap and clad is ½(CLADOD–FUELOD), so the ID of the fuel is TKMOD2+CLADOD– FUELOD. See Sect. M7.4.6 for data input instructions.

MP-79 *** ERROR *** THE ORIGIN MUST BE 0.0 FOR SPHERICAL OR CYLINDRICAL GEOMETRY.

This message from subroutine MULTRG is printed if the origin, ORGN of Table M7.4.8, Sect. M.4.7, is nonzero for a cylinder or sphere. Either the MULTIREGION unit cell data are out of order or a nonzero number has been entered for ORGN. Correct the data and resubmit the problem.

MP-80 *** ERROR *** NOT ENOUGH STORAGE IN CLAPSE - FIRST NUMBER IS THE AMOUNT NEEDED, SECOND IS THE AMOUNT AVAILABLE.

PERTINENT CONSTANTS

This message from subroutine CLAPSE indicates that the allocated computer storage is insufficient to allow collapsing the thermal cross sections to one group for shielding calculations. 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. A STOP 201 is executed when this message is printed.

MP-81 *** ERROR *** DANCOFF FACTOR MUST BE BETWEEN 0.0 AND 1.0.

This message from subroutine MOREDT is printed if DAN(n)= is specified in MORE DATA with a value greater than 1.0 or less than 0.0. Dancoff factors must lie between 0 and 1. The problem will not be run if message MP-81 is printed. Correct the data and resubmit the problem. See Sect. M7.4.7 for assistance.

MP-82 THE FIRST MODERATOR THICKNESS IS NEGATIVE. THE ASYMMETRIC SLAB CELL DIMENSIONS FOR TKMOD2, CLADOD, AND PITCH ARE INCONSISTENT

This message from subroutine LATCEL indicates an error in the description of an asymmetric slab cell. The thickness of the first moderator is not specified in the input data and is calculated as PITCH–TKMOD2/2– CLADOD. If the thickness of the first moderator is negative, this message is printed.

MP-83 *** ERROR *** AN INPUT DATA ERROR HAS BEEN ENCOUNTERED IN THE MATERIAL INFORMATION PROCESSOR DATA ENTERED FOR THIS PROBLEM.

This message from subroutine C4DATA is printed if the subroutine library routine LRDERR returns a value of "TRUE," indicating that a reading error was encountered in the Material Information Processor input data. Locate the unnumbered message stating "***** ERROR IN INPUT. CARD IMAGE PRINTED ON NEXT LINE *****." Correct the data and resubmit the problem.

MP-84 *** WARNING *** FOR MIXTURE _____ THE DANCOFF FACTOR OF _____ IS OUTSIDE THE RANGE OF 0 TO 1. IT WILL BE RESET TO THE CLOSER BOUND.

This message from subroutine RESDA is printed when the DANCOFF factor is less than 10^{-4} outside the allowed range of 0 to 1. This is usually due to roundoff in calculating the Dancoff factor.

MP-85 *** ERROR *** FOR MIXTURE _____ THE DANCOFF FACTOR OF _____ IS OUTSIDE THE RANGE OF 0 TO 1. IT WILL BE RESET TO THE CLOSER BOUND. THE PROBLEM WILL NOT BE EXECUTED.

This message from subroutine RESDA is printed when the Dancoff factor is more than 10^{-4} outside the allowed range of 0 to 1. Check the input data to be sure that the specified Dancoff factor is between 0 and 1. See Sect. M7.4.8 or C6.4.8 for input specifications for the Dancoff factor. If the Dancoff factor was not specified in the optional parameter data, the message is due to a code error.

MP-86 ***ERROR*** THE FUEL DENSITY FOR SOLUTION ____ IN MIXTURE ____ SPECIFIES A FUEL DENSITY OF ___ G/L, WHICH EXCEEDS THE FUEL DENSITY OF A HYDRATED CRYSTAL, AND WILL LEAD TO ERRONEOUS DENSITIES WHEN USED AS A SOLUTION

This message from subroutine SLNS is printed only for solution standard compositions (those that begin with SOLN) that are incorrectly specified. Each solution standard composition is composed of (1) a fuel-salt, fs, (2) water, H_2O, and (3) an acid. A fully hydrated fuel-salt is defined as $fs \cdot nH_2O$ where **n** defines the number of water molecules associated with the fuel-salt crystal (water of hydration). The values of **n** are:

n	Solution	Hydrated Salt
2	UO_2F_2	$UO_2F_2 \cdot 2H_2O$
6	$UO_2(NO_3)_2$	$UO_2(NO_3)_2 \cdot 6H_2O$
5	$Pu(NO_3)_4$	$Pu(NO_3)_4 \cdot 5H_2O$

If the fuel density is so large that there is not enough water in the solution to form fully hydrated crystals of fuel-salt, this message will be printed. The solution name, mixture number, and specified fuel density are printed in the error message. The problem will not run if this message is printed. Correct the input data for this solution standard composition in the specified mixture and resubmit the problem.

MP-87 ***WARNING*** THE FUEL DENSITY FOR SOLUTION ___ IN MIXTURE ___SPECIFIES A FUEL DENSITY OF _____ G/L. THIS MAY BE GREATER THAN THE SATURATED SOLUTION FUEL DENSITY, AND MAY GIVE INCORRECT DENSITIES AS A SOLUTION. CHECK THE DENSITIES CAREFULLY.

This message from subroutine SLNS is printed because the fuel density for the specified solution standard composition may be high enough to allow precipitation of the fuel-salt. Each solution standard composition is composed of (1) a fuel-salt (fs), (2) water (H_2O), and (3) an acid. The water/fuel-salt ratio, **n**, is the ratio of the moles of water to moles of fuel-salt. The minimum threshold values of **n** used to trigger this message are:

n	Solution
8	UO_2F_2
17	$UO_2(NO_3)_2$
17	$Pu(NO_3)_4$

The solution name, mixture number, and specified fuel density are printed in the error message. The problem will run and it is the responsibility of the user to verify that the resulting solution is correct.

MP-88 ***ERROR*** THE LIBRARY SPECIFIED IS A PRE-NITAWL-II LIBRARY

This error message from subroutine SETUPA indicates the specified library was created to be used with a version of NITAWL prior to NITAWL-II. See Table M4.1.1 for a list of acceptable cross-section libraries. If the library is correctly specified, its format is not consistent with the NITAWL-II format.

MP-89 ***ERROR*** THE MATERIAL SPECIFIED IN THE _____TH STANDARD COMPOSITION SPECIFICATION DOES NOT CONTAIN ANY MULTIPLE ISOTOPE NUCLIDES. ISOTOPIC SPECIFICATIONS ARE NOT ALLOWED.

This error message from subroutine SCDATA indicates that the nth standard composition specification does not contain multiple isotopic nuclides but isotopic data (NCZA and ATPM) were included. It could

possibly indicate a missing END statement. When determining the nth specification, arbm and basic standard composition specifications count as one each and solution specifications count as three each (fuel salt, water, and an acid).

MP-90 ***ERROR*** TOO MANY ISOTOPES WERE SPECIFIED FOR THE ____TH ELEMENT OF THE _____TH STANDARD COMPOSITION SPECIFICATION.

This error message from subroutine SCDATA indicates the nth element of the mth standard composition specification contains more isotopes than are allowed. Reduce the number of isotopes used to describe the material. When determining the mth standard composition specification, arbitrary materials and basic standard composition specifications count as one each and solution specifications count as three each (fuel salt, water, and an acid).

MP-91 ***ERROR*** THE USER SPECIFIED A NEGATIVE VOLUME FRACTION FOR _____.

This self-explanatory error message from subroutine STDCMP indicates a negative density multiplier or volume fraction (VF). It was entered for the standard composition named in the message.

MP-92 ***ERROR*** THE USER SPECIFIED A NEGATIVE OR 0 MIXTURE NUMBER FOR ___.

This self-explanatory error message from subroutine STDCMP indicates that a negative or zero mixture number (MX) was entered for the standard composition named in the message.

MP-93 ***ERROR*** THE USER SPECIFIED A NEGATIVE OR 0 DENSITY FOR _____.

This self-explanatory error message from subroutine STDCMP indicates that a negative or zero density or specific gravity (SPGR or ROTH) was specified for the standard composition named in the message.

MP-94 ***ERROR*** THE USER SPECIFIED A NEGATIVE OR 0.0 FUEL DENSITY FOR SOLUTION _____.

This self-explanatory error message from subroutine STDCMP indicates that a negative or zero fuel density (FD) was specified for the solution standard composition named in the message.

MP-95 ***ERROR*** THE USER SPECIFIED A NEGATIVE ACID MOLARITY FOR SOLUTION _____.

This self-explanatory error message from subroutine STDCMP indicates that a negative or zero acid molarity (AML) was specified for the solution standard composition named in the message.

MP-96 ***ERROR*** ILLEGAL ENDING KEYWORD FOR DANCOFF.)= SHOULD HAVE BEEN ENTERED, BUT _____ WAS READ INSTEAD.

This error from MOREDT indicates a DAN(keyword was read, but after the mixture number, the required)= keyword was not found. Correct the Dancoff specification.

MP-97 ***ERROR*** A ZONE WIDTH MODIFIER WAS SPECIFIED FOR ZONE _____. IT MUST BE BETWEEN 1 AND _____.

This error from MOREDT indicates that a zone width search modifier was specified for a zone greater than the number of zones, or less than 1. Correct the zone number.

C6.7.2 MESSAGES FROM CRITICALITY SAFETY SEQUENCE NO. 6

The following messages originate in the part of CSAS6 that reads, checks, and prepares data for KENO-VI. The same set of error messages are also used for CSAS4 that reads, checks, and prepares data for KENO V.a and MODIFY. CSAS6 is not capable of performing searches at this time. An error message referring to a SEARCH routine, from a CSAS26 or CSAS26X problem, indicates a code error.

CS-50 *** ERROR *** SEARCH COMMAND NUMBER ____ IS UNABLE TO PERFORM A PITCH SEARCH BECAUSE THE DIMENSIONS OF REGION _____ OF UNIT _____ ARE NOT EXPLICITLY DEFINED.

This message from subroutine PCHSRH indicates that the specified search command is not valid for the specified region. An ARRAY or CORE region cannot be altered; nor can a REPLICATE or REFLECTOR region immediately following an ARRAY or CORE region.

CS-55 *** ERRORS WERE ENCOUNTERED IN PROCESSING THE CSAS-KENO5 DATA. EXECUTION IS IMPOSSIBLE. ***

This message from subroutine SASSY is printed if errors were found in the KENO-VI input data for CSAS. If a search is being made, data reading will continue until all the data have been entered or a fatal error terminates the data reading. When the data reading and checking have been completed, the problem will terminate without executing. Check the printout to locate the errors responsible for this message.

CS-62 *** ERROR *** MIXTURE _____ IN THE GEOMETRY WAS NOT CREATED IN THE STANDARD COMPOSITIONS SPECIFICATION DATA.

This message from subroutine MIXCHK indicates that a mixture specified in the KENO-VI geometry was not created in the standard composition data. If mixture 500 (a cell-weighted, homogenized mixture) is to be used in the KENO-VI geometry data, CSAS2X or CSAS4X must be specified to create it.

CS-65 *** ERROR *** INSUFFICIENT SPACE ALLOCATION. C4DATA WAS NOT CALLED.

This message from the main program, CSAS, is printed if the space requested in the job control language is not enough to hold the program. There is not enough space available to load the material input processor and data preprocessor. Increase the amount of space requested in the job control language and resubmit the problem. A STOP 207 is executed when this message is printed.

CS-66 *** ERROR *** INSUFFICIENT SPACE ALLOCATION. SASSY WAS NOT CALLED.

This message from the main program, CSAS, is printed if the space requested in the job control language is not enough to hold the program. There is not enough space available to load the KENO-VI input processor. Increase the amount of space requested in the job control language and resubmit the problem. A STOP 208 is executed when this message is printed.

CS-67 *** ERROR *** INSUFFICIENT SPACE ALLOCATION. RDOPT WAS NOT CALLED.

This message from the main program, CSAS, is printed if the space requested in the job control language is not enough to hold the program. There is not enough space available to load the processor for the search data. Increase the amount of space requested in the job control language and resubmit the problem. A STOP 209 is executed when this message is printed.

CS-68 *** ERROR *** AN INPUT DATA ERROR HAS BEEN ENCOUNTERED IN THE ___ DATA ENTERED FOR THIS PROBLEM.

This message from the main program, CSAS, is printed if the subroutine library routine LRDERR returns a value of "TRUE," indicating that a reading error has been encountered in the "KENO PARAMETER" data or the CSAS "SEARCH" data. The appropriate data type is printed in the message. Locate the unnumbered message stating "***** ERROR IN INPUT. CARD IMAGE PRINTED ON NEXT LINE *****." Correct the data and resubmit the problem.

CS-69 ***ERROR*** MIXTURE _____ IS AN INAPPROPRIATE MIXTURE NUMBER FOR USE IN THE KENO GEOMETRY DATA BECAUSE IT IS A COMPONENT OF THE CELL-WEIGHTED MIXTURE CREATED BY XSDRNPM.

This message from subroutine CMXCHK indicates that a mixture that is a component of a cell-weighted mixture has been used in the KENO-VI geometry data.

CS-70 ***** ERROR ***** SEARCH OR OPTIMIZATION DATA MUST BE ENTERED FOR CSAS6, CSAS6X, AND CSAS3. NO SEARCH DATA WAS ENTERED.

This message from subroutine RDOPT is self-explanatory. If the user does not desire to run a search, another sequence such as CSAS25, CSAS2X, or CSAS1X should be chosen.

CS-71 *** ERROR *** _____ IS NOT A VALID SEARCH TYPE.

This message is from subroutine RDOPT. The allowed search types include OPTIMIZATION, DIMENSION, and CONCENTRATION. The first four characters of the search data after the words READ SEARCH must be OPTI, OPT, OPTM, DIM, DIME, DMSN, CON, or CONC. The data may be misspelled or out of order.

CS-72 *** ERROR *** THE SEARCH TYPE IS INVALID. I=_____.

This message is from subroutine RDOPT. The numerical index, I, should be 1 for an optimum pitch search, 2 for a dimension search, and 3 for a concentration search. If it is none of these, the search type has been incorrectly specified or a code error has been introduced.

CS-73 ***** AN END OF FILE WAS ENCOUNTERED BEFORE ALL THE SEARCH DATA WAS READ.

This self-explanatory message is from subroutine RDOPT. Check the input data to be sure nothing was omitted or misspelled.

CS-74 ***** AN END SEARCH FLAG WAS READ BEFORE ALL THE SEARCH DATA WAS READ.

This self-explanatory message is from subroutine RDOPT. Check the input data for omissions and correct order.

CS-75 *** ERROR *** READ SEARCH FLAG WAS NOT FOUND. _____ WAS READ INSTEAD.

This self-explanatory message is from subroutine RDOPT. READ SEARCH was expected but was not found. Check the input data for omissions and correct order.

CS-76 *** ERROR *** END SEARCH FLAG WAS NOT FOUND. _____ WAS READ INSTEAD.

This self-explanatory message from subroutine RDOPT indicates that an end of file was encountered when looking for READ SEARCH. Check the input data for omissions, correct order, and spelling.

CS-77 *** ERROR *** AN END OF FILE WAS FOUND WHEN THE READ SEARCH FLAG WAS EXPECTED.

This self-explanatory message is from subroutine RDOPT. Check the input data for omissions, correct order, and spelling.

CS-78 *** ERROR *** _____ IS NOT A VALID OPTIMIZATION SEARCH TYPE.

This message is from subroutines FIXTYP and OPTYPE. It indicates that an invalid search type was read. The valid search names include OPTIMUM PITCH, OPTIMUM CONCENTRATION, and OPTIMUM DIMENSION. Either the data was entered improperly or a code error has been introduced. A STOP 215 is executed when this message is printed.

CS-79 *** ERROR *** THE SEARCH TYPE IS INVALID. I=_____.

This message from subroutines FIXTYP and OPTYPE indicates that the search type was misspelled or a code error has been introduced. A STOP 216 is executed when this message is printed.

CS-80 *** ERROR *** SEARCH DATA HAS BEEN DESTROYED. I=____ ICMND=____ IPNUM= ____ II=____ IGEOM=____

This message from subroutines CNCSRH or DIMSRH indicates that the search data cannot be interpreted. This is probably due to a code error.

CS-86 FIRST TWO NUMBERS ARE WORDS OF STORAGE NEEDED AND ALLOCATED. THIRD IS REQUIRED ADDITIONAL WORDS.

PERTINENT CONSTANTS

This message from subroutines FIXTYP and OPTYP indicates that the allocated computer storage will not hold the information required for a search. 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 words of storage necessary to hold the data to this point. Subsequent portions of the program may require even more storage. Increase the region size for the "go step" in the job control language and resubmit the problem. A STOP 211 is executed in conjunction with this message.

CS-88 *** NOT ENOUGH STORAGE TO LOAD THE KENO-VI MIXING TABLE.

This message from subroutine MXTBLE is printed if the allocated computer storage will not accommodate the KENO-VI mixing table data. Increase the requested computer storage in the job control language.

CS-89 *** ERROR *** _____ IS AN INVALID DIMENSION SEARCH COMMAND.

This message from subroutine DMSN indicates that the dimension search data are out of order, a search command is spelled incorrectly, or the search data are specified incorrectly.

CS-90 *** ERROR *** _____ IS AN INVALID SEARCH PARAMETER.

This message printed from subroutines FIXCNC, FIXDIM, FIXPCH, OPTCNC, OPTDMN, or OPTPCH indicates that a parameter entered in the search type specification data is not valid (see Sect. C6.4.9.1 and Table C6.4.15). The data could be misspelled or out of order. Omission of the keyword MORE before entering the individual search commands (Sect. C6.4.9.2) can cause this error.

CS-91 *** ERROR *** _____ IS AN INVALID CONCENTRATION SEARCH COMMAND.

This message from subroutine CNCN is caused by a misspelled or illegal search command when attempting to do a concentration search.

CS-94 *** ERROR *** REG= _____ IS AN INVALID SEARCH DATA ENTRY. THE REGION NUMBER MUST BE GREATER THAN ZERO AND NO LARGER THAN THE NUMBER OF REGIONS IN THE UNIT.

This message from subroutine DMSN indicates that the region to be altered is incorrectly specified. For example, if the unit being altered contains five geometry regions, the value specified for REG= can be as small as 1 and as large as 5.

CS-95 *** ERROR *** AN ERROR WAS ENCOUNTERED IN THE SEARCH DATA. THE LAST REGION NUMBER MUST BE AT LEAST AS LARGE AS THE FIRST REGION NUMBER. CHECK THE SEARCH DATA PRINTED BELOW.
keyword UNIT ____ REGIONS ____ TO ____ PARAMETER=____
SEARCH CONSTANTS ARE ____ ____ ____ ____ ____ ____

This message from subroutine DMSN indicates that the search data specified an invalid region number for the final region to be altered. Check the printed data and correct as appropriate.

CS-96 *** ERROR *** AN ERROR WAS ENCOUNTERED IN THE SEARCH DATA. THE REGION NUMBERS MUST BE GREATER THAN ZERO AND NO LARGER THAN THE NUMBER OF REGIONS IN THE UNIT. CHECK THE SEARCH DATA PRINTED BELOW.
keyword UNIT _____ REGIONS _____ TO _____ PARAMETER=_____
SEARCH CONSTANTS ARE _____ _____ _____ _____ _____ _____

This message from subroutine DMSN indicates that one of the specified region numbers is incorrect. Check the printed data and correct as appropriate.

CS-97 *** ERROR *** NO VALID SEARCH COMMANDS WERE FOUND IN THE DATA.

This message is accompanied by a STOP 235 and is printed from subroutines PCHSRH, CNCSRH, and DIMSRH. A common cause of this error is the omission of the MORE command before the individual search commands are entered. See Sects. C6.4.10.1 and C6.4.10.2.

CS-99 THIS PROBLEM WILL NOT BE RUN BECAUSE PARM=CHECK WAS ENTERED IN THE ANALYTICAL SEQUENCE SPECIFICATION.

This message from subroutine CSAS indicates that the problem data were read and checked and no errors were found. To execute the problem, remove the PARM=CHECK or PARM=CHK from the analytical sequence indicator data entry.

CS-100 THIS PROBLEM WILL NOT BE RUN BECAUSE ERRORS WERE ENCOUNTERED IN THE INPUT DATA.

This message from subroutine CSAS is self-explanatory. Examine the printout to locate the error or errors in the input data. Correct them and resubmit the problem.

C6.7.3 STOP CODES

The STOP codes that are utilized in CSAS and CSAS6 are listed in tabular form, indicating the subroutine where they occur and the associated error message. A STOP is executed when a fatal error is recognized. Locate 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 printed at the completion of the associated message.

Stop No.	Subroutine	Traceback	Associated Message
20			See Section C6.7.5
200	SHORTX	No	MP-64
201	CLAPSE	No	MP-80
203	MXTBLE	No	CS-88
207	CSAS	Yes	CS-65
208	CSAS	Yes	CS-66
209	CSAS	Yes	CS-67
211	OPTYP	No	CS-86
	FIXTYP	No	CS-86
212	LODATA	No	CS-81
213	RERITE	No	CS-84
214	CSAS	Yes	CS-68
215	OPTYP	No	CS-78
	FIXTYP	No	CS-78
216	OPTYP	No	CS-79
	FIXTYP	No	CS-79
220	MODIFY	No	CS-87
225	LODATA	Yes	CS-92
230	LODATA	Yes	CS-93
235	DIMSRH	Yes	CS-97
	OPTSRH	Yes	CS-97
	PCHSRH	Yes	CS-97
300	KNIGHT	Yes	MP-1
310	KNIGHT	Yes	MP-2
320	KNIGHT	Yes	MP-3
330	SETUPA	Yes	MP-4
340	MTABLE	Yes	MP-23
350	MIXTAB	Yes	MP-24
360	MIXTAB	Yes	MP-25
370	MIXTAB	Yes	MP-26
380	REORDR	No	MP-27
385	REORDR	No	MP-40
390	SETUPB	Yes	MP-19
395	IDENTS	No	MP-28
	SLNS	No	MP-28
396	CSPARM	No	MP-45

C6.7.4 MESSAGES ASSOCIATED WITH STOP 20 IN CSAS6

The following messages from Subroutine Library routines will result in a STOP 20 in the Material Information Processor and CSAS6:

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 CSAS 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 CSAS, this error may be caused by entering a direct-access unit number for FRD= or FWR= in MORE DATA.

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 that the data control block was not open. In CSAS 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 MORE DATA by entering the parameter DAB=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. For CSAS25, CSAS2X, CSAS26, CSAS26X, CSAS4, and CSAS4X, it may also be necessary to set NB8=nnn in the KENO parameter data.

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. In CSAS 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 I/O error has occurred.

C6.7.5 UNNUMBERED MESSAGES

Occasionally the code may terminate without printing a message that can be located via the message number. Some of these messages are:

***** END OF FILE READ ON UNIT n *****

This message is from subroutine ENFILE in the Subroutine Library. Unit n is the device from which data is being read. This message can be caused by lack of a double blank between the END for the last standard composition and the END COMP. It can also be caused by omitting the END COMP or misspelling COMP in the END COMP entry. Other causes include incomplete or missing data. A traceback accompanies this message. Correct the data and resubmit the problem.

***** ERROR IN INPUT. CARD IMAGE PRINTED ON NEXT LINE *****
card image is printed here
ON THE ABOVE CARD, CHARACTER NUMBER m (IMAGE=c) IS NOT VALID.

This message is from the Subroutine Library free-form reading routine DREAD. The character number, m, and the character image, c, printed in the message are recognized as being invalid for the type of data being read. For example, character data were encountered when numerical data were expected. This message can be caused by missing or incomplete data and by omitting double blanks after a labeled or unlabeled END. A traceback accompanies this message. Correct the data and resubmit the problem.

C6.A ALPHABETICAL INDEX OF SUBROUTINES

This section provides a convenient alphabetical index of the subroutines and functions and common blocks used in CSAS.

Table C6.A.1 provides an alphabetical listing of the subroutines and functions that comprise CSAS6. The first column lists the subroutine name, the second column lists the subroutine that calls it, and the third column contains a list of the subroutines it calls.

Table C6.A.2 provides an alphabetical index of the common blocks used in CSAS6.

Table C6.A.1 Alphabetical index of CSAS6 routines

Subroutine Name	Calling Subroutine	Called Subroutine
cmxchk	sassy6	lchkmx
cncn	fixtyp	aread
	optyp	clear
		fread
		inquir
		iread
		rite
cncsrh	fixtyp	prtsrh
	optyp	rite
		stop
dimsrh	fixtyp	prtsrh
	optyp	rite
		stop
dmsn	fixtyp	aread
	optyp	clear
		fread
		inquir
		iread
		rite
fixcnc	fixtyp	aread
		fread
		iread
fixdim	fixtyp	aread
		fread
		iread
fixpch	fixtyp	aread
		fread
		iread
		reed
fixtyp	rdopt	aread
		cncn
		cncsrh
		dimsrh
		dmsn
		fixcnc
		fixdim
		fixpch
		pchsrh
		reed
		stop

Table C6.A.1 (continued)

Subroutine Name	Calling Subroutine	Called Subroutine
mixchk	mxtble	lchkmx
mxtble	sassy6	clear inquir mixchk rite stop table
optcnc	optyp	aread fread iread
optdmn	optyp	aread fread iread
optpch	optyp	aread fread iread reed
optyp	rdopt	aread cncn cncsrh dimsrh dmsn optcnc optdmn optpch pchsrh reed stop
pchsrh	fixtyp optyp	prtsrh rite stop xxlim
prtsrh	cncsrh dimsrh pchsrh	
rdopt		aread clear fixtyp inquir optyp rite

Table C6.A.1 (continued)

Subroutine Name	Calling Subroutine	Called Subroutine
sassy		sassy6
sassy6	sassy	aralba
		cmxchk
		datain
		iosdun
		jomity
		lodwts
		move
		mxtble
		point
		pratbl
		prtara
		prtjom
		prtplt
		stop
		wrtrst
table	mxtble	

Table C6.A.2 Commons used in CSAS6

Common Name	Referencing Subroutine
albdat	sassy6
albnam	sassy6
ccdata	sassy6
cdata	sassy6
celmix	cmxchk
dimen	cncn dmsn fixtyp mxtble optyp sassy6
drtacs	cncn cncsrh dimsrh dmsn fixpch fixtyp mxtble optpch optyp pchsrh rdopt sassy6
errflg	sassy6
flg	cncsrh dimsrh fixcnc fixdim fixpch fixtyp optcnc optdmn optpch optyp pchsrh rdopt
ios	sassy6
logic	sassy6

Table C6.A.2 (continued)

Common Name	Referencing Subroutine
lpnt	rdopt
	sassy6
pass	sassy6
pointr	sassy6
rec1	cncn
	dmsn
	fixpch
	fixtyp
	optpch
	optyp
	prtsrh
	rdopt
	sassy6
stdata	sassy6
titl	prtsrh
unit	cncn
	cncsrh
	dimsrh
	dmsn
	fixcnc
	fixdim
	fixpch
	fixtyp
	mxtble
	optcnc
	optdmn
	optpch
	optyp
	pchsrh
	prtsrh
	rdopt
	sassy6
units	sassy6

C6.B SAMPLE PROBLEMS

This section contains sample problems to demonstrate some of the options available in CSAS and its associated sequences. A brief problem description and the associated input data are included for each problem. See Sect. C6.5 for additional examples.

SAMPLE PROBLEM 1 ALUMINUM 30 DEGREE PIPE ANGLE INTERSECTION

The purpose of this problem is to calculate the k-effective of a system composed of intersecting aluminum pipes, in the shape of a Y, filled with a 5% enriched UO_2F_2 solution. The UO_2F_2 solution at 299°K contains 907.0 gm/l of uranium, no excess acid, and has a specific gravity of 2.0289 gm/cm^3. The assembly is composed of a 212.1 cm long vertical pipe and a second pipe that intersects the vertical pipe 76.7 cm from the outside bottom at an angle of 29.26 degrees with the upper vertical pipe. Both pipes have 13.95 cm inner diameters and 14.11 cm outer diameters. The vertical pipe is open on the top and 1.3 cm thick on the bottom. The Y-leg pipe, in the YZ-plane, is 126.04 cm in length with the sealed end 0.64 cm thick. The assembly is filled with solution to a height 129.5 cm above the outside bottom of the vertical pipe. From the point where the pipes intersect the assembly is surrounded by water 37.0 cm in the ±X directions, 100 cm in the +Y direction, -37 cm in the -Y direction, to the top of the assembly in the +Z direction, and -99.6 cm in the -Z direction.

```
=CSAS26
KENO-VI  30 DEG Y  5%UO2F2  907.0G/L  128.2 SOLN HEIGHT  K=1.001 +- .004
44GROUPNDF5  INFHOMMEDIUM
SOLNUO2F2 1 907.0 0.0 SPG=2.0289 1.0 299 92235 5.0 92238 95.0 END
AL        2 1.0 END
H2O       3 1.0 END
END COMP
READ PARAMETERS
FLX=YES FDN=YES FAR=YES PGM=YES TBA=1.0 PLT=YES
END PARAMETERS
READ START NST=6 TFX=0.0 TFY=0.0 TFZ=0.0 LNU=1000
END START
READ GEOMETRY
GLOBAL
UNIT 1
COM='30 DEG Y'
CYLINDER 10  13.95  135.4 -75.4
CYLINDER 20  14.11  135.4 -76.7
CYLINDER 30  13.95  125.4   0.0   ROTATE A2=-29.26
CYLINDER 40  14.11  126.04  0.0   ROTATE A2=-29.26
CUBOID   50  2P37.0 100. -37.0 52.8 -75.4
CUBOID   60  2P37.0 100. -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
MEDIA  0  1 10 -50
MEDIA  0  1 30 -50 -10
MEDIA  3  1 60 -20 -40 -10
BOUNDARY  60
END GEOMETRY
READ PLOT  SCR=YES  LPI=10
TTL='Y-Z SLICE AT X=0.0  THROUGH CENTERLINE OF BOTH PIPES'
XUL=0.0  YUL=-39.0  ZUL=137.0 XLR=0.0  YLR=105.0  ZLR=-105.0
VAX=1 WDN=-1 NAX=400  END PLT0
TTL='X-Y SLICE AT Z=26.0  SLIGHTLY ABOVE POINT OF SEPARATION'
```

```
XUL=-40.0 YUL=105.0  ZUL=26.0 XLR=+40.0 YLR=-40.0  ZLR=26.0
UAX=1 VDN=-1 NAX=400 END PLT1
TTL='X-Y SLICE AT Z=75.0  WELL ABOVE POINT OF SEPARATION'
XUL=-40.0 YUL=105.0  ZUL=75.0 XLR=+40.0 YLR=-40.0  ZLR=75.0
UAX=1 VDN=-1 NAX=400 END PLT2
END PLOT
END DATA
END
=CLEC_OUT
END
```

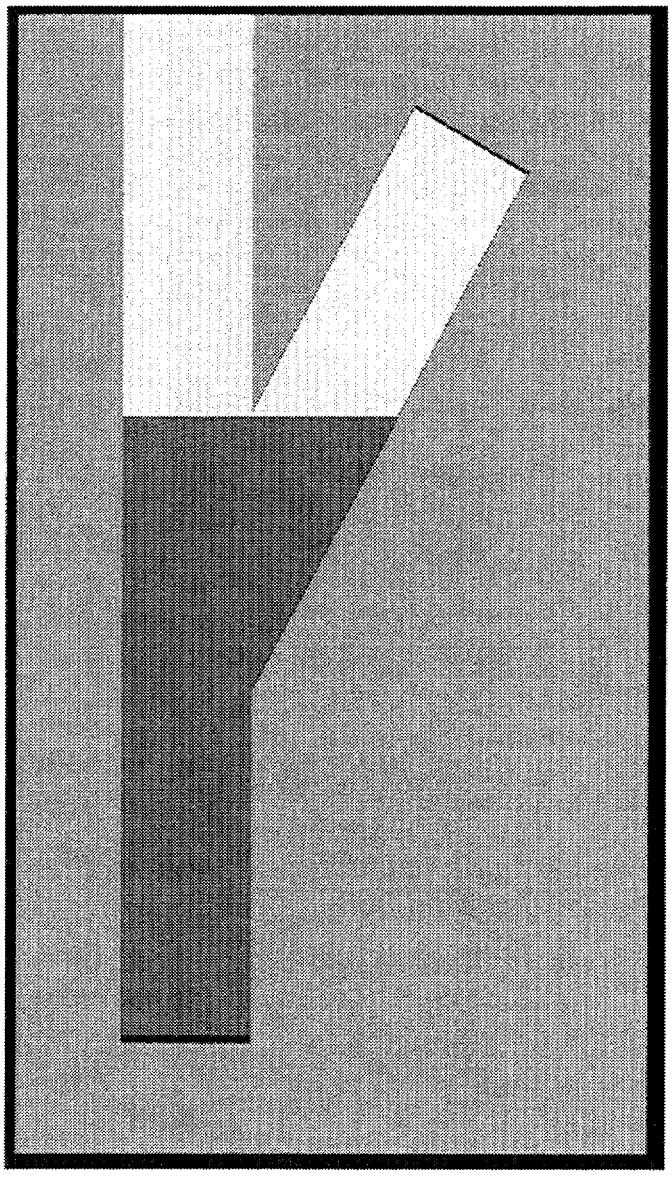


Figure C6.B.1 Critical assembly of UO_2F_2 solution in a 30°-Y aluminum pipe

SAMPLE PROBLEM 2 PLEXIGLASS CROSS

The purpose of this problem is to calculate the k-effective of a system composed of intersecting plexiglass pipes, in the shape of a cross, filled with a 5% enriched UO_2F_2 solution. The room temperature UO_2F_2 solution contains 896.1 gm/l of uranium, no excess acid, and has a specific gravity of 2.015 gm/cm^3. The pipes have a 13.335 cm inner diameter and 16.19 cm outer diameter. The vertical pipe is open on the top and 3.17 cm thick on the bottom. The horizontal pipe ends are 3.17 thick. The vertical pipe is 210.19 cm in length and filled with solution to a height of 117.2 cm. The 2 horizontal legs, positioned in the XZ-plane, intersect the vertical pipe 91.44 cm from the outside bottom at an 89 degree angle with the upper section of the pipe. Each horizontal is 91.44 cm in length and filled with the above specified UO_2F_2 solution. A water reflector surrounding the solution filled pipes extends out from the point where the pipes intersect 111.76 cm in the ±X directions, 20.64 cm in the ±Y directions, 29.03 cm in the +Z direction, and -118.428 cm in the -Z direction.

```
=CSAS26
KENOVI 89 DEG CROSS 5% UO2F2 SOLN, PLEXIGLASS PIPES, H2O REFL.
44GROUPNDF5  INFHOMMEDIUM
SOLNUO2F2  1 896.1 0.0 SPG=2.0150 1.0 298 92235 5.0 92238 95.0 END
PLEXIGLASS 3 1.0 END
H2O        2 1.0 END
END COMP
READ PARAM PLT=YES END PARAM
READ GEOM
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 0.0 ROTATE A1=90. A2=89.
CYLINDER  50  16.19  91.44 0.0 ROTATE A1=90. A2=89.
CYLINDER  60  13.335 88.27 0.0 ROTATE A1=-90. A2=89.
CYLINDER  70  16.19  91.44 0.0 ROTATE A1=-90. A2=89.
CUBOID    80  2P111.74 2P20.64 29.03 -118.428
CUBOID    90  2P111.74 2P40.64 121.92 -118.428
MEDIA 1 1 10
MEDIA 0 1 20 -10
MEDIA 3 1 30 -10 -20 -50 -70
MEDIA 1 1 40 -10 -20
MEDIA 3 1 50 -40 -10 -20
MEDIA 1 1 60 -10 -20
MEDIA 3 1 70 -60 -10 -20 -50
MEDIA 2 1 80 -10 -20 -30 -40 -50 -60 -70
MEDIA 0 1 90 -20 -30 -80
BOUNDARY  90
END GEOM
READ START NST=6  TFX=0. TFY=0. TFZ=0. LNU=1000 END START
READ PLOT  SCR=YES  LPI=10
TTL=' X-Z SLICE AT Y=0.0 '
XUL=-113. YUL=0. ZUL=122. XLR=113. YLR=0. ZLR=-120.
UAX=1.0 WDN=-1.0 NAX=400  END PLT0
TTL=' Y-Z SLCE AT X=0.0 '
XUL=0. YUL=-42. ZUL=122. XLR=0. YLR=42. ZLR=-120.
VAX=1.0 WDN=-1.0 NAX=400  END PLT1
TTL=' X-Y SLICE AT Z=0.0 '
XUL=-113.0 YUL=42. ZUL=0. XLR=113.0 YLR=-42. ZLR=0.
UAX=1.0 VDN=-1.0 NAX=400  END PLT2
END PLOT
END DATA
END
=CLEC_OUT
END
```

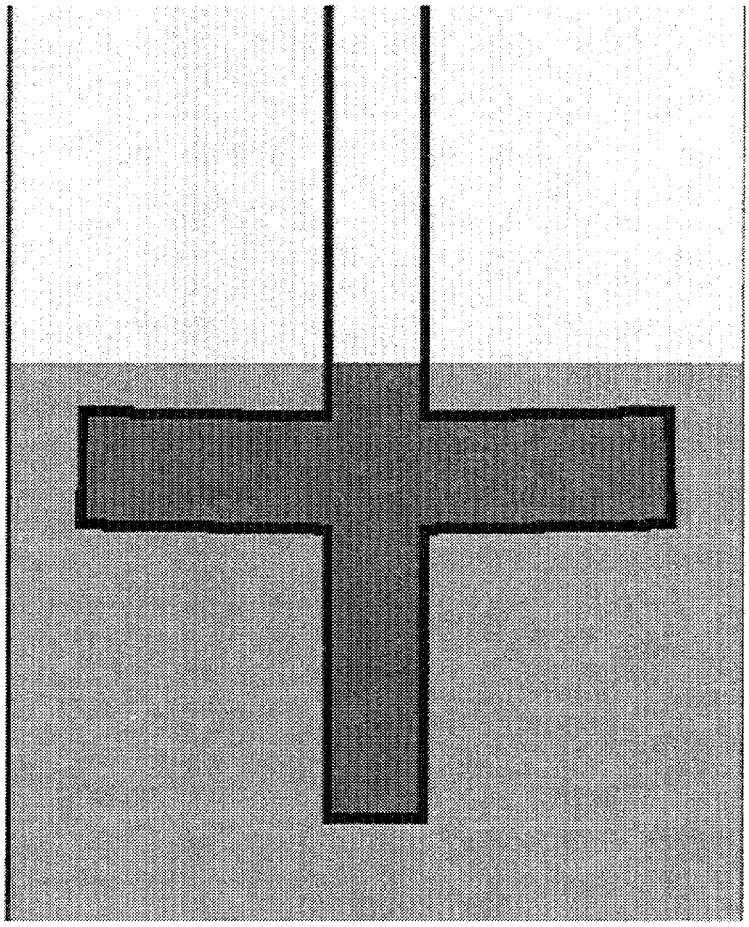


Figure C6.B.2 Critical assembly of UO_2F_2 solution in a plexiglass cross

SAMPLE PROBLEMS 3 - 6 SPHERE MODELS USING CHORDS AND MIRROR ALBEDOS

This set of 4 problems models an assembly consisting of a 93.2 % enriched bare uranium sphere, 8.741 cm in radius, having a density of 18.76 gm/cm^3. The first problem models the assembly as a single bare sphere. The second problem models the assembly as a hemisphere with mirror reflection on the flat surface. The third problem models the assembly as a quarter sphere with mirror reflection on the two flat surfaces. The fourth problem models the assembly as an eighth sphere with mirror reflection on the three flat surfaces. This set of problems is designed to illustrate the use of multiple chords in a problem.

```
=CSAS26
BARE 93.2% ENRICHED URANIUM SPHERE
44GROUP INF
URANIUM  1 DEN=18.76 1 293 92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
END COMP
READ GEOMETRY
```

```
GLOBAL UNIT 1
SPHERE 10  8.741
CUBOID   20  6P8.741
MEDIA  1 1 10
MEDIA  0 1 20 -10
BOUNDARY 20
END GEOMETRY
END DATA
END
=CLEC_OUT
END

=CSAS26
BARE 93.2% ENRICHED URANIUM SPHERE, HEMISPHERE WITH MIRROR ALBEDO FLAT FACE
44GROUP INF
URANIUM  1 DEN=18.76 1 293 92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
END COMP
READ GEOMETRY
GLOBAL UNIT 1
SPHERE 10  8.741  CHORD +X=0.0
CUBOID   20  0.0  8.741 8.741 -8.741 8.741 -8.741
MEDIA  1 1 10
MEDIA  0 1 20 -10
BOUNDARY 20
END GEOMETRY
READ BOUNDS -XB=MIRROR  END BOUNDS
END DATA
END
=CLEC_OUT
END

=CSAS26
BARE 93.2% ENRICHED URANIUM SPHERE, QUARTER SPHERE WITH MIRROR ALBEDO FLAT FACES
44GROUP INF
URANIUM  1 DEN=18.76 1 293 92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
END COMP
READ GEOMETRY
GLOBAL UNIT 1
SPHERE 10  8.741  CHORD +X=0.0  CHORD  +Y=0.0
CUBOID   20  8.741 0.0 8.741 0.0 8.741 -8.741
MEDIA  1 1 10
MEDIA  0 1 20 -10
BOUNDARY 20
END GEOMETRY
READ BOUNDS -XY=MIRROR  END BOUNDS
END DATA
END
=CLEC_OUT
END

=CSAS26
BARE 93.2% ENRICHED URANIUM SPHERE, EIGHTH SPHERE WITH MIRROR ALBEDO FLAT FACES
44GROUP INF
URANIUM  1 DEN=18.76 1 293 92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
END COMP
READ GEOMETRY
GLOBAL UNIT 1
SPHERE 10  8.741  CHORD +X=0.0  CHORD  +Y=0.0  CHORD +Z=0.0
CUBOID   20  8.741 0.0 8.741 0.0 8.741 0.0
MEDIA  1 1 10
MEDIA  0 1 20 -10
BOUNDARY 20
END GEOMETRY
READ BOUNDS -FC=MIRROR  END BOUNDS
END DATA
END
=CLEC_OUT
END
```

SAMPLE PROBLEM 7 GROTESQUE WITHOUT THE DIAPHRAGM

The purpose of this problem is to calculate the k-effective of a system composed of eight enriched uranium units placed on a diaphragm, with an irregularly shaped centerpiece positioned in the center hole of the diaphragm. The assembly and centerpiece are shown in Figure C6.B.3. The eight units consist of an approximate parallelepiped with an irregular top, a parallelepiped, and six cylinders of various sizes. The centerpiece, which penetrates the hole in the diaphragm, consists of a cylinder topped by a parallelepiped topped by a hemisphere. The diaphragm is not modeled in this example.

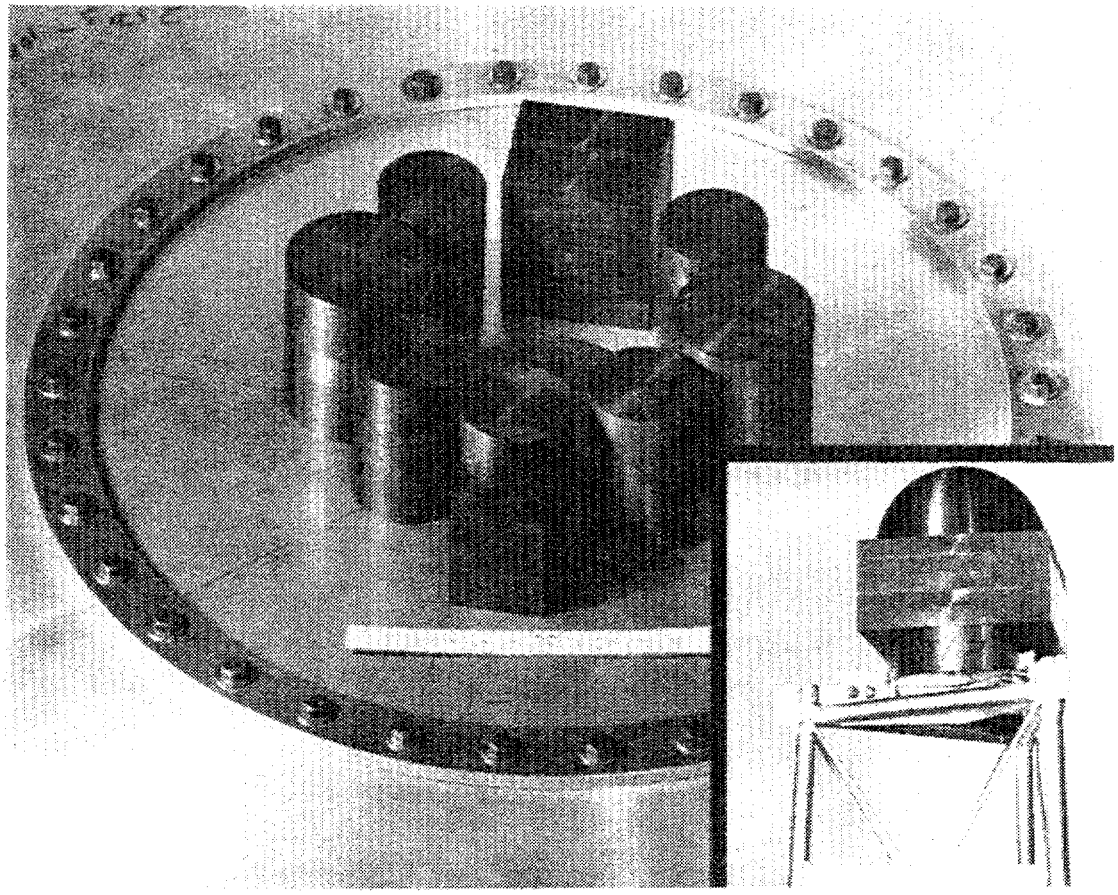


Figure C6.B.3 Grotesque experimental setup

```
=CSAS26
KENO-VI GROTESQUE WITHOUT THE DIAPHRAGM MODELED FROM ORNL/CSD/TM-220
44GROUP INF
URANIUM  1 DEN=18.76 1 293 92235 93.2 92238 5.6 92234 1.0 92236 0.2 END
END COMP
READ PARAM PGM=YES PLT=YES END PARAM
READ GEOM
GLOBAL UNIT 1
'*** ONE THROUGH THREE IS ITEM 1 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
'ONE    TOP PIECE OF ITEM 1
CUBOID 10  2P6.3515 1.2685 -3.8115 13.377 13.058
  ORIGIN Y=-17.464 Z=0.15 ROTATE A2=-1.35
'TWO    MIDDLE PIECE OF ITEM 1
CUBOID 20  2P6.3515 6.3515 -3.8115 13.058 11.155
  ORIGIN Y=-17.464 Z=0.15 ROTATE A2=-1.35
'THREE  BOTTOM PIECE OF ITEM 1
CUBOID 30  4P6.3515 11.155 0.
  ORIGIN Y=-17.464 Z=0.15 ROTATE A2=-1.35
'*** FOUR IS ITEM 2 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
CYLINDER 40 4.555 12.918 0.        ORIGIN X=-12.176 Y=-9.343 Z=0.111
  ROTATE A1=-52.5 A2=-1.400
'*** FIVE IS ITEM 3 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
CYLINDER 50 5.761 13.475 0.        ORIGIN X=-16.333 Y=1.681 Z=0.174
  ROTATE A1=83.5 A2=+1.173
'*** SIX IS ITEM 4 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
CYLINDER 60 4.5525 12.969 0.    ORIGIN X=-9.539 Y=11.168 Z=0.156
  ROTATE A1=40.5 A2=+1.970
'*** SEVEN AND EIGHT ARE ITEM 5 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
'SEVEN
CUBOID  70  2P3.81 8.13 -4.573 8.91 0.
  ORIGIN Y=15.698 Z=0.290 ROTATE A2=+2.58
'EIGHT
CYLINDER 80 4.573 13.229 0.91   ORIGIN Y=15.698 Z=0.290 ROTATE A2=+2.58
'*** NINE IS ITEM 6 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
CYLINDER 90 4.5545 12.974 0.    ORIGIN X=9.854 Y=10.964 Z=0.134
  ROTATE A1=-42.0 A2=+1.680
'*** TEN IS ITEM 7 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
CYLINDER 100 5.7495 13.475 0.    ORIGIN X=16.388 Y=1.434 Z=0.140
  ROTATE A1=-86.0 A2=+1.400
'*** ELEVEN IS ITEM 8 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
CYLINDER 110 4.5565 12.954 0.    ORIGIN X=12.029 Y=-9.398 Z=0.087
  ROTATE A1=38.0 A2=-1.100
'*12 THROUGH 14 IS THE CENTERPIECE IN DRAWING 84-10649 ORNL/CSD/TM-220
'TWELVE
CYLINDER 120 5.757 2.690 0.      ORIGIN X=-0.593 Y=-0.593 Z=-1.755
'THIRTEEN
CUBOID 130 4P6.35 5.718 0.       ORIGIN Z=0.937
'FOURTEEN
SPHERE    140 6.082 CHORD +Z=0.   ORIGIN X=-0.268 Y=0.268 Z=6.655
'*** FIFTEEN IS THE SYSTEM BOUNDARY ***
'FIFTEEN
CUBOID   150 4P25.0 15.0 -2.0
MEDIA 1 1 +10
MEDIA 1 1 +20 -10
MEDIA 1 1 +30 -20
MEDIA 1 1 +40
MEDIA 1 1 +50
MEDIA 1 1 +60
MEDIA 1 1 +70 -80
MEDIA 1 1 +80
MEDIA 1 1 +90
MEDIA 1 1 +100
MEDIA 1 1 +110
MEDIA 1 1 +120 -130
MEDIA 1 1 +130
MEDIA 1 1 +140 -130
MEDIA 0 1 150 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100
          -110 -120 -130 -140
```

```
BOUNDARY 150
END GEOM
READ PLOT  SCR=YES  LPI=10
TTL='GROTESQUE X-Y SLICE AT Z=0.5'
XUL=-25.5 YUL=25.5 ZUL=0.5 XLR=25.5 YLR=-25.5 ZLR=.5
UAX=1 VDN=-1  NAX=400 END
TTL='GROTESQUE X-Y SLICE AT Z=2.0'
XUL=-25.5 YUL=25.5 ZUL=2 XLR=25.5 YLR=-25.5 ZLR=2 END
TTL='GROTESQUE X-Y SLICE AT Z=9.5'
XUL=-25.5 YUL=25.5 ZUL=9.5 XLR=25.5 YLR=-25.5 ZLR=9.5 END
TTL='GROTESQUE Y-Z SLICE AT X=-0.593'
XUL=-.593 YUL=-25.5 ZUL=15.5 XLR=-.593 YLR=25.5 ZLR=-3.5
UAX=0 VAX=1  VDN=0 WDN=-1 NAX=400  END
TTL='GROTESQUE X-Z SLICE AT Y=0.0'
XUL=-25.5 YUL=0.0  ZUL=15.5 XLR=25.5 YLR=0.0 ZLR=-3.5
UAX=1 VAX=0 WAX=0 UDN=0 VDN=0 WDN=-1 NAX=400  END
TTL='GROTESQUE X-Z SLICE AT Y=12.125'
XUL=-25.5 YUL=12.125  ZUL=15.5 XLR=25.5 YLR=12.125 ZLR=-3.5
UAX=1 VAX=0 WAX=0 UDN=0 VDN=0 WDN=-1 NAX=400  END
TTL='GROTESQUE X-Z SLICE AT Y=-12.000'
XUL=-25.5 YUL=-12.000  ZUL=15.5 XLR=25.5 YLR=-12.000 ZLR=-3.5
UAX=1 VAX=0 WAX=0 UDN=0 VDN=0 WDN=-1 NAX=400  END
END PLOT
END DATA
END
```

C6.B.1 REFERENCES

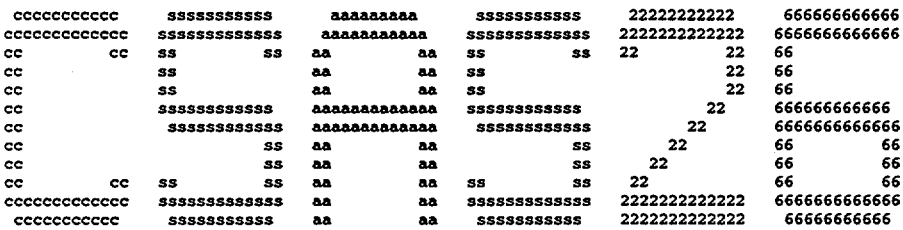
1. J. T. Thomas, "Critical Three-Dimensional Arrays of U(93.2)-Metal Cylinders," *Nucl. Sci. Eng.* **52**, 350 (November 1973).

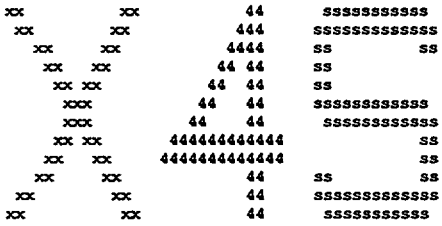
2. J. T. Thomas, *Critical Three-Dimensional Arrays of Neutron-Interacting Units, Part II*, ORNL/TM-868, Union Carbide Corp., Nucl. Div., Oak Ridge Natl. Lab. (July 1964).

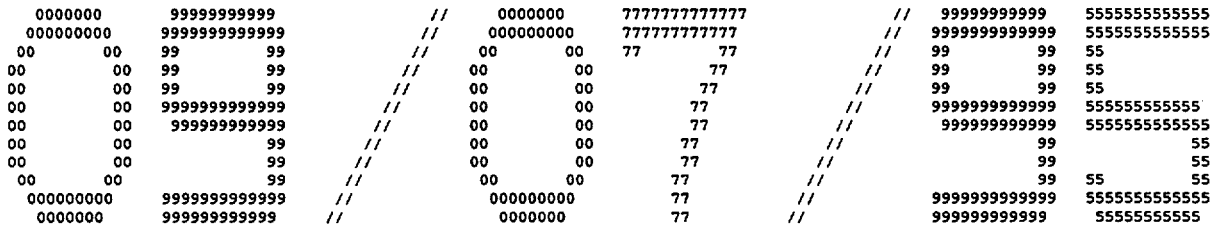
C6.C SAMPLE OUTPUT

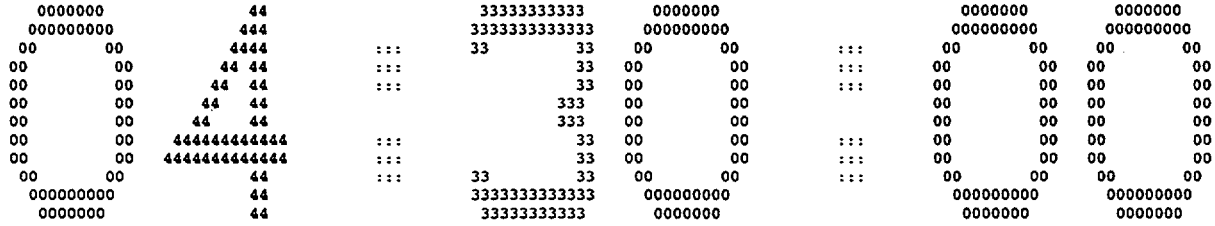
This section contains the computer printout generated by the control module for sample problems 1, 2, 3, and 7 (Y-Pipe, Cross, Sphere, Grotesque). Only the output from CSAS6 is included, output from the functional modules is not included. See Section C6.6 for a generic explanation of the control module output.

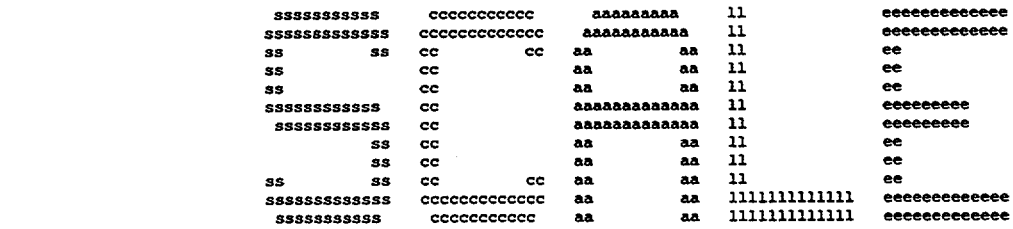
The k-effectives resulting from these calculations do not appear in the control module output, These problems describe critical experiments, so the KENO-VI output should yield a k-effective of 1.0 within statistical accuracy. The k-effectives may vary because of differences in the random number sequences on different computers.









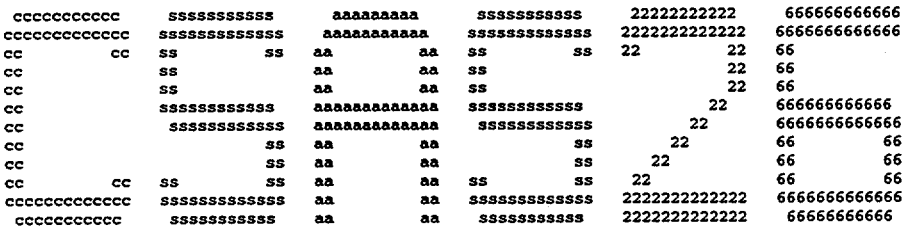


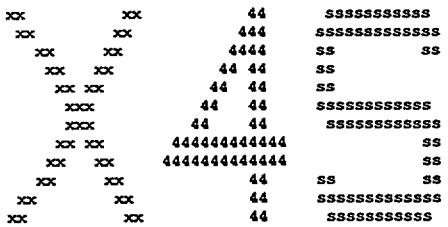

```
**********************************************************************************
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                  PROGRAM VERIFICATION INFORMATION                      *****
*****                                                                        *****
*****                 CODE SYSTEM:    SCALE  VERSION:    4.3              *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                                                                        *****
*****              PROGRAM:  CSAS6                                           *****
*****                                                                        *****
*****        CREATION DATE:  08/13/96                                        *****
*****                                                                        *****
*****              LIBRARY:  /SCALE4.3/BIN                                   *****
*****                                                                        *****
*****                                                                        *****
*****      PRODUCTION CODE:  CSAS6                                           *****
*****                                                                        *****
*****              VERSION:  3.18                                            *****
*****                                                                        *****
*****              JOBNAME:  X4S                                             *****
*****                                                                        *****
*****    DATE OF EXECUTION:  09/07/95                                        *****
*****                                                                        *****
*****    TIME OF EXECUTION:  04:30:00                                        *****
*****                                                                        *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
**********************************************************************************
```

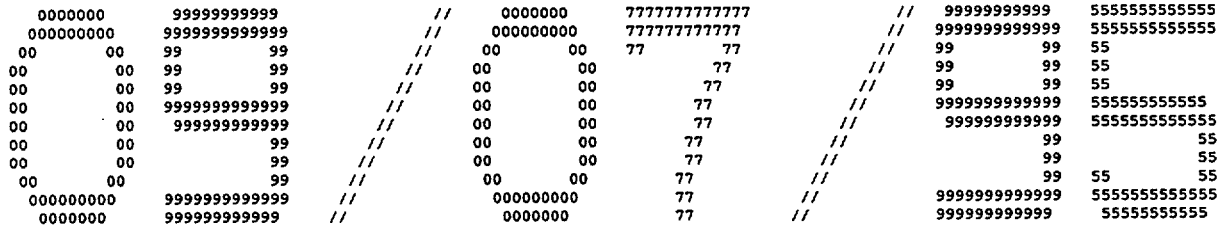
```
KENO-VI  30 DEG Y  5%UO2F2  907.0G/L  128.2 SOLN HEIGHT  K=1.001 +- .004

**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX             3 MIXTURES
MSC             3 COMPOSITION SPECIFICATIONS
IZM             1 MATERIAL ZONES
GE  INFHOMMEDIUM GEOMETRY
MORE            0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
MSLN            1 FUEL SOLUTIONS

**** PROBLEM COMPOSITION DESCRIPTION ****

SC  SOLNUO2F2    STANDARD COMPOSITION
MX              1 MIXTURE NO.
FD       907.0000 SOLUTION FUEL DENSITY
AML        0.0000 ACID MOLARITY
VF         1.0000 VOLUME FRACTION
TEMP        299.0 DEG KELVIN
SPG        2.0289 SPECIFIED SPECIFIC GRAVITY
SC  UO2F2        STANDARD COMPOSITION
            92000      1.00 ATOM/MOLECULE
                          92235     5.000 WT%
                          92238    95.000 WT%
             8016      2.00 ATOMS/MOLECULE
             9019      2.00 ATOMS/MOLECULE
SC  HFACID       STANDARD COMPOSITION
             1001      1.00 ATOM/MOLECULE
             9019      1.00 ATOM/MOLECULE
SC  H2O          STANDARD COMPOSITION
             1001      2.00 ATOMS/MOLECULE
             8016      1.00 ATOM/MOLECULE
END

SC  AL           STANDARD COMPOSITION
MX              2 MIXTURE NO.
VF         1.0000 VOLUME FRACTION
ROTH       2.7020 THEORETICAL DENSITY
NEL             1 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
            13027      1.00 ATOM/MOLECULE
END

SC  H2O          STANDARD COMPOSITION
MX              3 MIXTURE NO.
VF         1.0000 VOLUME FRACTION
ROTH       0.9982 THEORETICAL DENSITY
NEL             2 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
             1001      2.00 ATOMS/MOLECULE
             8016      1.00 ATOM/MOLECULE
END

**** PROBLEM GEOMETRY ****

**** INFINITE HOMOGENEOUS MEDIUM ****
MFUEL           1 MIXTURE NO. OF THE INFINITE HOMOGENEOUS MEDIUM
```

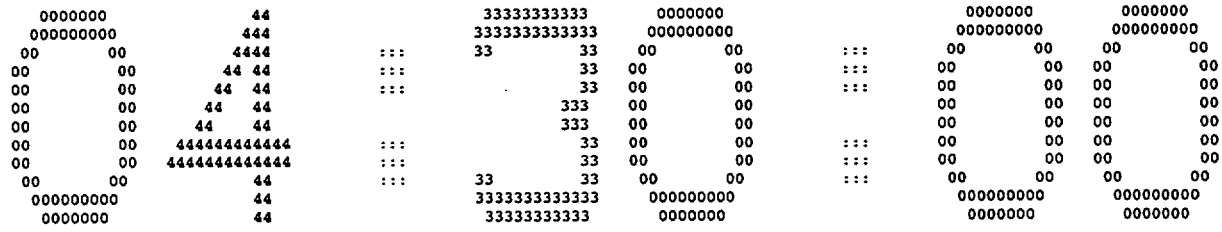
```
*** KENO-VI  30 DEG Y  5%UO2F2  907.0G/L  128.2 SOLN HEIGHT  K=1.001 +- .004 ***

********** DATA LIBRARY INFORMATION **********

   UNIT                                    VOLUME
  NUMBER          DATA SET NAME            NAME          UNIT FUNCTION
  ------          -------------            ----          -------------

    89      /SCALE4.3/DATA/SCALE.REV11.SCLIB          STANDARD COMPOSITION LIBRARY

    82      /SCALE4.3/DATA/SCALE.REV04.XN27         CROSS SECTION LIBRARY

    11      FT11F001                                SHORT CROSS SECTION LIBRARY

    90      FT90F001                                INPUT DATA DIRECT ACCESS

                        STANDARD COMPOSITION LIBRARY DATA
                        ---------------------------------

        UNIT NUMBER  :  89

        DATASET NAME :  /SCALE4.3/DATA/SCALE.REV11.SCLIB

        LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY
                        637 STANDARD COMPOSITIONS, 490 NUCLIDES
                        90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.

        CREATION DATE:   2/ 6/96

                             CROSS SECTION LIBRARY DATA
                             --------------------------

        UNIT NUMBER  :  82

        DATASET NAME :  /SCALE4.3/DATA/SCALE.REV04.XN27

        LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
                           BASED ON ENDF-B VERSION 4 DATA
                              COMPILED FOR NRC      1/27/89
                                 LAST UPDATED                  08/12/94
                                    L.M.PETRIE   -    ORNL

 ........    0 IO'S WERE USED BEFORE READING KENO V DATA     ........

 ........    0 IO'S WERE USED READING THE KENO-VI PARAMETER DATA     ........
```

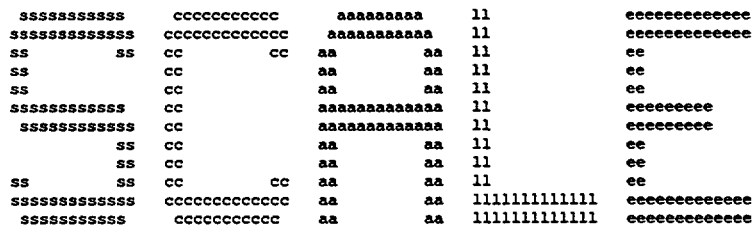
```
          KENO-VI  30 DEG Y  5%UO2F2  907.0G/L  128.2 SOLN HEIGHT  K=1.001 +- .004
                                                    GEOMETRY DESCRIPTION INPUT

  1 CYLINDER    RADIUS = 13.950    +Z= 135.40     -Z= -75.400

  2 CYLINDER    RADIUS = 14.110    +Z= 135.40     -Z= -76.700

  3 CYLINDER    RADIUS = 13.950    +Z= 125.40     -Z=  0.0000
            ANGLE 1=  0.000    ANGLE 2= -29.260    ANGLE 3=  0.000

  4 CYLINDER    RADIUS = 14.110    +Z= 126.04     -Z=  0.0000
            ANGLE 1=  0.000    ANGLE 2= -29.260    ANGLE 3=  0.000

  5 CUBOID    +X = 37.000   -X = -37.000   +Y = 100.00   -Y = -37.000   +Z = 52.800   -Z = -75.400

  6 CUBOID    +X = 37.000   -X = -37.000   +Y = 100.00   -Y = -37.000   +Z = 135.40   -Z = -99.600

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   10   50

ICNT/IRGSEC(II),II=1,ICNT    2   10   50

SECTOR DATA ASSOCIATED WITH MEDIA   2 AND IMPORTANCE REGION   1
   20  -10  -30

ICNT/IRGSEC(II),II=1,ICNT    3   20  -10  -30

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   30   50  -10

ICNT/IRGSEC(II),II=1,ICNT    3   30   50  -10

SECTOR DATA ASSOCIATED WITH MEDIA   2 AND IMPORTANCE REGION   1
   40  -30  -20

ICNT/IRGSEC(II),II=1,ICNT    3   40  -30  -20

SECTOR DATA ASSOCIATED WITH MEDIA   0 AND IMPORTANCE REGION   1
   10  -50

ICNT/IRGSEC(II),II=1,ICNT    2   10  -50

SECTOR DATA ASSOCIATED WITH MEDIA   0 AND IMPORTANCE REGION   1
   30  -50  -10

ICNT/IRGSEC(II),II=1,ICNT    3   30  -50  -10

SECTOR DATA ASSOCIATED WITH MEDIA   3 AND IMPORTANCE REGION   1
   60  -20  -40  -10

ICNT/IRGSEC(II),II=1,ICNT    4   60  -20  -40  -10

VECTOR DEFINITION ARRAY FOR UNIT     1
    60

            *************** DATA READING COMPLETED ***************

            ........    0 IO'S WERE USED PREPARING THE KENO-VI INPUT DATA    ........

            ........    0 IO'S WERE USED LOADING THE KENO-VI DATA    ........

            ........    0 IO'S WERE USED LOADING THE DATA    ........

            ........    0 IO'S WERE USED CHECKING THE KENO-VI GEOMETRY DATA    ........
            *****  RESTART DATA HAS BEEN WRITTEN ON UNIT 95  *****

            ........    0 IO'S WERE USED WRITING THE KENO-VI - CSAS DATA    ........

            ........    0 IO'S WERE USED PROCESSING CSAS INPUT DATA    ........

              CONTROL MODULE CSAS26   IS COMPLETE.
```







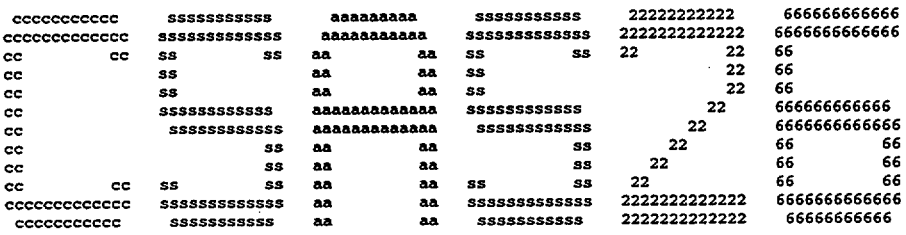


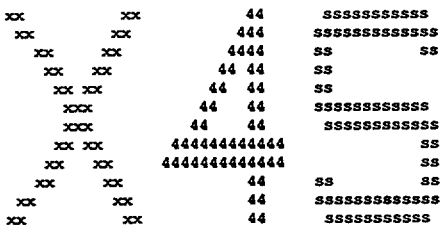


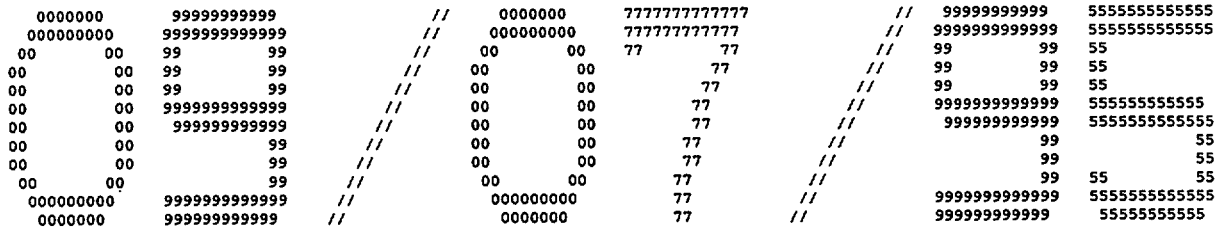

```
**********************************************************************************
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                  PROGRAM VERIFICATION INFORMATION                      *****
*****                                                                        *****
*****                 CODE SYSTEM:    SCALE  VERSION:    4.3              *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                                                                        *****
*****              PROGRAM:  CSAS6                                           *****
*****                                                                        *****
*****        CREATION DATE:  08/13/96                                        *****
*****                                                                        *****
*****              LIBRARY:  /SCALE4.3/BIN                                   *****
*****                                                                        *****
*****                                                                        *****
*****      PRODUCTION CODE:  CSAS6                                           *****
*****                                                                        *****
*****              VERSION:  3.18                                            *****
*****                                                                        *****
*****              JOBNAME:  X4S                                             *****
*****                                                                        *****
*****    DATE OF EXECUTION:  09/07/95                                        *****
*****                                                                        *****
*****    TIME OF EXECUTION:  04:30:00                                        *****
*****                                                                        *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
**********************************************************************************
```

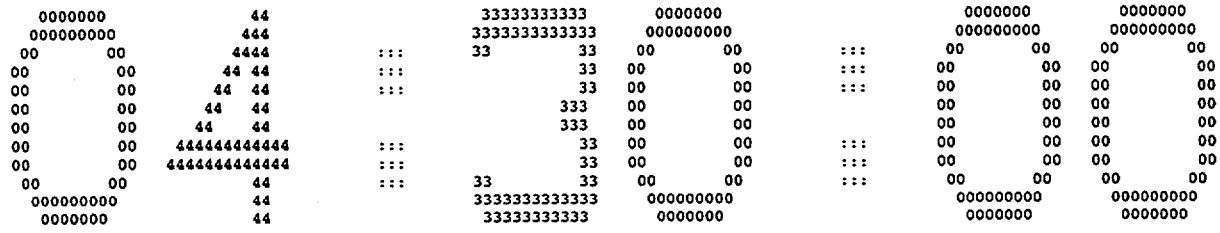
```
KENOVI 89 DEG CROSS 5% UO2F2 SOLN, PLEXIGLASS PIPES, H2O REFL.

**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX            3 MIXTURES
MSC            3 COMPOSITION SPECIFICATIONS
IZM            1 MATERIAL ZONES
GE  INFHOMMEDIUM GEOMETRY
MORE           0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
MSLN           1 FUEL SOLUTIONS

**** PROBLEM COMPOSITION DESCRIPTION ****

SC  SOLNUO2F2    STANDARD COMPOSITION
MX             1 MIXTURE NO.
FD      896.1000 SOLUTION FUEL DENSITY
AML       0.0000 ACID MOLARITY
VF        1.0000 VOLUME FRACTION
TEMP       298.0 DEG KELVIN
SPG       2.0150 SPECIFIED SPECIFIC GRAVITY
SC  UO2F2        STANDARD COMPOSITION
           92000      1.00 ATOM/MOLECULE
                        92235     5.000 WT%
                        92238    95.000 WT%
            8016      2.00 ATOMS/MOLECULE
            9019      2.00 ATOMS/MOLECULE
SC  HFACID       STANDARD COMPOSITION
            1001      1.00 ATOM/MOLECULE
            9019      1.00 ATOM/MOLECULE
SC  H2O          STANDARD COMPOSITION
            1001      2.00 ATOMS/MOLECULE
            8016      1.00 ATOM/MOLECULE
END

SC  PLEXIGLASS   STANDARD COMPOSITION
MX             3 MIXTURE NO.
VF        1.0000 VOLUME FRACTION
ROTH      1.1800 THEORETICAL DENSITY
NEL            3 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
            1001      8.00 ATOMS/MOLECULE
            6012      5.00 ATOMS/MOLECULE
            8016      2.00 ATOMS/MOLECULE
END

SC  H2O          STANDARD COMPOSITION
MX             2 MIXTURE NO.
VF        1.0000 VOLUME FRACTION
ROTH      0.9982 THEORETICAL DENSITY
NEL            2 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
            1001      2.00 ATOMS/MOLECULE
            8016      1.00 ATOM/MOLECULE
END

**** PROBLEM GEOMETRY ****
**** INFINITE HOMOGENEOUS MEDIUM ****
MFUEL          1 MIXTURE NO. OF THE INFINITE HOMOGENEOUS MEDIUM
```

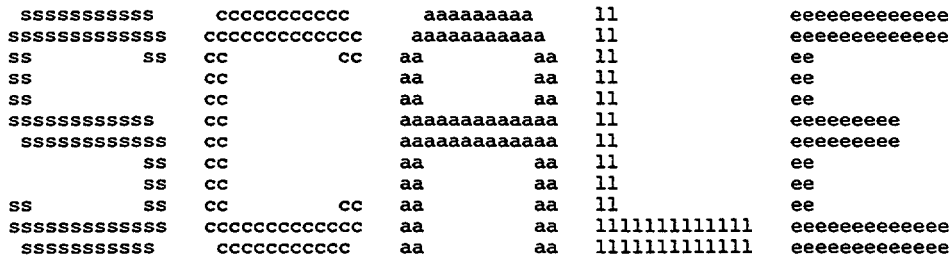
```
*** KENOVI 89 DEG CROSS 5% UO2F2 SOLN, PLEXIGLASS PIPES, H2O REFL. ***

********** DATA LIBRARY INFORMATION **********

  UNIT                                          VOLUME
 NUMBER          DATA SET NAME                  NAME      UNIT FUNCTION
 ------          -------------                  ----      -------------
   89    /SCALE4.3/DATA/SCALE.REV11.SCLIB                 STANDARD COMPOSITION LIBRARY
   82    /SCALE4.3/DATA/SCALE.REV04.XN27                  CROSS SECTION LIBRARY
   11    FT11F001                                         SHORT CROSS SECTION LIBRARY
   90    FT90F001                                         INPUT DATA DIRECT ACCESS

                    STANDARD COMPOSITION LIBRARY DATA
                    ---------------------------------

    UNIT NUMBER  :  89

    DATASET NAME :  /SCALE4.3/DATA/SCALE.REV11.SCLIB

    LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY
                    637 STANDARD COMPOSITIONS, 490 NUCLIDES
                    90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.

    CREATION DATE:   2/ 6/96

                      CROSS SECTION LIBRARY DATA
                      --------------------------

    UNIT NUMBER  :  82

    DATASET NAME :  /SCALE4.3/DATA/SCALE.REV04.XN27

    LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
                       BASED ON ENDF-B VERSION 4 DATA
                          COMPILED FOR NRC     1/27/89
                             LAST UPDATED                  08/12/94
                                L.M.PETRIE   -   ORNL

  ........    0 IO'S WERE USED BEFORE READING KENO V DATA    ........

  ........    0 IO'S WERE USED READING THE KENO-VI PARAMETER DATA    ........

 *************** DATA READING COMPLETED ***************

  ........    0 IO'S WERE USED PREPARING THE KENO-VI INPUT DATA    ........

  ........    0 IO'S WERE USED LOADING THE KENO-VI DATA    ........

  ........    0 IO'S WERE USED LOADING THE DATA    ........

  ........    0 IO'S WERE USED CHECKING THE KENO-VI GEOMETRY DATA    ........
 *****  RESTART DATA HAS BEEN WRITTEN ON UNIT 95  *****

  ........    0 IO'S WERE USED WRITING THE KENO-VI - CSAS DATA    ........

  ........    0 IO'S WERE USED PROCESSING CSAS INPUT DATA    ........

CONTROL MODULE CSAS26   IS COMPLETE.
```







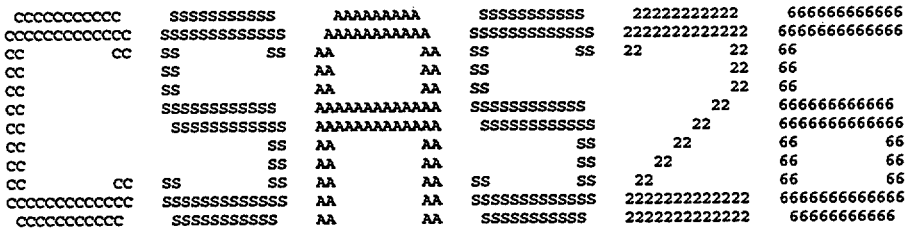


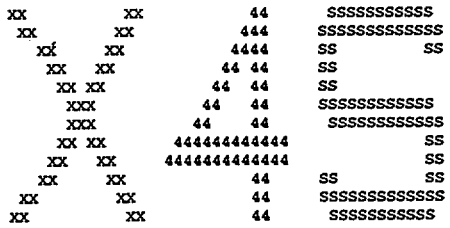


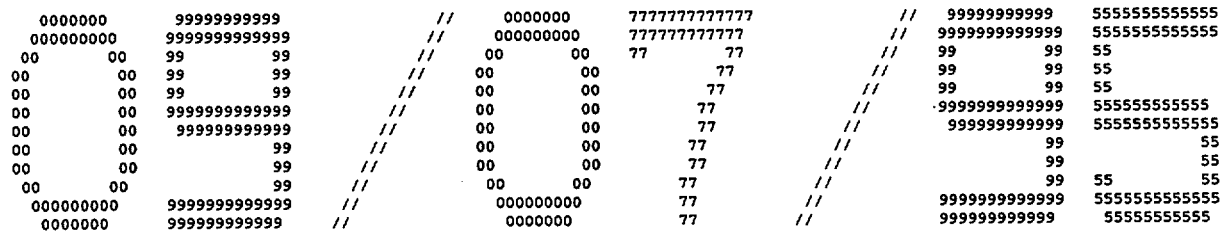

```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                  PROGRAM VERIFICATION INFORMATION                   *****
*****                                                                     *****
*****                 CODE SYSTEM:    SCALE  VERSION:    4.3           *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****              PROGRAM:  CSAS6                                        *****
*****                                                                     *****
*****        CREATION DATE:  08/13/96                                     *****
*****                                                                     *****
*****              LIBRARY:  /SCALE4.3/BIN                                *****
*****                                                                     *****
*****                                                                     *****
*****      PRODUCTION CODE:  CSAS6                                        *****
*****                                                                     *****
*****              VERSION:  3.18                                         *****
*****                                                                     *****
*****              JOBNAME:  X4S                                          *****
*****                                                                     *****
*****    DATE OF EXECUTION:  09/07/95                                     *****
*****                                                                     *****
*****    TIME OF EXECUTION:  04:30:00                                     *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

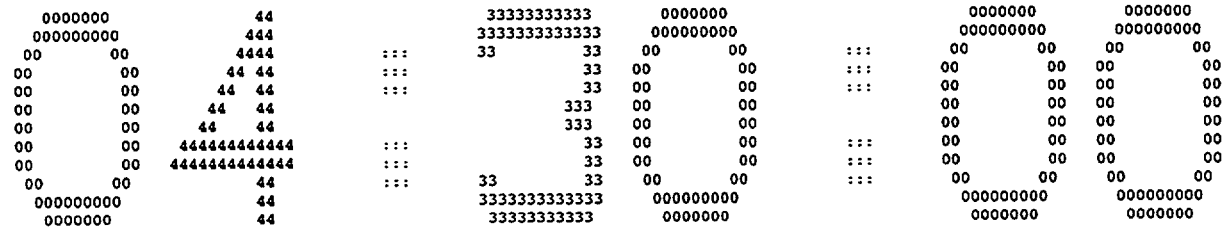
```
BARE 93.2% ENRICHED URANIUM SPHERE


**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX              1 MIXTURES
MSC              1 COMPOSITION SPECIFICATIONS
IZM              1 MATERIAL ZONES
GE  INFHOMMEDIUM GEOMETRY
MORE             0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
MSLN             0 FUEL SOLUTIONS


**** PROBLEM COMPOSITION DESCRIPTION ****

SC  URANIUM      STANDARD COMPOSITION
MX               1 MIXTURE NO.
VF          1.0000 VOLUME FRACTION
ROTH       18.7600 SPECIFIED DENSITY
NEL              1 NO. ELEMENTS
ICP              1 0/1 MIXTURE/COMPOUND
TEMP         293.0 DEG KELVIN
             92000      1.00 ATOM/MOLECULE
                             92235    93.200 WT%
                             92238     5.600 WT%
                             92234     1.000 WT%
                             92236     0.200 WT%
END


**** PROBLEM GEOMETRY ****


**** INFINITE HOMOGENEOUS MEDIUM ****
MFUEL            1 MIXTURE NO. OF THE INFINITE HOMOGENEOUS MEDIUM
```

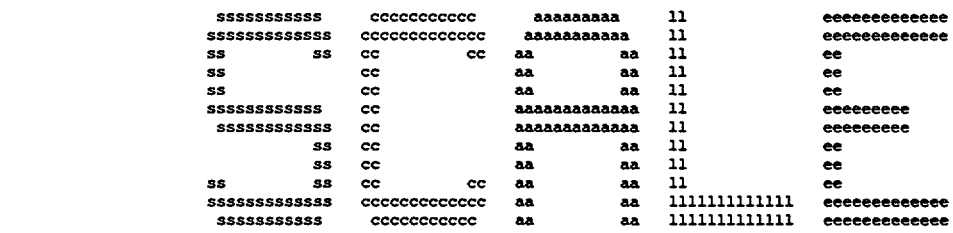
```
*********************************************************************************************************
***                                                                                                   ***
***                          BARE 93.2% ENRICHED URANIUM SPHERE                                       ***
***                                                                                                   ***
*********************************************************************************************************
*********************************************************************************************************
***                                                                                                   ***
***                          ********** DATA LIBRARY INFORMATION **********                          ***
***                                                                                                   ***
***      UNIT                                                VOLUME                                   ***
***     NUMBER                DATA SET NAME                  NAME        UNIT FUNCTION               ***
***     ------                -------------                  ----        -------------               ***
***                                                                                                   ***
***       89      /SCALE4.3/DATA/SCALE.REV11.SCLIB                       STANDARD COMPOSITION LIBRARY   ***
***                                                                                                   ***
***       82      /SCALE4.3/DATA/SCALE.REV04.XN27                        CROSS SECTION LIBRARY          ***
***                                                                                                   ***
***       11      FT11F001                                               SHORT CROSS SECTION LIBRARY    ***
***                                                                                                   ***
***       90      FT90F001                                               INPUT DATA DIRECT ACCESS       ***
***                                                                                                   ***
*********************************************************************************************************
*********************************************************************************************************
***                                                                                                   ***
***                                                                                                   ***
***                                  STANDARD COMPOSITION LIBRARY DATA                                ***
***                                  ---------------------------------                                ***
***                                                                                                   ***
***        UNIT NUMBER  :  89                                                                         ***
***                                                                                                   ***
***        DATASET NAME :  /SCALE4.3/DATA/SCALE.REV11.SCLIB                                           ***
***                                                                                                   ***
***        LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY                                       ***
***                        637 STANDARD COMPOSITIONS, 490 NUCLIDES                                    ***
***                        90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.                           ***
***                                                                                                   ***
***        CREATION DATE:   2/ 6/96                                                                   ***
***                                                                                                   ***
***                                                                                                   ***
***                                     CROSS SECTION LIBRARY DATA                                    ***
***                                     --------------------------                                    ***
***                                                                                                   ***
***        UNIT NUMBER  :  82                                                                         ***
***                                                                                                   ***
***        DATASET NAME :  /SCALE4.3/DATA/SCALE.REV04.XN27                                            ***
***                                                                                                   ***
***        LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY                                 ***
***                           BASED ON ENDF-B VERSION 4 DATA                                          ***
***                              COMPILED FOR NRC     1/27/89                                         ***
***                                 LAST UPDATED                                        08/12/94      ***
***                                    L.M.PETRIE   -   ORNL                                          ***
***                                                                                                   ***
***                                                                                                   ***
*********************************************************************************************************
*********************************************************************************************************

                .........    0 IO'S WERE USED BEFORE READING KENO V DATA     .........

                .........    0 IO'S WERE USED READING THE KENO-VI PARAMETER DATA     .........

                *************** DATA READING COMPLETED ***************

                .........    0 IO'S WERE USED PREPARING THE KENO-VI INPUT DATA     .........

                .........    0 IO'S WERE USED LOADING THE KENO-VI DATA     .........

                .........    0 IO'S WERE USED LOADING THE DATA     .........

                .........    0 IO'S WERE USED CHECKING THE KENO-VI GEOMETRY DATA     .........
                *****  RESTART DATA HAS BEEN WRITTEN ON UNIT 95  *****

                .........    0 IO'S WERE USED WRITING THE KENO-VI - CSAS DATA     .........

                .........    0 IO'S WERE USED PROCESSING CSAS INPUT DATA     .........

  CONTROL MODULE CSAS26   IS COMPLETE.
```












```
**********************************************************************************
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                  PROGRAM VERIFICATION INFORMATION                      *****
*****                                                                        *****
*****                 CODE SYSTEM:    SCALE  VERSION:    4.3              *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                                                                        *****
*****              PROGRAM:  CSAS6                                           *****
*****                                                                        *****
*****        CREATION DATE:  08/13/96                                        *****
*****                                                                        *****
*****              LIBRARY:  /SCALE4.3/BIN                                   *****
*****                                                                        *****
*****                                                                        *****
*****      PRODUCTION CODE:  CSAS6                                           *****
*****                                                                        *****
*****              VERSION:  3.18                                            *****
*****                                                                        *****
*****              JOBNAME:  X4S                                             *****
*****                                                                        *****
*****    DATE OF EXECUTION:  09/07/95                                        *****
*****                                                                        *****
*****    TIME OF EXECUTION:  04:30:00                                        *****
*****                                                                        *****
*****                                                                        *****
**********************************************************************************
**********************************************************************************
**********************************************************************************
```

```
KENO-VI GROTESQUE WITHOUT THE DIAPHRAGM MODELED FROM ORNL/CSD/TM-220


**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX             1 MIXTURES
MSC             1 COMPOSITION SPECIFICATIONS
IZM             1 MATERIAL ZONES
GE  INFHOMMEDIUM GEOMETRY
MORE            0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
MSLN            0 FUEL SOLUTIONS


**** PROBLEM COMPOSITION DESCRIPTION ****

SC  URANIUM      STANDARD COMPOSITION
MX              1 MIXTURE NO.
VF         1.0000 VOLUME FRACTION
ROTH      18.7600 SPECIFIED DENSITY
NEL             1 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
TEMP        293.0 DEG KELVIN
            92000      1.00 ATOM/MOLECULE
                            92235    93.200 WT%
                            92238     5.600 WT%
                            92234     1.000 WT%
                            92236     0.200 WT%
END


**** PROBLEM GEOMETRY ****


**** INFINITE HOMOGENEOUS MEDIUM ****
MFUEL           1 MIXTURE NO. OF THE INFINITE HOMOGENEOUS MEDIUM
```

```
*****************************************************************************************************
***                                                                                               ***
***                    KENO-VI GROTESQUE WITHOUT THE DIAPHRAGM MODELED FROM ORNL/CSD/TM-220       ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                        ********** DATA LIBRARY INFORMATION **********                         ***
***                                                                                               ***
***   UNIT                                                VOLUME                                  ***
***  NUMBER              DATA SET NAME                     NAME       UNIT FUNCTION               ***
***  ------              -------------                     ----       -------------               ***
***                                                                                               ***
***    89     /SCALE4.3/DATA/SCALE.REV11.SCLIB                        STANDARD COMPOSITION LIBRARY ***
***                                                                                               ***
***    82     /SCALE4.3/DATA/SCALE.REV04.XN27                         CROSS SECTION LIBRARY        ***
***                                                                                               ***
***    11     FT11F001                                                SHORT CROSS SECTION LIBRARY  ***
***                                                                                               ***
***    90     FT90F001                                                INPUT DATA DIRECT ACCESS     ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                                                                                               ***
***                             STANDARD COMPOSITION LIBRARY DATA                                 ***
***                             ---------------------------------                                 ***
***                                                                                               ***
***     UNIT NUMBER  :  89                                                                        ***
***                                                                                               ***
***     DATASET NAME :  /SCALE4.3/DATA/SCALE.REV11.SCLIB                                          ***
***                                                                                               ***
***     LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY                                      ***
***                     637 STANDARD COMPOSITIONS, 490 NUCLIDES                                   ***
***                     90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.                          ***
***                                                                                               ***
***     CREATION DATE:   2/ 6/96                                                                  ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
***                                CROSS SECTION LIBRARY DATA                                     ***
***                                --------------------------                                     ***
***                                                                                               ***
***     UNIT NUMBER  :  82                                                                        ***
***                                                                                               ***
***     DATASET NAME :  /SCALE4.3/DATA/SCALE.REV04.XN27                                           ***
***                                                                                               ***
***     LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY                                ***
***                        BASED ON ENDF-B VERSION 4 DATA                                         ***
***                           COMPILED FOR NRC     1/27/89                                       ***
***                              LAST UPDATED                                        08/12/94     ***
***                                 L.M.PETRIE   -   ORNL                                         ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************

                .........    0 IO'S WERE USED BEFORE READING KENO V DATA     .........

                .........    0 IO'S WERE USED READING THE KENO-VI PARAMETER DATA     .........
```

```
KENO-VI GROTESQUE WITHOUT THE DIAPHRAGM MODELED FROM ORNL/CSD/TM-220

GEOMETRY DESCRIPTION INPUT

'*** ONE THROUGH THREE IS ITEM 1 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***

'ONE    TOP PIECE OF ITEM 1

 1 CUBOID              +X =  6.3515     -X = -6.3515     +Y =  1.2685     -Y = -3.8115     +Z =  13.377     -Z =  13.058
                    XORIGIN=   0.000     YORIGIN= -17.464     ZORIGIN=   0.150

'TWO    MIDDLE PIECE OF ITEM 1
                    ANGLE 1=   0.000     ANGLE 2=  -1.350     ANGLE 3=   0.000

 2 CUBOID              +X =  6.3515     -X = -6.3515     +Y =  6.3515     -Y = -3.8115     +Z =  13.058     -Z =  11.155
                    XORIGIN=   0.000     YORIGIN= -17.464     ZORIGIN=   0.150

'THREE  BOTTOM PIECE OF ITEM 1
                    ANGLE 1=   0.000     ANGLE 2=  -1.350     ANGLE 3=   0.000

 3 CUBOID              +X =  6.3515     -X = -6.3515     +Y =  6.3515     -Y = -6.3515     +Z =  11.155     -Z =  0.0000
                    XORIGIN=   0.000     YORIGIN= -17.464     ZORIGIN=   0.150

'*** FOUR IS ITEM 2 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
                    ANGLE 1=   0.000     ANGLE 2=  -1.350     ANGLE 3=   0.000

 4 CYLINDER          RADIUS =  4.5550     +Z=  12.918     -Z=  0.0000
                    XORIGIN= -12.176     YORIGIN=  -9.343     ZORIGIN=   0.111

'*** FIVE IS ITEM 3 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
                    ANGLE 1= -52.500     ANGLE 2=  -1.400     ANGLE 3=   0.000

 5 CYLINDER          RADIUS =  5.7610     +Z=  13.475     -Z=  0.0000
                    XORIGIN= -16.333     YORIGIN=   1.681     ZORIGIN=   0.174

'*** SIX IS ITEM 4 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
                    ANGLE 1=  83.500     ANGLE 2=   1.173     ANGLE 3=   0.000

 6 CYLINDER          RADIUS =  4.5525     +Z=  12.969     -Z=  0.0000
                    XORIGIN=  -9.539     YORIGIN=  11.168     ZORIGIN=   0.156

'*** SEVEN AND EIGHT ARE ITEM 5 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***

'SEVEN
                    ANGLE 1=  40.500     ANGLE 2=   1.970     ANGLE 3=   0.000

 7 CUBOID              +X =  3.8100     -X = -3.8100     +Y =  8.1300     -Y = -4.5730     +Z =  8.9100     -Z =  0.0000
                    XORIGIN=   0.000     YORIGIN=  15.698     ZORIGIN=   0.290

'EIGHT
                    ANGLE 1=   0.000     ANGLE 2=   2.580     ANGLE 3=   0.000

 8 CYLINDER          RADIUS =  4.5730     +Z=  13.229     -Z= 0.91000
                    XORIGIN=   0.000     YORIGIN=  15.698     ZORIGIN=   0.290

'*** NINE IS ITEM 6 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
                    ANGLE 1=   0.000     ANGLE 2=   2.580     ANGLE 3=   0.000

 9 CYLINDER          RADIUS =  4.5545     +Z=  12.974     -Z=  0.0000
                    XORIGIN=   9.854     YORIGIN=  10.964     ZORIGIN=   0.134
'*** TEN IS ITEM 7 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
                    ANGLE 1= -42.000     ANGLE 2=   1.680     ANGLE 3=   0.000

10 CYLINDER          RADIUS =  5.7495     +Z=  13.475     -Z=  0.0000
                    XORIGIN=  16.388     YORIGIN=   1.434     ZORIGIN=   0.140

'*** ELEVEN IS ITEM 8 IN DRAWING 84-10649 ORNL/CSD/TM-220 ***
                    ANGLE 1= -86.000     ANGLE 2=   1.400     ANGLE 3=   0.000

11 CYLINDER          RADIUS =  4.5565     +Z=  12.954     -Z=  0.0000
                    XORIGIN=  12.029     YORIGIN=  -9.398     ZORIGIN=   0.087

'*12 THROUGH 14 IS THE CENTERPIECE IN DRAWING 84-10649 ORNL/CSD/TM-220

'TWELVE
                    ANGLE 1=  38.000     ANGLE 2=  -1.100     ANGLE 3=   0.000

12 CYLINDER          RADIUS =  5.7570     +Z=  2.6900     -Z=  0.0000

'THIRTEEN
                    XORIGIN=  -0.593     YORIGIN=  -0.593     ZORIGIN=  -1.755

13 CUBOID             +X =  6.3500     -X = -6.3500     +Y =  6.3500     -Y = -6.3500     +Z =  5.7180     -Z =  0.0000

'FOURTEEN
```

```
                  XORIGIN=   0.000     YORIGIN=   0.000     ZORIGIN=   0.937

 14 SPHERE            RADIUS =  6.0820

 14  +Z=              0.0000

'*** PIPTEEN IS THE SYSTEM BOUNDARY ***
'FIPTEEN
                  XORIGIN=  -0.268     YORIGIN=   0.268     ZORIGIN=   6.655

 15 CUBOID               +X =  25.000     -X = -25.000     +Y =  25.000     -Y = -25.000     +Z =  15.000     -Z = -2.0000

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   10

ICNT/IRGSEC(II),II=1,ICNT    1   10

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   20  -10

ICNT/IRGSEC(II),II=1,ICNT    2   20  -10

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   30  -20

ICNT/IRGSEC(II),II=1,ICNT    2   30  -20

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   40

ICNT/IRGSEC(II),II=1,ICNT    1   40

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   50

ICNT/IRGSEC(II),II=1,ICNT    1   50

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   60

ICNT/IRGSEC(II),II=1,ICNT    1   60

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   70  -80

ICNT/IRGSEC(II),II=1,ICNT    2   70  -80

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   80

ICNT/IRGSEC(II),II=1,ICNT    1   80

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
   90

ICNT/IRGSEC(II),II=1,ICNT    1   90

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
  100

ICNT/IRGSEC(II),II=1,ICNT    1  100

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
  110

ICNT/IRGSEC(II),II=1,ICNT    1  110

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
  120  ***

ICNT/IRGSEC(II),II=1,ICNT    2  120 -130

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
  130

ICNT/IRGSEC(II),II=1,ICNT    1  130

SECTOR DATA ASSOCIATED WITH MEDIA   1 AND IMPORTANCE REGION   1
  140  ***

ICNT/IRGSEC(II),II=1,ICNT    2  140 -130

SECTOR DATA ASSOCIATED WITH MEDIA   0 AND IMPORTANCE REGION   1
  150  -10  -20  -30  -40  -50  -60  -70  -80  -90  ***  ***  ***  ***  ***

ICNT/IRGSEC(II),II=1,ICNT   15  150  -10  -20  -30  -40  -50  -60  -70  -80

ICNT/IRGSEC(II),II=1,ICNT  -90 -100 -110 -120 -130 -140

VECTOR DEFINITION ARRAY FOR UNIT     1
```

```
150
                        *************** DATA READING COMPLETED ***************
                        ........    0 IO'S WERE USED PREPARING THE KENO-VI INPUT DATA    ........
                        ........    0 IO'S WERE USED LOADING THE KENO-VI DATA    ........
                        ........    0 IO'S WERE USED LOADING THE DATA    ........
                        ........    0 IO'S WERE USED CHECKING THE KENO-VI GEOMETRY DATA    ........
                        *****  RESTART DATA HAS BEEN WRITTEN ON UNIT 95  *****
                        ........    0 IO'S WERE USED WRITING THE KENO-VI - CSAS DATA    ........
                        ........    0 IO'S WERE USED PROCESSING CSAS INPUT DATA    ........

CONTROL MODULE CSAS26   IS COMPLETE.
```

NRC FORM 335 (2-89) NRCM 1102 1, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

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

NUREG/CR-0200, Rev. 6
ORNL/NUREG/CSD-2R6
Vol. 1, Part 1

2. TITLE AND SUBTITLE

SCALE: A MODULAR CODE SYSTEM FOR PERFORMING STANDARDIZED COMPUTER ANALYSES FOR LICENSING EVALUATION

Control Modules
C4, C6

3. DATE REPORT PUBLISHED

MONTH	YEAR
May	2000

4. FIN OR GRANT NUMBER

B0009

5. AUTHOR(S)

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6. TYPE OF REPORT

Technical

7. PERIOD COVERED *(Inclusive Dates)*

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

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

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

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

SCALE, a modular code system for Standardized Computer Analyses Licensing Evaluation, has been developed by Oak Ridge National Laboratory at the request of the U.S. Nuclear Regulatory Commission. The SCALE system utilizes well-established computer codes and methods within standard analysis sequences that (1) allow an input format designed for the occasional user and/or novice, (2) automate the data processing and coupling between modules, and (3) provide accurate and reliable results. System development has been directed at problem-dependent cross-section processing and analysis of criticality safety, shielding, heat transfer, and depletion/decay problems. Since the initial release of SCALE in 1980, the code system has been heavily used for evaluation of nuclear fuel facility and package designs. This revision documents Version 4.4 of the system.

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

SCALE, cross sections, criticality safety, shielding, heat transfer, depletion, decay, spent fuel, KENO, ORIGEN, XSDRNPM, MORSE, NITAWL, XSDRN, SAS1, SAS2, SAS3, SAS4, CSAS, ORIGEN-ARP, QADS, HEATING, HTAS1

13. AVAILABILITY STATEMENT

Unlimited

14. SECURITY CLASSIFICATION

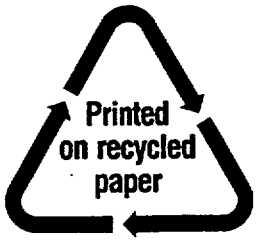
(This Page) Unclassified

(This Report) Unclassified

15. NUMBER OF PAGES

16. PRICE

NRC FORM 335 (2-89)



Federal Recycling Program