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Implementation of CTRLPOS, A VENTURE Module for Control Rod Position Criticality Searches, Control Rod Worth Curve Calculations, and General Criticality Searches

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Finally, the author would like to dedicate this work to the memory of his father, Lenard A. Smith, and in honor of his mother, Karen Smith.

Implementation of CTRLPOS, a VENTURE Module for Control Rod Position Criticality Searches, Control Rod Worth Curve Calculations, and General Criticality Searches

ABSTRACT

A module in the VENTURE reactor analysis code system, CTRLPOS, is developed to position control rods and perform control rod position criticality searches. The module is variably dimensioned so that calculations can be performed with any number of control rod banks each having any number of control rods. CTRLPOS can also calculate control rod worth curves for a single control rod or a bank of control rods. Control rod depletion can be calculated to provide radiation source terms. These radiation source terms can be used to predict radiation doses to personnel and estimate the shielding and long-term storage requirements for spent control rods. All of these operations are completely automated.

The numerous features of the module are discussed in detail. The necessary input data for the CTRLPOS module is explained. Several sample problems are presented to show the flexibility of the module.

The results presented with the sample problems show that the CTRLPOS module is a powerful tool which allows a wide variety of calculations to be easily performed.

CHAPTER 1

INTRODUCTION AND BACKGROUND

CTRLPOS, a VENTURE control rod positioning module, was developed to position control rods and control rod banks within the VENTURE neutronics system[1]. The VENTNEUT or VALENEUT[1] neutronics modules within the VENTURE system can be used to calculate k_{eff} values for control rod positioning. Since CTRLPOS uses CCCC interface files[2], with minor modification the module can be used within the TWODANT[3] or DIF3D[4] code systems.

The control rod movement process is completely automated so that only initial input is required from the user at the start of a calculation. CTRLPOS can perform control rod position criticality searches, calculate the burnup of control rods, and calculate control rod worth curves. CTRLPOS is not a stand-alone code and must be used in conjunction with other VENTURE modules.

This report outlines the development of the CTRLPOS module. Program options, capabilities, and limitations are discussed in a computer code user's manual format. The input requirements are explained and several sample problems are presented.

1.1 Reason for Development

The CTRLPOS module was developed to position the control rods in the VENTURE neutronics models of the Advanced Neutron Source[5].

Throughout the development of the module, care was taken to make the control rod treatment as general as possible so that the automatic search for the critical position of control rods and control rod banks and the control rod worth determination option could be used for other reactor types such as PWR, BWR, and MHTGR reactors. This flexibility allows the module to handle a wide range of problems, but it also increases the responsibility of the user to make sure the calculated results are reasonable.

The control rod position criticality search option is an important feature of the module. A bank of control rods or a single control rod can be moved until the multiplication factor, k_{eff}, is equal to a desired value, usually unity. Before the CTRLPOS module was implemented, a manual method was employed to do this search with DENMAN[1], a VENTURE utility module. This required a large amount of user interaction and manual adjustments of the control rods. In addition, because of the continuous movement of the control rods during fuel cycles, the calculation of the burnup of control rods was very difficult using this manual method.

The main goal in the development of CTRLPOS was to make this time-consuming process completely automated. User input instructions are only required at the beginning of a calculation. The module then performs the instructed options when called by the VENTURE input stream. The depletion of control rods can be determined over one or several fuel cycles. Before the development of CTRLPOS, the contents of a depleted control rod could only be determined using back-of-the-envelope calculations which must be based on many assumptions. CTRLPOS allows the isotopics of a depleted control rod to be determined in a rigorous manner. The isotopics are very important since they are used to determine the radiation source terms from the spent control rods. These source terms can be used to predict expected dose rates to personnel who must be involved in the control rod replacement process and also the necessary shielding and long-term storage requirements.

1.2 Other Control Rod Positioning Codes

1.2.1 RODMOD

RODMOD[6] is a VENTURE control rod positioning module. The module was previously developed to position control rods according to a prescribed schedule during a fuel cycle calculation. A criticality search option is not available in this module. The control rods are treated as a series of discrete zones and the control rod is moved on a zone-by-zone basis. Modification of RODMOD was one option considered at the start of the development of CTRLPOS. Because of the limitations of RODMOD, a decision was made to develop a totally new and very flexible module which required minimum user intervention.

1.2.2 Control Rod Programming for Boiling Water Reactors

Several computer programs, such as OPROD by Kawai et al. and OCTOPUS by Mehmet et al., have been developed to generate control rod programming patterns for boiling water reactors[7,8,9,10]. These programs determine control rod patterns which optimize the length of the fuel cycle. The calculated patterns assure the safe and effective depletion of BWR cores throughout a fuel cycle. An 'acceptable' pattern has to meet all thermal hydraulic and safety limits. These control rod positioning codes perform position criticality searches, but not within a neutronics system suitable for the treatment of other reactor types.

CHAPTER 2

METHODOLOGY

The CTRLPOS module was developed to allow the positioning and movement of the control rods of a reactor system to be modelled in many possible ways. Any number of control rod banks each containing any number of control rods can be modelled. Also, since the positioning of the control rods is based on zone volumes, the module can be used with one-, two-, or three-dimensional VENTURE problems (r, z, θ-z, r-z, x-y, θ-r-z, x-y-z, hexagonal, and hexagonal-z geometries).

The input to the CTRLPOS module was kept as simple as possible to avoid confusion and ultimately incorrect results. The user should be warned that CTRLPOS must not be treated as a 'black box'. All input and output should be carefully analyzed to assure the control rods are being treated as expected.

2.1 Options

The CTRLPOS module has three major options. Each option provides a dimension of flexibility for control rod treatment.

The first option allows for a control rod position criticality search. A single control rod or a bank of control rods can be moved within the model to perform the search until the target k_{eff} value is reached. This is an iterative procedure which uses previous rod positions and k_{eff} values to determine a new position which should possess the target k_{eff} value. Usually several k_{eff} calculation iterations are needed to correctly position the control rod or control rod banks.

The second option allows the user to model control rods which are not used to perform the criticality search. These control rods could be safety rods used only for the shutdown of the reactor or stuck control rods. With CTRLPOS the user can change the position of these control rods at any time in the fuel cycle. The only input requirement is the position where the rod will be placed. This option can also be used to change the position of the regulating control rods.

The third option is used to calculate control rod worth curves. The control rods are moved to a series of input positions and a k_{eff} calculation is performed at each position. The rod worth of a single control rod or a bank of control rods can be determined using this option. This option requires a single input section and can be used at any time in a fuel cycle.

Depletion of the reactor core and the control rod material is performed in the VENTURE system by the BURNER[1] module. The CTRLPOS module uses the material depletion information from BURNER to accurately account for the burnup of the control rods. This process is complicated since the zone where a section of a control rod is present changes with each movement of the control rod. These methods are explained in more detail later in this chapter.

2.2 Control Rod Banks, Rods and Zones

Multiple banks each containing one or more control rods can be treated by the CTRLPOS module. Currently, only Bank 1 can be automatically moved to search for a target k_{eff} value while other control rods (e.g. safety control rods) are moved 'manually' (i.e. according to a fixed, preset input schedule) by the module. A multi-bank k_{eff} search option using a given relative sequence of movement for the banks is planned to be added in the near future. For each control rod of each bank a series of control rod zones must be input. These zones define the range of motion for each control rod. The material in the zones on the first entrance to the module should contain the control rod nuclides. For each of these control rod zones, a follower zone is also input. The follower zones contain material that will 'follow' the rod should the rod be moved out of this control rod zone. Since a different follower material is allowed for each control rod zone, a follower that has different properties at different positions can be modelled (such as coolant in a BWR).

Figure 2-1 shows a simple control rod zone model with a single control rod. Zones 2, 3, and 4 contain the control rod material. Zones 1 through 5 define the control rod range of motion. For this model, all control rod zones have the same follower material, the reflector material found in zone 6. The actual format of the input data for the CTRLPOS module is discussed in Chapter 3.

There are no restrictions that force control rod motion to be

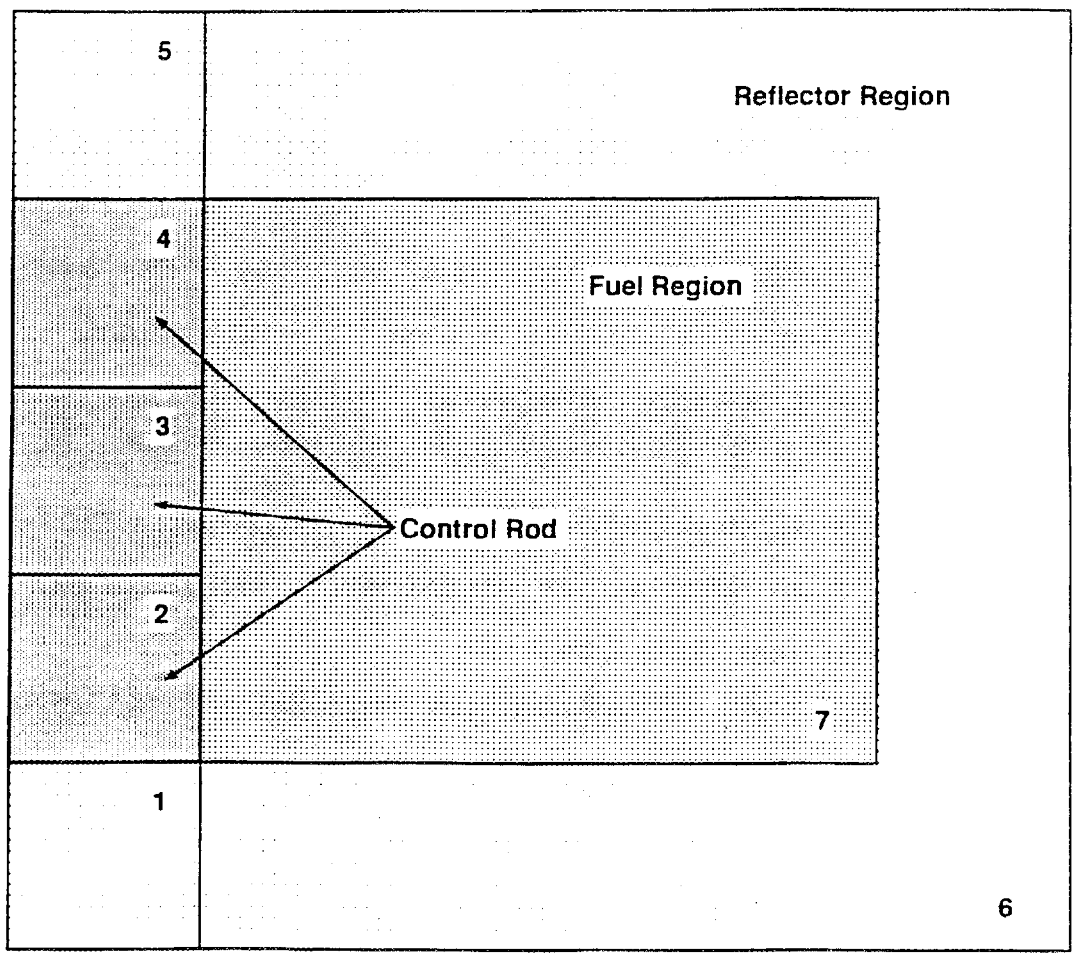


Figure 2-1 A simple control rod zone model with a single control rod.

only vertical. The zones do not even have to be consecutively ordered. This allows added flexibility, but also places more responsibility on the user. For example, the control rod can be moved opposite the desired direction of motion if the user inputs the data 'incorrectly'.

Control rod zone treatment is not on a zone-by-zone basis. The zones along the length of the control rod do not have to be the same size. Partial zone placement is possible and the control rod tip can be smeared over zones in the criticality search procedure. Figure 2-2 illustrates how control rod material is treated with the movement of the control rod. In this example, the control rod tip is moved to the center of zone 2. Zone 2 and zone 5 contain half control rod material and half reflector material. The CTRLPOS module smears the control rod material and the reflector material over each of these zones. Table 2-1 shows how the atom densities of each of the control rod zones are altered to account for the control rod movement. Calculations are included in Appendix A which illustrate how these densities are determined.

2.3 Nuclides in Control Rod Zones

2.3.1 Starting Control Rod Composition

The starting control rod composition is the material in the control rod zones on the first entrance to the CTRLPOS module. There is no restriction on what type of material is present in the control rod. For example, fissile material could be present in the

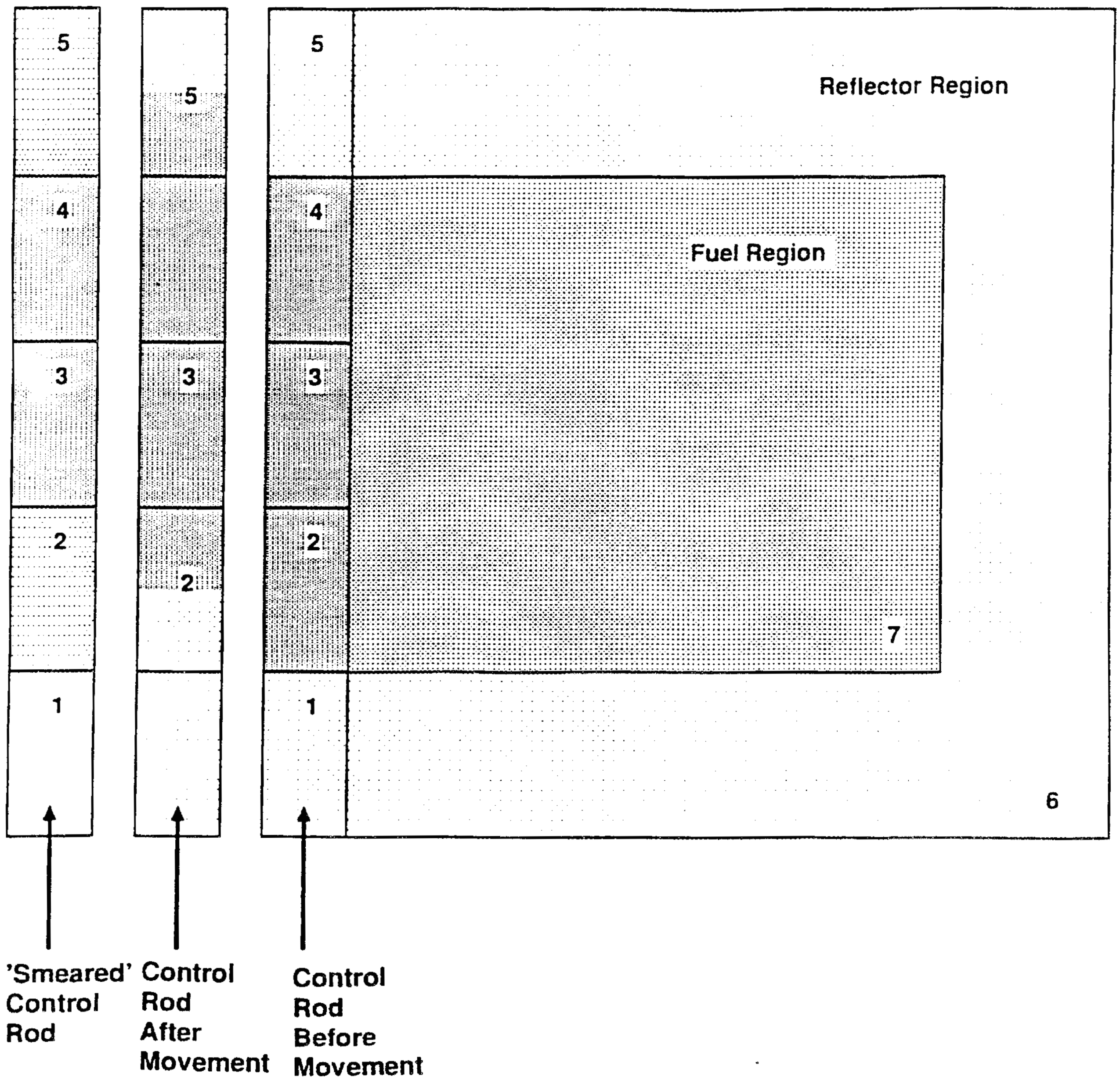


Figure 2-2 The treatment of control rod material with control rod movement.

Table 2-1 Relative atom densities for 'smeared' control rod zones.

Control rod zone number	Volume of zone, cm^3	Relative atom density at initial position[a]	'Smeared' relative atom density after control rod movement
1	10	FOLL=1.0	FOLL=1.0
2	10	CTRL=1.0	CTRL=0.5 FOLL=0.5
3	20	CTRL=1.0	CTRL=1.0
4	10	CTRL=1.0	CTRL=1.0
5	10	FOLL=1.0	CTRL=0.5 FOLL=0.5

[a] FOLL=Follower material.
CTRL=Control rod material.

'control rod' provided appropriate group constants are given. The beginning composition of the control rod is used to calculate the fraction of each nuclide present in each control rod zone after a burnup step.

2.3.2 Material Produced During Burnup

When CTRLPOS is used in conjunction with the BURNER module, nuclides in the control rod can be 'burned' to produce new nuclides in the control rod zones. To properly position these produced nuclides before moving the control rod to a new position, the production chains for nuclides in the control rod must be included in the CTRLPOS input. Burnup chains of nuclides such as the hafnium chain from ^{174}Hf to ^{180}Hf can be correctly treated by the module. For illustrative purposes, Table 2-2 shows the calculated atom densities after the control rod is moved to the position in Figure 2-2, depleted by the BURNER module, and then moved back to the initial inserted position. In this sample problem, the burnup of one control rod atom leads to the production of 0.75 atoms of PROD1 and 0.25 atoms of PROD2. Calculations illustrating how these atom densities are obtained are included in Appendix A.

If the top of the control rod is moved beyond the boundary of the VENTURE model, this rod information is saved and no exposure occurs to this material during a burnup calculation. The exposure of control rod follower material cannot be treated by the module. The user should always remember that the BURNER module uses the flux values from the last k_{eff} calculation to burn the material in

Table 2-2 Relative atom densities for a depleted control rod.

Control rod zone number	Relative atom density at initial position[a]	'Smeared' relative atom density after rod movement	Relative atom density after depletion	Relative atom density for depleted control rod at inserted position
1	FOLL=1.0	FOLL=1.0	FOLL=1.0	FOLL=1.0
2	CTRL=1.0	CTRL=0.5 FOLL=0.5	CTRL=0.4 FOLL=0.5 PROD1=0.075 PROD2=0.025	CTRL=0.65 PROD1=0.2625 PROD2=0.0875
3	CTRL=1.0	CTRL=1.0	CTRL=0.5 PROD1=0.375 PROD2=0.125	CTRL=0.575 PROD1=0.31875 PROD2=0.10625
4	CTRL=1.0	CTRL=1.0	CTRL=0.8 PROD1=0.15 PROD2=0.05	CTRL=0.85 PROD1=0.1125 PROD2=0.0375
5	FOLL=1.0	CTRL=0.5 FOLL=0.5	CTRL=0.45 FOLL=0.5 PROD1=0.0375 PROD2=0.0125	FOLL=1.0

[a] FOLL=Follower material.
CTRL=Control rod material.
PROD1=Product 1 from depletion of CTRL material.
PROD2=Product 2 from depletion of CTRL material.

each zone. To correctly burn control rod material, these flux values must be accurate for all zones where the control rods are present. Unconverged flux values in control rod zones will lead to incorrect burnup of the control rods.

Unconverged fluxes might lead to incorrect results in very large two- or three-dimensional studies. This is especially true for high leakage reactor systems such as the Advanced Neutron Source[5]. The k_{eff} value usually converges much quicker than the flux values in these large, multi-dimensional problems. Often the flux calculation has converged in the core region but has not converged at large distances into the reflector region. If the k_{eff} calculation is terminated prematurely and the unconverged flux values in the reflector region are used, the control rod may be burned inaccurately since the control rod could possibly be pulled almost completely out of the core and positioned very far out in the reflector region (see Figure 2-3). The user should always remember that the control rods may be at any position along their input range of motion.

In order to speed up the criticality searches, a solution might be the use only enough outer iterations in CTRLPOS to achieve an acceptable k_{eff} value for control rod positioning. Then, after exiting CTRLPOS but before calling BURNER, call the neutronics module and perform a k_{eff} calculation with enough outer iterations allowed to converge the flux values in all control rod zones. This solution approach saves calculation time since several position iterations are usually needed in CTRLPOS to correctly position the

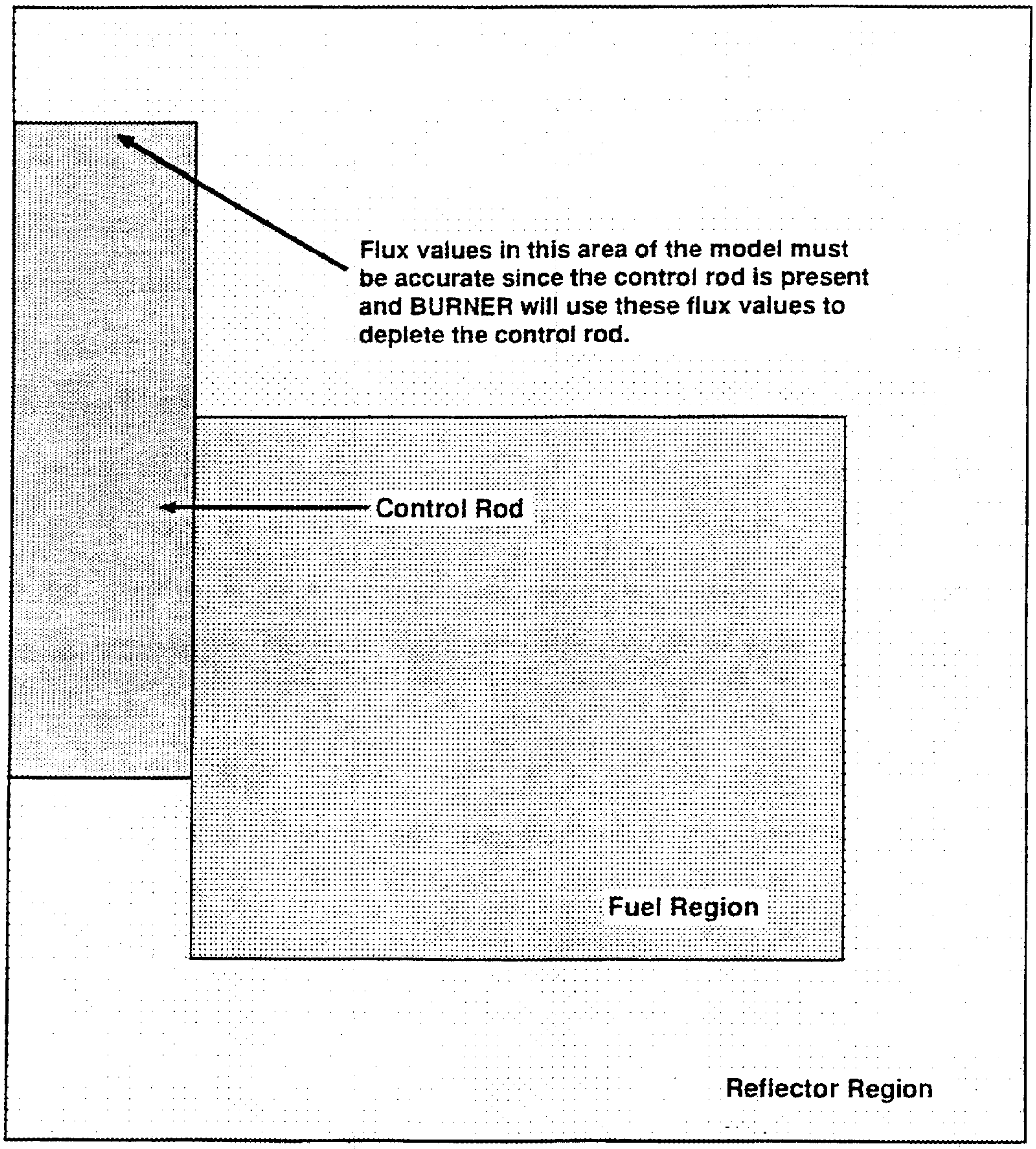


Figure 2-3 Control rod positioning illustrating the possibility of incorrect control rod burnup.

control rods.

Another case that can lead to erroneous results involves the treatment of the control rod tip. As mentioned before, the control rod tip is smeared over a control rod zone when performing calculations to reach the target k_{eff} value. In a smeared rod tip zone, the flux depression will be smaller than if the tip was well defined and not smeared. This effect can accelerate the depletion of the control rod tip. To fix this problem, an option in CTRLPOS will position the control rod at a control rod zone boundary before leaving the module. The iterative position search which smears the control rod tip zone is used to determine the control rod zone which has the target k_{eff} value, then the control rod is moved to the upper and lower boundary of this zone. The control rod is placed at the position which has the k_{eff} value closest to the target k_{eff} value. Assume that the position iteration procedure in CTRLPOS determines that the target k_{eff} value (unity in this case) is at position 1 in Figure 2-4. If the zone boundary option is used, the control rod would be moved to the lower boundary of zone 2 and a k_{eff} calculation would be performed. K_{eff} would also be calculated with the control rod at the upper boundary of zone 2. The rod would finally be positioned at the boundary with k_{eff} closest to the target k_{eff}, in this case the upper boundary of zone 2. With this option, the burnup of the control rod tip can be accurately calculated.

The user should also note that the number of position iterations required for convergence can be reduced if the control

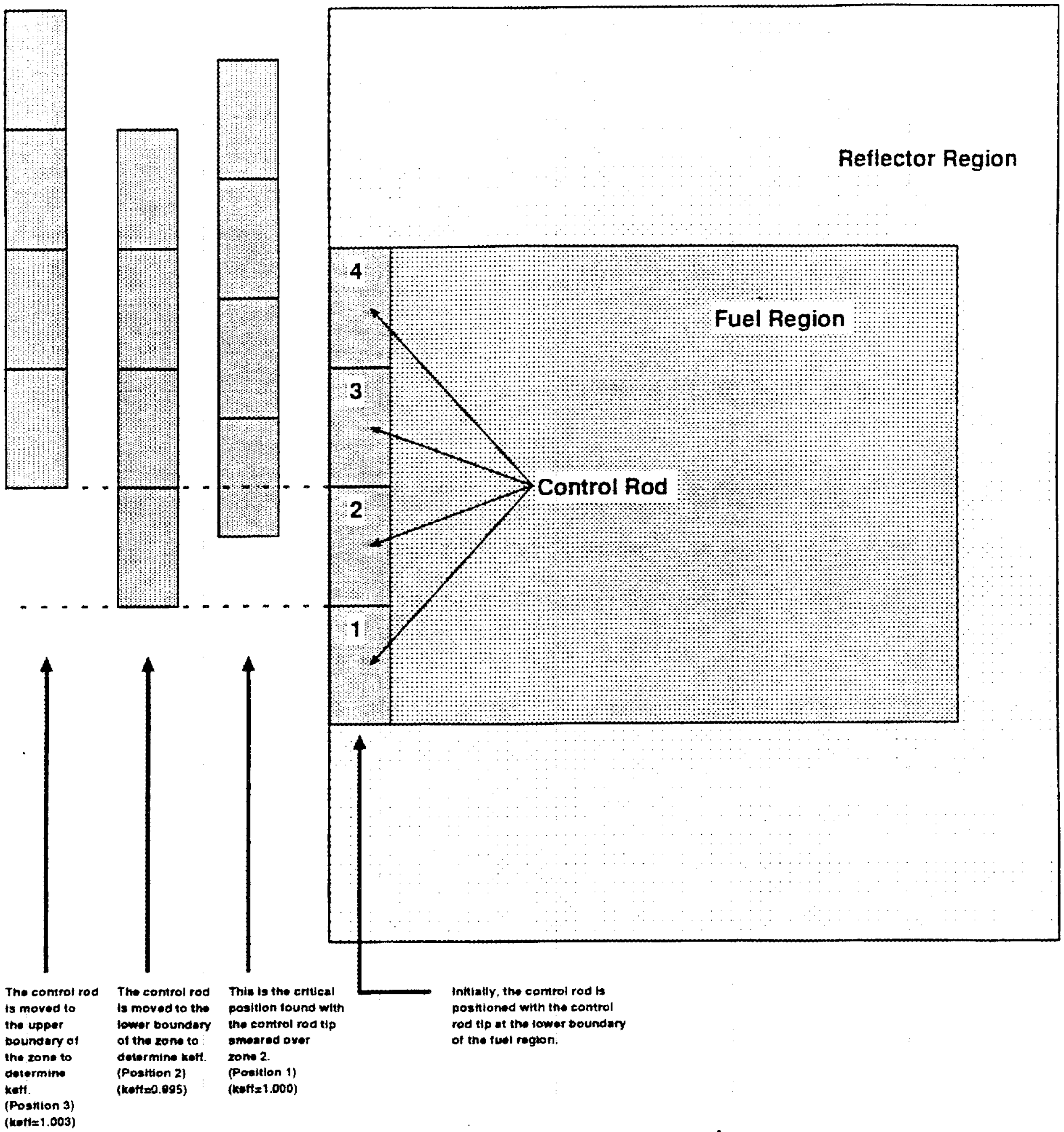


Figure 2-4 The positioning of a control rod to correctly deplete the control rod tip.

rod zones have small volumes. If the control rod tip is smeared over a large zone, a change in control rod position may change only the atom density of the control rod material in this zone. This change may have little effect on k_{eff}. The use of small control rods zones results in a more defined control rod tip; and, in some cases, fewer position iterations are needed to find the control rod position with the desired k_{eff} value.

2.4 Positioning of Control Rods

2.4.1 Initial Position

The control rod zone where the tip of the control rod is initially located is input to define the starting position of the control rod; the initial position can be the lower or upper surface of the specified control rod zone. This zone does not have to be the lowest zone in the control rod zone sequence. The position of the control rod at all times is defined by the total volume from the tip of the control rod to the initial position zone boundary. Therefore, the origin for each control rod is the zone boundary input as the starting position of its control rod tip. The volume parameter was used rather than height so the module could be used in one-, two-, and three-dimensional models. In Figure 2-2, the starting position of the control rod is the lower boundary of zone 2, or the 0.0 cm^3 position (the bottom of zone 2 is the origin). After movement, the new control rod position is 5 cm^3, the center of zone 2.

A first guess value of the control rod position, different from the initial rod position, must be input to initiate the criticality search procedure. Again, a control rod zone number is input to define this position. The control rod is moved to this position and a k_{eff} calculation is performed so two k_{eff} values and two control rod positions (the entry rod position and the first guess position) are known for the iteration procedure. The number of position iterations can be reduced if the first guess position is near the target k_{eff} position. The first guess position must be between the input positions that define the upper and lower limits of the control rod tip position. For instance, if the upper and lower limits of the control rod tip position in Figure 2-2 were defined as the lower boundary of zone 5 and the lower boundary of zone 2, respectively. A first guess position at the lower boundary of zone 1 would not be valid.

2.4.2 Iteration Procedure

The new control rod position which should yield the target k_{eff} value is determined using previous k_{eff} values and their respective control rod positions. The two known positions that possess the k_{eff} values closest to the target k_{eff} value are used to determine a guess for the next position. Several interpolation schemes are allowed, but experience has proven that linear interpolation works best. Some of the other methods such as Lagrangian interpolation based on more than two points can lead to an oscillatory control rod motion effect. Linear interpolation may require one or two extra k_{eff} calculations, but in the end it usually leads to a stable convergent solution of the positioning of the control rods.

CTRLPOS assumes that the k_{eff} values calculated at each position are sufficiently converged. If the k_{eff} calculation has not converged, then the control rod will be positioned incorrectly since wrong k_{eff} values are used to predict the new control rod position. For instance, the user should not try to position the control rod so that k_{eff} is within 1.0E-4 of unity if the k_{eff} convergence criteria of the VENTURE neutronics calculation is only 1.0E-3. The iteration procedure ends when the maximum number of position iterations, which is input by the user, is reached or the k_{eff} value calculated at a control rod position is within the specified tolerance of the target k_{eff} value.

On option, k_{eff} values and control rod positions determined by an earlier CTRLPOS module execution can be used by the interpolation scheme to predict the new control rod position. This option should be used only when the core characteristics do not change between CTRLPOS module entrances. Also, CTRLPOS has no way of determining if more than one control rod position has the desired k_{eff} value. A control rod worth curve could be calculated to determine if this is a property of the reactor system being examined. If more than one critical control rod position exists, the range of control rod motion should be input so that only the desired position can be reached.

2.4.3 Corrective Measures for Undesired Movement

Several corrective measures have been added to reduce incorrect control rod movement in the criticality position search. These measures are necessary in some cases to avoid excessive control rod movement.

The first measure makes sure the starting k_{eff} values match the control rod positions. On each CTRLPOS entrance (after the first entrance) when a criticality search is to be performed, a k_{eff} calculation is performed at two control rod positions. This is necessary since the old k_{eff} values will be incorrect if the core characteristics were changed by another VENTURE module. The core may have been burned, fuel assemblies may have been shuffled, fresh fuel assemblies may have been loaded, or a control rod not used in the criticality search may have been moved. The first k_{eff} value of the reactor core is determined for the current position of the control rods. The control rods are then moved to its position just prior to the last exit from CTRLPOS to obtain the second k_{eff} value. Once these two calculations are performed, the normal interpolation (extrapolation if the new position is outside the range of the two k_{eff} values) scheme is used to determine new control rod positions. The two most recent positions are used since in most cases (especially core depletion problems with small time steps) these positions have k_{eff} values close to the target k_{eff} value.

The second group of corrective measures are included to decrease sporadic control rod movements. When k_{eff} values (and corresponding control rod positions) are very close to the target

k_{eff} value, a small change in control rod position can lead to almost no change in the calculated value of k_{eff}. This situation might occur when a small target k_{eff} convergence criteria is set and the control rod position change corresponds to only a small change in the atom density of the material smeared over the control rod tip zone. The guess of a new control rod position might then lead to large control rod movements since the new control rod position is calculated by extrapolating between two k_{eff} values which differ by a very small amount. To limit large movement, a maximum control rod movement parameter is input by the user. This value is the maximum distance the control rod can be moved between two successive k_{eff} calculations. This parameter is not used in the first control rod position search or when the manual control rod movement option is used.

Another fix-up is required when a control rod position guess (which should yield the desired k_{eff} value) gives a k_{eff} value which is further from the target k_{eff} value than the previously predicted k_{eff}. This happens occasionally when a control rod is being positioned with a very tight tolerance on the target k_{eff} value. This fix-up is also important in a split core design that has a moderator region between two fuel regions. If the interpolation method predicts the same position two consecutive times, stored k_{eff} values and control rod positions are no longer used to determine new control rod positions. For the rest of the position iterations, the new control rod position is calculated using the interpolation (or extrapolation) scheme and only the k_{eff} values and positions from the last two k_{eff} calculations.

These 'fix-up' measures are not often needed to determine control rod positions; however, they are necessary to completely automate the control rod positioning procedure.

2.5 Rod Worth Curve and 'Manual' Movement

For the rod worth curve calculation and the manual control rod movement CTRLPOS options, a bank of control rods or a single control rod is moved to an input position. For the rod worth curve calculation, a series of positions can be input. A k_{eff} calculation is performed at each of these positions. After all positions are calculated, the rod is returned to the position where it was on entrance to the control rod worth curve section of the module. Both of these options allow the movement of a single control rod or a bank of control rods.

2.6 Restart Capabilities

The calculation of the control rod burnup over several fuel cycles can be done in two different ways. The first method is to calculate the burnup over several fuel cycles in a single continuous computer run. The core is depleted to the end of its cycle, then the core is refueled. If the core is refuelled by reloading the VENTURE model, both the core and the control rod will be replaced with 'fresh' material. On option, CTRLPOS will retain the previously burned control rod and this depleted control rod will be used to control the new core. If the DENMAN module is used to replace only the fuel region, this option is not necessary since the depleted control rod is not replaced with a new rod. Either of these procedures can be used to analyze the control rod for any number of cycles.

In the second method, the control rod is burned over only one fuel cycle at a time. CTRLIF, the CTRLPOS interface file containing all pertinent control rod information, is stored and reloaded when the next fuel cycle calculation starts. The VENTSTORE[11] module performs this task. This method can also be used to calculate the control rod burnup for any number of cycles. One advantage to this method is that the user always has the previously burned control rod information to restart the problem should a computer run crash. The user might also prefer this option if the calculation time for one fuel cycle is very long.

When using either of these two methods, the user must input data for two new control rod positions at the start of a new cycle calculation for each control rod. This is necessary since often at the end of a cycle the control rods are usually completely out of the core. To correctly position the control rods in a small number of iterations after the core has been refueled, it is better to drive the control rods into the core before the criticality position search begins. This capability is necessary since in most cases control rods are not replaced each time the reactor core is refueled.

CHAPTER 3

CTRLPOS MODULE DATA

3.1 CTRLCF, the CTRLPOS Control Record

The necessary data for the CTRLPOS module is entered in the VENTURE input file. Before calling CTRLPOS, the VENTURE control record for the module, CTRLCF, must be setup. The DUTLIN[1] input processor in the VENTURE system can be used to create this record. DUTLIN is used to add or replace records on the CONTRL interface file. The CONTRL interface file contains control records for several modules in the VENTURE system. These records contain instructions which tell each module what calculations are to be performed. For CTRLPOS, this record is named 'CTRLCF'. The required input for the 'CTRLCF' record is described in Figure 3-1. IX(1) is the variable that determines what option will be performed by CTRLPOS when the module is called.

The first entrance to the module is used to setup an output file for CTRLPOS. IX(1) should be either 1 or 5. Option 1 routes CTRLPOS output to the default VENTURE output file. This is usually not the preferred option since all the information for each k_{eff} calculation is also printed in this file. When option 5 is used, all CTRLPOS output is sent to a user-specified file name. The output for all other modules called by CTRLPOS is sent to the default VENTURE output file.

IX(1) must be either 10 (for a new run) or 20 with IX(13) not equal to zero (for a restart run) on the second CTRLPOS entrance. These options are necessary since the CTRLIF file must be created before CTRLPOS can be begin a control rod position search.

CTRLPOS is called by placing 'CTRLPOS' in columns 1-7 of the VENTURE input stream. For several IX(1) options, additional data is needed after this heading. Table 3-1 lists each of the cases where additional data must be input. Included in the table are remarks as to the purpose of the data. Figures B-2 through B-5 contain the format of the additional data. All data is free format except for the unique nuclide names required on cards 10 and 11 when IX(1) is equal to 10 (see Figure B-3). VENTURE uses both unique and absolute nuclide names. Each nuclide must have a unique name while several nuclides can have the same absolute name. For example, if ^{235}U were present in two different zones in a problem and different cross section sets were used in each zone, the unique nuclide names for the ^{235}U might be '1U235' and '2U235'. The absolute name for both of the nuclides could be 'U235'.

3.2 CTRLIF, the CTRLPOS Interface File

The CTRLIF file contains all control rod position and isotopic information. Figure B-6 lists the contents of this file. A description of the parameters which determine the length of each record is included (see Record 1). If a restart case is planned this file must be stored at the end of the fuel cycle. The file must be loaded into the VENTURE system before the next fuel cycle calculation can begin using the IX(1) equal to 20 with IX(13) not equal to 0 CTRLPOS option. The storage and retrieval of the CTRLIF interface file is done by the VENTSTORE[11] module.

Table 3-1 List of figures describing the additional data required for various CTRLPOS module options.

Variables which determine need for additional data	Figure describing data format	Remarks
IX(1)= 5	Figure B-2	Name of CTRLPOS output file
IX(1)=10	Figure B-3	Data required to setup CTRLIF file containing control rod information
IX(1)=20 with IX(13).NE.0	Figure B-4	Data changes control rod position after reactor core has been refueled
IX(1)=30	Figure B-5	Data provides positions for rod worth curve calculation

CHAPTER 4

SAMPLE PROBLEMS

Three different sample problems are provided to demonstrate some of the features of the CTRLPOS module. Monte Carlo, S_n transport theory, and diffusion theory results are compared for each problem. All calculations were performed on IBM RISC/6000 workstations. A short description of the nuclear analysis code packages used for these calculations is included in Appendix C.

The geometries of the sample problems are simple. These sample problems are for illustrative purposes to show several of the features of the CTRLPOS module and do not represent actual reactors.

Each sample problem has a fuel region with a light water reflector. The fuel region consists of UO_2F_2-H_2O solution with an $H/^{235}U$ ratio of 1270. This type of solution is often used in criticality benchmark experiments. The input and selected output for each sample problem are included in Appendix D.

4.1 Monte Carlo Calculations

Monte Carlo calculations were performed for each sample problem using MCNP, Version 4xe[13]. This version is an early release from Los Alamos National Laboratory. ENDF/B-V cross sections from the standard continuous energy libraries (provided with the code package) were used for all the materials. MCNP k_{eff}

values are shown with statistical uncertainties of two sigma. The statistical uncertainty printed in the MCNP output (the estimated relative error) is multiplied by two to obtain an uncertainty of two sigma. This gives a 95% confidence range for the reported k_{eff} value. For all MCNP calculations, 180 cycles with 1000 source particles per cycle were run. The first 30 cycles were skipped in order to achieve an asymptotic fission density distribution. A source distribution from a previous MCNP run was not used for any of the calculations. Figures 4-1, 4-2, and 4-3 show the typical behavior of k_{eff} versus the number of cycles for each sample problem. These figures show that the value of k_{eff} has reached a plateau that does not change much between cycles at the end of 180 cycles.

4.2 Cross Section Processing

Cross sections from the revised 99 neutron group ANSL-V master cross section library[14] were used for all transport and diffusion theory calculations. Figures 4-4, 4-5, and 4-6 show flowcharts of the cross section processing scheme for the 16, 8, and 4 neutron group working cross section libraries, respectively. The 99 group master library was processed using the SCALE 4.1 code system[15]. The CSASN module created a 99 neutron group working library. This module runs the BONAMI-S module to process unresolved resonances and NITAWL-II to process resolved resonances. CSASN was used for the resonance processing since only one set of input is required for the processing of both the unresolved and resolved resonances. Also, the module is part of the SCALE package which can be used to process AMPX format master cross section libraries, such as the 99 neutron group ANSL-V library.

XSDRNPM was used to calculate a 99 group neutron spectrum. This spectrum was used to perform a zone weighted collapse from 99 neutron groups to 16 neutron groups as shown in Figures 4-4, 4-5, and 4-6. Table 4-1 shows the energy boundaries for each group structure. In the generation of the 8 and 4 group libraries, the cross sections were first collapsed to the 16 energy group structure (See Figures 4-5 and 4-6). The 16 neutron group working library was then collapsed to 8 or 4 neutron group libraries.

A zone collapse was performed to create weighted spatially dependent cross section sets (named region cross section sets in this report). In each sample problem, two fuel region and two reflector region cross section sets were generated. A region cross section set is created by performing a zone weighted collapse in a geometric area of a problem. For instance, for the fuel region, two different region cross section sets were created. One set is for the inner fuel region (center of fuel) while the other set is for the outer fuel region (fuel near the reflector). Region cross section sets are used to provide cross sections which have been collapsed over the spectrum characteristic to the region's geometric position in the problem. The use of multiple region cross section sets can be very important in reactor cores where the neutron flux is very dependant on position (for example, high

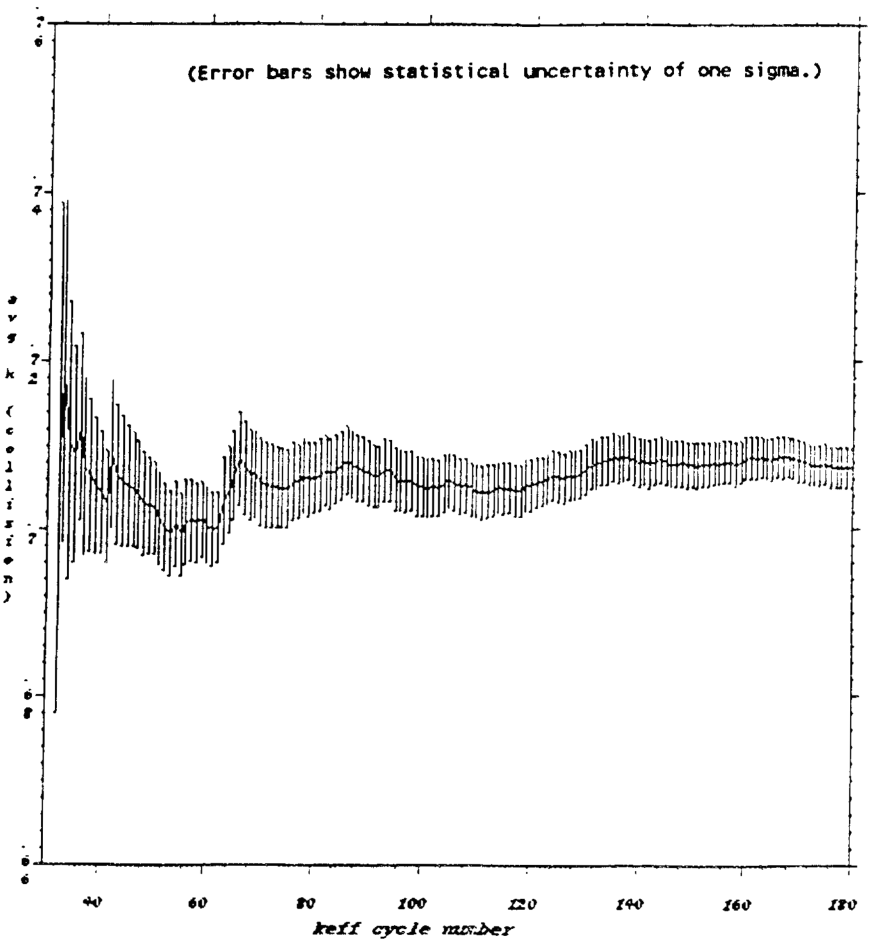


Figure 4-1 K_{eff} behavior versus number of cycles for MCNP calculations for Sample Problem 1.

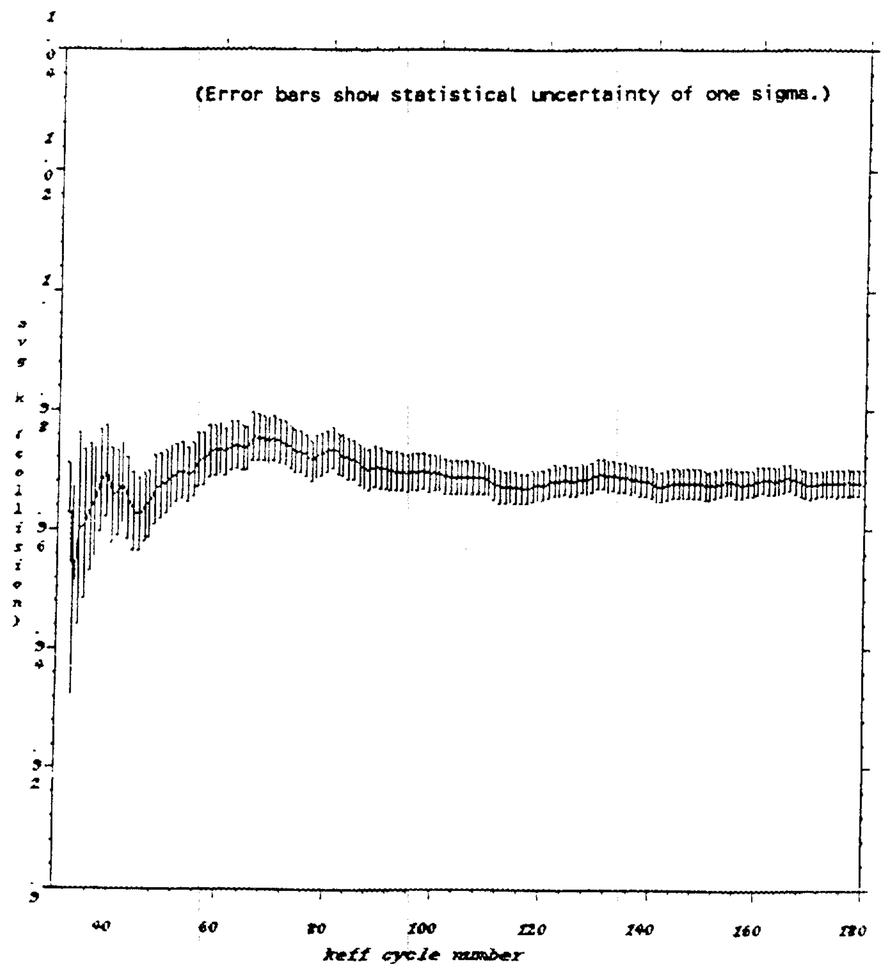


Figure 4-2 K_{eff} behavior versus number of cycles for MCNP calculations for Sample Problem 2.

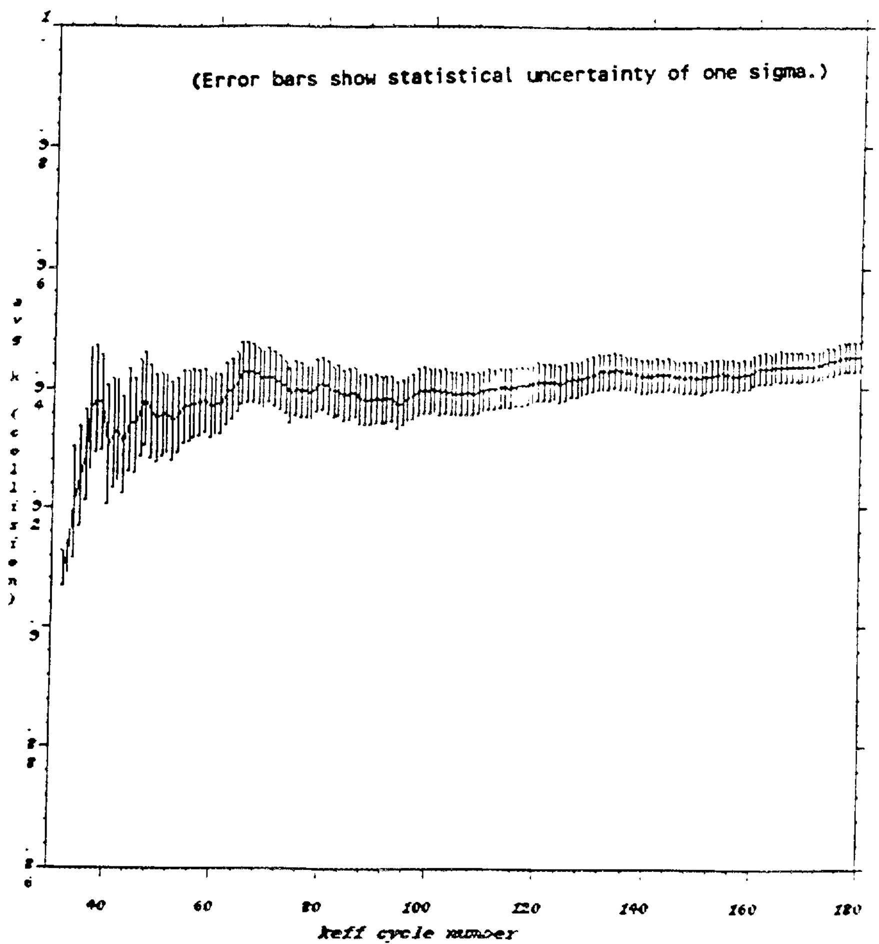


Figure 4-3 K_{eff} behavior versus number of cycles for MCNP calculations for Sample Problem 3.

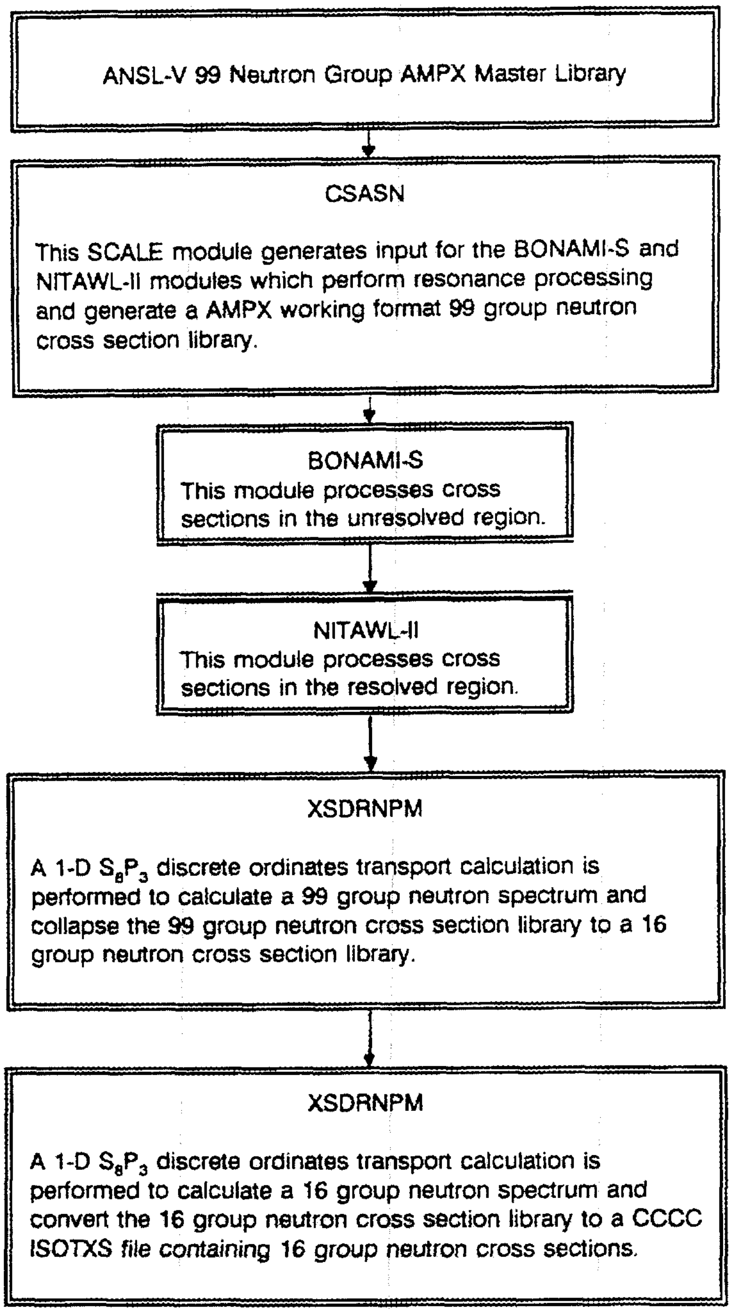


Figure 4-4 Flowchart of the calculational procedure used to generate 16 group neutron cross sections for CTRLPOS sample problems.

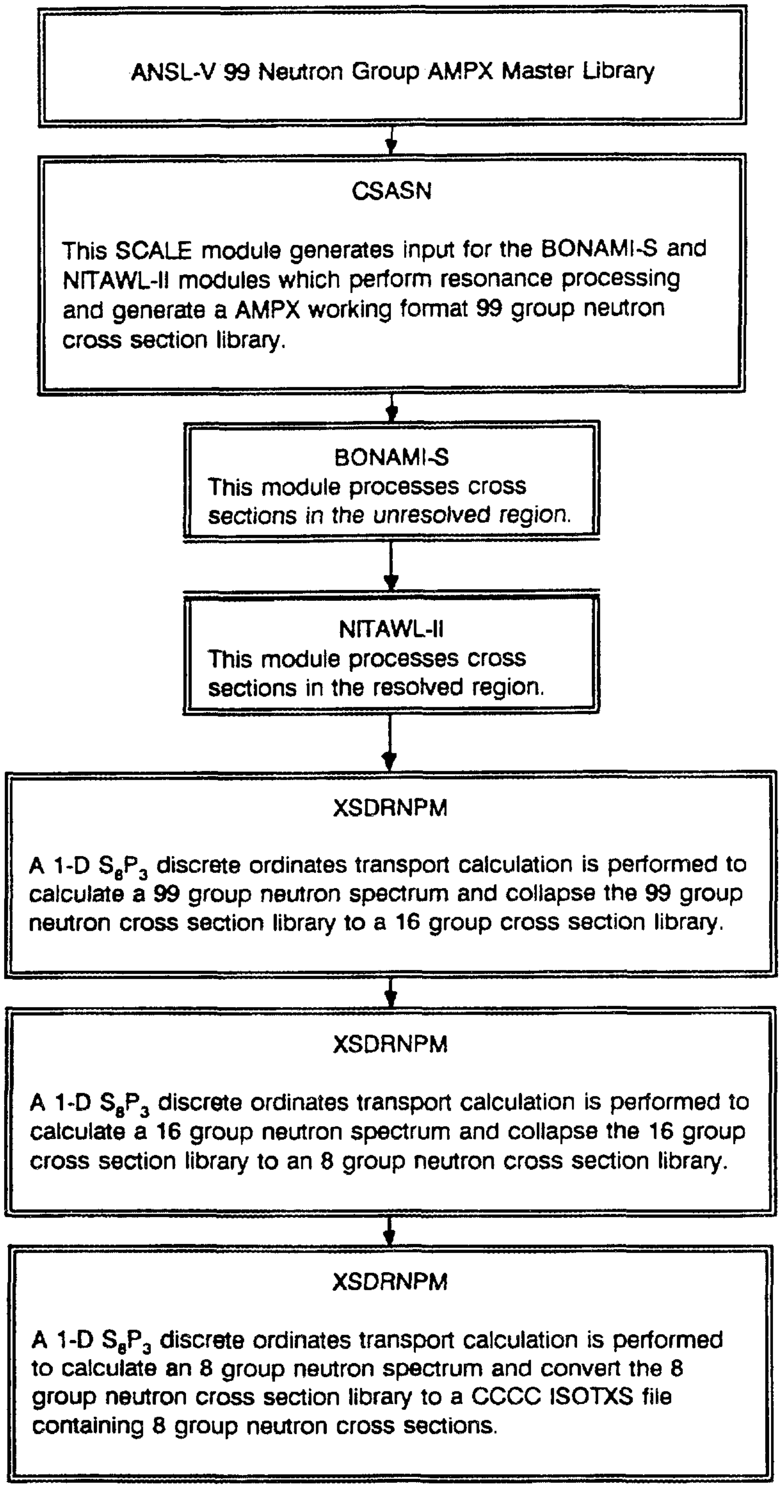


Figure 4-5 Flowchart of the calculational procedure used to generate 8 group neutron cross sections for CTRLPOS sample problems.

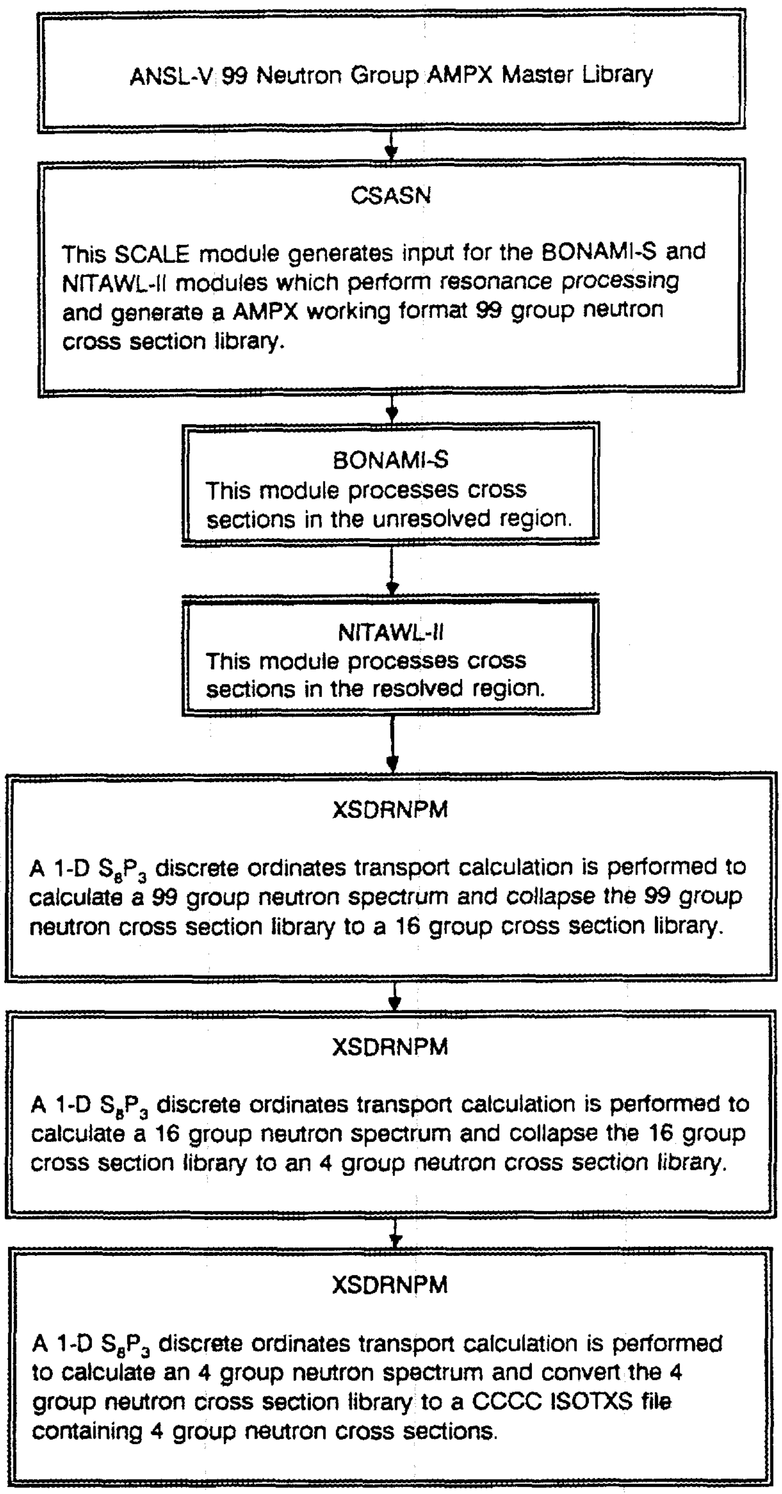


Figure 4-6 Flowchart of the calculational procedure used to generate 4 group neutron cross sections for CTRLPOS sample problems.

Table 4-1 Neutron energy group structures for sample problem calculations.

	Upper Energy (eV)	Neutron Group Structure				
		99	16[a]	8	4[b]	4[c]
1	2.0000E+07	1	1	1	1	1
2	1.5941E+07	2				
3	1.2706E+07	3				
4	1.0127E+07	4				
5	8.0722E+06	5				
6	6.4340E+06	6				
7	5.5234E+06	7				
8	4.7417E+06	8				
9	4.0707E+06	9				
10	3.4946E+06	10				
11	3.0000E+06	11	2			
12	2.7235E+06	12				
13	2.4725E+06	13				
14	2.2447E+06	14				
15	2.0378E+06	15				
16	1.8500E+06	16				
17	1.7497E+06	17				
18	1.6548E+06	18				
19	1.5651E+06	19				
20	1.4803E+06	20				
21	1.4000E+06	21	3			
22	1.2816E+06	22				
23	1.1732E+06	23				
24	1.0740E+06	24				
25	9.8315E+05	25				
26	9.0000E+05	26	4	2		
27	7.6525E+05	27				
28	6.5068E+05	28				
29	5.5326E+05	29				
30	4.7043E+05	30				
31	4.0000E+05	31	5			
32	3.0314E+05	32				
33	2.2974E+05	33				
34	1.7411E+05	34				
35	1.3195E+05	35				
36	1.0000E+05	36	6	3	2	2
37	7.0160E+04	37				
38	4.9224E+04	38				
39	3.4536E+04	39				
40	2.4230E+04	40				
41	1.7000E+04	41	7			
42	1.2017E+04	42				
43	8.4941E+03	43				
44	6.0042E+03	44				
45	4.2441E+03	45				
46	3.0000E+03	46	8			
47	2.1368E+03	47				
48	1.5220E+03	48				
49	1.0841E+03	49				
50	7.7217E+02	50				
51	5.5000E+02	51	9			
52	3.9110E+02	52				
53	2.7811E+02	53				
54	1.9776E+02	54				
55	1.4063E+02	55				
56	1.0000E+02	56	10	4	3	3

(CONTINUED)

Table 4-1 (continued)

57	7.8600E+01	57				
58	6.1780E+01	58				
59	4.8559E+01	59				
60	3.8168E+01	60				
61	3.0000E+01	61	11			
62	2.4082E+01	62				
63	1.9332E+01	63				
64	1.5518E+01	64				
65	1.2457E+01	65				
66	1.0000E+01	66	12	5		
67	7.8600E+00	67				
68	6.1780E+00	68				
69	4.8559E+00	69				
70	3.8168E+00	70				
71	3.0000E+00	71	13		4	
72	2.6996E+00	72				
73	2.4292E+00	73				
74	2.1859E+00	74				
75	1.9670E+00	75				
76	1.7700E+00	76				
77	1.3000E+00	77				
78	1.0000E+00	78	14	6		4
79	7.6500E-01	79				
80	6.2500E-01	80				
81	4.7900E-01	81				
82	3.9700E-01	82	15	7		
83	3.3000E-01	83				
84	2.7000E-01	82				
85	2.1500E-01	85				
86	1.6200E-01	86				
87	1.0400E-01	87	16	8		
88	5.0000E-02	88				
89	3.0000E-02	89				
90	1.0000E-02	90				
91	4.4500E-03	91				
92	3.2500E-03	92				
93	2.6000E-03	93				
94	2.1500E-03	94				
95	1.8000E-03	95				
96	1.4500E-03	96				
97	1.1500E-03	97				
98	8.5000E-04	98				
99	5.5000E-04	99				
	1.0000E-05					

[a] Hansen-Roach 16 group structure[16]
[b] 4 group structure with 3 ev cutoff
[c] 4 group structure with 1 ev cutoff

(End of Table 4-1)

leakage systems). Only one region cross section set was generated for the control rod material (hafnium) isotopes in Sample Problems 2 and 3.

A value of 1.0E-4 was used for both the eigenvalue and flux convergence criteria for all XSDRNPM runs. After collapsing the cross sections, a CCCC ISOTXS interface file was created. The VENTURE code system accesses this cross section format.

4.3 Diffusion Theory Calculations

The VENTURE computation system was utilized to perform all the diffusion theory reactor calculations. The VENTNEUT neutronics module performs a mesh-centered, finite-difference calculation in one-, two-, or three-dimensional geometry. Both the diffusion theory and the P1 approximation options were used for the sample problem calculations. For all the problems, a k_{eff} convergence criterion of 5.0E-6 was used with a flux convergence criterion of 5.0E-5. These values were selected since they are the default values and are rather small convergence criteria. The control rod positioning convergence criterion in CTRLPOS was 1.0E-3 for all the sample problems. In all cases, enough iterations were allowed to ensure convergence.

4.4 Sample Problem 1: Cylindrical Core Size Study

4.4.1 Purpose of Sample Problem 1

Sample Problem 1 demonstrates the use of the "control rod worth curve" CTRLPOS option. Some of the flexibility of the CTRLPOS module is shown since the option is used to determine k_{eff} values for different one-dimensional fuel region sizes.

4.4.2 Brief Description of Sample Problem 1

Sample Problem 1 examines a one-dimensional, homogeneous, infinite cylindrical fuel region with a light water reflector. Figure 4-7 shows a top and side view of the model. The model shows the problem has an inner and outer fuel region surrounded by a reflector region which is also divided into an inner and outer region. Both fuel regions contain the same fuel material. Both regions of the reflector contain light water. Table 4-2 shows the atom densities for each material used in Sample Problem 1.

The CTRLPOS module is used to calculate k_{eff} for various fuel region radii. At the start of the calculation, the reactor fuel region has a radius of 10 cm. The CTRLPOS module increases the fuel region radius and performs a k_{eff} calculation for the new core. This process is continued until the fuel region radius is 35 cm. As the fuel region increases in size, the reflector region decreases in size. When the fuel region radius is 10 cm, the reflector is 40 cm thick; and, when the fuel region radius is 35 cm, the reflector is 15 cm thick. The outer boundary of the reflector region was thus kept at a radius of 50 cm.

A flowchart of the calculational path for Sample Problem 1 is shown in Figure 4-8. The DUTLIN module is used to setup and make changes to 'CTRLCF', the CTRLPOS control file. The parameters in the 'CTRLCF' file are discussed in detail in Chapter 3. The CTRLPOS control rod worth curve option (Option 30) was used to position the 'control rod' (in this case the fuel region) at a series of zone boundaries. Note that the 'control rod' is in reality fuel material. The radius of the fuel region increases and the thickness of the reflector region decreases while the control rod worth curve calculation proceeds. The CTRLPOS module is used to calculate k_{eff} values for several core sizes.

Several different change cases were examined. The flexibility of CTRLPOS allows the movement of the fuel material to be modelled in several different ways. Figure 4-9 shows the four methods which were examined. For all four methods, the starting problem geometry is the same. The fuel region has a radius of 10 cm. Region cross section set 1 is used in the inner fuel region, and region cross section set 2 is used in the outer fuel region (next to the reflector). Two different region cross section sets are also used in the reflector, set 1 for the reflector next to the fuel and set 2 for the reflector at the outside boundary of the problem.

Methods 1 and 2 shown in Figure 4-9 differ only by the starting point of the control rod tip. In Method 1, the control rod tip is initially located at the center of the fuel region. The 'control rod' starts at the center of the fuel and ends at the outer edge of the reflector region. As the 'control rod' is moved outward, the radius of the fuel region increases and the thickness of the reflector region decreases. The zones of the fuel region that the 'control rod' is moved out of are filled with control rod follower material. In Method 1, the follower material is fuel using region cross section set 1.

Method 2 is the same as Method 1 except the control rod tip is initially located at the boundary between the inner and outer fuel regions. The inner fuel region which contains fuel using region cross section set 1 remains stationary in this method. As the 'control rod' is moved outward, the radius of the fuel region increases and the thickness of the reflector region decreases. The control rod follower is fuel using region cross section set 1. This follower material is placed in the zones that are left empty as the control rod tip is moved outward.

In Method 3, the control rod tip is initially located at the outer boundary of the outer fuel region. As the 'control rod' is moved outward increasing the size of the fuel region, fuel material using cross section set 2 is used as the control rod follower material. The original inner and outer fuel regions remain stationary. The fuel region size increases with the addition of fuel material to the outer edge of the outer fuel region while the reflector thickness decreases.

In Method 4, the control rod tip is initially located at the outer boundary of the outer fuel region. The follower material is fuel using region cross section set 1 until the fuel radius reaches

14.4 cm. At a fuel region radius of 14.4 cm, the core consists of fuel using region cross section set 1 out to a radius of 11.5 cm and fuel using region cross section set 2 from 11.5 cm to the outer edge of the fuel region at 14.4 cm. When the fuel region is larger than 14.4 cm, the follower material is changed to fuel using region cross section set 2. A fuel region with a radius greater than 14.4 cm consists of an inner fuel region with a radius of 11.5 cm containing fuel using region cross section set 1 and an outer fuel region which contains fuel using cross section set 2. Method 4 is different from the previous methods. The radius of the inner fuel region is increased until its radius is 11.5 cm; then, the thickness of the outer fuel region is increased. In this method, two different control rod followers are used.

Since CTRLPOS uses zone volumes and these volumes change as the fuel region radius increases, for most control rod positions the reflector/fuel interface is smeared over the zone which separates the fuel and reflector regions. All zones are 0.5 cm thick. The zone volume is dependent on the zones distance from the center of the fuel region. For instance, a 0.5 cm thick ring with an inside radius of 1.0 cm does not have the same volume as a 0.5 cm thick ring with an inside radius of 2.0 cm. Since each zone does not have the same volume, at certain 'control rod' positions the outside zone of the fuel region will contain both reflector and fuel material.

Another parameter that must be examined is the validity of using cross sections calculated at one fuel region size in a k_{eff}

calculation for a different fuel region size. In this sample problem, the radius of the fuel region and the thickness of the reflector region are being changed dramatically from the starting geometry. At the start of the calculations, the fuel region has a radius of 10 cm. The largest fuel region size examined has a radius of 35 cm. The validity of using cross sections created for a fuel region with a radius of 10 cm in a k_{eff} calculation for a fuel region with a 35 cm radius must be examined.

To examine this parameter, three different problem cross section sets were created and each method was examined using each problem cross section set. Problem cross section set 1 was created using a fuel region radius of 10 cm, problem cross section set 2 with a fuel region radius of 22.5 cm, and problem cross section set 3 with a radius of 35 cm.

A problem cross section set is not the same as a region cross section set. A problem cross section set is for a specific problem geometry. Problem cross section set 1 was created using a geometry that has a fuel region with a radius of 10 cm surrounded by a 40 cm thick reflector region. All three problem cross section sets contain two region cross section sets for the fuel region and two region cross section sets for the reflector region. Problem cross section set 2 was created for a fuel region with a radius of 22.5 cm and with a 27.5 cm thick reflector region. Problem cross section set 3 was created for a fuel region with a radius of 35 cm and with a 15 cm thick reflector region.

VENTURE calculations were performed using these different methods and problem cross section sets with both diffusion theory and P1 approximation options.

4.4.3 Results for Sample Problem 1

Table 4-3 compares the MCNP, XSDRNPM, and VENTURE results. These k_{eff} values are for the base cases. The base cases are the cases where the problem geometry in the three different code systems is identical. For example, for the 10 cm radius reactor core base case, the reactor fuel region radius was 10 cm and the reflector thickness was 40 cm in the MCNP, XSDRNPM, and VENTURE calculations. The k_{eff}'s using the 99 neutron group cross sections and the discrete ordinates transport model are smaller than the 4 group transport based values. The 4 group VENTURE k_{eff} values slightly over-estimate the MCNP results.

Figures 4-10 through 4-15 compare the CTRLPOS Method 1 results for different energy structures for the three problem cross section sets. Results for the VENTURE diffusion theory option are shown in Figures 4-10 through 4-12. Results for the VENTURE P1 approximation option are shown in Figures 4-13 through 4-15. In this problem, the different energy cutoff (1 ev versus 3 ev for group 4) and the diffusion theory and P1 approximation options yield small differences in k_{eff}. The same conclusion was found for Methods 2, 3, and 4 described in Figure 4-9.

Figure 4-16 compares the VENTURE 16 group Method 1 results for the three different problem cross section sets. The use of different problem cross section sets has little effect on the k_{eff}

values in this problem. This same result was observed for the three other methods. Figures 4-17 through 4-20 compare the CTRLPOS and MCNP k_{eff} results. Similar to the results of the base case shown in Table 4-3, when the fuel region is smaller than 10 cm, the 16 group k_{eff} values are about 3% lower than the MCNP results while the 4 group values appear to slightly over-estimate the MCNP results. When the fuel region has a radius between 25 and 35 cm, the 16 group results and the MCNP results agree very well. All four methods produce approximately the same k_{eff} values. This is probably because the cross sections for the two fuel regions are very similar. In other systems (a system with a large change in the neutron spectrum over the fuel region), each method might result in very different values for k_{eff}.

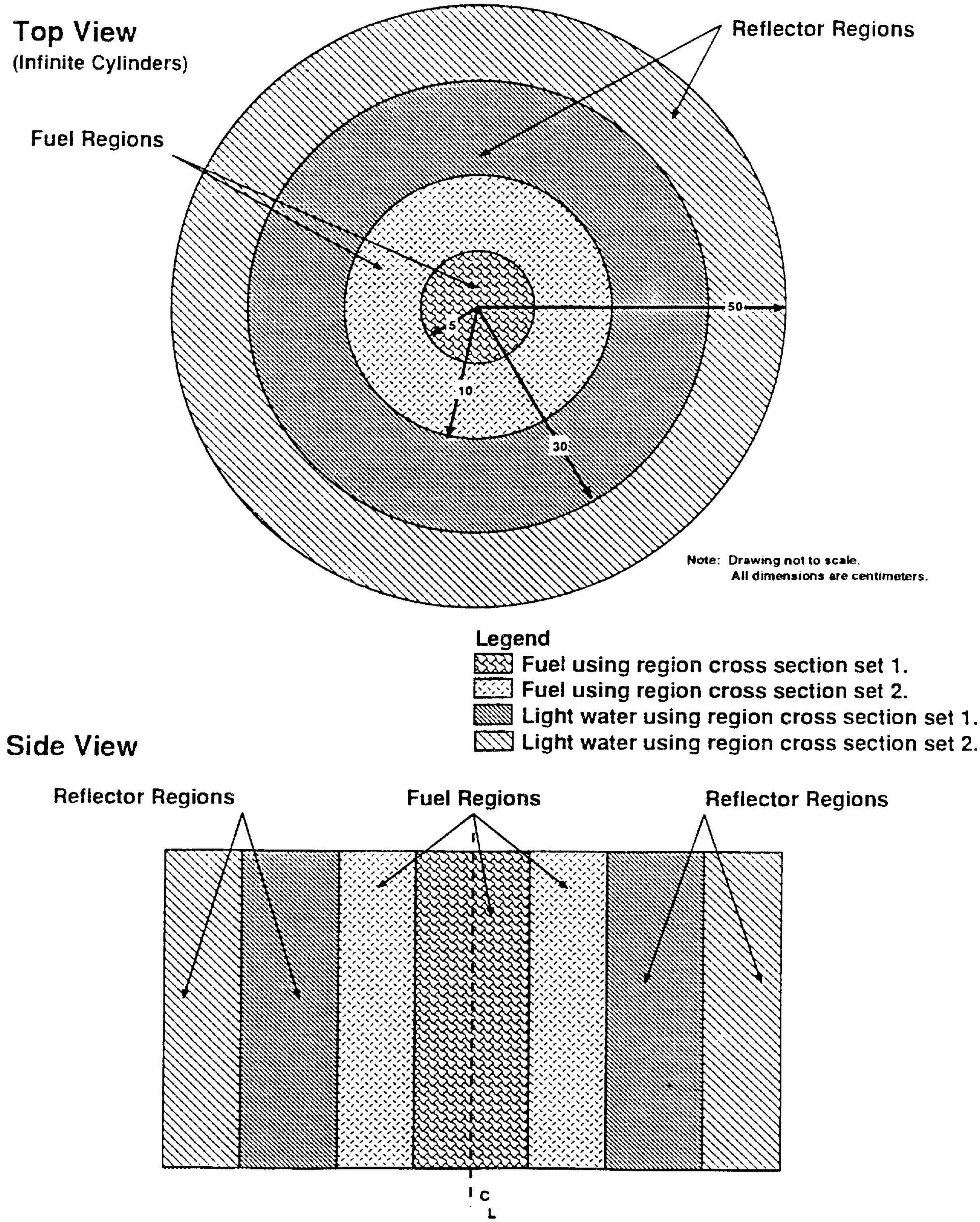


Figure 4-7 Top and side view of the geometry of Sample Problem 1.

Table 4-2 Atom densities for materials used in Sample Problem 1.

Nuclide	Material Atom Densities ($cm^{-3} \times 10^{-24}$)	
	Fuel (UO_2F_2-H_2O solution)	Reflector (H_2O)
H	6.6436-2[a]	6.6644-2
O	3.3330-2	3.3334-2
F	1.2338-4	0.0
^{234}U	5.5020-7	0.0
^{235}U	5.2312-5	0.0
^{236}U	2.6950-7	0.0
^{238}U	3.0091-6	0.0

[a] Read as 6.6436×10^{-2}

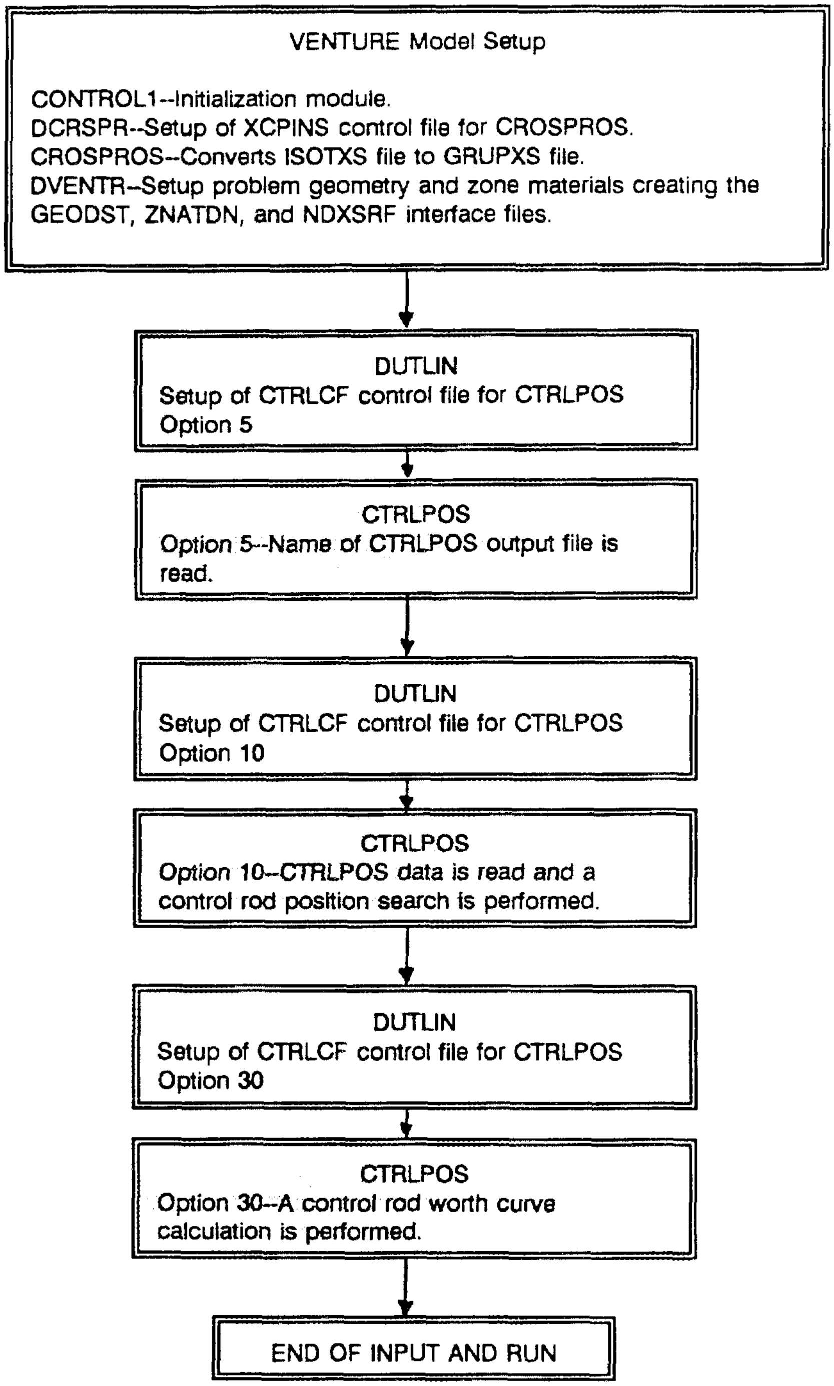


Figure 4-8 Flowchart of the VENTURE calculation for Sample Problem 1.

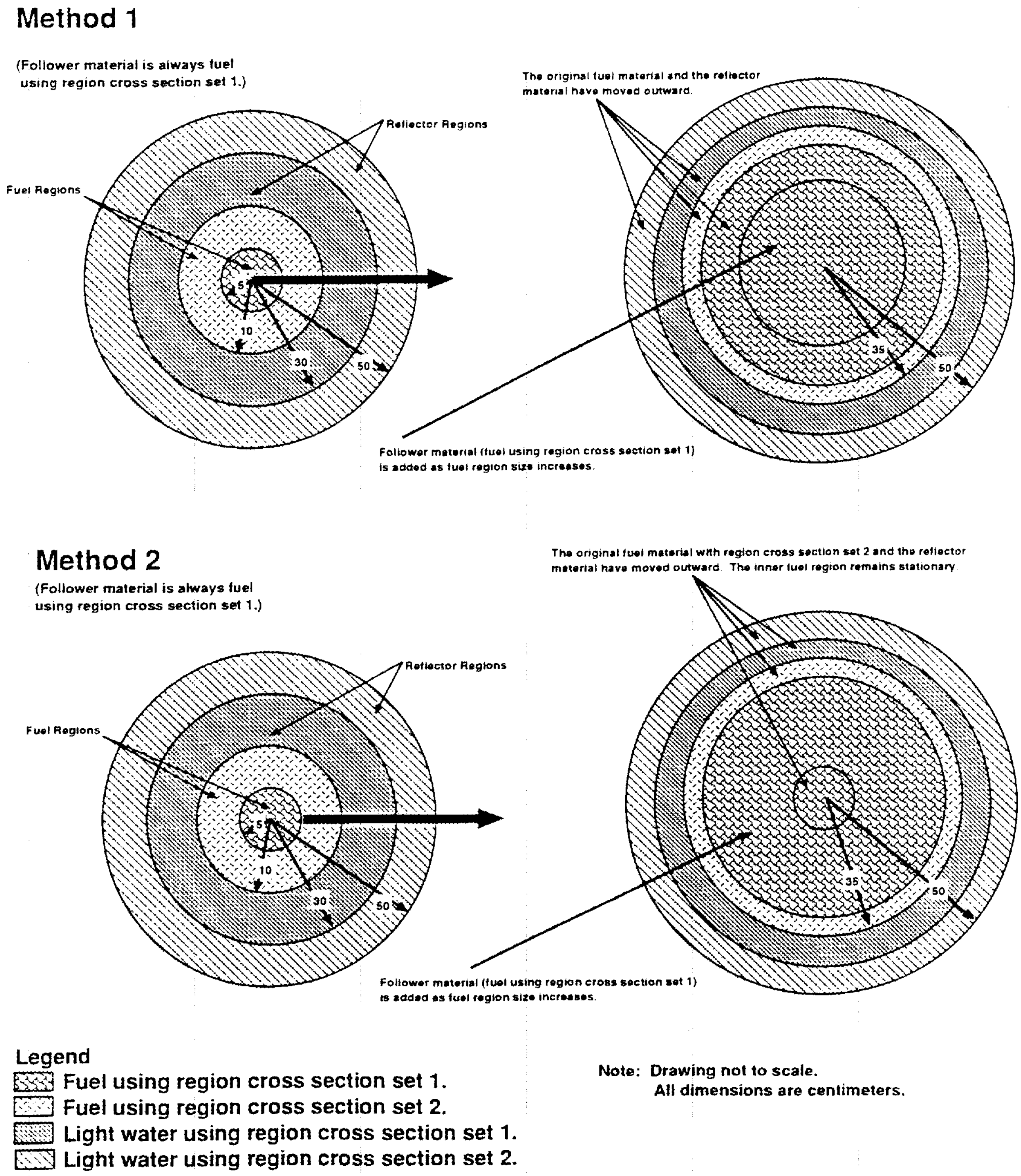
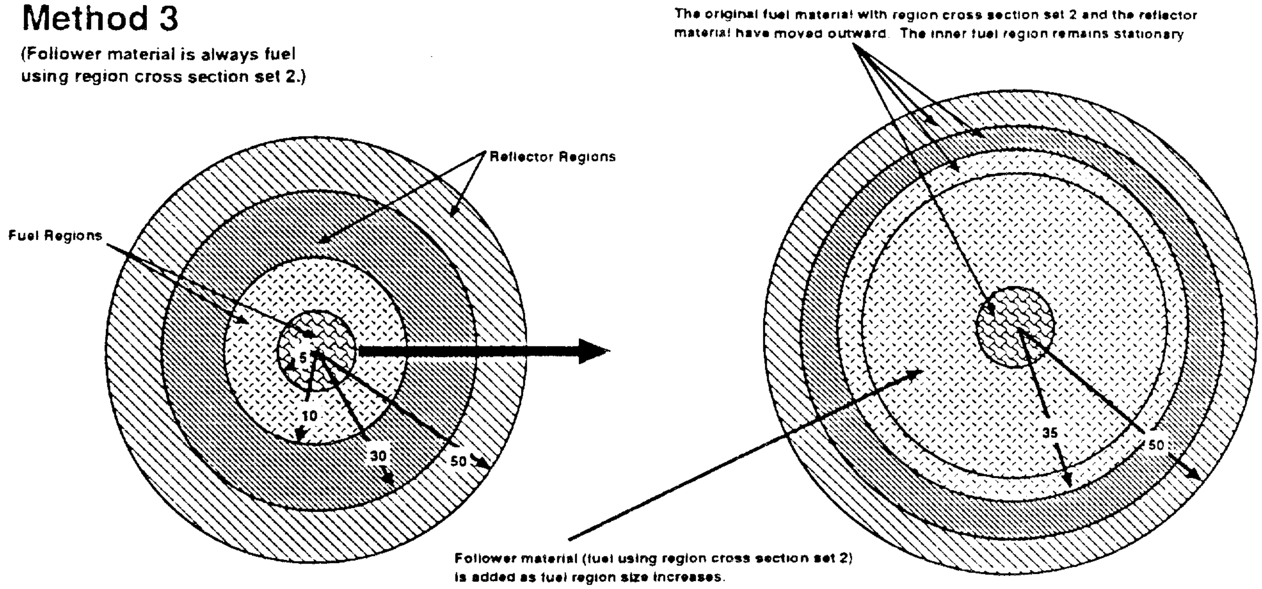


Figure 4-9 Different methods used to move the control rod material (fuel) in CTRLPOS Sample Problem 1.

Figure 4-9 (continued)

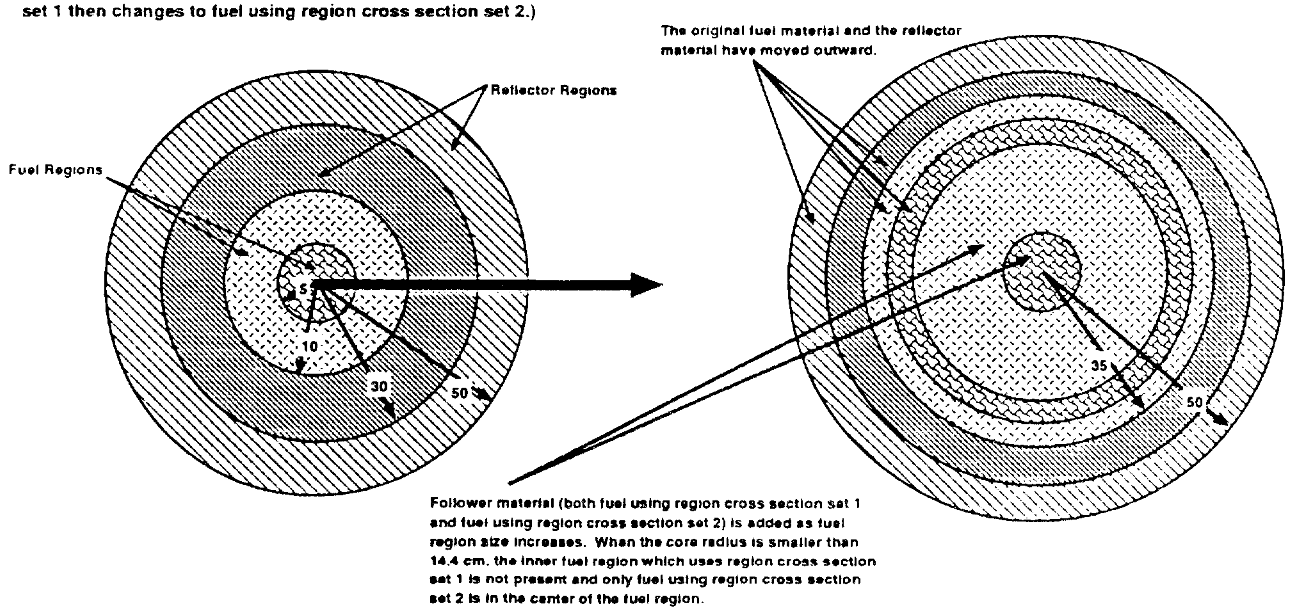
Method 3

(Follower material is always fuel using region cross section set 2.)



Method 4

(Follower material is always fuel using region cross section set 1 then changes to fuel using region cross section set 2.)



Legend
- Fuel using region cross section set 1.
- Fuel using region cross section set 2.
- Light water using region cross section set 1.
- Light water using region cross section set 2.

Note: Drawing not to scale.
All dimensions are centimeters.

Table 4-3 Base case k_{eff} results for Sample Problem 1.

Calculation Method	Geometry Configuration		
	10 cm radius reactor core	22.5 cm radius reactor core	35 cm radius reactor core
MCNP[a]	0.7105± 0.0033	1.0393± 0.0025	1.1488± 0.0022
VENTURE[b]-4 group Diffusion theory (1 ev cutoff)	0.7145	1.0548	1.1577
VENTURE-4 group P1 approximation (1 ev cutoff)	0.7126	1.0544	1.1575
VENTURE-4 group Diffusion theory (3 ev cutoff)	0.7190	1.0569	1.1588
VENTURE-4 group P1 approximation (3 ev cutoff)	0.7169	1.0564	1.1586
VENTURE-16 group Diffusion theory	0.6881	1.0365	1.1465
VENTURE-16 group P1 approximation	0.6844	1.0354	1.1461
XSDRNPM-99 group	0.7124	1.0454	1.1526
XSDRNPM-16 group	0.7133	1.0446	1.1501
XSDRNPM-4 group (1 ev cutoff)	0.7321	1.0593	1.1594
XSDRNPM-4 group (3 ev cutoff)	0.7367	1.0629	1.1605

[a] Reported statistical uncertainty for MCNP k_{eff}'s is two sigma obtained by multiplying the reported uncertainty of one sigma in the MCNP output by two. Values are reported for 1000 source particles per cycle. 180 cycles were run and the first 30 cycles were skipped.
[b] All VENTURE calculations were performed using a one-dimensional, infinite, cylindrical geometry model.

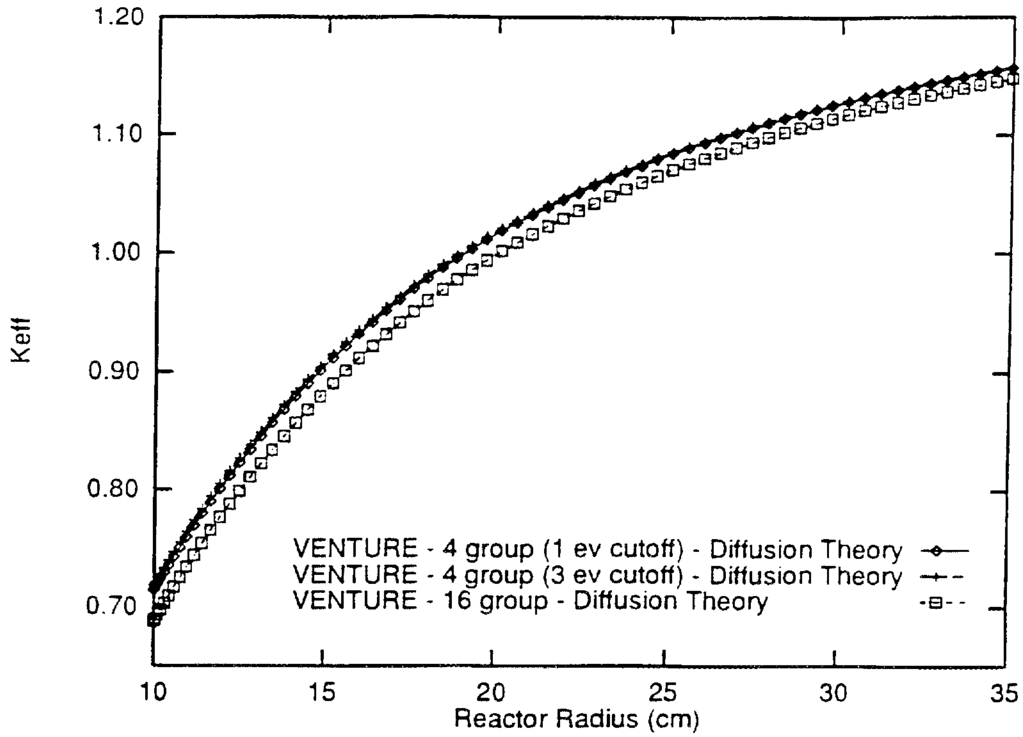


Figure 4-10 K_{eff} versus reactor size for diffusion theory cases using Method 1 and problem cross section set 1.

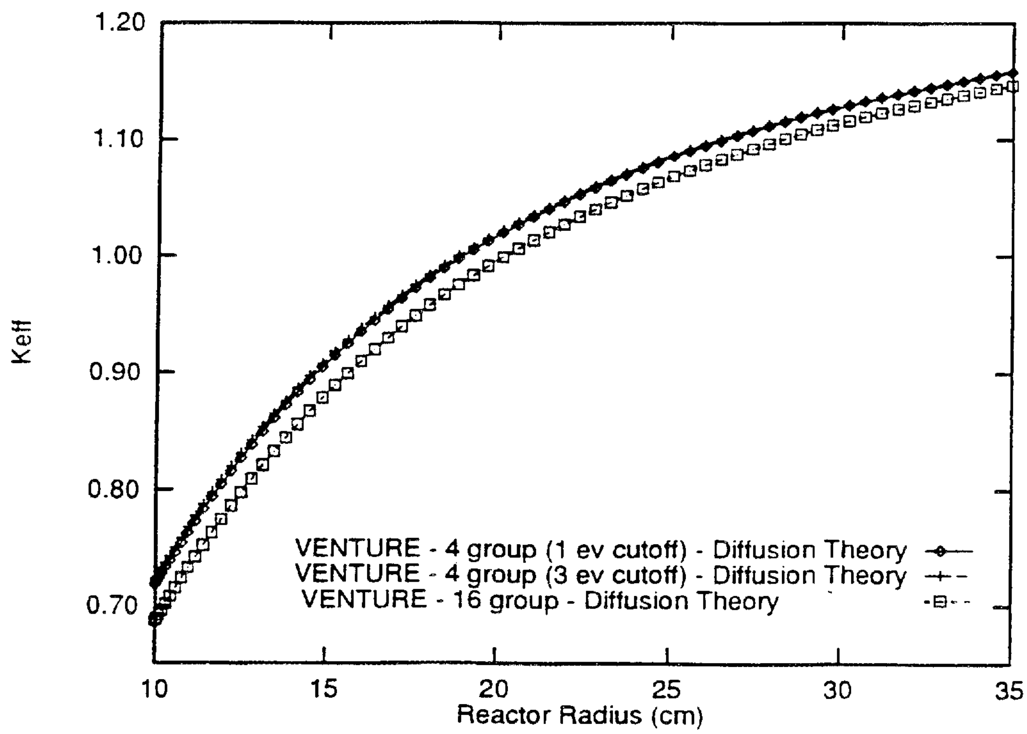


Figure 4-11 K_{eff} versus reactor size for diffusion theory cases using Method 1 and problem cross section set 2.

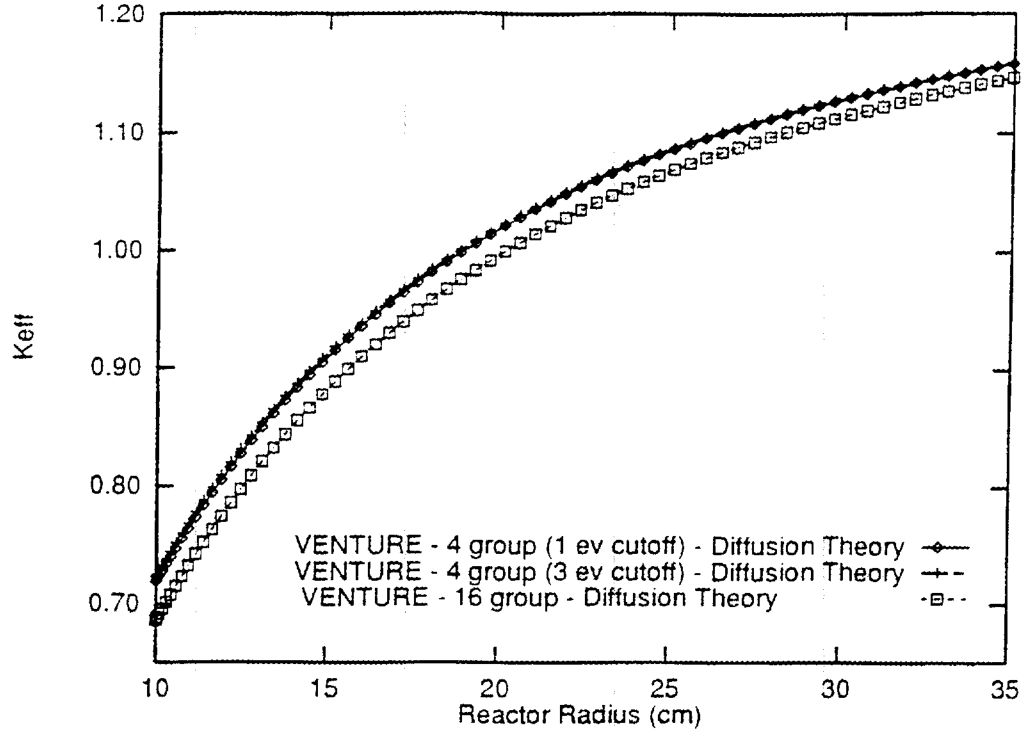


Figure 4-12 K_{eff} versus reactor size for diffusion theory cases using Method 1 and problem cross section set 3.

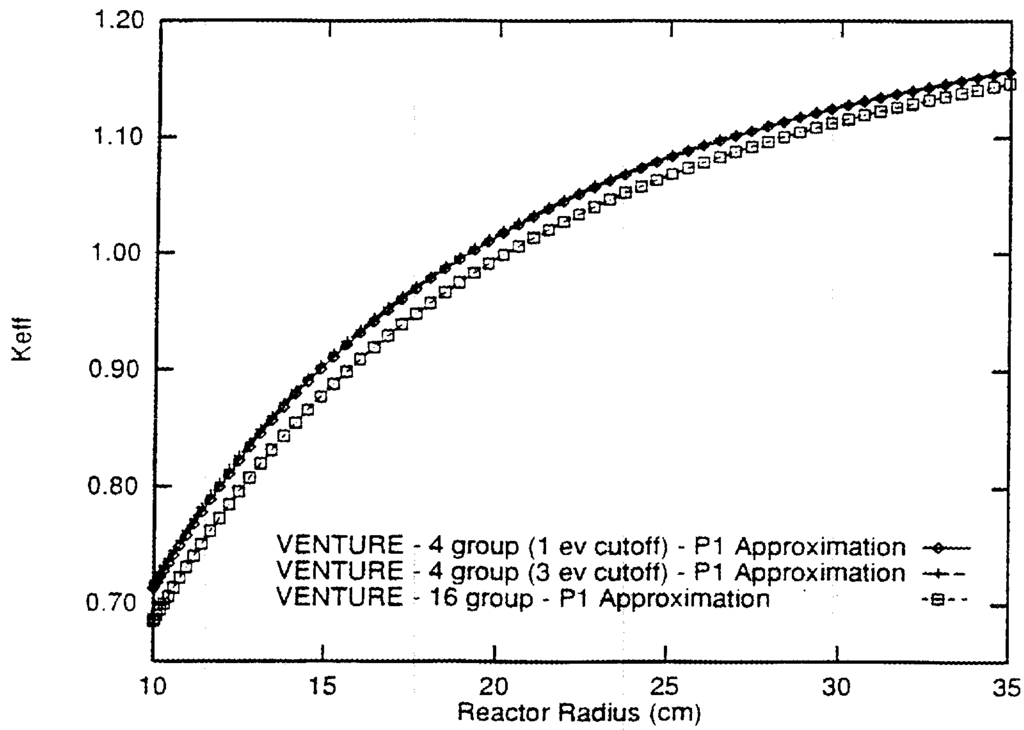


Figure 4-13 K_{eff} versus reactor size for P1 approximation cases using Method 1 and problem cross section set 1.

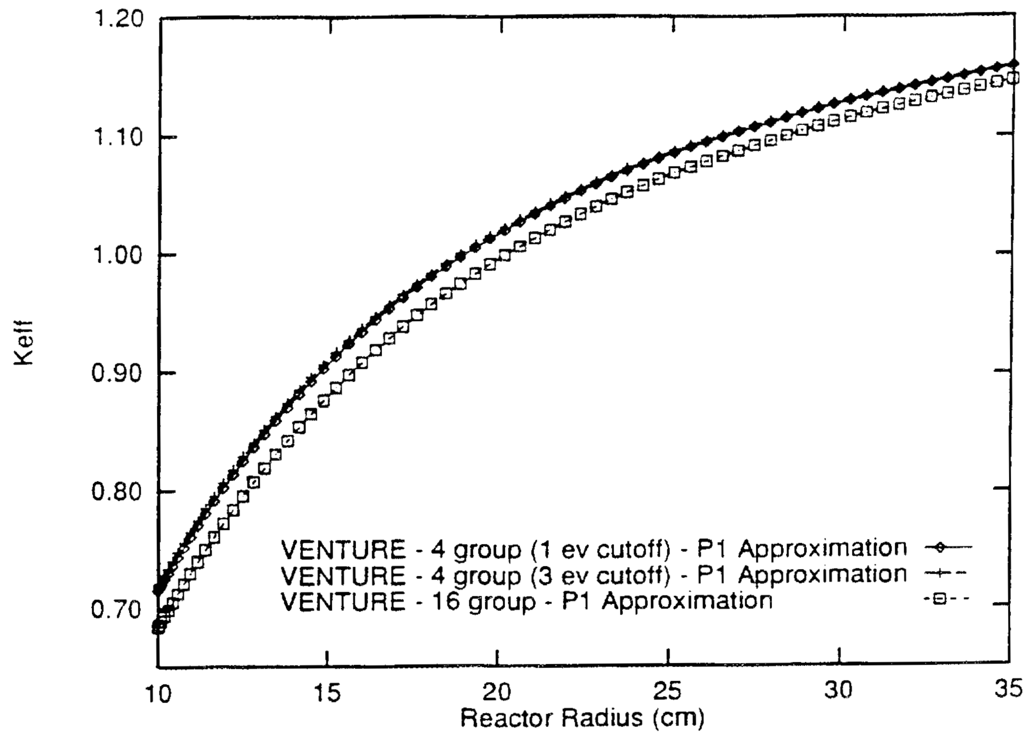


Figure 4-14 K_{eff} versus reactor size for P1 approximation cases using Method 1 and problem cross section set 2.

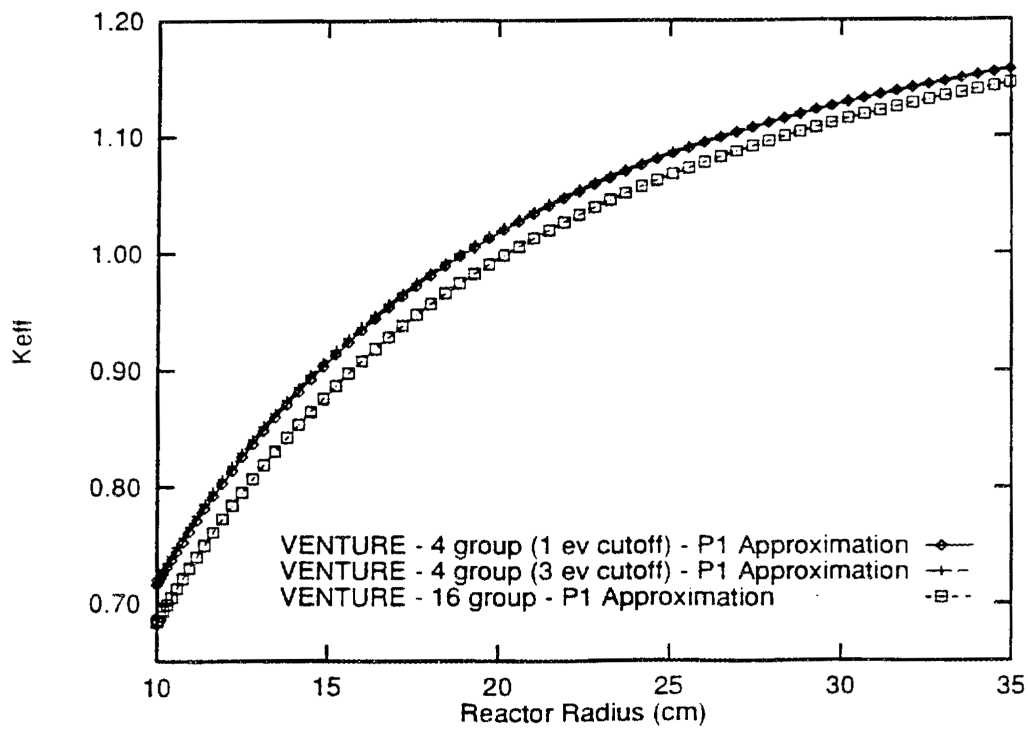


Figure 4-15 K_{eff} versus reactor size for P1 approximation cases using Method 1 and problem cross section set 3.

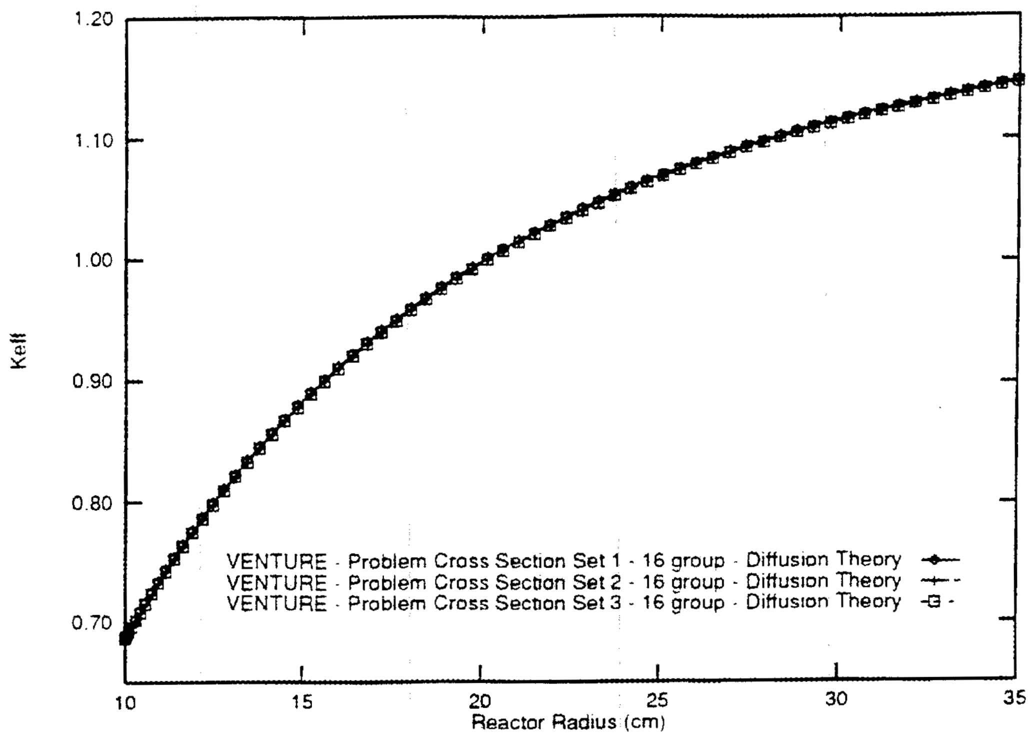


Figure 4-16 K_{eff} versus reactor size for the three different problem cross section sets using Method 1.

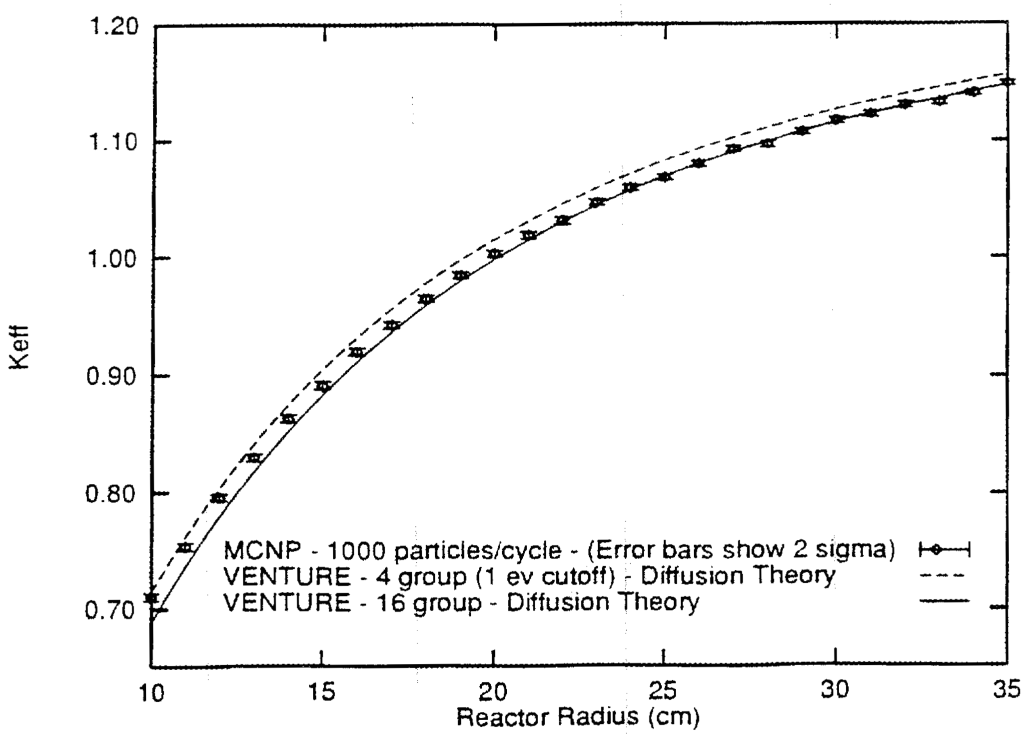


Figure 4-17 Comparison of MCNP and VENTURE results using Method 1 and problem cross section set 1.

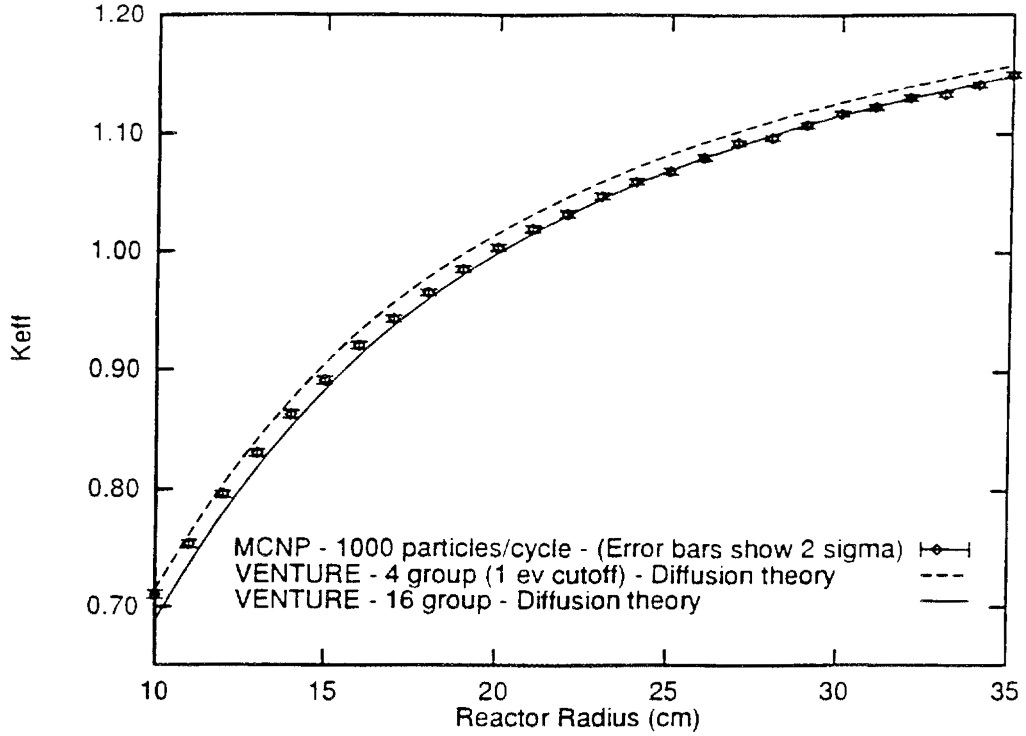


Figure 4-18 Comparison of MCNP and VENTURE results using Method 2 and problem cross section set 1.

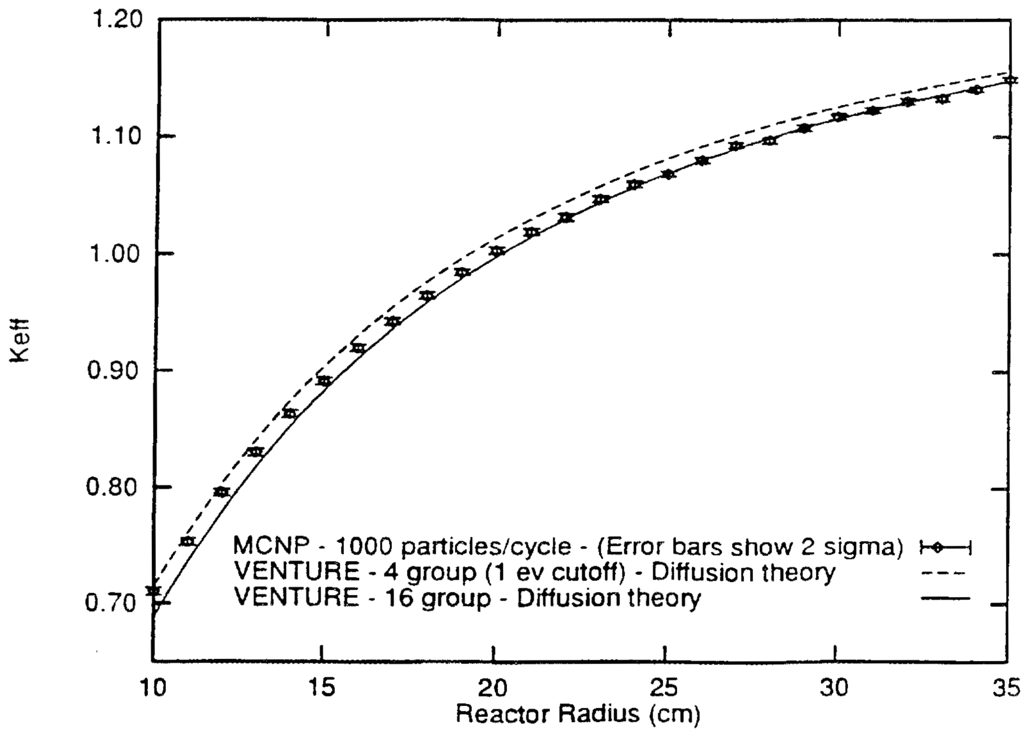


Figure 4-19 Comparison of MCNP and VENTURE results using Method 3 and problem cross section set 1.

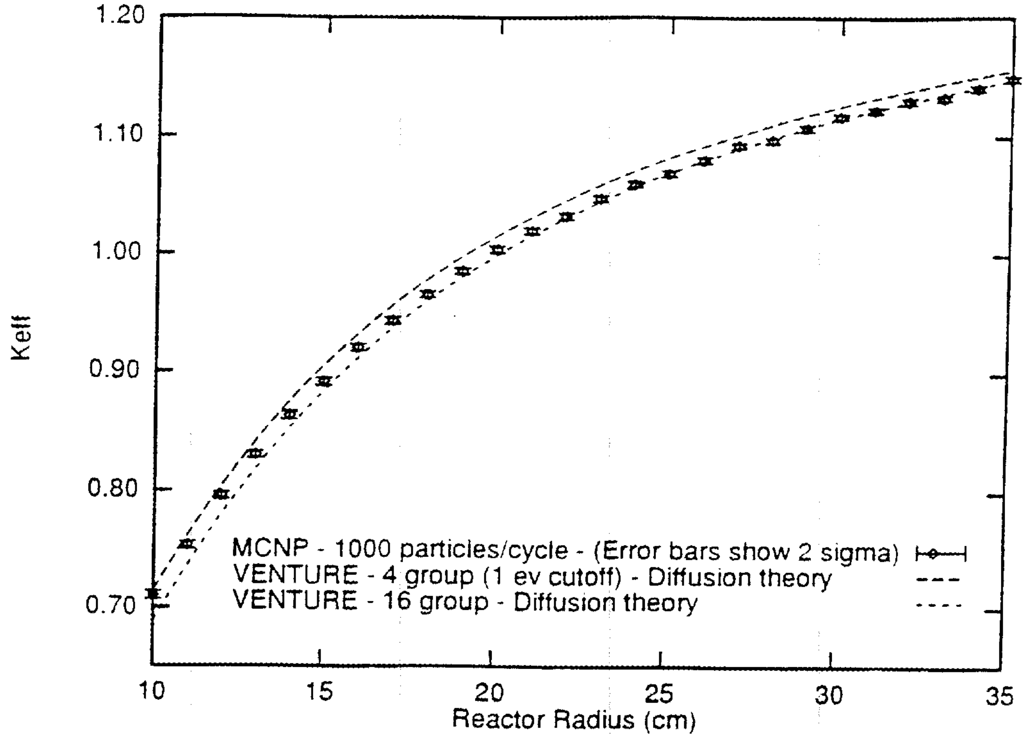


Figure 4-20 Comparison of MCNP and VENTURE results using Method 4 and problem cross section set 1.

4.5 Sample Problem 2: One-Dimensional Reactor with a Control Rod Ring

4.5.1 Purpose of Sample Problem 2

Sample Problem 2 demonstrates the control rod position search CTRLPOS option. The search option is used to adjust the density of hafnium in a zone in an one-dimensional cylindrical problem. The densities which yield desired k_{eff} values are determined.

4.5.2 Brief Description of Sample Problem 2

Sample Problem 2 examines a one-dimensional, infinite height fuel region with a reflector. Figure 4-21 shows the top and side view of the model. A one centimeter thick hafnium ring is used to control the reactor. Table 4-4 shows the atom densities for each material used in Sample Problem 2. Two different control rod materials are examined; (1) elemental hafnium and (2) a mixture of hafnium isotopes at natural abundance. Note that this sample problem is for illustrative purposes only to show some of the capabilities of the CTRLPOS module.

The CTRLPOS module was used to perform a search for the hafnium density that obtains a user-specified k_{eff} value. This search is performed by changing the target k_{eff} value and using option 20 of the CTRLPOS module. Figure 4-22 shows a flowchart of the calculational path for this problem. The CTRLPOS module was run several times with option 20 using different target k_{eff} values. This method was used since in this one-dimensional problem a control rod worth curve calculation using option 30 will yield only two control rod positions and their associated k_{eff} values. The control rod can be placed only at the top and bottom of the control rod zone since option 30 accepts only zone boundaries as input to determine positions for a control rod worth curve calculation.

The collapsed, weighted cross sections were created for hafnium with a hafnium density of 13.1 g/cm^3. The 16 group cross sections were created by the procedure presented in Figure 4-4, and the 8 group cross sections were created by the procedure shown in Figure 4-5. The XSDRNPM code was used to calculate a neutron spectrum for the geometry shown in Figure 4-21. This spectrum was used to perform a zone-weighted collapse for the material in the hafnium ring. Results were calculated using the elemental hafnium cross section and cross sections for a mixture of hafnium isotopes (^{174}Hf, ^{176}Hf, ^{177}Hf, ^{178}Hf, ^{179}Hf and ^{180}Hf) at natural abundance.

4.5.3 Results for Sample Problem 2

Table 4-5 compares the MCNP, XSDRNPM, and VENTURE results. These k_{eff} values are for the base case. The base case is the case where the problem geometry in the three different code systems is identical with hafnium material at a density of 13.1 g/cm^3 in the control ring. Since the individual hafnium isotopes (^{174}Hf, ^{176}Hf, ^{177}Hf, ^{178}Hf, ^{179}Hf and ^{180}Hf) are not available in the standard MCNP cross section libraries, k_{eff} was not determined with MCNP using the individual hafnium isotopes. Comparison of the k_{eff} values obtained by XSDRNPM and MCNP show that XSDRNPM gives higher values. The VENTURE k_{eff} values are lower than the MCNP value. The use of cross sections for the individual hafnium isotopes give slightly lower k_{eff} values than the use of the cross sections for elemental hafnium.

Figures 4-23 through 4-26 compare the results for k_{eff} obtained with VENTURE using both elemental hafnium and hafnium isotopes with the results obtained from MCNP. The VENTURE 16 group k_{eff} values are consistently lower than the MCNP values. The difference between the k_{eff} values is constant down to a hafnium density of about 2 g/cm^3. Below 2 g/cm^3, the elemental hafnium results match rather well. This difference may be because the hafnium cross sections created at 13.1 g/cm^3 are valid at these low densities.

Figures 4-27 and 4-28 compare the 16 group VENTURE k_{eff} results obtained using the XSDRNPM generated cross sections at a hafnium density of 13.1 g/cm^3. The k_{eff} results obtained using the cross sections of elemental hafnium are consistently higher than those obtained when the individual hafnium isotopes at natural abundance are employed. The k_{eff} values obtained by the P1 approximation in VENTURE are smaller than the values obtained by VENTURE diffusion theory and the results calculated with MCNP.

To determine if the use of cross sections created at one density is valid in this problem, calculations were performed with cross sections created by XSDRNPM using hafnium material at a density of 1 g/cm^3. Figures 4-29 through 4-32 compare the VENTURE results using XSDRNPM generated cross sections at a hafnium density of 1 g/cm^3 to the 13.1 g/cm^3 results. The cross sections processed at 1 g/cm^3 yield smaller k_{eff} values than the cross sections processed at 13.1 g/cm^3. The biases between the MCNP and VENTURE k_{eff} values at 1 g/cm^3 and 13.1 g/cm^3 are very similar in all four figures. This bias is the difference between the k_{eff} values obtained with VENTURE using cross sections collapsed at either 1 g/cm^3 or 13.1 g/cm^3 and the corresponding MCNP results. This comparison shows that the 13.1 g/cm^3 processed cross sections are not valid for k_{eff} calculations at low densities, and the 1 g/cm^3 processed cross sections are not valid for calculations at high densities. A possible solution for this limitation is discussed in Chapter 5.

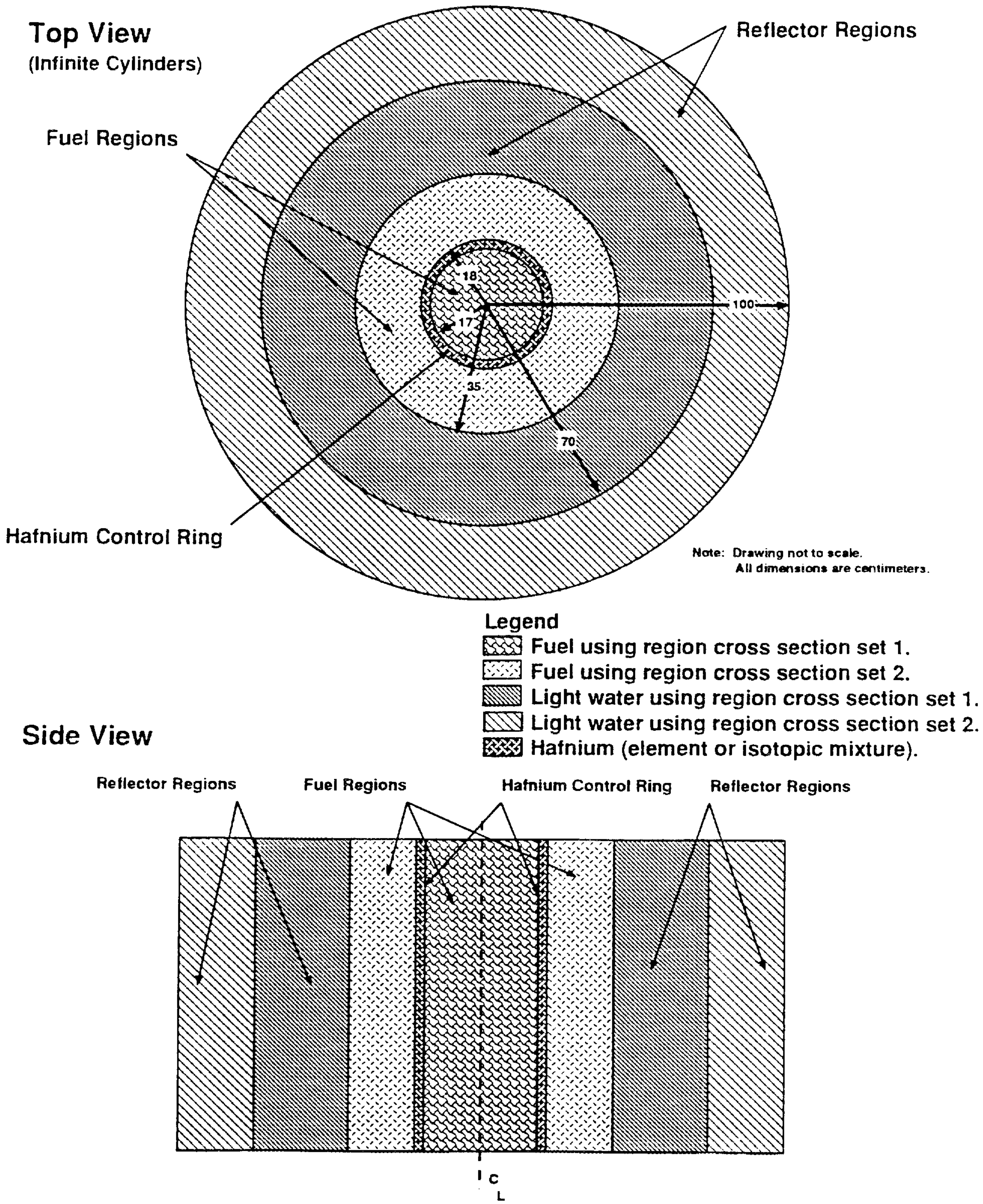


Figure 4-21 Top and side view of the geometry of Sample Problem 2.

Table 4-4 Atom densities for materials used in Sample Problem 2.

Nuclide	Material Atom Densities ($cm^{-3} \times 10^{-24}$)			
	Fuel (UO_2F_2-H_2O solution)	Reflector (H_2O)	Control Rod composed of hafnium isotopes	Control Rod composed of elemental hafnium
H	6.6436-2[a]	6.6644-2	0.0	0.0
O	3.3330-2	3.3334-2	0.0	0.0
F	1.2338-4	0.0	0.0	0.0
^{234}U	5.5020-7	0.0	0.0	0.0
^{235}U	5.2312-5	0.0	0.0	0.0
^{236}U	2.6950-7	0.0	0.0	0.0
^{174}Hf	0.0	0.0	7.1600-5	0.0
^{176}Hf	0.0	0.0	2.3009-3	0.0
^{177}Hf	0.0	0.0	8.2234-3	0.0
^{178}Hf	0.0	0.0	1.2065-2	0.0
^{179}Hf	0.0	0.0	6.0237-3	0.0
^{180}Hf	0.0	0.0	1.5513-2	0.0
Elemental Hf	0.0	0.0	0.0	4.4198-2

[a] Read as 6.6436×10^{-2}

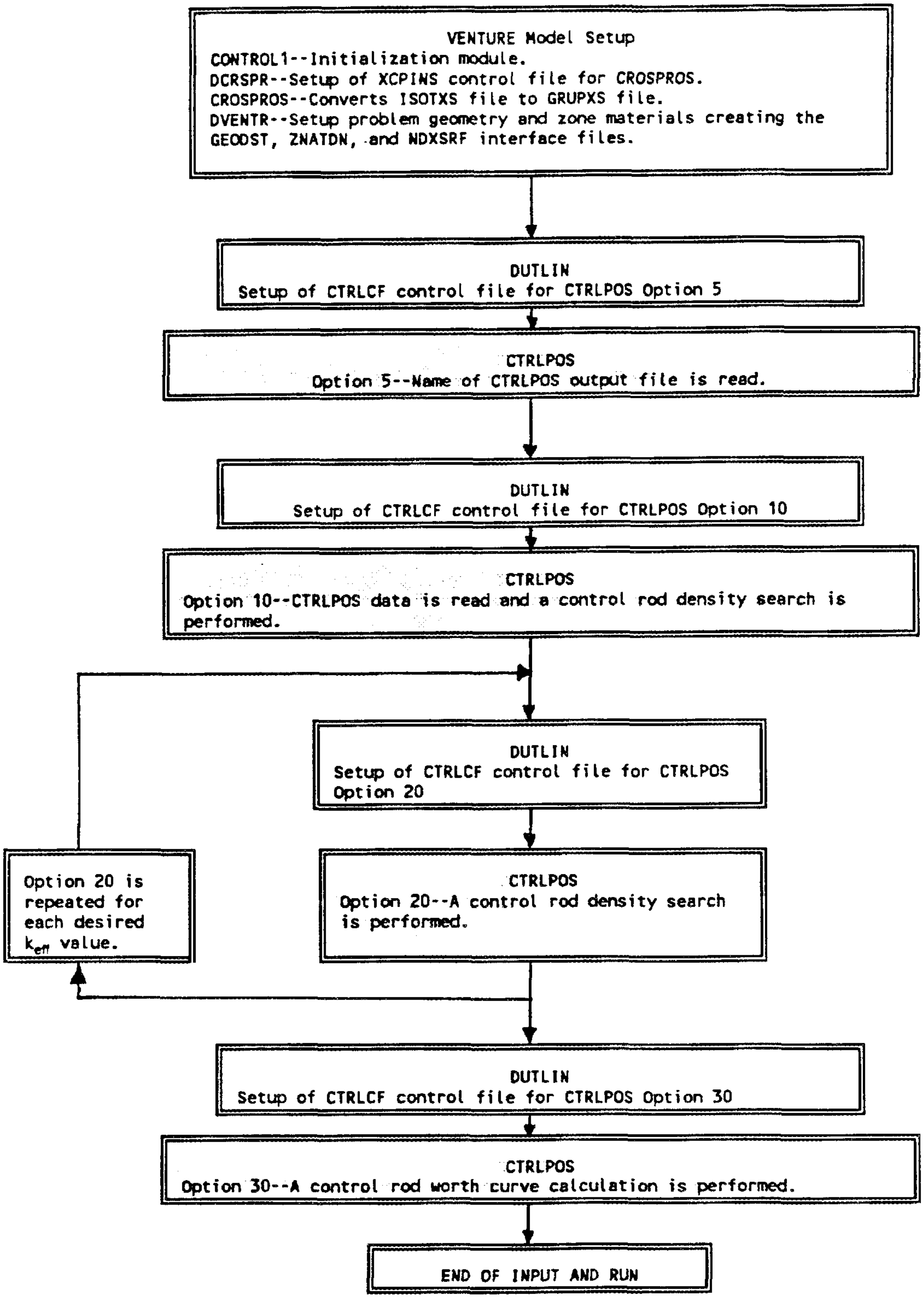


Figure 4-22 Flowchart of the VENTURE calculation for Sample Problem 2.

Table 4-5 Base case k_{eff} results for Sample Problem 2.

Calculation Method	Hafnium Material	
	Hafnium isotopes at natural abundance	Elemental Hafnium
MCNP[a]	-----[b]	0.9711± 0.0025
VENTURE[c]-8 group Diffusion theory	0.9630	0.9663
VENTURE-8 group P1 approximation	0.9598	0.9633
VENTURE-16 group Diffusion theory	0.9606	0.9638
VENTURE-16 group P1 approximation	0.9521	0.9557
XSDRNPM-99 group	0.9748	0.9780
XSDRNPM-16 group	0.9752	0.9785
XSDRNPM-8 group	0.9773	0.9806

[a] Reported statistical uncertainty for MCNP k_{eff}'s is two sigma obtained by multiplying the reported uncertainty of one sigma in the MCNP output by two. Values are reported for 1000 source particles per cycle. 180 cycles were run and the first 30 cycles were skipped.
[b] Individual hafnium isotopes are not available in the standard MCNP cross section library.
[c] All VENTURE calculations were performed using a one-dimensional, infinite, cylindrical geometry model.

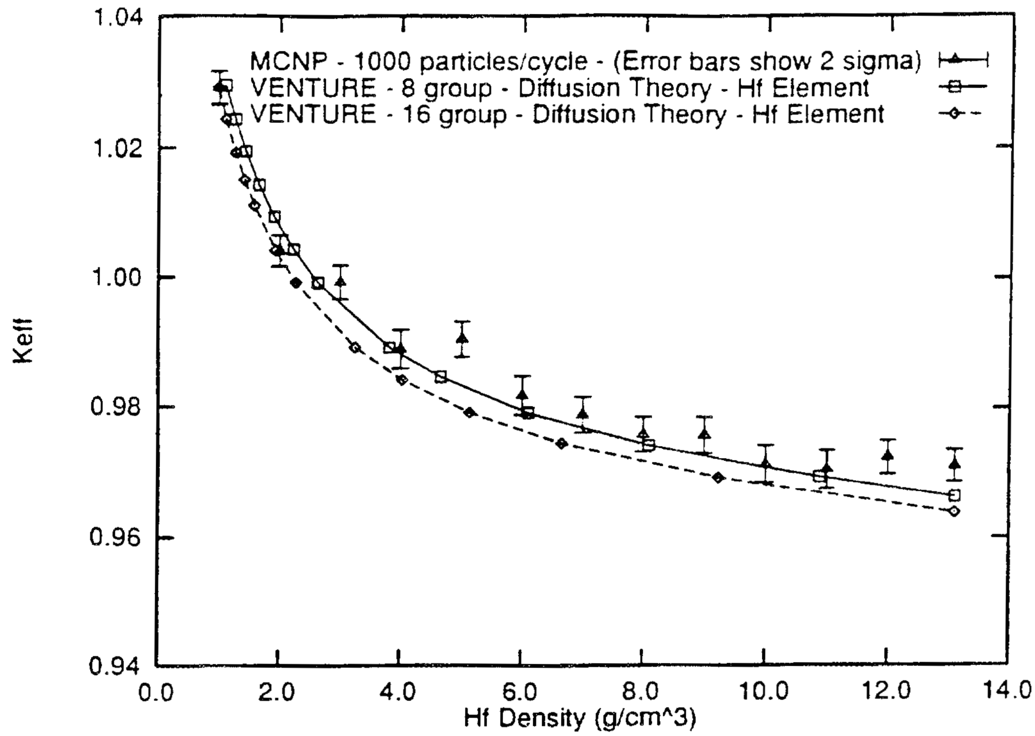


Figure 4-23 K_{eff} versus hafnium density in the control rod zone using elemental hafnium cross section and diffusion theory.

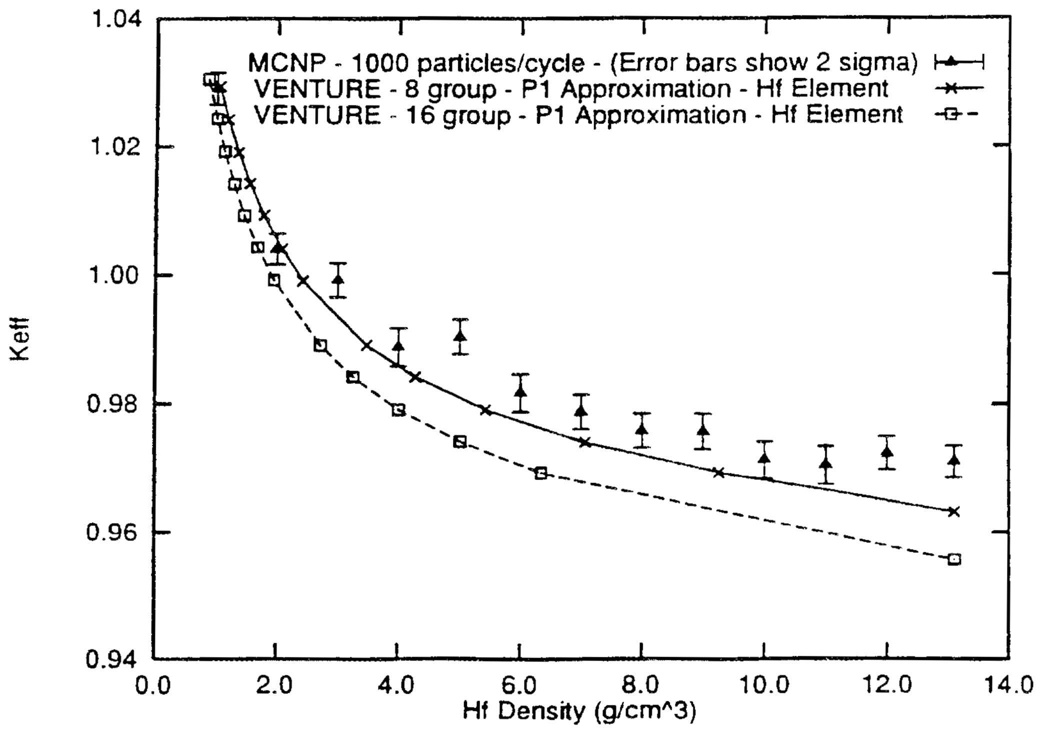


Figure 4-24 K_{eff} versus hafnium density in the control rod zone using elemental hafnium cross section and P1 approximation.

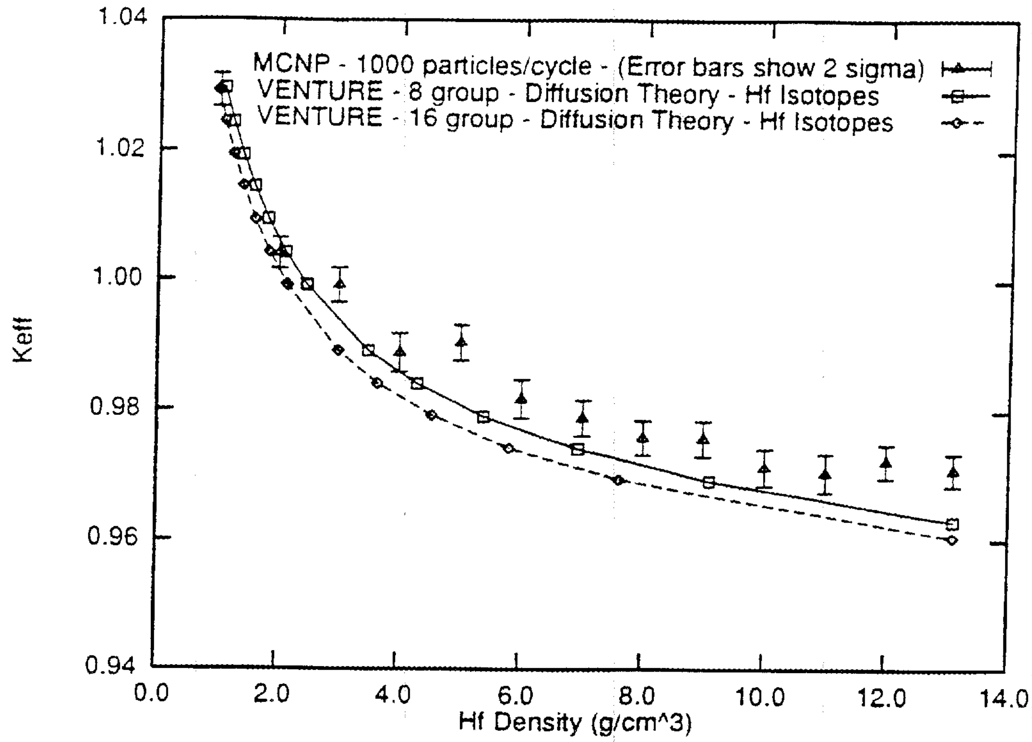


Figure 4-25 K_{eff} versus hafnium density in the control rod zone using individual hafnium isotope cross sections and diffusion theory.

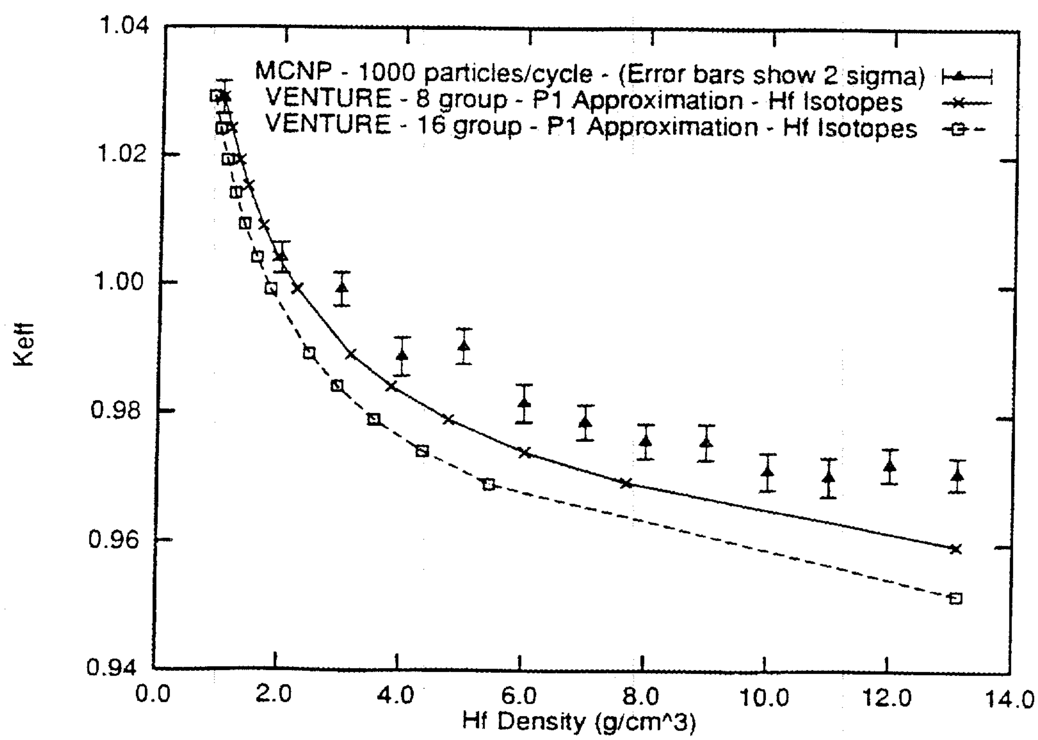


Figure 4-26 K_{eff} versus hafnium density in the control rod zone using individual hafnium isotope cross sections and P1 approximation.

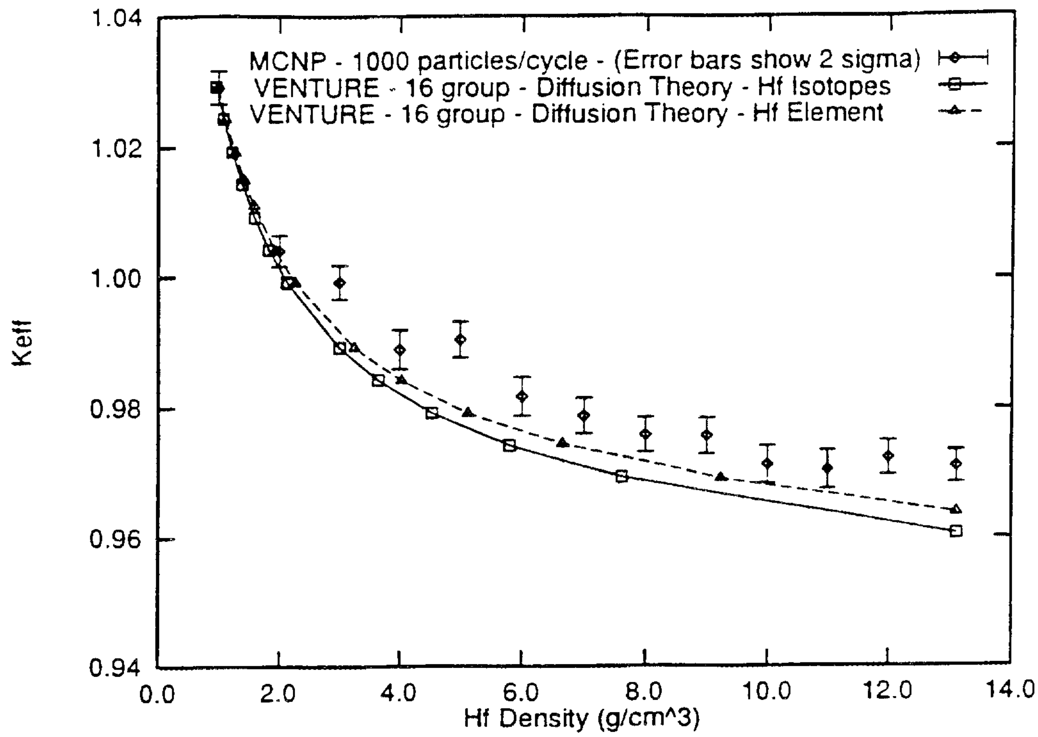


Figure 4-27 Comparison of diffusion theory results using elemental hafnium and individual hafnium isotope cross sections.

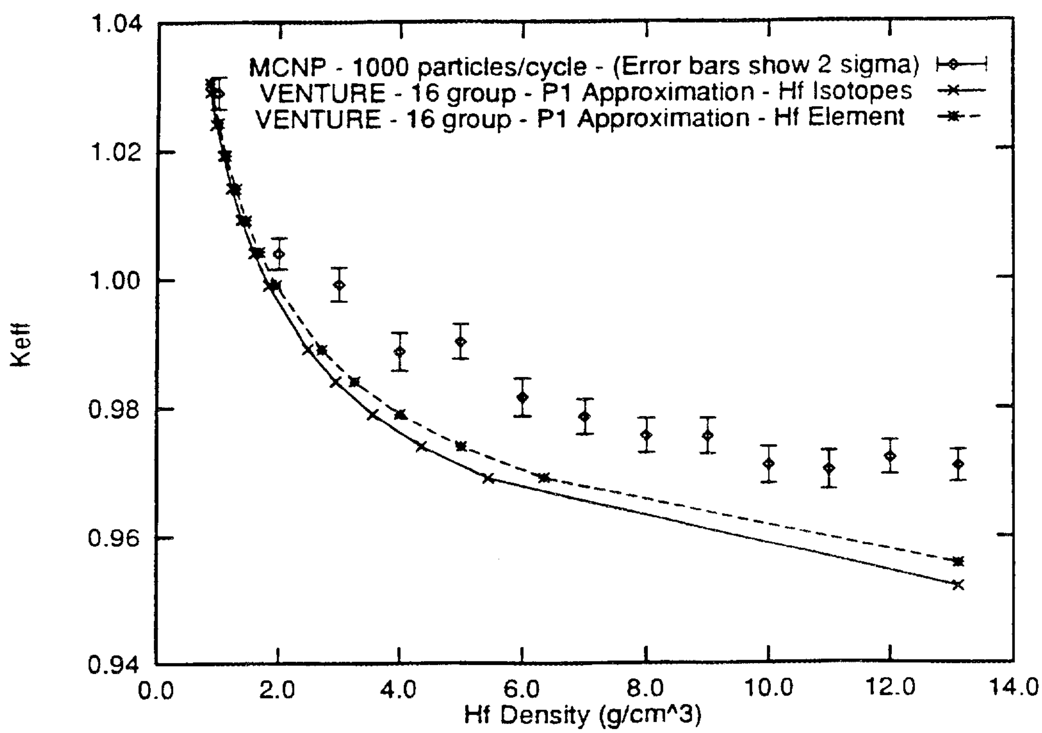


Figure 4-28 Comparison of P1 approximation results using elemental hafnium and individual hafnium isotope cross sections.

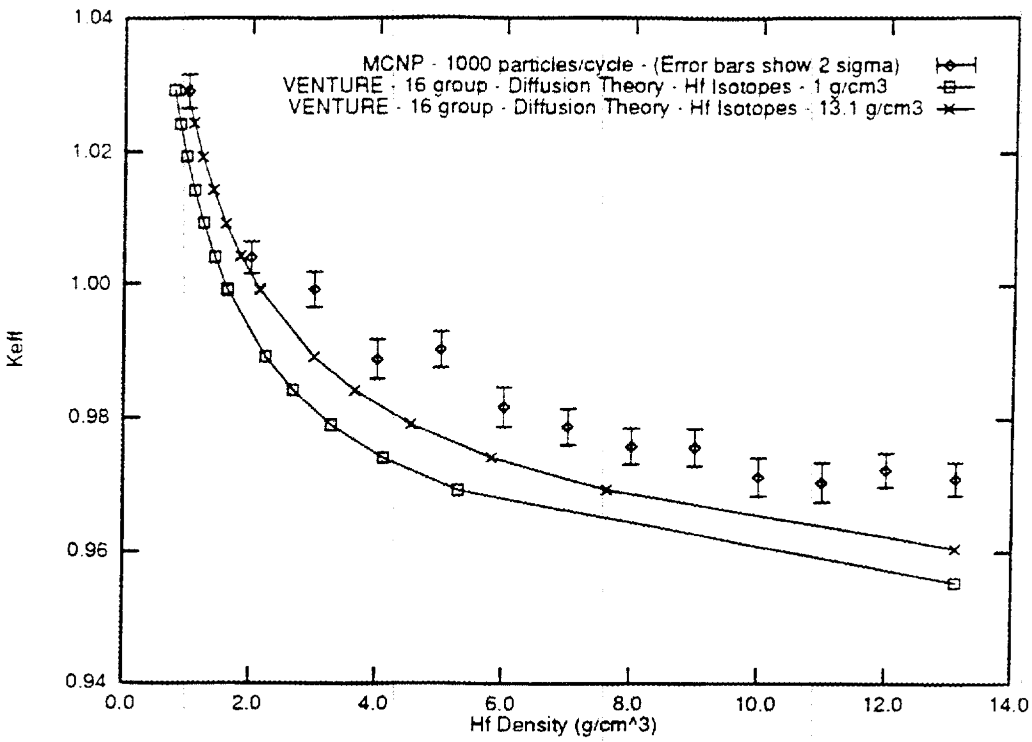


Figure 4-29 K_{eff} versus hafnium density using diffusion theory and individual hafnium isotope cross sections collapsed at different densities.

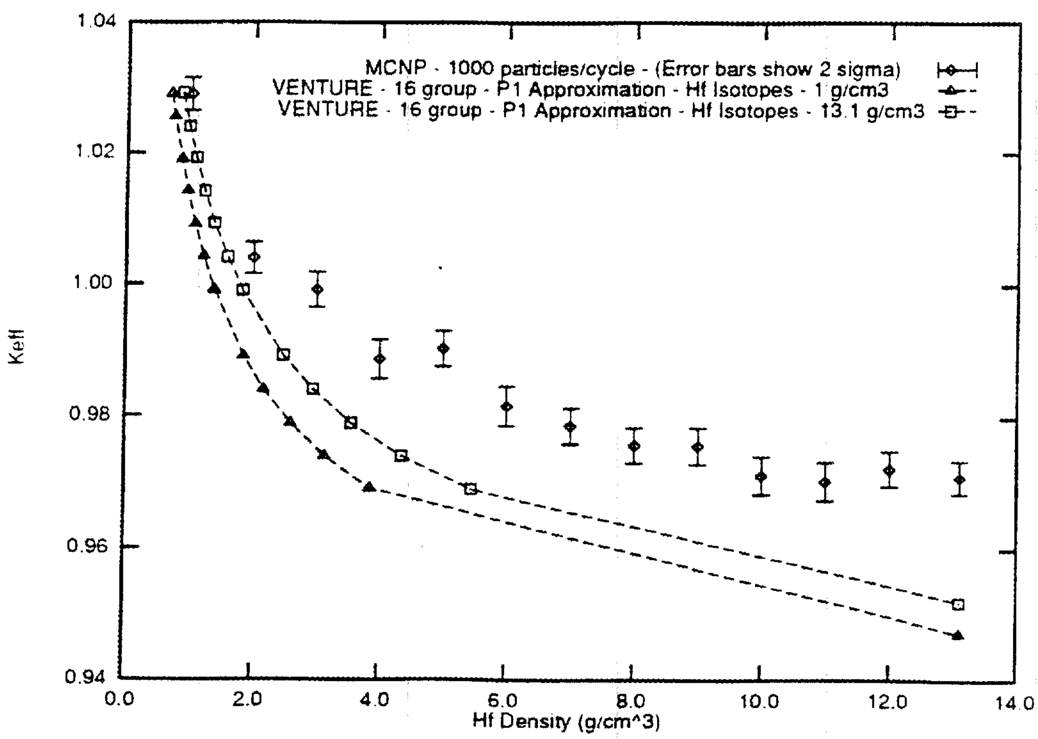


Figure 4-30 K_{eff} versus hafnium density using P1 approximation and individual hafnium isotope cross sections collapsed at different densities.

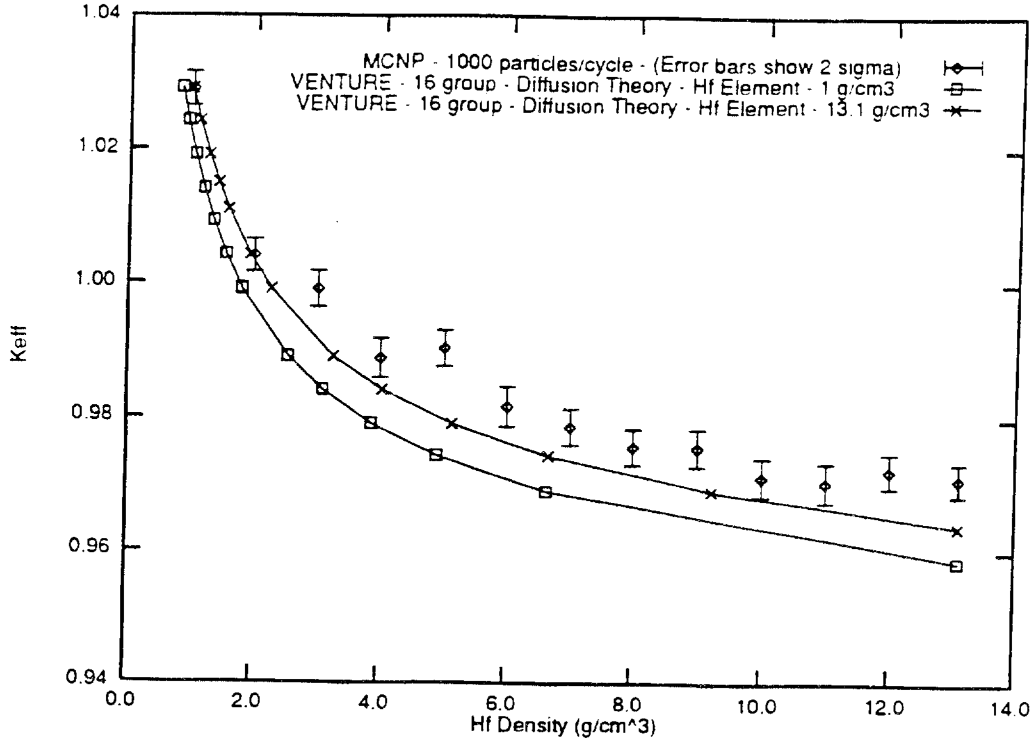


Figure 4-31 K_{eff} versus hafnium density using diffusion theory and elemental hafnium cross sections collapsed at different densities.

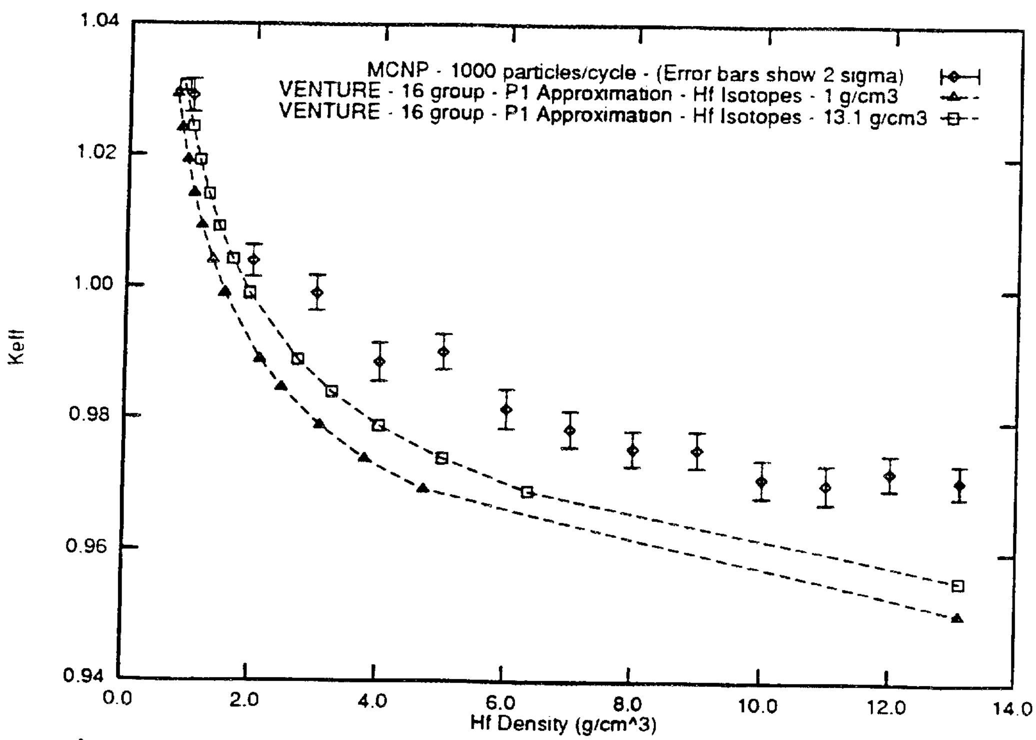


Figure 4-32 K_{eff} versus hafnium density using P1 approximation and elemental hafnium cross sections collapsed at different densities.

4.6 Sample Problem 3: Two-dimensional Reactor with a Control Rod Ring

4.6.1 Purpose of Sample Problem 3

Sample Problem 3 demonstrates the use of the control rod worth curve CTRLPOS option. The control rod is a hafnium ring which is modelled using a two-dimensional R-Z geometry. This problem shows some of the features of CTRLPOS that are useful when examining reactor systems which require control rod movement.

4.6.2 Brief Description of Sample Problem 3

Sample Problem 3 examines a two-dimensional cylindrical fuel region with a reflector. Figure 4-33 shows the top and side view of the model. A one centimeter thick hafnium ring is moved axially to adjust k_{eff}. Both the hafnium ring and the reactor have a height of 100 cm. The starting location of the control rod is fully inserted with the control rod tip located at the lower boundary of the fuel region. The hafnium ring is moved out of the fuel region into the reflector region above the fuel region to change the value of k_{eff}. Table 4-6 shows the atom densities used for the materials in the problem. This problem does not represent a real reactor system and these calculations are only for illustrative purposes.

The CTRLPOS module was used to calculate k_{eff} at various control rod positions. Figure 4-34 shows a flowchart of the calculational path for this problem. Option 30 of the CTRLPOS module was used to calculate a control rod worth curve. The weighted collapsed cross sections were created using a one-dimensional radial XSDRNPM model of a finite cylindrical core with the control rod fully inserted. The buckling correction in the perpendicular direction was not adjusted to account for the reflector regions above and below the fuel region. This correction was not examined since it should have little effect on the cross sections for this system and the purpose of this sample problem is to demonstrate the capabilities of the CTRLPOS module. Results for both elemental hafnium and a mixture of hafnium isotopes at natural abundance were obtained.

4.6.3 Results for Sample Problem 3

Table 4-7 compares the MCNP, XSDRNPM, and VENTURE results. These k_{eff} values are for the base case. The base case is the case where the problem geometry in the VENTURE and MCNP code systems is identical. For the base case the control rod is fully inserted in the fuel region. The XSDRNPM results are for a one-dimensional, cylindrical model. The VENTURE calculations were performed using two-dimensional R-Z geometry. The XSDRNPM calculated k_{eff} values over-estimate the MCNP values. The VENTURE results using 16 neutron groups, diffusion theory and elemental hafnium are within the statistical uncertainty of the MCNP result. As in Sample Problem 2, the calculated k_{eff}'s using the 99 neutron group library are lower for the hafnium isotopes than the elemental hafnium. However, in this problem diffusion theory and the P1 approximation yield similar k_{eff} values for the 4 group calculations. The reflector regions above and below the fuel region may affect the

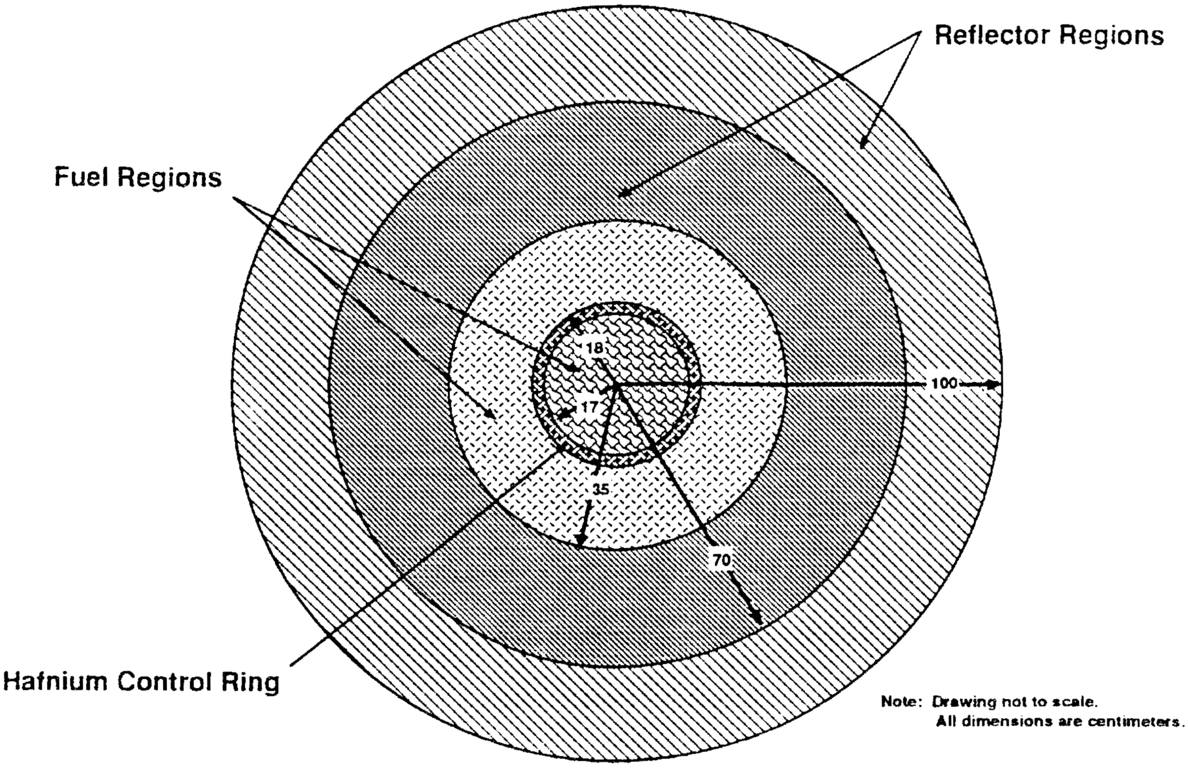
k_{eff} results obtained using the P1 approximation.

Figures 4-35 through 4-38 show the results of the CTRLPOS rod worth curve calculation for elemental hafnium and the mixture of hafnium isotopes at natural abundance. The 4 group VENTURE k_{eff} values are larger than the MCNP results at all rod positions. However, the bias between the calculated k_{eff} values at each control rod position is very similar at all control rod positions. The 16 neutron group values agree well with the MCNP results, especially when the control rod is above the -20 cm position. The 16 group diffusion theory results match the MCNP results slightly better than the P1 approximation results.

Figures 4-39 and 4-40 compare the results for the two different hafnium materials. The elemental hafnium results are higher than the hafnium isotope results below the -20 cm position. The k_{eff} values are almost the same above this position. The discrepancy between the values when the control rod is fully inserted may be because of inadequately calculated cross sections using the one-dimensional transport model. The cross sections used for the control rod may not be accurate for the control rod tip when the control rod is slightly removed from the fuel region.

Top View

(Radial transverse at core midplane)



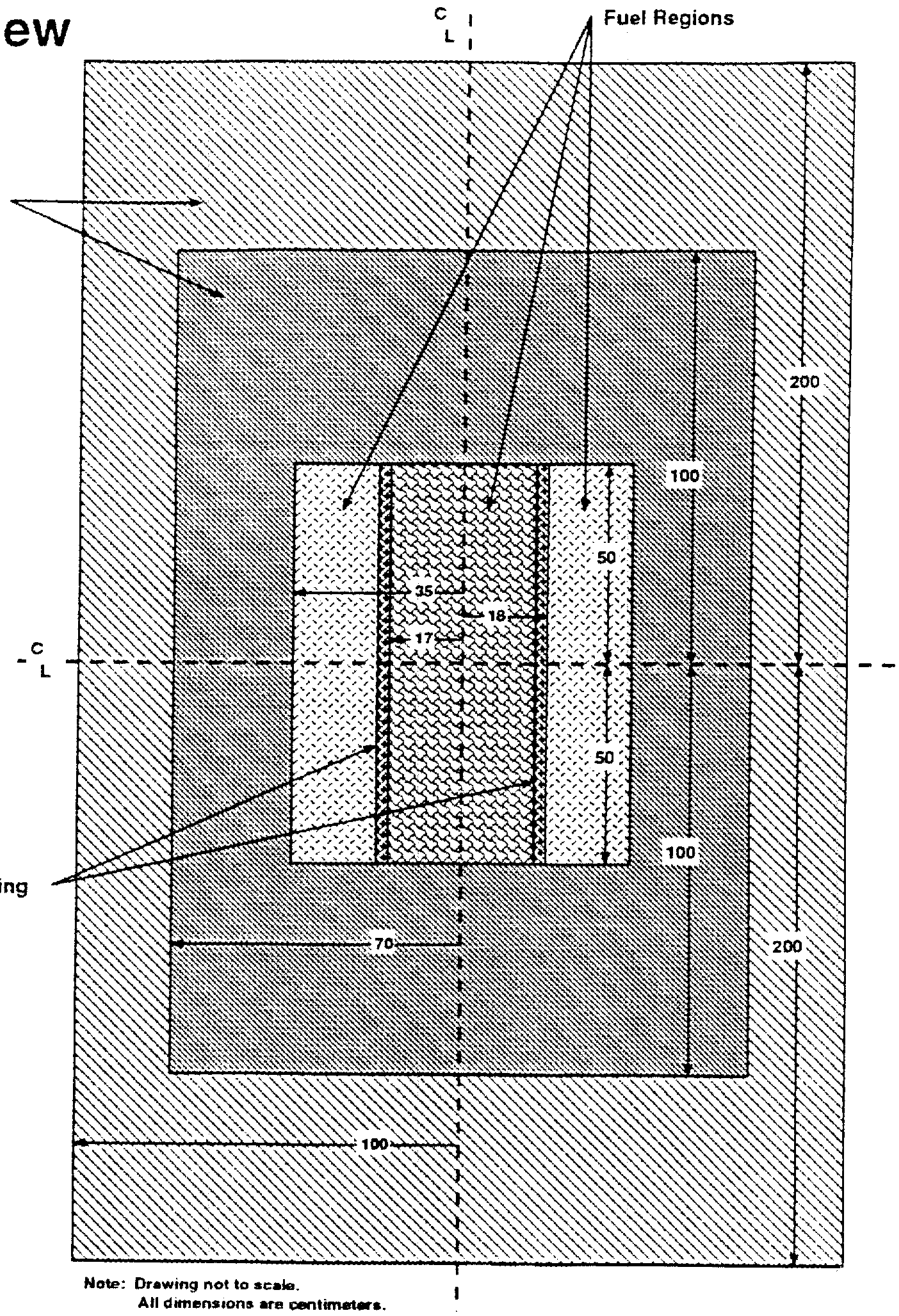
Legend

- Fuel using region cross section set 1.
- Fuel using region cross section set 2.
- Light water using region cross section set 1.
- Light water using region cross section set 2.
- Hafnium (element or isotopic mixture).

Figure 4-33 Top and side view of the geometry of Sample Problem 3.

Figure 4-33 (continued)

Side View



Legend

- Fuel using region cross section set 1.
- Fuel using region cross section set 2.
- Light water using region cross section set 1.
- Light water using region cross section set 2.
- Hafnium (element or isotopic mixture).

Table 4-6 Atom densities for materials used in Sample Problem 3.

Nuclide	Material Atom Densities ($cm^{-3} \times 10^{-24}$)			
	Fuel (UO_2F_2-H_2O solution)	Reflector (H_2O)	Control Rod composed of hafnium isotopes	Control Rod composed of elemental hafnium
H	6.6436-2[a]	6.6644-2	0.0	0.0
O	3.3330-2	3.3334-2	0.0	0.0
F	1.2338-4	0.0	0.0	0.0
^{234}U	5.5020-7	0.0	0.0	0.0
^{235}U	5.2312-5	0.0	0.0	0.0
^{236}U	2.6950-7	0.0	0.0	0.0
^{174}Hf	0.0	0.0	7.1600-5	0.0
^{176}Hf	0.0	0.0	2.3009-3	0.0
^{177}Hf	0.0	0.0	8.2234-3	0.0
^{178}Hf	0.0	0.0	1.2065-2	0.0
^{179}Hf	0.0	0.0	6.0237-3	0.0
^{180}Hf	0.0	0.0	1.5513-2	0.0
Elemental Hf	0.0	0.0	0.0	4.4198-2

[a] Read as 6.6436×10^{-2}

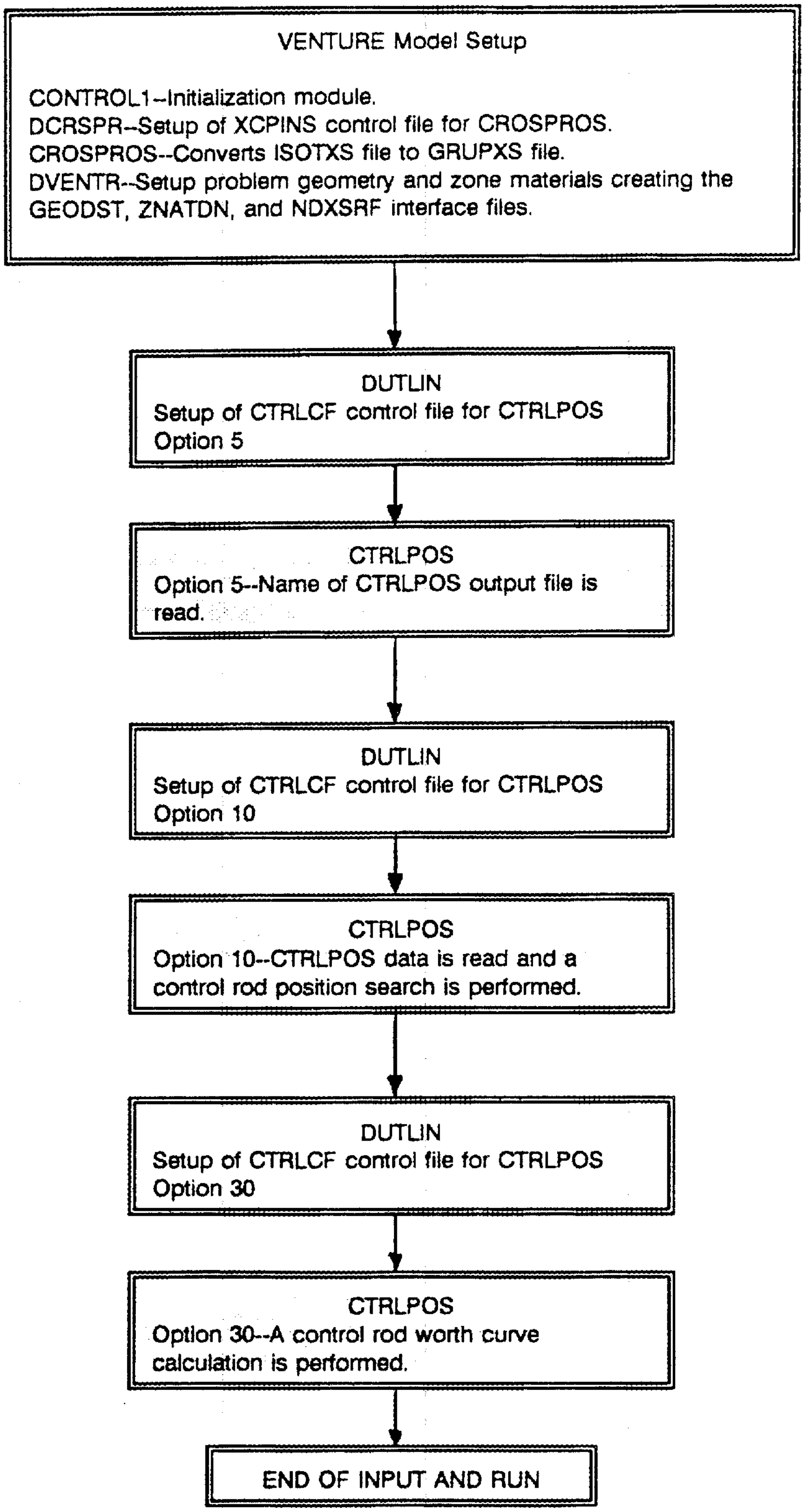


Figure 4-34 Flowchart of the VENTURE calculation for Sample Problem 3.

Table 4-7 Base case k_{eff} results for Sample Problem 3.

Calculation Method	Hafnium Material	
	Hafnium isotopes at natural abundance	Elemental Hafnium
MCNP[a]	------[b]	0.9468±0.0031
VENTURE[c]-4 group Diffusion theory (1 ev cutoff)	0.9591	0.9620
VENTURE-4 group P1 approximation (1 ev cutoff)	0.9588	0.9616
VENTURE-4 group Diffusion theory (3 ev cutoff)	0.9646	0.9677
VENTURE-4 group P1 approximation (3 ev cutoff)	0.9642	0.9672
VENTURE-16 group Diffusion theory	0.9401	0.9433
VENTURE-16 group P1 approximation	0.9322	0.9358
XSDRNPM-99 group	0.9596	0.9627
XSDRNPM-16 group	0.9578	0.9610
XSDRNPM-4 group (1 ev cutoff)	0.9702	0.9734
XSDRNPM-4 group (3 ev cutoff)	0.9750	0.9782

[a] Reported statistical uncertainty for MCNP k_{eff}'s is two sigma obtained by multiplying the reported uncertainty of one sigma in the MCNP output by two. Values are reported for 1000 source particles per cycle. 180 cycles were ran and the first 30 cycles were skipped.
[b] Individual hafnium isotopes are not available in the standard MCNP cross section library.
[c] All VENTURE calculations were performed using a two-dimensional R-Z geometry model.

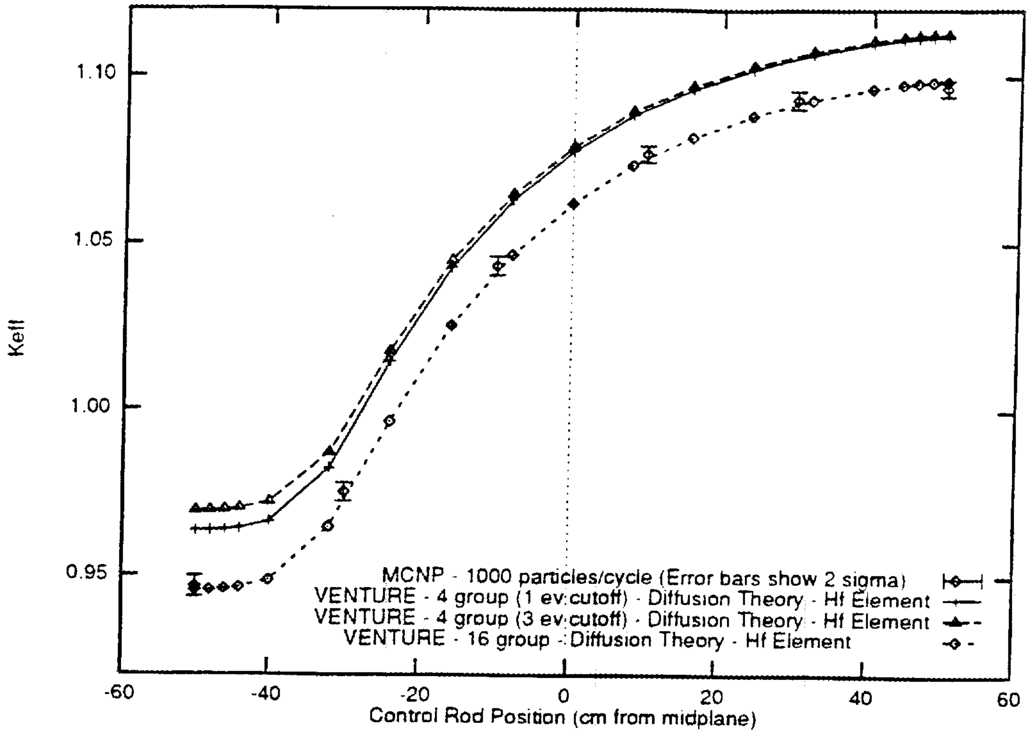


Figure 4-35 K_{eff} versus control rod position using elemental hafnium cross sections and diffusion theory.

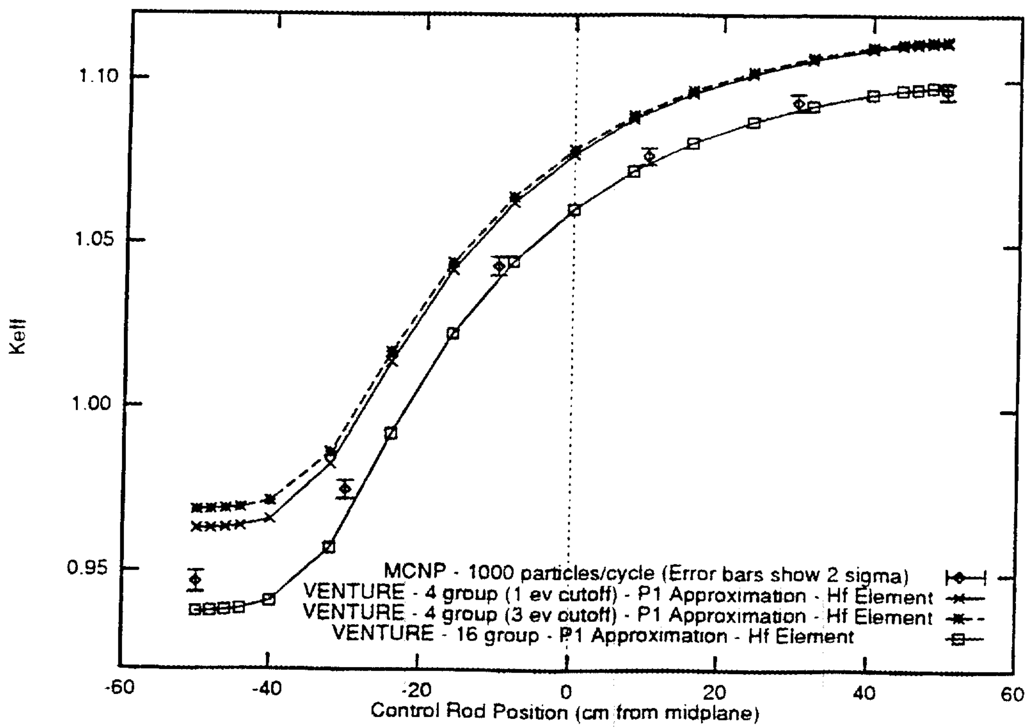


Figure 4-36 K_{eff} versus control rod position using elemental hafnium cross sections and P1 approximation.

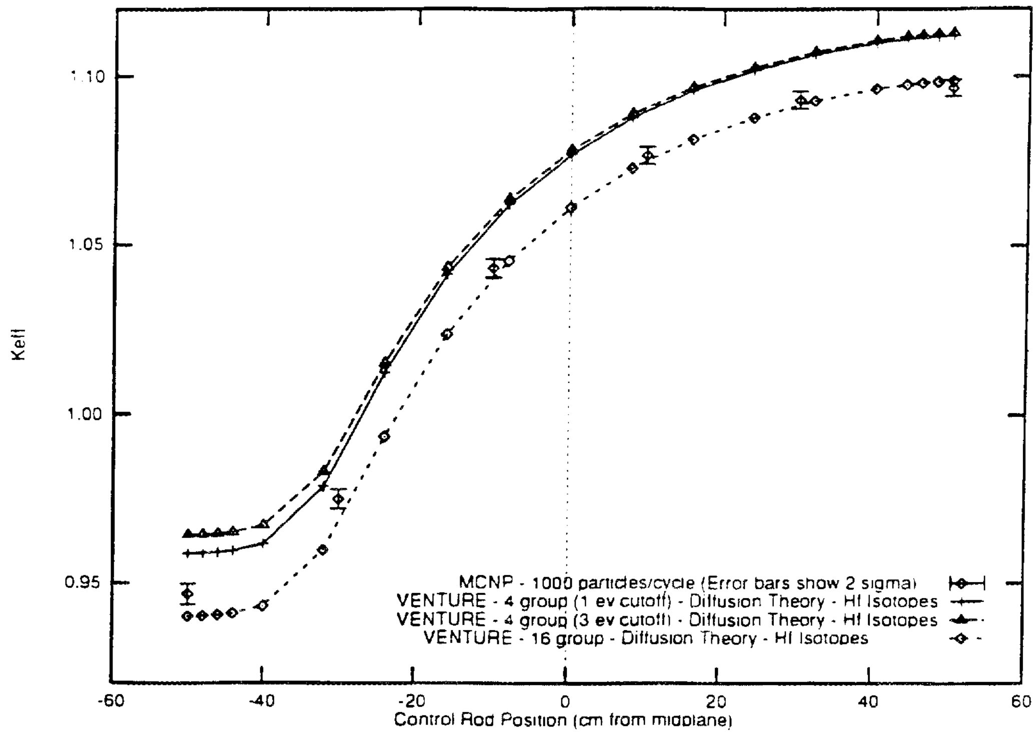


Figure 4-37 K_{eff} versus control rod position using individual hafnium isotope cross sections and diffusion theory.

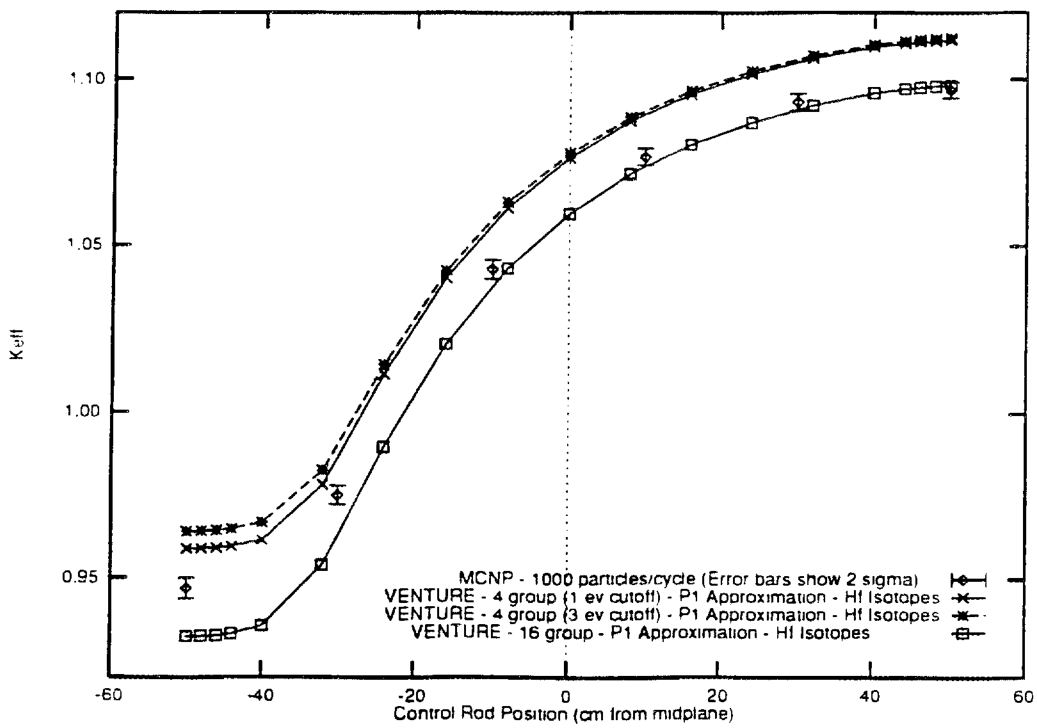


Figure 4-38 K_{eff} versus control rod position using individual hafnium isotope cross sections and P1 approximation.

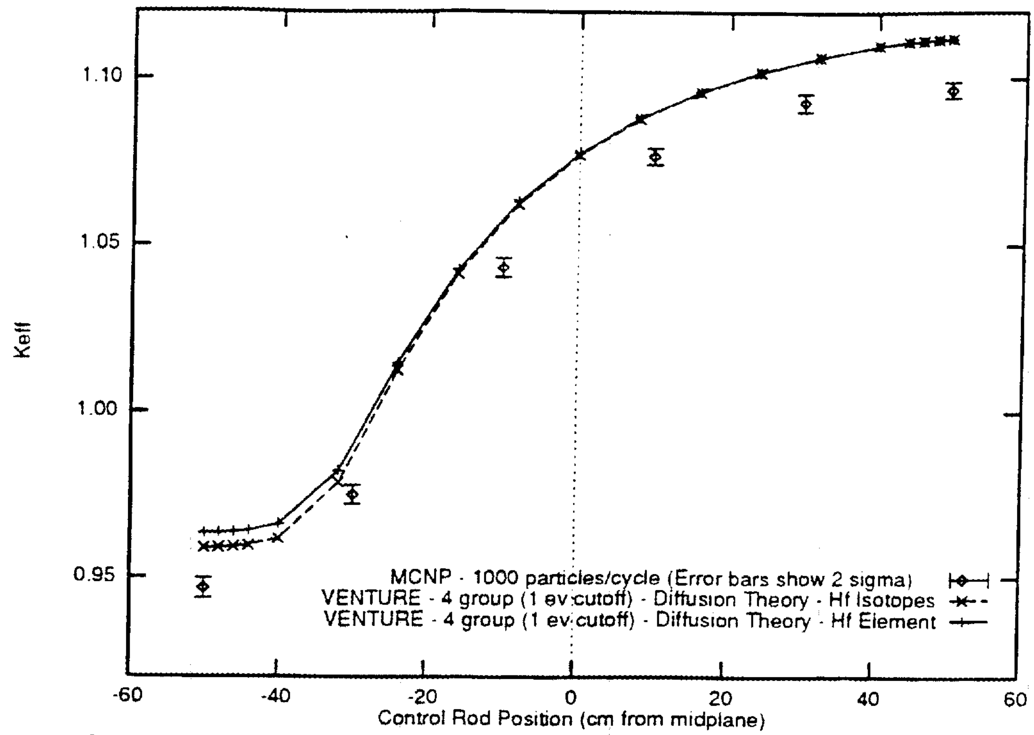


Figure 4-39 K_{eff} versus control rod position using 4 group elemental hafnium and individual hafnium isotope cross sections.

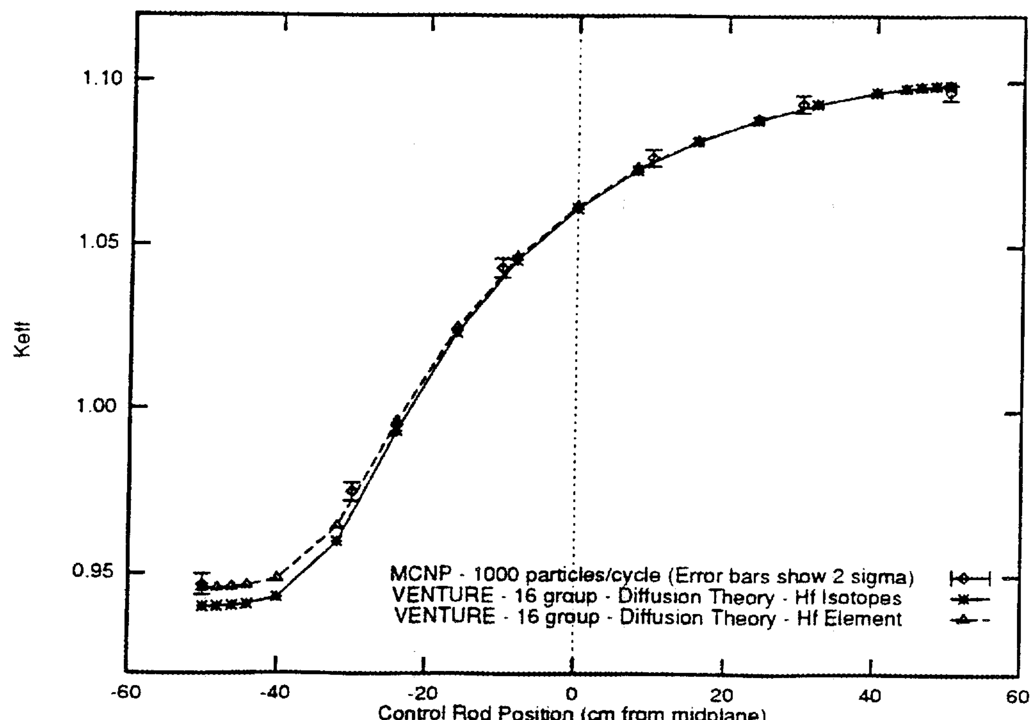


Figure 4-40 K_{eff} versus control rod position using 16 group elemental hafnium and individual hafnium isotope cross sections.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Several options and applications of the CTRLPOS module have been demonstrated in this report. The module is flexible so that a wide variety of control rod positioning schemes and other problems such as criticality and material density searches can be treated. With the module, the search of a control rod position for a desired k_{eff} value and the determination of control rod worth curves are completely automated. Also, the depletion of control rods can be calculated over one or several fuel cycles. This capability allows radiation source terms to be calculated which can be used to determine doses to maintenance personnel and the shielding and long-term storage requirements for the spent control rods. Currently, CTRLPOS is being used in a production mode for control rod positioning during the fuel cycle calculations for the Advanced Neutron Source.

5.2 Recommendations

Several features could be added to enhance the versatility and reduce the limitations of the CTRLPOS module. Some possible additions and/or changes are discussed below.

1) Multi-bank control rod position option: Currently only a

single control rod, a single bank of control rods, or all control rods in the model can be moved to perform a k_{eff} control rod position search. However, most large power reactors have control rod systems with multiple banks that are moved inside the reactor with a prescribed relative position sequence. An option that allows for multi-bank control rod k_{eff} position searches could be added to CTRLPOS.

2) Conversion of CTRLPOS for use with a discrete ordinates code: Since the CTRLPOS module uses CCCC interface files, the module could be used with the TWODANT code. This S_n transport code uses CCCC interface files. Transport theory should provide more accurate answers for control rod models than diffusion theory. However, the calculation time for transport theory problems is much larger than for diffusion theory problems.

3) Position dependent control rod material cross sections: A feature might be added to the code that allows the cross sections for the control rod material to be a function of the control rod position in the core.

4) Use of BURNER module nuclide depletion chains: Currently, the depletion chains for the materials present in the control rods are part of the CTRLPOS module input. This is satisfactory in most cases where the 'control rod' is a traditional (non-fissile) control rod material. However, the CTRLPOS depletion chain input was not designed for long complicated depletion chains such as those required for fuel

material. One possible way of adding this capability is to make use of the depletion chains in the CCCC EXPOSE interface file which is used by the BURNER module.

5) Development of an Adaptive Zone/Mesh Structure: The correct treatment of the control rod tip is important when determining critical positions and during depletion studies. One way to improve control rod tip treatment is through the development of an adaptive zone/mesh structure. Each time a control rod position is determined, the problem mesh and zone structure could be changed so that the control rod tip is always well defined and not smeared over a zone.

Two additional measures which could improve some of the results presented for the Chapter 4 Sample Problems are discussed below.

1) Cross section processing: The use of a two-dimensional discrete ordinates transport code to calculate a neutron spectrum, which is then used to obtain weighted cross sections, should be implemented. This would provide more accurate cross sections for the control rod material, especially at the control rod tip.

2) Treatment of hafnium resonances in control rod material: The results for k_{eff} using the XSDRNPM and VENTURE codes with cross sections for the hafnium isotopes are in disagreement with the results obtained using elemental hafnium. The energy group structure and cross section processing for hafnium is

important. Use of the ROLAIDS module[17] should be considered for problems containing hafnium. The NITAWL-II module does not treat resonance overlap; ROLAIDS takes into account the resonance overlap between isotopes.

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BIOGRAPHICAL SKETCH

Lenard Alan Smith, the son of Lenard and Karen Smith, was born on June 8, 1970, in Stuttgart, Arkansas. He attended elementary and middle school in DeValls Bluff, Arkansas and graduated from Russellville High School in May 1988 as one of five valedictorians. In August 1988, Alan started undergraduate studies at the University of Missouri-Rolla where he received a Bachelor's of Science degree in Nuclear Engineering with honors in May 1992.

Alan participated in the Graduate Student Research Program at Oak Ridge National Laboratory with the Reactor Physics Group in the Engineering Physics and Math Division during the summer of 1992. He started graduate studies at the University of Florida-Gainesville in August 1992 as a Department of Energy Applied Health Physics Fellow.

Appendix A

CALCULATION OF ATOM DENSITIES IN TABLES 2-1 AND 2-2

CTRLPOS uses the atom densities and zone volumes at the initial control rod position to calculate the new atom densities for each zone after the control rod has been moved. The calculations in Figure A-1 show how the 'smeared' control rod atom densities shown in Table 2-1 were determined. Zone volumes have units of cm^3. Atom densities are normalized to 1.00.

Variables are defined as follows:

NFOLL(I)= Calculated new follower atom density for zone I.

NCTRL(I)= Calculated new control rod atom density for zone I.

FOLLZ#= Atom density of follower material in zone # before control rod movement.

CTRLZ#= Atom density of control rod material in zone # before control rod movement.

TOTAL(I)= Total volume of zone I.

FPART(I)= Volume of zone I which contains follower material.

AREA(I,J)= Volume of zone I which is present in zone J when the control rod is in its new position.

FRAC(I,J)= Atom density of zone I which is present in zone J when the control rod is in its new position.

ZONE 1: $NFOLL(1) = FOLLZ6 = 1.0$

$NCTRL(1) = 0.0$ (No control rod material present in zone 1)

ZONE 2: $$NCTRL(2) = CTRLZ2 \times \left[\frac{AREA(2.2)}{TOTAL(2)}\right] = 1.0 \times \left[\frac{5.0}{10.0}\right] = 0.5$$

$$NFOLL(2) = FOLLZ6 \times \left[\frac{FPART(2)}{TOTAL(2)}\right] = 1.0 \times \left[\frac{5.0}{10.0}\right] = 0.5$$

ZONE 3: $$NCTRL(3) = CTRLZ2 \times \left[\frac{AREA(2,3)}{TOTAL(3)}\right] + CTRLZ3 \times \left[\frac{AREA(3,3)}{TOTAL(3)}\right]$$

$$= 1.0 \times \left[\frac{5.0}{20.0}\right] + 1.0 \times \left[\frac{15.0}{20.0}\right] = 1.0$$

$NFOLL(3) = 0.0$ (No follower present in zone 3.)

ZONE 4: $$NCTRL(4) = CTRLZ3 \times \left[\frac{AREA(3,4)}{TOTAL(4)}\right] + CTRLZ4 \times \left[\frac{AREA(4,4)}{TOTAL(4)}\right]$$

$$= 1.0 \times \left[\frac{5.0}{10.0}\right] + 1.0 \times \left[\frac{5.0}{10.0}\right] = 1.0$$

$NFOLL(4) = 0.0$ (No follower present in zone 4.)

ZONE 5: $$NCTRL(5) = CTRLZ4 \times \left[\frac{AREA(4,5)}{TOTAL(5)}\right] = 1.0 \times \left[\frac{5.0}{10.0}\right] = 0.5$$

$$NFOLL(5) = FOLLZ5 \times \left[\frac{AREA(5,5)}{TOTAL(5)}\right] = 1.0 \times \left[\frac{5.0}{10.0}\right] = 0.5$$

Note: Remainder of zone 5(5.0 cm^3) is out of model and data is saved

Figure A-1 Sample calculations for Table 2-1.

The calculations in Figure A-2 show how the depleted control rod atom densities shown in Table 2-2 were determined. The calculations for PROD1 and PROD2 are essentially the same as the calculations for the placement of the control rod material of Table 2-1, the only difference being that the production fraction must be considered. Zone volumes have units of cm^3. Atom densities are normalized to 1.00.

Variables are defined as follows:

NFOLL(I)= Calculated new follower atom density for zone I.

NCTRL(I)= Calculated new control rod atom density for zone I.

NPROD1(I)= Calculated new produced nuclide 1 atom density for zone I.

NPROD1(I)= Calculated new produced nuclide 1 atom density for zone I.

FOLLZ#= Atom density of follower material in zone # before control rod movement.

CTRLZ#= Atom density of control rod material in zone # before control rod movement.

TOTAL(I)= Total volume of zone I.

AREA(I,J)= Volume of zone I which is present in zone J when the control rod is in its new position.

FRAC(I,J)= Atom density of zone I which is present in zone J when the control rod is in its new position.

CRZ#(AFTER)= Control rod material atom density in zone # after depletion.

CRZ#(BEFORE)= Control rod material atom density in zone # before depletion.

FLZ#(AFTER)= Follower material atom density in zone # after depletion.

FLZ#(BEFORE)= Follower material atom density in zone # before depletion.

ZONE 1 NFOLL(1) = FOLLZ6 = 1.0

NCTRL(1) = 0.0 (No control rod material present in zone 1.)

ZONE 2. $$NCTRL(2) = \left[\frac{CRZ2(AFTER)}{CRZ2(BEFORE)}\right] \times \left[\frac{AREA(2)}{AREA(2)}\right] \times FRAC(2,2) + \left[\frac{CRZ3(AFTER)}{CRZ3(BEFORE)}\right] \times \left[\frac{AREA(3)}{AREA(2)}\right] \times FRAC(2,3)$$

$$= \left[\frac{0.4}{0.5}\right] \times \left[\frac{10.0}{10.0}\right] \times 0.5 + \left[\frac{0.5}{1.0}\right] \times \left[\frac{20.0}{10.0}\right] \times 0.25 = 0.65$$

NPROD1(2) = 0.2625
NPROD2(2) = 0.0875
NFOLL(2) = 0.0 (No follower material is present in zone 2.)

ZONE 3. $$NCTRL(3) = \left[\frac{CRZ3(AFTER)}{CRZ3(BEFORE)}\right] \times \left[\frac{AREA(3)}{AREA(3)}\right] \times FRAC(3,3) + \left[\frac{CRZ4(AFTER)}{CRZ4(BEFORE)}\right] \times \left[\frac{AREA(4)}{AREA(3)}\right] \times FRAC(3,4)$$

$$= \left[\frac{0.5}{1.0}\right] \times \left[\frac{20.0}{20.0}\right] \times 0.75 + \left[\frac{0.8}{1.0}\right] \times \left[\frac{10.0}{20.0}\right] \times 0.5 = 0.575$$

NPROD1(3) = 0.31875
NPROD2(3) = 0.10625
NFOLL(3) = 0.0 (No follower material is present in zone 3.)

ZONE 4 $$NCTRL(4) = \left[\frac{CRZ4(AFTER)}{CRZ4(BEFORE)}\right] \times \left[\frac{AREA(4)}{AREA(4)}\right] \times FRAC(4,4) + \left[\frac{CRZ5(AFTER)}{CRZ5(BEFORE)}\right] \times \left[\frac{AREA(5)}{AREA(4)}\right] \times FRAC(4,5)$$

$$= \left[\frac{0.8}{1.0}\right] \times \left[\frac{10.0}{10.0}\right] \times 0.5 + \left[\frac{0.45}{0.5}\right] \times \left[\frac{10.0}{10.0}\right] \times 0.5 = 0.85$$

NPROD1(4) = 0.1125
NPROD2(4) = 0.0375
NFOLL(4) = 0.0 (No follower material is present in zone 4.)

ZONE 5 NCTRL(5) = 0.0 (No control rod material is present in zone 5.)
NPROD1(5) = 0.0
NPROD2(5) = 0.0

$$NFOLL(5) = \left[\frac{FLZ5(AFTER)}{FLZ5(BEFORE)}\right] \times \left[\frac{AREA(5)}{AREA(5)}\right] \times FRAC(5,5)$$

+(Saved part of zone 5 which is the part moved out of the model)

$$= \left[\frac{0.5}{0.5}\right] \times \left[\frac{10.0}{10.0}\right] \times 0.5 + 0.5 = 1.0$$

Figure A-2 Sample calculations for Table 2-2.

Appendix B

CTRLPOS INPUT DATA AND INTERFACE FILE FORMAT

Figures describing the necessary input data format and requirements are included in this appendix. The format of the CTRLIF interface file is also included. These figures are discussed in Chapter 3.

Figure B-1 Specifications for CTRLCF, the CTRLPOS control record.

```
C-----------------------------------------------------------------------
CR              CTRLPOS Control Rod Positioning Instructions           -
C                                                                      -
CL      CTRLCF, (XX(I), I=1,100),(IX(I), I=1,100)                      -
C                                                                      -
CW                                                                     -
C                                                                      -
CD      CTRLCF   Control Rod Positioning Module Data Identifier        -
CD               (6HCTRLCF)                                            -
C                                                                      -
CC      NOTE:    The interface files 'CONTRL' 'NDXSRF'                 -
CC               'RZFLUX' and 'GEODST' are required.                   -
CC               XX( ) is a REAL*8 variable.                           -
CC               IX( ) is an INTEGER variable.                         -
C                                                                      -
CD      XX(1)    Target keff value when positioning control rod.       -
C                                                                      -
CD      XX(2)    Tolerance allowed between XX(1) and the keff          -
CD               value calculated after control rod positioning.       -
C                                                                      -
CD      XX(3)    Maximum value of the volume through which the         -
CD               control rod can move in one change of position        -
CD               when IX(1)=20.                                        -
C                                                                      -
CD      XX(4)    Maximum number of atom density values allowed         -
CD               per control rod bank.  This value is only used        -
C                when IX(23)=1.                                        -
C                                                                      -
CD      XX(5-100)  Reserved.                                           -
C                                                                      -
CD      IX(1)    Determines what action will be taken by the           -
CD               CTRLPOS module.  On the first entrance IX(1)=1        -
CD               or IX(1)=5.  On the second entrance of a run          -
CD               IX(1)=10 or IX(1)=20 with IX(13).NE.0 for a           -
CD               restart case.                                         -
CD                 1--CTRLPOS output will be sent to default           -
CD                    VENTURE output file.                             -
CD                 5--CTRLPOS output will be sent to a user            -
CD                    specified file name.                             -
CD                    (More input needed from input stream.)           -
CD                10--Setup control rod data.  Control rod             -
CD                    position criticality search is also done.        -
CD                    (More input needed from input stream.)           -
CD                20--Perform keff search by moving control rod        -
CD                    to new position.                                 -
CD                25--Print out control rod information.               -
CD                30--Calculate control rod worth curve.               -
CD                    (More input needed from input stream.)           -
CD                40--Move control rod to an input position.           -
```

(CONTINUED)

```
C                                                                    -
CD     IX(2)     Determines the module that performs the keff        -
CD               calculations.                                       -
CD                0--VENTNEUT module.                                -
CD                1--VALENEUT module.                                -
C                                                                    -
CD     IX(3)     Type of interpolation scheme used for the           -
CD               determination of new control rod position.          -
CD                0--Linear using Lagrange two point method.         -
CD                    (Recommended Method)                           -
CD                1--Lagrange using IX(4) number of points.          -
CD                3--Linear regression using IX(4) number of pts.    -
CD                4--Newton's divided difference using all stored    -
CD                    points.                                        -
C                                                                    -
CD     IX(4)     Number of points used for interpolation when        -
CD               IX(3)=1 or 3.                                       -
C                                                                    -
CD     IX(5)     Manipulation of stored keff values and positions.   -
CD                0--Zero array after each exit of module.           -
CD                    (Recommended)                                  -
CD                1--Retain stored values to use for positioning     -
CD                    in the next entrance of CTRLPOS.               -
C                                                                    -
CD     IX(6)     Control rods used for keff search.                  -
CD                0--All banks and control rods will be moved.       -
CD                1--Bank 1 will be moved to determine new keff.     -
CD                    Other control rods are positioned using        -
CD                    IX(1)=40.                                      -
C                                                                    -
CD     IX(7)     Option to print out control rod atom densities.     -
CD                0--Do not print.                                   -
CD                1--Print.                                          -
C                                                                    -
CD     IX(8)     Option to print out control rod atom densities      -
CD               before each entrance to keff calculation module.    -
CD                0--Do not print.                                   -
CD                1--Print.                                          -
C                                                                    -
CD     IX(9)     Positioning of control rod before exit from         -
CD               the CTRLPOS module.                                 -
CD                0--Control rod tip can be partially inside         -
CD                    a zone.                                        -
CD                1--Place control rod tip at the zone boundary      -
CD                    which has the keff value nearest XX(1).        -
CD                    This option requires two additional keff       -
CD                    calculations.                                  -
C                                                                    -
CD     IX(10)    Number of position iterations allowed for           -
CD               each keff search.  A keff calculation is done       -
CD               for each iteration.                                 -
                          (CONTINUED)
```

```
C                                                              -
CD      IX(11)   Maximum number of outer iterations allowed by -
CD               the neutronics module for each k_eff calculation -
C                                                              -
CD      IX(12)   Reserved.                                     -
C                                                              -
CD      IX(13)   Option to use the control rods from last reactor -
CD               history.  The 'burned' control rods are used  -
CD               after the core has been refueled.             -
CD               (Used only when IX(1)=20.)                    -
CD                0--The reactor core has not been refueled and no-
CD                   control rod changes are necessary.        -
CD                   (Default)                                 -
CD                1--Use current 'burned' control rod.         -
CD                   (More input needed from input stream.)    -
CD                2--Use the 'unburned' control rod after      -
CD                   refueling.  The material placed in the    -
CD                   control rod zones after the core change will -
CD                   now make up the control rod.              -
CD                   (More input needed from input stream.)    -
C                                                              -
CD      IX(14)   Bank number for control rod worth curve.      -
CD               (Used only when IX(1)=30.)                    -
C                                                              -
CD      IX(15)   Control rod used for control rod worth curve. -
CD               (Used only when IX(1)=30.)                    -
CD                0--Move all control rods in bank IX(14).     -
CD                N--Move only control rod N of bank IX(14).   -
C                                                              -
CD      IX(16)   Reserved.                                     -
C                                                              -
CD      IX(17)   Bank number for control rod re-position.      -
CD               (Used only when IX(1)=40.)                    -
C                                                              -
CD      IX(18)   Control rod used for control rod re-position. -
CD               (Used only when IX(1)=40.)                    -
CD                0--Move all control rods in bank IX(17).     -
CD                N--Move only control rod N of bank IX(17).   -
C                                                              -
CD      IX(19)   Zone number where control rod will be positioned.-
CD               If IX(18)=0, then enter control rod zone number -
CD               for first control rod in bank IX(17).         -
CD               (Used only when IX(1)=40.)                    -
C                                                              -
CD      IX(20)   Boundary of zone IX(19) where control rod will be-
CD               positioned.(Used only when IX(1)=40.)         -
CD                0--Lower boundary of zone IX(19).            -
CD                1--Upper boundary of zone IX(19).            -
C                                                              -
```

(CONTINUED)

```
CD     IX(21)    Option to return the control rod to the entrance -
CD               position UPON THE NEXT ENTRANCE to CTRLPOS.      -
CD               For both cases, IX(1) must equal 40 and IX(21)   -
CD               must equal 1.                                    -
CD               (Designed for use with VENTPLOT[12] module to    -
CD                allow plotting of control rod atom densities.)  -
CD                0--Leave control rod at position IX(19).        -
CD                    (Default)                                   -
CD                1--On next module entrance, return control rod  -
CD                   to original position.  IX(1) must equal 40 on-
CD                   the second CTRLPOS module entrance.          -
C                                                                 -
CD     IX(22)    RESERVED
C                                                                 -
CD     IX(23)    Atom density array storage option.               -
CD                0--An array will be used which is dimensioned   -
CD                   for the maximum number of nuclides in the    -
CD                   problem for every control rod zone of every  -
CD                   rod of every bank.                           -
CD                   (Default)                                    -
CD                1--An array will be used which is dimensioned   -
CD                   for XX(4) values for each control rod        -
CD                   bank.  Only non-zero atom density values are -
CD                   stored in memory.  This may be necessary for -
CD                   large problems.                              -
C                                                                 -
CD     IX(24)    Container array memory option.                   -
CD                0--All CTRLPOS data is kept in the container    -
CD                   array and the neutronics modules use only    -
CD                   the remaining available computer memory.     -
CD                   (Default)                                    -
CD                1--Before each keff calculation the CTRLIF file -
CD                   will be written and the computer memory will -
CD                   be available for the neutronics calculation. -
C                                                                 -
CD     IX(25)    Debug print parameter.                           -
CD                0--No debug output.                             -
CD              1-7--Various levels of debugging output with 7    -
CD                   being the most extensive output.             -
C                                                                 -
CD     IX(26-100)  Reserved.                                      -
C                                                                 -
C------------------------------------------------------------------
```

(End of Figure B-1)

Figure B-2 CTRLPOS data read from input stream for IX(1) equal to 5.

```
C-------------------------------------------------------------------
CD   When IX(1)=5, Card 1 is read.  This provides the name for     -
CD   the CTRLPOS output file.                                      -
C                                                                  -
CD   Card 1: The name of the CTRLPOS output file should start in  -
CD           column 1.  The file name can be up to 30 characters  -
CD           long.                                                 -
C                                                                  -
C                          (END OF DATA)                           -
C-------------------------------------------------------------------
```

(End of Figure B-2)

Figure B-3 CTRLPOS data read from input stream for IX(1) equal to 10.

```
C-----------------------------------------------------------------
CD   When IX(1)=10, Cards 2-14 are read for each control rod       -
CD   bank.  Cards 3-13 are read for each rod of each bank.         -
CD   CTRLPOS scans the input to determine the number of banks,     -
CD   rods, and zones in the setup.                                 -
CD   All input is free field unless otherwise noted.               -
C                                                                  -
CD   Card 1: 'BEGIN-INPUT' or 'begin-input' starting in column 1.-
C                                                                  -
CD   Card 2: 'BEGIN-BANK' or 'begin-bank' starting in column 1.    -
C                                                                  -
CD   Card 3: 'BEGIN-ROD' or 'begin-rod' starting in column 1.      -
C                                                                  -
CD   Card 4: ZTIPCR    Zone where the tip of this control rod      -
CD                     is located.                                 -
C                                                                  -
CD           IB_ZT     Boundary of zone ZTIPCR where the           -
CD                     control rod tip is located.                 -
CD                      0--Lower boundary of zone ZTIPCR.          -
CD                      1--Upper boundary of zone ZTIPCR.          -
C                                                                  -
CD           FGBANK    Zone number where the control               -
CD                     rod will be moved for the 'first guess'.    -
CD                     This zone can be above or below the tip of -
CD                     the control rod.                            -
CD                     NOTE:  If FGBANK=ZTIPCR the CTRLPOS module -
CD                     will stop.                                  -
C                                                                  -
CD           IB_FG     Boundary of zone FGBANK where the           -
CD                     control rod will be positioned.             -
CD                      0--Lower boundary of zone FGBANK.          -
CD                      1--Upper boundary of zone FGBANK.          -
C                                                                  -
CD   Card 5: URANZ     Zone which defines the upper limit of       -
CD                     the control rod's limit of motion.          -
C                                                                  -
CD           IB_UR     Boundary of zone URANZ which                -
CD                     defines the upper control rod motion limit.-
CD                      0--Lower boundary of zone URANZ.           -
CD                      1--Upper boundary of zone URANZ.           -
C                                                                  -
CD           LRANZ     Zone which defines the lower limit of       -
CD                     the control rod's limit of motion.          -
C                                                                  -
```

(CONTINUED)

```
CD          IB_LR    Boundary of zone LRANZ which                   -
CD                   defines the lower control rod motion limit.-
CD                    0--Lower boundary of zone LRANZ.               -
CD                    1--Upper boundary of zone LRANZ.               -
C                                                                    -
CD   Card 6: 'BEGIN-ZONE' or 'begin-zone' starting in column 1.     -
C                                                                    -
CD   Card 7: ZREAC    Zone number in the VENTURE model for           -
CD                   this control rod zone. The first ZREAC         -
CD                   value is the zone number at the                -
CD                   lower limit end of the control rod motion      -
CD                   in the model, i.e., the insert limit end       -
CD                   of the control rod.  The last ZREAC value      -
CD                   is the end of the control rod which will       -
CD                   be removed from the model when the control     -
CD                   rod is withdrawn from the reactor core.        -
C                                                                    -
CD          ZFOLL    Zone number in the VENTURE model for           -
CD                   the control rod follower for the control       -
CD                   rod zone ZREAC.  This zone should              -
CD                   always contain the replacement                 -
CD                   follower material.                             -
C                                                                    -
CD          ZCON_ROD Identification of the zone containing          -
CD                   control rod material.                          -
CD                    0--Zone does not contain control rod          -
CD                       material.                                  -
CD                    1--Zone contains control rod material.        -
CD                       The volume of this zone will be used       -
CD                       when calculating the average values        -
CD                       for the control rod material               -
CD                       over the control rod and the control       -
CD                       rod bank.  These average atom densities-
CD                       are printed for each rod and bank for      -
CD                       the user.                                  -
C                                                                    -
CD   Card 8: 'END-ZONE' or 'end-zone' starting in column 1.         -
C                                                                    -
CD   Card 9: 'BEGIN-ISOTOPE' or 'begin-isotope' starting in         -
CD          column 1.                                               -
C                                                                    -
CD  Card 10: NAME_PROD_ISOT Name of the 'production nuclide' for    -
CD                 this chain.  The name should                     -
CD                 be the unique nuclide name right                 -
CD                 justified in columns 1-8.                        -
C                                                                    -
```

(CONTINUED)

```
CD  Card 11: NAME_MADE Name of the 'produced nuclide'.              -
CD                     The name should be the unique nuclide        -
CD                     name and right justified in columns 1-8.     -
CD                     All produced nuclides for NAME_PROD_ISOT     -
CD                     should be listed. (For example B-10 might    -
CD                     be depleted to produce He and Li both with   -
CD                     FRAC_MADE's of 1.0.                          -
C                                                                   -
CD           FRAC_MADE Fraction of produced nuclide made when       -
CD                     when a production nuclide is destroyed.      -
C                                                                   -
CD  Card 12: 'END-ISOTOPE' or 'end-isotope' starting in column 1.-
C                                                                   -
CD  Card 13: 'END-ROD' or 'end-rod' starting in column 1.           -
C                                                                   -
CD  Card 14: 'END-BANK' or 'end-bank' starting in column 1.         -
C                                                                   -
CD  Card 15: 'END-INPUT' or 'end-input' starting in column 1.       -
C                                                                   -
C                         (END OF DATA)                             -
C--------------------------------------------------------------------
```

(End of Figure B-3)

Figure B-4 CTRLPOS data read from input stream for IX(1) equal to 20 with IX(13) not equal to 0.

```
C-----------------------------------------------------------------
CD       When IX(1)=20 with IX(13).NE.0, Cards 1-3 are required. -
CD       This data changes the position of the control rods after-
CD       the reactor core has been refueled.  Card 2 should be   -
CD       input for each control rod of each bank.                -
C                                                                -
CD   Card 1: 'BEGIN-INPUT' or 'begin-input' starting in column 1.-
C                                                                -
CD   Card 2: CH_BANK  Bank number of control rod.                -
C                                                                -
CD           CH_ROD   Rod number of control rod.                 -
C                                                                -
CD           IGUESS1_20 Zone number for first guess where        -
CD                    control rod will be positioned.            -
C                                                                -
CD           IB1_20   Boundary of zone IGUESS1_20 where          -
CD                    control rod will be positioned.            -
CD                     0--Lower boundary of zone IGUESS1_20.     -
CD                     1--Upper boundary of zone IGUESS1_20.     -
C                                                                -
CD           IGUESS2_20 Zone number for second guess where       -
CD                    control rod will be positioned.            -
CD                    NOTE:  If IGUESS1_20=IGUESS2_20 and        -
CD                    IB1_20=IB2_20, the CTRLPOS module will     -
CD                    stop.                                      -
C                                                                -
CD           IB2_20   Boundary of zone IGUESS2_20 where          -
CD                    control rod will be positioned.            -
CD                     0--Lower boundary of zone IGUESS2_20.     -
CD                     1--Upper boundary of zone IGUESS2_20.     -
C                                                                -
CD   Card 3: 'END-INPUT' or 'end-input' starting in column 1.    -
C                                                                -
C                          (END OF DATA)                         -
C-----------------------------------------------------------------
```

(End of Figure B-4)

Figure B-5 CTRLPOS data read from input stream for IX(1) equal to 30.

```
C---------------------------------------------------------------------
CD      When IX(1)=30, Cards 1-3 are read.  Card 2 should be        -
CD      repeated for each control rod position.                     -
CD      This data provides the positions for a rod worth curve.     -
C                                                                   -
CD  Card 1: 'BEGIN-INPUT' or 'begin-input' starting in column 1.-
C                                                                   -
CD  Card 2: RODPOS   Zone number where control rod will be          -
CD                    positioned and keff will be determined.       -
C                                                                   -
CD          IBOUND   Boundary of zone RODPOS where control          -
CD                   rod will be positioned.                        -
CD                    0--Lower boundary of zone RODPOS.             -
CD                    1--Upper boundary of zone RODPOS.             -
C                                                                   -
CD  Card 3: 'END-INPUT' or 'end-input' starting in column 1.        -
C                                                                   -
C                           (END OF DATA)                           -
C---------------------------------------------------------------------
```

(End of Figure B-5)

Figure B-6 Specifications for CTRLIF, the CTRLPOS interface file.

```
C-----------------------------------------------------------------------
C                              REVISED 11/01/93                        -
C                                                                      -
CF            CTRLIF                                                   -
C                                                                      -
CE            CONTROL ROD POSITION AND SETUP DATA                      -
C                                                                      -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR          FILE IDENTIFICATION                                        -
C                                                                      -
CL      HNAME,(HUSE(I),I=1,2),IVERS                                    -
C                                                                      -
CW      (3*IDP+1) = NUMBER OF WORDS                                    -
C                                                                      -
CD      HNAME         FILE NAME (A6) 'CTRLIF'.                         -
CD      HUSE          USER IDENTIFICATION (A6).                        -
CD      IVERS         FILE VERSION NUMBER.                             -
C                                                                      -
CN      IDP           1 FOR LONG WORD, 2 FOR SHORT WORD MACHINES.      -
C                                                                      -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR        CTRLPOS POINTER PARAMETERS (1D RECORD)                       -
C                                                                      -
CL      (NBANKS, MAXROD, MAXNRZ, MAXCHN, MAXMAD, LIMIT_CTRL,           -
CL       NNS_CTRL, NON_CTRL, NZONE_CTRL, NAN_CTRL, NSN_CTRL,           -
CL       NSZ_CTRL, IBIG_CTRL)                                          -
C                                                                      -
CW      13          = NUMBER OF WORDS.                                 -
C                                                                      -
CD      NBANKS        NUMBER OF CONTROL ROD BANKS IN CASE.             -
C                                                                      -
CD      MAXROD        MAXIMUM NUMBER OF CONTROL RODS IN ANY BANK.      -
C                                                                      -
CD      MAXNRZ        MAXIMUM NUMBER OF ZONES IN ANY CONTROL ROD OF    -
CN                    ANY BANK.                                        -
C                                                                      -
CD      MAXCHN        MAXIMUM NUMBER OF PRODUCTION CHAINS IN ANY       -
CN                    CONTROL ROD OF ANY BANK.                         -
C                                                                      -
CD      MAXMAD        MAXIMUM NUMBER OF PRODUCED NUCLIDES FOR ANY      -
CN                    PRODUCTION CHAIN IN ANY CONTROL ROD OF ANY       -
CN                    BANK.                                            -
C                                                                      -
```

(CONTINUED)

```
CD     LIMIT_CTRL  VALUE OF XX(4) IN 'CTRLCF' CONTROL FILE.  THIS-
CN                 IS THE MAXIMUM NUMBER OF NON-ZERO ATOM DENSITY-
CN                 VALUES THAT CAN BE IN AN CTRLPOS ATOM DENSITY -
CN                 ARRAY.  THIS VALUE IS ONLY USED IF IX(23)=1.  -
C                                                                -
CD     NNS_CTRL    MAXIMUM NUMBER OF NUCLIDES IN ANY CROSS       -
CN                 SECTION SET.                                  -
C                                                                -
CD     NON_CTRL    NUMBER OF NUCLIDES IN CROSS SECTION DATA.     -
C                                                                -
CD     NZONE_CTRL  MAXIMUM NUMBER OF CONTROL ROD ZONES IN ANY    -
CN                 CONTROL ROD OF ANY BANK.                      -
C                                                                -
CD     NAN_CTRL    NUMBER OF DIFFERENT NUCLIDES IN DATA.         -
C                                                                -
CD     NSN_CTRL    NUMBER OF NUCLIDE SETS IDENTIFIED.            -
C                                                                -
CD     IBIG_CTRL   VALUE OF IX(23) IN 'CTRLCF' CONTROL FILE.     -
CN                 THIS IS THE FLAG WHICH DETERMINES WHICH WAY   -
CN                 THE ATOM DENSITY ARRAY IN CTRLPOS WILL BE     -
CN                 HANDLED.                                      -
C                                                                -
C                  (END OF DATA RECORD 1)                        -
C-----------------------------------------------------------------

C-----------------------------------------------------------------
C                                                                -
C  RECORD NUMBER      LENGTH                    PARAMETER        -
C                                                                -
C       2    NBANKS                             NRODS            -
C       3    IDP*NON_CTRL                       HNNAME           -
C       4    IDP*NON_CTRL                       HANAME           -
C       5    NSN_CTRL*NNS_CTRL                  NOS              -
C       6    IDP*101*NBANKS*MAXROD              R1POS            -
C       7    IDP*101                            K1VAL            -
C       8    IDP*(MAXNRZ+2)*NBANKS*MAXROD       R2POS            -
C       9    IDP*(MAXNRZ+2)                     K2VAL            -
C      10    MAXNRZ+1                           RWZON            -
C      11    MAXNRZ+1                           IRWB             -
C      12    IDP*NBANKS*MAXROD                  POSSAV           -
C      13    1                                  IREPOS_SAVE      -
C      14    NBANKS*MAXROD                      ZTIPCR           -
C      15    NBANKS*MAXROD                      FGBANK           -
C      16    NBANKS*MAXROD                      LRANZ            -
C      17    NBANKS*MAXROD                      URANZ            -
C      18    NBANKS*MAXROD                      IB_ZT            -
C      19    NBANKS*MAXROD                      IB_FG            -
C      20    NBANKS*MAXROD                      IB_LR            -
C      21    NBANKS*MAXROD                      IB_UR            -
C      22    NBANKS*MAXROD                      NZREAC           -
C      23    NBANKS*MAXROD                      ZTDATA           -
```

(CONTINUED)

```
C       24    NBANKS*MAXROD                     FGDATA                  -
C       25    NBANKS*MAXROD                     LRDATA                  -
C       26    NBANKS*MAXROD                     URDATA                  -
C       27    NBANKS*MAXROD*MAXNRZ              ZREAC                   -
C       28    NBANKS*MAXROD*MAXNRZ              ZFOLL                   -
C       29    NBANKS*MAXROD*MAXNRZ              ZCON_ROD                -
C       30    IDP*NBANKS*MAXROD*MAXNRZ          ZVFOL                   -
C       31    IDP*NBANKS*MAXROD*MAXNRZ          ZVREAC                  -
C       32    IDP*NBANKS*MAXROD*(MAXNRZ+1)      TZVRX                   -
C       33    NBANKS*MAXROD                     NUM_CHAIN               -
C       34    IDP*NBANKS*MAXROD*MAXCHN          NAME_PROD_ISOT          -
C       35    NBANKS*MAXROD*MAXCHN              NUM_MADE                -
C       36    IDP*NBANKS*MAXROD*MAXCHN*MAXMAD   NAME_MADE               -
C       37    NBANKS*MAXROD*MAXCHN*MAXMAD       FRAC_MADE               -
C       38    NBANKS*MAXROD*MAXCHN              PROD_CTRL               -
C       39    NBANKS*MAXROD*MAXCHN*MAXMAD       BADCTR                  -
C       40    IDP*NBANKS*MAXROD                 POSNOW                  -
C       41    IDP*NBANKS*MAXROD                 POSOLD                  -
C       42    IDP*NBANKS*MAXROD                 POSOLD1                 -
C       43    IDP*NBANKS*MAXROD                 POSOLD_CTRL             -
C       44    IDP*NBANKS*MAXROD                 POSOLD_ISAVE            -
C       45    IDP*NBANKS*MAXROD                 POSOLD_PREDICT          -
C       46    NBANKS*MAXROD                     ZONECV                  -
C       47    NBANKS*MAXROD                     IZONE_CTRL              -
C       48    IDP*NBANKS*MAXROD                 AFRAC_ZONE              -
C       49    1                                 # OF WORDS ON REC 50-
C       50    <VALUE OF RECORD 49>              IV                      -
C       51    1                                 # OF WORDS ON REC 51-
C       52    <VALUE OF RECORD 51>              JV                      -
C       53    5                                 IMAX_NUMBER             -
C       54    1                                 # OF WORDS ON REC 55-
C       55    IDP*<VALUE OF RECORD 54>          AFRAC_STORE             -
C       56    1                                 # OF WORDS ON REC 57-
C       57    IDP*<VALUE OF RECORD 56>          ADEN_CTRL               -
C       58    1                                 # OF WORDS ON REC 59-
C       59    IDP*<VALUE OF RECORD 58>          ADEN_FIRST              -
C       60    1                                 # OF WORDS ON REC 61-
C       61    IDP*<VALUE OF RECORD 60>          ADEN_STORE              -
C       62    1                                 # OF WORDS ON REC 63-
C       63    IDP*<VALUE OF RECORD 62>          ADEN_BURN               -
C       64    IDP                               '        '(8 SPACES)-
C                                                                       -
C                    (END OF CTRLIF INTERFACE FILE)                     -
C-----------------------------------------------------------------------
```

(End of Figure B-6)

Appendix C

DESCRIPTION OF NUCLEAR CODES

Several nuclear analysis code packages were used to perform the sample problem calculations presented in Chapter 4. A short description of each package is provided below.

C.1 VENTURE

The VENTURE reactor analysis code system uses multigroup, finite-difference diffusion theory to solve reactor core static neutronics problems in one, two, or three dimensions. The BURNER module provides the capability for depletion calculations. The CTRLPOS module is now part of the VENTURE system. The VENTURE system was developed at the Oak Ridge National Laboratory.

C.2 MCNP

MCNP is a general purpose Monte Carlo code used for neutron, photon, and electron transport. The KCODE option in MCNP provides the capability of determining k_{eff} for a system. The combinatorial geometry used in MCNP allows the modelling of complex geometries in three dimensions. The code was developed at the Los Alamos National Laboratory.

C.3 SCALE

The SCALE code system is a collection of modules with the capability of performing criticality, shielding, and heat transfer analyses. Several control modules are available which automate certain calculation sequences. The CSASN control module runs BONAMI-S and NITAWL-II to process cross sections using Bondarenko factor data for the unresolved resonace region and the Nordheim Integral Treatment for the resolved resonances. This creates a working cross section library from an AMPX master cross section library. XSDRNPM-S, a one-dimensional discrete ordinates transport code, can use this working library to generate weighted, collapsed cross section sets. These collapsed sets can be written into the CCCC ISOTXS interface file format, which can be accessed by the VENTURE code system. The SCALE package was developed at the Oak Ridge National Laboratory.

Appendix D

SAMPLE PROBLEM INPUT AND SELECTED OUTPUT

The input and selected output of the sample problems presented in Chapter 4 are included in this appendix. For each problem, the input for MCNP, SCALE, and VENTURE (which includes the CTRLPOS module input) are given. The input for each CTRLPOS method is given for Sample Problem 1. Only the CTRLPOS output for each sample problem is included in this report.

D.1 INPUT AND OUTPUT FOR SAMPLE PROBLEM 1

D.1.1 SAMPLE 1 MCNP INPUT

```
message:    out=cts2v1.o srctp=cts2v1.s runtpe=cts2v1.r
            mctal=cts2v1.m

CTRLPOS Sample Problem 1--Core Size Study, Case 1
c
1     6 9.994552-2 -30                    $ Core Region
                   imp:n=1
200   3 1.00032-1  +30 -3                 $ Core or Reflector Region
                   imp:n=1
2     3 1.00032-1  +3 -4                  $ Core or Reflector Region
                   imp:n=1
3     3 1.00032-1  +4 -5                  $ Core or Reflector Region
                   imp:n=1
4     3 1.00032-1  +5 -6                  $ Core or Reflector Region
                   imp:n=1
5     3 1.00032-1  +6 -7                  $ Core or Reflector Region
                   imp:n=1
6     3 1.00032-1  +7 -8                  $ Core or Reflector Region
                   imp:n=1
7     3 1.00032-1  +8 -9                  $ Core or Reflector Region
                   imp:n=1
8     3 1.00032-1  +9 -10                 $ Core or Reflector Region
                   imp:n=1
9     3 1.00032-1  +10 -11                  $ Core or Reflector Region
                   imp:n=1
10    3 1.00032-1  +11 -12                  $ Core or Reflector Region
                   imp:n=1
11    3 1.00032-1  +12 -13                  $ Core or Reflector Region
                   imp:n=1
12    3 1.00032-1  +13 -14                  $ Core or Reflector Region
                   imp:n=1
13    3 1.00032-1  +14 -15                  $ Core or Reflector Region
                   imp:n=1
14    3 1.00032-1  +15 -16                  $ Core or Reflector Region
                   imp:n=1
15    3 1.00032-1  +16 -17                  $ Core or Reflector Region
                   imp:n=1
16    3 1.00032-1  +17 -18                  $ Core or Reflector Region
                   imp:n=1
17    3 1.00032-1  +18 -19                  $ Core or Reflector Region
                   imp:n=1
18    3 1.00032-1  +19 -20                  $ Core or Reflector Region
                   imp:n=1
19    3 1.00032-1  +20 -21                  $ Core or Reflector Region
                   imp:n=1
20    3 1.00032-1  +21 -22                  $ Core or Reflector Region
                   imp:n=1
21    3 1.00032-1  +22 -23                  $ Core or Reflector Region
                   imp:n=1
22    3 1.00032-1  +23 -24                  $ Core or Reflector Region
                   imp:n=1
23    3 1.00032-1  +24 -25                  $ Core or Reflector Region
                   imp:n=1
24    3 1.00032-1  +25 -26                  $ Core or Reflector Region
                   imp:n=1
25    3 1.00032-1  +26 -27                  $ Core or Reflector Region
                   imp:n=1
26    3 1.00032-1  +27 -28                  $ Reflector Region
                   imp:n=1
9999  0            +28                      $ Outside world

30   cz     10.0          $ Cylindrical Surfaces for regions
3    cz     11.0
4    cz     12.0
5    cz     13.0
6    cz     14.0
```

```
7     cz      15.0
8     cz      16.0
9     cz      17.0
10     cz     18.0
11     cz     19.0
12     cz     20.0
13     cz     21.0
14     cz     22.0
15     cz     23.0
16     cz     24.0
17     cz     25.0
18     cz     26.0
19     cz     27.0
20     cz     28.0
21     cz     29.0
22     cz     30.0
23     cz     31.0
24     cz     32.0
25     cz     33.0
26     cz     34.0
27     cz     35.0
28     cz     50.0

c       ***** Fuel *****
c       Material 6--UO2F2-H2O Solution     Total Density= 9.994552-2
c                   H/235U atomic ratio=1270
c
m6      1001.50c  6.6436-2  92238.50c 3.0091-6
        8016.50c  3.3330-2  9019.50c  1.2338-4    92234.50c 5.5020-7
        92235.50c 5.2312-5  92236.50c 2.6950-7
mt6     lwtr.01t
c
c
c       ***** Reflector *****
c       Material 3--H2O reflector    Total density= 9.984-2
c
m3      1001.50c  0.066644    8016.50c 0.033344
mt3     lwtr.01t
c
c
kcode   1000 1.0 30 180     $ 100 particles, 30 settle cycles, 180 total cycles
c
prdmp   180 180 180 1      $ Dump information to files after 180 cycles
c
ksrc    0 0 0   0 -10 0   0 10 0      $ Beginning source positions
```

END OF SAMPLE 1 MCNP INPUT

D.1.2 SAMPLE 1 SCALE INPUT

```
=csasn
  CTRLPOS Sample 1 -- Infinite Cylindrical Reactor with Reflector
  99gr    multiregion
  u-235   1 0 5.2312-5  end
  u-238   1 0 3.0091-6  end
  u-234   1 0 5.5020-7  end
  u-236   1 0 2.6950-7  end
  h       1 0 6.6436-2  end
  o       1 0 3.3330-2  end
  f       1 0 1.2338-4  end
  h       2 0 0.066644  end
  o       2 0 0.033344  end
 end comp
 cylindrical vacuum  reflected  0. end
 1   10.
 2   50.
 end zone
 more data dab=1000 end
end
=xsdrn_jp
  CTRLPOS Sample 1 -- Infinite Cylindrical Reactor with Reflector
-1$$  1000000
0$$  a3 4 e
1$$  2 4 100 1 0 2 9 8 3 1 10 200 0 0 e
2$$  -2 0 0 0 0 e
3$$  1 0 0 1 e
4$$  0 16 0 -2 3 4 19 e
5**  1.0-4 1.0-4 0  e
t
13$$  7r1 2r2
14$$ 92235 92238 92234 92236 1001 8016 9019
     201001 208016
15**  5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4 0.066644 0.033344
t
34##  20r1.0  80r0.0
t
35**  99i0 50.
36$$  10r1 10r2 40r3 40r4
39$$  1 1 2 2
51$$ 10r1 10r2  5r3 5r4 5r5 5r6 5r7 5r8 5r9 5r10 5r11 5r12
     7r13 4r14 5r15 13r16
t
end
=xsdrn_jp
  CTRLPOS Sample 1 -- Infinite Cylindrical Reactor with Reflector
-1$$  1000000
0$$  a3 3 20 30  e
1$$  2 4 100 1 0 4 18 8 3 1 10 100 0 0 e
2$$  -2 0 0 0 0 e
3$$  1 0 0 1  e
4$$  0 4 0 -2 3 4 7 e
5**  1.0-4 1.0-4 0  e
t
13$$  7r1 7r2 2r3 2r4
14$$ 192235 192238 192234 192236 11001 18016 19019
     292235 292238 292234 292236 21001 28016 29019
     3201001 3208016
     4201001 4208016
15**  5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      0.066644 0.033344
      0.066644 0.033344
t
```

```
34##  20r1.0  80r0.0
t
35**  99i0 50.
36$$  10r1 10r2 40r3 40r4
39$$  1 2 3 4
51$$   5r1 4r2 4r3 3r4
t
end
=xsdrn_jp
  CTRLPOS Sample 1 -- Infinite Cylindrical Reactor with Reflector
-1$$  1000000
0$$  a3 30 20 29 e
1$$  2 4 100 1 0 4 18 8 3 1 10 100 0 0 e
2$$  -2 0 0 0 0 e
3$$  1 0 0 1  e
4$$  0 4 20 -2 18 4 7 -1 e
5**  1.0-4 1.0-4 0  e
t
13$$  7r1 7r2 2r3 2r4
14$$ 1192235 1192238 1192234 1192236 111001 118016 119019
     2292235 2292238 2292234 2292236 221001 228016 229019
     33201001 33208016
     44201001 44208016
15**  5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      0.066644 0.033344
      0.066644 0.033344
16$$ 11192235 11192238 11192234 11192236 1111001 1118016 1119019
     22292235 22292238 22292234 22292236 2221001 2228016 2229019
     333201001 333208016
     444201001 444208016
18## 6h192235 6h192238 6h192234 6h192236 6h 11001
     6h 18016 6h 19019
     6h292235 6h292238 6h292234 6h292236 6h 21001
     6h 28016 6h 29019
     6h 31001 6h 38016
     6h 41001 6h 48016
t
34##  20r1.0  80r0.0
t
35**  99i0 50.
36$$  10r1 10r2 40r3 40r4
39$$  1 2 3 4
51$$  1 2 3 4
t
end
```

END OF SAMPLE 1 SCALE INPUT

D.1.3 SAMPLE 1, METHOD 1 VENTURE/CTRLPOS INPUT

```
=CONTROL1
CTRLPOS Sample Problem 1 -- Infinite Cylindrical
'00000000111111111122222222223333333333444444444455555555556666666666777777777778
'23456789012345678901234567890123456789012345678901234567890123456789012345678890
800000    04                              1                    1
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 0
  ISOTXS
END                                                                     00000670
DCRSPR
'234567890123456789012345678901234567890123456789012345678901234567890
        1  1         1  1                                            0  0
              18               1
192235 92235           235.         3.236  -11              1
292235 92235           235.         3.236  -11              1
192234 92234           234.         3.19   -11              1
292234 92234           234.         3.19   -11              1
192236 92236           236.         3.26   -11              3
292236 92236           236.         3.26   -11              3
192238 92238           238.         3.31   -11              2
292238 92238           238.         3.31   -11              2
 11001  1001            1.                                  6
 21001  1001            1.                                  6
 31001  1001            1.                                  6
 41001  1001            1.                                  6
 18016  8016           16.                                  6
 28016  8016           16.                                  6
 38016  8016           16.                                  6
 48016  8016           16.                                  6
 19019  9019           19.                                  6
 29019  9019           19.                                  6
END
CROSPROS
END
DVENTR                                                         " *** 2 = DVENTR
001                                                                     CARD 1
                                               1.00+1    1.00      1.0  CARD 2
                                                                        CARD 3
                                                                        CARD 4
'01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  2  0  0  0  0                 100     0           1                   CARD 5
'01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  1  0  0  0  0  0  0  0  0  0  0  0  0  0  2  0  1  2  1        0  0   CARD 6
002                                                                     CARD 1
                                                                        CARD 2
                                  0                     00              CARD 3
                                                                        CARD 4
 0.0                                                 .0645              CARD 5
 0.0                                                          2.09 -05  CARD 6
003
'01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  2  1  2                        0
004
'231234567891231234567891231234567891231234567891231234567891231234567891
 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000
 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000
 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000
 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000
 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000
 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000
 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000 10    0.5000
```

```
 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000
 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000
 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000
 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000
 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000
 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000
 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000
 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000
 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000 10   0.5000
 10   0.5000 10   0.5000 10   0.5000 10   0.5000  0   0.0000
' ***
005
  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72
 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96
 97 98 99100
012
  0
                                                                        BLANK
013
 18
 18
'    |     |     |     |     |     |     |     |     |     |     |     |
192235292235192234292234192236292236192238292238 11001 21001 31001 41001
 18016 28016 38016 48016 19019 29019
020
  1 10
'   Inner Core Region
192235 5.23120E-05192238 3.00910E-06192234 5.50200E-07192236 2.69500E-07
 11001 6.64360E-02 18016 3.33300E-02 19019 1.23380E-04
 11 20
'   Outer Core Region
292235 5.23120E-05292238 3.00910E-06292234 5.50200E-07292236 2.69500E-07
 21001 6.64360E-02 28016 3.33300E-02 29019 1.23380E-04
 21 60
'   Inner Reflector Region
 31001 6.66440E-02 38016 3.33440E-02
 61100
'   Outer Reflector Region
 41001 6.66440E-02 48016 3.33440E-02
  0  0
END
'*****  Option 5 used to define CTRLPOS output file name
OUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000       0.0010       1000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
  5  0  0  2  0  1  0  0  0 10 35  1  0  1  0  0  0  0  0  0  0  0  0  0
END
CTRLPOS
'*****  File name for CTRLPOS output
ctrls1a.out.1
END
'*****  Option 10 used to read in CTRLPOS data
OUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 10  0  0  2  0  1  1  0  0 15 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'*****  CTRLPOS DATA FOR SAMPLE PROBLEM 1 -- METHOD 1.
'*****  The 'control rod' zones start with zone 2 at the center of the core
'*****   and end with zone 100.  The first position guess is the outer boundary
'*****   of zone 5 while the tip of the control rod starts at zone 2.
'*****   The limits of control rod motion are the inner boundary of zone 2 and
'*****   the outer boundary of zone 100.  Zone 1 will be the follower for all
```

```
'******    the control rod zones.  Control rod material is in zones 2-20 at the
'******    start of the process.  In this case, CTRLPOS moves the material in
'******    zones 2-100 outward adding follower(zone 1 material) and decreasing
'******    the size of the reflector.
CTRLPOS
begin-input
begin-bank
begin-rod
2,0,5,1
100,1,2,0
begin-zone
2,1,1
3,1,1
4,1,1
5,1,1
6,1,1
7,1,1
8,1,1
9,1,1
10,1,1
11,1,1
12,1,1
13,1,1
14,1,1
15,1,1
16,1,1
17,1,1
18,1,1
19,1,1
20,1,1
21,1,0
22,1,0
23,1,0
24,1,0
25,1,0
26,1,0
27,1,0
28,1,0
29,1,0
30,1,0
31,1,0
32,1,0
33,1,0
34,1,0
35,1,0
36,1,0
37,1,0
38,1,0
39,1,0
40,1,0
41,1,0
42,1,0
43,1,0
44,1,0
45,1,0
46,1,0
47,1,0
48,1,0
49,1,0
50,1,0
51,1,0
52,1,0
53,1,0
54,1,0
55,1,0
56,1,0
57,1,0
58,1,0
59,1,0
```

```
60,1,0
61,1,0
62,1,0
63,1,0
64,1,0
65,1,0
66,1,0
67,1,0
68,1,0
69,1,0
70,1,0
71,1,0
72,1,0
73,1,0
74,1,0
75,1,0
76,1,0
77,1,0
78,1,0
79,1,0
80,1,0
81,1,0
82,1,0
83,1,0
84,1,0
85,1,0
86,1,0
87,1,0
88,1,0
89,1,0
90,1,0
91,1,0
92,1,0
93,1,0
94,1,0
95,1,0
96,1,0
97,1,0
98,1,0
99,1,0
100,1,0
end-zone
end-rod
end-bank
end-input
END
'*****  Option 20 used to perform a keff position search
OUTLIN
CTRLCF        0 6   0 24  1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.900       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 15 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'CTRLPOS
'END
'*****  Option 30 used to calculate a control rod worth curve
OUTLIN
CTRLCF        0 6   0 24  1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.900       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 30  0  0  2  0  1  1  0  0 15 99  0  0  1  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
begin-input
2,0
2,1
3,1
```

```
4,1
5,1
6,1
7,1
8,1
9,1
10,1
11,1
12,1
13,1
14,1
15,1
16,1
17,1
18,1
19,1
20,1
21,1
22,1
23,1
24,1
25,1
26,1
27,1
28,1
29,1
30,1
31,1
32,1
33,1
34,1
35,1
36,1
37,1
38,1
39,1
40,1
41,1
42,1
43,1
44,1
45,1
46,1
47,1
48,1
49,1
50,1
51,1
52,1
53,1
54,1
55,1
56,1
57,1
58,1
59,1
60,1
61,1
62,1
63,1
64,1
65,1
66,1
67,1
68,1
69,1
70,1
end-input
END
```

```
'VENTNEUT
'END
```

END OF SAMPLE 1, METHOD 1 VENTURE/CTRLPOS INPUT

D.1.4 SAMPLE 1, METHOD 2 CTRLPOS INPUT

```
'*****  Option 5 used to define CTRLPOS output file name
DUTLIN
CTRLCF        0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000       0.0010       1000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
  5  0  0  2  0  1  0  0  0 10 35  1  0  1  0  0  0  0  0  0  0  0  0  0
END
CTRLPOS
'*****  File name for CTRLPOS output
ctrls1a.out.2
END
'*****  Option 10 used to read in CTRLPOS data
DUTLIN
CTRLCF        0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 10  0  0  2  0  1  1  0  0 15 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'*****  CTRLPOS DATA FOR SAMPLE PROBLEM 1 -- METHOD 2.
'*****  The 'control rod' zones start with zone 11 at the center of the core
'*****   and end with zone 100.  The first position guess is the outer boundary
'*****   of zone 21 while the tip of the control rod starts at zone 11.
'*****   The limits of control rod motion are the inner boundary of zone 11 and
'*****   the outer boundary of zone 100.  Zone 1 will be the follower for all
'*****   the control rod zones.  Control rod material is in zones 11-20 at the
'*****   start of the process.  This method is essentially exactly the same as
'*****   Method 1 since zone 1 material is used as the follower in all zones.
'*****   The only difference is the the inner core region remains
'*****   stationary.
CTRLPOS
begin-input
begin-bank
begin-rod
11,0,21,1
100,1,11,0
begin-zone
11,1,1
12,1,1
13,1,1
14,1,1
15,1,1
16,1,1
17,1,1
18,1,1
19,1,1
20,1,1
21,1,0
22,1,0
23,1,0
24,1,0
25,1,0
26,1,0
27,1,0
28,1,0
29,1,0
30,1,0
31,1,0
32,1,0
33,1,0
34,1,0
35,1,0
36,1,0
37,1,0
38,1,0
```

```
39,1,0
40,1,0
41,1,0
42,1,0
43,1,0
44,1,0
45,1,0
46,1,0
47,1,0
48,1,0
49,1,0
50,1,0
51,1,0
52,1,0
53,1,0
54,1,0
55,1,0
56,1,0
57,1,0
58,1,0
59,1,0
60,1,0
61,1,0
62,1,0
63,1,0
64,1,0
65,1,0
66,1,0
67,1,0
68,1,0
69,1,0
70,1,0
71,1,0
72,1,0
73,1,0
74,1,0
75,1,0
76,1,0
77,1,0
78,1,0
79,1,0
80,1,0
81,1,0
82,1,0
83,1,0
84,1,0
85,1,0
86,1,0
87,1,0
88,1,0
89,1,0
90,1,0
91,1,0
92,1,0
93,1,0
94,1,0
95,1,0
96,1,0
97,1,0
98,1,0
99,1,0
100,1,0
end-zone
end-rod
end-bank
end-input
END
******  Option 20 used to perform a keff position search
OUTLIN
```

```
CTRLCF         0 6   0 24  1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.900       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 15 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'CTRLPOS
'END
'*****  Option 30 used to calculate a control rod worth curve
OUTLIN
CTRLCF         0 6   0 24  1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.900       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 30  0  0  2  0  1  1  0  0 15 99  0  0  1  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
begin-input
11,0
11,1
12,1
13,1
14,1
15,1
16,1
17,1
18,1
19,1
20,1
21,1
22,1
23,1
24,1
25,1
26,1
27,1
28,1
29,1
30,1
31,1
32,1
33,1
34,1
35,1
36,1
37,1
38,1
39,1
40,1
41,1
42,1
43,1
44,1
45,1
46,1
47,1
48,1
49,1
50,1
51,1
52,1
53,1
54,1
55,1
56,1
57,1
58,1
59,1
60,1
```

```
61,1
62,1
63,1
64,1
65,1
66,1
67,1
68,1
69,1
70,1
end-input
END
'VENTNEUT
'END
```

END OF SAMPLE 1, METHOD 2 CTRLPOS INPUT

D.1.5 SAMPLE 1, METHOD 3 CTRLPOS INPUT

```
'*****  Option 5 used to define CTRLPOS output file name
OUTLIN
CTRLCF        0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000       0.0010       1000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
  5  0  0  2  0  1  0  0  0 10 35  1  0  1  0  0  0  0  0  0  0  0  0  0
END
CTRLPOS
'*****  File name for CTRLPOS output
ctrls1a.out.3
END
'*****  Option 10 used to read in CTRLPOS data
OUTLIN
CTRLCF        0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 10  0  0  2  0  1  1  0  0 15 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'*****  CTRLPOS DATA FOR SAMPLE PROBLEM 1 -- METHOD 3.
'*****  The 'control rod' zones start with zone 12 at the center of the core
'*****   and end with zone 100.  The first position guess is the outer boundary
'*****   of zone 21 while the tip of the control rod starts at zone 12.
'*****   The limits of control rod motion are the inner boundary of zone 12 and
'*****   the outer boundary of zone 100.  Zone 11 will be the follower for all
'*****   the control rod zones.  Control rod material is in zones 12-20 at the
'*****   start of the process.  This method is different from the first two
'*****   since the control rod starts at the center of the core and the
'*****   material in zone 11 (outer core material) follows the rod as it moves.
CTRLPOS
begin-input
begin-bank
begin-rod
12,0,21,1
100,1,12,0
begin-zone
12,11,1
13,11,1
14,11,1
15,11,1
16,11,1
17,11,1
18,11,1
19,11,1
20,11,1
21,11,0
22,11,0
23,11,0
24,11,0
25,11,0
26,11,0
27,11,0
28,11,0
29,11,0
30,11,0
31,11,0
32,11,0
33,11,0
34,11,0
35,11,0
36,11,0
37,11,0
38,11,0
39,11,0
40,11,0
```

```
41,11,0
42,11,0
43,11,0
44,11,0
45,11,0
46,11,0
47,11,0
48,11,0
49,11,0
50,11,0
51,11,0
52,11,0
53,11,0
54,11,0
55,11,0
56,11,0
57,11,0
58,11,0
59,11,0
60,11,0
61,11,0
62,11,0
63,11,0
64,11,0
65,11,0
66,11,0
67,11,0
68,11,0
69,11,0
70,11,0
71,11,0
72,11,0
73,11,0
74,11,0
75,11,0
76,11,0
77,11,0
78,11,0
79,11,0
80,11,0
81,11,0
82,11,0
83,11,0
84,11,0
85,11,0
86,11,0
87,11,0
88,11,0
89,11,0
90,11,0
91,11,0
92,11,0
93,11,0
94,11,0
95,11,0
96,11,0
97,11,0
98,11,0
99,11,0
100,11,0
end-zone
end-rod
end-bank
end-input
END
'***** Option 20 used to perform a keff position search
OUTLIN
CTRLCF        0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
```

```
       0.900        0.0010        1000.0        5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 15 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'CTRLPOS
'END
'*****  Option 30 used to calculate a control rod worth curve
DUTLIN
CTRLCF          0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.900        0.0010        1000.0        5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 30  0  0  2  0  1  1  0  0 15 99  0  0  1  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
begin-input
12,0
12,1
13,1
14,1
15,1
16,1
17,1
18,1
19,1
20,1
21,1
22,1
23,1
24,1
25,1
26,1
27,1
28,1
29,1
30,1
31,1
32,1
33,1
34,1
35,1
36,1
37,1
38,1
39,1
40,1
41,1
42,1
43,1
44,1
45,1
46,1
47,1
48,1
49,1
50,1
51,1
52,1
53,1
54,1
55,1
56,1
57,1
58,1
59,1
60,1
61,1
62,1
63,1
```

```
64,1
65,1
66,1
67,1
68,1
69,1
70,1
end-input
END
'VENTNEUT
'END
```

END OF SAMPLE 1, METHOD 3 CTRLPOS INPUT

D.1.6 SAMPLE 1, METHOD 4 CTRLPOS INPUT

```
'***** Option 5 used to define CTRLPOS output file name
DUTLIN
CTRLCF        0 6   0 24  1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
      1.000       0.0010       1000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
  5  0  0  2  0  1  0  0  0 10 35  1  0  1  0  0  0  0  0  0  0  0  0  0
END
CTRLPOS
'***** File name for CTRLPOS output
ctrls1a.out.4
END
DUTLIN
CTRLCF        0 6   0 24  1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
      1.000       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 10  0  0  2  0  1  1  0  0 15 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'***** CTRLPOS DATA FOR SAMPLE PROBLEM 1 -- METHOD 4.
'***** The 'control rod' zones start with zone 12 at the center of the core
'*****  and end with zone 101.  The first position guess is the outer boundary
'*****  of zone 22 while the tip of the control rod starts at zone 12.
'*****  The limits of control rod motion are the inner boundary of zone 12 and
'*****  the outer boundary of zone 101.  Zone 1 will be the follower for the
'*****  inner control rod zones while zone 11 will be the follower for the
'*****  outer the control rod zones.  Control rod material is in zones
'*****  12-21 at the start of the process.  This differs from the other
'*****  examples because of the change in the follower material.  This change
'*****  is an attempt to properly use the to different material cross sections
'*****  in their respective area of the model.
CTRLPOS
begin-input
begin-bank
begin-rod
12,0,22,1
101,1,12,0
begin-zone
12,1,1
13,1,1
14,1,1
15,1,1
16,1,1
17,1,1
18,1,1
19,1,1
20,1,1
21,1,0
22,1,0
23,1,0
24,1,0
25,11,0
26,11,0
27,11,0
28,11,0
29,11,0
30,11,0
31,11,0
32,11,0
33,11,0
34,11,0
35,11,0
36,11,0
37,11,0
38,11,0
39,11,0
```

```
40,11,0
41,11,0
42,11,0
43,11,0
44,11,0
45,11,0
46,11,0
47,11,0
48,11,0
49,11,0
50,11,0
51,11,0
52,11,0
53,11,0
54,11,0
55,11,0
56,11,0
57,11,0
58,11,0
59,11,0
60,11,0
61,11,0
62,11,0
63,11,0
64,11,0
65,11,0
66,11,0
67,11,0
68,11,0
69,11,0
70,11,0
71,11,0
72,11,0
73,11,0
74,11,0
75,11,0
76,11,0
77,11,0
78,11,0
79,11,0
80,11,0
81,11,0
82,11,0
83,11,0
84,11,0
85,11,0
86,11,0
87,11,0
88,11,0
89,11,0
90,11,0
91,11,0
92,11,0
93,11,0
94,11,0
95,11,0
96,11,0
97,11,0
98,11,0
99,11,0
100,11,0
101,11,0
end-zone
end-rod
end-bank
end-input
END
******  Option 20 used to perform a keff position search
OUTLIN
```

```
CTRLCF          0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.900       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 15 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'CTRLPOS
'END
'*****  Option 30 used to calculate a control rod worth curve
OUTLIN
CTRLCF          0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.900       0.0010       1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 30  0  0  2  0  1  1  0  0 15 99  0  0  1  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
begin-input
12,0
12,1
13,1
14,1
15,1
16,1
17,1
18,1
19,1
20,1
21,1
22,1
23,1
24,1
25,1
26,1
27,1
28,1
29,1
30,1
31,1
32,1
33,1
34,1
35,1
36,1
37,1
38,1
39,1
40,1
41,1
42,1
43,1
44,1
45,1
46,1
47,1
48,1
49,1
50,1
51,1
52,1
53,1
54,1
55,1
56,1
57,1
58,1
59,1
60,1
61,1
```

```
62,1
63,1
64,1
65,1
66,1
67,1
68,1
69,1
70,1
71,1
end-input
END
'VENTNEUT
'END
```

END OF SAMPLE 1, METHOD 4 CTRLPOS INPUT

D.1.7 SAMPLE 1, METHOD 1 CTRLPOS OUTPUT

```
*********************************************************************************
*** CTRLPOS - CONTROL ROD POSITION MODULE - VERSION 1 - OCTOBER 1, 1992 ***

                         ***** CTRLPOS OPTION 10 *****
---------------------------------------------------------------------------------

---------------------------------------------------------------------------------
***** CONTENTS OF *CTRLCF* CONTROL FILE *****

XX( 1- 4)  * 1.00000D+00* 1.00000D-03* 1.00000D+03* 5.00000D+03*
IX( 1- 5)  *     10*      0*      0*      2*      0*
IX( 6-10)  *      1*      1*      0*      0*     15*
IX(11-15)  *     99*      0*      0*      0*      0*
IX(16-20)  *      0*      0*      0*      0*      0*
IX(21-25)  *      0*      0*      0*      1*      0*

 1-TARGET KEFF VALUE                          =  1.00000D+00
 2-ALLOWED KEFF TOLERANCE                     =  1.00000D-03
 3-MAXIMUM VALUE FOR CONTROL ROD MOVEMENT =     1.00D+03
 4-MAXIMUM NUMBER OF ATOM DENSITY VALUES (IF IX(23).NE.0) =       5000

 1-CTRLPOS OPTION NUMBER                    =      10
 2-NEUTRONICS MODULE                        =       0
 3-INTERPOLATION SCHEME                     =       0
 4-NUMBER OF POINTS IN SCHEME               =       2
 5-STORAGE OF KEFF VALUES                   =       0
 6-CONTROL RODS FOR KEFF SEARCH             =       1
 7-PRINT OUT OF ATOM DENSITIES              =       1
 8-PRINT OUT ATOM DENSITIES AT EACH POSITION =      0
 9-CONTROL ROD TIP PARTIAL ZONE PLACEMENT   =       0
10-NUMBER OF POSITION ITERATIONS            =      15
11-NUMBER OF OUTERS FOR NEUTRONICS MODULE   =      99
12-RESERVED                                 =       0
13-BURNED CONTROL ROD OPTION                =       0

***** PARAMETERS FOR CTRLPOS OPTION 30 *****
14-BANK NUMBER FOR CONTROL ROD WORTH CURVE  =       0
15-CONTROL ROD FOR WORTH CURVE              =       0
16-RESERVED                                 =       0

***** PARAMETERS FOR CTRLPOS OPTION 40 *****
17-BANK NUMBER FOR ROD/BANK RE-POSITIONING  =       0
18-CONTROL ROD NUMBER FOR RE-POSITIONING    =       0
19-ZONE NUMBER FOR RE-POSITIONING           =       0
20-ZONE BOUNDARY FOR RE-POSITIONING         =       0
21-VENTPLOT PLOT OPTION                     =       0

22-REVERSE CONTROL ROD MOTION OPTION        =       0
23-ATOM DENSITY ARRAY STORAGE OPTION        =       0
24-CONTAINER ARRAY MEMORY OPTION            =       1
25-DEBUG OUTPUT PARAMETER                   =       0

---------------------------------------------------------------------------------

---------------------------------------------------------------------------------
BANK #  1 HAS   1 RODS.

NUMBER OF CONTROL ROD BANKS =   1

BANK #  1 ROD #  1 HAS  99 ZONES AND   0 PRODUCTION CHAINS.

BANK #  1 ROD #  1 CHAIN #  0 HAS   0 PRODUCED ISOTOPES.
---------------------------------------------------------------------------------

---------------------------------------------------------------------------------
TOTAL AVAILABLE MEMORY   =    4800000 WORDS.
```

LOWER MEMORY FOR CTRLPOS = 92531 WORDS.
UPPER MEMORY FOR CTRLPOS = 26928 WORDS.
TOTAL MEMORY FOR CTRLPOS = 119459 WORDS.

EXTRA MEMORY = 4680541 WORDS.

BANK # 1 ROD # 1
CONTROL ROD TIP IS LOWER BOUNDARY OF ZONE 2
FIRST GUESS POSITION IS UPPER BOUNDARY OF ZONE 5
UPPER CONTROL ROD LIMIT IS UPPER BOUNDARY OF ZONE 100
LOWER CONTROL ROD LIMIT IS LOWER BOUNDARY OF ZONE 2

***** INFORMATION ON MEMORY REQUIREMENTS FOR ATOM DENSITY ARRAYS *****

MAXIMUM NUMBER OF ATOM DENSITY VALUES POSSIBLE = 12276.
NOTE *** THIS VALUE DOES NOT ACCOUNT FOR THE PRODUCTION
OF NEW ISOTOPES IN THE FOLLOWER MATERIAL ***
TOTAL MEMORY REQUIRED FOR IX(23).EQ.0 = 119459 WORDS.
TOTAL MEMORY REQUIRED FOR IX(23).NE.0 = 305767 WORDS.

IX(23).EQ.0 OPTION SAVES 186308 WORDS OF MEMORY.
YOU ARE USING BEST OPTION TO SAVE MEMORY.

BANK # 1 ROD # 1 NUMBER OF ZONES = 99

	CONTROL ROD ZONE NUMBER	FOLLOWER ZONE NUMBER	CONTROL ROD ZONE VOLUME	FOLLOWER ZONE VOLUME	TOTAL ZONE VOLUME	ROD FLAG
1	2	1	2.35619D+00	7.85398D-01	2.35619D+00	1
2	3	1	3.92699D+00	7.85398D-01	6.28319D+00	1
3	4	1	5.49779D+00	7.85398D-01	1.17810D+01	1
4	5	1	7.06858D+00	7.85398D-01	1.88496D+01	1
5	6	1	8.63938D+00	7.85398D-01	2.74889D+01	1
6	7	1	1.02102D+01	7.85398D-01	3.76991D+01	1
7	8	1	1.17810D+01	7.85398D-01	4.94801D+01	1
8	9	1	1.33518D+01	7.85398D-01	6.28319D+01	1
9	10	1	1.49226D+01	7.85398D-01	7.77544D+01	1
10	11	1	1.64934D+01	7.85398D-01	9.42478D+01	1
11	12	1	1.80642D+01	7.85398D-01	1.12312D+02	1
12	13	1	1.96350D+01	7.85398D-01	1.31947D+02	1
13	14	1	2.12057D+01	7.85398D-01	1.53153D+02	1
14	15	1	2.27765D+01	7.85398D-01	1.75929D+02	1
15	16	1	2.43473D+01	7.85398D-01	2.00277D+02	1
16	17	1	2.59181D+01	7.85398D-01	2.26195D+02	1
17	18	1	2.74889D+01	7.85398D-01	2.53684D+02	1
18	19	1	2.90597D+01	7.85398D-01	2.82743D+02	1
19	20	1	3.06305D+01	7.85398D-01	3.13374D+02	1
20	21	1	3.22013D+01	7.85398D-01	3.45575D+02	0
21	22	1	3.37721D+01	7.85398D-01	3.79347D+02	0
22	23	1	3.53429D+01	7.85398D-01	4.14690D+02	0
23	24	1	3.69137D+01	7.85398D-01	4.51604D+02	0
24	25	1	3.84845D+01	7.85398D-01	4.90088D+02	0
25	26	1	4.00553D+01	7.85398D-01	5.30144D+02	0
26	27	1	4.16261D+01	7.85398D-01	5.71770D+02	0
27	28	1	4.31969D+01	7.85398D-01	6.14967D+02	0
28	29	1	4.47677D+01	7.85398D-01	6.59734D+02	0
29	30	1	4.63385D+01	7.85398D-01	7.06073D+02	0
30	31	1	4.79093D+01	7.85398D-01	7.53982D+02	0
31	32	1	4.94801D+01	7.85398D-01	8.03462D+02	0
32	33	1	5.10509D+01	7.85398D-01	8.54513D+02	0
33	34	1	5.26217D+01	7.85398D-01	9.07135D+02	0
34	35	1	5.41925D+01	7.85398D-01	9.61327D+02	0
35	36	1	5.57633D+01	7.85398D-01	1.01709D+03	0
36	37	1	5.73341D+01	7.85398D-01	1.07442D+03	0
37	38	1	5.89049D+01	7.85398D-01	1.13333D+03	0
38	39	1	6.04757D+01	7.85398D-01	1.19381D+03	0

39	40	1	6.20465D+01	7.85398D-01	1.25585D+03	0
40	41	1	6.36173D+01	7.85398D-01	1.31947D+03	0
41	42	1	6.51880D+01	7.85398D-01	1.38466D+03	0
42	43	1	6.67588D+01	7.85398D-01	1.45142D+03	0
43	44	1	6.83296D+01	7.85398D-01	1.51975D+03	0
44	45	1	6.99004D+01	7.85398D-01	1.58965D+03	0
45	46	1	7.14712D+01	7.85398D-01	1.66112D+03	0
46	47	1	7.30420D+01	7.85398D-01	1.73416D+03	0
47	48	1	7.46128D+01	7.85398D-01	1.80877D+03	0
48	49	1	7.61836D+01	7.85398D-01	1.88496D+03	0
49	50	1	7.77544D+01	7.85398D-01	1.96271D+03	0
50	51	1	7.93252D+01	7.85398D-01	2.04204D+03	0
51	52	1	8.08960D+01	7.85398D-01	2.12293D+03	0
52	53	1	8.24668D+01	7.85398D-01	2.20540D+03	0
53	54	1	8.40376D+01	7.85398D-01	2.28944D+03	0
54	55	1	8.56084D+01	7.85398D-01	2.37504D+03	0
55	56	1	8.71792D+01	7.85398D-01	2.46222D+03	0
56	57	1	8.87500D+01	7.85398D-01	2.55097D+03	0
57	58	1	9.03208D+01	7.85398D-01	2.64129D+03	0
58	59	1	9.18916D+01	7.85398D-01	2.73319D+03	0
59	60	1	9.34624D+01	7.85398D-01	2.82665D+03	0
60	61	1	9.50332D+01	7.85398D-01	2.92168D+03	0
61	62	1	9.66040D+01	7.85398D-01	3.01829D+03	0
62	63	1	9.81748D+01	7.85398D-01	3.11646D+03	0
63	64	1	9.97456D+01	7.85398D-01	3.21621D+03	0
64	65	1	1.01316D+02	7.85398D-01	3.31752D+03	0
65	66	1	1.02887D+02	7.85398D-01	3.42041D+03	0
66	67	1	1.04458D+02	7.85398D-01	3.52487D+03	0
67	68	1	1.06029D+02	7.85398D-01	3.63090D+03	0
68	69	1	1.07600D+02	7.85398D-01	3.73850D+03	0
69	70	1	1.09170D+02	7.85398D-01	3.84767D+03	0
70	71	1	1.10741D+02	7.85398D-01	3.95841D+03	0
71	72	1	1.12312D+02	7.85398D-01	4.07072D+03	0
72	73	1	1.13883D+02	7.85398D-01	4.18460D+03	0
73	74	1	1.15454D+02	7.85398D-01	4.30005D+03	0
74	75	1	1.17024D+02	7.85398D-01	4.41708D+03	0
75	76	1	1.18595D+02	7.85398D-01	4.53567D+03	0
76	77	1	1.20166D+02	7.85398D-01	4.65584D+03	0
77	78	1	1.21737D+02	7.85398D-01	4.77758D+03	0
78	79	1	1.23308D+02	7.85398D-01	4.90088D+03	0
79	80	1	1.24878D+02	7.85398D-01	5.02576D+03	0
80	81	1	1.26449D+02	7.85398D-01	5.15221D+03	0
81	82	1	1.28020D+02	7.85398D-01	5.28023D+03	0
82	83	1	1.29591D+02	7.85398D-01	5.40982D+03	0
83	84	1	1.31161D+02	7.85398D-01	5.54098D+03	0
84	85	1	1.32732D+02	7.85398D-01	5.67372D+03	0
85	86	1	1.34303D+02	7.85398D-01	5.80802D+03	0
86	87	1	1.35874D+02	7.85398D-01	5.94389D+03	0
87	88	1	1.37445D+02	7.85398D-01	6.08134D+03	0
88	89	1	1.39015D+02	7.85398D-01	6.22035D+03	0
89	90	1	1.40586D+02	7.85398D-01	6.36094D+03	0
90	91	1	1.42157D+02	7.85398D-01	6.50310D+03	0
91	92	1	1.43728D+02	7.85398D-01	6.64682D+03	0
92	93	1	1.45299D+02	7.85398D-01	6.79212D+03	0
93	94	1	1.46869D+02	7.85398D-01	6.93899D+03	0
94	95	1	1.48440D+02	7.85398D-01	7.08743D+03	0
95	96	1	1.50011D+02	7.85398D-01	7.23744D+03	0
96	97	1	1.51582D+02	7.85398D-01	7.38903D+03	0
97	98	1	1.53153D+02	7.85398D-01	7.54218D+03	0
98	99	1	1.54723D+02	7.85398D-01	7.69690D+03	0
99	100	1	1.56294D+02	7.85398D-01	7.85320D+03	0

------------------------ TIME IN DAYS .000 ---------------------------

BANK # 1 ROD # 1 ATOM DENSITIES

ZONE 2 192235 5.231200D-05 (1.0000) 192234 5.502000D-07 (1.0000) 192236 2.695000D-07 (

```
1.0000)
 192238   3.009100D-06 (     1.0000)  11001   6.643600D-02 (     1.0000)  18016   3.333000D-02 (     1.0000)
  19019   1.233800D-04 (     1.0000)
 ZONE     3 192235    5.231200D-05 (     1.0000) 192234    5.502000D-07 (     1.0000) 192236    2.695000D-07 (
1.0000)
 192238   3.009100D-06 (     1.0000)  11001   6.643600D-02 (     1.0000)  18016   3.333000D-02 (     1.0000)
  19019   1.233800D-04 (     1.0000)
 ZONE     4 192235    5.231200D-05 (     1.0000) 192234    5.502000D-07 (     1.0000) 192236    2.695000D-07 (
1.0000)
 192238   3.009100D-06 (     1.0000)  11001   6.643600D-02 (     1.0000)  18016   3.333000D-02 (     1.0000)
  19019   1.233800D-04 (     1.0000)
 ZONE     5 192235    5.231200D-05 (     1.0000) 192234    5.502000D-07 (     1.0000) 192236    2.695000D-07 (
1.0000)
 192238   3.009100D-06 (     1.0000)  11001   6.643600D-02 (     1.0000)  18016   3.333000D-02 (     1.0000)
  19019   1.233800D-04 (     1.0000)
 ZONE     6 192235    5.231200D-05 (     1.0000) 192234    5.502000D-07 (     1.0000) 192236    2.695000D-07 (
1.0000)
 192238   3.009100D-06 (     1.0000)  11001   6.643600D-02 (     1.0000)  18016   3.333000D-02 (     1.0000)
  19019   1.233800D-04 (     1.0000)
 ZONE     7 192235    5.231200D-05 (     1.0000) 192234    5.502000D-07 (     1.0000) 192236    2.695000D-07 (
1.0000)
 192238   3.009100D-06 (     1.0000)  11001   6.643600D-02 (     1.0000)  18016   3.333000D-02 (     1.0000)
  19019   1.233800D-04 (     1.0000)
 ZONE     8 192235    5.231200D-05 (     1.0000) 192234    5.502000D-07 (     1.0000) 192236    2.695000D-07 (
1.0000)
 192238   3.009100D-06 (     1.0000)  11001   6.643600D-02 (     1.0000)  18016   3.333000D-02 (     1.0000)
  19019   1.233800D-04 (     1.0000)
 ZONE     9 192235    5.231200D-05 (     1.0000) 192234    5.502000D-07 (     1.0000) 192236    2.695000D-07 (
1.0000)
 192238   3.009100D-06 (     1.0000)  11001   6.643600D-02 (     1.0000)  18016   3.333000D-02 (     1.0000)
  19019   1.233800D-04 (     1.0000)
 ZONE    10 192235    5.231200D-05 (     1.0000) 192234    5.502000D-07 (     1.0000) 192236    2.695000D-07 (
1.0000)
 192238   3.009100D-06 (     1.0000)  11001   6.643600D-02 (     1.0000)  18016   3.333000D-02 (     1.0000)
  19019   1.233800D-04 (     1.0000)
 ZONE    11 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE    12 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE    13 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE    14 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE    15 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE    16 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE    17 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE    18 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE    19 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
```

```
 292238   3.009100D-06 (     1.0000)  21001    6.643600D-02 (     1.0000)  28016    3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE   20 292235    5.231200D-05 (     1.0000) 292234    5.502000D-07 (     1.0000) 292236    2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001    6.643600D-02 (     1.0000)  28016    3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
 ZONE   21  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   22  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   23  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   24  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   25  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   26  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   27  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   28  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   29  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   30  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   31  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   32  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   33  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   34  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   35  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   36  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   37  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   38  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   39  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   40  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   41  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   42  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   43  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   44  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   45  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   46  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   47  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   48  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   49  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   50  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   51  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   52  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   53  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   54  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   55  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   56  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   57  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   58  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   59  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   60  31001    6.664400D-02 (     1.0000)  38016    3.334400D-02 (     1.0000)
 ZONE   61  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   62  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   63  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   64  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   65  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   66  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   67  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   68  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   69  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   70  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   71  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   72  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   73  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   74  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   75  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   76  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   77  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   78  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   79  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   80  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   81  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   82  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE   83  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
```

```
ZONE  84  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  85  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  86  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  87  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  88  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  89  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  90  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  91  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  92  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  93  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  94  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  95  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  96  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  97  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  98  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE  99  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)
ZONE 100  41001   6.664400D-02 (    1.0000)  48016   3.334400D-02 (    1.0000)

***** AVERAGE VALUES FOR CONTROL ROD MATERIAL *****
 VOLUME OF CONTROL ROD MATERIAL USED TO CALCULATE ATOM DENSITIES.
192235   1.297967D-05 (    1.0000) 292235   3.933233D-05 (    1.0000) 192234   1.365158D-07 (    1.0000)
292234   4.136842D-07 (    1.0000) 192236   6.686842D-08 (    1.0000) 292236   2.026316D-07 (    1.0000)
192238   7.466188D-07 (    1.0000) 292238   2.262481D-06 (    1.0000)  11001   1.648412D-02 (    1.0000)
 21001   4.995188D-02 (    1.0000)  18016   8.269850D-03 (    1.0000)  28016   2.506015D-02 (    1.0000)
 19019   3.061308D-05 (    1.0000)  29019   9.276692D-05 (    1.0000)
--------------------------------------------------------------------------

***** STARTING POSITIONS FOR ALL CONTROL RODS *****
STARTING POSITION -- POSNOW(  1,  1)=    0.000000000D+00

***** KEFF AT STARTING POSITION =      .7145979


***** FIRST GUESS POSITIONS FOR MOVING CONTROL RODS *****
FIRST GUESS POSITION -- POSNOW(  1,  1)=    1.884955573D+01

***** KEFF AT FIRST GUESS POSITION =      .7293161

--------------------------------------------------------------------------
ITERATION #  0 -- AT THE CURRENT POSITION KEFF =      .7293161
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1            1.884955573D+01                   3.655142871D+02

--------------------------------------------------------------------------
ITERATION #  1 -- AT THE CURRENT POSITION KEFF =      .8970353
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1            3.655142871D+02                   5.783355914D+02

--------------------------------------------------------------------------
ITERATION #  2 -- AT THE CURRENT POSITION KEFF =      .9530511
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1            5.783355914D+02                   7.567085669D+02

--------------------------------------------------------------------------
ITERATION #  3 -- AT THE CURRENT POSITION KEFF =      .9874110
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1            7.567085669D+02                   8.220619304D+02

--------------------------------------------------------------------------
ITERATION #  4 -- AT THE CURRENT POSITION KEFF =      .9980261
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****
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BANK    ROD    **** CURRENT POSITION ****     **** NEW PREDICTED POSITION ****
  1      1          8.220619304D+02                   8.342143381D+02

---------------------------------------------------------------------------
ITERATION #  5 -- AT THE CURRENT POSITION KEFF =      .9999254

***** CONTROL RODS WERE SUCCESSFUL POSITIONED TO THE TARGET KEFF VALUE *****


***** ENDING POSITION FOR ALL CONTROL RODS *****
ENDING POSITION -- POSNOW( 1,  1)=   8.342143381D+02

* TOTAL CPU TIME =      .30 MINUTES - TOTAL CLOCK TIME =      .00 MINUTES *
***************** NORMAL END OF CONTROL ROD POSITION MODULE ***************
***************************************************************************

***************************************************************************
*** CTRLPOS - CONTROL ROD POSITION MODULE - VERSION 1 - OCTOBER 1, 1992 ***

                        ***** CTRLPOS OPTION 30 *****
---------------------------------------------------------------------------

---------------------------------------------------------------------------
***** CONTENTS OF *CTRLCF* CONTROL FILE *****

XX( 1- 4)  * 9.000000D-01* 1.000000D-03* 1.000000D+03* 5.000000D+03*
IX( 1- 5)  *   30*     0*     0*     2*     0*
IX( 6-10)  *    1*     1*     0*     0*    15*
IX(11-15)  *   99*     0*     0*     1*     0*
IX(16-20)  *    0*     0*     0*     0*     0*
IX(21-25)  *    0*     0*     0*     1*     0*

 1-TARGET KEFF VALUE                           =  9.000000D-01
 2-ALLOWED KEFF TOLERANCE                      =  1.000000D-03
 3-MAXIMUM VALUE FOR CONTROL ROD MOVEMENT =     1.000D+03
 4-MAXIMUM NUMBER OF ATOM DENSITY VALUES (IF IX(23).NE.0) =        5000

 1-CTRLPOS OPTION NUMBER                     =     30
 2-NEUTRONICS MODULE                         =      0
 3-INTERPOLATION SCHEME                      =      0
 4-NUMBER OF POINTS IN SCHEME                =      2
 5-STORAGE OF KEFF VALUES                    =      0
 6-CONTROL RODS FOR KEFF SEARCH              =      1
 7-PRINT OUT OF ATOM DENSITIES               =      1
 8-PRINT OUT ATOM DENSITIES AT EACH POSITION =      0
 9-CONTROL ROD TIP PARTIAL ZONE PLACEMENT    =      0
10-NUMBER OF POSITION ITERATIONS             =     15
11-NUMBER OF OUTERS FOR NEUTRONICS MODULE    =     99
12-RESERVED                                  =      0
13-BURNED CONTROL ROD OPTION                 =      0

***** PARAMETERS FOR CTRLPOS OPTION 30 *****
14-BANK NUMBER FOR CONTROL ROD WORTH CURVE   =      1
15-CONTROL ROD FOR WORTH CURVE               =      0
16-RESERVED                                  =      0

***** PARAMETERS FOR CTRLPOS OPTION 40 *****
17-BANK NUMBER FOR ROD/BANK RE-POSITIONING   =      0
18-CONTROL ROD NUMBER FOR RE-POSITIONING     =      0
19-ZONE NUMBER FOR RE-POSITIONING            =      0
20-ZONE BOUNDARY FOR RE-POSITIONING          =      0
21-VENTPLOT PLOT OPTION                      =      0

22-REVERSE CONTROL ROD MOTION OPTION         =      0
23-ATOM DENSITY ARRAY STORAGE OPTION         =      0
24-CONTAINER ARRAY MEMORY OPTION             =      1
25-DEBUG OUTPUT PARAMETER                    =      0
```

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-----------------------------------------------------------------------

-----------------------------------------------------------------------
TOTAL AVAILABLE MEMORY   =    4800000 WORDS.
LOWER MEMORY FOR CTRLPOS =      92531 WORDS.
UPPER MEMORY FOR CTRLPOS =      26928 WORDS.
TOTAL MEMORY FOR CTRLPOS =     119459 WORDS.

            EXTRA MEMORY =    4680541 WORDS.
-----------------------------------------------------------------------

BANK # 1     ROD # 1   ATOM DENSITIES

 ZONE     2 192235    5.2312000-05 (     1.0000) 192234    5.5020000-07 (     1.0000) 192236    2.6950000-07 (
1.0000)
 192238    3.0091000-06 (     1.0000)  11001    6.6436000-02 (     1.0000)  18016    3.3330000-02 (     1.0000)
  19019    1.2338000-04 (     1.0000)
 ZONE     3 192235    5.2312000-05 (     1.0000) 192234    5.5020000-07 (     1.0000) 192236    2.6950000-07 (
1.0000)
 192238    3.0091000-06 (     1.0000)  11001    6.6436000-02 (     1.0000)  18016    3.3330000-02 (     1.0000)
  19019    1.2338000-04 (     1.0000)
 ZONE     4 192235    5.2312000-05 (     1.0000) 192234    5.5020000-07 (     1.0000) 192236    2.6950000-07 (
1.0000)
 192238    3.0091000-06 (     1.0000)  11001    6.6436000-02 (     1.0000)  18016    3.3330000-02 (     1.0000)
  19019    1.2338000-04 (     1.0000)
 ZONE     5 192235    5.2312000-05 (     1.0000) 192234    5.5020000-07 (     1.0000) 192236    2.6950000-07 (
1.0000)
 192238    3.0091000-06 (     1.0000)  11001    6.6436000-02 (     1.0000)  18016    3.3330000-02 (     1.0000)
  19019    1.2338000-04 (     1.0000)
 ZONE     6 192235    5.2312000-05 (     1.0000) 192234    5.5020000-07 (     1.0000) 192236    2.6950000-07 (
1.0000)
 192238    3.0091000-06 (     1.0000)  11001    6.6436000-02 (     1.0000)  18016    3.3330000-02 (     1.0000)
  19019    1.2338000-04 (     1.0000)
 ZONE     7 192235    5.2312000-05 (     1.0000) 192234    5.5020000-07 (     1.0000) 192236    2.6950000-07 (
1.0000)
 192238    3.0091000-06 (     1.0000)  11001    6.6436000-02 (     1.0000)  18016    3.3330000-02 (     1.0000)
  19019    1.2338000-04 (     1.0000)
 ZONE     8 192235    5.2312000-05 (     1.0000) 192234    5.5020000-07 (     1.0000) 192236    2.6950000-07 (
1.0000)
 192238    3.0091000-06 (     1.0000)  11001    6.6436000-02 (     1.0000)  18016    3.3330000-02 (     1.0000)
  19019    1.2338000-04 (     1.0000)
 ZONE     9 192235    5.2312000-05 (     1.0000) 192234    5.5020000-07 (     1.0000) 192236    2.6950000-07 (
1.0000)
 192238    3.0091000-06 (     1.0000)  11001    6.6436000-02 (     1.0000)  18016    3.3330000-02 (     1.0000)
  19019    1.2338000-04 (     1.0000)
 ZONE    10 192235    5.2312000-05 (     1.0000) 192234    5.5020000-07 (     1.0000) 192236    2.6950000-07 (
1.0000)
 192238    3.0091000-06 (     1.0000)  11001    6.6436000-02 (     1.0000)  18016    3.3330000-02 (     1.0000)
  19019    1.2338000-04 (     1.0000)
 ZONE    11 292235    5.2312000-05 (     1.0000) 292234    5.5020000-07 (     1.0000) 292236    2.6950000-07 (
1.0000)
 292238    3.0091000-06 (     1.0000)  21001    6.6436000-02 (     1.0000)  28016    3.3330000-02 (     1.0000)
  29019    1.2338000-04 (     1.0000)
 ZONE    12 292235    5.2312000-05 (     1.0000) 292234    5.5020000-07 (     1.0000) 292236    2.6950000-07 (
1.0000)
 292238    3.0091000-06 (     1.0000)  21001    6.6436000-02 (     1.0000)  28016    3.3330000-02 (     1.0000)
  29019    1.2338000-04 (     1.0000)
 ZONE    13 292235    5.2312000-05 (     1.0000) 292234    5.5020000-07 (     1.0000) 292236    2.6950000-07 (
1.0000)
 292238    3.0091000-06 (     1.0000)  21001    6.6436000-02 (     1.0000)  28016    3.3330000-02 (     1.0000)
  29019    1.2338000-04 (     1.0000)
 ZONE    14 292235    5.2312000-05 (     1.0000) 292234    5.5020000-07 (     1.0000) 292236    2.6950000-07 (
1.0000)
 292238    3.0091000-06 (     1.0000)  21001    6.6436000-02 (     1.0000)  28016    3.3330000-02 (     1.0000)
  29019    1.2338000-04 (     1.0000)
 ZONE    15 292235    5.2312000-05 (     1.0000) 292234    5.5020000-07 (     1.0000) 292236    2.6950000-07 (
1.0000)
 292238    3.0091000-06 (     1.0000)  21001    6.6436000-02 (     1.0000)  28016    3.3330000-02 (     1.0000)
  29019    1.2338000-04 (     1.0000)
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```
ZONE    16 292235   5.231200D-05 (     1.0000) 292234   5.502000D-07 (     1.0000) 292236   2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
ZONE    17 292235   5.231200D-05 (     1.0000) 292234   5.502000D-07 (     1.0000) 292236   2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
ZONE    18 292235   5.231200D-05 (     1.0000) 292234   5.502000D-07 (     1.0000) 292236   2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
ZONE    19 292235   5.231200D-05 (     1.0000) 292234   5.502000D-07 (     1.0000) 292236   2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
ZONE    20 292235   5.231200D-05 (     1.0000) 292234   5.502000D-07 (     1.0000) 292236   2.695000D-07 (
1.0000)
 292238   3.009100D-06 (     1.0000)  21001   6.643600D-02 (     1.0000)  28016   3.333000D-02 (     1.0000)
  29019   1.233800D-04 (     1.0000)
ZONE    21  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    22  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    23  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    24  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    25  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    26  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    27  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    28  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    29  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    30  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    31  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    32  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    33  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    34  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    35  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    36  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    37  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    38  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    39  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    40  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    41  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    42  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    43  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    44  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    45  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    46  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    47  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    48  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    49  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    50  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    51  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    52  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    53  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    54  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    55  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    56  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    57  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    58  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    59  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    60  31001   6.664400D-02 (     1.0000)  38016   3.334400D-02 (     1.0000)
ZONE    61  41001   6.664400D-02 (     1.0000)  48016   3.334400D-02 (     1.0000)
ZONE    62  41001   6.664400D-02 (     1.0000)  48016   3.334400D-02 (     1.0000)
ZONE    63  41001   6.664400D-02 (     1.0000)  48016   3.334400D-02 (     1.0000)
ZONE    64  41001   6.664400D-02 (     1.0000)  48016   3.334400D-02 (     1.0000)
ZONE    65  41001   6.664400D-02 (     1.0000)  48016   3.334400D-02 (     1.0000)
ZONE    66  41001   6.664400D-02 (     1.0000)  48016   3.334400D-02 (     1.0000)
ZONE    67  41001   6.664400D-02 (     1.0000)  48016   3.334400D-02 (     1.0000)
ZONE    68  41001   6.664400D-02 (     1.0000)  48016   3.334400D-02 (     1.0000)
ZONE    69  41001   6.664400D-02 (     1.0000)  48016   3.334400D-02 (     1.0000)
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ZONE   70  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   71  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   72  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   73  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   74  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   75  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   76  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   77  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   78  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   79  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   80  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   81  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   82  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   83  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   84  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   85  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   86  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   87  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   88  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   89  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   90  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   91  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   92  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   93  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   94  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   95  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   96  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   97  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   98  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE   99  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)
ZONE  100  41001    6.6644000-02 (     1.0000)  48016    3.3344000-02 (     1.0000)

***** AVERAGE VALUES FOR CONTROL ROD MATERIAL *****
 VOLUME OF CONTROL ROD MATERIAL USED TO CALCULATE ATOM DENSITIES.
192235   1.297967D-05 (     1.0000) 292235   3.933233D-05 (     1.0000) 192234   1.365158D-07 (     1.0000)
292234   4.136842D-07 (     1.0000) 192236   6.686842D-08 (     1.0000) 292236   2.026316D-07 (     1.0000)
192238   7.466188D-07 (     1.0000) 292238   2.262481D-06 (     1.0000)  11001   1.648412D-02 (     1.0000)
 21001   4.995188D-02 (     1.0000)  18016   8.269850D-03 (     1.0000)  28016   2.506015D-02 (     1.0000)
 19019   3.061308D-05 (     1.0000)  29019   9.276692D-05 (     1.0000)
-----------------------------------------------------------------------
CONTROL ROD BANK =   1

***** ALL RODS IN BANK WILL BE POSITIONED *****

NUMBER OF POSITIONS =  70

***** ONLY ZONE POSITIONS FOR BANK #    1, ROD #    1 PRINTED HERE *****
NUMBER      ZONE      BOUNDARY          POSITION
   1          2           0          0.0000000000D+00
   2          2           1          2.3561944960+00
   3          3           1          6.2831852440+00
   4          4           1          1.1780972240+01
   5          5           1          1.8849555730+01
   6          6           1          2.7488935230+01
   7          7           1          3.7699111700+01
   8          8           1          4.9480084180+01
   9          9           1          6.2831852670+01
  10         10           1          7.7754418130+01
  11         11           1          9.4247778650+01
  12         12           1          1.1231193610+02
  13         13           1          1.3194689060+02
  14         14           1          1.5315264010+02
  15         15           1          1.7592918660+02
  16         16           1          2.0027653000+02
  17         17           1          2.2619466850+02
  18         18           1          2.5368360400+02
  19         19           1          2.8274333640+02
  20         20           1          3.1337386390+02
  21         21           1          3.4557518840+02
```

22	22	1	3.793473098D+02
23	23	1	4.146902282D+02
24	24	1	4.516039436D+02
25	25	1	4.900884521D+02
26	26	1	5.301437576D+02
27	27	1	5.717698600D+02
28	28	1	6.149667594D+02
29	29	1	6.597344558D+02
30	30	1	7.060729492D+02
31	31	1	7.539822357D+02
32	32	1	8.034623191D+02
33	33	1	8.545131996D+02
34	34	1	9.071348770D+02
35	35	1	9.613273513D+02
36	36	1	1.017090623D+03
37	37	1	1.074424687D+03
38	38	1	1.133329549D+03
39	39	1	1.193805207D+03
40	40	1	1.255851662D+03
41	41	1	1.319468915D+03
42	42	1	1.384656964D+03
43	43	1	1.451415807D+03
44	44	1	1.519745450D+03
45	45	1	1.589645886D+03
46	46	1	1.661117116D+03
47	47	1	1.734159146D+03
48	48	1	1.808771970D+03
49	49	1	1.884955594D+03
50	50	1	1.962710011D+03
51	51	1	2.042035229D+03
52	52	1	2.122931241D+03
53	53	1	2.205398045D+03
54	54	1	2.289435651D+03
55	55	1	2.375044049D+03
56	56	1	2.462223248D+03
57	57	1	2.550973241D+03
58	58	1	2.641294026D+03
59	59	1	2.733185612D+03
60	60	1	2.826647992D+03
61	61	1	2.921681172D+03
62	62	1	3.018285146D+03
63	63	1	3.116459920D+03
64	64	1	3.216205487D+03
65	65	1	3.317521847D+03
66	66	1	3.420409009D+03
67	67	1	3.524866963D+03
68	68	1	3.630895718D+03
69	69	1	3.738495267D+03
70	70	1	3.847665608D+03

***** SAVED POSITIONS FOR ALL CONTROL RODS *****
SAVED POSITION -- POSSAV(1, 1)= 8.342143381D+02

------------------------ TIME IN DAYS .000 ---------------------------

***** MOVING CONTROL RODS TO POSITIONS FOR WORTH CURVE *****

***** ONLY ZONE POSITIONS FOR BANK # 1, ROD # 1 PRINTED HERE *****

#	ZONE	BNDRY	BANK	ROD	POSITION	KEFF	DKEFF	DK/VOL	DKO/VOL
1	2	0	1	1	0.00000D+00	.7145979	.0000000	.0000000	.0000000
2	2	1	1	1	2.35619D+00	.7165064	.0026671	.0011320	.0011320
3	3	1	1	1	6.28319D+00	.7196427	.0043677	.0011122	.0011196
4	4	1	1	1	1.17810D+01	.7239419	.0059562	.0010834	.0011027
5	5	1	1	1	1.88496D+01	.7293161	.0073961	.0010463	.0010815
6	6	1	1	1	2.74889D+01	.7356579	.0086580	.0010022	.0010565
7	7	1	1	1	3.76991D+01	.7429895	.0099166	.0009713	.0010334

8	8	1	1	1	4.94801D+01	.7512037	.0109948	.0009333	.0010094
9	9	1	1	1	6.28319D+01	.7600368	.0116898	.0008755	.0009808
10	10	1	1	1	7.77544D+01	.7696218	.0125323	.0008398	.0009536
11	11	1	1	1	9.42478D+01	.7796588	.0129569	.0007856	.0009240
12	12	1	1	1	1.12312D+02	.7901637	.0133836	.0007409	.0008943
13	13	1	1	1	1.31947D+02	.8009616	.0135726	.0006912	.0008638
14	14	1	1	1	1.53153D+02	.8120614	.0137628	.0006490	.0008337
15	15	1	1	1	1.75929D+02	.8232235	.0136516	.0005994	.0008030
16	16	1	1	1	2.00277D+02	.8346230	.0137521	.0005648	.0007737
17	17	1	1	1	2.26195D+02	.8459521	.0134824	.0005202	.0007442
18	18	1	1	1	2.53684D+02	.8572514	.0132683	.0004827	.0007155
19	19	1	1	1	2.82743D+02	.8685297	.0130703	.0004498	.0006878
20	20	1	1	1	3.13374D+02	.8796280	.0126972	.0004145	.0006607
21	21	1	1	1	3.45575D+02	.8905405	.0123294	.0003829	.0006344
22	22	1	1	1	3.79347D+02	.9013501	.0120650	.0003572	.0006093
23	23	1	1	1	4.14690D+02	.9119067	.0116438	.0003295	.0005851
24	24	1	1	1	4.51604D+02	.9222040	.0112287	.0003042	.0005617
25	25	1	1	1	4.90088D+02	.9322306	.0108136	.0002810	.0005393
26	26	1	1	1	5.30144D+02	.9420633	.0104921	.0002619	.0005180
27	27	1	1	1	5.71770D+02	.9516101	.0100829	.0002422	.0004976
28	28	1	1	1	6.14967D+02	.9608690	.0096826	.0002242	.0004780
29	29	1	1	1	6.59734D+02	.9698324	.0092851	.0002074	.0004594
30	30	1	1	1	7.06073D+02	.9785108	.0089085	.0001922	.0004415
31	31	1	1	1	7.53982D+02	.9869538	.0085914	.0001793	.0004246
32	32	1	1	1	8.03462D+02	.9951225	.0082426	.0001666	.0004084
33	33	1	1	1	8.54513D+02	1.0030079	.0078928	.0001546	.0003930
34	34	1	1	1	9.07135D+02	1.0106200	.0075606	.0001437	.0003783
35	35	1	1	1	9.61327D+02	1.0179708	.0072472	.0001337	.0003643
36	36	1	1	1	1.01709D+03	1.0250709	.0069505	.0001246	.0003509
37	37	1	1	1	1.07442D+03	1.0319166	.0066561	.0001161	.0003382
38	38	1	1	1	1.13333D+03	1.0385371	.0063952	.0001086	.0003261
39	39	1	1	1	1.19381D+03	1.0449241	.0061311	.0001014	.0003145
40	40	1	1	1	1.25585D+03	1.0510879	.0058814	.0000948	.0003035
41	41	1	1	1	1.31947D+03	1.0570304	.0056378	.0000886	.0002930
42	42	1	1	1	1.38466D+03	1.0627626	.0054082	.0000830	.0002829
43	43	1	1	1	1.45142D+03	1.0682876	.0051852	.0000777	.0002734
44	44	1	1	1	1.51975D+03	1.0736152	.0049746	.0000728	.0002642
45	45	1	1	1	1.58965D+03	1.0787556	.0047765	.0000683	.0002555
46	46	1	1	1	1.66112D+03	1.0837113	.0045833	.0000641	.0002471
47	47	1	1	1	1.73416D+03	1.0884914	.0044012	.0000603	.0002392
48	48	1	1	1	1.80877D+03	1.0931045	.0042291	.0000567	.0002315
49	49	1	1	1	1.88496D+03	1.0975734	.0040799	.0000536	.0002242
50	50	1	1	1	1.96271D+03	1.1018789	.0039150	.0000504	.0002173
51	51	1	1	1	2.04204D+03	1.1060340	.0037639	.0000474	.0002106
52	52	1	1	1	2.12293D+03	1.1100448	.0036197	.0000447	.0002042
53	53	1	1	1	2.20540D+03	1.1139164	.0034817	.0000422	.0001980
54	54	1	1	1	2.28944D+03	1.1176560	.0033515	.0000399	.0001922
55	55	1	1	1	2.37504D+03	1.1212593	.0032188	.0000376	.0001865
56	56	1	1	1	2.46222D+03	1.1247473	.0031059	.0000356	.0001811
57	57	1	1	1	2.55097D+03	1.1281177	.0029921	.0000337	.0001759
58	58	1	1	1	2.64129D+03	1.1313751	.0028833	.0000319	.0001710
59	59	1	1	1	2.73319D+03	1.1345259	.0027811	.0000303	.0001662
60	60	1	1	1	2.82665D+03	1.1375709	.0026803	.0000287	.0001616
61	61	1	1	1	2.92168D+03	1.1405158	.0025855	.0000272	.0001572
62	62	1	1	1	3.01829D+03	1.1433645	.0024947	.0000258	.0001529
63	63	1	1	1	3.11646D+03	1.1461301	.0024158	.0000246	.0001488
64	64	1	1	1	3.21621D+03	1.1487993	.0023262	.0000233	.0001449
65	65	1	1	1	3.31752D+03	1.1513834	.0022469	.0000222	.0001411
66	66	1	1	1	3.42041D+03	1.1538889	.0021737	.0000211	.0001375
67	67	1	1	1	3.52487D+03	1.1563143	.0020997	.0000201	.0001340
68	68	1	1	1	3.63090D+03	1.1586642	.0020302	.0000191	.0001306
69	69	1	1	1	3.73850D+03	1.1609406	.0019628	.0000182	.0001273
70	70	1	1	1	3.84767D+03	1.1631399	.0018926	.0000173	.0001242

***** OPTION 30 COMPLETE -- CONTROL RODS RE-POSITIONED *****

***** ENDING POSITION FOR ALL CONTROL RODS *****
ENDING POSITION -- POSNOW(1, 1)= 8.342143381D+02

```
* TOTAL CPU TIME =      2.98 MINUTES - TOTAL CLOCK TIME =      .00 MINUTES *
***************** NORMAL END OF CONTROL ROD POSITION MODULE ***************
***************************************************************************
```

END OF SAMPLE 1, METHOD 1 CTRLPOS OUTPUT

D.2 INPUT AND OUTPUT FOR SAMPLE PROBLEM 2

D.2.1 SAMPLE 2 MCNP INPUT

```
message:    out=cts4v1.o srctp=cts4v1.s runtpe=cts4v1.r
            mctal=cts4v1.m

CTRLPOS Sample Problem 2--Control Rod Study, Case 1
c
1     6 9.994552-2   2 -3              $  Outer Core
                        imp:n=1
2     6 9.994552-2  -1                 $  Center Core
                        imp:n=1
3     3 1.00032-1    3 -4              $  Water next to core
                        imp:n=1
4     7 -13.1        1 -2              $  Control rod in core
                        imp:n=1
9999  0              4                 $  Outside World

1    cz       17.0                     $ Cylinders
2    cz       18.0
3    cz       35.0
4    cz      100.0

c       ***** Fuel *****
c       Material 6--UO2F2-H2O Solution     Total Density= 9.994552-2
c                     H/235U atomic ratio=1270
c
m6      1001.50c  6.6436-2  92238.50c 3.0091-6
        8016.50c  3.3330-2  9019.50c  1.2338-4   92234.50c 5.5020-7
        92235.50c 5.2312-5  92236.50c 2.6950-7
mt6     lwtr.01t
c
c
c       ***** Reflector *****
c       Material 2--H2O reflector    Total density= 9.984-2
c
m3      1001.50c  0.066644    8016.50c 0.033344
mt3     lwtr.01t
c
c
c       ***** Control Material *****
c       Material 7--Hf Control Rod    Total density= 4.419755-2
c
m7      72000.50c    1
c
c
kcode   1000 1.0 30 180          $ 1000 particles, 30 settle cycles, 180 cycles
c
prdmp   180 180 180 1            $ Dump information to file after 180 cycles
c
ksrc    0 0 0                    $ Beginning source guess
```

END OF SAMPLE 2 MCNP INPUT

D.2.2 SAMPLE 2 SCALE INPUT

```
=csasn
  CTRLPOS Sample 2 -- Infinite Cylindrical Reactor with Control
  99gr    multiregion
  u-235   1 0 5.2312-5  end
  u-238   1 0 3.0091-6  end
  u-234   1 0 5.5020-7  end
  u-236   1 0 2.6950-7  end
  h       1 0 6.6436-2  end
  o       1 0 3.3330-2  end
  f       1 0 1.2338-4  end
  h       2 0 0.066644  end
  o       2 0 0.033344  end
  hf-174  3 0 7.16000-5 end
  hf-176  3 0 2.30092-3 end
  hf-177  3 0 8.22339-3 end
  hf-178  3 0 1.20646-2 end
  hf-179  3 0 6.02368-3 end
  hf-180  3 0 1.55133-2 end
 end comp
 cylindrical vacuum  reflected  0. end
 1   17.
 3   18.
 1   35.
 2   100.
 end zone
 more data dab=600 end
end
=xsdrn_jp
  CTRLPOS Sample 2 -- Infinite Cylindrical Reactor with Control
-1$$  1000000
0$$  a3 4 e
'1$$  2 5 100 1 0 3 15 8 3 1 10 10 0 0 e
1$$  2 5 100 1 0 3 15 8 3 1 10 200 0 0 e
2$$  -2 0 0 0 0 e
3$$  1 0 0 1 e
4$$  0 16 0 -2 3 4 19 e
5**  1.0-4 1.0-4 0  e
t
13$$  7r1 6r2 2r3
14$$ 92235 92238 92234 92236 1001 8016 9019
     72174 72176 72177 72178 72179 72180
     201001 208016
15**  5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      7.16000-5  2.30092-3  8.22339-3 1.20646-2  6.02368-3  1.55133-2
      0.066644 0.033344
t
34##  17r1.0 10r0.0 16r1.0 57r0.0
t
35**  16i0. 9i17. 15i18. 56i35. 100.
36$$  17r1 10r2 16r3 27r4  30r5
39$$  1 2 1 3 3
51$$ 10r1 10r2  5r3 5r4 5r5 5r6 5r7 5r8 5r9 5r10 5r11 5r12
     7r13 4r14 5r15 13r16
t
end
=xsdrn_jp
  CTRLPOS Sample 2 -- Infinite Cylindrical Reactor with Control
-1$$  1000000
0$$  a3 3 20 30 e
1$$  2 5 100 1 0 5 24 8 3 1 10 200 0 0 e
2$$  -2 0 0 0 0 e
3$$  1 0 0 1  e
4$$  0 8 0 -2 3 4 7 e
5**  1.0-4 1.0-4 0  e
t
```

```
13$$ 7r1 6r2 7r3 2r4 2r5
14$$ 192235 192238 192234 192236 11001 18016 19019
     272174 272176 272177 272178 272179 272180
     392235 392238 392234 392236 31001 38016 39019
     4201001 4208016
     5201001 5208016
15**  5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      7.16000-5  2.30092-3  8.22339-3 1.20646-2  6.02368-3  1.55133-2
      5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      0.066644 0.033344
      0.066644 0.033344
t
34##  17r1.0 10r0.0 16r1.0 57r0.0
t
35**  16i0. 9i17. 15i18. 56i35. 100.
36$$  17r1 10r2 16r3 27r4 30r5
39$$  1 2 3 4 5
51$$  3r1 2r2 4r3 2r4 2r5 6 7 8
t
end
=xsdrn_jp
  CTRLPOS Sample 2 -- Infinite Cylindrical Reactor with Control
-1$$  1000000
0$$  a3 30 20 29 e
1$$  2 5 100 1 0 5 24 8 3 1 10 200 0 0 e
2$$  -2 0 0 0 0 e
3$$  1 0 0 1  e
4$$  0 8 20 -2 24 4 7 -1 e
5**  1.0-4 1.0-4 0  e
t
13$$ 7r1 6r2 7r3 2r4 2r5
14$$ 1192235 1192238 1192234 1192236 111001 118016 119019
     2272174 2272176 2272177 2272178 2272179 2272180
     3392235 3392238 3392234 3392236 331001 338016 339019
     44201001 44208016
     55201001 55208016
15**  5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      7.16000-5  2.30092-3  8.22339-3 1.20646-2  6.02368-3  1.55133-2
      5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      0.066644 0.033344
      0.066644 0.033344
16$$ 11192235 11192238 11192234 11192236 1111001 1118016 1119019
     22272174 22272176 22272177 22272178 22272179 22272180
     33392235 33392238 33392234 33392236 3331001 3338016 3339019
     444201001 444208016
     555201001 555208016
18## 6h192235 6h192238 6h192234 6h192236 6h 11001 6h 18016
     6h 19019
     6h272174 6h272176 6h272177 6h272178 6h272179 6h272180
     6h392235 6h392238 6h392234 6h392236 6h 31001 6h 38016
     6h 39019
     6h 41001 6h 48016
     6h 51001 6h 58016
t
34##  17r1.0 10r0.0 16r1.0 57r0.0
t
35**  16i0. 9i17. 15i18. 56i35. 100.
36$$  17r1 10r2 16r3 27r4 30r5
39$$  1 2 3 4 5
51$$  1 2 3 4 5 6 7 8
t
end
```

END OF SAMPLE 2 SCALE INPUT

D.2.3 SAMPLE 2 VENTURE/CTRLPOS INPUT

```
=CONTROL1
CTRLPOS Sample Problem 2 -- Infinite Cylindrical Hf Rod in Core
'0000000011111111112222222222333333333344444444445555555555666666666677777777778
'2345678901234567890123456789012345678901234567890123456789012345678901234567890
800000     04                                       1                            1
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 0
  ISOTXS
END                                                                         00000670
DCRSPR
'2345678901234567890123456789012345678901234567890123456789012345678901234567890
        1  1          1  1                                            0  0
             24                1
192235 92235              235.         3.236  -11             1
392235 92235              235.         3.236  -11             1
192234 92234              234.         3.19   -11             1
392234 92234              234.         3.19   -11             1
192236 92236              236.         3.26   -11             3
392236 92236              236.         3.26   -11             3
192238 92238              238.         3.31   -11             2
392238 92238              238.         3.31   -11             2
 11001  1001                1.                                6
 31001  1001                1.                                6
 41001  1001                1.                                6
 51001  1001                1.                                6
 18016  8016               16.                                6
 38016  8016               16.                                6
 48016  8016               16.                                6
 58016  8016               16.                                6
 19019  9019               19.                                6
 39019  9019               19.                                6
272174 72174              174.                                7
272176 72176              176.                                7
272177 72177              177.                                7
272178 72178              178.                                7
272179 72179              179.                                7
272180 72180              180.                                7
END
CROSPROS
END
DVENTR                                                      " *** 2 = DVENTR
001                                                                      CARD 1
                                             1.00+1     1.00      1.0        CARD 2
                                                                         CARD 3
                                                                         CARD 4
'01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  2  0  0  0  0              100     0           1                       CARD 5
'01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  1  0  0  0  0  0  0  0  0  0  0  0  0  2  0  1  2  1        0  0       CARD 6
002                                                                      CARD 1
                                                                         CARD 2
                                0                       00               CARD 3
                                                                         CARD 4
 0.0                                              .0645                  CARD 5
 0.0                                                        2.09 -05 CARD 6
003
'01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  2  1  2                        0
004
'23123456789123123456789123123456789123123456789123123456789123123456789
136  17.0000 30   1.0000  8   0.0001136  17.0000200  25.0000240  30.0000
```

```
  0   0.0000
' ***
005
  1  2  3  4  5  6
012
  0
                                                                       BLANK
013
 24
 24
'     |     |     |     |     |     |     |     |     |     |     |     |
192235392235192234392234192236392236192238392238 11001 31001 41001 51001
 18016 38016 48016 58016 19019 39019272174272176272177272178272179272180
020
  1  1
'       Inner Core Region
192235 5.23120E-05192238 3.00910E-06192234 5.50200E-07192236 2.69500E-07
 11001 6.64360E-02 18016 3.33300E-02 19019 1.23380E-04
  2  2
'         Natural Hf atom densities
272174 7.16000E-05272176 2.30092E-03272177 8.22339E-03272178 1.20646E-02
272179 6.02368E-03272180 1.55133E-02
  3  3
'         Natural Hf atom densities * 10E-8
272174 7.16000E-13272176 2.30092E-11272177 8.22339E-11272178 1.20646E-09
272179 6.02368E-11272180 1.55133E-10
  4  4
'       Outer Core Region
392235 5.23120E-05392238 3.00910E-06392234 5.50200E-07392236 2.69500E-07
 31001 6.64360E-02 38016 3.33300E-02 39019 1.23380E-04
  5  5
'       Inner Reflector Region
 41001 6.66440E-02 48016 3.33440E-02
  6  6
'       Outer Reflector Region
 51001 6.66440E-02 58016 3.33440E-02
  0  0
END
'*****  Option 5 used to define CTRLPOS output file name
OUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000       0.0010      1000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
  5  0  0  2  0  1  0  0  0 10 35  1  0  1  0  0  0  0  0  0  0  0  0  0
END
CTRLPOS
'*****  File name for CTRLPOS output
ctrls2.out.1
END
'*****  Option 10 used to read in CTRLPOS data
OUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000       0.0010      1000.0      5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 10  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'*****  CTRLPOS DATA FOR SAMPLE PROBLEM 2
'*****  The 'control rod' zone is only zone 2.  The first position guess is the
'*****   upper boundary of zone 2 while the tip of the control rod starts at
'*****   the lower boundary of zone 2.  Of course, the limits of control rod
'*****   motion are the upper and lower boundaries of this zone. The follower
'*****   material is in zone 3 which is a very thin zone which will not
'*****   affect the problem.  This zone is needed since Hf follower at a
'*****   very small density is needed so control rod position searches can be
'*****   done.
CTRLPOS
begin-input
```

```
begin-bank
begin-rod
2,0,2,1
2,1,2,0
begin-zone
2,3,1
end-zone
end-rod
end-bank
end-input
END
'***** Option 20 used to perform a keff position search
DUTLIN
CTRLCF       0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.970       0.0010        1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF       0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.975       0.0010        1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF       0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.980       0.0010        1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF       0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.985       0.0010        1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF       0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.990       0.0010        1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF       0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.995       0.0010        1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  1
END
DUTLIN
CTRLCF       0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000       0.0010        1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
```

```
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.005       0.0010        1000.0        5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.010       0.0010        1000.0        5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.015       0.0010        1000.0        5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.020       0.0010        1000.0        5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.025       0.0010        1000.0        5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
DUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.030       0.0010        1000.0        5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
END
'*****  Option 30 used to calculate a control rod worth curve
DUTLIN
CTRLCF         0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       0.950       0.0010        1000.0        5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 30  0  0  2  0  1  1  0  0 25 99  0  0  1  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
begin-input
2,0
```

```
2,1
end-input
END
'VENTNEUT
'END
```

END OF SAMPLE 2 VENTURE/CTRLPOS INPUT

D.2.4 SAMPLE 2 CTRLPOS OUTPUT

```
****************************************************************************
*** CTRLPOS - CONTROL ROD POSITION MODULE - VERSION 1 - OCTOBER 1, 1992 ***

                         ***** CTRLPOS OPTION 10 *****
---------------------------------------------------------------------------

---------------------------------------------------------------------------
***** CONTENTS OF *CTRLCF* CONTROL FILE *****

XX( 1- 4)  * 1.000000D+00* 1.000000D-03* 1.000000D+03* 5.000000D+03*
IX( 1- 5)  *     10*     0*     0*     2*     0*
IX( 6-10)  *      1*     1*     0*     0*    25*
IX(11-15)  *     99*     0*     0*     0*     0*
IX(16-20)  *      0*     0*     0*     0*     0*
IX(21-25)  *      0*     0*     0*     1*     0*

 1-TARGET KEFF VALUE                       =  1.000000D+00
 2-ALLOWED KEFF TOLERANCE                  =  1.000000D-03
 3-MAXIMUM VALUE FOR CONTROL ROD MOVEMENT  =     1.000D+03
 4-MAXIMUM NUMBER OF ATOM DENSITY VALUES (IF IX(23).NE.0) =       5000

 1-CTRLPOS OPTION NUMBER                      =      10
 2-NEUTRONICS MODULE                          =       0
 3-INTERPOLATION SCHEME                       =       0
 4-NUMBER OF POINTS IN SCHEME                 =       2
 5-STORAGE OF KEFF VALUES                     =       0
 6-CONTROL RODS FOR KEFF SEARCH               =       1
 7-PRINT OUT OF ATOM DENSITIES                =       1
 8-PRINT OUT ATOM DENSITIES AT EACH POSITION  =       0
 9-CONTROL ROD TIP PARTIAL ZONE PLACEMENT     =       0
10-NUMBER OF POSITION ITERATIONS              =      25
11-NUMBER OF OUTERS FOR NEUTRONICS MODULE     =      99
12-RESERVED                                   =       0
13-BURNED CONTROL ROD OPTION                  =       0

***** PARAMETERS FOR CTRLPOS OPTION 30 *****
14-BANK NUMBER FOR CONTROL ROD WORTH CURVE    =       0
15-CONTROL ROD FOR WORTH CURVE                =       0
16-RESERVED                                   =       0

***** PARAMETERS FOR CTRLPOS OPTION 40 *****
17-BANK NUMBER FOR ROD/BANK RE-POSITIONING    =       0
18-CONTROL ROD NUMBER FOR RE-POSITIONING      =       0
19-ZONE NUMBER FOR RE-POSITIONING             =       0
20-ZONE BOUNDARY FOR RE-POSITIONING           =       0
21-VENTPLOT PLOT OPTION                       =       0

22-REVERSE CONTROL ROD MOTION OPTION          =       0
23-ATOM DENSITY ARRAY STORAGE OPTION          =       0
24-CONTAINER ARRAY MEMORY OPTION              =       1
25-DEBUG OUTPUT PARAMETER                     =       0

---------------------------------------------------------------------------

---------------------------------------------------------------------------
BANK #   1 HAS    1 RODS.

NUMBER OF CONTROL ROD BANKS =    1

BANK #   1 ROD #   1 HAS    1 ZONES AND    0 PRODUCTION CHAINS.

BANK #   1 ROD #   1 CHAIN #   0 HAS    0 PRODUCED ISOTOPES.
---------------------------------------------------------------------------

---------------------------------------------------------------------------
TOTAL AVAILABLE MEMORY   =     4800000 WORDS.
```

```
LOWER MEMORY FOR CTRLPOS =      22615 WORDS.
UPPER MEMORY FOR CTRLPOS =        484 WORDS.
TOTAL MEMORY FOR CTRLPOS =      23099 WORDS.

           EXTRA MEMORY =    4776901 WORDS.
--------------------------------------------------------------------------

BANK # 1      ROD #  1
CONTROL ROD TIP IS LOWER BOUNDARY OF ZONE     2
FIRST GUESS POSITION IS UPPER BOUNDARY OF ZONE     2
UPPER CONTROL ROD LIMIT IS UPPER BOUNDARY OF ZONE     2
LOWER CONTROL ROD LIMIT IS LOWER BOUNDARY OF ZONE     2


--------------------------------------------------------------------------
***** INFORMATION ON MEMORY REQUIREMENTS FOR ATOM DENSITY ARRAYS *****

MAXIMUM NUMBER OF ATOM DENSITY VALUES POSSIBLE =         13.
NOTE *** THIS VALUE DOES NOT ACCOUNT FOR THE PRODUCTION
        OF NEW ISOTOPES IN THE FOLLOWER MATERIAL ***
TOTAL MEMORY REQUIRED FOR IX(23).EQ.0     =      23099 WORDS.
TOTAL MEMORY REQUIRED FOR IX(23).NE.0     =      22853 WORDS.

IX(23).NE.0 OPTION SAVES AT LEAST        246 WORDS OF MEMORY.
SET XX(3) (LIMIT VALUE) GREATER THAN        13.
NOTE *** YOU CAN SAVE MEMORY BY CHANGING TO IX(23).NE.0 ***
--------------------------------------------------------------------------

BANK # 1   ROD # 1     NUMBER OF ZONES =      1
    CONTROL ROD   FOLLOWER     CONTROL ROD     FOLLOWER       TOTAL        ROD
    ZONE NUMBER  ZONE NUMBER   ZONE VOLUME    ZONE VOLUME  ZONE VOLUME     FLAG
  1     2             3        1.09956D+02    1.13098D-02  1.09956D+02      1


------------------------ TIME IN DAYS       .000 ---------------------------

BANK # 1      ROD # 1   ATOM DENSITIES

ZONE     2 272174    7.160000D-05 (     1.0000) 272176    2.300920D-03 (     1.0000) 272177    8.223390D-03 (
1.0000)
272178    1.206460D-02 (     1.0000) 272179    6.023680D-03 (     1.0000) 272180    1.551330D-02 (     1.0000)

***** AVERAGE VALUES FOR CONTROL ROD MATERIAL *****
 VOLUME OF CONTROL ROD MATERIAL USED TO CALCULATE ATOM DENSITIES.
272174    7.160000D-05 (     1.0000) 272176    2.300920D-03 (     1.0000) 272177    8.223390D-03 (     1.0000)
272178    1.206460D-02 (     1.0000) 272179    6.023680D-03 (     1.0000) 272180    1.551330D-02 (     1.0000)
--------------------------------------------------------------------------

***** STARTING POSITIONS FOR ALL CONTROL RODS *****
STARTING POSITION -- POSNOW(  1,  1)=    0.000000000D+00

***** KEFF AT STARTING POSITION =      .9630272


***** FIRST GUESS POSITIONS FOR MOVING CONTROL RODS *****
FIRST GUESS POSITION -- POSNOW(  1,  1)=    1.099557419D+02

***** KEFF AT FIRST GUESS POSITION =     1.1438609

--------------------------------------------------------------------------
ITERATION #  0 -- AT THE CURRENT POSITION KEFF =     1.1438609
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD     **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1           1.099557419D+02                    2.248127786D+01

--------------------------------------------------------------------------
```

```
ITERATION #  1 -- AT THE CURRENT POSITION KEFF =     .9668990
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            2.248127786D+01                   3.884349441D+01

---------------------------------------------------------------------------
ITERATION #  2 -- AT THE CURRENT POSITION KEFF =     .9704440
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            3.884349441D+01                   5.096339318D+01

---------------------------------------------------------------------------
ITERATION #  3 -- AT THE CURRENT POSITION KEFF =     .9737892
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            5.096339318D+01                   6.005508032D+01

---------------------------------------------------------------------------
ITERATION #  4 -- AT THE CURRENT POSITION KEFF =     .9769915
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            6.005508032D+01                   6.693553691D+01

---------------------------------------------------------------------------
ITERATION #  5 -- AT THE CURRENT POSITION KEFF =     .9800482
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            6.693553691D+01                   7.217523560D+01

---------------------------------------------------------------------------
ITERATION #  6 -- AT THE CURRENT POSITION KEFF =     .9829227
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            7.217523560D+01                   7.618414870D+01

---------------------------------------------------------------------------
ITERATION #  7 -- AT THE CURRENT POSITION KEFF =     .9855700
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            7.618414870D+01                   7.926282018D+01

---------------------------------------------------------------------------
ITERATION #  8 -- AT THE CURRENT POSITION KEFF =     .9879534
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            7.926282018D+01                   8.163438133D+01

---------------------------------------------------------------------------
ITERATION #  9 -- AT THE CURRENT POSITION KEFF =     .9900527
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            8.163438133D+01                   8.346602235D+01

---------------------------------------------------------------------------
ITERATION # 10 -- AT THE CURRENT POSITION KEFF =     .9918648
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1      1            8.346602235D+01                   8.488381251D+01
```

```
--------------------------------------------------------------------------
ITERATION # 11 -- AT THE CURRENT POSITION KEFF =      .9934018
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.488381251D+01                    8.598330649D+01

--------------------------------------------------------------------------
ITERATION # 12 -- AT THE CURRENT POSITION KEFF =      .9946857
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.598330649D+01                    8.683731252D+01

--------------------------------------------------------------------------
ITERATION # 13 -- AT THE CURRENT POSITION KEFF =      .9957446
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.683731252D+01                    8.750149916D+01

--------------------------------------------------------------------------
ITERATION # 14 -- AT THE CURRENT POSITION KEFF =      .9966088
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.750149916D+01                    8.801861505D+01

--------------------------------------------------------------------------
ITERATION # 15 -- AT THE CURRENT POSITION KEFF =      .9973080
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.801861505D+01                    8.842157185D+01

--------------------------------------------------------------------------
ITERATION # 16 -- AT THE CURRENT POSITION KEFF =      .9978698
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.842157185D+01                    8.873578283D+01

--------------------------------------------------------------------------
ITERATION # 17 -- AT THE CURRENT POSITION KEFF =      .9983186
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.873578283D+01                    8.898093998D+01

--------------------------------------------------------------------------
ITERATION # 18 -- AT THE CURRENT POSITION KEFF =      .9986755
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.898093998D+01                    8.917229594D+01

--------------------------------------------------------------------------
ITERATION # 19 -- AT THE CURRENT POSITION KEFF =      .9989582
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.917229594D+01                    8.932171606D+01

--------------------------------------------------------------------------
ITERATION # 20 -- AT THE CURRENT POSITION KEFF =      .9991817

***** CONTROL RODS WERE SUCCESSFUL POSITIONED TO THE TARGET KEFF VALUE *****
```

```
***** ENDING POSITION FOR ALL CONTROL RODS *****
ENDING POSITION -- POSNOW( 1,  1)=    8.932171606D+01

* TOTAL CPU TIME =      2.57 MINUTES - TOTAL CLOCK TIME =       .00 MINUTES *
***************** NORMAL END OF CONTROL ROD POSITION MODULE ***************
****************************************************************************

****************************************************************************
*** CTRLPOS - CONTROL ROD POSITION MODULE - VERSION 1 - OCTOBER 1, 1992 ***

                         ***** CTRLPOS OPTION 20 *****
----------------------------------------------------------------------------

----------------------------------------------------------------------------
***** CONTENTS OF *CTRLCF* CONTROL FILE *****

XX( 1- 4)  * 9.70000D-01* 1.00000D-03* 1.00000D+03* 5.00000D+03*
IX( 1- 5)  *    20*     0*     0*     2*     0*
IX( 6-10)  *     1*     1*     0*     0*    25*
IX(11-15)  *    99*     0*     0*     0*     0*
IX(16-20)  *     0*     0*     0*     0*     0*
IX(21-25)  *     0*     0*     0*     1*     0*

 1-TARGET KEFF VALUE                          =  9.70000D-01
 2-ALLOWED KEFF TOLERANCE                     =  1.00000D-03
 3-MAXIMUM VALUE FOR CONTROL ROD MOVEMENT =      1.00D+03
 4-MAXIMUM NUMBER OF ATOM DENSITY VALUES (IF IX(23).NE.0) =       5000

 1-CTRLPOS OPTION NUMBER                       =      20
 2-NEUTRONICS MODULE                           =       0
 3-INTERPOLATION SCHEME                        =       0
 4-NUMBER OF POINTS IN SCHEME                  =       2
 5-STORAGE OF KEFF VALUES                      =       0
 6-CONTROL RODS FOR KEFF SEARCH                =       1
 7-PRINT OUT OF ATOM DENSITIES                 =       1
 8-PRINT OUT ATOM DENSITIES AT EACH POSITION =        0
 9-CONTROL ROD TIP PARTIAL ZONE PLACEMENT     =       0
10-NUMBER OF POSITION ITERATIONS               =      25
11-NUMBER OF OUTERS FOR NEUTRONICS MODULE     =      99
12-RESERVED                                    =       0
13-BURNED CONTROL ROD OPTION                   =       0

***** PARAMETERS FOR CTRLPOS OPTION 30 *****
14-BANK NUMBER FOR CONTROL ROD WORTH CURVE   =       0
15-CONTROL ROD FOR WORTH CURVE                =       0
16-RESERVED                                    =       0

***** PARAMETERS FOR CTRLPOS OPTION 40 *****
17-BANK NUMBER FOR ROD/BANK RE-POSITIONING   =       0
18-CONTROL ROD NUMBER FOR RE-POSITIONING     =       0
19-ZONE NUMBER FOR RE-POSITIONING             =       0
20-ZONE BOUNDARY FOR RE-POSITIONING           =       0
21-VENTPLOT PLOT OPTION                        =       0

22-REVERSE CONTROL ROD MOTION OPTION          =       0
23-ATOM DENSITY ARRAY STORAGE OPTION          =       0
24-CONTAINER ARRAY MEMORY OPTION              =       1
25-DEBUG OUTPUT PARAMETER                      =       0

----------------------------------------------------------------------------

----------------------------------------------------------------------------
TOTAL AVAILABLE MEMORY   =    4800000 WORDS.
LOWER MEMORY FOR CTRLPOS =      22615 WORDS.
UPPER MEMORY FOR CTRLPOS =        484 WORDS.
TOTAL MEMORY FOR CTRLPOS =      23099 WORDS.

            EXTRA MEMORY =    4776901 WORDS.
----------------------------------------------------------------------------
```

```
------------------------ TIME IN DAYS       .000 ---------------------------

BANK # 1    ROD # 1   ATOM DENSITIES

ZONE    2 272174   7.160000D-05 (     1.0000) 272176   2.300920D-03 (     1.0000) 272177   8.223390D-03 (
1.0000)
272178   1.206460D-02 (     1.0000) 272179   6.023680D-03 (     1.0000) 272180   1.551330D-02 (     1.0000)

***** AVERAGE VALUES FOR CONTROL ROD MATERIAL *****
 VOLUME OF CONTROL ROD MATERIAL USED TO CALCULATE ATOM DENSITIES.
272174   7.160000D-05 (     1.0000) 272176   2.300920D-03 (     1.0000) 272177   8.223390D-03 (     1.0000)
272178   1.206460D-02 (     1.0000) 272179   6.023680D-03 (     1.0000) 272180   1.551330D-02 (     1.0000)
---------------------------------------------------------------------------

***** STARTING POSITIONS FOR ALL CONTROL RODS *****
STARTING POSITION -- POSNOW(  1,   1)=    8.932171606D+01

***** KEFF AT STARTING POSITION =       .9991817


***** KEFF BEING CALCULATED AT PREVIOUS CONTROL ROD POSITION *****
PREVIOUS POSITION -- POSNOW(  1,   1)=    8.917229594D+01

**** KEFF AT PREVIOUS POSITION =       .9989582

---------------------------------------------------------------------------
ITERATION #  0 -- AT THE CURRENT POSITION KEFF =       .9989582
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

WARNING ***** LOWER CONTROL ROD POSITION EXCEEDED *****
        ***** CONTROL RODS WILL BE PLACED AT POSITION LIMIT *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             8.932171606D+01                    0.000000000D+00

---------------------------------------------------------------------------
ITERATION #  1 -- AT THE CURRENT POSITION KEFF =       .9630272
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             0.000000000D+00                    1.733387430D+01

---------------------------------------------------------------------------
ITERATION #  2 -- AT THE CURRENT POSITION KEFF =       .9659325
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             1.733387430D+01                    2.618151316D+01

---------------------------------------------------------------------------
ITERATION #  3 -- AT THE CURRENT POSITION KEFF =       .9676313
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             2.618151316D+01                    3.095561178D+01

---------------------------------------------------------------------------
ITERATION #  4 -- AT THE CURRENT POSITION KEFF =       .9686303
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1             3.095561178D+01                    3.358482620D+01

---------------------------------------------------------------------------
ITERATION #  5 -- AT THE CURRENT POSITION KEFF =       .9692101

***** CONTROL RODS WERE SUCCESSFUL POSITIONED TO THE TARGET KEFF VALUE *****
```

```
***** ENDING POSITION FOR ALL CONTROL RODS *****
ENDING POSITION -- POSNOW( 1,  1)=    3.35848262OD+01

* TOTAL CPU TIME =      3.37 MINUTES - TOTAL CLOCK TIME =      .00 MINUTES *
***************** NORMAL END OF CONTROL ROD POSITION MODULE ***************
***************************************************************************
---------*******---------*********---------
---------*******---------*********---------
---------*******---------*********---------
ctrlpos option 20 was also performed for target keff values of 0.975, 0.980,
0.985, 0.990, 0.995, 1.000, 1.005, 1.010, 1.015, 1.020, and 1.030.
---------*******---------*********---------
---------*******---------*********---------
---------*******---------*********---------
***************************************************************************
*** CTRLPOS - CONTROL ROD POSITION MODULE - VERSION 1 - OCTOBER 1, 1992 ***

                         ***** CTRLPOS OPTION 20 *****
---------------------------------------------------------------------------

---------------------------------------------------------------------------
***** CONTENTS OF *CTRLCF* CONTROL FILE *****

XX( 1- 4)  * 1.03000D+00* 1.00000D-03* 1.00000D+03* 5.00000D+03*
IX( 1- 5)  *    20*     0*     0*     2*     0*
IX( 6-10)  *     1*     1*     0*     0*    25*
IX(11-15)  *    99*     0*     0*     0*     0*
IX(16-20)  *     0*     0*     0*     0*     0*
IX(21-25)  *     0*     0*     0*     1*     0*

 1-TARGET KEFF VALUE                         =  1.03000D+00
 2-ALLOWED KEFF TOLERANCE                    =  1.00000D-03
 3-MAXIMUM VALUE FOR CONTROL ROD MOVEMENT =      1.00D+03
 4-MAXIMUM NUMBER OF ATOM DENSITY VALUES (IF IX(23).NE.0) =       5000

 1-CTRLPOS OPTION NUMBER                     =      20
 2-NEUTRONICS MODULE                         =       0
 3-INTERPOLATION SCHEME                      =       0
 4-NUMBER OF POINTS IN SCHEME                =       2
 5-STORAGE OF KEFF VALUES                    =       0
 6-CONTROL RODS FOR KEFF SEARCH              =       1
 7-PRINT OUT OF ATOM DENSITIES               =       1
 8-PRINT OUT ATOM DENSITIES AT EACH POSITION =       0
 9-CONTROL ROD TIP PARTIAL ZONE PLACEMENT    =       0
10-NUMBER OF POSITION ITERATIONS             =      25
11-NUMBER OF OUTERS FOR NEUTRONICS MODULE    =      99
12-RESERVED                                  =       0
13-BURNED CONTROL ROD OPTION                 =       0

***** PARAMETERS FOR CTRLPOS OPTION 30 *****
14-BANK NUMBER FOR CONTROL ROD WORTH CURVE   =       0
15-CONTROL ROD FOR WORTH CURVE               =       0
16-RESERVED                                  =       0

***** PARAMETERS FOR CTRLPOS OPTION 40 *****
17-BANK NUMBER FOR ROD/BANK RE-POSITIONING   =       0
18-CONTROL ROD NUMBER FOR RE-POSITIONING     =       0
19-ZONE NUMBER FOR RE-POSITIONING            =       0
20-ZONE BOUNDARY FOR RE-POSITIONING          =       0
21-VENTPLOT PLOT OPTION                      =       0

22-REVERSE CONTROL ROD MOTION OPTION         =       0
23-ATOM DENSITY ARRAY STORAGE OPTION         =       0
24-CONTAINER ARRAY MEMORY OPTION             =       1
25-DEBUG OUTPUT PARAMETER                    =       0

---------------------------------------------------------------------------
```

```
--------------------------------------------------------------------------
TOTAL AVAILABLE MEMORY   =     4800000 WORDS.
LOWER MEMORY FOR CTRLPOS =       22615 WORDS.
UPPER MEMORY FOR CTRLPOS =         484 WORDS.
TOTAL MEMORY FOR CTRLPOS =       23099 WORDS.

           EXTRA MEMORY =      4776901 WORDS.
--------------------------------------------------------------------------

------------------------- TIME IN DAYS       .000 ---------------------------

BANK # 1     ROD # 1    ATOM DENSITIES

ZONE     2 272174   7.160000D-05 (     1.0000) 272176   2.300920D-03 (     1.0000) 272177   8.223390D-03 (
1.0000)
272178   1.206460D-02 (     1.0000) 272179   6.023680D-03 (     1.0000) 272180   1.551330D-02 (     1.0000)

***** AVERAGE VALUES FOR CONTROL ROD MATERIAL *****
 VOLUME OF CONTROL ROD MATERIAL USED TO CALCULATE ATOM DENSITIES.
272174   7.160000D-05 (     1.0000) 272176   2.300920D-03 (     1.0000) 272177   8.223390D-03 (     1.0000)
272178   1.206460D-02 (     1.0000) 272179   6.023680D-03 (     1.0000) 272180   1.551330D-02 (     1.0000)
--------------------------------------------------------------------------

***** STARTING POSITIONS FOR ALL CONTROL RODS *****
STARTING POSITION -- POSNOW(  1,   1)=    9.972098912D+01

***** KEFF AT STARTING POSITION =     1.0241767


***** KEFF BEING CALCULATED AT PREVIOUS CONTROL ROD POSITION *****
PREVIOUS POSITION -- POSNOW(  1,   1)=    9.961465790D+01

**** KEFF AT PREVIOUS POSITION =     1.0237651

--------------------------------------------------------------------------
ITERATION #  0 -- AT THE CURRENT POSITION KEFF =      1.0237651
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1            9.972098912D+01                    9.972098541D+01

--------------------------------------------------------------------------
ITERATION #  1 -- AT THE CURRENT POSITION KEFF =      1.0241767
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

WARNING ***** UPPER CONTROL ROD POSITION EXCEEDED *****
        ***** CONTROL RODS WILL BE PLACED AT POSITION LIMIT *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1            9.972098541D+01                    1.099557419D+02

--------------------------------------------------------------------------
ITERATION #  2 -- AT THE CURRENT POSITION KEFF =      1.1438609
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1            1.099557419D+02                    1.002189616D+02

--------------------------------------------------------------------------
ITERATION #  3 -- AT THE CURRENT POSITION KEFF =      1.0261786
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1            1.002189616D+02                    1.005351380D+02

--------------------------------------------------------------------------
ITERATION #  4 -- AT THE CURRENT POSITION KEFF =      1.0275171
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****
```

```
BANK     ROD     **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1        1           1.005351380D+02                      1.007361881D+02

--------------------------------------------------------------------------------
ITERATION #  5 -- AT THE CURRENT POSITION KEFF =     1.0283974
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD     **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1        1           1.007361881D+02                      1.008641522D+02

--------------------------------------------------------------------------------
ITERATION #  6 -- AT THE CURRENT POSITION KEFF =     1.0289701
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK     ROD     **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1        1           1.008641522D+02                      1.009456477D+02

--------------------------------------------------------------------------------
ITERATION #  7 -- AT THE CURRENT POSITION KEFF =     1.0293400

***** CONTROL RODS WERE SUCCESSFUL POSITIONED TO THE TARGET KEFF VALUE *****


***** ENDING POSITION FOR ALL CONTROL RODS *****
ENDING POSITION -- POSNOW(  1,   1)=     1.009456477D+02

* TOTAL CPU TIME =      19.63 MINUTES - TOTAL CLOCK TIME =        .00 MINUTES *
***************** NORMAL END OF CONTROL ROD POSITION MODULE ***************
***************************************************************************

***************************************************************************
*** CTRLPOS - CONTROL ROD POSITION MODULE - VERSION 1 - OCTOBER 1, 1992 ***

                       ***** CTRLPOS OPTION 30 *****
--------------------------------------------------------------------------------

--------------------------------------------------------------------------------
***** CONTENTS OF *CTRLCF* CONTROL FILE *****

XX( 1- 4)  * 9.50000D-01* 1.00000D-03* 1.00000D+03* 5.00000D+03*
IX( 1- 5)  *    30*      0*      0*      2*      0*
IX( 6-10)  *     1*      1*      0*      0*     25*
IX(11-15)  *    99*      0*      0*      1*      0*
IX(16-20)  *     0*      0*      0*      0*      0*
IX(21-25)  *     0*      0*      0*      1*      0*

 1-TARGET KEFF VALUE                          =  9.50000D-01
 2-ALLOWED KEFF TOLERANCE                     =  1.00000D-03
 3-MAXIMUM VALUE FOR CONTROL ROD MOVEMENT =       1.00D+03
 4-MAXIMUM NUMBER OF ATOM DENSITY VALUES (IF IX(23).NE.0) =       5000

 1-CTRLPOS OPTION NUMBER                       =       30
 2-NEUTRONICS MODULE                           =        0
 3-INTERPOLATION SCHEME                        =        0
 4-NUMBER OF POINTS IN SCHEME                  =        2
 5-STORAGE OF KEFF VALUES                      =        0
 6-CONTROL RODS FOR KEFF SEARCH                =        1
 7-PRINT OUT OF ATOM DENSITIES                 =        1
 8-PRINT OUT ATOM DENSITIES AT EACH POSITION =          0
 9-CONTROL ROD TIP PARTIAL ZONE PLACEMENT     =        0
10-NUMBER OF POSITION ITERATIONS               =       25
11-NUMBER OF OUTERS FOR NEUTRONICS MODULE     =       99
12-RESERVED                                    =        0
13-BURNED CONTROL ROD OPTION                   =        0

***** PARAMETERS FOR CTRLPOS OPTION 30 *****
14-BANK NUMBER FOR CONTROL ROD WORTH CURVE    =        1
15-CONTROL ROD FOR WORTH CURVE                 =        0
16-RESERVED                                    =        0
```

```
***** PARAMETERS FOR CTRLPOS OPTION 40 *****
17-BANK NUMBER FOR ROD/BANK RE-POSITIONING  =       0
18-CONTROL ROD NUMBER FOR RE-POSITIONING    =       0
19-ZONE NUMBER FOR RE-POSITIONING           =       0
20-ZONE BOUNDARY FOR RE-POSITIONING         =       0
21-VENTPLOT PLOT OPTION                     =       0

22-REVERSE CONTROL ROD MOTION OPTION        =       0
23-ATOM DENSITY ARRAY STORAGE OPTION        =       0
24-CONTAINER ARRAY MEMORY OPTION            =       1
25-DEBUG OUTPUT PARAMETER                   =       0

---------------------------------------------------------------------------

---------------------------------------------------------------------------
TOTAL AVAILABLE MEMORY   =    4800000 WORDS.
LOWER MEMORY FOR CTRLPOS =      22615 WORDS.
UPPER MEMORY FOR CTRLPOS =        484 WORDS.
TOTAL MEMORY FOR CTRLPOS =      23099 WORDS.

            EXTRA MEMORY =    4776901 WORDS.
---------------------------------------------------------------------------

BANK # 1      ROD # 1    ATOM DENSITIES

ZONE    2 272174    7.160000D-05 (     1.0000) 272176    2.300920D-03 (     1.0000) 272177    8.223390D-03 (
1.0000)
272178    1.206460D-02 (     1.0000) 272179    6.023680D-03 (     1.0000) 272180    1.551330D-02 (     1.0000)

***** AVERAGE VALUES FOR CONTROL ROD MATERIAL *****
 VOLUME OF CONTROL ROD MATERIAL USED TO CALCULATE ATOM DENSITIES.
272174    7.160000D-05 (     1.0000) 272176    2.300920D-03 (     1.0000) 272177    8.223390D-03 (     1.0000)
272178    1.206460D-02 (     1.0000) 272179    6.023680D-03 (     1.0000) 272180    1.551330D-02 (     1.0000)
---------------------------------------------------------------------------
CONTROL ROD BANK =  1

***** ALL RODS IN BANK WILL BE POSITIONED *****

NUMBER OF POSITIONS =    2

***** ONLY ZONE POSITIONS FOR BANK #    1, ROD #    1 PRINTED HERE *****
NUMBER      ZONE       BOUNDARY           POSITION
   1          2           0           0.000000000D+00
   2          2           1           1.099557419D+02

***** SAVED POSITIONS FOR ALL CONTROL RODS *****
SAVED POSITION -- POSSAV(  1,   1)=     1.009456477D+02


------------------------- TIME IN DAYS        .000 ----------------------------

***** MOVING CONTROL RODS TO POSITIONS FOR WORTH CURVE *****

***** ONLY ZONE POSITIONS FOR BANK #    1, ROD #    1 PRINTED HERE *****

  #  ZONE BNDRY BANK ROD   POSITION       KEFF       DKEFF    DK/VOL   DK0/VOL

  1     2    0     1    1   0.00000D+00  .9630272  .0000000  .0000000  .0000000
  2     2    1     1    1   1.09956D+02 1.1438609  .1716596  .0015612  .0015612

***** OPTION 30 COMPLETE -- CONTROL RODS RE-POSITIONED *****

***** ENDING POSITION FOR ALL CONTROL RODS *****
ENDING POSITION -- POSNOW(  1,   1)=     1.009456477D+02

* TOTAL CPU TIME =     19.90 MINUTES - TOTAL CLOCK TIME =      .00 MINUTES *
***************** NORMAL END OF CONTROL ROD POSITION MODULE ***************
**************************************************************************
```

END OF SAMPLE 2 CTRLPOS OUTPUT

D.3 INPUT AND OUTPUT FOR SAMPLE PROBLEM 3

D.3.1 SAMPLE 3 MCNP INPUT

```
message:    out=cts3v1.o srctp=cts3v1.s runtpe=cts3v1.r
            mctal=cts3v1.m

CTRLPOS Sample Problem 3--Control Rod Study, Case 1
c
1     6 9.994552-2  2 -3 -11 12          $ Outer Core
                          imp:n=1
2     3 1.00032-1  -4 -12 13             $ Water below Core
                          imp:n=1
3     3 1.00032-1  -1 -10 11             $ Water above center core
                          imp:n=1
4     6 9.994552-2  -1 -11 12            $ Center Core
                          imp:n=1
5     3 1.00032-1   3 -4  -11 12         $ Water next to core
                          imp:n=1
6     3 1.00032-1   2 -4 -10 11          $ Water above outer core
                          imp:n=1
7     7 -13.1       1 -2 -11  12         $ Control rod in core
                          imp:n=1
8     3 1.00032-1   1 -2 -10 11          $ Control rod above core
                          imp:n=1
9999  0          10:-13:4                $ Outside World

10   pz      200.        $ Planes
11   pz       50.
12   pz      -50.
13   pz     -200.
c
1    cz      17.0        $ Cylinders
2    cz      18.0
3    cz      35.0
4    cz     100.0
c
c    "Moving Control rod planes" Rod is always 100 cm long.
c
110   pz      -50.0        $ Lower limit
120   pz       50.0        $ Upper limit

c      ***** Fuel *****
c      Material 6--UO2F2-H2O Solution    Total Density= 9.994552-2
c                 H/235U atomic ratio=1270
c
m6     1001.50c  6.6436-2  92238.50c 3.0091-6
       8016.50c  3.3330-2  9019.50c  1.2338-4   92234.50c 5.5020-7
       92235.50c 5.2312-5  92236.50c 2.6950-7
mt6    lwtr.01t
c
c      ***** Reflector *****
c      Material 3--H2O reflector    Total density= 9.984-2
c
m3     1001.50c  0.066644    8016.50c 0.033344
mt3    lwtr.01t
c
c      ***** Control Material *****
c      Material 7--Hf Control Rod    Total density= 4.419755-2
c
m7     72000.50c   1
c
c
kcode   1000 1.0 30 180      $ 1000 particles, 30 settle cycles, 180 total cycles
c
prdmp   180 180 180 1       $ Dump information to files after 180 cycles
c
ksrc    0 0 0               $ Beginning source guess
```

END OF SAMPLE 3 MCNP INPUT

D.3.2 SAMPLE 3 SCALE INPUT

```
=csasn
  CTRLPOS Sample 3 -- Cylindrical Reactor with Control Rod
  99gr     multiregion
  u-235    1 0 5.2312-5  end
  u-238    1 0 3.0091-6  end
  u-234    1 0 5.5020-7  end
  u-236    1 0 2.6950-7  end
  h        1 0 6.6436-2  end
  o        1 0 3.3330-2  end
  f        1 0 1.2338-4  end
  h        2 0 0.066644  end
  o        2 0 0.033344  end
  hf-174   3 0 7.16000-5 end
  hf-176   3 0 2.30092-3 end
  hf-177   3 0 8.22339-3 end
  hf-178   3 0 1.20646-2 end
  hf-179   3 0 6.02368-3 end
  hf-180   3 0 1.55133-2 end
 end comp
 buckledcyl  vacuum  reflected  0. 100. end
 1   17.
 3   18.
 1   35.
 2   100.
 end zone
 more data dab=1000 end
end
=xsdrn_jp
  CTRLPOS Sample 3 -- Cylindrical Reactor with Control Rod
-1$$  1000000
0$$  a3 4 e
1$$  2 5 100 1 0 3 15 8 3 1 10 200 0 0 e
2$$  -2 0 0 0 0 e
3$$  1 0 0 1 e
4$$  0 16 0 -2 3 4 19 e
5**  1.0-4 1.0-4 0 0 0 1.420892 100. e
t
13$$  7r1 6r2 2r3
14$$ 92235 92238 92234 92236 1001 8016 9019
     72174 72176 72177 72178 72179 72180
     201001 208016
15**  5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      7.16000-5  2.30092-3  8.22339-3 1.20646-2  6.02368-3  1.55133-2
      0.066644 0.033344
t
34##  17r1.0 10r0.0 16r1.0 57r0.0
t
35**  16i0. 9i17. 15i18. 56i35. 100.
36$$  17r1 10r2 16r3 27r4  30r5
39$$  1 2 1 3 3
51$$ 10r1 10r2  5r3 5r4 5r5 5r6 5r7 5r8 5r9 5r10 5r11 5r12
     7r13 4r14 5r15 13r16
t
end
=xsdrn_jp
  CTRLPOS Sample 3 -- Cylindrical Reactor with Control Rod
-1$$  1000000
0$$  a3 3 20 30 e
1$$  2 5 100 1 0 5 24 8 3 1 10 200 0 0 e
2$$  -2 0 0 0 0 e
3$$  1 0 0 1  e
4$$  0 4 0 -2 3 4 7 e
5**  1.0-4 1.0-4 0 0 0 1.420892 100. e
t
13$$ 7r1 6r2 7r3 2r4 2r5
```

```
14$$ 192235 192238 192234 192236 11001 18016 19019
     272174 272176 272177 272178 272179 272180
     392235 392238 392234 392236 31001 38016 39019
     4201001 4208016
     5201001 5208016
15**  5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      7.16000-5  2.30092-3  8.22339-3 1.20646-2  6.02368-3  1.55133-2
      5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      0.066644 0.033344
      0.066644 0.033344
t
34##  17r1.0 10r0.0 16r1.0 57r0.0
t
35**  16i0. 9i17. 15i18. 56i35. 100.
36$$  17r1 10r2 16r3 27r4  30r5
39$$  1 2 3 4 5
51$$  5r1 4r2 4r3 3r4
t
end
=xsdrn_jp
  CTRLPOS Sample 3 -- Cylindrical Reactor with Control Rod
-1$$  1000000
0$$  a3 30 20 29 e
1$$  2 5 100 1 0 5 24 8 3 1 10 200 0 0 e
2$$  -2 0 0 0 0 e
3$$  1 0 0 1  e
4$$  0 4 20 -2 24 4 7 -1 e
5**  1.0-4 1.0-4 0 0 0 1.420892 100. e
t
13$$ 7r1 6r2 7r3 2r4 2r5
14$$ 1192235 1192238 1192234 1192236 111001 118016 119019
     2272174 2272176 2272177 2272178 2272179 2272180
     3392235 3392238 3392234 3392236 331001 338016 339019
     44201001 44208016
     55201001 55208016
15**  5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      7.16000-5  2.30092-3  8.22339-3 1.20646-2  6.02368-3  1.55133-2
      5.2312-5 3.0091-6 5.5020-7 2.6950-7 6.6436-2 3.3330-2
      1.2338-4
      0.066644 0.033344
      0.066644 0.033344
16$$ 11192235 11192238 11192234 11192236 1111001 1118016 1119019
     22272174 22272176 22272177 22272178 22272179 22272180
     33392235 33392238 33392234 33392236 3331001 3338016 3339019
     444201001 444208016
     555201001 555208016
18## 6h192235 6h192238 6h192234 6h192236 6h 11001 6h 18016
     6h 19019
     6h272174 6h272176 6h272177 6h272178 6h272179 6h272180
     6h392235 6h392238 6h392234 6h392236 6h 31001 6h 38016
     6h 39019
     6h 41001 6h 48016
     6h 51001 6h 58016
t
34##  17r1.0 10r0.0 16r1.0 57r0.0
t
35**  16i0. 9i17. 15i18. 56i35. 100.
36$$  17r1 10r2 16r3 27r4  30r5
39$$  1 2 3 4 5
51$$  1 2 3 4
t
end
```

END OF SAMPLE 3 SCALE INPUT

D.3.3 SAMPLE 3 VENTURE/CTRLPOS INPUT

```
=CONTROL1
CTRLPOS Sample Problem 3 -- R-Z Model with Hf Rod
'00000000111111111122222222223333333333444444444455555555556666666666777777777778
'23456789012345678901234567890123456789012345678901234567890123456789012345678890
800000    04                             1                    1
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99 99
 0
  ISOTXS
END                                                                     00000670
DCRSPR
'2345678901234567890123456789012345678901234567890123456789012345678890
        1  1        1  1                                            0  0
             24              1
192235 92235             235.         3.236  -11                1
392235 92235             235.         3.236  -11                1
192234 92234             234.         3.19   -11                1
392234 92234             234.         3.19   -11                1
192236 92236             236.         3.26   -11                3
392236 92236             236.         3.26   -11                3
192238 92238             238.         3.31   -11                2
392238 92238             238.         3.31   -11                2
 11001   1001              1.                                   6
 31001   1001              1.                                   6
 41001   1001              1.                                   6
 51001   1001              1.                                   6
 18016   8016             16.                                   6
 38016   8016             16.                                   6
 48016   8016             16.                                   6
 58016   8016             16.                                   6
 19019   9019             19.                                   6
 39019   9019             19.                                   6
272174 72174             174.                                   7
272176 72176             176.                                   7
272177 72177             177.                                   7
272178 72178             178.                                   7
272179 72179             179.                                   7
272180 72180             180.                                   7
END
CROSPROS
END
DVENTR                                                    " *** 2 = DVENTR
001                                                                     CARD 1
                                         1.00+1     1.00      1.0       CARD 2
                                                                        CARD 3
                                                                        CARD 4
'01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  2  0  0  0  0                 100     0           1                   CARD 5
'01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  1  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0  1  1  1        0  0   CARD 6
002                                                                     CARD 1
                                                                        CARD 2
                                   0                      00            CARD 3
                                                                        CARD 4
 0.0                                               .0645                CARD 5
 0.0                                                         2.09 -05   CARD 6
003
'01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  7  1  2  2  2                0
004
'000000001111111111222222222233333333334444444444555555555566666666667777
'234567890123456789012345678901234567890123456789012345678901234567890123456789012
```

```
20  10.0000 21   7.0000 15   1.0000 21   7.0000 20  10.0000 14  25.0000
15  30.0000 00  0.00000
I ***
25  50.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000  4  2.00000
 4   2.0000  4   2.0000  4   2.0000  4   2.0000  4   2.0000 25 50.00000
50 100.0000  0   0.0000
005
 5  5  5  5  5  5  5
 5  5101  5  5  5  5
 5  5102  5  5  5  5
 5  5103  5  5  5  5
 5  5104  5  5  5  5
 5  5105  5  5  5  5
 5  5106  5  5  5  5
 5  5107  5  5  5  5
 5  5108  5  5  5  5
 5  5109  5  5  5  5
 5  5110  5  5  5  5
 5  5111  5  5  5  5
 5  5112  5  5  5  5
 5  5113  5  5  5  5
 5  5114  5  5  5  5
 5  5115  5  5  5  5
 5  5116  5  5  5  5
 5  5117  5  5  5  5
 5  5118  5  5  5  5
 5  5119  5  5  5  5
 5  5120  5  5  5  5
 5  5121  5  5  5  5
 5  5122  5  5  5  5
 5  5123  5  5  5  5
 5  5124  5  5  5  5
 5  5125  5  5  5  5
 4  4126  4  4  4  5
 4  4127  4  4  4  5
 4  4128  4  4  4  5
 4  4129  4  4  4  5
 4  4130  4  4  4  5
 4  4131  4  4  4  5
 4  4132  4  4  4  5
 4  4133  4  4  4  5
 4  4134  4  4  4  5
 4  4135  4  4  4  5
 4  4136  4  4  4  5
 4  4137  4  4  4  5
 4  4138  4  4  4  5
 4  4139  4  4  4  5
 4  4140  4  4  4  5
 4  4141  4  4  4  5
 4  4142  4  4  4  5
 4  4143  4  4  4  5
 4  4144  4  4  4  5
 4  4145  4  4  4  5
 4  4146  4  4  4  5
```

```
   4  4147  4  4  4  5
   4  4148  4  4  4  5
   4  4149  4  4  4  5
   4  4150  4  4  4  5
   1  1151  3  3  4  5
   1  1152  3  3  4  5
   1  1153  3  3  4  5
   1  1154  3  3  4  5
   1  1155  3  3  4  5
   1  1156  3  3  4  5
   1  1157  3  3  4  5
   1  1158  3  3  4  5
   1  1159  3  3  4  5
   1  1160  3  3  4  5
   1  1161  3  3  4  5
   1  1162  3  3  4  5
   1  1163  3  3  4  5
   1  1164  3  3  4  5
   1  1165  3  3  4  5
   1  1166  3  3  4  5
   1  1167  3  3  4  5
   1  1168  3  3  4  5
   1  1169  3  3  4  5
   1  1170  3  3  4  5
   1  1171  3  3  4  5
   1  1172  3  3  4  5
   1  1173  3  3  4  5
   1  1174  3  3  4  5
   1  1175  3  3  4  5
   1  1176  3  3  4  5
   1  1177  3  3  4  5
   1  1178  3  3  4  5
   1  1179  3  3  4  5
   1  1180  3  3  4  5
   1  1181  3  3  4  5
   1  1182  3  3  4  5
   1  1183  3  3  4  5
   1  1184  3  3  4  5
   1  1185  3  3  4  5
   1  1186  3  3  4  5
   1  1187  3  3  4  5
   1  1188  3  3  4  5
   1  1189  3  3  4  5
   1  1190  3  3  4  5
   1  1191  3  3  4  5
   1  1192  3  3  4  5
   1  1193  3  3  4  5
   1  1194  3  3  4  5
   1  1195  3  3  4  5
   1  1196  3  3  4  5
   1  1197  3  3  4  5
   1  1198  3  3  4  5
   1  1199  3  3  4  5
   1  1200  3  3  4  5
   4  4  4  4  4  4  5
   5  5  5  5  5  5  5
012
  0
                                                                                  BLANK
013
 24
 24
'   ID      O  IINV   IHE   ILI  IB10   B11   IAL   ICR   IMN   IFE   INI
192235392235192234392234192236392236192238392238 11001 31001 41001 51001
 18016 38016 48016 58016 19019 390192721742721762721772721782721792721 80
020
  1  1
192235 5.23120E-05192238 3.00910E-06192234 5.50200E-07192236 2.69500E-07
 11001 6.64360E-02 18016 3.33300E-02 19019 1.23380E-04
```

```
151200
272174 7.16000E-05272176 2.30092E-03272177 8.22339E-03272178 1.20646E-02
272179 6.02368E-03272180 1.55133E-02
  3  3
392235 5.23120E-05392238 3.00910E-06392234 5.50200E-07392236 2.69500E-07
 31001 6.64360E-02 38016 3.33300E-02 39019 1.23380E-04
126150
 41001 6.66440E-02 48016 3.33440E-02
  4  4
 41001 6.66440E-02 48016 3.33440E-02
101125
 51001 6.66440E-02 58016 3.33440E-02
  5  5
 51001 6.66440E-02 58016 3.33440E-02
  0  0
END
VENTNEUT
END
DUTLIN
DTNINS         0 30  0 96  1
'000000001111111111222222222233333333334444444444555555555566666666667777777778
'2345678901234567890123456789012345678901234567890123456789012345678901234567890
                                             10.         1.0         1.0


                                                      6.45-2
                                                                  2.09-5
' 1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
     0  0  2  0  0     0  2                    0  0  1  0 10  0  0  0  0
'25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
     0  0  0  0  0     1  0                    0  0  0  0 00  0  0  0  0
'49 40 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72
        1  1  1  1
  1
END
'*****  Option 5 used to define CTRLPOS output file name
DUTLIN
CTRLCF         0 6   0 24  1
'-----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000      0.0010      1000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
  5  0  0  2  0  1  0  0  0 10 35  1  0  1  0  0  0  0  0  0  0  0  0  0
END
CTRLPOS
'*****  File name for CTRLPOS output
ctrls3.out.1
END
'*****  Option 10 used to read in CTRLPOS data
DUTLIN
CTRLCF         0 6   0 24  1
'-----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
       1.000      0.0010      1000.0      5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 10  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'*****  CTRLPOS DATA FOR SAMPLE PROBLEM  3.
'*****  The 'control rod' zones start with zone 200 and end with zone 101.
'*****   The first position guess is the upper boundary of zone 125 while the
'*****   tip of the control rod starts at zone 200. The limits of control rod
'*****   rod motion are the upper boundary of zone 101 and the lower boundary
'*****   of zone 200.  Zone 4 will be the follower for the control rod zones
'*****   in the core and just above the core.  Far above the core the follower
'*****   is the material in zone 5.  Control rod material is in zones
'*****   200-151 at the start of the process.
CTRLPOS
begin-input
begin-bank
begin-rod
200,0,125,1
```

```
101,1,200,0
begin-zone
200,4,1
199,4,1
198,4,1
197,4,1
196,4,1
195,4,1
194,4,1
193,4,1
192,4,1
191,4,1
190,4,1
189,4,1
188,4,1
187,4,1
186,4,1
185,4,1
184,4,1
183,4,1
182,4,1
181,4,1
180,4,1
179,4,1
178,4,1
177,4,1
176,4,1
175,4,1
174,4,1
173,4,1
172,4,1
171,4,1
170,4,1
169,4,1
168,4,1
167,4,1
166,4,1
165,4,1
164,4,1
163,4,1
162,4,1
161,4,1
160,4,1
159,4,1
158,4,1
157,4,1
156,4,1
155,4,1
154,4,1
153,4,1
152,4,1
151,4,1
150,4,0
149,4,0
148,4,0
147,4,0
146,4,0
145,4,0
144,4,0
143,4,0
142,4,0
141,4,0
140,4,0
139,4,0
138,4,0
137,4,0
136,4,0
135,4,0
134,4,0
```

```
133,4,0
132,4,0
131,4,0
130,4,0
129,4,0
128,4,0
127,4,0
126,4,0
125,4,0
124,5,0
123,5,0
122,5,0
121,5,0
120,5,0
119,5,0
118,5,0
117,5,0
116,5,0
115,5,0
114,5,0
113,5,0
112,5,0
111,5,0
110,5,0
109,5,0
108,5,0
107,5,0
106,5,0
105,5,0
104,5,0
103,5,0
102,5,0
101,5,0
end-zone
end-rod
end-bank
end-input
END
'*****  Option 20 used to perform a keff position search
DUTLIN
CTRLCF          0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
      0.970       0.0010        1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 20  0  0  2  0  1  1  0  0 25 99  0  0  0  0  0  0  0  0  0  0  0  0  1
END
'CTRLPOS
'END
'*****  Option 30 used to calculate a control rod worth curve
DUTLIN
CTRLCF          0 6   0 24   1
'----1-----|-----2-----|-----3-----|-----4-----|-----5-----|-----6-----|
      0.950       0.0010        1000.0       5000.0
'-1--2--3--4--5--6--7--8--9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24
 30  0  0  2  0  1  1  0  0 25 99  0  0  1  0  0  0  0  0  0  0  0  0  1
END
CTRLPOS
begin-input
200,0
200,1
199,1
198,1
'197,1
196,1
'195,1
'194,1
'193,1
192,1
'191,1
```

```
'190,1
'189,1
188,1
'187,1
'186,1
'185,1
184,1
'183,1
'182,1
'181,1
180,1
'179,1
'178,1
'177,1
176,1
'175,1
'174,1
'173,1
172,1
'171,1
'170,1
'169,1
168,1
'167,1
'166,1
'165,1
164,1
'163,1
'162,1
'161,1
160,1
'159,1
'158,1
'157,1
156,1
'155,1
154,1
153,1
152,1
151,1
end-input
END
```

END OF SAMPLE 3 VENTURE/CTRLPOS INPUT

D.3.4 SAMPLE 3 CTRLPOS OUTPUT

```
******************************************************************************
*** CTRLPOS - CONTROL ROD POSITION MODULE - VERSION 1 - OCTOBER 1, 1992 ***

                          ***** CTRLPOS OPTION 10 *****
----------------------------------------------------------------------------

----------------------------------------------------------------------------
***** CONTENTS OF *CTRLCF* CONTROL FILE *****

XX( 1- 4)  * 1.000000D+00* 1.000000D-03* 1.000000D+03* 5.000000D+03*
IX( 1- 5)  *     10*      0*      0*      2*      0*
IX( 6-10)  *      1*      1*      0*      0*     25*
IX(11-15)  *     99*      0*      0*      0*      0*
IX(16-20)  *      0*      0*      0*      0*      0*
IX(21-25)  *      0*      0*      0*      1*      0*

 1-TARGET KEFF VALUE                         =  1.000000D+00
 2-ALLOWED KEFF TOLERANCE                    =  1.000000D-03
 3-MAXIMUM VALUE FOR CONTROL ROD MOVEMENT =     1.000D+03
 4-MAXIMUM NUMBER OF ATOM DENSITY VALUES (IF IX(23).NE.0) =       5000

 1-CTRLPOS OPTION NUMBER                     =      10
 2-NEUTRONICS MODULE                         =       0
 3-INTERPOLATION SCHEME                      =       0
 4-NUMBER OF POINTS IN SCHEME                =       2
 5-STORAGE OF KEFF VALUES                    =       0
 6-CONTROL RODS FOR KEFF SEARCH              =       1
 7-PRINT OUT OF ATOM DENSITIES               =       1
 8-PRINT OUT ATOM DENSITIES AT EACH POSITION =       0
 9-CONTROL ROD TIP PARTIAL ZONE PLACEMENT    =       0
10-NUMBER OF POSITION ITERATIONS             =      25
11-NUMBER OF OUTERS FOR NEUTRONICS MODULE    =      99
12-RESERVED                                  =       0
13-BURNED CONTROL ROD OPTION                 =       0

***** PARAMETERS FOR CTRLPOS OPTION 30 *****
14-BANK NUMBER FOR CONTROL ROD WORTH CURVE   =       0
15-CONTROL ROD FOR WORTH CURVE               =       0
16-RESERVED                                  =       0

***** PARAMETERS FOR CTRLPOS OPTION 40 *****
17-BANK NUMBER FOR ROD/BANK RE-POSITIONING   =       0
18-CONTROL ROD NUMBER FOR RE-POSITIONING     =       0
19-ZONE NUMBER FOR RE-POSITIONING            =       0
20-ZONE BOUNDARY FOR RE-POSITIONING          =       0
21-VENTPLOT PLOT OPTION                      =       0

22-REVERSE CONTROL ROD MOTION OPTION         =       0
23-ATOM DENSITY ARRAY STORAGE OPTION         =       0
24-CONTAINER ARRAY MEMORY OPTION             =       1
25-DEBUG OUTPUT PARAMETER                    =       0

----------------------------------------------------------------------------

----------------------------------------------------------------------------
BANK #   1 HAS    1 RODS.

NUMBER OF CONTROL ROD BANKS =    1

BANK #   1 ROD #   1 HAS 100 ZONES AND    0 PRODUCTION CHAINS.

BANK #   1 ROD #   1 CHAIN #   0 HAS    0 PRODUCED ISOTOPES.
----------------------------------------------------------------------------

----------------------------------------------------------------------------
TOTAL AVAILABLE MEMORY   =     4800000 WORDS.
```

```
LOWER MEMORY FOR CTRLPOS =      103395 WORDS.
UPPER MEMORY FOR CTRLPOS =       29800 WORDS.
TOTAL MEMORY FOR CTRLPOS =      133195 WORDS.

            EXTRA MEMORY =    4666805 WORDS.
----------------------------------------------------------------------

BANK # 1       ROD #  1
CONTROL ROD TIP IS LOWER BOUNDARY OF ZONE   200
FIRST GUESS POSITION IS UPPER BOUNDARY OF ZONE   125
UPPER CONTROL ROD LIMIT IS UPPER BOUNDARY OF ZONE   101
LOWER CONTROL ROD LIMIT IS LOWER BOUNDARY OF ZONE   200



----------------------------------------------------------------------
***** INFORMATION ON MEMORY REQUIREMENTS FOR ATOM DENSITY ARRAYS *****

MAXIMUM NUMBER OF ATOM DENSITY VALUES POSSIBLE =      11200.
NOTE *** THIS VALUE DOES NOT ACCOUNT FOR THE PRODUCTION
         OF NEW ISOTOPES IN THE FOLLOWER MATERIAL ***
TOTAL MEMORY REQUIRED FOR IX(23).EQ.0     =      133195 WORDS.
TOTAL MEMORY REQUIRED FOR IX(23).NE.0     =      287785 WORDS.

IX(23).EQ.0 OPTION SAVES     154590 WORDS OF MEMORY.
YOU ARE USING BEST OPTION TO SAVE MEMORY.
----------------------------------------------------------------------

BANK # 1   ROD # 1     NUMBER OF ZONES =    100
```

	CONTROL ROD ZONE NUMBER	FOLLOWER ZONE NUMBER	CONTROL ROD ZONE VOLUME	FOLLOWER ZONE VOLUME	TOTAL ZONE VOLUME	ROD FLAG
1	200	4	2.19911D+02	1.87160D+06	2.19911D+02	1
2	199	4	2.19911D+02	1.87160D+06	4.39823D+02	1
3	198	4	2.19911D+02	1.87160D+06	6.59734D+02	1
4	197	4	2.19911D+02	1.87160D+06	8.79646D+02	1
5	196	4	2.19911D+02	1.87160D+06	1.09956D+03	1
6	195	4	2.19911D+02	1.87160D+06	1.31947D+03	1
7	194	4	2.19911D+02	1.87160D+06	1.53938D+03	1
8	193	4	2.19911D+02	1.87160D+06	1.75929D+03	1
9	192	4	2.19911D+02	1.87160D+06	1.97920D+03	1
10	191	4	2.19911D+02	1.87160D+06	2.19911D+03	1
11	190	4	2.19911D+02	1.87160D+06	2.41903D+03	1
12	189	4	2.19911D+02	1.87160D+06	2.63894D+03	1
13	188	4	2.19911D+02	1.87160D+06	2.85885D+03	1
14	187	4	2.19911D+02	1.87160D+06	3.07876D+03	1
15	186	4	2.19911D+02	1.87160D+06	3.29867D+03	1
16	185	4	2.19911D+02	1.87160D+06	3.51858D+03	1
17	184	4	2.19911D+02	1.87160D+06	3.73850D+03	1
18	183	4	2.19911D+02	1.87160D+06	3.95841D+03	1
19	182	4	2.19911D+02	1.87160D+06	4.17832D+03	1
20	181	4	2.19911D+02	1.87160D+06	4.39823D+03	1
21	180	4	2.19911D+02	1.87160D+06	4.61814D+03	1
22	179	4	2.19911D+02	1.87160D+06	4.83805D+03	1
23	178	4	2.19911D+02	1.87160D+06	5.05796D+03	1
24	177	4	2.19911D+02	1.87160D+06	5.27788D+03	1
25	176	4	2.19911D+02	1.87160D+06	5.49779D+03	1
26	175	4	2.19911D+02	1.87160D+06	5.71770D+03	1
27	174	4	2.19911D+02	1.87160D+06	5.93761D+03	1
28	173	4	2.19911D+02	1.87160D+06	6.15752D+03	1
29	172	4	2.19911D+02	1.87160D+06	6.37743D+03	1
30	171	4	2.19911D+02	1.87160D+06	6.59734D+03	1
31	170	4	2.19911D+02	1.87160D+06	6.81726D+03	1
32	169	4	2.19911D+02	1.87160D+06	7.03717D+03	1
33	168	4	2.19911D+02	1.87160D+06	7.25708D+03	1
34	167	4	2.19911D+02	1.87160D+06	7.47699D+03	1
35	166	4	2.19911D+02	1.87160D+06	7.69690D+03	1
36	165	4	2.19911D+02	1.87160D+06	7.91681D+03	1
37	164	4	2.19911D+02	1.87160D+06	8.13672D+03	1
38	163	4	2.19911D+02	1.87160D+06	8.35664D+03	1

39	162	4	2.19911D+02	1.87160D+06	8.57655D+03	1
40	161	4	2.19911D+02	1.87160D+06	8.79646D+03	1
41	160	4	2.19911D+02	1.87160D+06	9.01637D+03	1
42	159	4	2.19911D+02	1.87160D+06	9.23628D+03	1
43	158	4	2.19911D+02	1.87160D+06	9.45619D+03	1
44	157	4	2.19911D+02	1.87160D+06	9.67611D+03	1
45	156	4	2.19911D+02	1.87160D+06	9.89602D+03	1
46	155	4	2.19911D+02	1.87160D+06	1.01159D+04	1
47	154	4	2.19911D+02	1.87160D+06	1.03358D+04	1
48	153	4	2.19911D+02	1.87160D+06	1.05558D+04	1
49	152	4	2.19911D+02	1.87160D+06	1.07757D+04	1
50	151	4	2.19911D+02	1.87160D+06	1.09956D+04	1
51	150	4	2.19911D+02	1.87160D+06	1.12155D+04	0
52	149	4	2.19911D+02	1.87160D+06	1.14354D+04	0
53	148	4	2.19911D+02	1.87160D+06	1.16553D+04	0
54	147	4	2.19911D+02	1.87160D+06	1.18752D+04	0
55	146	4	2.19911D+02	1.87160D+06	1.20951D+04	0
56	145	4	2.19911D+02	1.87160D+06	1.23150D+04	0
57	144	4	2.19911D+02	1.87160D+06	1.25350D+04	0
58	143	4	2.19911D+02	1.87160D+06	1.27549D+04	0
59	142	4	2.19911D+02	1.87160D+06	1.29748D+04	0
60	141	4	2.19911D+02	1.87160D+06	1.31947D+04	0
61	140	4	2.19911D+02	1.87160D+06	1.34146D+04	0
62	139	4	2.19911D+02	1.87160D+06	1.36345D+04	0
63	138	4	2.19911D+02	1.87160D+06	1.38544D+04	0
64	137	4	2.19911D+02	1.87160D+06	1.40743D+04	0
65	136	4	2.19911D+02	1.87160D+06	1.42942D+04	0
66	135	4	2.19911D+02	1.87160D+06	1.45142D+04	0
67	134	4	2.19911D+02	1.87160D+06	1.47341D+04	0
68	133	4	2.19911D+02	1.87160D+06	1.49540D+04	0
69	132	4	2.19911D+02	1.87160D+06	1.51739D+04	0
70	131	4	2.19911D+02	1.87160D+06	1.53938D+04	0
71	130	4	2.19911D+02	1.87160D+06	1.56137D+04	0
72	129	4	2.19911D+02	1.87160D+06	1.58336D+04	0
73	128	4	2.19911D+02	1.87160D+06	1.60535D+04	0
74	127	4	2.19911D+02	1.87160D+06	1.62734D+04	0
75	126	4	2.19911D+02	1.87160D+06	1.64934D+04	0
76	125	4	2.19911D+02	1.87160D+06	1.67133D+04	0
77	124	5	2.19911D+02	7.91131D+06	1.69332D+04	0
78	123	5	2.19911D+02	7.91131D+06	1.71531D+04	0
79	122	5	2.19911D+02	7.91131D+06	1.73730D+04	0
80	121	5	2.19911D+02	7.91131D+06	1.75929D+04	0
81	120	5	2.19911D+02	7.91131D+06	1.78128D+04	0
82	119	5	2.19911D+02	7.91131D+06	1.80327D+04	0
83	118	5	2.19911D+02	7.91131D+06	1.82527D+04	0
84	117	5	2.19911D+02	7.91131D+06	1.84726D+04	0
85	116	5	2.19911D+02	7.91131D+06	1.86925D+04	0
86	115	5	2.19911D+02	7.91131D+06	1.89124D+04	0
87	114	5	2.19911D+02	7.91131D+06	1.91323D+04	0
88	113	5	2.19911D+02	7.91131D+06	1.93522D+04	0
89	112	5	2.19911D+02	7.91131D+06	1.95721D+04	0
90	111	5	2.19911D+02	7.91131D+06	1.97920D+04	0
91	110	5	2.19911D+02	7.91131D+06	2.00119D+04	0
92	109	5	2.19911D+02	7.91131D+06	2.02319D+04	0
93	108	5	2.19911D+02	7.91131D+06	2.04518D+04	0
94	107	5	2.19911D+02	7.91131D+06	2.06717D+04	0
95	106	5	2.19911D+02	7.91131D+06	2.08916D+04	0
96	105	5	2.19911D+02	7.91131D+06	2.11115D+04	0
97	104	5	2.19911D+02	7.91131D+06	2.13314D+04	0
98	103	5	2.19911D+02	7.91131D+06	2.15513D+04	0
99	102	5	2.19911D+02	7.91131D+06	2.17712D+04	0
100	101	5	2.19911D+02	7.91131D+06	2.19911D+04	0

------------------------ TIME IN DAYS .000 ---------------------------

BANK # 1 ROD # 1 ATOM DENSITIES

ZONE 200 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 199 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 198 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 197 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 196 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 195 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 194 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 193 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 192 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 191 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 190 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 189 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 188 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 187 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 186 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 185 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 184 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 183 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 182 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 181 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 180 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 179 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 178 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)

ZONE 177 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 176 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 175 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 174 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 173 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 172 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 171 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 170 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 169 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 168 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 167 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 166 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 165 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 164 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 163 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 162 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 161 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 160 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 159 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 158 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 157 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 156 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)
ZONE 155 272174 7.1600000D-05 (1.0000) 272176 2.3009200D-03 (1.0000) 272177 8.2233900D-03 (
1.0000)
272178 1.2064600D-02 (1.0000) 272179 6.0236800D-03 (1.0000) 272180 1.5513300D-02 (1.0000)

```
ZONE  154 272174    7.160000D-05 (     1.0000) 272176    2.300920D-03 (     1.0000) 272177    8.223390D-03 (
1.0000)
 272178   1.206460D-02 (     1.0000) 272179    6.023680D-03 (     1.0000) 272180    1.551330D-02 (     1.0000)
 ZONE  153 272174    7.160000D-05 (     1.0000) 272176    2.300920D-03 (     1.0000) 272177    8.223390D-03 (
1.0000)
 272178   1.206460D-02 (     1.0000) 272179    6.023680D-03 (     1.0000) 272180    1.551330D-02 (     1.0000)
 ZONE  152 272174    7.160000D-05 (     1.0000) 272176    2.300920D-03 (     1.0000) 272177    8.223390D-03 (
1.0000)
 272178   1.206460D-02 (     1.0000) 272179    6.023680D-03 (     1.0000) 272180    1.551330D-02 (     1.0000)
 ZONE  151 272174    7.160000D-05 (     1.0000) 272176    2.300920D-03 (     1.0000) 272177    8.223390D-03 (
1.0000)
 272178   1.206460D-02 (     1.0000) 272179    6.023680D-03 (     1.0000) 272180    1.551330D-02 (     1.0000)
 ZONE  150  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  149  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  148  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  147  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  146  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  145  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  144  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  143  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  142  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  141  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  140  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  139  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  138  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  137  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  136  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  135  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  134  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  133  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  132  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  131  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  130  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  129  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  128  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  127  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  126  41001    6.664400D-02 (     1.0000)  48016    3.334400D-02 (     1.0000)
 ZONE  125  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  124  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  123  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  122  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  121  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  120  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  119  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  118  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  117  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  116  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  115  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  114  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  113  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  112  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  111  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  110  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  109  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  108  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  107  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  106  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  105  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  104  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  103  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  102  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)
 ZONE  101  51001    6.664400D-02 (     1.0000)  58016    3.334400D-02 (     1.0000)

***** AVERAGE VALUES FOR CONTROL ROD MATERIAL *****
 VOLUME OF CONTROL ROD MATERIAL USED TO CALCULATE ATOM DENSITIES.
272174   7.160000D-05 (     1.0000) 272176   2.300920D-03 (     1.0000) 272177   8.223390D-03 (     1.0000)
272178   1.206460D-02 (     1.0000) 272179   6.023680D-03 (     1.0000) 272180   1.551330D-02 (     1.0000)
--------------------------------------------------------------------------------
```

```
***** STARTING POSITIONS FOR ALL CONTROL RODS *****
STARTING POSITION -- POSNOW(  1,   1)=    0.0000000000D+00

***** KEFF AT STARTING POSITION =      .9590846


***** FIRST GUESS POSITIONS FOR MOVING CONTROL RODS *****
FIRST GUESS POSITION -- POSNOW(  1,   1)=    1.6713272770D+04

***** KEFF AT FIRST GUESS POSITION =    1.1122112

--------------------------------------------------------------------------
ITERATION #  0 -- AT THE CURRENT POSITION KEFF =     1.1122112
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1           1.6713272770D+04                    4.4657852260D+03

--------------------------------------------------------------------------
ITERATION #  1 -- AT THE CURRENT POSITION KEFF =     1.0577382
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1           4.4657852260D+03                    1.8521320180D+03

--------------------------------------------------------------------------
ITERATION #  2 -- AT THE CURRENT POSITION KEFF =      .9727853
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1           1.8521320180D+03                    2.6894172170D+03

--------------------------------------------------------------------------
ITERATION #  3 -- AT THE CURRENT POSITION KEFF =     1.0041287
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1           2.6894172170D+03                    2.5791262310D+03

--------------------------------------------------------------------------
ITERATION #  4 -- AT THE CURRENT POSITION KEFF =      .9973702
***** TWO POINT LAGRANGE INTERPOLATION USED TO DETERMINE NEW POSITION *****

BANK    ROD      **** CURRENT POSITION ****      **** NEW PREDICTED POSITION ****
  1       1           2.5791262310D+03                    2.6220417580D+03

--------------------------------------------------------------------------
ITERATION #  5 -- AT THE CURRENT POSITION KEFF =     1.0002433

***** CONTROL RODS WERE SUCCESSFUL POSITIONED TO THE TARGET KEFF VALUE *****


***** ENDING POSITION FOR ALL CONTROL RODS *****
ENDING POSITION -- POSNOW(  1,   1)=    2.6220417580D+03

* TOTAL CPU TIME =   315.21 MINUTES - TOTAL CLOCK TIME =       .00 MINUTES *
****************** NORMAL END OF CONTROL ROD POSITION MODULE ****************
*****************************************************************************

*****************************************************************************
*** CTRLPOS - CONTROL ROD POSITION MODULE - VERSION 1 - OCTOBER 1, 1992 ***

                         ***** CTRLPOS OPTION 30 *****
--------------------------------------------------------------------------

--------------------------------------------------------------------------
***** CONTENTS OF *CTRLCF* CONTROL FILE *****

XX( 1- 4)  * 9.500000D-01* 1.000000D-03* 1.000000D+03* 5.000000D+03*
```

```
IX( 1- 5)  *    30*     0*     0*     2*     0*
IX( 6-10)  *     1*     1*     0*     0*    25*
IX(11-15)  *    99*     0*     0*     1*     0*
IX(16-20)  *     0*     0*     0*     0*     0*
IX(21-25)  *     0*     0*     0*     1*     0*

 1-TARGET KEFF VALUE                          =  9.500000D-01
 2-ALLOWED KEFF TOLERANCE                     =  1.000000D-03
 3-MAXIMUM VALUE FOR CONTROL ROD MOVEMENT =     1.000+03
 4-MAXIMUM NUMBER OF ATOM DENSITY VALUES (IF IX(23).NE.0) =       5000

 1-CTRLPOS OPTION NUMBER                      =      30
 2-NEUTRONICS MODULE                          =       0
 3-INTERPOLATION SCHEME                       =       0
 4-NUMBER OF POINTS IN SCHEME                 =       2
 5-STORAGE OF KEFF VALUES                     =       0
 6-CONTROL RODS FOR KEFF SEARCH               =       1
 7-PRINT OUT OF ATOM DENSITIES                =       1
 8-PRINT OUT ATOM DENSITIES AT EACH POSITION =        0
 9-CONTROL ROD TIP PARTIAL ZONE PLACEMENT   =       0
10-NUMBER OF POSITION ITERATIONS             =      25
11-NUMBER OF OUTERS FOR NEUTRONICS MODULE   =      99
12-RESERVED                                  =       0
13-BURNED CONTROL ROD OPTION                 =       0

***** PARAMETERS FOR CTRLPOS OPTION 30 *****
14-BANK NUMBER FOR CONTROL ROD WORTH CURVE  =       1
15-CONTROL ROD FOR WORTH CURVE               =       0
16-RESERVED                                  =       0

***** PARAMETERS FOR CTRLPOS OPTION 40 *****
17-BANK NUMBER FOR ROD/BANK RE-POSITIONING  =       0
18-CONTROL ROD NUMBER FOR RE-POSITIONING    =       0
19-ZONE NUMBER FOR RE-POSITIONING            =       0
20-ZONE BOUNDARY FOR RE-POSITIONING          =       0
21-VENTPLOT PLOT OPTION                      =       0

22-REVERSE CONTROL ROD MOTION OPTION         =       0
23-ATOM DENSITY ARRAY STORAGE OPTION         =       0
24-CONTAINER ARRAY MEMORY OPTION             =       1
25-DEBUG OUTPUT PARAMETER                    =       0

--------------------------------------------------------------------------

--------------------------------------------------------------------------
TOTAL AVAILABLE MEMORY   =     4800000 WORDS.
LOWER MEMORY FOR CTRLPOS =      103395 WORDS.
UPPER MEMORY FOR CTRLPOS =       29800 WORDS.
TOTAL MEMORY FOR CTRLPOS =      133195 WORDS.

           EXTRA MEMORY =     4666805 WORDS.
--------------------------------------------------------------------------

BANK # 1     ROD # 1    ATOM DENSITIES

ZONE  200 272174    7.1600000D-05 (     1.0000) 272176    2.3009200-03 (     1.0000) 272177    8.2233900-03 (
1.0000)
272178   1.2064600-02 (     1.0000) 272179   6.0236800-03 (     1.0000) 272180   1.5513300-02 (     1.0000)
ZONE  199 272174    7.1600000D-05 (     1.0000) 272176    2.3009200-03 (     1.0000) 272177    8.2233900-03 (
1.0000)
272178   1.2064600-02 (     1.0000) 272179   6.0236800-03 (     1.0000) 272180   1.5513300-02 (     1.0000)
ZONE  198 272174    7.1600000D-05 (     1.0000) 272176    2.3009200-03 (     1.0000) 272177    8.2233900-03 (
1.0000)
272178   1.2064600-02 (     1.0000) 272179   6.0236800-03 (     1.0000) 272180   1.5513300-02 (     1.0000)
ZONE  197 272174    7.1600000D-05 (     1.0000) 272176    2.3009200-03 (     1.0000) 272177    8.2233900-03 (
1.0000)
272178   1.2064600-02 (     1.0000) 272179   6.0236800-03 (     1.0000) 272180   1.5513300-02 (     1.0000)
ZONE  196 272174    7.1600000D-05 (     1.0000) 272176    2.3009200-03 (     1.0000) 272177    8.2233900-03 (
1.0000)
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272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  195 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  194 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  193 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  192 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  191 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  190 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  189 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  188 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  187 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  186 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  185 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  184 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  183 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  182 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  181 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  180 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  179 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  178 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  177 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  176 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  175 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  174 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
 272178  1.206460D-02 (   1.0000) 272179  6.023680D-03 (   1.0000) 272180  1.551330D-02 (   1.0000)
 ZONE  173 272174  7.160000D-05 (   1.0000) 272176  2.300920D-03 (   1.0000) 272177  8.223390D-03 (
1.0000)
```

272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 172 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 171 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 170 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 169 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 168 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 167 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 166 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 165 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 164 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 163 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 162 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 161 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 160 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 159 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 158 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 157 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 156 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 155 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 154 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 153 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 152 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 151 272174 7.1600000-05 (1.0000) 272176 2.3009200-03 (1.0000) 272177 8.2233900-03 (
1.0000)
272178 1.2064600-02 (1.0000) 272179 6.0236800-03 (1.0000) 272180 1.5513300-02 (1.0000)
ZONE 150 41001 6.6644000-02 (1.0000) 48016 3.3344000-02 (1.0000)
ZONE 149 41001 6.6644000-02 (1.0000) 48016 3.3344000-02 (1.0000)

```
ZONE  148  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  147  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  146  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  145  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  144  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  143  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  142  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  141  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  140  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  139  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  138  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  137  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  136  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  135  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  134  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  133  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  132  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  131  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  130  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  129  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  128  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  127  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  126  41001     6.6644000-02 (      1.0000)  48016     3.3344000-02 (      1.0000)
ZONE  125  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  124  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  123  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  122  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  121  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  120  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  119  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  118  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  117  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  116  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  115  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  114  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  113  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  112  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  111  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  110  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  109  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  108  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  107  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  106  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  105  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  104  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  103  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  102  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)
ZONE  101  51001     6.6644000-02 (      1.0000)  58016     3.3344000-02 (      1.0000)

***** AVERAGE VALUES FOR CONTROL ROD MATERIAL *****
 VOLUME OF CONTROL ROD MATERIAL USED TO CALCULATE ATOM DENSITIES.
272174   7.160000D-05 (     1.0000) 272176   2.300920D-03 (     1.0000) 272177   8.223390D-03 (     1.0000)
272178   1.206460D-02 (     1.0000) 272179   6.023680D-03 (     1.0000) 272180   1.551330D-02 (     1.0000)
-----------------------------------------------------------------------------
CONTROL ROD BANK =   1

***** ALL RODS IN BANK WILL BE POSITIONED *****

NUMBER OF POSITIONS =   19

***** ONLY ZONE POSITIONS FOR BANK #    1, ROD #    1 PRINTED HERE *****
NUMBER      ZONE      BOUNDARY          POSITION
   1         200          0          0.000000000D+00
   2         200          1          2.199114838D+02
   3         199          1          4.398229675D+02
   4         198          1          6.597344513D+02
   5         196          1          1.099557419D+03
   6         192          1          1.979203354D+03
   7         188          1          2.858849289D+03
```

8	184	1	3.738495224D+03
9	180	1	4.618141159D+03
10	176	1	5.497787094D+03
11	172	1	6.377433029D+03
12	168	1	7.257078964D+03
13	164	1	8.136724899D+03
14	160	1	9.016370834D+03
15	156	1	9.896016769D+03
16	154	1	1.033583974D+04
17	153	1	1.055575122D+04
18	152	1	1.077566270D+04
19	151	1	1.099557419D+04

***** SAVED POSITIONS FOR ALL CONTROL RODS *****
SAVED POSITION -- POSSAV(1, 1)= 2.622041758D+03

------------------------- TIME IN DAYS .000 ----------------------------

***** MOVING CONTROL RODS TO POSITIONS FOR WORTH CURVE *****

***** ONLY ZONE POSITIONS FOR BANK # 1, ROD # 1 PRINTED HERE *****

#	ZONE	BNDRY	BANK	ROD	POSITION	KEFF	DKEFF	DK/VOL	DKO/VOL
1	200	0	1	1	0.00000D+00	.9590846	.0000000	.0000000	.0000000
2	200	1	1	1	2.19911D+02	.9591602	.0000789	.0000004	.0000004
3	199	1	1	1	4.39823D+02	.9593927	.0002424	.0000011	.0000007
4	198	1	1	1	6.59734D+02	.9598349	.0004608	.0000021	.0000012
5	196	1	1	1	1.09956D+03	.9618968	.0021458	.0000049	.0000027
6	192	1	1	1	1.97920D+03	.9788072	.0174271	.0000198	.0000103
7	188	1	1	1	2.85885D+03	1.0122393	.0335825	.0000382	.0000189
8	184	1	1	1	3.73850D+03	1.0411547	.0281635	.0000320	.0000220
9	180	1	1	1	4.61814D+03	1.0620744	.0198929	.0000226	.0000221
10	176	1	1	1	5.49779D+03	1.0770211	.0139748	.0000159	.0000211
11	172	1	1	1	6.37743D+03	1.0878874	.0100386	.0000114	.0000197
12	168	1	1	1	7.25708D+03	1.0959564	.0073898	.0000084	.0000184
13	164	1	1	1	8.13672D+03	1.1020458	.0055408	.0000063	.0000170
14	160	1	1	1	9.01637D+03	1.1066390	.0041593	.0000047	.0000158
15	156	1	1	1	9.89602D+03	1.1099291	.0029686	.0000034	.0000147
16	154	1	1	1	1.03358D+04	1.1110609	.0010192	.0000023	.0000142
17	153	1	1	1	1.05558D+04	1.1114841	.0003808	.0000017	.0000139
18	152	1	1	1	1.07757D+04	1.1118070	.0002905	.0000013	.0000137
19	151	1	1	1	1.09956D+04	1.1120273	.0001981	.0000009	.0000134

***** OPTION 30 COMPLETE -- CONTROL RODS RE-POSITIONED *****

***** ENDING POSITION FOR ALL CONTROL RODS *****
ENDING POSITION -- POSNOW(1, 1)= 2.622041758D+03

* TOTAL CPU TIME = 1067.79 MINUTES - TOTAL CLOCK TIME = .00 MINUTES *
****************** NORMAL END OF CONTROL ROD POSITION MODULE ****************
****

END OF SAMPLE 3 CTRLPOS OUTPUT

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