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ROD: A NUCLEAR AND FUEL-CYCLE ANALYSIS CODE FOR CIRCULATING-FUEL REACTORS

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FOREWORD

The evolutionary nature of the ROD program (see Section 2, The History of ROD) has led to certain practical limitations on the information presented in this report. We have described the uses for which the program was intended, the theory and methodology employed, and rather completely the information required for applying the program. We have not attempted a comprehensive description of the programming itself.

ABSTRACT

ROD (Reactor Optimum Design) is a computer code for simultaneously optimizing the core design and performing the fuel-cycle analysis for circulating-fuel reactors. It consists of a multigroup diffusion calculation, including multiple thermal groups with neutron upscatter, in one-dimension or in two-dimensional synthesis, combined with an equilibrium fuel-cycle calculation. Cross sections in the CITATION format are required. The equilibrium calculation is a detailed model of the fuel cycle, including the effects of processing and of nuclear transmutation and decay. Fuel-cycle costs and fission-product concentrations are calculated, the fission products by an independent calculation from internally stored two-group cross sections. Special features of ROD are an optimization routine based on the gradient-projection method, a flux-plotting option, and a subprogram for simple time-dependent calculations based on reaction rates from the main program.

Keywords: breeding performance, computer codes, fluid-fueled reactors, fuel-cycle costs, nuclear analysis, optimizations, conceptual design, cores, delayed neutrons, equilibrium, fission products, neutron flux, parametric studies, processing, time dependent.

ACKNOWLEDGMENTS

A number of persons, not excluding the authors of this report, have made significant contributions to the development of the ROD code. H. F. Bauman and H. T. Kerr have been the principle users of ROD and have guided its development from the user's standpoint. The theoretical development has been the work of L. G. Alexander, T. W. Kerlin, and C. W. Craven, Jr. The programming was done by J. L. Lucius and G. W. Cunningham. Sections of pre-existing programs which have been incorporated into ROD (see Chapter 2, The History of ROD) were written by J. Replogle, W. T. Kephart, M. J. Bell, and R. S. Carlsmith.

COMPUTER CODE ABSTRACT

1. Name: ROD
2. Computer for Which Code is Designed: The code is designed for computers in the IBM-360 series which have directly addressable storage of 300 thousand words or more.
3. Problems Solved: For nuclear reactors the code solves the eigenvalue problem with or without a critical concentration search for one dimension or for a two-dimensional synthesis, giving flux and fission-density distributions. It performs a fuel-cycle analysis, including costs, for circulating-fuel reactors, either at equilibrium, for continuous processing, or time-dependent (by assuming a separable time-dependence) for batch or continuous processing. The equilibrium problem may be solved for up to three independent fuel or fertile streams. The equilibrium concentrations for the fuel-chain nuclides and up to 200 fission-product nuclides are obtained. The optimum values of selected core-design and fuel-cycle parameters may be obtained, based on the maximization of a selected function related to the reactor performance.
4. Method of Solution: The neutronics calculation is performed by a multigroup, one-dimensional or synthetic two-dimensional diffusion calculation, including multiple thermal groups with neutron upscatter. The equilibrium calculation uses the reaction rates from the diffusion calculation to determine the equilibrium concentrations of the fuel-chain nuclides. The concentrations of the fission products are obtained from a self-contained two-group calculation. An iterative process is continued until the diffusion and equilibrium calculations converge on a common set of nuclide concentrations. The optimization is based on the gradient-projection method. The time-dependent calculation (optional) uses average reaction rates from the main calculation to calculate the concentrations of the principle fuel nuclides as a function of time.
5. Restrictions on Complexity of the Problem: The major limiting values which restrict the complexity of a problem are 15 energy groups,

including four thermal groups, 30 nuclides per region, 10 regions per dimension, 2 dimensions, 50 nuclides in the equilibrium calculation, 200 fission products, and 20 optimization variables.

6. Typical Machine Time: The running time on the IBM 360/75 varies widely depending on the type of problem. Single cases require from about one minute for a one-dimensional problem with six groups (5 fast, 1 thermal) to about 5 minutes for a two-dimensional synthesis problem with 9 groups (5 fast, 4 thermal). Cases run as part of a series (as in an optimization) run in a half to a third the time required for a single case (because they are started with the flux distribution from the previous case). An optimization with five variables, nine groups, in one dimension runs in about an hour.
7. Unusual Features of the Program: The ability to closely model the behavior of a circulating-fuel reactor, including such factors as the loss of delayed neutrons from fuel circulating outside the core, is an unusual feature of the program. Others are the availability of routines for optimization and for flux plotting.
8. Related and Auxiliary Programs: The code is designed to use a microscopic cross-section tape generated by the code XSDRN.
9. Status: ROD is in production use at ORNL on the IBM 360/75 and 360/91.
10. Machine Requirements: About 300 thousand words of core storage and three I/O devices excluding input-output and system requirements are needed by the program. Two additional I/O devices, for auxiliary output and flux-plotting, are optional. Plotting requires a CALCOMP CRT plotter.
11. Programming Language Used: FORTRAN IV.
12. Operating System: IBM 05/360 with FORTRAN H compiler.
13. Programming Information: The program consists of about 6000 FORTRAN statements. Arrays of fixed dimensions are provided for all data within the program, which requires about 300 thousand 4-byte words of core storage.
14. Users Information: The code and report may be obtained through the Argonne Code Center at Argonne National Laboratory.

15. References:

1. H. F. Bauman et al., ROD: A Nuclear and Fuel-Cycle Analysis Code for Circulating-Fuel Reactors, USAEC Report ORNL-TM-3359, Oak Ridge National Laboratory.

2. N. M. Greene and C. W. Craven, Jr., XSDRN: A Discrete Ordinates Spectral Averaging Code, USAEC Report ORNL-TM-2500, Oak Ridge National Laboratory, July 1969.

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CHAPTER 1

INTRODUCTION

The Rod (Reactor Optimum Design) code is unique among reactor analysis codes in two respects; it was developed for the core design and fuel-cycle analysis of circulating-fuel reactors; and it incorporates a package for the optimization of certain design parameters. It is limited to one-dimensional, or a synthesis of two one-dimensional, neutron diffusion calculations, and is therefore suited for conceptual design studies of reactors rather than the detailed calculation of a given core geometry.

Circulating-fuel reactors, which include the aqueous homogeneous and the molten-salt reactor types, are different in several characteristics from fixed-fuel reactors. The fuel is perfectly mixed so that its composition at a given time is the same everywhere in the system. However, there may be more than one fluid stream, as when a fertile stream is used as a blanket, or the fuel may be circulated through a fixed moderator, as in the molten-salt reactor, so that the overall core composition may be different in different core zones. Circulating-fuel reactors are usually designed for continuous processing of the fuel to remove fission products and to adjust the fissile concentration. In many designs, the fuel reaches an equilibrium composition in a relatively short time. The calculation of the reactor performance at equilibrium is then a most important consideration. Finally, in circulating-fuel reactors, delayed neutrons emitted from the fuel circulating outside the core, as in a heat exchanger, are largely lost to the chain reaction and must be accounted for in the reactor neutron balance. The ROD code has been designed to take all of these factors into account.

ROD also includes a subprogram for nonequilibrium calculations, designed to calculate an average performance for a reactor over some interval of time (e.g., a reactor lifetime), either with batch fuel processing or with continuous processing. This option may also be used to calculate the average performance of a reactor in the interval from start-up until equilibrium is established. The method uses average reaction rates from a space-energy dependent calculation to calculate the time-dependent concentrations of the most important nuclides. This is, of

course, an approximation, in that space-energy and time-dependent effects are not considered simultaneously.

The optimization package in ROD is based on the gradient-projection method, or the method of steepest ascent. It will vary a given set of parameters (e.g., core dimensions, processing cycle times) within limits, in a series of cases to search out the values of the parameters which maximize the value of a given objective function (e.g., the breeding ratio, the inverse of the fuel-cycle cost). Optimization may be used in combination with a parameter survey; for example, the effect of a given parameter can be determined with other parameters adjusted to their optimum values for each case, rather than merely held fixed at some arbitrary value.

CHAPTER 2

THE HISTORY OF ROD

The ROD code was not "written" but rather "evolved". Parts of ROD were written, put together, taken apart, and revised by a number of people over a long period of time. A code with the scope and versatility of ROD could probably not have been attained without this long period of development. However, the evolutionary character of ROD has resulted almost inevitably in some disadvantages, chiefly that the input and output lack a consistent format, that many sections of the code have not been described by their authors except in the original FORTRAN, that parts of it are seldom used or obsolete, and that the program has become complex and difficult to change. Fortunately, the code was considerably unified in adapting it for the IBM System 360 computers in 1968.

In the beginning (in the 1950's) fluid-fuel reactor calculations were made with the one-dimensional diffusion-theory code GNU, written in machine language at General Motors Corporation, and ERC (for equilibrium reactor calculation), an equilibrium code written in FORTRAN at ORNL. In 1960, GNU was replaced by MODRIC,[1] also a one-dimensional diffusion-theory code, but written in FORTRAN, which made modification of the program more practical. At this time, of course, the neutronic and equilibrium calculations were performed separately.

The moment of conception for ROD came in 1961 when J. L. Lucius, under the direction of L. G. Alexander and T. W. Kerlin, joined MODRIC and ERC into a single code called MERC.[2] In this combination, a neutron diffusion calculation alternated with an equilibrium calculation, so that reaction rates were supplied from the diffusion calculation to the equilibrium calculation, and new equilibrium concentrations were supplied to the succeeding diffusion calculation until both converged on a single set of concentrations. This process is still the heart of the ROD calculation.

Over the next few years the code was expanded and improved. The fission-product treatment in ERC was expanded to treat first 75 and later 125 nuclides. The number of fuel streams for which equilibrium could be calculated was increased from two to three. A provision was added for calculating the withdrawal of fuel at a final concentration beyond the

equilibrium burnup — useful in calculating certain solid-fuel cores such as a pebble-bed. A two-dimensional synthesis was developed, by C. W. Craven, Jr., in which a two-dimensional calculation was synthesized from two one-dimensional calculations; for example, a cylindrical core from an axial and a radial calculation.

In 1964, T. W. Kerlin suggested that the most efficient method for finding the set of parameters which gave the best performance in a particular core design was to use a computerized optimization technique. About this same time, W. L. Kephart at the Oak Ridge Gaseous Diffusion Plant had developed an optimization code (unpublished) based on the gradient-projection method.[3] We decided to link MERC with the optimization package; the results was a combined code called OPTIMERC. Development of OPTIMERC continued through 1965 and it was used extensively for molten-salt reactor calculations through mid-1968.

The OPTIMERC code had one major operational fault, which was that the entire program would not fit into the core of the IBM 7090 computer in use at that time. During a calculation, therefore, information was continually stored and retrieved from magnetic tape. This resulted in long running times — up to 2 or 3 hr for complex optimization problems — and frequent job failures because of tape input-output errors.

The IBM 360 Model 75, which became available at ORNL in 1967, seemed ideal for a large program like OPTIMERC because of its large core capacity. To take full advantage of the new computer, however, it was necessary to reprogram OPTIMERC to eliminate much of the information handling. We decided not only to reprogram OPTIMERC for the Model 75, but to take this opportunity to integrate better the various parts of the program, and to enlarge the capacity of the code to handle larger problems.

The programming of the new code, which was named ROD (for Reactor Optimum Design), was undertaken by G. W. Cunningham, under the direction of J. L. Lucius and the guidance of C. W. Craven, Jr., H. T. Kerr, and H. F. Bauman. The important new features of the ROD code were:

1. All operations, after reading of the cross-section information, are contained in core.

2. Multiple thermal groups (with upscatter) are permitted.

3. Two-dimensional synthesis is performed by energy groups.

4. ERC was expanded:

   a) up to four materials are permitted, of which three may be treated as fuel streams,

   b) the maximum number of nuclides in the equilibrium calculation was expanded from 25 to 50,

   c) the maximum number of fission-product nuclides was expanded from 125 to 200.

5. Standard optimization variables and objective function were built-in (no programming required).

6. A standard CITATION cross-section tape is read.

7. Cross-section sets are assigned by region; up to five cross-section sets are permitted.

At about this time, M. J. Bell, of the ORNL Chemical Technology Division, needed a method for calculating in detail the effects of the processing removal of various fission products from a molten-salt reactor. He used the basic ROD calculation, but substituted his own subroutine for the calculation of the fission-product absorptions. This treatment is now an option in ROD. Its use is limited to single cases (i.e., optimization is precluded).

In 1970, an option was added to ROD to permit the calculation of the average performance of a reactor over one or more batch processing cycles. It is based on a zero-dimension, one-group, time-dependent code (unpublished) written by R. S. Carlsmith in 1966, which we expanded and revised for inclusion in ROD. Called HISTRY, it takes reaction rates from the diffusion calculation to calculate the concentrations of the important fuel nuclides as a function of time. The time-weighted average concentrations are then supplied to the next diffusion calculation, and this iterative process continued until there is no further change in the average concentrations.

This brief history of ROD shows how it has grown and developed over a period of years, and we can only assume that further additions and improvements will be made. Some future developments that have already been suggested are:

1. Replacing MODRIC with ORNL's latest diffusion code, CITATION, which would permit finite-difference two-dimensional calculations.

2. Reprogramming of the "solid-fuel" option (which was not included in the conversion of OPTIMERC to ROD).

3. The standardization of the input format and the elimination of dual nuclide-identifications.

Since some of these changes, and others not yet conceived, may be made in the future, this report has been organized so far as possible into independent chapters.

CHAPTER 3

THE FUNCTIONS OF THE ROD PROGRAM

The ROD program consists of four principal parts called MODRIC, ERC, OPTI, and HISTRY. The functions of these parts, as well as several important options, are described in this section. A flow diagram of the program is given in Fig. 3.1.

MODRIC is the neutronics section of the code. It is a multigroup, one-dimensional or synthesis two-dimensional, diffusion-theory calculation. It can perform a criticality search, or simply solve the eigenvalue problem. It can be run independently, without preparing input data for the other sections of the code. The main output of MODRIC is the critical concentrations and the flux and fission density distributions.

ERC calculates the equilibrium composition of the reactor and performs the economics calculations. It requires reaction rates from MODRIC and in turn supplies nuclide concentrations for the next MODRIC iteration. Iterations between MODRIC and ERC proceed until the calculations converge on a common set of nuclide concentrations.

ERC calculates the equilibrium concentrations of the principle fuel nuclides, for which reaction rates are obtained from MODRIC, and also the concentrations of up to 200 fission-product nuclides, for each of which it makes a two-group calculation based on a thermal cross section and a resonance integral. The two-group cross-section data, along with fission yields, are stored in a separate section of the data deck known as "permanent data."

The 250 ERC nuclides may be divided into as many as ten groups for processing, each with its own processing equation in each stream. Cost data may be supplied for any of the principle nuclides from which the various components of the fuel-cycle cost are calculated. Most of the ROD output is assembled in the ERC section, including the neutron balance, fissile inventory, breeding ratio, fuel yield, and feed and production rates for the principle nuclides.

OPTI is an optimization package, based on the gradient-projection method. It controls the running of a series of cases, in which certain reactor parameters may be varied systematically within limits, in order

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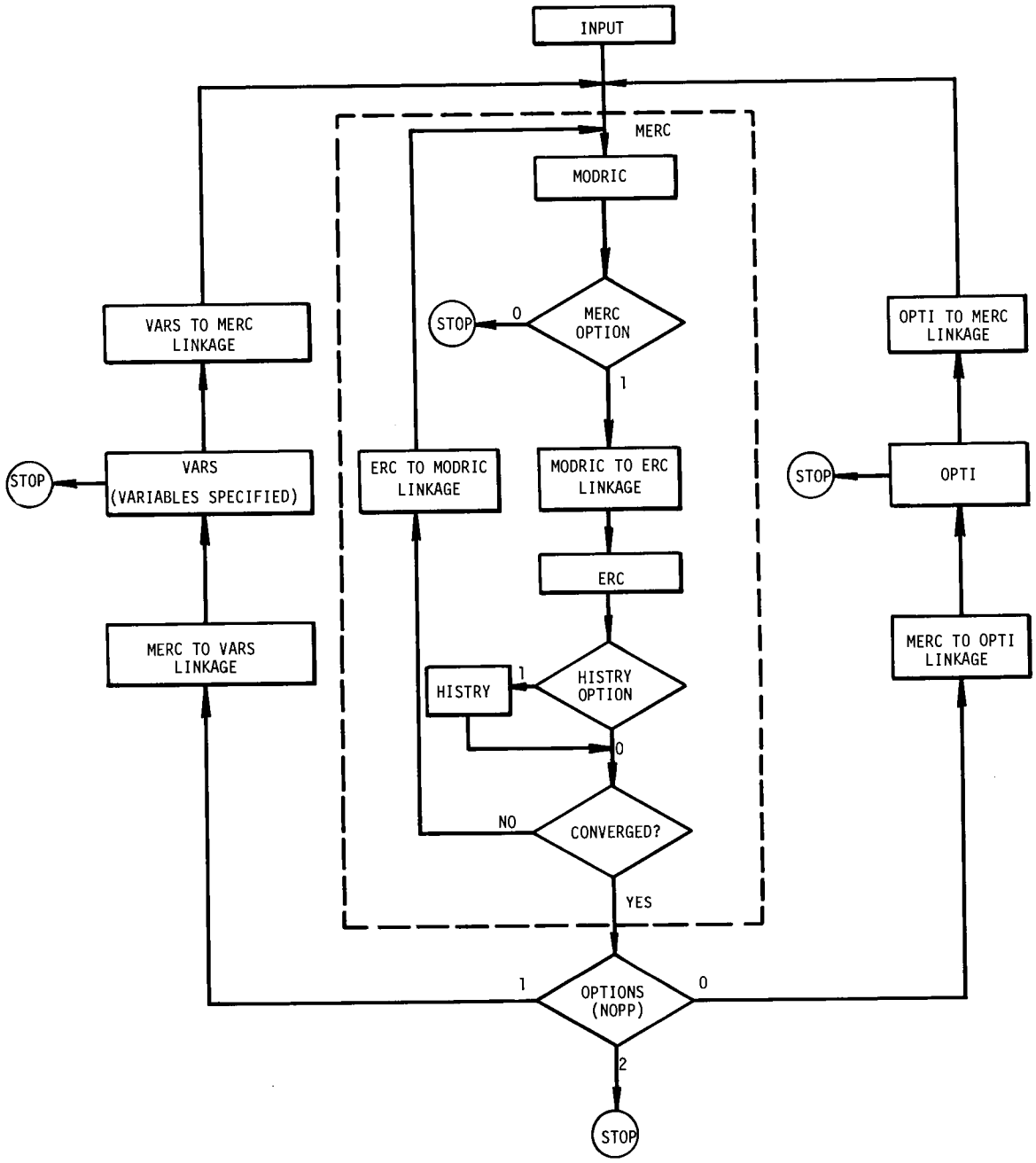

Fig. 3.1. Flow of the ROD Program.

to find, within some tolerance, the set of parameters which gives a maximum value of a prescribed objective function. Parameters which may be varied by OPTI include region thicknesses and fuel volume fractions, the boundary position between adjoining regions, processing cycle times, and, in HISTRY, the time in a batch cycle that the feed is switched from one fissile fuel to another. The objective function is a sum of the following components, each of which may be weighted with an optional constant coefficient, including zero: breeding ratio, fuel yield, reciprocal fuel-cycle cost, reciprocal discounted fuel cost, specific power, an inverse function of the maximum fast flux, and a function of the breeding gain and the specific power called the conservation coefficient.

HISTRY is a subprogram which can calculate the concentrations of the principle fuel nuclides as a function of time, rather than just at equilibrium. It uses reaction rates obtained from MODRIC-ERC (MERC), and supplies time-weighted average nuclide concentrations to the next iteration of MERC. The iteration process proceeds until MERC and HISTRY converge on a common set of concentrations. The HISTRY option is designed to calculate the average performance of a reactor during a batch processing cycle, or over a reactor lifetime of several processing cycles. It calculates the discounted fuel cost, based on a present-worth calculation of all purchases and sales of fissile fuel and carrier materials, over the lifetime of the reactor for a specified discount rate. It also provides useful information on the feed and production rates and inventories of the principle fuel nuclides as a function of time. Its main limitation is that the space-energy calculation is considered independent of time; which results in some lack of rigor in the burnup calculation. ROD-HISTRY, therefore, should not be considered as a substitute for more sophisticated burnup codes.

Among the main options available in ROD, perhaps the most useful is the "variables specified" option. This is a provision in the OPTI section of the code to control the running of a series of cases in which any of the standard optimization parameters ("variables") are preset to any desired values. After the base case, essentially the only data required are the values of those parameters which are to be changed from the

preceding case, since all other data are held fixed. Furthermore each case is started with the flux and fission density distribution from a previous case, which gives, typically, a factor of 3 or 4 saving in computation time over the running of an identical series of cases independently.

The output options are very important. So much output is potentially available from the (typically) 60 or 70 cases of an optimization problem that we have devised an elaborate system for selecting output. The cases are divided into four categories as follows:

1. A base case (the first case run).
2. The final or optimum case from an optimization; or the "variables specified" cases when this option is selected.
3. The final case from each optimization cycle (gradient projection).
4. Intermediate cases in an optimization.

The output itself is divided into 29 segments, any or none of which may be selected for each type of case above. In addition, an input edit of 15 segments is available. Two independent sets of output may be specified for any problem. The first, or "detailed" output, can include any or all of the edit options. The second, or "short" output, can include most of the edit options except some of the infrequently required tables. Either set may be omitted.

Finally, an option is available for flux plotting. It is included in the output options by type of case as described above. The plotting information is recorded on magnetic tape for use on a CRT (cathode ray tube) plotter. The fluxes for any or all energy groups may be selected for plotting on either a linear or logarithmic scale.

CHAPTER 4

INPUT DESCRIPTION

The input for ROD is divided into four main sections:

A. MODRIC, including HISTRY

B. ERC

C. Fission product and delayed neutron data

D. OPTI

The input description is given as concisely as possible. Items marked by an asterisk are discussed in greater detail in the following section, "Discussion of Input." The numbers following the variable name, where given, are suggested values for the data. These are intended to be helpful to users with little or no experience with ROD, and may not be appropriate for every case.

The input instructions are intended to be self-explanatory; however, the following introduction may be helpful.

The diffusion calculation is one-dimensional, along a line such as a reactor axis or radius. The reactor composition must be specified for the various regions along each line of computation. The results of the calculation are applied to a three-dimensional volume, usually in spherical or cylindrical geometry. For 2-D synthesis calculations, in particular, it is necessary to specify the composition of the subregions of the reactor that are not along an axis or radius of calculation. Usually a number of subregions are of the same composition; for example, axial, radial, and "corner" blanket subregions may all have the same composition. A superregion is a set of subregions all of the same composition. The superregion composition is specified by assigning a volume fraction for each <u>material</u> to that superregion.

A material is defined by its nuclide composition. There are two classes of materials; those of fixed composition, such as a graphite moderator or a Hastelloy-N structural material, and those of composition determined by the feed, processing, and nuclear reaction rates of the system. The latter materials are referred to as streams; a fuel stream for a molten-salt reactor, for example, typically consists of the carrier salt nuclides, the fissile and fertile nuclides, and the fission-product nuclides.

The program limitations on the number of materials, regions, and other input parameters are summarized in Table 4.1.

Table 4.1. Program Limits for ROD Input Parameters

Limits in MODRIC	
Number of materials	4
Note: The first three materials may be treated as streams (with processing).	
Number of nuclides, per region	30
Number of search nuclides	30
Number of energy groups	15
Number of space dimensions	2
Number of regions, per dimension	10
Number of superregions	20
Limits in ERC	
Number of principal nuclides	50
Number of fission-product nuclides	200
Limits in OPTI	
Number of variables	20

Section A. MODRIC

Card Number, Description, and Format

A-1 Title (18A4).

A-2 Comment (18A4).

A-3 Program control (F2.0,I2,I1).

Column	Name	Suggested Value	Description
1-2	FLIP		Dimension option >0 Two-dimensional synthesis ≤0 One dimension
3-4	MAX3P	5	Maximum number of MODRIC-ERC iterations per case
5	MERC		MODRIC only option >0 MODRIC and ERC =0 MODRIC only

Cards A-4 to 7. Output options for detailed printout. See Table 4.2. The detailed output may be omitted by means of a dummy control card (refer to Chapter 6).

A-4 Base case (case zero), (50I1).

A-5 Final case in an optimization; variables specified cases (50I1).

A-6 Final case in each optimization cycle (50I1).

A-7 Intermediate cases in an optimization (50I1).

Cards A-8 to 11. Output options for short printout. (Same as cards A-4 to 7.) To omit short printout, leave cards A-8 to 11 blank.

A-12 Convergence information.* (2I3,6E10.4,I10)

1-3	NRFLX		Not used
4-6	NRFLXN	1	Flux normalization = 1 Normalize dimension 1 true flux to dimension 2 = 0 Do not normalize as above

*Asterisks refer to Chapter 5, Discussion of Input.

Table 4.2. Output Options

Enter 1 where output is desired. Otherwise enter 0 or leave blank.

Column on Card	Output Table Controlled
1[a]	MODRIC data by group, region, and dimension. Usually omitted.
2[a]	Macroscopic cross sections and homogenized atom densities by region after each criticality search. Usually omitted.
3[a]	MODRIC data by region and dimension. Usually omitted.
4[a]	Normalized 2-D synthesis MODRIC data by nuclide, region and dimension after each MODRIC pass. Usually omitted.
5[a]	Data supplied as input to ERC. Atom densities and reaction rates by nuclide and material.
6	k-effective and upscattering data by iteration. Usually omitted.
7	The main ERC output table and neutron balance.[c] Atom densities, inventories, and feed and production rates by nuclide and material.
8	Fission product atom densities and absorptions by nuclide.
9	Atom densities supplied to MODRIC each MERC iteration. Usually omitted.
10	Region thicknesses and other region information. (This table is also obtained in option 21.)
11	Volumes, total and by material, by super region.
12	Processing information.
13	MODRIC neutron balance by group and dimension.
14	Neutron absorptions and productions by region and dimension.
15[a]	Macroscopic cross sections by group, region, and dimension.
16	Homogenized atom densities by region and dimension.
17[a]	MODRIC fluxes and fission densities. Specify for "MODRIC only" runs.
18	Normalixed point fluxes and fission density distribution.
19[a]	Exercise option to plot fluxes.
20[b]	Table of optimization data. Usually omitted.
21[b]	Region thicknesses and other region information. Super-region volume fractions.

Table 4.2 (contd)

Column on Card	Output Table Controlled
22[b]	Objective function output summary and optimization variables used.
23	Edit of data supplied to the HISTRY subprogram.
Note: Options 24 to 38 control the edit of input information. These options are ignored except when specified for the base case (case zero).	
24	Initial atom densities by material.
25	MODRIC control and search information.
26	Cross-section listing. Enter the specified integer to obtain one of the following four options:
	0 No output
	1 Title of each cross-section set
	2 Title and list of nuclides in each cross-section set
	3[a] Complete listing of each cross-section set
27	Energy group boundary table.
28	Dimension information.
29[a]	Initial fission density distribution.
30	Initial homogenized atom densities by region.
31	ERC input card edit.
32	Nuclide correspondence table.
33	Subregion--super region correspondence. (The "picture" of the reactor.)
34	Super region volume fractions.
35[a]	Permanent data. (Atomic mass, beta decay constant, two-group cross sections, fission yield, by nuclide.)
36	Delayed neutron data.
37[a]	Source and recycle-fraction data by material.
38	HISTRY input edit.

Table 4.2 (contd)

Column on Card	Output Table Controlled
Note: Options 39 to 43 are output options for the HISTRY subprogram. Option 39 must be specified to obtain any of the HISTRY output. HISTRY k_{eff} by iteration may be specified on card A-18.	
39	Atom densities, inventories, eigenvalues, and conversion ratios.
40	Cumulative purchases.
41	Incremental purchases.
42	Neutron absorptions and productions.
43	Costs.
50[a]	ERC output for non-converged nuclides by iteration. Used only for study of ERC convergence.

[a]Option not available for short printout.

[b]Option not available for base case.

[c]ERC output every pass may be specified on card B-1.

7-16	FDGVØL		Factor for true flux and fission power density calculation. Enter:

One-dimension:

Sphere	1.0
Cylinder	Overall height
Slab	Product of overall lengths of second and third sides

Two-dimension:

Slab-cylinder	2.0
Slab-slab	Overall length of third side

17-26	CØNCSO	2.0	Factor by which the convergence criteria are tightened for base case.
27-36	CØNIT1	2.0	Factor by which the convergence criteria are loosened for the first MERC iteration.
37-46	CDELT	1.0E-05	The convergence requirement on the change of upscatter acceleration treatment from iteration to iteration.
47-56	CTØL	1.0E-04	The tolerance on the upscatter acceleration treatment approach to unity.
57-66	CP1CØN	1.2	Factor which limits the change in dc/dk in the criticality search.
67-76	NITEXT	3	The minimum number of MODRIC iterations required after the upscatter treatment has converged.

Cards A-13 to 17 control the flux plotting option. If no flux plots are required, these cards may be left blank. The symbols used to designate the neutron energy groups are given in Table 4.3.

A-13 Flux plot control (4I5,4E10.4).

1-5	IWADFP	Not used
6-10	IGRID	Grid options:

= 1 Linear

= 2 Semilog, space-coordinate logrithmic

= 3 Semilog, flux logrithmic

= 4 Log-log

Table 4.3. Symbols Used in Flux Plots

Symbol	Neutron Energy Group
·	1, 11
⯃	2, 12
△	3, 13
+	4, 14
×	5, 15
◇	6
Y	7
✳	8
⧖	9
☆	10

11-15	IPTLIN	Point-line options:
		= 0 Points only
		= 1 Line only
		= 2 Points and line
		= 3 Histogram
16-20	NPRNG	Range options:
		= 0 Range determined by data extrema
		= 1 Range specified in next four fields
21-30	XMINN	Minimum of space-coordinate range
31-40	XMAXX	Maximum of space-coordinate range
41-50	YMINN	Minimum of flux range
51-60	YMAXX	Maximum of flux range

A-14,1-36 Plot title (9A4).

A-15,1-36 Space-coordinate axis label (9A4).

A-16,1-36 Flux axis label (9A4).

A-17 Groups to be plotted (16I2).

1-2	NØGPS	Total number of groups to be plotted.
3-4	NPLTGP(I)	Remaining fields identical. Enter group number of each group to be plotted.

Cards A-18 to 34 are for input to the HISTRY subprogram. If HISTRY is not used, these cards may be left blank.

A-18 HISTRY control information (6I5,30X,E10.4).

1-5	ISTRY		Activate HISTRY subprogram.
			> 0 Yes
			= 0 No
6-10	KLIM	30	Limit on K iterations.
11-15	KBUG	0	Printout, K by iteration.
			> 0 Yes
			= 0 No
16-20	NV		Activate converter-breeder option.*
			= 0 Not activated
			When k_{eff} is greater than 1.0:

			= 1 Bypass the criticality search
			= 2 Withdraw feed in criticality search
			= 3 Withdraw uranium mixture in fuel in criticality search; return as needed before resuming normal feed
21-25	NCY		Number of batch processing cycles.
26-30	NFS		Second feed key nuclide number.* (Ignored when SWCH is zero.)
61-70	SWCH		Time, full-power months, of switch to second feed. Zero for no second feed.

A-19 HISTRY data (8E10.4).

1-10	TMAX		Time, full-power months per cycle.
11-20	DT	0.05	Time step, months.
21-30	XPR	240	Number of time steps per normal data period.*
31-40	PUR		Feed options:
			= 0 ^{235}U feed, Th fertile
			> 0 Pu feed, Th fertile
			< 0 Low enriched U feed
41-50	TAU		Time constant for ^{233}Pa removal, if any; fraction removed per second.
51-60	THMX		Maximum atom density of fertile nuclide if fertile-buildup option is used.* Otherwise zero.
61-70	SHIFT	7.0	The number of data printouts before the frequency of output shifts from twelve times normal to normal.*
71-80	TØLK	0.0001	Tolerance on k_{eff}.

A-19.1 Carrier cost control information* (6I5).

1-5	NS		The number of carrier nuclides for which costs are specified in ERC. Zero to five permitted.

6-10	NSC(I)	Remaining fields identical. Enter the ERC number of each carrier nuclide for which a cost is specified.

A-20 Control of the restarting atom densities (after the first cycle) (14F5.1)

Enter a restart factor for each nuclide in order.

1.0	If the nuclide is recovered and recycled.
0.0	Otherwise.

The above entries apply to the fertile nuclide if its atom density is held constant throughout the cycle. If it is allowed to deplete during the cycle, enter:

-2.0	If it is recovered and recycled.
-1.0	Otherwise.

A-21 to 34 HISTRY nuclide information.* One card for each nuclide (4E10.4,2X,A8).

1-10	CSP(I)	Initial atom density for nuclide I.
11-20	FRM(I)	Feed fractions for feed nuclides. Otherwise 0.0.
21-30	FRS(I)	Feed fractions for second feed, if any.
31-40	SL(I)	Removal fraction for sale, if any.
43-50	DENT(I)	Nuclide identification.

This ends the HISTRY data section.

A-35 designates a series of cards of identical format on which the initial atom density of each nuclide in each material is entered.

A-35 Atom densities by material (I2,5(I3,E11.4)).

1-2	MX	Material number.*
3-5	IH(I)	MODRIC nuclide number (NPET).
6-16	TEMP(I)	Atom density (atom/bn-cm) in material (RHØT). Must be non-zero.

Remaining pairs of fields identical. Use as many cards as required for each material. Enter the material number in the I2 field on each card.

A-36 Blank card

A-37 Material names (8A4).

1-8	HØLMAT	Name of material 1.

Remaining fields identical. Enter names of materials in order.

A-38 designates a series of cards, one for each region level in dimension 1, in order, on which the super region number is entered for each subregion of the reactor. These cards create a 2-D "picture" of the super-region distribution in the reactor. For 2-D problems in cylindrical geometry, by convention, the axial dimension is 1 and the radial dimension is 2.

A-38 Super-region subregion correspondence (picture).* (I3,3X,10I3).

1-3	L	Region level in dimension 1.
4-6		Blank
7-9	NTEMP(K)	Super-region number assigned to subregion defined by region levels (L,K), where K is the region level in dimension 2.

Other fields identical. Enter in order of K up to number of region levels in dimension 2.

A-39 Blank card

A-40 designates a series of cards, one for each super region, in order, on which the volume fraction of each material is entered.

A-40 Volume fractions of materials in each super region (I2,2A4,4E7.4).

1-2	J	Super-region number.
3-10	HØLVØL	Super-region name.
11-17	VFS(M,J)	Volume fraction of material M.

Remaining fields identical. Enter volume fractions in order by material. Note: The volume fraction of the last material X is set by the code so that the volume fractions sum to 1.0 in each super region.

A-41 Group structure.* (3I2)

1-2	NG	Total number of energy groups
3-4	NETH	Group number of the last epithermal group.
5-6	NTH	Group number of the last thermal group.

A-42 MODRIC convergence information.* (I10,2E10.4,5I10).

1-10	ICØN	3	Convergence options: = 1 on k_{eff} = 2 on fission density = 3 on both
11-20	EPS1	3.0E-05	Convergence requirement on k_{eff} in successive iterations.
21-30	EPS2	3.0E-04	Convergence requirement on fission density in successive iterations.
31-40	ITMAX	300	Maximum number of MODRIC iterations allowed.
41-50	IFD		Not used
51-60	IFØ		Not used
61-70	NXØPT	1	Perform criticality search: = 1 Yes = 0 No
71-80	MAXØPT	100	Maximum number of optimization cases (may not exceed 200).

When no criticality search is specified, omit cards A-43 and 44.

A-43 MODRIC search information.* (I10,3E10.4,I5).

1-10	ICH	3	= 3 Search on atom density. Note: No other MODRIC search options are used in ROD.
11-20	RMD	1.0	Desired k_{eff}.
21-30	XK	3.0	Initial estimate of dc/dk, fractional change in atom density of search nuclides per unit change in k.*
31-40	EPSL	1.0E-04	Tolerance for k_{eff}.
41-45	MS	1	The material altered by the criticality search.

A-44 Criticality search nuclides.* (24I3).

1-3	NSE	Total number of search nuclides.
4-6	NPC(L)	Remaining fields identical. Enter the MODRIC number of each search nuclide.

Use an additional card (same format) if needed.

Cards A-45 to 54 specify information for dimension 1.

A-45 Two-dimensional synthesis information.* (40I2). May be left blank for a 1-D case.

1-2	KØRE(LD)	Core region number.
3-4	IR3C(I, LD)	Ten identical fields. Enter numbers of regions, in order, to which core region buckling from other dimension is to be applied.
23-24	MTAB(I, LD)	Ten identical fields. Enter numbers of regions, in order, to which transverse leakage is to be distributed.

A-46 designates a series of cards, one for each region, in order, on which the region information is entered.

A-46 Region information (2X,2A4,E10.3,3I5).

3-10	AME	Region name.
11-20	THICK	Region thickness, cm.
21-25	MESH	Number of mesh spaces.*
26-30	NXS	ROD order number of cross section set to be applied in region. (Limited to integers 1 through 5).
31-35	NF	Region contains fissile material.* = 0 No = 1 Yes

A-47 Blank card

A-48 Shell thickness.* (7(I3,E7.4)). If no shells are specified, use a blank card.

1-3	IH(I)	Region number to the inside of the shell.
4-10	TEMP(I)	Shell thickness, cm.

Remaining pairs of fields identical. Enter region numbers and shell thicknesses in order. End data with a blank field. Use an additional card if needed.

A-49 designates a series of cards on which the boundary conditions are specified by energy group, one card for each set of boundary conditions, in order by groups. If the same boundary conditions apply to all groups, only one card is required. The constants a, b, and c apply to the origin, or inner boundary, and d, e, and f to the outer boundary. Appropriate values for the constants may be selected from Table 4.4.

Table 4.4. Boundary Condition Constants

Boundary Condition	Constant		
	a or d	b or e	c or f
Reflected, current zero	0.0	1.0	0.0
No return current, extrapolation distance = 2.13D	0.94	1.0	0.0
No return current, extrapolation distance = 2.0D	1.0	1.0	0.0
Flux zero	1.0	0.0	0.0

A-49 Boundary conditions (2I2,I6,6E10.4).

1-2	IL	Group number of highest energy group for which boundary conditions apply.
3-4	IU	Group number of lowest energy group for which boundary conditions apply.
5-10	KCK	Not used
11-20	TEMP(1)	a (refer to Table 4.2).
21-30	TEMP(2)	b
31-40	TEMP(3)	c
41-50	TEMP(4)	d
51-60	TEMP(5)	e
61-70	TEMP(6)	f

A-50 designates a series of cards on which are entered the attenuation coefficients for shells between regions, if any. If all coefficients are to be 1.0, or if no shells are specified, use a blank card.

A-50 Shell attenuation coefficients by energy group (3(2I2,2E8.4)).

1-2	IS(L)	Group
3-4	IH(L)	Region inside of shell.
5-12	TEMP(L)	g (refer to Eq. B.9, Appendix B)
13-20	TEMH(L)	h (refer to Eq. B.10, Appendix B)

Remaining groups of four fields identical. Enter coefficients in order by group and region. End data with a blank field.

A-51 Geometry, buckling, and initial fission density distribution options (3I2).

1-2	IPØPT(LD)		Geometry option: = 1 Slab = 2 Cylinder = 3 Sphere
3-4	IBØPT(LD)	2	Buckling option: = 1 Group and region dependent = 2 Independent of group and region = 3 Input by group and region Note: The buckling option is ignored in spherical geometry, or when the 2-D synthesis is specified.
5-6	IFØPT(LD)	2	Initial fission density distribution: = 1 Flat = 2 Cosine

Omit card A-52 unless buckling option 1 was selected. Omit for sphere and 2-D synthesis.

A-52 Buckling option 1.* (3E10.4).

1-10	TWD(LD)	Gamma
11-20	YH(LD)	y or h, cm
21-30	Z(LD)	Z, cm

Card A-53. Omit for sphere. Blank for 2-D synthesis.

A-53 Buckling option 2 (E10.4). Omit unless option 2 was selected.

1-10	BSQ(LD)	Value for buckling.

Card A-54. Omit for sphere, 2-D synthesis.

A-54 Buckling option 3 (7E10.4). Omit unless option 3 was selected.

Enter bucklings in order by group and region.

For a two-dimensional synthesis, repeat cards A-45 to 54 with information for dimension 2. Otherwise, this ends the dimension information.

A-55 designates a series of cards on which the ERC nuclide number is indicated for each MODRIC nuclide, by material. Requires at least one card per material. Use as many cards as needed. Nuclides may be entered in any order. Fields may be left blank where convenient. Omit A-55 for "MODRIC only" runs.

A-55 MODRIC-ERC nuclide number correspondence (I2,10(I3,1X,I3)).

1-2	J	Material number.
3-5	NTEMP(I)	ERC nuclide number.*
7-10	IDTEMP(I)	MODRIC nuclide number.

Remaining pairs of fields identical. Fields may be left blank.

A-56 Blank card. Omit for "MODRIC only".

A-57 Blank card. Omit for "MODRIC only".

A-58 Cross section set assignment.* (5I3).

1-3	NXØDR(I)	Set number of cross section set on CITATION tape to be stored in core.

Remaining fields identical. Up to five cross section sets may be stored for use in the ROD calculation. The order in which they are specified establishes the ROD order number for card A-46.

For MODRIC only, end the data here.

Section B. ERC

The card number in the ERC section not only identifies the input, but is also an integer variable, entered in columns 1 to 3 on each card, which defines the format for the data on that card. This allows the data cards in this section to be assembled in any order, and, although they are usually arranged in sequence, no error is introduced by misplacing a card within the section.

B-1 ERC data (3X,9I5).

Column	Name	Suggested Value	Description
1-3	KARD	001	
4-8	LØD	0	Output by MERC iteration option.* = 0 Normal > 0 Output options 7, 9, and 38-43, if specified, printout for each MERC iteration.
9-13	NEW		Not used
14-18	MAX	40	Maximum number of ERC iterations.
19-23	I89		Not used
24-28	IFPØ	2	Fission product option (refer to Appendix 3). = 0 Omit fission product calculation = 1 All fission product nuclides calculated in ERC. = 2 Normal. Reaction rates for selected fission products may be calculated in MODRIC.*
29-33	IRE		ERC number of fission product reference element.*
34-38	NRØ1		Not used
39-43	NØPP		ROD options: = 0 Optimization = 1 Variables specified = 2 Base case only.* = -1 Processing study option.*

44-48	NWPCV		Processing cost option.*
			> 0 Volume basis
			≤ 0 Other

B-2 ERC convergence and other data (3X,6E10.4).

1-3	KARD	002	
4-13	CØNVEG	1.0E-04	Convergence, ERC atom densities.
14-23	B26	0.5	Atom density damping/forcing coefficient.*
24-33	B27	2.0	Limit on change of atom density per iteration.*
34-43	P		Reactor power, Mw(thermal).
44-53	F36		Plant factor.*
54-63	E36		Thermal efficiency.

B-3 ERC residence times and other data (3X,6E10.4).

1-3	KARD	003	
4-13	GK53		Fission-product resonance integral.
14-23	AK		Not used
24-33	B55		Fuel residence time, in core, sec. (For loss of delayed neutrons calculation.)
34-43	B56		Fuel residence time, out of core, sec.
44-53	B57	0.4	Scaling factor for processing plant capital cost.*
54-63	WINT		Interest rate, fraction per annum.

B-4 Tolerance for MERC convergence and other data (3X,3E10.4).

1-3	KARD	004	
4-13	W7		Fission-product thermal spectrum factor.*
14-23	SEPS	1.0E-03	Tolerance for MERC convergence.
24-33	UPLTJ	1.01	Limiting factor for change of the recycle fraction per iteration.*

Cards B-5 to 7 are currently not activated.

B-8 Transverse dimension factor (3X,E10.4). Omit for sphere or 2-D synthesis.

1-3	KARD	008	
4-13	FUDGE		Transverse dimension factor:
			Cylinder - overall height, cm

Slab - product of second and third overall lengths, cm^2.

Cards B-9 to 13 specify the processing information. In the B-9 and B-10 series, one card is required for each material to be processed as a stream.

B-9 Processing data (3X,3I5).

1-3	KARD	009	
4-8	J		Material number.
9-13	NTIME		Number of processing cycle times to be defined for material J (limit 10).
14-18	NPGEQ		Number of processing equations to be defined for material J (limit 10).

Card B-10 may be omitted if all times are in days.

B-10 Time units (3X,I5,10A4).

1-3	KARD	010	
4-8	J		Material number.
9-12	TUNITS(1)	DAYS	The first time is the master cycle time which must be given in days.

Other fields identical. Enter units for processing times in order. Only the following entries are permitted:

SECS
MINS
HØUR
DAYS
YEAR

Card B-11 designates a series of cards, one for each processing time for each material stream on which time and cost information are entered. Cards may be omitted for times not being used, without changing the "number of times" on card B-9.

B-11 Processing cycle times (3X,2I3,2E10.4).

1-3	KARD	011	
4-6	J		Material number.
7-9	NT		Time number.

10-19	GPTIME (J,NT)	Processing cycle time, in units specified on card B-10.* Enter full-capacity operating time, not calendar time.
20-29	WPCV(J, NT)	Processing cost factor, volume basis.* (Zero permitted.)

B-12 designates a series of cards, one for each processing equation, on which the times used in each equation are indicated by entering 1.0 in the proper positions.

B-12 Processing equations.* (3X,2I3,10F6.0).

1-3	KARD 012	
4-6	J	Material number.
7-9	K	Processing equation number.

Remaining ten fields identical. Enter 1.0 in each field corresponding to a cycle time to be used in the processing equation.

	(Time)
10-15	(1)
16-21	(2)
22-27	(3)
28-33	(4)
34-39	(5)
40-45	(6)
46-51	(7)
52-57	(8)
58-63	(9)
64-69	(10)

Card B-13 designates a series of cards, one for each processing equation, on which the group of nuclides to be treated by each equation may be given a keyword identification.

B-13 Processing nuclide group names (3X,2I3,3A4).

1-3	KARD 013	
4-6	J	Material number.
7-9	K	Number of the processing equation.
10-21	HØLPGE	Keyword name of the nuclide group to be treated by the equation.

Cards B-14 to 19 are currently not activated.

B-20 designates a series of cards, one for each material to be treated as a stream.

B-20 Stream data (3X,I3,4E10.4,I10,E10.4).

1-3	KARD	020	
4-6	J		Material number.
7-16	SPIVEV (J)		External volume, ft^3.*
17-26			Not used
27-36	STP(J)		Holdup time in the processing plant, days.*
37-46	STR(J)		Operating time on reserve fuel, days.*
47-56	NW1(J)	0	Withdrawal option: = 0 Fluid fuel = 1 Solid fuel. (Note: The solid fuel option is currently not activated.)
57-66	XE21(J)		A fixed poison fraction (used for xenon).*

B-21 designates a series of cards, one for each group of contiguous nuclides for which information is identical, for which nonstandard values of the following data are to be entered. (Omit for nuclides for which standard values apply.)

	Name	Std. Value
Fraction processed per cycle	E(I,J)	1.0
Fraction removed in processing	SCE(I,J)	1.0
Fraction recycle to same stream (J=JD)	RCF(I,J,JD)	1.0
Fraction recycled to other streams (J≠JD)	RCF(I,J,JD)	0.0

B-21 Removal and recycle data* (3X,I2,2I3,I1,2E8.4,I2,4E7.4).

1-3	KARD	021	
4-5	J		Material number.
6-8	I		First nuclide for which data applies.
9-11	I1		Last nuclide for which data applies.
12	NESCE		E and SCE data control: = 0 Use standard values. = 1 Read values from following two fields.

13-20	DUM1	Enter E(I,J), fraction processed per cycle.
21-28	DUM2	Enter SCE(I,J), fraction removed, or lost in recycling.
29-30	NRCF	Recycle fraction control: = 0 Use standard values. = 1 Read from next four fields.
31-37	DUM(1)	Recycle fraction to material 1.
38-44	DUM(2)	Recycle fraction to material 2.
45-51	DUM(3)	Recycle fraction to material 3.
52-58	DUM(4)	Recycle fraction to material 4.

B-22 designates a series of cards, one for each principal nuclide in each material treated as a stream, on which the feed, atom density, and recycle options are entered. The options are listed in Table 4.5. Cards may be omitted for nuclides for which all data are zero.

B-22 Feed, atom density, and recycle options.* (3X,2I3,F7.3,I3,5X,3I5).

1-3	KARD 033	
4-6	J	Material number.
7-9	I	ERC nuclide number.
10-16	Q(I,J)	Special feed rate or atom density specifications. See Table 4.5
17-19	IUMØ	
25-29	M655(I, J)	Feed option (Q).
30-34	N(I,J)	Atom density option (N).
35-39	J655(I, J)	Recycle option (J).

B-23 designates a series of cards, one for each principal nuclide, on which are entered data required for the material balance.

B-23 ERC material balance data (3X,7I3,2E10.3,2A4,I3).

1-3	KARD 023	
4-6	I	ERC nuclide number.
7-9	IP(I,1)	Processing source nuclide number.*
10-12	IP(I,2)	Processing source nuclide number.
13-15	IT(I,1)	Transmutation source nuclide number.
16-18	IT(I,2)	Transmutation source nuclide number.

Table 4.5. Feed, Atom Density, and Recycle Options, Card B-22

Option Number	Description
Feed Options:	
0	No feed.
1	Feed rate calculated by ERC to maintain the equilibrium or critical concentration.
2	Feed rate specified as input. Enter (kg/day) in the form ±0.yyy±xx in columns 11-19, where xx is the exponent for the data yyy.
3	Feed rate proportional to the feed rate of another nuclide. Enter in the form ±xx.yyy±zz in columns 10-19, where: xx = the reference feed nuclide ±.yyy±zz = the ratio of the feed rate of nuclide I to that of the reference feed nuclide.
Atom Density Options:	
0	Atom density held constant.
1	Equilibrium atom density calculated by ERC.
2	Critical atom density calculated by ERC. This option permitted for one nuclide only.
3	Atom density adjusted by ERC to keep reaction rate constant.
4	Special ^{238}U option. Calculates the average atom density of ^{238}U over the reactor lifetime for startup with ^{235}U feed. Enter in the form ±xx.yyy±zz in columns 10-19, where: xx = the core lifetime, calendar years. ±yyy±zz = the ratio of ^{238}U to ^{235}U in the feed. Refer to Eq. (A.32), Appendix A. Specific for ^{235}U as ERC nuclide 5.
5	Specifies a pseudo-nuclide representing the loss of delayed neutrons.
6	Specifies a pseudo-nuclide for the fixed poison fraction.
7	Specifies a pseudo-nuclide representing the lumped fission products.

Table 4.5 (contd)

Option Number	Description
Recycle Fraction Options:	
0	Recycle fractions held constant.
The following options allow ERC to calculate the recycle fractions for the fuel nuclides for a breeder reactor in which excess fuel may be produced for sale. In each case, any remaining fuel from materials 1, 2, and 3 is recycled to material 1.	
1	Specifies the key nuclide for the sale of excess fuel, if any, based on the composition of material 1.
2	Specifies the key nuclide for the sale of excess fuel, if any, based on the mixed composition of materials 1, 2, and 3.
3	Specifies the key nuclide for the sale of excess fuel, if any, based on the composition of material 3.
4	Specifies the key nuclide for the sale of excess fuel, if any, based on the mixed composition of materials 2 and 3.
5	Specifies a nuclide to be sold in proportion to the key nuclide in option 1.
6	Specifies a nuclide to be sold in proportion to the key nuclide in option 2.
7	Specifies a nuclide to be solid in proportion to the key nuclide in option 3.
8	Specifies a nuclide to be sold in proportion to the key nuclide in option 4.

19-21	ID(I,1)	Decay source nuclide number.
22-24	ID(I,2)	Decay source nuclide number.
25-34	AMASS(I)	Atomic mass of nuclide I.
35-44	AMBA(I)	Beta decay constant for nuclide I.
45-52	HØLL	Nuclide name.
53-55	NPGFNI(I)	Number of processing group.*

B-24 designates a series of cards, one for each nuclide, in each material, for which cost data are assigned.

B-24 Value of materials (3X,2I3,3E10.4).

1-3	KARD	024	
4-6	J		Material number.
7-9	I		ERC nuclide number.
10-19	W1(I,J)		Value of nuclide I in materials 1, 2, and 3 in the reactor system. The value assigned to nuclide I in material 1 is automatically assigned in materials 2 and 3 also.*
20-29	W3(I,J)		Unit processing cost, $/kg (non-zero for weight-basis calculation only).*
30-39	W4(I,J)		Processing unit capital cost factor (non-zero for capital cost basis calculation only).*
40-49	W5(I,J)		Value of nuclide I in material J as feed material. Assign for each material.

B-25 designates a series of cards, one for each nuclide for which an interest rate different from that entered on card B-3 is specifield for the calculation of an inventory charge. Omit if none are different.

B-25 Interest rates (3X,I3,E10.4).

1-3	KARD	025	
4-6	I		ERC nuclide number.
7-16	W2(I)		Interest rate, fraction per year.

Cards B-26 to 28 are currently not activated.

B-29 List fertile nuclides (3X,23I3).

1-3	KARD	029
4-6	L22N1	

Remaining fields identical. Enter the ERC nuclide numbers designating the fertile nuclides for the breeding ratio calculation. Refer to Eq. (A.37), Appendix A.

B-30 List fissile precursors (3X,23I3).

1-3	KARD	030
4-6	L22N2	

Remaining fields identical. Enter the ERC nuclide numbers of fissile precursors, for example, ^{233}Pa.

B-31 List fissile nuclides for breeding ratio (3X,23I3).

1-3	KARD	031
4-6	L22D	

Remaining fields identical. Enter the ERC nuclide numbers designating the fissile nuclides for the breeding ratio calculation.

B-32 List fissile nuclide for mean eta (3X,23I3).

1-3	KARD	032
4-6	L23D	

Remaining fields identical. Enter the ERC nuclide numbers designating the fissile nuclides for the mean eta calculation. Refer to Eq. (A.38), Appendix A.

B-33 List fissile nuclides and precursors for inventory (3X,23I3).

1-3	KARD	033
4-6	L29N	

Remaining fields identical. Enter the ERC nuclide numbers designating the fissile nuclides and precursors for the fissile inventory calculation. Refer to Eq. (A.45), Appendix A.

B-34 List fissile nuclides and precursors for processing loss (3X,23I3).

1-3	KARD	034
4-6	L30N	

Remaining fields identical. Enter the ERC nuclide numbers designating the fissile nuclides and precursors for the processing loss calculation (numerator). Refer to Eq. (A.46), Appendix A.

B-35 List fissile nuclides for processing loss (3X,23I3).

1-3	KARD	035
4-6	L30D	

Remaining fields identical. Enter the ERC nuclide numbers designating the fissile nuclides (only) for the processing loss calculation (denominator).

Card B-36 is currently not activated.

B-37 List fissile nuclides for fixed poison fraction (3X,23I3).

1-3	KARD	037
4-6	N21L	

Remaining fields identical. Enter the ERC nuclide numbers designating the fissile nuclides (only) for the fixed poison-fraction calculation. Refer to Eq. (A.34), Appendix A.

B-38 Blank card. This ends ERC data Section B.

Section C. Fission Product and Delayed Neutron Data

This section contains the fission yields, two-group cross sections, and transmutation and decay chain data for up to 200 fission-product nuclides. It is referred to as permanent data, because, once set up, it may be used for the calculation of any thermal reactor. However, the processing group number has been superimposed on the permanent data in this section, and this would be expected to change with the processing method employed. Finally, the last six cards in this section contain the data for six groups of delayed neutron precursors.

C-1 Fissionable nuclide correspondence (6I3).

Fields may be left blank for nuclides not being used. Specific for ERC numbers in the range of 1 to 13.

1-3	NFPYS(1)	ERC nuclide number for ^{232}Th.
4-6	NFPYS(2)	ERC nuclide number for ^{233}U.
7-9	NFPYS(3)	ERC nuclide number for ^{235}U.
10-12	NFPYS(4)	ERC nuclide number for ^{238}U.
13-15	NFPYS(5)	ERC nuclide number for ^{239}Pu.
16-18	NFPYS(6)	ERC nuclide number for ^{241}Pu.

C-2 designates a group of up to 200 cards, one for each fission-product nuclide. End the fission-product data with a blank card.

C-2 Fission-product permanent data (5I3,E9.1,8E6.1,2A4,T80,I1).

1-3	I	ERC nuclide number (starting with 51).
4-6	IT1	Transmutation source nuclide number.
7-9	IT2	Transmutation source nuclide number.
10-12	ID1	Decay source nuclide number.
13-15	ID2	Decay source nuclide number.
16-24	BDECAY	Beta decay constant.
25-30	SA2200	Absorption cross section (2200 m/sec).
31-36	RESINT	Resonance integral.
37-42	YT(1)	Fission yield from ^{232}Th.
43-48	YT(2)	Fission yield from ^{233}U.
49-54	YT(3)	Fission yield from ^{235}U.
55-60	YT(4)	Fission yield from ^{238}U.

61-66	YT(5)	Fission yield from ^{239}Pu.
67-72	YT(6)	Fission yield from ^{241}Pu.
73-79	HØL1	Nuclide name.
80	NPG	Processing group number.

C-3 designates a group of six cards, one for each delayed neutron group.

C-3 Delayed neutron data (I2,7E10.4).

1-2	I	Delayed neutron group.
3-12	AMA3(I)	Decay constant.
13-22	YT(1)	Delayed neutron fraction for ^{232}Th.
23-32	YT(2)	Delayed neutron fraction for ^{233}U.
33-42	YT(3)	Delayed neutron fraction for ^{235}U.
43-52	YT(4)	Delayed neutron fraction for ^{238}U.
53-62	YT(5)	Delayed neutron fraction for ^{239}Pu.
63-72	YT(6)	Delayed neutron fraction for ^{241}Pu.

This ends data Section C. It is the end of the data for running a single case; that is, when the optimization or variables specified options are not required.

Section D. OPTI

The data for optimization or for the variables specified option are entered in this section. When these options are not required, this section may be omitted.

The coefficients for the standard terms of the objective function are entered on card D-1. The value of each coefficient determines the weight of each objective in the optimization. Terms that need not be considered in a particular optimization may be given zero coefficients.

D-1 Objective function coefficients.* (7E10.4).

1-10	ØBC1	Coefficient for breeding ratio.
11-20	ØBC2	Coefficient for fuel yield.
21-30	ØBC3	Coefficient for reciprocal of fuel-cycle cost.
31-40	ØBC4	Coefficient for reciprocal of fuel specific inventory.
41-50	ØBC5	Coefficient for the group one (damage) fast flux factor.
51-60	ØBC6	Coefficient for the conservation coefficient.
61-70	ØBC7	Coefficient for the reciprocal of discounted fuel cost (from HISTRY).

D-2 Allowable flux (E10.4).

1-10	FLXALW	The allowable group 1 (fast) flux. Must be none-zero if the coefficient of the flux factor (card D-1) is non-zero.

Cards D-3 to 5 form a set; one such set is required for each variables-specified case. The independent variables which may be specified (that is, assigned fixed values) or optimized are given in Table 4.6. They include region thicknesses, the volume fractions of each material in each superregion, the locations of region boundaries, processing cycle times, and the time at which feeds may be switched in a HISTRY cycle.

Table 4.6. Types of Variables

Description	Type Number	Indices		
		1	2	3
Region thickness	1	Region	Dimension	None
Volume fraction	2	Material	Super region	None
Boundary[a]	9	Region	Dimension	None
Processing cycle time	10	Material	Time number	None
Feed switch time	11	None		

[a]Omit cards D-3 to 5 for optimization.

D-3 Number of variables (2I5).

1-5	NVSPC	Case number.
6-10	NVAR	Number of variables specified for given case.

D-4 Case information (I5,E10.4,I5).

1-5	MAX35	MERC iteration limit for case.
6-15	HELP	Factor by which all convergence criteria are multiplied for case.
16-20	NSET	Control of initial flux, fission density distribution, and atom densities: = 0 Taken from previous case > 0 Taken from base case.

D-5 designates a group of cards, one for each variable whose value is to be changed from the preceding case. The number of cards in this group must equal NVAR on card D-3.

Note: A card "D-9, optimization variable" is compatible in format and may be used as a D-5 card. The fields containing optimization information are not read at this point.

D-5 Specified variable (4I3,10X,E10.4,40X,2A4).

1-3	ITYPE(I)	Variable type number (see Table 4.6).
4-6	INDX1(I)	First subscript.
7-9	INDX2(I)	Second subscript.
10-12	INDX3(I)	Third subscript, if any.
23-32	XB(I)	Specified value for variable.
73-80	HØLØPT	Name of variable.

End the variables-specified data with a blank card. This ends the data deck for a variables-specified run.

D-6 Number of OPTI cycles (I3).

1-3	MAXCYC	10	Maximum number of optimization cycles (gradient projections).*

D-7 OPTI control (3I5,E5.0,5E10.4).

1-5	N		Number of OPTI variables.*
6-10	KNTVEC	-1	Vector count for parallel-tangent acceleration method. = −1 New case. (No other options activated)
11-15	NHØLD	0	Number of cycles a variable is held at a limit (zero permitted).*
16-20	CMM	+1.0	Ascent/descent control. = +1.0 to maximize objective function = −1.0 to minimize objective function
21-30	ALPHA	0.05	Fraction of range each variable is moved to calculate derivatives.
31-40	BETA	0.10	Fraction of range that the controlling variable is moved in the initial step along a vector.
41-50	SF1	1.1	Step factor by which BETA is multiplied after each successful step.
51-60	EPS	0.0003	Step tolerance; a lower limit on the fractional improvement in the objective function required for a step to be considered successful.

61-70	PER	0.003	Cycle tolerance; a lower limit on the fractional improvement in the objective function per cycle required for continuation of the optimization.

D-8 OPTI control (I5,2E10.4,I5).

1-5	NØRED		Bypass the reduced-step option: = 1 Yes = 0 No
6-15	REDAB	2.0	Factor by which ALPHA and BETA are reduced in the reduced-step option.
16-25	ALPLIM	0.02	Minimum ALPHA permitted.*
26-30	KAFLSM	0	Activate end-effect option 1. Ridge-analysis factor reduced when derivative is negative.* = 1 Yes = 0 No
31-35	INTV	0	Activate end-effect option 2. Variables with negative derivatives restrained after an unsuccessful first step. Interval scan omitted. = 1 No = 0 Yes

D-9 designates a group of cards, one for each variable, on which the starting value and range are entered. The number of cards in this group must equal N on card D-7.

D-9 Optimization variable* (4I3,3E10.4,25X,F5.0,2A4).

1-3	ITYPE(I)	Variable type number. (Refer to Table 4.6).
4-6	INDX1(I)	First subscript.
7-9	INDX2(I)	Second subscript.
10-12	INDX3(I)	Third subscript, if any.
13-22	XL(I)	Minimum value (lower limit of range).
23-32	XB(I)	Initial value.
33-42	XH(I)	Maximum value (upper limit of range).

68-72	SLEFAC (I)	1.0	Initial value of ridge-analysis factor. Must be non-zero and not greater than 1.0. Usually 1.0.

This ends the ROD data for an optimization run.

This ends the input description.

CHAPTER 5

DISCUSSION OF INPUT

Many of the features of ROD require more exposition than is appropriate for the preceding section, "Description of Input". Such items, which have been marked with asterisks in the description, are discussed in this section. Each discussion is keyed to the appropriate input card number.

A-12 Convergence Information

Refer to card A-42 for a discussion of the convergence criteria.

A-18 HISTRY Control Information

Converter-breeder option. At the beginning of a batch processing cycle, a converter reactor may have a temporary excess of fissile material, because fission-product poisoning has been reduced to zero and fissile material (e.g., ^{233}U) may be available from precursors (e.g., ^{233}Pa) produced in the previous cycle. HISTRY normally "sells" any excess fissile material. The converter-breeder option provides the following alternatives, which apply when k_{eff} exceeds 1.0:

1. Shut off the criticality search. This allows the excess fissile to be retained in the system, thus delaying the point at which fissile feed must again be resumed. This expedient introduces a small error in the fissile balance, (because k_{eff} is greater than 1.0) but may be the best alternative when k_{eff} only slightly exceeds 1.0 for a short time.

2. Withdraw feed in the criticality search. Note, however, that it is usually not practical to withdraw feed from an actual reactor.

3. Withdraw, in the criticality search, uranium nuclides in the proportions present in the fuel stream. This simulates withholding some of the uranium separated from the fuel at the end of a cycle, and feeding it back as needed during the following cycle, before resuming normal feed. The simulation is imperfect in that the instantaneous fuel composition is used rather than the composition at the end of the cycle. This alternative is recommended when considerable excess fuel is available at the beginning of a cycle.

Second feed. For reactors with plutonium feed, where uranium is recovered at the end of a cycle but plutonium is not, there is an advantage in switching to a uranium feed near the end of the cycle. To activate this option, enter the time in the cycle at which the feed is to be switched and specify the ERC number of the key nuclide of the second feed (e.g., 5, for ^{235}U, for enriched uranium as second feed). Also specify the feed fractions for the second feed on cards A-21 to 34.

A-19 HISTRY Data

Frequency of output. The frequency of output is determined by specifying the number of timesteps in a data storage interval. A frequency of once or twice a year is adequate for most of a typical cycle. However, the fuel composition usually changes rapidly at the beginning of a cycle, and the program provides for 12 times the normal frequency of output at the beginning of a cycle, that is, data once or twice a month. SHIFT specifies the total number of printouts at the higher frequency (starting with the first at time zero).

Fertile buildup option. Certain fuel cycles are characterized by a fissile inventory which starts at a high level and decreases. One then has the option of starting with a lower fissile and fertile inventory and adding fertile material with time instead of removing fissile. To exercise this option, specify the final fertile atom-density desired as THMX, and enter a smaller atom-density for the initial value.

A-19.1 HISTRY Carrier Cost Control Information

Fuel carrier cost data are usually part of the ERC input. The carrier cost in HISTRY is calculated from the ratio, carrier cost per kilogram of thorium purchased, which is calculated from ERC data as follows:

$$SCR = \frac{\sum_{\substack{I=1,NS \\ M=NSC(I)}} (SI(M,1)*W1(M,1))}{SI(1,1)} + W1(1,1)$$

where

SCR = the carrier cost ratio,

SI(M,1) = the inventory of carrier nuclide M in material 1,

SI(1,1) = the inventory of thorium in material 1,

W1(I,1) = the cost per kilogram assigned to each nuclide,

NSC(I) = the ERC numbers of the carrier nuclides specified on card A-19.1.

A-21 HISTRY Nuclide Information

The HISTRY subprogram is set up for a specific configuration of the ERC data as follows:

Nuclides 1 to 12 in order are: ^{232}Th, ^{233}Pa, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{237}U, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu.

HISTRY nuclide 13, fixed absorbers, corresponds to the summation of ERC nuclides 13 to 50, except 25.

HISTRY nuclide 14, fission products, corresponds to the summation of ERC nuclides 25 (lumped fission products), 229 (^{149}Sm), and 231 (^{151}Sm).

A-35 Atom Densities by Material

By convention, the fuel stream is material 1, the fertile stream, if any, is material 2, and the moderator, if any, is the last material specified.

A-38 Super Region Subregion Correspondence

The "super region" was conceived as a convenient method of indicating the distribution of materials (that is, the volume fractions) in regions of the 2-D reactor that do not lie on one of the calculational axes. It is convenient to assign subregions of identical composition the same super region number. (The same form of data is followed for a 1-D reactor, although the form then has no special utility.)

A-41 Group Structure

When only one thermal group is indicated, the upscatter treatment is shut off. We have noted that the use of multiple thermal groups with upscatter, although valuable in certain cases, results in increased running time by a factor of 2 or more.

A-42,43 MODRIC Convergence and Search Information

A certain balance in the convergence requirements of the various sections of the code is essential to the efficient functioning of ROD. It is convenient to use EPSL, the tolerance for k_{eff}, as a reference. Experience has shown that the ratio of the value of a given convergence criterion to that selected for EPSL should be about as indicated in Table 5.1. The recommended absolute value of EPSL of 1.0×10^{-4} is adequate for most single or "variables specified" cases, and gives results for the breeding ratio and fissile inventory consistent to about one part per thousand. It is sometimes necessary to tighten the convergence criteria for difficult optimization problems, because the direction of the optimization depends on the ratio of the results of two very similar cases, and therefore may be very sensitive to slight imprecision in the individual cases.

Table 5.1. Recommended Balance Among Convergence Criteria

Input Card Number	Name	Description	Recommended Ratio to EPSL
A-43	EPSL	Tolerance for k_{eff}	1.0
A-42	EPS1	Convergence on k_{eff}	0.3
A-42	EPS2	Convergence on fission density	3.0
A-12	CTØL	Tolerance, upscatter acceleration	1.0
A-12	CDELT	Convergence, upscatter acceleration	0.1
B-2	CØNVEG	Convergence, ERC atom densities	1.0
B-4	SEPS	Tolerance, MERC balance	10.0

The balance between tightness of convergence and the running time is critical for optimizations. When the convergence criteria are set tight enough (say, 10^{-5} for EPSL) to get very precise derivative calculations, the running times become long. If set too loose (say, 10^{-3} for EPSL) the derivative calculations may become so imprecise as to direct an optimization

vector in a false direction. Optimizations usually run most efficiently at moderately tight convergence (near 10^{-4} for EPSL).

Two "tricks" are employed in ROD to save running time (refer to card A-12). We have found that optimization runs can be made efficiently with relatively looser convergence when the convergence is tighter for the base case. This gives a firm starting flux distribution for the first optimization case, whereas otherwise the flux distribution may tend to change over the first few cases even though the convergence criteria are satisfied. The other trick is to loosen the convergence slightly for the first MERC iteration, since it is wasteful for the diffusion calculation to be tightly converged until it has received a set of altered concentrations from ERC. To accommodate this provision, and to prevent MERC from stopping with a fortuitous balance while MODRIC and ERC are not converged, the program requires a minimum of two MERC iterations per case.

A-43 MODRIC Search Information

The value of dC/dk, the ratio of change in composition to change in k_{eff}, is highly dependent on the reactor composition. The best guide for selecting an initial value is to look at the final value calculated in a similar case (given as CP1 in the output).

A-44 Criticality Search Nuclides

It is usually more efficient to specify as search nuclides all the nuclides in the fissile chain rather than just the main fuel nuclide. Specifically, those nuclides whose concentrations tend to vary with the concentration of the fuel nuclide should be included as search nuclides, while those nuclides which tend to reach an equilibrium concentration independent of the fuel nuclide should not be included. If such "independent" nuclides are treated as search nuclides, they tend to cause the calculation to oscillate between MODRIC and ERC. Suspect this effect if more than three MERC iterations are required for convergence.

A-45 Two-Dimensional Synthesis Information

The two-dimensional synthesis is described in Chapter 7, p. 7.6.

By convention, for a 2-D synthesis in cylindrical geometry, dimension 1 is axial and dimension 2 is radial.

In the 2-D synthesis, there is a provision for adjusting the flux in the core to take into account neutrons which leave the core in the transverse direction. The region specified as "core" can only be the center region of the reactor. The computed net flow of neutrons out of this region (by group) determines a buckling for the calculation of transverse "leakage" in the other dimension. The leakage neutrons may be distributed in proportion to the absorptions in as many regions as may be desired. These are the "transverse leakage distribution" regions and should always include the core region.

A-46 Region Information

A reasonable number of mesh spaces per region might range from 5 for a small region to 50 for a large region. Avoid large differences in the size of a mesh interval from one region to the next. The running time is not very sensitive to the number of mesh spaces, and is moderately affected by the number of regions.

The fission-density distribution is calculated over all regions specified as containing fissile material.

A-48 and 50 Shell Thicknesses and Attenuation Coefficients

If desired, regions may be separated by "shells" in which the neutron current may be attenuated (refer to Appendix B).

A-52 Buckling Option 1

This option calculates the buckling by group and region from the equations:

Slab:

$$B^2 = \left(\frac{\pi}{y + \gamma D}\right)^2 + \left(\frac{\pi}{z + \gamma D}\right)^2$$

Cylinder:

$$B^2 = \left(\frac{\pi}{h + D}\right)^2 ,$$

where

y,z,h = perpendicular dimensions of the reactor,

γ = constant for calculating the extrapolation distance,

D = diffusion coefficient, a function of group and region.

A-55 MODRIC-ERC Nuclide Number Correspondence

The fissionable nuclides (for which fission yields are given on card C-2) must be assigned ERC nuclide numbers in the range 1 to 13.

A-58 Cross-Section Set Assignment

For many calculations the use of a single cross-section set weighted for the average flux-spectrum is adequate. However, for cases in which the flux-spectrum effects are different in different regions of the reactor, cross sections appropriate to the various spectra can be prepared and assigned to the different regions.

B-1 ERC Data

A "MERC iteration" is one pass through MODRIC and ERC. Typically two or three MERC iterations are required for convergence. Normally, output is obtained for only the final iteration. For the purpose of code development, some of the ERC and HISTRY output may be obtained each iteration.

The fission-product reference element must correspond to an artificial element in MODRIC which has cross sections for a 1/v absorber with $\sigma_a^{2200} = 1.0$.

Some of the important fission products (e.g., ^{149}Sm) may be included explicitly in the multigroup diffusion calculation, if desired. To do this, select fission product option 2, list the nuclides in the MODRIC-ERC correspondence table, and include them on the cross-section tape. Such nuclides are edited separately by material in the second part of the ERC output table (output option 7), but are included in the lumped fission products in the preceding summary neutron balance.

Base-case only option. When this option is specified the program will stop after running the base case (case zero) even when the data deck is otherwsie set up for the optimization or variables-specified options. It may be used to check the base case before proceeding with, say, a long optimization run.

The processing study option substitutes a more sophisticated fission-product treatment for that normally used in ERC. It is described in Appendix D.

Three processing cost options are available (refer to card B-24). For molten-salt reactors, the processing cost depends mainly on the volume of salt stream processed, and is, therefore, usually calculated on the "volume basis."

B-2 ERC Convergence and Other Data

The atom-density damping/forcing coefficient is a factor by which the calculated change in atom density per iteration is multiplied. It is usually set less than 1.0 to dampen cycling of the atom densities from iteration to iteration.

The limit on the change in atom density permitted per iteration is used to help prevent cycling and to prevent atom densities from becoming negative. The limit is in effect for each ERC iteration after the first.

The plant factor is defined as the anticipated energy production as a fraction of the energy that would be produced if the plant were operated continuously at full power.

B-3 ERC Residence Times and Other Data

The capital cost of a processing plant is assumed to be proportional to its capacity raised to a fractional power called the scaling factor.

B-4 Tolerance for MERC Convergence and Other Data

The fission-product thermal spectrum factor is defined as follows:

$$W = \frac{1}{\Delta u_f \frac{\pi}{4} \left(\frac{298}{T + 273}\right)},$$

where

Δu_f = lethargy width of fast energy groups,

T = temperature, °C.

The limiting factor for change of the recycle fraction is used to dampen oscillations in ERC, and is applied in each iteration after the first.

B-11 Processing Cycle Times

A processing cycle time is the time required to process one system volume of a material. Processing may consist of several steps, and each step can have its own cycle time. Usually the cost of processing can be related to one or two main steps, and these may have a processing cost factor, volume basis, assigned to them, as follows:

$$PCV_{n,j} = U_{n,j}\, t_{n,j}^{(1-SF)} ,$$

where

PCV = processing cost factor, volume basis,

n = number of processing cycle time associated with a given processing step,

j = material number,

U = unit processing cost, dollars per cubic foot of material j, for processing step n in a reference plant,

t = throughput, cubic feet of material j processed per day in step n in the reference plant,

SF = scaling factor. The capital cost of a processing plant is assumed to be proportional to its capacity raised to a fractional power, the scaling factor.

Processing cycle time 1 is used as a reference cycle time for calculating the material holdup in the processing plant. Refer to Eq. (A.40), Appendix A.

B-12 Processing Equations

The removal rate of any nuclide in ERC is calculated for each material stream by the processing equation to which it is assigned. The removal rate is calculated from the cycle times for the processing steps in which it is removed. The cycle times that apply to each group equation are indicated on the processing equation card by entering a 1.0 in the position corresponding to the number of each cycle time. For example, if the nuclides in processing group one are removed from material one in processing steps 2 and 4, the card for material one processing equation one should

have 1.0 entered in fields 2 (col. 16-21) and 4 (col. 28-33), which correspond to cycle times 2 and 4; the other fields are left blank.

B-20 Stream Data

The code calculates the volume of each material in the reactor core. However, in a circulating-fuel reactor, a considerable volume of the fuel stream is outside the core in piping and heat exchangers. To allow the code to calculate the true reactor inventories and inventory costs, the amount of such external volume for each stream may be entered here.

In addition, if the stream is processed, the holdup time in the processing plant may be entered. The volume of the holdup is then calculated as a function of the reactor volume and the ratio of the holdup time to the reference processing cycle time (processing cycle time 1).

Reserve fuel. If the reactor requires a fissile feed, a fuel reserve sufficient to feed the reactor for some period of time may be included in the inventory. This is calculated from the net burnup (burnup less production) of the feed nuclide (see Eq. A.43, Appendix A.

Fixed poison fraction. The strong fission-product poison ^{135}Xe may be treated as a special case in molten-salt reactors. It is insoluble in the salt, and is either removed by gas stripping or is absorbed by the graphite moderator. Its true removal efficiency is not easily determined. The problem has been side-stepped by assigning a removal efficiency of 1.0 to the gas-stripping process, and adding a fixed poison-fraction to allow for the holdup of xenon in the moderator.

B-21 Removal and Recycle Data

The "removal efficiency" in processing may be defined as the product of E, the fraction processed per cycle, and SCE, the fraction removed (or lost, for nuclides which are recycled). Normally the removal efficiency is 1.0, and E and SCE are automatically assigned the value of 1.0. This value is not appropriate for all nuclides, however, and other values may be assigned on cards B-21. Some examples are:

(a) Nuclides which are recycled (either back to the stream from which they were removed, or to another stream) such as the uranium nuclides.

They may be assigned an SCE of 0.0, or a small non-zero value representing the fraction lost per cycle in processing.

(b) Nuclides which are only partially removed by processing. An appropriate removal fraction may be assigned.

(c) Nuclides which are removed in smaller side streams taken from another processing step. They may be assigned the appropriate processing fraction. (Alternatively, such nuclides may be placed in separate processing groups, to which independent processing cycle times can be assigned.)

(d) To simulate batch processing. E values greater than 1.0 may be assigned to groups of fission products to simulate the greater removal in batch processing compared to continuous processing for the same cycle time. E values less than 1.0 may be assigned to nuclides such as the plutoniums, when, because of decreasing concentrations during a cycle, their removal at the end of a batch cycle is less than would be obtained by continuous removal (based on their average concentrations and the average carrier discard rate).

Recycle fraction. Any nuclide which, wholly or partially, is not removed in processing, presumably remains in its original stream and is returned to the reactor. In the calculation this is considered recycle to the same stream, and the recycle fraction for a stream to itself is automatically set at 1.0. Similarly, the recycle fraction from one stream to another stream is automatically set at 0.0.

Sometimes it is essential to recycle certain nuclides from one stream to another, as in the case of a reactor with a separate fertile stream, or blanket. The key to the high performance of such reactors is in the transfer of the fissile material bred in the fertile stream to a fuel stream. Nuclides to be so transferred must be assigned ERC nuclide numbers in the range 1 to 25, and their recycle fractions set appropriately on cards B-21. The permitted values for the recycle fractions are 1.0 and 0.0. The lumped fission products may not be transferred.

B-22 Feed, Atom-Density, and Recycle Options

ERC works best when one nuclide, usually the most important fuel nuclide, is selected as the "key nuclide" for these options. It is normally assigned feed option 1, atom-density option 2, and one of the

recycle key-nuclide options 1 to 4. It is also usually a criticality-search nuclide in MODRIC. This selection allows MERC to either feed or sell the key nuclide, as required, as MERC converges on a solution.

For a reactor with a breeding ratio near 1.0, we might wish to sell one nuclide if the reactor were a breeder, and feed another nuclide if it were not. In theory, MERC could do this, but in practice, because of imbalance in ERC, it may sell one fuel nuclide while feeding the other. We recommend that a preliminary case be run to determine the breeding ratio, and the key nuclide then be selected accordingly.

When the HISTRY option is used, atom-density option 2 (criticality) may be specified for the key nuclide, but option 0 should be specified for the other nuclides in the fertile-fissile chain. This will hold the atom densities fixed in ERC at the time-averaged values obtained from HISTRY.

B-23 ERC Material-Balance Data

Any nuclide for which one of the non-zero recycle options was specified (card B-22) must be specified as its own processing source. In addition, ^{233}Pa should be specified as a processing source for ^{233}U, assuming that ^{233}U formed by the decay of ^{233}Pa in the processing plant is returned to the reactor. The processing group number determines the processing equation applied to a given nuclide in each material. Note that the processing equations are material-dependent while the processing group assignments are not. The number of processing groups is limited to ten. The reference processing cycle time is applied to all nuclides for which no processing group number is specified.

B-24 Value of Materials

The value of each material may be specified (for the purpose of computing inventory and replacement costs) by assigning a value to one or more nuclides in that material. A different value may be assigned to a nuclide in the system from the value assigned to the same nuclide as feed material. This allows, for example, that ^{235}U be assigned a higher value as feed material than as a part of the fuel stream, where it is contaminated with ^{236}U.

Three options are available for computing processing costs. One, based on the volume of material processed, has already been discussed. The others are the weight-basis option, based on the weight of some nuclide or nuclides processed, and the capital-cost-basis option, based on the unit capital cost of the processing plant. (Refer to Eq. A.60, Appendix A). The options are selected merely by making the appropriate coefficient non-zero.

The processing unit-capital-cost factor is defined, for a reference processing plant, as follows:

$$U = \frac{(C)(i)}{Q^s} ,$$

where

U = unit capital cost factor,

C = capital investment, $,

i = interest rate,

Q = throughput of nuclide I, kg/day,

s = scaling factor (refer to card B-3).

D-1 Objective-Function Coefficients

The standard equation for the objective function is:

$$O = aB + bY + c/M + d/I + eF + fC + g/D ,$$

where

O = objective function,

a,b,c,d,e,f,g = coefficients,

B = breeding ratio,

Y = fuel yield, percent of fissile inventory per year,

M = fuel-cycle cost, mills/kwhr,

I = specific inventory, kg fissile/MW(thermal),

F = flux factor,

$$- \frac{F_a - F_m}{10^{14}}$$

F_a = allowable group-1 flux; input on card D-2,

F_m = a maximum group-1 point flux in the core, calculated in MERC.

When $(F_a - F_m) \geqslant 0$, F is set to zero.

C = conservation coefficient,

$$\frac{100(B-1)}{I^2},$$

D = discounted fuel cost (from HISTRY), in mills/kwhr.

D-2 Allowable Flux

The allowable group-1 flux may be specified as required to limit the fast-neutron damage to the materials in the core. Whenever the allowable flux is exceeded, the flux factor, a negative term, reduces the value of the objective function. The net effect is to shift the optimum to that set of conditions which gives the highest performance consistent with a peak flux exceeding the allowable flux by some margin which depends on the relative weight given the flux factor.

D-6 Number of OPTI Cycles

The number of OPTI cycles (gradient projections) should be set to stop the run before the running-time limit is exceeded. An OPTI cycle, or gradient projection, consists of the calculation of derivatives to determine a gradient vector, the taking of steps along the vector, and the calculation of the maximum of the objective function along the vector. When a run is stopped in the middle of a cycle, the information generated for that cycle is wasted. Specifying zero as the number of cycles will halt the calculation at the end of the base case.

D-7 OPTI Control

Although 20 OPTI variables are allowed, there are good reasons for holding the number of variables as small as possible. The most obvious is to save running time. Less obvious but perhaps more important is a certain decrease in precision as the number of variables is increased. This may be explained as follows: As steps are taken along a vector, we can think of the variables one by one reaching their optimum values

and continuing on beyond, until the variables beyond their optima are balanced by those that have not reached their optima, and the objective function reaches its maximum. The greater the number of variables, the more likely that some of them will stop at some distance from their true optima. This effect can be countered by tightening the convergence criteria and reducing the step size, but, of course, at the expense of increasing the running time.

When a variable reaches one of its limiting values, it may be held there for any specified number of optimization cycles. During these cycles, no derivative is calculated for the held variable and it does not affect the size of step of the other variables.

D-8 OPTI Control

The minimum ALPHA is the mechanism which halts the step-reduction procedure. If a step reduction would result in an ALPHA less than the minimum, the reduction is not permitted and the optimization is terminated. The minimum ALPHA determines the "fineness" to which the optimum is located. In reactor calculations there is little incentive to locate the optimum with great precision, and the step reduction is often bypassed, or held to one reduction by the choice of minimum ALPHA.

End-effect options. The end-effect is described in Chapter 7, p.7.15. End-effect option 1 applies a reduction in the ridge-analysis factor whenever the derivative is negative, as well as whenever it changes sign. When this option is used, it may be advantageous to select initial values for the variables such that the initial derivatives are likely to be positive.

End-effect option 2 is applied only after a normal first step has been unsuccessful. This must occur at least once at the end of every optimization. The variables with negative derivatives are then restrained (by a factor of 0.01) and steps are started along a vector determined essentially by the positive derivatives. The interval scan is omitted. Often, successful steps can be taken along the new vector. In general, we recommend the activation of end-effect option 2.

D-9 Optimization Variable

The sensitivity of an optimization to a given variable is influenced by the range assigned that variable. The step factors ALPHA and BETA are defined as fractional factors of the range; therefore, when the range is large, the steps will be large and the resulting change in the objective function is likely to be large. The optimization works best when the change in the objective function is about the same for each variable — that is, when the "derivatives" are of roughly the same magnitude. Often this is not the case. When the optimization is dominated by one or two variables, the "ridge effect" may result; that is, the path of the optimization jumps back and forth across a "ridge" as the value of the dominant variable is alternately too high and too low. The "parallel tangent" and "ridge-analysis" techniques are used in OPTI to get around the ridge effect (see Chapter 7), but the optimization must run several cycles to accumulate the information required for these techniques. When the user knows from experience that a given variable will tend to dominate, the sensitivity of the optimization to this variable can be reduced by giving it a small range compared to the range of other variables. However, a small range is not always practical. The range should be large enough to include, with high probability, the optimum value of the variable (otherwise the entire run could be wasted). When the range cannot practically be reduced, the sensitivity to a given variable may be reduced by assigning it a fractional initial ridge-analysis factor. The ridge-analysis factor is applied to both derivative and vector-step calculations.

Frozen variable. If the minimum and maximum values of a variable are set equal to its initial value, it becomes a "frozen" variable. No derivatives or other calculations are made for frozen variables. The frozen variable has two uses:

(1) To remove a variable from the optimization, perhaps just for a particular run, without removing it from the edit of the variables.

(2) To satisfy the requirement that the region thicknesses on either side of a boundary variable be variables, without increasing the number of active variables.

CHAPTER 6

USER INFORMATION

Control Cards

Typical control cards for running ROD on the ORNL IBM 360/75 or 360/91[a] computers are:

```
//HFBQ      JOB (12073),'Y-12 9104-2 H BAUMAN',MSGLEVEL=1,
// CLASS=F,TYPRUN=HOLD,REGION=1536K
//ROD EXEC LINKNGO,PARM.LINK='LIST',REGION.GO=1536K
//LINK.FT33F001 DD UNIT=TAPE9,LABEL=(,NL),VOLUME=SER=33,[b]                X
//              DISP=(OLD,PASS),[b]                                        X
//              DCB=(RECFM=FBS,LRECL=80,BLKSIZE=3200)[b]
//LINK.SYSIN DD *
 INCLUDE FT33F001
/*
//GO.FT09F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3458),[c]
// SPACE=(3458,(2000),RLSE)[c]
//GO.FT08F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3458),
// SPACE=(3458,(600),RLSE)
//GO.FT01F001 DD UNIT=SYSDA,SPACE=(TRK,(27)),DCB=(RECFM=F,BLKSIZE=80)
//GO.FT02F001 DD UNIT=TAPE9,LABEL=(,NL),VOLUME=SER=2,DISP=OLD,             X
//              DCB=(RECFM=VB,LRECL=3600,BLKSIZE=3604)
//GO.CRTTAPE DD UNIT=TAPE9,LABEL=(,NL),DISP=OLD,VOLUME=SER=4[d]
//GO.FT10F001 DD *
/*
//
```

---

[a]When running on the ORNL/91, only two nine-track tapes are available; therefore, when plotting is required, the program must reside on disk.

[b]For running with the program on tape. If the program resides on disk, the following cards should be used instead:

```
//LINK.FT33F001 DD VOLUME=REF=ZZZZZZ,DISP=SHR,                            X
//              DCB=(RECFM=FBS,LRECL=80,BLKSIZE=3200),                    X
//              DSNAME=AZ.G4.P35614.C12073.BAUMAN.A
```

[c]To omit detailed output, replace these two cards with the following:

```
//GO.FT09F001 DD DUMMY
```

[d]For plotting only. Otherwise, omit this card so that no plotting tape will be mounted.

The input/output devices are listed in Table 6.1. ROD requires a minimum core region allocation of 1200K bytes (300K words).

Table 6.1. Input/Output Devices Used for the ROD Program

Logical Number	Stepname·ddname	Use
1	GØ.FT01F001	Disk-scratch
2	GØ.FT02F001	Tape or disk – cross section library
4	GØ.CRTTAPE	Tape, for plotting, 9 track
8	GØ.FT08F001	Auxiliary output
9	GØ.FT09F001	Standard output
10	GØ.FT10F001	Standard input
33	LINK.FT33F001	Tape or disk for ROD

Cross-Section Tape

The cross-section tape used by ROD is in the same format as that used by the code CITATION.[3] This binary tape is normally prepared by the code XSDRN[4] but may be prepared from cards using the CITATION auxiliary program.

The format for a cross-section set on the tape is given in Table 6.2.

The n,2n reaction, if any, is included in the fission cross section as follows:

$$\sigma_f^* = \sigma_f^{true} + \sigma_{n,2n} ,$$

$$\overline{\nu\sigma_f^*} = \overline{\nu\sigma_f^{true}} + 2.0 \times \sigma_{n,2n} ,$$

$$\overline{\nu^*} = \frac{\overline{\nu\sigma_f^*}}{\sigma_f^*} ,$$

where σ_f^* and $\overline{\nu^*}$ are reported on the cross-section tape.

Table 6.2. Format of the ROD Cross-Section Tape

Record Number	Variable Name	Description
1	(TPTIT(I),I=1,18)	
	TPTIT	72 character title for set
2	NTYPE,NTAPE,NGT, NDS,NUS	
	NTYPE	Not used
	NTAPE	Number of nuclides in set
	NGT	Number of energy groups in set
	NDS	Not used
	NUS	Not used
3	(FUS(I),I=L,NGT), (ET(I),I=1,NGT), (EM(I),I=1,NGT)	
	FUS	Fission source distribution function by group
	ET	Upper energy of each discrete group (eV)
	EM	Mean energy of each discrete group (eV), that is, the energy corresponding to the midpoint lethargy of the group
Repeat records 4 and 5 for each nuclide.		
4	NID,N2,N3,N4, N5,(AME(I),I=1,6), (TAB(I),I=1,60)	
	NID	Nuclide number
	N2	Not used
	N3	Not used
	N4	Not used
	N5	Not used
	AME	24 character nuclide name
	TAB	Not used

Table 6.2 (contd)

Record Number	Variable Name	Description
5	(ALA(IG),FISS(IG), ALTR(IG),FNUS(IG), DUMMY,IG=1,NGT), ((FMU(IG,L),L=1,NGT, IG=1,NGT)	
	ALA(IG)	Absorption cross section for group IG
	FISS(IG)	Fission cross section for group IG
	ALTR(IG)	Transport cross section for group IG
	FNUS(IG)	Neutrons/fission for group IG
	DUMMY	Not used
	FMU(IG,L)	Total scattering from group IG to group L
6	NEND	
	NEND	Closure record (=-1)

As many sets as desired may be included on the tape, but only five may be used by the code for any given case.

The $^{9}Be(n,\alpha)$ cross section is treated specifically by MODRIC nuclides number 4 and 70 so that the buildup of ^{6}Li from ^{9}Be may be treated explicitly. For ^{9}Be (MODRIC nuclide number 4) the group 1 absorption cross section on the tape is given by

$$\sigma_a^4(1) = \sigma_{n,\alpha}^4(1) + \sigma_{n,2n}^4(1) \ .$$

We say that

$$\sigma_a^4(1) = \sigma_{n,2n}^4(1)$$

and create a MODRIC nuclide number 70 such that

$$\sigma_a^{70}(1) = \sigma_{n,\alpha}^4(1) \ .$$

The cross-section tape must have nuclides number 4 and 70 on it, in that order, where the cross sections listed for nuclide 70 are all zero.

ROD Subroutines

The subroutines in ROD, with their function and the location from which they are called, are given in Table 6.3.

Table 6.3. The ROD Subroutines

Subroutine	Called From	Description
	A. Input and Calculation Subroutines	
MAIN		Control calculation.
ZERØ	MAIN	Zeroes common.
SPLIT		General input.
PART2	SPLIT	Diffusion calculation input.
RPCS1	MAIN	Processes microscopic cross section tape.
CIN	MAIN	Equilibrium calculation input.
BTMØD	ERCØUT	Converts the equilibrium material densities to the form used by the diffusion calculation. (Entry point in CIN)
MØD8C	MAIN	Diffusion calculation.
CRSCH	MØD8C	Criticality search.
RCSHN	DØALL,MØD8C	Performs a geometry-dependent region boundary correction on flux and fission density integrations.
SAMMY	MØD8C	Calculates k-effective for two-dimensional synthesis.
ERCP	MAIN,MØD8C	Argument = 0: Calculates absorptions, fissions, and neutrons produced by nuclide and region.
		Argument = 9: Two-dimensional synthesis; normalizes dimension one results to dimension two, and sets up the linkage between the diffusion calculation and equilibrium calculation.
DØALL	MAIN,MOD8C PART2	Argument = 2: Computes region densities from material densities.
		Argument = 3: Modifies densities after criticality search.
		Argument = -3: Corrects macroscopic cross sections after criticality search.
		Argument = 5: Calculates a complete set of macroscopic cross sections.
		Argument = 6: Calculates mesh and region boundaries.

Table 6.3 (contd)

Subroutine	Called From	Description
		Argument = 7: Fission density normalization.
ERCM	MAIN	Equilibrium calculation.
CYCL8	ERCM	Recycle calculation.
ERCØUT	ERCM	Fuel-cycle and economics calculations.
HISTRY	ERCØUT	Time-dependent calculation.
ALLDØ	ERCM,MAIN	Argument = 1: Performs the linkage to the optimization routine. Calculates the objective function.
		Argument = 2: Performs the linkage from the optimization routine back to the diffusion-equilibrium calculation. Assures that the super region volume fractions sum to unity by modifying the final material (moderator) volume fraction. Recalculates the diffusion volume fractions. Performs the boundary variable manipulation.
		Argument = 3: Calculates the region volumes and the equilibrium material volumes. Treats the processing equations by calculating removal efficiencies.
WLKEP	MAIN	Optimization routine.
FLUX	MAIN	Calculates true flux and average fission power density.
ØUTSET	WLKEP	Controls the output options in optimization.
EPSILN	MAIN	Multiplies all convergence epsilons by an input constant (variables-specified cases only).
TIGHT	MAIN	Divides all convergence epsilons by an input constant.
SLACK	MAIN	Multiplies all convergence epsilons by an input constant.
BELL	MAIN	Interfaces a special fission-product treatment.
SET	MAIN	Stores a set of material densities, fluxes, and fission densities for use at a later time.

Table 6.3 (contd)

Subroutine	Called From	Description
RESET	MAIN	Restores the previously saved material densities, fluxes, and fission densities. (Entry point in SET)
BØUND	ALLDØ	Changes region thicknesses when the boundary variable option has been specified for an optimization or variables-specified case.
FIXQ	CIN	Input processing routine.
BLØCK DATA		Initializes CØMMØN/PRESET/.
		B. Edit Subroutines
ED01	SPLIT	Edits nuclide number correspondence table.
ED02	SPLIT	Edits super region subregion correspondence.
ED03	ALLDØ,SPLIT	Edits super region volume fractions.
ED04	ALLDØ,MAIN	Edits region thickness, mesh spaces, cross-section set, whether fissionable, distance to start of region, and distance to end of region.
ED05	MAIN	Edits super region volumes and material volumes.
ED07	MAIN,MØD8C	Edits macroscopic cross sections.
ED08	MAIN	Edits the material densities after the equilibrium calculation.
ED09	MAIN,MØD8C	Edits homogenized region densities.
ED10	MAIN	Edits processing information.
ED12	MAIN	Edits group neutron balance.
ED13	ERCP,MAIN	Edits absorptions, neutrons produced, and fissions by nuclide and region.
ED14	MAIN	Edits optimization summary table.
ED15	MAIN	Edits total region absorptions, neutrons produced, fissions, and ratio of productions to absorptions.
ED16	MAIN	Edits forward leakage, transverse leakage, absorption, fission, and neutrons produced by region.

Table 6.3 (contd)

Subroutine	Called From	Description
ED17	SPLIT	Edits plotting input options.
ED18	SPLIT	Edits diffusion calculation convergence and control information.
ED20	MAIN	Edits true flux, fission density, and average fission power density.
ED21	ED22,ERCØUT	Edits short summary table of the equilibrium calculation results. The table includes breeding ratio, eta, yield, fuel-cycle cost, fissile inventory and processing losses.
ED22	ERCØUT	Edits equilibrium calculation summary table.
ED22E	ERCØUT	Edits equilibrium calculation summary table. (Entry point in ED22)
ED23	ERCØUT	Edits fission-product densities and absorptions for material one only.
ED24	ERCP	Edits input to equilibrium calculation from diffusion calculation. The table includes densities, absorptions, neutrons produced, and fissions by nuclide and material.
ED25	WLKEP	Edits input for an optimization case.
ED26	MAIN	Edits input for a variables-specified case.
ED27	ERCØUT	Edits input to HISTRY from MERC.
CØUT	CIN	Edits input for ERC.
GØNE	WLKEP	Edits debugging information for optimization.
DIVID	MAIN	Controls case heading printout.
FHLPR	DIVID	Prints case heading.
BLØCK DATA		Initializes CØMMØN/LETTER/. Stores characters to be printed.
HISØUT	HISTRY	Edits results from HISTRY.

Table 6.3 (contd)

Subroutine	Called From	Description
	C. Plotting Subroutines	
SETPLT	MAIN	Initializes plotting package.
ELXPLT	MAIN	Sets up the fluxes to be plotted.
ADDTIT	FLXPLT	Puts additional heading on plots.
PLTTRM	MAIN	Terminates plotting.
GEØPLT	Never called	Dummy subroutine.
ØPTPLT	MAIN	Dummy subroutine
BPLØT[5]	FLXPLT	
BLAB	BPLØT	
XY	BPLØT	
LG	BPLØT	
TITLE	BPLØT	
LINE	BPLØT	
LINSCL	BPLØT	
HIST	BPLØT	
CRTGRD	BPLØT	
RANGE	BPLØT	
	D. Additional System Subroutines and Functions Required	
ALØG	BPLØT,RPCS1	Natural logarithm function.
ALØG10	CRTGRD	Common Logarithm function.
CØS	PART2	Cosine function.
CRT[a]	BPLØT,CRTGRD, HIST,LINE, PLTTRM,SETPLT, TITLE	
CRTNUM[a]	ADDTIT,LG,XY	
CRTSYM[a]	ADDTIT,BPLØT, LG,LINE,TITLE	
EXP	ERCM,MAIN	Exponential function.

Table 6.3 (contd)

Subroutine	Called From	Description
ICLØCK	CIN,ERCM, ERCØUT,MAIN, MØD8C,WLKEP	Returns CPU time in hundredths of seconds.
IDAY	DIVID	Returns the date as 8 EBCDIC characters.
SLITE	MAIN,PART2	Alters status of sense lights.
SLITET	MAIN	Tests and records status of sense lights.
SQRT	HISTRY	Square root function.

[a]Plotting routines for a CALCØMP model 835 cathode-ray tube plotter.

CHAPTER 7

THEORY

MODRIC-ERC*

MODRIC is a typical neutron-diffusion-theory code. It allows 50 neutron energy groups with downscattering from a group to any of the following ten groups. It has been modified in ROD, where only 15 energy groups are permitted, but where a multiple-thermal group treatment with upscatter has been added.

It will perform concentration searches on specified elements. The output consists of critical concentrations, group macroscopic cross sections, normalized nuclear events (absorptions, fission, leakage, etc.) by region and group, absorptions and fissions by material and region, group flux distributions, and fission density distributions. The basic MODRIC equations are given in Appendix B.

Basically, ERC solves two main equations. They are:

$$V_j \frac{dN_{ij}}{dt} = Q^f_{ij} + R_{ij} + F_{ij} + T_{ij} + D_{ij} - N_{ij}(t_{ij} + d_{ij} + q_{ij} - r_{ij}) = 0 \ , \quad (7.1)$$

$$\left[N^s_{ij} - N^{s-1}_{ij}\right] \nu_i \sum_k C^f_{ijk} = \sum_{ijk} N^{s-1}_{ij} C^a_{ijk} - \sum_{ijk} N^{s-1}_{ij} C^f_{ijk} \nu_i \ , \quad (7.2)$$

Equation (7.2) is just the conservation requirement, saying that enough fissile material must be added (or removed) in iteration s to overcome the neutron production deficiency (or excess) in iteration (s-1). These are inner iterations in ERC. The terms are defined as:

---

*This section has been largely excerpted from Ref. 2.

V_j = volume of stream j, cm^3,

N_{ij} = atoms of nuclide i per barn cm of stream j,

t = time, sec,

Q_{ij} = feed rate of nuclide i into stream j, atoms/sec,

R_{ij} = rate of production of nuclide i in stream j due to recycle from other streams, atoms/sec,

F_{ij} = rate of production of fission fragment i in stream j, atoms/sec,

T_{ij} = rate of production of nuclide i in stream j due to neutron absorptions in other nuclides, atoms/sec,

D_{ij} = rate of production of nuclide i in stream j due to radioactive decay of other nuclides, atoms/sec,

t_{ij} = rate coefficient for loss of nuclide i in stream j because of neutron capture, atoms/sec/atom/barn cm,

d_{ij} = rate coefficient for loss of nuclide i in stream j because of radioactive decay, atoms/sec/atom/barn cm,

q_{ij} = rate coefficient for loss of nuclide i in stream j because of processing removal, atoms/sec/atom/barn cm,

r_{ij} = rate coefficient for production of nuclide i in stream j because of recycle from stream j, atoms/sec/atom/barn cm,

ν_i = neutrons produced per fission in nuclide i,

C^f_{ijk} = reaction rate coefficient, number of fissions in nuclide i per atom/barn cm in stream j in region k per fission neutron born in reactor,

C^a_{ijk} = reaction rate coefficient, number of absorptions in nuclide i per atom/barn cm in stream j in region k per fission neutron born in reactor.

Subscripts:

i = nuclide,

j = stream, or material,

k = region.

The use of stream and region indexes allows reactors with two or more streams in the same region to be analyzed.

The sequence of computations goes as follows. MODRIC, with trial values of the N_{ij}, calculates absorption rates which are converted (in ERC) to the reaction rate coefficients, C_{ijk}. These are used in Eq. (7.1), with specified feed and removal rates, to calculate new values of the N_{ij}. Equation (7.2) then indicates the adjustment to be made in the concentration of a key fissile nuclide in order to restore the balance between neutron productions and losses. Since this new concentration is no longer consistent with the solution of Eq. (7.1), an adjustment in feed rate, Q_{ij}, or removal rate coefficient, q_{ij}, must be made and Eq. (7.1) solved again for a new set of N_{ij}'s, which are then tested again in Eq. (7.2). This sequence of computations is indicated in Fig. 7.1. Note that an essential step in the ERC inner iteration, not shown on Fig. 7.1, is the adjustment of Q_{ij} or q_{ij}, by application of a single equation from the coupled set, Eq. (7.1) with the adjusted N^s_{ij} obtained from Eq. (7.2), prior to the next complete solution of the system of equations, Eq. (7.1), with the revised feed or removal rate.

The equilibrium concentration calculations in ERC use reaction rate coefficients (C_{ijk}) obtained from an earlier MODRIC calculation. However, the initial concentrations used in the MODRIC calculation will not, in general, agree with the equilibrium concentrations computed by ERC. This new set of concentrations will alter the neutron spectrum and flux distribution, thereby changing the reaction rate coefficients. Therefore, it is necessary to repeat the MODRIC criticality calculation with the latest value for the estimated concentrations to get new reaction rate coefficients. This process is repeated until the MODRIC and ERC concentrations converge.

The reaction rate coefficients (C_{ijk}) used in ERC are spectrum-averaged cross sections which are available directly from MODRIC. The MODRIC calculation gives A_{ik} and νF_{ik}, the absorptions and neutron productions in nuclide i in region k, normalized to 1.0 total neutron produced. The distribution of nuclear events between multiple streams in a region is accomplished by introducing the stream volume fractions, f_{jk}, in this manner:

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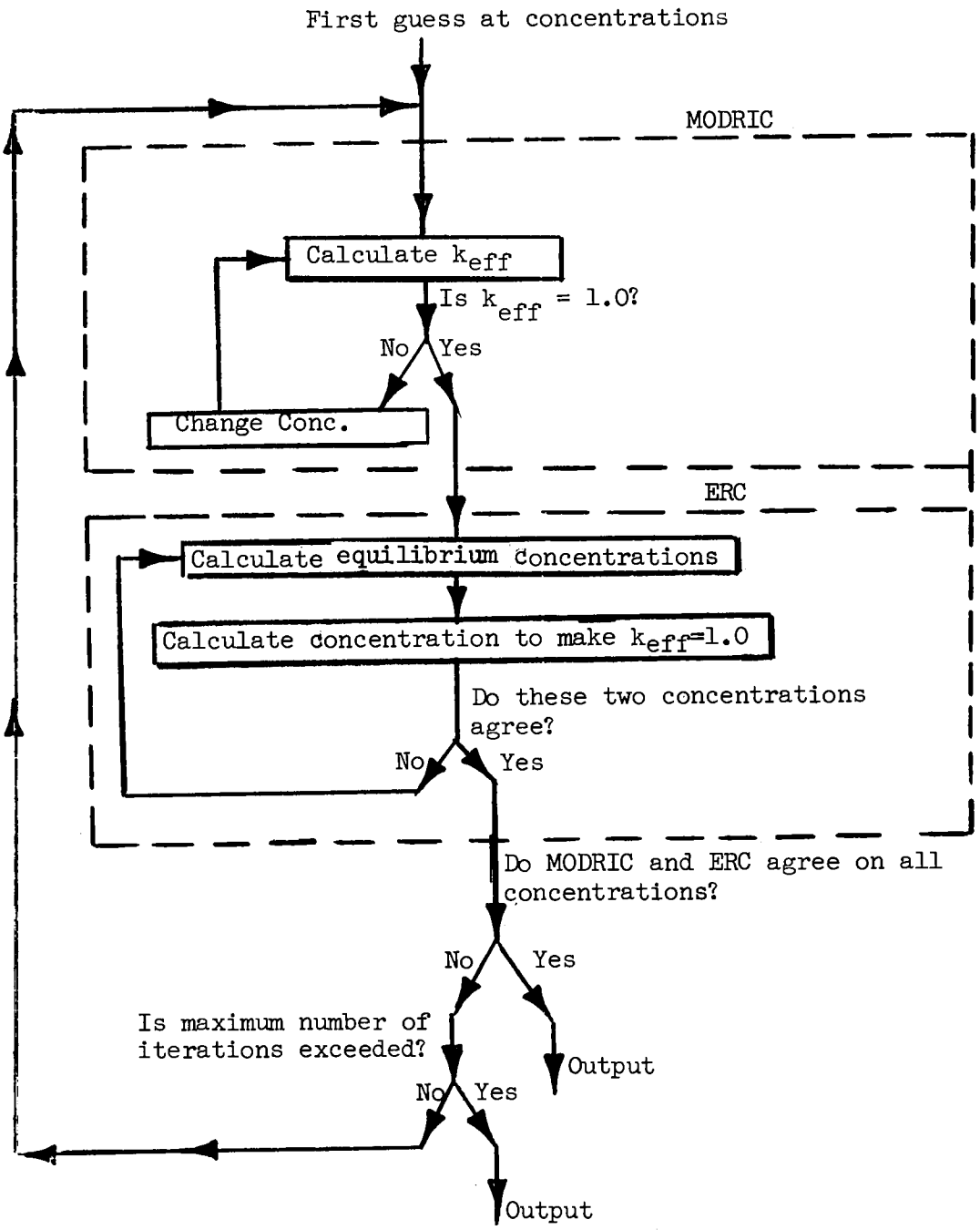

Fig. 7.1. MERC Flow Diagram.

$$A_{ijk} = a_{ik} \cdot \left(\frac{\text{atoms of i in stream j in region k}}{\text{atoms of i in region k}}\right) , \tag{7.3}$$

$$\nu_i F_{ijk} = \nu_i F_{ik} \cdot \left(\frac{\text{atoms of i in stream j in region k}}{\text{atoms of i in region k}}\right) . \tag{7.4}$$

The multiplying factor in each term is

$$\left(\frac{\text{atoms of i in stream j in region k}}{\text{atoms of i in region k}}\right) = \frac{N_{ij}\ f_{jk}}{\sum_j N_{ij}\ f_{jk}} , \tag{7.5}$$

where the units on these factors are

$$N_{ij} = \frac{\text{atoms of i in stream j}}{\text{barn cm of stream j}} , \tag{7.6}$$

$$f_{jk} = \frac{\text{cm}^3 \text{ of stream j in region k}}{\text{cm}^3 \text{ of region k}} . \tag{7.7}$$

The nuclide, stream, and region dependent absorption and production terms are automatically transferred from the MODRIC link to the ERC link of the MERC calculation. ERC obtains the reaction rate coefficients (intensive quantities) from the absorption and production terms (extensive quantities) by dividing by N_{ij}, the stream concentration

$$C^a_{ijk} = \frac{A_{ijk}}{N_{ij}} , \tag{7.8}$$

$$\nu_i C^f_{ijk} = \frac{\nu_i\ F_{ijk}}{N_{ij}} . \tag{7.9}$$

The absolute reaction rate coefficient ($\overline{C}_{ijk}$) is obtained in the ERC calculation using the total neutron production rate as determined by the reactor power

$$\overline{C}^a_{ijk} = C^a_{ijk} \times 3.1 \times 10^{16}\ P\ \overline{\nu} \times 10^{-24} , \tag{7.10}$$

where

3.1×10^{16} = number of fissions/sec/megawatt,

P = power level in megawatts,

$\bar{\nu}$ = average number of neutrons produced per fission =

$$\frac{\sum_{ijk} N_{ij} C^{f}_{ijk} \nu_i}{\sum_{ijk} N_{ij} C^{f}_{ijk}} . \tag{7.11}$$

A similar argument applies for the fission reaction rate.

The ERC equations, including those for calculation of inventories and fuel-cycle costs, are given in Appendix A.

Two-Dimensional Synthesis

The two-dimensional synthesis in ROD is based on the assumption that for a symmetrical cylindrical reactor, the shape of the flux distribution in the axial direction everywhere is well represented by the flux distribution along the axis, and similarly that the shape of the flux distribution in the radial direction everywhere is well represented by a radial flux distribution at the midplane. The complete spatial flux distribution may then be inferred from two one-dimensional calculations, one along the axis and the other along a radius at the midplane.

The two-dimensional synthesis is implemented in the MODRIC section of ROD as follows:

Starting from an assigned initial flux distribution (e.g., cosine), a new set of fluxes and neutron reaction rates is calculated, for the first neutron energy group, along the reactor axis. At each region boundary, the net transport of neutrons (for the group) across the boundary is calculated. The user may select an appropriate boundary (e.g., that of the core region) where a buckling is calculated for use in the second dimension.

Still for the first energy group, a new set of fluxes and reaction rates is calculated for the radial dimension. The radial fluxes are normalized to the axial dimension. The buckling obtained from the first dimension may be applied to specified regions to calculate the transverse leakage or net transport of neutrons transverse to the line of calculation.

The reactions of these neutrons are assigned to the various nuclides and regions in proportion to the reaction rates obtained for specified regions selected from the first dimension (the transverse leakage distribution regions). At the same time the net forward transport of neutrons across each boundary is calculated, from which an appropriate boundary may be selected for the calculation of a buckling to be used in the first dimension.

MODRIC then performs the same calculations for each of the remaining energy groups in turn. The reactions from the axial and radial calculations including the transverse distribution reactions are summed and normalized to give the required fission rate. MODRIC iterations are continued until the flux, fission density, and k_{eff} convergence criteria are met.

OPTI

The optimization routine (OPTI) is based on the method of steepest ascent. It permits up to 20 reactor parameters to be varied, within limits, in order to find a maximum (or minimum) in a specified objective function, calculated from the MERC output (see Chapter 5, paragraph D-1). It requires two links with MERC; one to transmit the values of the variables to MERC at the start of the calculation, and another to calculate and return to OPTI the resulting value of the objective function.

Starting values, and ranges, defined by upper and lower limits, are supplied for each variable. OPTI transmits the starting values to MERC, which runs a base-point case and returns the base-point result (value of the objective function). OPTI then changes the first variable by a small increment (ALPHA, a specified fraction of the range) and obtains a new objective function result from MERC to approximate the (partial) derivative of the objective function with respect to the first variable:

$$\frac{\partial O}{\partial X_i} \approx \frac{\Delta O}{\Delta X_i} , \qquad (7.12)$$

where

O = objective function,

X_i = variable i.

By this method, derivatives are calculated for each variable in turn. The derivatives determine the direction of a vector (in hyperspace) originating at the base point and extending in the direction of the most rapid increase in the objective function, that is, the path of steepest ascent. OPTI now changes the values of all the variables simultaneously in order to take steps along this vector. The variable with the largest derivative is changed by a unit, (BETA, a specified fraction of its range), while each of the other variables is changed by a fraction of a unit, determined by the ratio of its derivative to the largest derivative. At the end of each step, a new value for the objective function is obtained from MERC. OPTI compares this value with the previous one; if it is greater, by a specified increment, OPTI proceeds with another step; if not, a parabola is fitted to the last three points along the vector, and the maximum of the parabola is taken as a new base point. If the value of the objective function at the maximum of the parabola does not exceed the value for the last successful step, the parabolic fit is rejected and the last successful step is taken as the new base point.

Additional optimization cycles, like the one just described, are started from each new base point, until the increase in the objective function in the last cycle is less than a specified increment, or until no successful step is found in the cycle. OPTI can then declare the last base point to be the optimum, and terminate the search, or can reduce the size of the increments (ALPHA and BETA) and carry the search further.

Reducing the size of the increments increases the precision of the optimization; in particular, the finite-difference approximation to the derivative approaches the true value as the increment ALPHA approaches zero. In practice, the precision of the optimization is limited by the precision of the calculation of the objective function; e.g., in ROD, by the precision of the MERC calculation. The increments must not be reduced to the point that the vector calculations founder in the imprecision of the reactor calculations.

The steepest ascent method works very well for regular response surfaces; however, in many practical problems the response surface forms a sharp ridge; the steepest ascent method is notoriously inefficient for such cases, because the path of the search tends to zig-zag back and forth across the ridge. However, acceleration methods have been developed which handle such problems fairly well. Two acceleration methods available in OPTI are the "parallel tangent" method and a method invented in the development of OPTIMERC called the "ridge analysis" method.

Consider, for simplicity, a two-variable problem, so that the response surface can be represented by a contour map in which the x and y coordinates are the two variables, expressed as fractions of their range, and the contour height is the value of the objective function. For the case of a regular response surface, the maximum, or peak, is surrounded by nearly circular contours as shown in Fig. 7.2, so that a vector indicating the path of steepest ascent points toward the maximum. But suppose that the contours are elliptically elongated, forming a sharp ridge, as shown in Fig. 7.3. A vector indicating the direction of steepest ascent from any random point (except on the ridge) now points <u>across</u> the crest of the ridge rather than toward the peak. Consequently, the search path tends to zig-zag back and forth across the ridge, gradually working up toward the peak (vectors V_1 to V_6, Fig. 7.3).

The "ridge analysis" method is based on the observation that the derivative, dO/dY, with respect to a dominating variable will change sign every time a vector crosses a ridge. If the Y component of the succeeding vector is decreased by a suitable factor every time dO/dY changes sign, the X component becomes relatively more important and the vectors (R_2 to R_4, Fig. 7.4) tend to follow the ridge.

The "parallel tangent" method is based on the observation that alternate base points tend to line up along a ridge. When this is so, a vector determined by two alternate base points will point toward the peak (vector P_5, determined by base points V_2 and V_4, Fig. 7.5).

Both methods may be used simultaneously (vector RP_5, determined by base points R_2 and R_4, Fig. 7.6).

The ridge-analysis method is "free", that is, it does not require that additional cases be calculated. The parallel-tangent method, since

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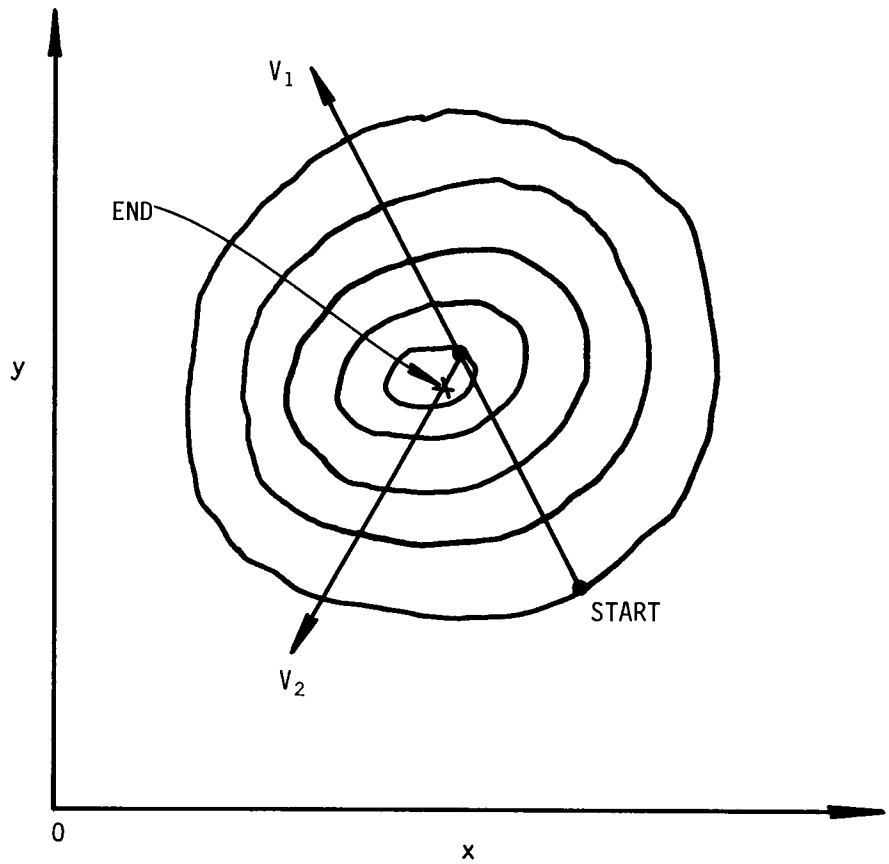

Fig. 7.2. Path of Hypothetical Optimization for a Regular Response Surface.

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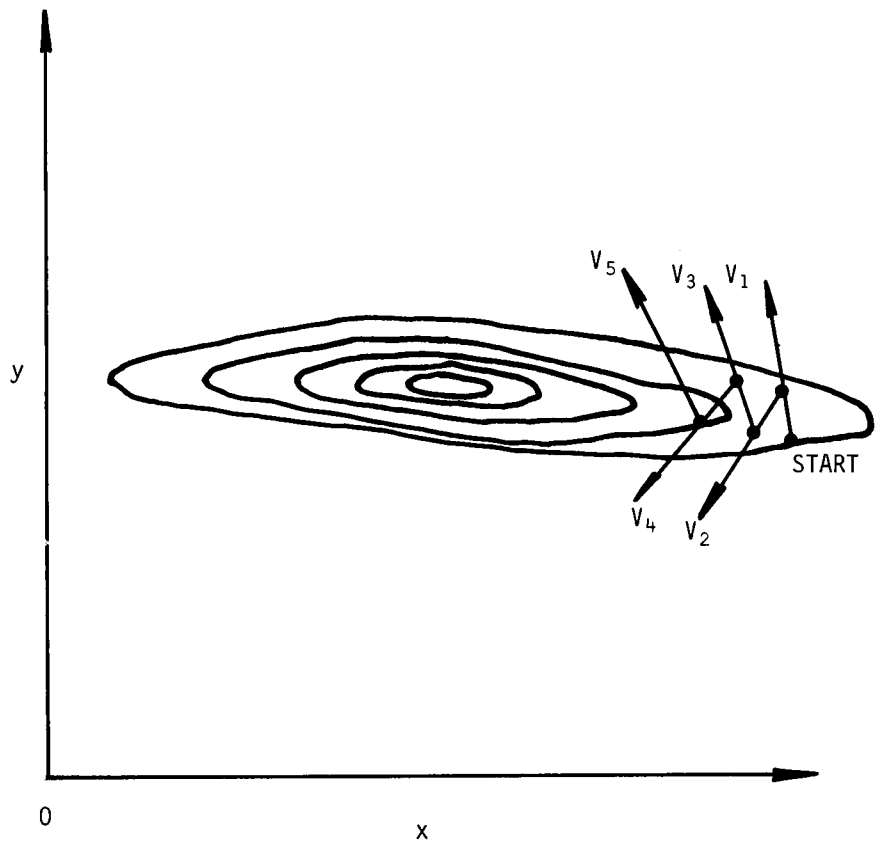

Fig. 7.3. Path of Hypothetical Optimization for a Ridged Response Surface.

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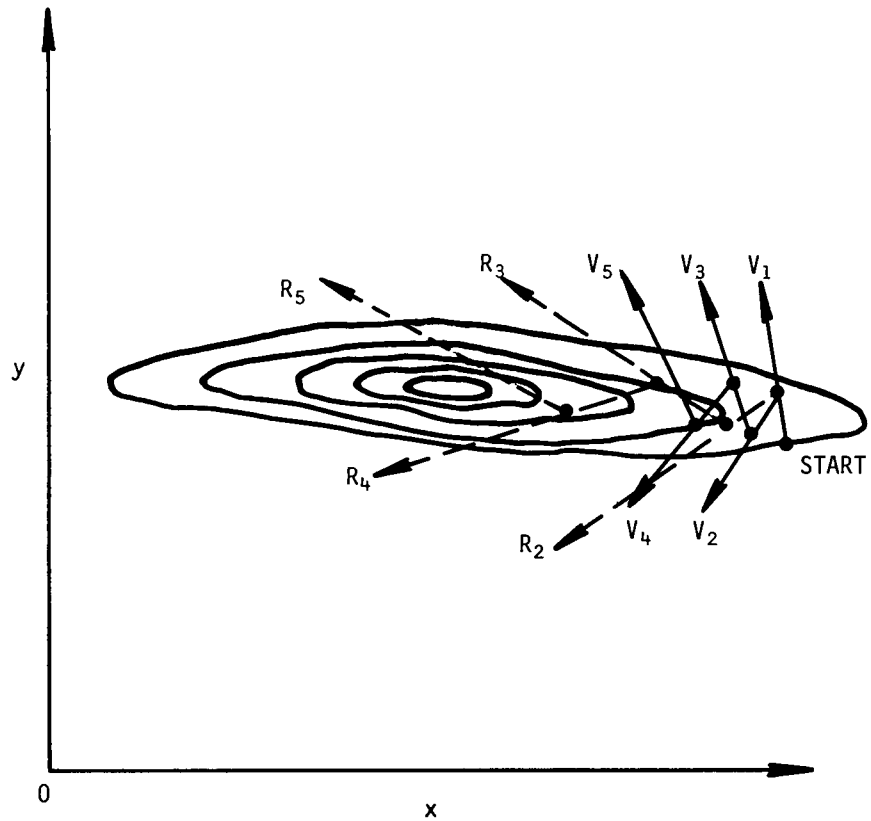

Fig. 7.4. Path of Hypothetical Optimization Employing the Ridge-Analysis Technique.

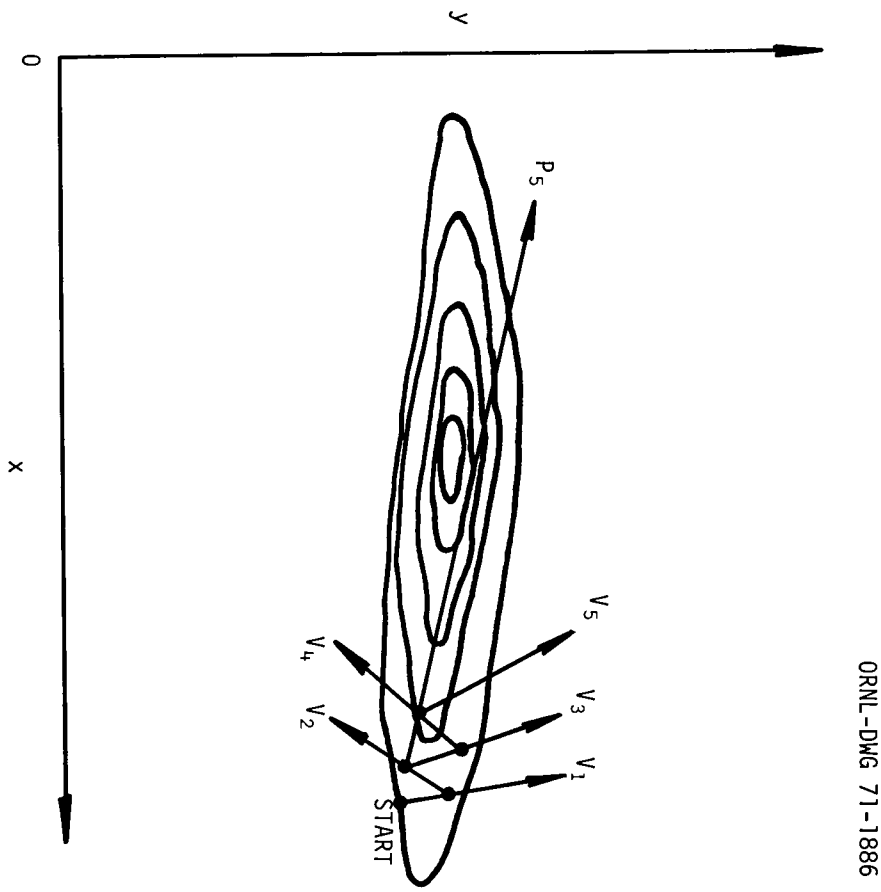

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Fig. 7.5. Path of Hypothetical Optimization Employing the Parralel-Tangent Technique.

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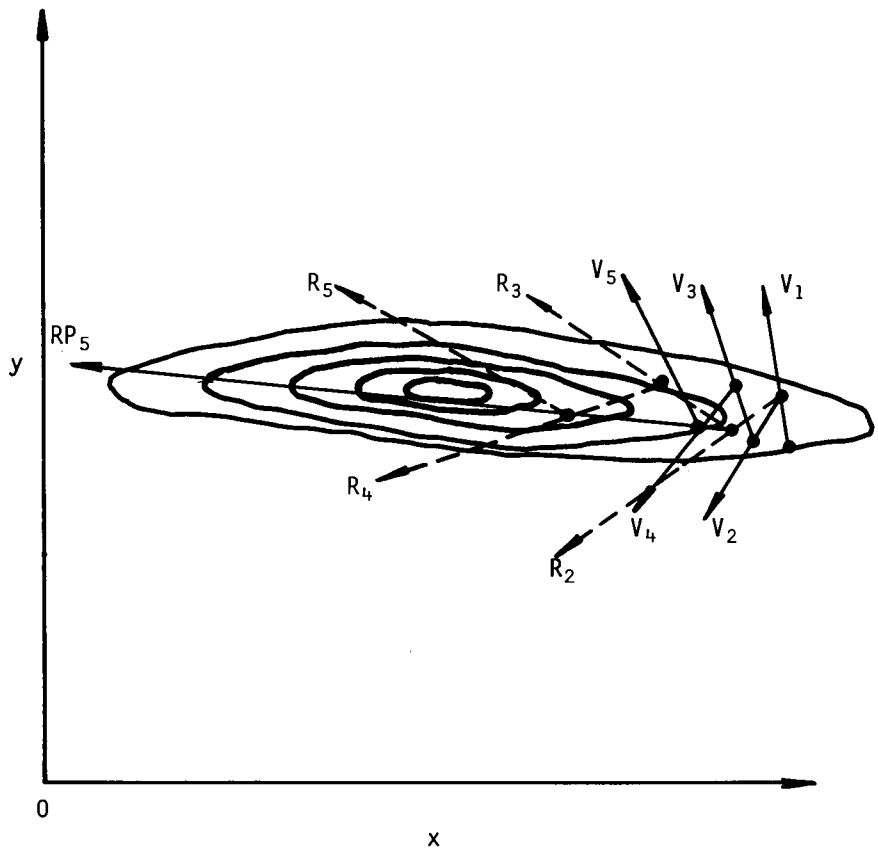

Fig. 7.6. Path of Hypothetical Optimization Employing the Ridge-Analysis and Parallel-Tangent Techniques Simultaneously.

it employs an "extra" (P) vector not in the normal series, requires that at least one additional case be calculated to determine whether any successful steps can be taken along the P vector.

In ROD, the ridge-analysis method is used in calculating every vector after the first, and the parallel-tangent method is used to calculate "RP" vectors after every normal vector following the third. Experience has shown that the RP vectors, although much of their work may have already been done by the ridge-analysis method, are successful often enough to justify using both methods together.

Another phenomenon, the "end effect", occurs as the optimum is approached. It occurs because the approximation to the derivative is one-sided; that is, the increment is taken in only one (the positive) direction. If a variable is at about its optimum value, increasing or decreasing its value can only give a poorer result; therefore, the one-sided approximation to the derivative becomes negative as the optimum is approached, whereas the true derivative would approach zero. Toward the end of the optimization, often all the derivatives but one have become negative. The presence of one positive derivative means that one variable, at least, must have a more favorable value; it may be, however, that no successful step is found. This can occur when the variables with negative derivatives are actually at about their optima, so that stepping in either the positive or negative direction would be unfavorable. As the variable with the positive derivative is stepped toward its optimum, the others step off their optima, and the net effect is an unsuccessful step. There are several theoretical solutions to this problem; the most obvious is to use a two-sided approximation to the derivative. However, this would double the number of cases required to calculate derivatives. We have elected to provide two options that require no additional cases. The first is to apply the reduction in the ridge-analysis factor whenever the derivative is negative (in addition to whenever it changes sign). Thus variables with consistently negative derivatives are restrained more and more as the optimization proceeds. The other is to limit the movement of variables with negative derivatives (by a factor of 0.01) after a normal first step along a vector has been unsuccessful. This is done

instead of the interval scan described below. The procedure is bypassed when the derivatives are either all negative or all positive.

Another procedure in OPTI, called the interval scan, is used when the first step along a vector is unsuccessful. It runs one or more cases along the vector in the interval between the base point and the first step, starting a factor of 0.6 from the base, to test whether the optimum might lie in this interval. If one or more successful steps are taken in this interval, the usual parabolic fit is applied; if not, the cycle is considered unsuccessful.

HISTRY

The premise of the HISTRY code is that a great amount of useful information can be obtained from a simple time-dependent reactor calculation when a good set of average reaction rates are available for the principle nuclides in the fertile-fissile chain. HISTRY can give an approximation to the time-dependent fuel-cycle analysis of a reactor, adequate for many purposes (e.g., conceptual design studies) where the effort of a full space-energy-time dependent calculation may not be justified.

HISTRY solves the time-dependent material-balance equations for the chain of 12 nuclides beginning with ^{232}Th and ending with ^{242}Pu. All other neutron absorbers are lumped together into two groups; the fixed absorbers, mainly moderator, core structure, and fuel carrier nuclides, and the fission products. The fission products may be treated either as a fixed poison, or as a poison which builds-in as a parabolic function during the cycle.

The first step in HISTRY is a criticality search. The initial k_{eff} is adjusted so that k_{eff} will average 1.0 over each time step. Various nuclides or mixtures of nuclides may be designated for feed or for sale (depending on whether or not the reactor is breeding at the given time-step). After the critical concentrations are determined, the concentrations of the other nuclides at the end of the time-step are calculated from the material-balance equations. The above calculations are repeated for as many time-steps as specified over the reactor cycle. For the case

of batch processing, the reactor lifetime may be divided into several batch processing cycles. HISTRY calculates atom densities, inventories, neutron absorptions and productions, and purchases or sales for each nuclide as a function of time. The time-averaged atom densities are calculated and returned to MERC for the next iteration.

The fuel and carrier costs are calculated by the discounted cash flow method.

CHAPTER 8

SAMPLE PROBLEM

The following sample problem was selected to demonstrate as many features of the ROD code as possible. Accordingly, it is a two-dimensional synthesis calculation in cylindrical geometry for a molten-salt breeder reactor having both a fissile and a fertile stream. Both streams are processed continuously, the fuel stream by the reductive-extraction process and the fertile stream by fluorination. In addition, four typical parameters were selected for optimization; namely, the core radius, the core salt-fraction, the blanket thickness, and the blanket processing cycle time.

The reactor is symmetrical axially and radially about the midpoint. It consists of a cylindrical core surrounded axially by plenum and reflector regions. Radially, the core is separated from the blanket by a metal wall 3 mm thick. To avoid very small mesh intervals, which could lead to flux convergence problems, the wall is represented by a 1-cm-thick zone with volume fractions 0.3 metal (material 3) and 0.7 graphite (material 4). The reactor is enclosed by a metal vessel 10 cm thick.

Three terms in the objective function were selected for the optimization; the inverse fuel-cycle cost, the flux factor, and the conservation coefficient. The allowable flux was selected to give a graphite moderator life of about four years.

Table 8.1 is a list of the data deck for this case. Tables 8.2 and 8.3 give respectively the detailed and short output for the base case. Table 8.4 gives the output for the optimization, including the final optimized case. (Only detailed output was specified.) The last table in the output is a summary of the optimization, giving the value of the objective function and of each optimization variable for each case.

The axial and radial flux plots for energy groups 1, 5, and 9 are shown in Figs. 8.1 and 8.2. The symbols used in the flux plots are given in Table 4.3.

Table 8.1. List of the Input Data Deck for the Sample Problem

```
//HFBOF120 JOB (12073),'Y-12 9104-2 H·BAUMAN',MSGLEVEL=1,
// CLASS=F,TYPRUN=HOLD,REGION=1536K
/*ROUTE  PRINT LOCAL
/*ROUTE  PUNCH LOCAL
//ROD EXEC FORTHCLG,PARM.FORT='OPT=2,BCD,DECK,NOSOURCE,NOMAP',
// PARM.LINK='LIST',
// REGION.GO=1536K
//FORT.SYSIN DD *
/*
//LINK.FT33F001 DD UNIT=TAPE9,LABEL=(,NL),VOLUME=SER=33,                X
//               DISP=(OLD,PASS),                                       X
//               DCB=(RECFM=FBS,LRECL=80,BLKSIZE=3200)
//LINK.SYSIN DD *
 INCLUDE FT33F001
/*
//GO.FT09F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3458),
// SPACE=(3458,(2000),RLSE)
//GO.FT08F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3458),
// SPACE=(3458,(600),RLSE)
//GO.FT01F001 DD UNIT=SYSDA,SPACE=(TRK,(27)),DCB=(RECFM=F,BLKSIZE=80)
//GO.FT02F001 DD UNIT=TAPE9,LABEL=(,NL),VOLUME=SER=2,DISP=OLD,          X
//               DCB=(RECFM=VB,LRECL=3600,BLKSIZE=3604)
//GO.FT10F001 DD *
 ROD-18  P X4916  X1306  BLANKETED MSBR 1000 MWE  TF  9  10TH23BE       0
         SINGLE-FLUID CORE, BARREN BLANKET  H=10M OP4 COR R,VF  BL R,CT
 1 51
    1 1 111111 1 1      11211111111111
    1 1111111111 1  11
      1 1 1  1   1  11

      1                    1
    1 11111111 1 1  11
      1              11
                        1
    1       2.0       2.0       2.0    .00001     .0001       1.2          3
        1        1        0.0     500.0       0.0   2.0 +14
      TF 9  BLANKETED MSBR
    RADIUS OR HALF-HEIGHT, CM
                FLUX
 3 1 5 9
    0   10    0    1    3    0
 96.0       0.05       240.       1.0                              12.0       0.0001
 -1.0  1.0  1.0  1.0  1.0  1.0  0.0  1.0  0.0  0.0  0.0  0.0  1.0  0.0
 3.194 -03                      TH 232
                                PA 233
                                U 233
                                U 234
                                U 235
                                U 236
                                NP 237
                                U 238
 6.0   -08 0.6                  PU 239
 2.4   -08 0.24                 PU 240
 1.2   -08 0.12                 PU 241
 4.0   -09 0.04                 PU 242
 1.0                            POISON
 1.0                            F PROD
 1 93  5.73  -05 94  1.96  -05 95  4.47  -06 96  4.76  -06 97  5.16  -07
 1 98  1.73  -07 79  3.28  -06 80  3.78  -06 81  3.49  -06 82  5.18  -06
 1  4  .007115   70  .007115    7  .02063     9  .04761    90  .003094
 1  6  2.48  -07 91  3.16  -06 99 1.0     -8 33  4.30  -03 77  6.29  -05
 1 54  8.37  -11 49  3.89  -09 51  1.45  -08
 2 93  2.18  -07 94  2.94  -10 95  1.15  -13 96  4.23  -17 97  5.29  -19
 2  4  .007115   70  .007115    7  .02063     9  .04761    90  .003094
```

```
 2  6  2.48  -07 91  3.16  -07 99 1.0      -8 33  1.42  -06 77  1.36  -04
 2 49  3.89  -09 51  1.45  -08
 3 24  .007119   26  .004743   28  .064      42  .009375
 4 12  .0953

FUELSALTFERTILE INOR    GRAPHITE
  1      1  2  3  6
  2      4  2  3  6
  3      5  2  3  6
  4      6  6  6  6

 1 CORE(1)  0.140  0.000  0.000  0.860
 2 WALL     0.000  0.000  0.300  0.700
 3 BLANKET  0.000  0.500  0.000  0.500
 4 PLENA    0.500  0.000  0.000  0.500
 5 AX REFL   .010    0.0  0.000  0.990
 6 VESSEL   0.000  0.000  1.000  0.000
 9 5 9
          3   .00003      .0003        300                                1        100
          3       1.0        3.0    .00010    1
 10 93 94 95 96 97 98 79 80 81 82
 1 1 2 3                1 2 3 4
A1 CORE(1)      360.0   36    1    1
A2   PLENA       30.0   06    2    1
A3 REFLECT      100.0   20    3    1
A4  VESSEL       10.0    5    1    0

 1 9              0.0       1.0       0.0       .94       1.0       0.0
 1 2 2

 1 1                    1 2 3 4
R1 CORE(1)      200.0   40    1    1
R2 WALL           1.0    3    1    1
R3 BLANKET       20.0   20    2    1
R4  VESSEL       10.0    5    1    0

 1 9              0.0       1.0       0.0       .94       1.0       0.0

 2 2 2

 1  1= 90  2= 91  3= 93  4= 94  5= 95  6= 96  7= 97  8= 98  9= 79 10= 80
 1 11= 81 12= 82 13=  4 14= 70 15=  7 16=  6 17=  9 18= 99 20  77 21  54
 1229= 49231= 51 25= 33
 2  1= 90  2= 91  3= 93  4= 94  5= 95  6= 96  7= 97  8=     9=     10=
 2 11=    12=    13=  4 14= 70 15=  7 16=  6 17=  9 18= 99 20  77 21=
 2229= 49231= 51 25= 33
 3 26= 24 27= 26 28= 28 29= 42
 4 23= 12

 3  5  9
  1            40          2   18          0     1
  2    .00010      0.50      2.00   2250.0          .8      .4444
  3 .45552                 6.0       5.1             0.3
  4     .1654    .00100     1.010
  9    1    9    8
  9    2    4    8
 10    1DAYSSECSDAYSSECSDAYSYEARYEARDAYSDAYS
 10    2DAYSSECSYEARSECS
 11  1  1      25.00    1200.0
 11  1  2       50.0       0.0
 11  1  3      600.0       0.0
 11  1  4       50.0       0.0
```

```
11  1  5      200.0        0.0
11  1  6        6.0        0.0
11  1  7       16.0        0.0
11  1  8       10.0      600.0
11  1  9      300.0        0.0
11  2  1      20.00      400.0
11  2  2       50.0        0.0
11  2  3       16.0        0.0
11  2  4       50.0        0.0
12  1  1    1.0
12  1  2          1.0
12  1  3                1.0
12  1  4                      1.0
12  1  5                            1.0                      1.0
12  1  6                                  1.0
12  1  7                                        1.0
12  1  8                                              1.0
12  2  1                1.0
12  2  2          1.0
12  2  3                1.0
12  2  4                      1.0
12  2  5                1.0
12  2  6                1.0
12  2  7                1.0
12  2  8    1.0
13  1  1  RARE EARTH
13  1  2 DEP & SMOKE
13  1  3  EXTRACT HF
13  1  4   GAS STRIP
13  1  5FLUORINATION
13  1  6      DISCARD
13  1  7AVE/LIFETIME
13  1  8       PA-233
13  2  1      RECYCLE
13  2  2 DEP & SMOKE
13  2  3      RECYCLE
13  2  4   GAS STRIP
13  2  5      RECYCLE
13  2  6      RECYCLE
13  2  7      RECYCLE
13  2  8       PA-233
20  1  650.                      0.25        1.0                .005
20  2  650.                      0.25        0.0                .000
21 1  2  51      1.0  1.0E-6
21 12362421      1.0      .1
21 2  1   1      0.0      0.0
21 2  2  71      1.0      0.0 1     1.0
21 2 13 171      0.0      0.0
22  1  1                     1
22  1  2                          1
22  1  3                     1    2     1
22  1  4                          1     5
22  1  5                          1     5
22  1  6                          1     5
22  1  7                          1
22  1  8  5.753-01          0     1
22  1  9                          1
22  1 10                          1
22  1 11                          1
22  1 12                          1
22  1 13                     1
22  1 14                     1
22  1 15                     1
22  1 16 15.500-04          3     1
22  1 20                          5
22  1 21                          6
```

```
22   1 25                                  7
22   1229                                  1
22   1231                                  1
22   2  1                            1
22   2  2                                  1
22   2  3                                  1
22   2  4                                  1
22   2  5                                  1
22   2  6                                  1
22   2  7                                  1
22   2 25                                  7
22   2229                                  1
22   2231                                  1
23   1                              232.000          TH-232     6
23   2          1                   233.000 .29279 -6PA-233     8
23   3   3  2          2            233.000          U-233      8
23   4   4      3  2                234.000          U-234      8
23   5   5      4                   235.000          U-235      8
23   6   6      5                   236.000          U-236      7
23   7   7      6                   237.000          NP-237     7
23   8   8      7                   238.000          U-238      7
23   9   9      8                   239.000          PU-239     3
23  10          9                   240.000          PU-240     3
23  11         10                   241.000          PU-241     3
23  12         11                   242.000          PU-242     3
23  13                                9.012          BE-9       6
23  14                                               BE-9 NA
23  15                                7.000          LI-7       6
23  16         14                     6.000          LI-6       6
23  17                               18.998          F          6
23  18                                               FP REF E
23  19                                               LEAKAGE
23  20                                               DEL NEUT
23  21                                               FIX P FR
23  23                               12.011          GRAPHITE   1
23  25 25                                            LUMP FP
23  26                               51.996          CHROME
23  27                               55.847          IRON
23  28                               58.710          NICKEL
23  29                               95.940          MOLY
24   1   1      18.98                                18.98
24   1   2  13.    +3
24   1   3  13.0  &3                                13.0  &3
24   1   5  11.2  &3                                11.2  &3
24   1   9   9.3  &3                                 9.3  &3
24   1  11   9.3  &3                                 9.3  &3
24   1  13      86.17                                86.17
24   1  15     122.57                               122.57
24   2   1      18.98                                18.98
25   1      0.132
25   2      0.132
25   3      0.132
25   5      0.132
25   9      0.132
25  11      0.132
25  13      0.132
25  15      0.132
29   1   4   8 10
30   2
031  3   5   9 11
032  3   5   9 11
033  2   3   5   9 11
034  2   3   5   9 11
035  3   5   9 11
37   3   5   9 11
```

```
 1  3  5  8  9 11
51              0.0       3.3    61.  .0036 .0046 .0014 .0003 .0011        BR-81   5
52 51           5.363E-6              .010  .0069 .0028 .0005 .0017 .0007 BR-82   5
53 52           8.022E-5              .0199 .0114 .00544.0009 .0029 .0010 BR-83   5
54        52    0.0       45.    196.                                      KR-82   4
55 54 55 53     1.013E-3 205.  219.                                        KR-83M  4
56 53 55        0.0       .16    5.5  .0365 .0191 .0100 .0016 .0047 .0020 KR-84   4
57 56           4.375E-5 7.0    29.  .0450 .0246 .0130 .0027 .0054 .0030 KR-85M  4
58 57           0.0       .06    .04  .0600 .0320 .0202 .0046 .0075 .0040 KR-86   4
59 58           1.480E-4 500.        .0660 .0447 .0249 .0080 .0091 .0050 KR-87   4
60 59           6.875E-5             .0630 .0482 .0321 .0126 .0126 .0063 KR-88   4
61 60           3.609E-3             .0648 .0565 .0431 .0225 .0153 .0081 KR-89   4
62 61           2.100E-2             .0621 .0525 .0490 .0289 .0187 .0119 KR-90   4
63 62           6.930E-2             .0432 .0394 .0350 .0264 .0153 .0102 KR-91   4
64        57    0.0       .91    1.67                                      RB-85   6
65 64           4.312E-70.     0.                                         RB-86   6
66 65     59    0.0       .12    .21                                       RB-87   6
67        65    0.0       1.65   .65                                       SR-86   6
68 67           0.0                                                        SR-87   6
69 66 68        0.0       .005   .06  .0070 .0054 .0036 .0014 .0014 .0007 SR-88   6
70 69     61    1.588E-7.5     .2   .0072 .0063 .0048 .0025 .0017 .0009 SR-89   6
71 70     62   7.850E-101.0    1.8  .0110 .0093 .0087 .0051 .0033 .0021 SR-90   6
72 71     63    1.985E-50.     0.   .0288 .0263 .0234 .0176 .0102 .0068 SR-91   6
73 63 72        7.130E-5             .0612 .0597 .0543 .0405 .0279 .0189 SR-92   6
74        70    0.0       1.31   .78                                       Y -89   1
75 74     71    2.9[illegible]4E-63.5  1.4                                 Y -90   1
76 75     72    1.3[illegible]3E-71.07 .42                                 Y -91   1
77 76     73    5.347E-5             .0068 .0066 .0060 .0045 .0031 .0021 Y -92   1
78 73 77        1.869E-5             .0599 .0667 .0613 .0437 .0371 .0238 Y -93   1
79        75    0.0       .10    .04                                       ZR-90   3
80 79     76    0.0       1.58   9.0                                       ZR-91   3
81 80     77    0.0       .25    .55                                       ZR-92   3
82 81     78    0.0       1.1    28.  .0032 .0035 .0032 .0023 .0020 .0013 ZR-93   3
83 78 82        0.0       .076   .20  .0570 .0670 .0640 .0470 .0450 .0320 ZR-94   3
84 83           1.234E-70.     0.   .0515 .0622 .0627 .0480 .0500 .0400 ZR-95   3
85 84           0.0       .053   .07  .0480 .0564 .0633 .0510 .0510 .0500 ZR-96   3
86 85           1.133E-50.     0.   .0453 .0548 .0609 .0550 .0560 .0570 ZR-97   3
87 86           1.160E-2             .0360 .0525 .0578 .0590 .0590 .0600 ZR-98   3
88 87           2.100E-2             .0274 .0496 .0606 .0630 .0610 .0620 ZR-99   3
89        84    2.292E-70.     0.0                                        NB-95   2
90        86    1.582E-4                                                  NB-97   2
91        88    4.813E-3                                                  NB-99   2
92 88 91        3.850E-3             .0104 .[illegible]9 .0630 .0630 .0710 .0630 NB-100  2
93 92           1.155E-2             .0062 .0284 .0500 .0630 .0590 .0640 NB-101  2
94        89    0.0       13.9   106.                                      MO-95   2
95 89 94        0.0       1.2    26.                                       MO-96   2
96 95     90    0.0       2.2    16.                                       MO-97   2
97 90 96        0.0       .51    5.6                                       MO-98   2
98 97     91    2.895E-6                                                  MO-99   2
99 98     92    0.0       .5     6.3                                       MO-100  2
100 99    93    7.911E-4                                                  MO-101  2
101 93100       1.004E-3             .0036 .0216 .0410 .0630 .0590 .0630 MO-102  2
102             4.620E-3             .0008 .0092 .0130 .0480 .0590 .0600 MO-104  2
103       98    0.0       22.    140.                                      TC-99   2
104      100    8.250E-4                                                  TC-101  2
105101          9.625E-3             .0016 .0160 .0300 .0620 .0560 .0620 TC-103  2
106105   102    6.417E-4                                                  TC-104  2
107102106       1.283E-3             .0005 .0050 .00[illegible] .0370 .0550 .0580 TC-105  2
108103          0.0       7.5    3.0                                       RU-100  2
109108   104    0.0       5.0    77.0                                      RU-101  2
110104109       0.0       1.44   11.0                                      RU-102  2
111110   105    2.020E-7                                                  RU-103  2
112111   106    0.0       .7     8.0                                       RU-104  2
113112   107    4.327E-5.2     .08                                       RU-105  2
114107113       2.175E-89.     16.  .0004 .0022 .0028 .0290 .0450 .0550 RU-106  2
115114          2.511E-3             .0005 .0012 .0019 .0130 .0360 .0500 RU-107  2
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116115          2.686E-3            .0005 .0007 .0009 .0064 .0260 .0400 RU-108 2
117       111   0.0     149.  1030.                                      RH-103 2
118117          1.650E-240.                                              RH-104 2
119118    113   5.348E-614400.17000.                                     RH-105 2
120       115   5.250E-4                                                 RH-107 2
121       118   0.0     6.    19.                                        PD-104 2
122121    119   0.0     11.   76.                                        PD-105 2
123119122       0.0     6.    12.                                        PD-106 2
124123    120   0.0     10.   40.                                        PD-107 2
125120124       0.0     10.4  154.                                       PD-108 2
126116125       1.437E-5            .0006 .0004 .0003 .0030 .0155 .0310 PD-109 2
127126          0.0     .21   10.   .0006 .0003 .0002 .0014 .0055 .0220 PD-110 2
128127          5.022E-4            .0006 .0003 .0002 .0007 .0020 .0130 PD-111 2
129128          9.169E-6            .0007 .0002 .0001 .0006 .0012 .0070 PD-112 2
130129          8.250E-3            .0007 .0002 .0001 .0005 .0007 .0040 PD-113 2
131       126   0.0     87.   1437.                                      AG-109 2
132131          3.085E-882.                                              AG-110M2
133132    128   1.056E-6                                                 AG-111 2
134133    129   6.016E-5                                                 AG-112 2
135134    130   3.056E-5                                                 AG-113 2
136130135       1.386E-1            .0007 .0002 .0001 .0005 .0004 .0020 AG-114 2
137136          5.500E-3            .0007 .0002 .0001 .0004 .0004 .0010 AG-115 2
138137          4.620E-3            .0007 .0001 .0001 .0004 .0004 .0006 AG-116 2
139       132   0.0     .2    30.                                        CD-110 3
140139    133   0.0     2.    52.                                        CD-111 3
141140    134   0.0     .03   13.                                        CD-112 3
142141    135   0.0     20000.652.                                       CD-113 3
143142    136   0.0     1.24  15.                                        CD-114 3
144143    137   3.633E-6                                                 CD-115 3
145144    138   0.0     1.5   1.2                                        CD-116 3
146       144   0.0     207.  3300.                                      IN-115 3
147             8.357E-7            .0002 .0006 .0001 .0004 .0005 .0006 SN-125 3
148147          0.0     .3    .118  .0004 .0026 .0010 .0007 .0018 .0020 SN-126 3
149148          1.013E-4            .0005 .0037 .0015 .0008 .0022 .0024 SN-127 3
150       147   1.098E-81.56  .62   .0002 .0004 .0001 .0002 .0003 .0004 SB-125 2
151150    148   6.418E-7                                                 SB-126 2
152151    149   2.116E-6            .0004 .0024 .0010 .0005 .0015 .0016 SB-127 2
153149152       1.965E-5            .0018 .0105 .0041 .0026 .0074 .0070 SB-128 2
154153          4.185E-5            .0040 .0170 .0080 .0053 .0140 .0120 SB-129 2
155154          1.627E-3            .0088 .0233 .0200 .0110 .0250 .0220 SB-130M2
156155          5.022E-4            .0136 .0273 .0234 .0184 .0304 .0272 SB-131 2
157156          5.500E-3            .0287 .0468 .0438 .0470 .0530 .0480 SB-132 2
158157          2.817E-3            .0222 .0353 .0395 .0312 .0414 .0360 SB-133 2
159       150   0.0     1.56  24.                                        TE-125 2
160159    151   0.0     .8    9.3                                        TE-126 2
161160    152   2.070E-5                                                 TE-127 2
162161    153   0.0     .3    10.                                        TE-128 2
163162    154   1.604E-4                                                 TE-129 2
164163    155   0.0     .5    .2                                         TE-130 2
165164    156   4.813E-4            .0034 .0068 .0059 .0046 .0075 .0068 TE-131 2
166165    157   2.501E-6                                                 TE-132 2
167166    158   2.221E-4            .0148 .0235 .0264 .0208 .0276 .0240 TE-133M2
168158167       2.686E-4            .0510 .0599 .0806 .0570 .0750 .0640 TE-134 2
169168          2.310E-2            .0504 .0526 .0577 .0540 .0648 .0585 TE-135 2
170       161   0.0     7.    162.                                       I -127 5
171       163   0.0     32.   39.                                        I -129 5
172171    164   1.528E-518.   7.1                                        I -130 5
173172    165   9.966E-750.   20.                                        I -131 5
174173    166   8.370E-5                                                 I -132 5
175174    167   9.255E-6                                                 I -133 5
176       169   2.874E-5            .0056 .0058 .0064 .0060 .0072 .0065 I -135 5
177170          0.0     2.5   .99                                        XE-128 4
178177    171   0.0     21.                                              XE-129 4
179178    172   0.0     2.5   .99                                        XE-130 4
180179    173   0.0     120.  800.                                       XE-131 4
181180    174   0.0     .2    1.8                                        XE-132 4
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182181    175     1.522E-6190.   75.                                                XE-133 4
183175182         0.0      .2    .6                                                 XE-134 4
184183    176     2.093E-52.8E+64544.                                               XE-135 4
185176184         0.0      .15   .1     .0640 .0668 .0646 .0600 .0660 .0660 XE-136 4
186185            2.962E-3              .0637 .0631 .0584 .0570 .0618 .0608 XE-137 4
187186            6.794E-4              .0694 .0675 .0545 .0570 .0599 .0599 XE-138 4
188187            1.690E-2              .0601 .0529 .0524 .0480 .0480 .0496 XE-139 4
189188            4.330E-2              .0462 .0403 .0386 .0348 .0336 .0366 XE-140 4
190       182     0.0      29.   420.                                                CS-133 6
191190            9.550E-9134.   53.                                                CS-134 6
192191    184     0.0      8.7   62.                                                CS-135 6
193192            6.171E-7                                                          CS-136 6
194193    186     .7471E-9.11    .3     .0034 .0033 .0031 .0030 .0033 .0032 CS-137 6
195       191     0.0      2.    .79                                                BA-134 6
196195    192     0.0      5.                                                        BA-135 6
197196    193     0.0      .4    13.                                                BA-136 6
198197    194     0.0      5.1   2.                                                 BA-137 6
199194198         0.0      .7    .5     .0037 .0036 .0029 .0030 .0032 .0032 BA-138 6
200       189     6.268E-712.    4.7    .0308 .0268 .0258 .0232 .0224 .0244 BA-140 6
201199    188     0.0      8.9   11.    .0150 .0132 .0131 .0120 .0120 .0124 LA-139 1
202201    200     4.790E-63.1    1.2                                                LA-140 1
203200202         5.066E-5              .0840 .0624 .0640 .0540 .0560 .0600 LA-141 1
204       202     0.0      .66   .5                                                 CE-140 1
205204    203     2.431E-7                                                          CE-141 1
206203205         0.0      1.0   1.3    .0830 .0679 .0601 .0510 .0500 .0580 CE-142 1
207206            5.835E-66.     2.4    .0800 .0591 .0603 .0480 .0460 .0560 CE-143 1
208207            2.865E-86.     2.6    .0750 .0451 .0562 .0450 .0380 .0480 CE-144 1
209       205     0.0      11.6  24.                                                PR-141 1
210209    206     9.976E-618.    7.1                                                PR-142 1
211210    207     5.856E-789.    190.                                               PR-143 1
212208            3.231E-5              .0660 .0338 .0398 .0390 .0310 .0360 PR-145 1
213       210     0.0      18.   7.1                                                ND-142 1
214213    211     0.0      324.  130.                                               ND-143 1
215211214         0.0      5.    12.                                                ND-144 1
216215    212     0.0      60.   245.                                               ND-145 1
217212216         0.0      10.   25.     .0550 .0258 .0307 .0330 .0260 .0280 ND-146 1
218217            7.228E-7              .0382 .0193 .0236 .0280 .0205 .0220 ND-147 1
219218            0.0      3.4   48.    .0180 .0128 .0171 .0240 .0170 .0160 ND-148 1
220219            9.625E-5              .0095 .0077 .0113 .0210 .0130 .0120 ND-149 1
221220            0.0      3.    14.    .0040 .0055 .0067 .0130 .0100 .0080 ND-150 1
222       218     8.289E-9235.   3220.                                               PM-147 1
223222            1.976E-727000.32000.                                              PM-148M1
224222            1.488E-61500.  44000.                                             PM-148 1
225223224220      3.626E-6                                                          PM-149 1
226221            6.780E-6              .0020 .0035 .0044 .0090 .0080 .0050 PM-151 1
227       222     0.0      87.   708.                                               SM-147 1
228227    223224  0.0      9.    50.                                                SM-148 1
229228    225     0.0      40800.3400.                                              SM-149 1
230225229         0.0      97.   255.                                               SM-150 1
231230    226     .2746E-915000.2500.                                               SM-151 1
232226231         0.0      216.  2500.   .0009 .0022 .0028 .0060 .0060 .0030 SM-152 1
233232            4.097E-6              .0004 .0015 .0017 .0038 .0034 .0020 SM-153 1
234233            0.0      5.5   25.    .0002 .0005 .0008 .0022 .0025 .0015 SM-154 1
235               2.139E-5                    .0001 .0001 .0008 .0010 .0007 SM-156 1
236       231     0.0      8730.                                                     EU-151 1
237236            1.832E-95000.                                                     EU-152 1
238237    233     0.0      450.  1380.                                               EU-153 1
239238            1.373E-91500. 594.                                                EU-154 1
240234239         1.293E-814000.5540. .0001 .0003 .0003 .0013 .0016 .0010 EU-155 1
241240    235     5.209E-7                                                          EU-156 1
242235241         1.250E-5                          .0001 .0004 .0007       EU-157 1
243       237     0.0      180.                                                     GD-152 1
244243            0.0                                                               GD-153 1
245244    239     0.0      23.                                                      GD-154 1
246245    240     0.0      58000.1630.                                              GD-155 1
247246    241     0.0      4.    44.                                                GD-156 1
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248247    242     0 0      2.4245 740.                                          GD-157 1
249242248          .0      3.9    29.                        .0002 .0004       GD-158 1
250249            .070E-5                                     .0001 .0002       GD-159 1

 1     .01260     .00069     .00023     .00024     .00019     .00007     .00006
 2     .03370     .00305     .00079     .00142     .00202     .00063     .00072
 3     .13900     .00315     .00067     .00128     .00239     .00045     .00049
 4     .32500     .00907     .00074     .00257     .00573     .00059     .00095
 5    1.13000     .00350     .00014     .0007      .00332     .00018     .00036
 6    2.50000     .00087     .00009     .006       .00111     .00009     .00007
                             10 0                 250.0      100.0
   1.21+14
 10
    4    -1     0 +1.0        .05        .10       1.00       .0003       .003
    0         2.0       0.02     1
  1  1  2          150.0      200.0      250.0                                0.2 CORE RAD
  1  3  2           10.0       20.0      110.0                                1.0 THK R B
  2  1  1            .11       .140        .17                                0.5 VF S COR
 10  2  1           10.0       20.0      310.0                                1.0 BLK CY T
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Table 8.2. Detailed Output for the Base Case

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ROD-18  P X4916  X1306  BLANKETED MSBR 1000 MWE  TF  S  10TH23BE      Q

        SINGLE-FLUID CORE, BARREN BLANKET  H=10M OP4 CDR R,VF  BL R,CT

MATERIAL    1  DENSITIES

NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY
 93  5.7300E-05  94  1.9600E-05  95  4.4700E-06  96  4.7600E-06  97  5.1600E-07  98  1.7300E-07  79  3.2800E-06
 80  3.7800E-06  81  3.4900E-06  82  5.1800E-06   4  7.1150E-03  70  7.1150E-03   7  2.0630E-02   9  4.7610E-02
 90  3.0940E-03   6  2.4800E-07  91  3.1600E-06  99  1.0000E-08  33  4.3000E-03  77  6.2900E-05  54  8.3700E-11
 49  3.8900E-09  51  1.4500E-08

MATERIAL    2  DENSITIES

NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY
 93  2.1800E-07  94  2.9400E-10  95  1.1500E-13  96  4.2300E-17  97  5.2900E-19   4  7.1150E-03  70  7.1150E-03
  7  2.0630E-02   9  4.7610E-02  90  3.0940E-03   6  2.4800E-07  91  3.1600E-07  99  1.0000E-08  33  1.4200E-06
 77  1.3600E-04  49  3.8900E-09  51  1.4500E-08

MATERIAL    3  DENSITIES

NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY
 24  7.1190E-03  26  4.7430E-03  28  6.4000E-02  42  9.3750E-03

MATERIAL    4  DENSITIES

NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY NUCLIDE DENSITY
 12  9.5300E-02

MERC   1  MAXP   5  IWPFC   0  FLIP  1.

NUMBER OF GROUPS   9  NETH   5  NTH   9  NUMBER OF MATERIALS   4

ICON   3  EPS1   3.000E-05  EPS2   3.000E-04  ITMAX  300  IFD   0  IFC   0  NXOPT   1  MAXOPT 100

CONCSO-THE FACTOR BY WHICH THE CONVERGENCE CRITERIA IS TIGHTENED FOR CASE ZERO IS                    2.00E 00

CONIT1-THE FACTOR BY WHICH THE CONVERGENCE CRITERIA IS LOOSENED FOR THE FIRST ITERATION OF EACH CASE IS  2.00E 00

CP1CON-THE FACTOR WHICH LIMITS DC/DK IN CRITICALITY SEARCH IS                                          1.200

CDELT-THE EPSILON ON CHANGE OF UPSCATTER TREATMENT FROM ITERATION TO ITERATION IS                    1.00E-05

CTOL-THE EPSILON ON THE UPSCATTER TREATMENT APPROACH TO UNITY IS                                     1.00E-04

NITEXT-THE MINIMUM NUMBER OF ITERATIONS MODRIC MUST GO AFTER THE UPSCATTER TREATMENT HAS CONVERGED IS          3

A CONCENTRATION SEARCH WILL BE MADE

SEARCH TYPE CONTROL   3

THE DESIRED K EFFECTIVE  1.0000E 00

ESTIMATE OF DH/DL  3.0000E 00

TOLERANCE FOR K EFFECTIVE  1.0000E-04

THE SEARCH MATERIAL    1  QAL  0.0

NUCLIDES TO BE ALTERED BY SEARCH    93  94  95  96  97  98  79  80  81  82

FLUXES WILL BE PLOTTED USING THE CATHODE RAY TUBE PLOTTER
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GRID WILL BE LINEAR

PLOT POINTS ONLY
RANGE OF PLOTS DETERMINEC FRCM INPUT
  RMIN=  0.0
  RMAX=  0.5000000E 03
PHIMIN=  0.0
PHIMAX=  0.2000000E 15

GROUPS TO BE PLOTTED ARE   1  5  9
ENTERED PART2
```

INFORMATION ABOUT DIMENSICN 1

CORE REGION 1

REGIONS TO WHICH CORE REGICN BUCKLING IS TO BE APPLIED 1 2 3 0 0 0 0 0 0 0

TRANSVERSE LEAKAGE DISTRIBUTICN REGICNS 1 2 3 4

CORE VOLUME 4.90000E 02

REGION	MESH PCINTS	THICKNESS	XSECT SET	FISSIONABLE
1	36	3.6000E 02	1	1
2	6	3.0000E 01	2	1
3	20	1.0000E 02	3	1
4	5	1.0000E 01	1	0

BOUNDARY CONDITIONS

GROUP	A	B	C	D	E	F
1	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
2	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
3	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
4	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
5	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
6	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
7	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
8	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
9	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0

DIFFUSION VOLUME FRACTICNS

REGION	MTL 1	MTL 2	MTL 3	MTL 4
1	0.14000	0.0	0.0	0.86000
2	0.50000	0.0	0.0	0.50000
3	0.01000	0.0	0.0	0.99000
4	0.0	0.0	1.00000	0.0

GEOMETRY, SLAB

INITIAL FISSION DENSITYOBTAINED BY OPTICN 2

1.5103E 00	1.5095E 00	1.5074E 00	1.5038E 00	1.4988E 00	1.4924E 00	1.4846E 00	1.4754E 00	1.4648E 00	1.4528E 00
1.4394E 00	1.4246E 00	1.4086E 00	1.3911E 00	1.3724E 00	1.3524E 00	1.3311E 00	1.3085E 00	1.2847E 00	1.2596E 00
1.2334E 00	1.2060E 00	1.1775E 00	1.1479E 00	1.1172E 00	1.0854E 00	1.0526E 00	1.0188E 00	9.8399E-01	9.4829E-01
9.1170E-01	8.7424E-01	8.3596E-01	7.9688E-01	7.5705E-01	7.1651E-01	6.7529E-01	6.7529E-01	6.5443E-01	6.3342E-01
6.1227E-01	5.9096E-01	5.6952E-01	5.4794E-01	5.4794E-01	5.2624E-01	5.0441E-01	4.8245E-01	4.6039E-01	4.3822E-01
4.1594E-01	3.9356E-01	3.7110E-01	3.4854E-01	3.2590E-01	3.0318E-01	2.8040E-01	2.5754E-01	2.3463E-01	2.1166E-01
1.8864E-01	1.6557E-01	1.4247E-01	1.1933E-01	9.6166E-02	0.0	0.0	0.0	0.0	0.0
0.0									

REGION 1 DENSITIES

93	8.02200E-06	94	2.74400E-06	95	6.25800E-07	96	6.66400E-07	97	7.22400E-08	98	2.42200E-08
79	4.59200E-07	80	5.29200E-07	81	4.88600E-07	82	7.25200E-07	4	9.96100E-04	70	9.96100E-04
7	2.88820E-03	9	6.66540E-03	90	4.33160E-04	6	3.47200E-08	91	4.42400E-07	99	1.40000E-09
33	6.02000E-04	77	8.80600E-06	54	1.17180E-11	49	5.44599E-10	51	2.03000E-09	12	8.19579E-02

REGION 2 DENSITIES

93	2.86500E-05	94	9.79999E-06	95	2.23500E-06	96	2.38000E-06	97	2.58000E-07	98	8.65000E-08
79	1.64000E-06	80	1.89000E-06	81	1.74500E-06	82	2.59000E-06	4	3.55750E-03	70	3.55750E-03
7	1.03150E-02	9	2.38050E-02	90	1.54700E-03	6	1.24000E-07	91	1.58000E-06	99	5.00000E-09
33	2.15000E-03	77	3.14500E-05	54	4.18500E-11	49	1.94500E-09	51	7.25000E-09	12	4.76500E-02

REGION 3 DENSITIES

93	5.73000E-07	94	1.96000E-07	95	4.47000E-08	96	4.76000E-08	97	5.16000E-09	98	1.73000E-09

79	3.28000E-08	80	3.78000E-08	81	3.49000E-08	82	5.18000E-08	4	7.11500E-05	70	7.11500E-05
7	2.06300E-04	9	4.76100E-04	90	3.09400E-05	6	2.48000E-09	91	3.16000E-08	99	9.99999E-11
33	4.30000E-05	77	6.29000E-07	54	8.37000E-13	49	3.89000E-11	51	1.45000E-10	12	9.43469E-02
REGION	4 DENSITIES										
24	7.11900E-03	26	4.74300E-03	28	6.40000E-02	42	9.37500E-03				

INFORMATION ABOUT DIMENSICN 2

CORE REGION 1

REGIONS TO WHICH CORE REGICN BUCKLING IS TO BE APPLIED 1 0 0 0 0 0 0 0 0 0

TRANSVERSE LEAKAGE DISTRIBUTICN REGIONS 1 2 3 4

CORE VOLUME 1.53438E 05

REGION	MESH PCINTS	THICKNESS	XSECT SET	FISSIONABLE
1	40	2.0000E 02	1	1
2	3	1.0000E 00	1	1
3	20	2.0000E 01	2	1
4	5	1.0000E 01	1	0

BOUNDARY CONDITIONS

GROUP	A	B	C	D	E	F
1	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
2	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
3	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
4	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
5	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
6	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
7	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
8	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0
9	0.0	1.0000E 00	0.0	9.4000E-01	1.0000E 00	0.0

DIFFUSION VOLUME FRACTIONS

REGION	MTL 1	MTL 2	MTL 3	MTL 4
1	0.14000	0.0	0.0	0.86000
2	0.0	0.0	0.30000	0.70000
3	0.0	0.50000	0.0	0.50000
4	0.0	0.0	1.00000	0.0

GEOMETRY, CYLINDER

INITIAL FISSION DENSITYOBTAINED BY OPTION 2

2.0008E 00	1.9996E 00	1.9961E 00	1.9903E 00	1.9822E 00	1.9718E 00	1.9590E 00	1.9441E 00	1.9268E 00	1.9073E 00
1.8856E 00	1.8617E 00	1.8356E 00	1.8074E 00	1.7771E 00	1.7447E 00	1.7103E 00	1.6740E 00	1.6356E 00	1.5954E 00
1.5533E 00	1.5094E 00	1.4638E 00	1.4164E 00	1.3674E 00	1.3168E 00	1.2647E 00	1.2111E 00	1.1561E 00	1.0998E 00
1.0422E 00	9.8335E-01	9.2338E-01	8.6233E-01	8.0029E-01	7.3731E-01	6.7347E-01	6.0886E-01	5.4353E-01	4.7757E-01
4.1106E-01	4.1106E-01	4.0661E-01	4.0215E-01	3.9770E-01	3.9770E-01	3.8432E-01	3.7092E-01	3.5750E-01	3.4407E-01
3.3062E-01	3.1716E-01	3.0368E-01	2.9019E-01	2.7668E-01	2.6316E-01	2.4963E-01	2.3609E-01	2.2253E-01	2.0897E-01
1.9539E-01	1.8181E-01	1.6822E-01	1.5462E-01	1.4101E-01	1.2740E-01	0.0	0.0	0.0	0.0
0.0	0.0								

REGION 1 DENSITIES

93	8.02200E-06	94	2.74400E-06	95	6.25800E-07	96	6.66400E-07	97	7.22400E-08	98	2.42200E-08
79	4.59200E-07	80	5.29200E-07	81	4.88600E-07	82	7.25200E-07	4	9.96100E-04	70	9.96100E-04
7	2.88820E-03	9	6.66540E-03	90	4.33160E-04	6	3.47200E-08	91	4.42400E-07	99	1.40000E-09
33	6.02000E-04	77	8.80600E-06	54	1.17180E-11	49	5.44599E-10	51	2.03000E-09	12	8.19579E-02

REGION 2 DENSITIES

24	2.13570E-03	26	1.42290E-03	28	1.92000E-02	42	2.81250E-03	12	6.67099E-02		

REGION 3 DENSITIES

93	1.09000E-07	94	1.47000E-10	95	5.75000E-14	96	2.11500E-17	97	2.64500E-19	4	3.55750E-03
70	3.55750E-03	7	1.03150E-02	9	2.38050E-02	90	1.54700E-03	6	1.24000E-07	91	1.58000E-07
99	5.00000E-09	33	7.10000E-07	77	6.80000E-05	49	1.94500E-09	51	7.25000E-09	12	4.76500E-02

REGION 4 DENSITIES
24 7.11900E-03 26 4.74300E-03 28 6.40000E-02 42 9.37500E-03
LEAVING PART2

DIFFUSION TO EQUILIBRIUM CORRESPONDENCE TABLE

ERC NUMBER	MCDRIC NUMBERS BY MATERIAL			
	MTL 1	MTL 2	MTL 3	MTL 4
1	90	90	0	0
2	91	91	0	0
3	93	93	0	0
4	94	94	0	0
5	95	95	0	0
6	96	96	0	0
7	97	97	0	0
8	98	0	0	0
9	79	0	0	0
10	80	0	0	0
11	81	0	0	0
12	82	0	0	0
13	4	4	0	0
14	70	70	0	0
15	7	7	0	0
16	6	6	0	0
17	9	9	0	0
18	99	99	0	0
20	77	77	0	0
21	54	0	0	0
23	0	0	0	12
25	33	33	0	0
26	0	0	24	0
27	0	0	26	0
28	0	0	28	0
29	0	0	42	0
229	49	49	0	0
231	51	51	0	0

SUPER REGION-SUB REGION CORRESPONDENCE

```
DIMENSION ONE
   INDEX
     4          6  6  6  6
     3          5  2  3  6
     2          4  2  3  6
     1          1  2  3  6

                1  2  3  4
            DIMENSION TWO INDEX
```

SUPER REGION VOLUME FRACTIONS

SUPER REGION		MATERIAL 1	2	3	4
1	CORE(1)	0.140000	0.0	0.0	0.860000
2	WALL	0.0	0.0	0.300000	0.700000
3	BLANKET	0.0	0.500000	0.0	0.500000
4	PLENA	0.500000	0.0	0.0	0.500000
5	AX REFL	0.010000	0.0	0.0	0.990000
6	VESSEL	0.0	0.0	1.000000	0.0

```
NUCLIDES USED IN THE DIFFUSION CALCULATION
 93  94  95  96  97  98  79  80  81  82   4  70   7   9  90   6  91  99  33  77  54  49  51  12  24  26  28  42
ENTERED RPCS1

MICROSCOPIC CROSS-SECTIONS IN SET NO.    1  ORDER NO. ON TAPE    3

MSR  1  SET  3  10TH23BE (900K)  VF=.12  C/TH=226

    1          MODRIC NUCLIDE   90      THORIUM-232-R

    2          MODRIC NUCLIDE   91      PROTACTINIUM-233

    3          MODRIC NUCLIDE   93      URANIUM-233

    4          MODRIC NUCLIDE   94      URANIUM-234-R

    5          MODRIC NUCLIDE   95      URANIUM-235

    6          MODRIC NUCLIDE   96      URANIUM-236-R

    7          MODRIC NUCLIDE   98      URANIUM-238-R

    8          MODRIC NUCLIDE   97      NEPTUNIUM-237

    9          MODRIC NUCLIDE   79      PLUTONIUM-239

   10          MODRIC NUCLIDE   80      PLUTONIUM-240-R

   11          MODRIC NUCLIDE   81      PLUTONIUM-241

   12          MODRIC NUCLIDE   82      PLUTONIUM-242-R

   13          MODRIC NUCLIDE    6      LITHIUM-6

   14          MODRIC NUCLIDE    7      LITHIUM-7

   15          MODRIC NUCLIDE    4      BERYLLIUM  NATURAL
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  16          MODRIC NUCLIDE   12      CARBON    NATURAL     SI
  17          MODRIC NUCLIDE    9      FLUORINE    NATURAL
  18          MODRIC NUCLIDE   24      CHROMIUM    NATURAL
  19          MODRIC NUCLIDE   26      IRON        NATURAL
  20          MODRIC NUCLIDE   28      NICKEL      NATURAL
  21          MODRIC NUCLIDE   42      MOLYBDENUM NATURAL
  22          MODRIC NUCLIDE   54      XENON-135
  23          MODRIC NUCLIDE   49      SAMARIUM-149
  24          MODRIC NUCLIDE   51      SAMARIUM-151
  25          MODRIC NUCLIDE   70      1/V NUCLIDE  SIGA=1.0 '
  26          MODRIC NUCLIDE   77      1/V NUCLIDE  SIGA=1.0 '
  27          MODRIC NUCLIDE   99      1/V NUCLIDE  SIGA=1.0 '
  28          MODRIC NUCLIDE   33      1/V NUCLIDE  SIGA=1.0 '
MICROSCOPIC CROSS-SECTIONS IN SET NO.    2  ORDER NO. ON TAPE    5
MSR  1  SET  5  14TH178E (900K)  VF=.20  C/TH= 91
   1          MODRIC NUCLIDE   90      THORIUM-232-R
   2          MODRIC NUCLIDE   91      PROTACTINIUM-233
   3          MODRIC NUCLIDE   93      URANIUM-233
   4          MODRIC NUCLIDE   94      URANIUM-234-R
   5          MODRIC NUCLIDE   95      URANIUM-235
   6          MODRIC NUCLIDE   96      URANIUM-236-R
   7          MODRIC NUCLIDE   98      URANIUM-238-R
   8          MODRIC NUCLIDE   97      NEPTUNIUM-237
   9          MODRIC NUCLIDE   79      PLUTONIUM-239
  10          MODRIC NUCLIDE   80      PLUTONIUM-240-R
  11          MODRIC NUCLIDE   81      PLUTONIUM-241
  12          MODRIC NUCLIDE   82      PLUTONIUM-242-R
  13          MODRIC NUCLIDE    6      LITHIUM-6
  14          MODRIC NUCLIDE    7      LITHIUM-7
  15          MODRIC NUCLIDE    4      BERYLLIUM  NATURAL
  16          MODRIC NUCLIDE   12      CARBON    NATURAL     SI
  17          MODRIC NUCLIDE    9      FLUORINE    NATURAL
  18          MODRIC NUCLIDE   24      CHROMIUM    NATURAL
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  19          MODRIC NUCLICE   26      IRON       NATURAL
  20          MODRIC NUCLICE   28      NICKEL     NATURAL
  21          MODRIC NUCLIDE   42      MOLYBDENUM NATURAL
  22          MODRIC NUCLICE   54      XENCN-135
  23          MODRIC NUCLICE   49      SAMARIUM-149
  24          MODRIC NUCLICE   51      SAMARIUM-151
  25          MODRIC NUCLIDE   70      1/V NUCLIDE  SIGA=1.0 '
  26          MODRIC NUCLICE   77      1/V NUCLIDE  SIGA=1.0 '
  27          MODRIC NUCLICE   99      1/V NUCLIDE  SIGA=1.0 '
  28          MODRIC NUCLICE   33      1/V NUCLIDE  SIGA=1.0 '
MICROSCOPIC CROSS-SECTICNS IN SET NC.    3  OROER NO. CN TAPE    9
MSR  1  SET  9  10TH23BE (900K)  VF=.01  C/TH=2517
   1          MODRIC NUCLIDE   90      THORIUM-232-R
   2          MODRIC NUCLICE   91      PROTACTINIUM-233
   3          MODRIC NUCLICE   93      URANIUM-233
   4          MODRIC NUCLICE   94      URANIUM-234-R
   5          MODRIC NUCLICE   95      URANIUM-235
   6          MODRIC NUCLICE   96      URANIUM-236-R
   7          MODRIC NUCLIDE   98      URANIUM-238-R
   8          MODRIC NUCLIDE   97      NEPTUNIUM-237
   9          MODRIC NUCLICE   79      PLUTONIUM-239
  10          MODRIC NUCLICE   80      PLUTONIUM-240-R
  11          MODRIC NUCLICE   81      PLUTONIUM-241
  12          MODRIC NUCLIOE   82      PLUTONIUM-242-R
  13          MODRIC NUCLICE    6      LITHIUM-6
  14          MODRIC NUCLIDE    7      LITHIUM-7
  15          MODRIC NUCLICE    4      BERYLLIUM  NATURAL
  16          MODRIC NUCLICE   12      CARBON   NATURAL     SI
  17          MODRIC NUCLICE    9      FLUCRINE   NATURAL
  18          MODRIC NUCLIDE   24      CHRCMIUM   NATURAL
  19          MODRIC NUCLICE   26      IRON       NATURAL
  20          MODRIC NUCLICE   28      NICKEL     NATURAL
  21          MODRIC NUCLICE   42      MOLYBDENUM NATURAL
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22          MODRIC NUCLIDE   54      XENON-135
23          MODRIC NUCLIDE   49      SAMARIUM-149
24          MODRIC NUCLIDE   51      SAMARIUM-151
25          MODRIC NUCLIDE   70      1/V NUCLIDE  SIGA=1.0 '
26          MODRIC NUCLIDE   77      1/V NUCLIDE  SIGA=1.0 '
27          MODRIC NUCLIDE   99      1/V NUCLIDE  SIGA=1.0 '
28          MODRIC NUCLIDE   33      1/V NUCLIDE  SIGA=1.0 '
```

```
GROUP      FISSION          LETHARGY         UPPER            MEAN             LOWER
           SPECTRUM         WIDTH            ENERGY(EV)       ENERGY(EV)       ENERGY(EV)
    1     7.491118E-01     2.899992E 00     1.491820E 07     3.499380E 06     8.208537E 05
    2     2.491277E-01     3.250000E 00     8.208500E 05     1.616349E 05     3.182780E 04
    3     1.768081E-03     3.249998E 00     3.182780E 04     6.267266E 03     1.234097E 03
    4     0.0              3.250002E 00     1.234100E 03     2.430082E 02     4.785107E 01
    5     0.0              3.247586E 00     4.785120E 01     9.431949E 00     1.859131E 00
    6     0.0              8.836027E-01     1.859129E 00     1.195191E 00     7.683609E-01
    7     0.0              1.452153E 00     7.683511E-01     3.717307E-01     1.798444E-01
    8     0.0              1.099551E 00     1.798425E-01     1.037834E-01     5.989119E-02
    9     0.0              2.536047E 00     5.989060E-02     1.685245E-02     4.742056E-03
LEAVING RPCS1

THE READING OF THE CROSS-SECTION TAPE TOOK     3.0300  SEC
ENTERED CIN
   1              40          2   18          1    1
   2    .00010       0.50       2.00   2250.0          .8      .4444
   3 .45552                 6.0       5.1              0.3
   4     .1654     .00100      1.010
   9    1    9    8
   9    2    4    8
  10    1DAYSSECSDAYSSECSDAYSYEARYEARDAYSDAYS
  10    2DAYSSECSYEARSECS
  11  1  1      25.00     1200.0
  11  1  2       50.0        0.0
  11  1  3      600.0        0.0
  11  1  4       50.0        0.0
  11  1  5      200.0        0.0
  11  1  6        6.0        0.0
  11  1  7       16.0        0.0
  11  1  8       10.0      600.0
  11  1  9      300.0        0.0
  11  2  1      20.00      400.0
  11  2  2       50.0        0.0
  11  2  3       16.0        0.0
  11  2  4       50.0        0.0
  12  1  1    1.0
  12  1  2          1.0
  12  1  3                1.0
  12  1  4                      1.0
  12  1  5                            1.0                    1.0
  12  1  6                                  1.0
  12  1  7                                        1.0
  12  1  8                                              1.0
  12  2  1                1.0
  12  2  2          1.0
  12  2  3                1.0
  12  2  4                      1.0
  12  2  5                1.0
  12  2  6                1.0
  12  2  7                1.0
  12  2  8    1.0
  13  1  1  RARE EARTH
  13  1  2 DEP & SMOKE
  13  1  3  EXTRACT HF
  13  1  4   GAS STRIP
  13  1  5FLUORINATION
  13  1  6     DISCARD
  13  1  7AVE/LIFETIME
  13  1  8       PA-233
  13  2  1     RECYCLE
  13  2  2 DEP & SMOKE
  13  2  3     RECYCLE
```

```
--  -  -
13  2  4   GAS STRIP
13  2  5     RECYCLE
13  2  6     RECYCLE
13  2  7     RECYCLE
13  2  8      PA-233
20  1  650.                      0.25       1.0              .005
20  2  650.                      0.25       0.0              .000
21 1  2  51      1.0  1.0E-6
21 12362421      1.0      .1
21 2  1   1      0.0     0.0
21 2  2  71      1.0     0.0 1    1.0
21 2 13 171      0.0     0.0
22  1  1                    1
22  1  2                         1
22  1  3                    1    2    1
22  1  4                         1    5
22  1  5                         1    5
22  1  6                         1    5
22  1  7                         1
22  1  8  5.753-01          0    1
22  1  9                         1
22  1 10                         1
22  1 11                         1
22  1 12                         1
22  1 13                    1
22  1 14                    1
22  1 15                    1
22  1 16 15.500-04          3    1
22  1 20                         5
22  1 21                         6
22  1 25                         7
22  1229                         1
22  1231                         1
22  2  1                    1
22  2  2                         1
22  2  3                         1
22  2  4                         1
22  2  5                         1
22  2  6                         1
22  2  7                         1
22  2 25                         7
22  2229                         1
22  2231                         1
23  1                       232.000          TH-232     6
23  2        1              233.000 .29279 -6PA-233     8
23  3  3  2        2        233.000          U-233      8
23  4  4      3  2          234.000          U-234      8
23  5  5      4              235.000          U-235      8
23  6  6      5              236.000          U-236      7
23  7  7      6              237.000          NP-237     7
23  8  8      7              238.000          U-238      7
23  9  9      8              239.000          PU-239     3
23 10         9              240.000          PU-240     3
23 11        10              241.000          PU-241     3
23 12        11              242.000          PU-242     3
23 13                          9.012          BE-9       6
23 14                                         BE-9 NA
23 15                          7.000          LI-7       6
23 16        14                6.000          LI-6       6
23 17                         18.998          F          6
23 18                                         FP REF E
23 19                                         LEAKAGE
23 20                                         DEL NEUT
23 21                                         FIX P FR
23 23                         12.011          GRAPHITE   1
23 25 25                                      LUMP FP
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23 26                          51.996          CHRCME
23 27                          55.847          IRON
23 28                          58.710          NICKEL
23 29                          95.940          MOLY
24  1  1      18.98                            18.98
24  1  2  13.    +3
24  1  3  13.0  &3                          13.0  &3
24  1  5  11.2  &3                          11.2  &3
24  1  9   9.3  &3                           9.3  &3
24  1 11   9.3  &3                           9.3  &3
24  1 13     86.17                             86.17
24  1 15    122.57                            122.57
24  2  1     18.98                             18.98
25  1     0.132
25  2     0.132
25  3     0.132
25  5     0.132
25  9     0.132
25 11     0.132
25 13     0.132
25 15     0.132
29  1  4  8 10
30  2
31  3  5  9 11
32  3  5  9 11
33  2  3  5  9 11
34  2  3  5  9 11
35  3  5  9 11
37  3  5  9 11
 0
```

PERMANENT DATA TABLE

	NUCLIDE	ATOMIC MASS	BETA DECAY CONSTANT	ABS XSECT 2200M	RESONANCE INTEGRAL	YIELDS TH-232	U-233	U-235	U-238	PU-239	PU-241
1	TH-232	232.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	PA-233	233.0000	2.927900E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	U-233	233.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	U-234	234.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	U-235	235.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	U-236	236.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	NP-237	237.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	U-238	238.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	PU-239	239.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	PU-240	240.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	PU-241	241.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	PU-242	242.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	BE-9	9.0120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	BE-9 NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	LI-7	7.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	LI-6	6.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	F	18.9980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	FP REF E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	GRAPHITE	12.0110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	CHROME	51.9960	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	IRON	55.8470	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	NICKEL	58.7100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	MOLY	95.9400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	BR-81 5	0.0	0.0	3.299999E 00	6.100000E 01	0.003600	0.004600	0.001400	0.000300	0.001100	0.0
52	BR-82 5	0.0	5.362999E-06	0.0	0.0	0.010000	0.006900	0.002800	0.000500	0.001700	0.000700
53	BR-83 5	0.0	8.021999E-05	0.0	0.0	0.019900	0.011400	0.005440	0.000900	0.002900	0.001000
54	KR-82 4	0.0	0.0	4.500000E 01	1.960000E 02	0.0	0.0	0.0	0.0	0.0	0.0
55	KR-83M 4	0.0	1.013000E-03	2.050000E 02	2.190000E 02	0.0	0.0	0.0	0.0	0.0	0.0
56	KR-84 4	0.0	0.0	1.600000E-01	5.500000E 00	0.036500	0.019100	0.010000	0.001600	0.004700	0.002000
57	KR-85M 4	0.0	4.375000E-05	7.000000E 00	2.900000E 01	0.045000	0.024600	0.013000	0.002700	0.005400	0.003000
58	KR-86 4	0.0	0.0	6.000000E-02	4.000000E-02	0.060000	0.032000	0.020200	0.004600	0.007500	0.004000
59	KR-87 4	0.0	1.480000E-04	5.000000E 02	0.0	0.066000	0.044700	0.024900	0.008000	0.009100	0.005000

60	KR-88	4	0.0	6.875000E-05	0.0	0.0	0.063000	0.048200	0.032100	0.012600	0.012600	0.006300
61	KR-89	4	0.0	3.609000E-03	0.0	0.0	0.064800	0.056500	0.043100	0.022500	0.015300	0.008100
62	KR-90	4	0.0	2.100000E-02	0.0	0.0	0.062100	0.052500	0.049000	0.028900	0.018700	0.011900
63	KR-91	4	0.0	6.930000E-02	0.0	0.0	0.043200	0.039400	0.035000	0.026400	0.015300	0.010200
64	RB-85	6	0.0	0.0	9.100000E-01	1.669999E 00	0.0	0.0	0.0	0.0	0.0	0.0
65	RB-86	6	0.0	4.312000E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
66	RB-87	6	0.0	0.0	1.159999E-01	2.100000E-01	0.0	0.0	0.0	0.0	0.0	0.0
67	SR-86	6	0.0	0.0	1.650000E 00	6.500000E-01	0.0	0.0	0.0	0.0	0.0	0.0
68	SR-87	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
69	SR-88	6	0.0	0.0	4.999999E-03	6.000000E-02	0.007000	0.005400	0.003600	0.001400	0.001400	0.000700
70	SR-89	6	0.0	1.588000E-07	5.000000E-01	2.000000E-01	0.007200	0.006300	0.004800	0.002500	0.001700	0.000900
71	SR-90	6	0.0	7.849998E-10	1.000000E 00	1.799999E 00	0.011000	0.009300	0.008700	0.005100	0.003300	0.002100
72	SR-91	6	0.0	1.584999E-05	0.0	0.0	0.028800	0.026300	0.023400	0.017600	0.010200	0.006800
73	SR-92	6	0.0	7.129999E-05	0.0	0.0	0.061200	0.059700	0.054300	0.040500	0.027900	0.018900
74	Y -89	1	0.0	0.0	1.309999E 00	7.800000E-01	0.0	0.0	0.0	0.0	0.0	0.0
75	Y -90	1	0.0	2.593999E-06	3.500000E 00	1.400000E 00	0.0	0.0	0.0	0.0	0.0	0.0
76	Y -91	1	0.0	1.383000E-07	1.070000E 00	4.200000E-01	0.0	0.0	0.0	0.0	0.0	0.0
77	Y -92	1	0.0	5.346999E-05	0.0	0.0	0.006800	0.006600	0.006000	0.004500	0.003100	0.002100
78	Y -93	1	0.0	1.869000E-05	0.0	0.0	0.059900	0.066700	0.061300	0.043700	0.037100	0.023800
79	ZR-90	3	0.0	0.0	9.999996E-02	4.000000E-02	0.0	0.0	0.0	0.0	0.0	0.0
80	ZR-91	3	0.0	0.0	1.580000E 00	9.000000E 00	0.0	0.0	0.0	0.0	0.0	0.0
81	ZR-92	3	0.0	0.0	2.500000E-01	5.500000E-01	0.0	0.0	0.0	0.0	0.0	0.0
82	ZR-93	3	0.0	0.0	1.099999E 00	2.800000E 01	0.003200	0.003500	0.003200	0.002300	0.002000	0.001300
83	ZR-94	3	0.0	0.0	7.599998E-02	2.000000E-01	0.057000	0.067000	0.064000	0.047000	0.045000	0.032000
84	ZR-95	3	0.0	1.234000E-07	0.0	0.0	0.051500	0.062200	0.062700	0.048000	0.050000	0.040000
85	ZR-96	3	0.0	0.0	5.300000E-02	6.999999E-02	0.048000	0.056400	0.063300	0.051000	0.051000	0.050000
86	ZR-97	3	0.0	1.133000E-05	0.0	0.0	0.045300	0.054800	0.060900	0.055000	0.056000	0.057000
87	ZR-98	3	0.0	1.160000E-02	0.0	0.0	0.036000	0.052500	0.057800	0.059000	0.059000	0.060000
88	ZR-99	3	0.0	2.100000E-02	0.0	0.0	0.027400	0.049600	0.060600	0.063000	0.061000	0.062000
89	NB-95	2	0.0	2.292000E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	NB-97	2	0.0	1.582000E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
91	NB-99	2	0.0	4.812997E-03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
92	NB-100	2	0.0	3.850000E-03	0.0	0.0	0.010400	0.044900	0.063000	0.063000	0.071000	0.063000
93	NB-101	2	0.0	1.155000E-02	0.0	0.0	0.006200	0.028400	0.050000	0.063000	0.059000	0.064000
94	MO-95	2	0.0	0.0	1.390000E 01	1.060000E 02	0.0	0.0	0.0	0.0	0.0	0.0
95	MO-96	2	0.0	0.0	1.200000E 00	2.600000E 01	0.0	0.0	0.0	0.0	0.0	0.0
96	MO-97	2	0.0	0.0	2.200000E 00	1.600000E 01	0.0	0.0	0.0	0.0	0.0	0.0
97	MO-98	2	0.0	0.0	5.100000E-01	5.599999E 00	0.0	0.0	0.0	0.0	0.0	0.0
98	MO-99	2	0.0	2.895000E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	MO-100	2	0.0	0.0	5.000000E-01	6.299999E 00	0.0	0.0	0.0	0.0	0.0	0.0
100	MO-101	2	0.0	7.910999E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
101	MO-102	2	0.0	1.004000E-03	0.0	0.0	0.003600	0.021600	0.041000	0.063000	0.059000	0.063000
102	MO-104	2	0.0	4.619997E-03	0.0	0.0	0.000800	0.009200	0.018000	0.048000	0.059000	0.060000
103	TC-99	2	0.0	0.0	2.200000E 01	1.400000E 02	0.0	0.0	0.0	0.0	0.0	0.0
104	TC-101	2	0.0	8.250000E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
105	TC-103	2	0.0	9.624999E-03	0.0	0.0	0.001600	0.016000	0.030000	0.062000	0.056000	0.062000
106	TC-104	2	0.0	6.416999E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
107	TC-105	2	0.0	1.283000E-03	0.0	0.0	0.000500	0.005000	0.009000	0.037000	0.055000	0.058000
108	RU-100	2	0.0	0.0	7.500000E 00	3.000000E 00	0.0	0.0	0.0	0.0	0.0	0.0
109	RU-101	2	0.0	0.0	5.000000E 00	7.700000E 01	0.0	0.0	0.0	0.0	0.0	0.0
110	RU-102	2	0.0	0.0	1.440000E 00	1.100000E 01	0.0	0.0	0.0	0.0	0.0	0.0
111	RU-103	2	0.0	2.020000E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
112	RU-104	2	0.0	0.0	7.000000E-01	8.000000E 00	0.0	0.0	0.0	0.0	0.0	0.0
113	RU-105	2	0.0	4.326999E-05	2.000000E-01	7.999998E-02	0.0	0.0	0.0	0.0	0.0	0.0
114	RU-106	2	0.0	2.175000E-08	9.000000E 00	1.600000E 01	0.000400	0.002200	0.003800	0.029000	0.045000	0.055000
115	RU-107	2	0.0	2.511000E-03	0.0	0.0	0.000500	0.001200	0.001900	0.013000	0.036000	0.050000
116	RU-108	2	0.0	2.686000E-03	0.0	0.0	0.000500	0.000700	0.000900	0.006400	0.026000	0.040000
117	RH-103	2	0.0	0.0	1.490000E 02	1.030000E 03	0.0	0.0	0.0	0.0	0.0	0.0
118	RH-104	2	0.0	1.650000E-02	4.000000E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
119	RH-105	2	0.0	5.348000E-06	1.440000E 04	1.700000E 04	0.0	0.0	0.0	0.0	0.0	0.0
120	RH-107	2	0.0	5.249998E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
121	PD-104	2	0.0	0.0	6.000000E 00	1.900000E 01	0.0	0.0	0.0	0.0	0.0	0.0
122	PD-105	2	0.0	0.0	1.100000E 01	7.600000E 01	0.0	0.0	0.0	0.0	0.0	0.0
123	PD-106	2	0.0	0.0	6.000000E 00	1.200000E 01	0.0	0.0	0.0	0.0	0.0	0.0
124	PD-107	2	0.0	0.0	1.000000E 01	4.000000E 01	0.0	0.0	0.0	0.0	0.0	0.0
125	PD-108	2	0.0	0.0	1.040000E 01	1.540000E 02	0.0	0.0	0.0	0.0	0.0	0.0

126	PD-109 2	0.0	1.437000E-05	0.0	0.0	0.000600	0.000400	0.000300	0.003000	0.015500	0.031000
127	PD-110 2	0.0	0.0	2.100000E-01	1.000000E 01	0.000600	0.000300	0.000200	0.001400	0.005500	0.022000
128	PD-111 2	0.0	5.021999E-04	0.0	0.0	0.000600	0.000300	0.000200	0.000700	0.002000	0.013000
129	PD-112 2	0.0	5.169000E-06	0.0	0.0	0.000700	0.000200	0.000100	0.000600	0.001200	0.007000
130	PD-113 2	0.0	8.249998E-03	0.0	0.0	0.000700	0.000200	0.000100	0.000500	0.000700	0.004000
131	AG-109 2	0.0	0.0	8.700000E 01	1.437000E 03	0.0	0.0	0.0	0.0	0.0	0.0
132	AG-110M2	0.0	3.085000E-08	8.200000E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
133	AG-111 2	0.0	1.056000E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
134	AG-112 2	0.0	6.015999E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
135	AG-113 2	0.0	3.056000E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
136	AG-114 2	0.0	1.386000E-01	0.0	0.0	0.000700	0.000200	0.000100	0.000500	0.000400	0.002000
137	AG-115 2	0.0	5.500000E-03	0.0	0.0	0.000700	0.000200	0.000100	0.000400	0.000400	0.001000
138	AG-116 2	0.0	4.619997E-03	0.0	0.0	0.000700	0.000100	0.000100	0.000400	0.000400	0.000600
139	CD-110 3	0.0	0.0	2.000000E-01	3.000000E 01	0.0	0.0	0.0	0.0	0.0	0.0
140	CD-111 3	0.0	0.0	2.000000E 00	5.200000E 01	0.0	0.0	0.0	0.0	0.0	0.0
141	CD-112 3	0.0	0.0	3.000000E-02	1.300000E 01	0.0	0.0	0.0	0.0	0.0	0.0
142	CD-113 3	0.0	0.0	2.000000E 04	6.520000E 02	0.0	0.0	0.0	0.0	0.0	0.0
143	CD-114 3	0.0	0.0	1.240000E 00	1.500000E 01	0.0	0.0	0.0	0.0	0.0	0.0
144	CD-115 3	0.0	3.632999E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
145	CD-116 3	0.0	0.0	1.500000E 00	1.200000E 00	0.0	0.0	0.0	0.0	0.0	0.0
146	IN-115 3	0.0	0.0	2.070000E 02	3.300000E 03	0.0	0.0	0.0	0.0	0.0	0.0
147	SN-125 3	0.0	8.357000E-07	0.0	0.0	0.000200	0.000600	0.000100	0.000400	0.000500	0.000600
148	SN-126 3	0.0	0.0	3.000000E-01	1.180000E-01	0.000400	0.002600	0.001000	0.000700	0.001800	0.002000
149	SN-127 3	0.0	1.013000E-04	0.0	0.0	0.000500	0.003700	0.001500	0.000800	0.002200	0.002400
150	SB-125 2	0.0	1.098000E-08	1.559999E 00	6.199999E-01	0.000200	0.000400	0.000100	0.000200	0.000300	0.000400
151	SB-126 2	0.0	6.418000E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
152	SB-127 2	0.0	2.115999E-06	0.0	0.0	0.000400	0.002400	0.001000	0.000500	0.001500	0.001600
153	SB-128 2	0.0	1.964999E-05	0.0	0.0	0.001800	0.010500	0.004100	0.002600	0.007400	0.007000
154	SB-129 2	0.0	4.185000E-05	0.0	0.0	0.004000	0.017000	0.008000	0.005300	0.014000	0.012000
155	SB-130M2	0.0	1.627000E-03	0.0	0.0	0.008800	0.023300	0.020000	0.011000	0.025000	0.022000
156	SB-131 2	0.0	5.021999E-04	0.0	0.0	0.013600	0.027300	0.023400	0.018400	0.030400	0.027200
157	SB-132 2	0.0	5.500000E-03	0.0	0.0	0.028700	0.046800	0.043800	0.047000	0.053000	0.048000
158	SB-133 2	0.0	2.817000E-03	0.0	0.0	0.022200	0.035300	0.039500	0.031200	0.041400	0.036000
159	TE-125 2	0.0	0.0	1.559999E 00	2.400000E 01	0.0	0.0	0.0	0.0	0.0	0.0
160	TE-126 2	0.0	0.0	8.000000E-01	9.299999E 00	0.0	0.0	0.0	0.0	0.0	0.0
161	TE-127 2	0.0	2.070000E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
162	TE-128 2	0.0	0.0	3.000000E-01	1.000000E 01	0.0	0.0	0.0	0.0	0.0	0.0
163	TE-129 2	0.0	1.604000E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
164	TE-130 2	0.0	0.0	5.000000E-01	2.000000E-01	0.0	0.0	0.0	0.0	0.0	0.0
165	TE-131 2	0.0	4.812998E-04	0.0	0.0	0.003400	0.006800	0.005900	0.004600	0.007600	0.006800
166	TE-132 2	0.0	2.500999E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
167	TE-133M2	0.0	2.221000E-04	0.0	0.0	0.014800	0.023500	0.026400	0.020800	0.027600	0.024000
168	TE-134 2	0.0	2.685999E-04	0.0	0.0	0.051000	0.059900	0.080600	0.057000	0.075000	0.064000
169	TE-135 2	0.0	2.310000E-02	0.0	0.0	0.050400	0.052600	0.057700	0.054000	0.064800	0.058500
170	I -127 5	0.0	0.0	7.000000E 00	1.620000E 02	0.0	0.0	0.0	0.0	0.0	0.0
171	I -129 5	0.0	0.0	3.200000E 01	3.900000E 01	0.0	0.0	0.0	0.0	0.0	0.0
172	I -130 5	0.0	1.527999E-05	1.800000E 01	7.099999E 00	0.0	0.0	0.0	0.0	0.0	0.0
173	I -131 5	0.0	9.965997E-07	5.000000E 01	2.000000E 01	0.0	0.0	0.0	0.0	0.0	0.0
174	I -132 5	0.0	8.370000E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
175	I -133 5	0.0	9.255000E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
176	I -135 5	0.0	2.873999E-05	0.0	0.0	0.005600	0.005800	0.006400	0.006000	0.007200	0.006500
177	XE-128 4	0.0	0.0	2.500000E 00	9.899999E-01	0.0	0.0	0.0	0.0	0.0	0.0
178	XE-129 4	0.0	0.0	2.100000E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
179	XE-130 4	0.0	0.0	2.500000E 00	9.899999E-01	0.0	0.0	0.0	0.0	0.0	0.0
180	XE-131 4	0.0	0.0	1.200000E 02	8.000000E 02	0.0	0.0	0.0	0.0	0.0	0.0
181	XE-132 4	0.0	0.0	2.000000E-01	1.799999E 00	0.0	0.0	0.0	0.0	0.0	0.0
182	XE-133 4	0.0	1.521999E-06	1.900000E 02	7.500000E 01	0.0	0.0	0.0	0.0	0.0	0.0
183	XE-134 4	0.0	0.0	2.000000E-01	6.000000E-01	0.0	0.0	0.0	0.0	0.0	0.0
184	XE-135 4	0.0	2.092999E-05	2.800000E 06	4.544000E 03	0.0	0.0	0.0	0.0	0.0	0.0
185	XE-136 4	0.0	0.0	1.500000E-01	9.999996E-02	0.064000	0.066800	0.064600	0.060000	0.066000	0.066000
186	XE-137 4	0.0	2.962000E-03	0.0	0.0	0.063700	0.063100	0.058400	0.057000	0.061800	0.060800
187	XE-138 4	0.0	6.793998E-04	0.0	0.0	0.069400	0.067500	0.054500	0.057000	0.059900	0.059900
188	XE-139 4	0.0	1.690000E-02	0.0	0.0	0.060100	0.052900	0.052400	0.048000	0.048000	0.049600
189	XE-140 4	0.0	4.330000E-02	0.0	0.0	0.046200	0.040300	0.038600	0.034800	0.033600	0.036600
190	CS-133 6	0.0	0.0	2.900000E 01	4.200000E 02	0.0	0.0	0.0	0.0	0.0	0.0
191	CS-134 6	0.0	9.550000E-09	1.340000E 02	5.300000E 01	0.0	0.0	0.0	0.0	0.0	0.0

192	CS-135 6	0.0	0.0	8.700000E 00	6.200000E 01	0.0	0.0	0.0	0.0	0.0	0.0
193	CS-136 6	0.0	6.171000E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
194	CS-137 6	0.0	7.470999E-10	1.100000E-01	3.000000E-01	0.003400	0.003300	0.003100	0.003000	0.003300	0.003200
195	BA-134 6	0.0	0.0	2.000000E 00	7.900000E-01	0.0	0.0	0.0	0.0	0.0	0.0
196	BA-135 6	0.0	0.0	5.000000E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
197	BA-136 6	0.0	0.0	4.000000E-01	1.300000E 01	0.0	0.0	0.0	0.0	0.0	0.0
198	BA-137 6	0.0	0.0	5.099999E 00	2.000000E 00	0.0	0.0	0.0	0.0	0.0	0.0
199	BA-138 6	0.0	0.0	7.000000E-01	5.000000E-01	0.003700	0.003600	0.002900	0.003000	0.003200	0.003200
200	BA-140 6	0.0	6.268000E-07	1.200000E 01	4.700000E 00	0.030800	0.026800	0.025800	0.023200	0.022400	0.024400
201	LA-139 1	0.0	0.0	8.900000E 00	1.100000E 01	0.015000	0.013200	0.013100	0.012000	0.012000	0.012400
202	LA-140 1	0.0	4.789999E-06	3.099999E 00	1.200000E 00	0.0	0.0	0.0	0.0	0.0	0.0
203	LA-141 1	0.0	5.065999E-05	0.0	0.0	0.084000	0.062400	0.064000	0.054000	0.056000	0.060000
204	CE-140 1	0.0	0.0	6.600000E-01	5.000000E-01	0.0	0.0	0.0	0.0	0.0	0.0
205	CE-141 1	0.0	2.431000E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
206	CE-142 1	0.0	0.0	1.000000E 00	1.299999E 00	0.083000	0.067900	0.060100	0.051000	0.050000	0.058000
207	CE-143 1	0.0	5.835000E-06	6.000000E 00	2.400000E 00	0.080000	0.059100	0.060300	0.048000	0.046000	0.056000
208	CE-144 1	0.0	2.865000E-08	6.000000E 00	2.599999E 00	0.075000	0.045100	0.056200	0.045000	0.038000	0.048000
209	PR-141 1	0.0	0.0	1.160000E 01	2.400000E 01	0.0	0.0	0.0	0.0	0.0	0.0
210	PR-142 1	0.0	9.975999E-06	1.800000E 01	7.099999E 00	0.0	0.0	0.0	0.0	0.0	0.0
211	PR-143 1	0.0	5.856000E-07	8.900000E 01	1.900000E 02	0.0	0.0	0.0	0.0	0.0	0.0
212	PR-145 1	0.0	3.231000E-05	0.0	0.0	0.066000	0.033800	0.039800	0.039000	0.031000	0.036000
213	ND-142 1	0.0	0.0	1.800000E 01	7.099999E 00	0.0	0.0	0.0	0.0	0.0	0.0
214	ND-143 1	0.0	0.0	3.240000E 02	1.300000E 02	0.0	0.0	0.0	0.0	0.0	0.0
215	ND-144 1	0.0	0.0	5.000000E 00	1.200000E 01	0.0	0.0	0.0	0.0	0.0	0.0
216	ND-145 1	0.0	0.0	6.000000E 01	2.450000E 02	0.0	0.0	0.0	0.0	0.0	0.0
217	ND-146 1	0.0	0.0	1.000000E 01	2.500000E 01	0.055000	0.025800	0.030700	0.033000	0.026000	0.028000
218	ND-147 1	0.0	7.228000E-07	0.0	0.0	0.038200	0.019300	0.023600	0.028000	0.020500	0.022000
219	ND-148 1	0.0	0.0	3.400000E 00	4.800000E 01	0.018000	0.012800	0.017100	0.024000	0.017000	0.016000
220	ND-149 1	0.0	9.624999E-05	0.0	0.0	0.009500	0.007700	0.011300	0.021000	0.013000	0.012000
221	ND-150 1	0.0	0.0	3.000000E 00	1.400000E 01	0.004000	0.005500	0.006700	0.013000	0.010000	0.008000
222	PM-147 1	0.0	8.289000E-09	2.350000E 02	3.220000E 03	0.0	0.0	0.0	0.0	0.0	0.0
223	PM-148M1	0.0	1.975999E-07	2.700000E 04	3.200000E 04	0.0	0.0	0.0	0.0	0.0	0.0
224	PM-148 1	0.0	1.488000E-06	1.500000E 03	4.400000E 04	0.0	0.0	0.0	0.0	0.0	0.0
225	PM-149 1	0.0	3.626000E-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
226	PM-151 1	0.0	6.779999E-06	0.0	0.0	0.002000	0.003500	0.004400	0.009000	0.008000	0.005000
227	SM-147 1	0.0	0.0	8.700000E 01	7.080000E 02	0.0	0.0	0.0	0.0	0.0	0.0
228	SM-148 1	0.0	0.0	9.000000E 00	5.000000E 01	0.0	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	0.0	0.0	4.080000E 04	3.400000E 03	0.0	0.0	0.0	0.0	0.0	0.0
230	SM-150 1	0.0	0.0	9.700000E 01	2.550000E 02	0.0	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	0.0	2.745999E-10	1.500000E 04	2.500000E 03	0.0	0.0	0.0	0.0	0.0	0.0
232	SM-152 1	0.0	0.0	2.160000E 02	2.500000E 03	0.000900	0.002200	0.002800	0.006000	0.006000	0.003000
233	SM-153 1	0.0	4.097000E-06	0.0	0.0	0.000400	0.001500	0.001700	0.003800	0.003400	0.002000
234	SM-154 1	0.0	0.0	5.500000E 00	2.500000E 01	0.000200	0.000500	0.000800	0.002200	0.002500	0.001500
235	SM-156 1	0.0	2.138999E-05	0.0	0.0	0.0	0.000100	0.000100	0.000800	0.001000	0.000700
236	EU-151 1	0.0	0.0	8.730000E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
237	EU-152 1	0.0	1.832000E-09	5.000000E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
238	EU-153 1	0.0	0.0	4.500000E 02	1.380000E 03	0.0	0.0	0.0	0.0	0.0	0.0
239	EU-154 1	0.0	1.373000E-09	1.500000E 03	5.940000E 02	0.0	0.0	0.0	0.0	0.0	0.0
240	EU-155 1	0.0	1.293000E-08	1.400000E 04	5.540000E 03	0.000100	0.000300	0.000300	0.001300	0.001600	0.001000
241	EU-156 1	0.0	5.209000E-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
242	EU-157 1	0.0	1.250000E-05	0.0	0.0	0.0	0.0	0.000100	0.000400	0.000700	0.0
243	GD-152 1	0.0	0.0	1.800000E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
244	GD-153 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
245	GD-154 1	0.0	0.0	2.300000E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
246	GD-155 1	0.0	0.0	5.800000E 04	1.630000E 03	0.0	0.0	0.0	0.0	0.0	0.0
247	GD-156 1	0.0	0.0	4.000000E 00	4.400000E 01	0.0	0.0	0.0	0.0	0.0	0.0
248	GD-157 1	0.0	0.0	2.420000E 05	7.400000E 02	0.0	0.0	0.0	0.0	0.0	0.0
249	GD-158 1	0.0	0.0	3.900000E 00	2.900000E 01	0.0	0.0	0.0	0.000200	0.000400	0.0
250	GD-159 1	0.0	1.070000E-05	0.0	0.0	0.0	0.0	0.0	0.000100	0.000200	0.0

DELAYED NEUTRON DATA

GROUP	DECAY CONSTANT	DELAYED NEUTRON FRACTIONS TH-232	U-233	U-235	U-238	PU-239	PU-241
1	0.012600	0.000690	0.000230	0.000240	0.000190	0.000070	0.000080
2	0.033700	0.003050	0.000790	0.001420	0.002020	0.000630	0.000720
3	0.139000	0.003150	0.000670	0.001280	0.002390	0.000450	0.000490
4	0.325000	0.009070	0.000740	0.002570	0.005730	0.000690	0.000950
5	1.129999	0.003500	0.000140	0.000750	0.003320	0.000180	0.000360
6	2.500000	0.000870	0.000090	0.000270	0.001110	0.000090	0.000070

SOURCES

	NUCLIDE	PROCESSING		TRANSMUTATION		DECAY	
1	TH-232	0	0	0	0	0	0
2	PA-233	0	0	1	0	0	0
3	U-233	3	2	0	0	2	0
4	U-234	4	0	3	2	0	0
5	U-235	5	0	4	0	0	0
6	U-236	6	0	5	0	0	0
7	NP-237	7	0	6	0	0	0
8	U-238	8	0	7	0	0	0
9	PU-239	9	0	8	0	0	0
10	PU-240	0	0	9	0	0	0
11	PU-241	0	0	10	0	0	0
12	PU-242	0	0	11	0	0	0
13	BE-9	0	0	0	0	0	0
14	BE-9 NA	0	0	0	0	0	0
15	LI-7	0	0	0	0	0	0
16	LI-6	0	0	14	0	0	0
17	F	0	0	0	0	0	0
18	FP REF E	0	0	0	0	0	0
19	LEAKAGE	0	0	0	0	0	0
20	DEL NEUT	0	0	0	0	0	0
21	FIX P FR	0	0	0	0	0	0
22		0	0	0	0	0	0
23	GRAPHITE	0	0	0	0	0	0
24		0	0	0	0	0	0
25	LUMP FP	25	0	0	0	0	0
26	CHROME	0	0	0	0	0	0
27	IRON	0	0	0	0	0	0
28	NICKEL	0	0	0	0	0	0
29	MOLY	0	0	0	0	0	0
30		0	0	0	0	0	0
31		0	0	0	0	0	0
32		0	0	0	0	0	0
33		0	0	0	0	0	0
34		0	0	0	0	0	0
35		0	0	0	0	0	0
36		0	0	0	0	0	0
37		0	0	0	0	0	0
38		0	0	0	0	0	0
39		0	0	0	0	0	0
40		0	0	0	0	0	0
41		0	0	0	0	0	0
42		0	0	0	0	0	0
43		0	0	0	0	0	0
44		0	0	0	0	0	0
45		0	0	0	0	0	0
46		0	0	0	0	0	0
47		0	0	0	0	0	0
48		0	0	0	0	0	0
49		0	0	0	0	0	0
50		0	0	0	0	0	0
51	BR-81 5	0	0	0	0	0	0
52	BR-82 5	0	0	51	0	0	0
53	BR-83 5	0	0	52	0	0	0
54	KR-82 4	0	0	0	0	52	0
55	KR-83M 4	0	0	54	55	53	0
56	KR-84 4	0	0	53	55	0	0
57	KR-85M 4	0	0	56	0	0	0
58	KR-86 4	0	0	57	0	0	0
59	KR-87 4	0	0	58	0	0	0
60	KR-88 4	0	0	59	0	0	0

	NUCLIDE	PROCESSING		TRANSMUTATION		DECAY	
126	PD-109 2	0	0	116	125	0	0
127	PD-110 2	0	0	126	0	0	0
128	PD-111 2	0	0	127	0	0	0
129	PD-112 2	0	0	128	0	0	0
130	PD-113 2	0	0	129	0	0	0
131	AG-109 2	0	0	0	0	126	0
132	AG-110M2	0	0	131	0	0	0
133	AG-111 2	0	0	132	0	128	0
134	AG-112 2	0	0	133	0	129	0
135	AG-113 2	0	0	134	0	130	0
136	AG-114 2	0	0	130	135	0	0
137	AG-115 2	0	0	136	0	0	0
138	AG-116 2	0	0	137	0	0	0
139	CD-110 3	0	0	0	0	132	0
140	CD-111 3	0	0	139	0	133	0
141	CD-112 3	0	0	140	0	134	0
142	CD-113 3	0	0	141	0	135	0
143	CD-114 3	0	0	142	0	136	0
144	CD-115 3	0	0	143	0	137	0
145	CD-116 3	0	0	144	0	138	0
146	IN-115 3	0	0	0	0	144	0
147	SN-125 3	0	0	0	0	0	0
148	SN-126 3	0	0	147	0	0	0
149	SN-127 3	0	0	148	0	0	0
150	SB-125 2	0	0	0	0	147	0
151	SB-126 2	0	0	150	0	148	0
152	SB-127 2	0	0	151	0	149	0
153	SB-128 2	0	0	149	152	0	0
154	SB-129 2	0	0	153	0	0	0
155	SB-130M2	0	0	154	0	0	0
156	SB-131 2	0	0	155	0	0	0
157	SB-132 2	0	0	156	0	0	0
158	SB-133 2	0	0	157	0	0	0
159	TE-125 2	0	0	0	0	150	0
160	TE-126 2	0	0	159	0	151	0
161	TE-127 2	0	0	160	0	152	0
162	TE-128 2	0	0	161	0	153	0
163	TE-129 2	0	0	162	0	154	0
164	TE-130 2	0	0	163	0	155	0
165	TE-131 2	0	0	164	0	156	0
166	TE-132 2	0	0	165	0	157	0
167	TE-133M2	0	0	166	0	158	0
168	TE-134 2	0	0	158	167	0	0
169	TE-135 2	0	0	168	0	0	0
170	I -127 5	0	0	0	0	161	0
171	I -129 5	0	0	0	0	163	0
172	I -130 5	0	0	171	0	164	0
173	I -131 5	0	0	172	0	165	0
174	I -132 5	0	0	173	0	166	0
175	I -133 5	0	0	174	0	167	0
176	I -135 5	0	0	0	0	169	0
177	XE-128 4	0	0	170	0	0	0
178	XE-129 4	0	0	177	0	171	0
179	XE-130 4	0	0	178	0	172	0
180	XE-131 4	0	0	179	0	173	0
181	XE-132 4	0	0	180	0	174	0
182	XE-133 4	0	0	181	0	175	0
183	XE-134 4	0	0	175	182	0	0
184	XE-135 4	0	0	183	0	176	0
185	XE-136 4	0	0	176	184	0	0

61	KR-89	4	0	0	60	0	0	0	186	XE-137	4	0	0	185	0	0	0
62	KR-90	4	0	0	61	0	0	0	187	XE-138	4	0	0	186	0	0	0
63	KR-91	4	0	0	62	0	0	0	188	XE-139	4	0	0	187	0	0	0
64	RB-85	6	0	0	0	0	57	0	189	XE-140	4	0	0	188	0	0	0
65	RB-86	6	0	0	64	0	0	0	190	CS-133	6	0	0	0	0	182	0
66	RB-87	6	0	0	65	0	59	0	191	CS-134	6	0	0	190	0	0	0
67	SR-86	6	0	0	0	0	65	0	192	CS-135	6	0	0	191	0	184	0
68	SR-87	6	0	0	67	0	0	0	193	CS-136	6	0	0	192	0	0	0
69	SR-88	6	0	0	66	68	0	0	194	CS-137	6	0	0	193	0	186	0
70	SR-89	6	0	0	69	0	61	0	195	BA-134	6	0	0	0	0	191	0
71	SR-90	6	0	0	70	0	62	0	196	BA-135	6	0	0	195	0	192	0
72	SR-91	6	0	0	71	0	63	0	197	BA-136	6	0	0	196	0	193	0
73	SR-92	6	0	0	63	72	0	0	198	BA-137	6	0	0	197	0	194	0
74	Y -89	1	0	0	0	0	70	0	199	BA-138	6	0	0	194	198	0	0
75	Y -90	1	0	0	74	0	71	0	200	BA-140	6	0	0	0	0	189	0
76	Y -91	1	0	0	75	0	72	0	201	LA-139	1	0	0	199	0	188	0
77	Y -92	1	0	0	76	0	73	0	202	LA-140	1	0	0	201	0	200	0
78	Y -93	1	0	0	73	77	0	0	203	LA-141	1	0	0	200	202	0	0
79	ZR-90	3	0	0	0	0	75	0	204	CE-140	1	0	0	0	0	202	0
80	ZR-91	3	0	0	79	0	76	0	205	CE-141	1	0	0	204	0	203	0
81	ZR-92	3	0	0	80	0	77	0	206	CE-142	1	0	0	203	205	0	0
82	ZR-93	3	0	0	81	0	78	0	207	CE-143	1	0	0	206	0	0	0
83	ZR-94	3	0	0	78	82	0	0	208	CE-144	1	0	0	207	0	0	0
84	ZR-95	3	0	0	83	0	0	0	209	PR-141	1	0	0	0	0	205	0
85	ZR-96	3	0	0	84	0	0	0	210	PR-142	1	0	0	209	0	206	0
86	ZR-97	3	0	0	85	0	0	0	211	PR-143	1	0	0	210	0	207	0
87	ZR-98	3	0	0	86	0	0	0	212	PR-145	1	0	0	208	0	0	0
88	ZR-99	3	0	0	87	0	0	0	213	ND-142	1	0	0	0	0	210	0
89	NB-95	2	0	0	0	0	84	0	214	ND-143	1	0	0	213	0	211	0
90	NB-97	2	0	0	0	0	86	0	215	ND-144	1	0	0	211	214	0	0
91	NB-99	2	0	0	0	0	88	0	216	ND-145	1	0	0	215	0	212	0
92	NB-100	2	0	0	88	91	0	0	217	ND-146	1	0	0	212	216	0	0
93	NB-101	2	0	0	92	0	0	0	218	ND-147	1	0	0	217	0	0	0
94	MO-95	2	0	0	0	0	89	0	219	ND-148	1	0	0	218	0	0	0
95	MO-96	2	0	0	89	94	0	0	220	ND-149	1	0	0	219	0	0	0
96	MO-97	2	0	0	95	0	90	0	221	ND-150	1	0	0	220	0	0	0
97	MO-98	2	0	0	90	96	0	0	222	PM-147	1	0	0	0	0	218	0
98	MO-99	2	0	0	97	0	91	0	223	PM-148M	1	0	0	222	0	0	0
99	MO-100	2	0	0	98	0	92	0	224	PM-148	1	0	0	222	0	0	0
100	MO-101	2	0	0	99	0	93	0	225	PM-149	1	0	0	223	224	220	0
101	MO-102	2	0	0	93	100	0	0	226	PM-151	1	0	0	221	0	0	0
102	MO-104	2	0	0	0	0	0	0	227	SM-147	1	0	0	0	0	222	0
103	TC-99	2	0	0	0	0	98	0	228	SM-148	1	0	0	227	0	223	224
104	TC-101	2	0	0	0	0	100	0	229	SM-149	1	0	0	228	0	225	0
105	TC-103	2	0	0	101	0	0	0	230	SM-150	1	0	0	225	229	0	0
106	TC-104	2	0	0	105	0	102	0	231	SM-151	1	0	0	230	0	226	0
107	TC-105	2	0	0	102	106	0	0	232	SM-152	1	0	0	226	231	0	0
108	RU-100	2	0	0	103	0	0	0	233	SM-153	1	0	0	232	0	0	0
109	RU-101	2	0	0	108	0	104	0	234	SM-154	1	0	0	233	0	0	0
110	RU-102	2	0	0	104	109	0	0	235	SM-156	1	0	0	0	0	0	0
111	RU-103	2	0	0	110	0	105	0	236	EU-151	1	0	0	0	0	231	0
112	RU-104	2	0	0	111	0	106	0	237	EU-152	1	0	0	236	0	0	0
113	RU-105	2	0	0	112	0	107	0	238	EU-153	1	0	0	237	0	233	0
114	RU-106	2	0	0	107	113	0	0	239	EU-154	1	0	0	238	0	0	0
115	RU-107	2	0	0	114	0	0	0	240	EU-155	1	0	0	234	239	0	0
116	RU-108	2	0	0	115	0	0	0	241	EU-156	1	0	0	240	0	235	0
117	RH-103	2	0	0	0	0	111	0	242	EU-157	1	0	0	235	241	0	0
118	RH-104	2	0	0	117	0	0	0	243	GD-152	1	0	0	0	0	237	0
119	RH-105	2	0	0	118	0	113	0	244	GD-153	1	0	0	243	0	0	0
120	RH-107	2	0	0	0	0	115	0	245	GD-154	1	0	0	244	0	239	0
121	PD-104	2	0	0	0	0	118	0	246	GD-155	1	0	0	245	0	240	0
122	PD-105	2	0	0	121	0	119	0	247	GD-156	1	0	0	246	0	241	0
123	PD-106	2	0	0	119	122	0	0	248	GD-157	1	0	0	247	0	242	0
124	PD-107	2	0	0	123	0	120	0	249	GD-158	1	0	0	242	248	0	0
125	PD-108	2	0	0	120	124	0	0	250	GD-159	1	0	0	249	0	0	0

MATERIAL 1 INPUT DATA

			E	SCE	SPEC FEED	SYSTEM $/KG	UPC $/KG	REF PPUC	FEED $/KG	Q N J
1	90	TH-232	1.0000E 00	1.0000E 00	0.0	1.8980E 01	0.0	0.0	1.8980E 01	1 0 0
2	91	PA-233	1.0000E 00	1.0000E-06	0.0	1.3000E 04	0.0	0.0	0.0	0 1 0
3	93	U-233	1.0000E 00	1.0000E-06	0.0	1.3000E 04	0.0	0.0	1.3000E 04	1 2 1
4	94	U-234	1.0000E 00	1.0000E-06	0.0	0.0	0.0	0.0	0.0	0 1 5
5	95	U-235	1.0000E 00	1.0000E-06	0.0	1.1200E 04	0.0	0.0	1.1200E 04	0 1 5
6	96	U-236	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 1 5
7	97	NP-237	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 1 0
8	98	U-238	1.0000E 00	1.0000E 00	5.7530E-01	0.0	0.0	0.0	0.0	0 1 0
9	79	PU-239	1.0000E 00	1.0000E 00	0.0	9.3000E 03	0.0	0.0	9.3000E 03	0 1 0
10	80	PU-240	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 1 0
11	81	PU-241	1.0000E 00	1.0000E 00	0.0	9.3000E 03	0.0	0.0	9.3000E 03	0 1 0
12	82	PU-242	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 1 0
13	4	BE-9	1.0000E 00	1.0000E 00	0.0	8.6170E 01	0.0	0.0	8.6170E 01	1 0 0
14	70	BE-9 NA	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	1 0 0
15	7	LI-7	1.0000E 00	1.0000E 00	0.0	1.2257E 02	0.0	0.0	1.2257E 02	1 0 0
16	6	LI-6	1.0000E 00	1.0000E 00	5.0000E-05	0.0	0.0	0.0	0.0	3 1 0
17	9	F	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 0 0
18	99	FP REF E	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 0 0
20	77	DEL NEUT	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 5 0
21	54	FIX P FR	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 6 0
25	33	LUMP FP	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 7 0

RECYCLE FRACTIONS

1 1	1	1.0	1 2	1	0.0	1 3	1	0.0
1 1	2	1.0	1 2	2	0.0	1 3	2	0.0
1 1	3	1.0	1 2	3	0.0	1 3	3	0.0
1 1	4	1.0	1 2	4	0.0	1 3	4	0.0
1 1	5	1.0	1 2	5	0.0	1 3	5	0.0
1 1	6	1.0	1 2	6	0.0	1 3	6	0.0
1 1	7	1.0	1 2	7	0.0	1 3	7	0.0
1 1	8	1.0	1 2	8	0.0	1 3	8	0.0
1 1	9	1.0	1 2	9	0.0	1 3	9	0.0
1 1	10	1.0	1 2	10	0.0	1 3	10	0.0
1 1	11	1.0	1 2	11	0.0	1 3	11	0.0
1 1	12	1.0	1 2	12	0.0	1 3	12	0.0
1 1	13	1.0	1 2	13	0.0	1 3	13	0.0
1 1	14	1.0	1 2	14	0.0	1 3	14	0.0
1 1	15	1.0	1 2	15	0.0	1 3	15	0.0
1 1	16	1.0	1 2	16	0.0	1 3	16	0.0
1 1	17	1.0	1 2	17	0.0	1 3	17	0.0
1 1	18	1.0	1 2	18	0.0	1 3	18	0.0
1 1	19	1.0	1 2	19	0.0	1 3	19	0.0
1 1	20	1.0	1 2	20	0.0	1 3	20	0.0
1 1	21	1.0	1 2	21	0.0	1 3	21	0.0
1 1	22	1.0	1 2	22	0.0	1 3	22	0.0
1 1	23	1.0	1 2	23	0.0	1 3	23	0.0
1 1	24	1.0	1 2	24	0.0	1 3	24	0.0
1 1	25	1.0	1 2	25	0.0	1 3	25	0.0

MATERIAL 2 INPUT DATA

			E	SCE	SPEC FEED	SYSTEM $/KG	UPC $/KG	REF PPUC	FEED $/KG	Q N J
1	90	TH-232	0.0	0.0	0.0	1.8980E 01	0.0	0.0	1.8980E 01	1 0 0
2	91	PA-233	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0.0	0 1 0
3	93	U-233	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0.0	0 1 0
4	94	U-234	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0.0	0 1 0
5	95	U-235	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0.0	0 1 0
6	96	U-236	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0.0	0 1 0
7	97	NP-237	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0.0	0 1 0
13	4	BE-9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0 0
14	70	BE-9 NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0 0

15	7	LI-7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0 0
16	6	LI-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0 0
17	9	F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0 0
18	99	FP REF E	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 0 0
20	77	DEL NEUT	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 0 0
25	33	LUMP FP	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 7 0

RECYCLE FRACTIONS

2 1	1	0.0	2 2	1	1.0	2 3	1	0.0
2 1	2	1.0	2 2	2	0.0	2 3	2	0.0
2 1	3	1.0	2 2	3	0.0	2 3	3	0.0
2 1	4	1.0	2 2	4	0.0	2 3	4	0.0
2 1	5	1.0	2 2	5	0.0	2 3	5	0.0
2 1	6	1.0	2 2	6	0.0	2 3	6	0.0
2 1	7	1.0	2 2	7	0.0	2 3	7	0.0
2 1	8	0.0	2 2	8	1.0	2 3	8	0.0
2 1	9	0.0	2 2	9	1.0	2 3	9	0.0
2 1	10	0.0	2 2	10	1.0	2 3	10	0.0
2 1	11	0.0	2 2	11	1.0	2 3	11	0.0
2 1	12	0.0	2 2	12	1.0	2 3	12	0.0
2 1	13	0.0	2 2	13	1.0	2 3	13	0.0
2 1	14	0.0	2 2	14	1.0	2 3	14	0.0
2 1	15	0.0	2 2	15	1.0	2 3	15	0.0
2 1	16	0.0	2 2	16	1.0	2 3	16	0.0
2 1	17	0.0	2 2	17	1.0	2 3	17	0.0
2 1	18	0.0	2 2	18	1.0	2 3	18	0.0
2 1	19	0.0	2 2	19	1.0	2 3	19	0.0
2 1	20	0.0	2 2	20	1.0	2 3	20	0.0
2 1	21	0.0	2 2	21	1.0	2 3	21	0.0
2 1	22	0.0	2 2	22	1.0	2 3	22	0.0
2 1	23	0.0	2 2	23	1.0	2 3	23	0.0
2 1	24	0.0	2 2	24	1.0	2 3	24	0.0
2 1	25	0.0	2 2	25	1.0	2 3	25	0.0

MATERIAL 3 INPUT DATA

			E	SCE	SPEC FEED	SYSTEM $/KG	UPC $/KG	REF PPUC	FEED $/KG	O N J
26	24	CHROME	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 0 0
27	26	IRON	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 0 0
28	28	NICKEL	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 0 0
29	42	MOLY	1.0000E 00	1.0000E 00	0.0	0.0	0.0	0.0	0.0	0 0 0

RECYCLE FRACTIONS

3 1	1	0.0	3 2	1	0.0	3 3	1	1.0
3 1	2	0.0	3 2	2	0.0	3 3	2	1.0
3 1	3	0.0	3 2	3	0.0	3 3	3	1.0
3 1	4	0.0	3 2	4	0.0	3 3	4	1.0
3 1	5	0.0	3 2	5	0.0	3 3	5	1.0
3 1	6	0.0	3 2	6	0.0	3 3	6	1.0
3 1	7	0.0	3 2	7	0.0	3 3	7	1.0
3 1	8	0.0	3 2	8	0.0	3 3	8	1.0
3 1	9	0.0	3 2	9	0.0	3 3	9	1.0
3 1	10	0.0	3 2	10	0.0	3 3	10	1.0
3 1	11	0.0	3 2	11	0.0	3 3	11	1.0
3 1	12	0.0	3 2	12	0.0	3 3	12	1.0
3 1	13	0.0	3 2	13	0.0	3 3	13	1.0
3 1	14	0.0	3 2	14	0.0	3 3	14	1.0
3 1	15	0.0	3 2	15	0.0	3 3	15	1.0
3 1	16	0.0	3 2	16	0.0	3 3	16	1.0
3 1	17	0.0	3 2	17	0.0	3 3	17	1.0
3 1	18	0.0	3 2	18	0.0	3 3	18	1.0
3 1	19	0.0	3 2	19	0.0	3 3	19	1.0
3 1	20	0.0	3 2	20	0.0	3 3	20	1.0
3 1	21	0.0	3 2	21	0.0	3 3	21	1.0
3 1	22	0.0	3 2	22	0.0	3 3	22	1.0

```
3 1    23     0.0          3 2    23     0.0          3 3    23     1.0
3 1    24     0.0          3 2    24     0.0          3 3    24     1.0
3 1    25     0.0          3 2    25     0.0          3 3    25     1.0
                          MATERIAL   4  INPUT CATA

                    E          SCE      SPEC FEED  SYSTEM $/KG  UPC $/KG  REF PPUC    FEED $/KG       Q N J

 23   12  GRAPHITE   1.0000E 00 1.0000E 00 0.0        0.0        0.0        0.0        0.0              0 0 0

   3,    2    3    5

   6,    2    3    4    5    6    8

   4,    1    4    8   10

   1,    2

   4,    3    5    9   11

   4,    3    5    9   11

   5,    2    3    5    9   11

   5,    2    3    5    9   11

   4,    3    5    9   11

   0,    0

   0,    0
LEAVING CIN   10.9300  SEC

THE PRELIMINARY SETUP TOOK   18.5600  SEC
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START MERC ITERATION   1 OF CASE   0


ENTERED MOD8C

 THE UP-SCATTERING CONVERGED ON ITERATION   39

ITNO   87 SEARCH  1 ANS 0.9583378 KNEW 1.0138874 KOLD 0.0       CO 0.0       C1 1.0000000 C2 0.9583378 CP1  3.0000E 00

ITNO  122 SEARCH  2 ANS 0.9923790 KNEW 1.0020714 KOLD 1.0138874 CO 1.0000000 C1 0.9583378 C2 0.9510342 CP1  3.5259E 00

ITNO  145 SEARCH  3 ANS 0.9995667 KNEW 1.0001106 KOLD 1.0020714 CO 0.9583378 C1 0.9510342 C2 0.9506221 CP1  3.7249E 00

ITERATION LIMIT EXCEEDED IN DIFFUSION CALC.
LEAVING MOD8C  150.1300  SEC
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ERC INPUT

MATERIAL 1

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
1	90	TH-232	3.094000E-03	1.045814E 02	7.381155E-01	3.147128E-01
2	91	PA-233	3.159959E-06	1.710552E 03	1.107362E 01	4.070175E 00
3	93	U-233	5.447063E-05	5.660539E 03	1.263029E 04	5.045512E 03
4	94	U-234	1.863216E-05	1.498773E 03	1.740334E 01	6.462464E 00
5	95	U-235	4.249278E-06	5.084637E 03	1.012241E 04	4.144625E 03
6	96	U-236	4.524960E-06	5.745313E 02	6.973348E 00	2.526937E 00
7	97	NP-237	4.905209E-07	3.393205E 03	1.918256E 01	7.131305E 00
8	98	U-238	1.644576E-07	4.838184E 02	3.061169E 00	1.127771E 00
9	79	PU-239	3.118039E-06	2.297193E 04	4.101060E 04	1.422929E 04
10	80	PU-240	3.593350E-06	1.472914E 04	2.437614E 01	7.354989E 00
11	81	PU-241	3.317669E-06	1.793374E 04	4.035006E 04	1.318533E 04
12	82	PU-242	4.924221E-06	1.848650E 03	2.155061E 01	6.461149E 00
13	4	BE-9	7.114959E-03	4.239941E-01	7.002733E-01	3.501367E-01
14	70	BE-9 NA	7.114999E-03	1.248977E-01	0.0	0.0
15	7	LI-7	2.063000E-02	2.874536E-01	0.0	0.0
16	6	LI-6	2.480000E-07	7.358449E 03	1.342286E-03	6.711429E-04
17	9	F	4.761000E-02	1.662969E-01	0.0	0.0
18	99	FP REF E	9.999997E-09	7.782332E 00	0.0	0.0
19	333	LEAKAGE	1.000000E 00	9.605610E-04	0.0	0.0
20	77	DEL NEUT	6.290000E-05	7.782336E 00	0.0	0.0
21	54	FIX P FR	8.369999E-11	1.902032E 07	7.491682E-03	3.745848E-03
25	33	LUMP FP	4.299998E-03	7.782339E 00	0.0	0.0
229	49	SM-149 1	3.889998E-09	6.131380E 05		
231	51	SM-151 1	1.450000E-08	4.701636E 04		

MATERIAL 2

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
1	90	TH-232	3.094000E-03	4.955011E 00	1.649700E-02	7.035084E-03
2	91	PA-233	3.160000E-07	1.039777E 02	2.725307E-01	1.007338E-01
3	93	U-233	2.180000E-07	2.994912E 02	6.666899E 02	2.663450E 02
4	94	U-234	2.939999E-10	7.509915E 01	4.567885E-01	1.709467E-01
5	95	U-235	1.150000E-13	2.583357E 02	5.118862E 02	2.096041E 02
6	96	U-236	4.229999E-17	3.259470E 01	1.572202E-01	5.701157E-02
7	97	NP-237	5.290000E-19	2.017402E 02	4.909118E-01	1.836733E-01
13	4	BE-9	7.114959E-03	1.156892E-02	1.560604E-02	7.803015E-03
14	70	BE-9 NA	7.114999E-03	2.786590E-03	0.0	0.0
15	7	LI-7	2.063000E-02	1.465289E-02	0.0	0.0
16	6	LI-6	2.480000E-07	3.751316E 02	3.029467E-05	1.514733E-05
17	9	F	4.761000E-02	7.011272E-03	0.0	0.0
18	99	FP REF E	9.999997E-09	3.968053E-01	0.0	0.0
20	77	DEL NEUT	1.360000E-04	3.968055E-01	0.0	0.0
25	33	LUMP FP	1.420000E-06	3.968054E-01	0.0	0.0
229	49	SM-149 1	3.889998E-09	2.948004E 04		
231	51	SM-151 1	1.450000E-08	2.234035E 03		

MATERIAL 3

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
26	24	CHROME	7.119000E-03	1.404850E-01	1.109536E-05	5.547678E-06
27	26	IRON	4.742999E-03	1.157839E-01	3.179308E-06	1.589656E-06
28	28	NICKEL	6.399995E-02	2.107915E-01	1.054541E-06	5.272714E-07
29	42	MOLY	9.374999E-03	6.109850E-01	2.716082E-05	1.358042E-05

MATERIAL 4

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
23	12	GRAPHITE	9.529996E-02	2.024884E-01	0.0	0.0

```
ENTERED ERCM

ERC NUCLIDE   3 IN MATERIAL  1 HAS CONC. OPT. 2
NON CONVERGENCE  40  ITERATIONS
ENTERED ERCOUT
BO= 1.000020E 00     BS= 8.375682E-01     F1= 9.997231E-01     ETA= 2.225546E 00
IF= 1.027422E 03     PL= 1.089710E-03     Y = 6.546158E-02     FCC= 6.889355E-01
BR= 1.000881E 00     NO OF ITERS= 41      KI= 1.000878E 00     KC = 9.999998E-01
ENTERED BTMOD
LEAVING BTMOD
LEAVING ERCOUT    0.3300  SEC
LEAVING ERCM   44.4700  SEC

BACK FROM ERC MATERIAL DENSITY

 MATERIAL    1
 93  5.9241E-05  94  2.5721E-05  95  7.5415E-06  96  7.7967E-06  97  1.1963E-06  98  4.9487E-06  79  9.1063E-08
 80  4.4258E-08  81  3.0743E-08  82  2.8584E-08   4  7.1150E-03  70  7.1150E-03   7  2.0630E-02   9  4.7610E-02
 90  3.0940E-03   6  2.1931E-07  91  1.3081E-06  99  1.0000E-08  33  3.8514E-04  77  1.5266E-04  54  1.1811E-10
 49  3.6312E-09  51  9.2178E-09

 MATERIAL    2
 93  5.8576E-08  94  1.6008E-10  95  1.3678E-13  96  2.0075E-14  97  1.3033E-15   4  7.1150E-03  70  7.1150E-03
  7  2.0630E-02   9  4.7610E-02  90  3.0940E-03   6  2.4800E-07  91  1.1617E-07  99  1.0000E-08  33  6.0141E-06
 77  1.3600E-04  49  1.2814E-11  51  6.2452E-11

 MATERIAL    3
 24  7.1190E-03  26  4.7430E-03  28  6.4000E-02  42  9.3750E-03

 MATERIAL    4
 12  9.5300E-02
MOD-ERC-OPT PASS TIME =  195.6500 SEC
```

```
START MERC ITERATION   2 OF CASE   0


ENTERED MOD8C

 THE UP-SCATTERING CONVERGED ON ITERATION   16

ITNO   16 SEARCH  1 ANS 0.8759632 KNEW 1.0413456 KOLD 0.0       CO 0.0       C1 1.0000000 C2 0.8759632 CP1  3.0000E 00

ITNO   68 SEARCH  2 ANS 1.0297327 KNEW 0.9895819 KOLD 1.0413456 CO 1.0000000 C1 0.8759632 C2 0.9020084 CP1  2.5000E 00

ITNO  106 SEARCH  3 ANS 0.9968032 KNEW 1.0012970 KOLD 0.9895819 CO 0.8759632 C1 0.9020084 C2 0.8991248 CP1  2.2232E 00

     CRITICALITY SEARCH-CONVERGED VALUES
ITNO   129  D1  K-EFFECTIVE      0.9992949  D2  K-EFFECTIVE      0.9993083  SYSTEM K-EFFECTIVE      0.9999893
LEAVING MOD8C   65.9000  SEC
```

ERC INPUT

MATERIAL 1

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
1	90	TH-232	3.094000E-03	1.263130E 02	7.438456E-01	3.171566E-01
2	91	PA-233	1.308131E-06	1.940250E 03	1.116423E 01	4.103583E 00
3	93	U-233	5.326509E-05	7.468449E 03	1.673918E 04	6.687102E 03
4	94	U-234	2.312679E-05	1.762668E 03	1.755063E 01	6.517396E 00
5	95	U-235	6.780723E-06	6.915777E 03	1.388670E 04	5.686102E 03
6	96	U-236	7.010211E-06	5.995172E 02	7.027808E 00	2.546681E 00
7	97	NP-237	1.075604E-06	4.237195E 03	1.934290E 01	7.191139E 00
8	98	U-238	4.449469E-06	4.988721E 02	3.084916E 00	1.136522E 00
9	79	PU-239	8.187646E-08	3.178188E 04	5.679059E 04	1.970465E 04
10	80	PU-240	3.979347E-08	1.725978E 04	2.458325E 01	7.417718E 00
11	81	PU-241	2.764156E-08	2.470571E 04	5.557025E 04	1.815922E 04
12	82	PU-242	2.570028E-08	1.962045E 03	2.172653E 01	6.514007E 00
13	4	BE-9	7.114999E-03	4.550809E-01	7.056865E-01	3.528433E-01
14	70	BE-9 NA	7.114999E-03	1.258648E-01	0.0	0.0
15	7	LI-7	2.063000E-02	3.975807E-01	0.0	0.0
16	6	LI-6	2.193148E-07	1.018160E 04	1.352862E-03	6.764310E-04
17	9	F	4.761000E-02	1.964032E-01	0.0	0.0
18	99	FP REF E	9.999997E-09	1.076975E 01	0.0	0.0
19	333	LEAKAGE	1.000000E 00	9.213742E-04	0.0	0.0
20	77	DEL NEUT	1.526574E-04	1.076975E 01	0.0	0.0
21	54	FIX P FR	1.181125E-10	2.701837E 07	7.550851E-03	3.775431E-03
25	33	LUMP FP	3.851370E-04	1.076975E 01	0.0	0.0
229	49	SM-149 1	3.631175E-09	8.675220E 05		
231	51	SM-151 1	9.217821E-09	6.579000E 04		

MATERIAL 2

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
1	90	TH-232	3.094000E-03	5.509095E 00	1.580484E-02	6.739911E-03
2	91	PA-233	1.161720E-07	1.088318E 02	2.614747E-01	9.665483E-02
3	93	U-233	5.857584E-08	3.500593E 02	7.820420E 02	3.124307E 02
4	94	U-234	1.600833E-10	8.147110E 01	4.386662E-01	1.641819E-01
5	95	U-235	1.367790E-13	3.099775E 02	6.186472E 02	2.533235E 02
6	96	U-236	2.007483E-14	3.251329E 01	1.506408E-01	5.462623E-02
7	97	NP-237	1.303337E-15	2.275033E 02	4.713129E-01	1.763572E-01
13	4	BE-9	7.114999E-03	1.205835E-02	1.495125E-02	7.475618E-03
14	70	BE-9 NA	7.114999E-03	2.669673E-03	0.0	0.0
15	7	LI-7	2.063000E-02	1.783403E-02	0.0	0.0
16	6	LI-6	2.480000E-07	4.563582E 02	2.902359E-05	1.451179E-05
17	9	F	4.761000E-02	7.743903E-03	0.0	0.0
18	99	FP REF E	9.999997E-09	4.827650E-01	0.0	0.0
20	77	DEL NEUT	1.360000E-04	4.827653E-01	0.0	0.0
25	33	LUMP FP	6.014054E-06	4.827654E-01	0.0	0.0
229	49	SM-149 1	1.281367E-11	3.666963E 04		
231	51	SM-151 1	6.245227E-11	2.747445E 03		

MATERIAL 3

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
26	24	CHROME	7.119000E-03	1.697600E-01	1.056454E-05	5.282272E-06
27	26	IRON	4.742999E-03	1.356425E-01	3.027204E-06	1.513604E-06
28	28	NICKEL	6.399995E-02	2.541462E-01	1.004090E-06	5.020457E-07
29	42	MOLY	9.374999E-03	6.240054E-01	2.586139E-05	1.293071E-05

MATERIAL 4

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
23	12	GRAPHITE	9.529996E-02	2.782845E-01	0.0	0.0

```
ENTERED ERCM
ENTERED ERCOUT
BO= 1.000018E 00      BS= 9.969132E-01      F1= 9.997718E-01      ETA= 2.234957E 00
IF= 9.311016E 02      PL= 7.827347E-04      Y = 6.738908E-01      FCC= 6.560699E-01
BR= 1.008257E 00      NO OF ITERS= 27       KI= 9.999722E-01      KC = 9.999995E-01
ENTERED BTMOD
LEAVING BTMOD
LEAVING ERCOUT    0.3000  SEC
LEAVING ERCM   29.2200  SEC

BACK FROM ERC MATERIAL DENSITY

 MATERIAL    1
 93  5.3682E-05  94  2.4427E-05  95  6.1491E-06  96  7.5750E-06  97  9.7617E-07  98  4.6025E-06  79  6.4241E-08
 80  3.6706E-08  81  2.2155E-08  82  2.4839E-08   4  7.1150E-03  70  7.1150E-03   7  2.0630E-02   9  4.7610E-02
 90  3.0940E-03   6  1.7712E-07  91  1.3288E-06  99  1.0000E-08  33  2.8668E-04  77  1.0952E-04  54  8.2799E-11
 49  3.0961E-09  51  8.6582E-09

 MATERIAL    2
 93  5.4747E-08  94  1.3316E-10  95  1.0374E-13  96  1.5115E-14  97  8.4035E-16   4  7.1150E-03  70  7.1150E-03
  7  2.0630E-02   9  4.7610E-02  90  3.0940E-03   6  2.4800E-07  91  1.0857E-07  99  1.0000E-08  33  3.9510E-06
 77  1.3600E-04  49  1.0122E-11  51  5.0681E-11

 MATERIAL    3
 24  7.1190E-03  26  4.7430E-03  28  6.4000E-02  42  9.3750E-03

 MATERIAL    4
 12  9.5300E-02
MOD-ERC-OPT PASS TIME =    96.2000 SEC
```

```
START MERC ITERATION   3 OF CASE   0


ENTERED MOO8C

ITNO    3 SEARCH  1 ANS C.5978628 KNEW 1.0007124 KOLD 0.0       CO 0.C       C1 1.0000000 C2 0.9978628 CP1  3.0000E 00

ITNO    6 SEARCH  2 ANS 1.0003433 KNEW 0.9998637 KOLD 1.0007124 CO 1.0000000 C1 0.9978628 C2 0.9982059 CP1  2.5183E 00

 THE UP-SCATTERING CONVERGEC CN ITERATICN   10

     CRITICALITY SEARCH-CONVERGED VALUES
ITNO    13  01  K-EFFECTIVE      0.9994026  D2  K-EFFECTIVE      0.9994252  SYSTEM K-EFFECTIVE      1.000C095
LEAVING MOO8C    8.7800  SEC
```

ERC INPUT

MATERIAL 1

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
1	90	TH-232	3.094000E-03	1.267381E 02	7.438098E-01	3.171414E-01
2	91	PA-233	1.328797E-06	1.941779E 03	1.116373E 01	4.103404E 00
3	93	U-233	5.358554E-05	7.504059E 03	1.682062E 04	6.719637E 03
4	94	U-234	2.438297E-05	1.766672E 03	1.754990E 01	6.517127E 00
5	95	U-235	6.138100E-06	6.954008E 03	1.396583E 04	5.718508E 03
6	96	U-236	7.561413E-06	5.956118E 02	7.027473E 00	2.546560E 00
7	97	NP-237	9.744144E-07	4.251961E 03	1.934198E 01	7.190795E 00
8	98	U-238	4.594208E-06	4.984275E 02	3.084767E 00	1.136468E 00
9	79	PU-239	6.412586E-08	3.195925E 04	5.710971E 04	1.981536E 04
10	80	PU-240	3.663991E-08	1.727667E 04	2.458199E 01	7.417337E 00
11	81	PU-241	2.211491E-08	2.484455E 04	5.588302E 04	1.826143E 04
12	82	PU-242	2.479484E-08	1.961740E 03	2.172557E 01	6.513718E 00
13	4	BE-9	7.114999E-03	4.556567E-01	7.056528E-01	3.528262E-01
14	70	BE-9 NA	7.114999E-03	1.258568E-01	0.0	0.0
15	7	LI-7	2.063000E-02	4.002984E-01	0.0	0.0
16	6	LI-6	1.771183E-07	1.024078E 04	1.352798E-03	6.763989E-04
17	9	F	4.761000E-02	1.970134E-01	0.0	0.0
18	99	FP REF E	9.999997E-09	1.083237E 01	0.0	0.0
19	333	LEAKAGE	1.000000E 00	9.206440E-04	0.0	0.0
20	77	DEL NEUT	1.095208E-04	1.083238E 01	0.0	0.0
21	54	FIX P FR	8.279868E-11	2.719381E 07	7.550485E-03	3.775252E-03
25	33	LUMP FP	2.866786E-04	1.083238E 01	0.0	0.0
229	49	SM-149 1	3.096073E-09	8.730391E 05		
231	51	SM-151 1	8.658194E-09	6.620231E 04		

MATERIAL 2

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
1	90	TH-232	3.094000E-03	5.519708E 00	1.579193E-02	6.734408E-03
2	91	PA-233	1.085722E-07	1.088738E 02	2.612695E-01	9.657919E-02
3	93	U-233	5.474717E-08	3.510127E 02	7.842241E 02	3.133027E 02
4	94	U-234	1.331565E-10	8.157632E 01	4.383312E-01	1.640570E-01
5	95	U-235	1.037433E-13	3.109854E 02	6.207393E 02	2.541802E 02
6	96	U-236	1.511525E-14	3.249818E 01	1.505182E-01	5.458173E-02
7	97	NP-237	8.403486E-16	2.279622E 02	4.709477E-01	1.762212E-01
13	4	BE-9	7.114999E-03	1.206822E-02	1.493904E-02	7.469516E-03
14	70	BE-9 NA	7.114999E-03	2.667454E-03	0.0	0.0
15	7	LI-7	2.063000E-02	1.789626E-02	0.0	0.0
16	6	LI-6	2.480000E-07	4.579473E 02	2.899987E-05	1.449994E-05
17	9	F	4.761000E-02	7.758368E-03	0.0	0.0
18	99	FP REF E	9.999997E-09	4.844465E-01	0.0	0.0
20	77	DEL NEUT	1.360000E-04	4.844465E-01	0.0	0.0
25	33	LUMP FP	3.951041E-06	4.844465E-01	0.0	0.0
229	49	SM-149 1	1.012186E-11	3.681281E 04		
231	51	SM-151 1	5.068128E-11	2.757664E 03		

MATERIAL 3

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
26	24	CHROME	7.119000E-03	1.703669E-01	1.055495E-05	5.277472E-06
27	26	IRON	4.742999E-03	1.401371E-01	3.024454E-06	1.512229E-06
28	28	NICKEL	6.399995E-02	2.550449E-01	1.003178E-06	5.015897E-07
29	42	MOLY	9.374999E-03	6.241836E-01	2.583790E-05	1.291897E-05

MATERIAL 4

I	INE	NUCLIDE	DENSITY	ABSORPTIONS	NEUTRONS PRODUCED	FISSIONS
23	12	GRAPHITE	5.529996E-02	2.798957E-01	0.0	0.0

ENTERED ERCM
ENTERED ERCOUT

RAPID SEPTEMBER 1967 ROD-18 P X4916 X1306 BLANKETED MSBR 1000 MWE TF 9 10TH23BE Q

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	5.0000E-05
RESONANCE INTEGRAL FACTOR	1.8944E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.0863E 00
CONCENTRATION DAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR.	1.01000

MATERIAL	VOLUME	TIME S	TIME P	TIME R	OPTION
1	1.2393E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	1.1088E 03	2.0000E 01	2.5000E-01	0.0	0
3	6.2285E 02	0.0	0.0	0.0	0
4	4.2485E 03	0.0	0.0	0.0	0

BO= 1.000019E 00 BS= 9.999524E-01 F1= 9.997725E-01 ETA= 2.235180E 00
IF= 9.295564E 02 PL= 7.769279E-04 Y = 6.883615E-01 FCC= 6.554781E-01
BR= 1.008421E 00 NO OF ITERS= 10 KI= 9.999943E-01 KC = 9.999991E-01

/**********RATES,KG PER DAY**********//*******FUEL CYCLE COSTS*******/

NUCLIDE	ABS	CAP	FIS	TOT INV,KG	FEED	PROCESS	LOSS	PRODUCT	INV.	REPL.	PROC	CREDIT
1 TH-232	0.9147	0.9124	0.0022	7.925E 04	2.147E 01	1.910E 01	1.910E 01	0.0	0.0283	0.0170	0.2170	0.0
2 PA-233	0.0058	0.0058	0.0000	9.331E 01	0.0	1.871E 00	1.805E-06	0.0	0.0228	0.0	0.0	0.0
3 U-233	0.8991	0.0940	0.8050	7.491E 02	0.0	7.280E 01	7.277E-05	1.922E-02	0.1832	0.0	0.0	0.0104
4 U-234	0.0964	0.0960	0.0004	3.411E 02	0.0	3.327E 01	3.327E-05	8.790E-03	0.0	0.0	0.0	0.0
5 U-235	0.0952	0.0169	0.0783	8.594E 01	0.0	8.384E 00	8.384E-06	2.215E-03	0.0181	0.0	0.0	0.0010
6 U-236	0.0101	0.0101	0.0000	1.041E 02	0.0	1.783E-02	1.783E-02	0.0	0.0	0.0	0.0	0.0
7 NP-237	0.0092	0.0092	0.0000	1.342E 01	0.0	2.298E-03	2.298E-03	0.0	0.0	0.0	0.0	0.0
8 U-238	0.0051	0.0051	0.0000	6.372E 01	0.0	1.091E-02	1.091E-02	0.0	0.0	0.0	0.1062	0.0
9 PU-239	0.0046	0.0017	0.0028	8.881E-01	0.0	1.480E-03	1.480E-03	0.0	0.0002	0.0	0.0	0.0
10 PU-240	0.0014	0.0014	0.0000	5.117E-01	0.0	8.525E-04	8.525E-04	0.0	0.0	0.0	0.0	0.0
11 PU-241	0.0012	0.0003	0.0009	3.088E-01	0.0	5.145E-04	5.145E-04	0.0	0.0001	0.0	0.0	0.0
12 PU-242	0.0001	0.0001	0.0000	3.490E-01	0.0	5.814E-04	5.814E-04	0.0	0.0	0.0	0.0	0.0
13 BE-9	0.0074	0.0017	0.0057	7.080E 03	1.707E 00	1.706E 00	1.706E 00	0.0	0.0115	0.0061	0.0	0.0
14 BE-9 NA	0.0020	0.0020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 LI-7	0.0193	0.0193	0.0	1.594E 04	3.844E 00	3.842E 00	3.842E 00	0.0	0.0368	0.0196	0.0	0.0
16 LI-6	0.0043	0.0043	0.0000	1.393E-01	1.647E-04	2.817E-05	2.817E-05	0.0	0.0	0.0	0.0	0.0
17 F	0.0218	0.0218	0.0	0.0	0.0	2.407E 01	2.407E 01	0.0	0.0	0.0	0.0	0.0
18 FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 LEAKAGE	0.0021	0.0021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 DEL NEUT	0.0028	0.0028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 FIX P FR	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 GRAPHITE	0.0596	0.0596	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 LUMP FP	0.0142	0.0142	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 CHROME	0.0027	0.0027	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 IRON	0.0015	0.0015	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 NICKEL	0.0365	0.0365	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 MOLY	0.0131	0.0131	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.2352								0.3009	0.0428	0.3233	0.0115

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	3.92146E-01	4.18268E 04	4.18315E 04	2.13712E 01	1.90990E 01	0.0
2	PA-233	1.32880E-06	1.32925E-06	2.58123E-03	1.80472E 01	8.93881E 01	0.0	1.80472E 00	0.0
3	U-233	5.35855E-05	5.35962E-05	4.02208E-01	7.27674E 02	7.48440E 02	0.0	7.27673E 01	1.92227E-02
4	U-234	2.43830E-05	2.44032E-05	4.31193E-02	3.32742E 02	3.41061E 02	0.0	3.32742E 01	8.78996E-03
5	U-235	6.13810E-06	6.12283E-06	4.25802E-02	8.38429E 01	8.59390E 01	0.0	8.38428E 00	2.21485E-03
6	U-236	7.56141E-06	7.57158E-06	4.54022E-03	1.04122E 02	1.04127E 02	0.0	1.78292E-02	0.0
7	NP-237	9.74414E-07	9.71909E-07	4.13271E-03	1.34221E 01	1.34227E 01	0.0	2.29830E-03	0.0
8	U-238	4.59421E-06	4.59470E-06	2.29023E-03	6.37207E 01	6.37234E 01	0.0	1.09111E-02	0.0
9	PU-239	6.41259E-08	6.37420E-08	2.03724E-03	8.87707E-01	8.88077E-01	0.0	1.47951E-03	0.0
10	PU-240	3.66399E-08	3.65751E-08	6.31927E-04	5.11498E-01	5.11711E-01	0.0	8.52495E-04	0.0
11	PU-241	2.21149E-08	2.19837E-08	5.46201E-04	3.08720E-01	3.08849E-01	0.0	5.14533E-04	0.0
12	PU-242	2.47948E-08	2.47395E-08	4.85348E-05	3.48861E-01	3.49006E-01	0.0	5.81435E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.24217E-03	3.73631E 03	3.73673E 03	1.70681E 00	1.70607E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	8.95527E-04	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	8.25854E-03	8.41480E 03	8.41575E 03	3.84382E 00	3.84237E 00	0.0
16	LI-6	1.77118E-07	1.76432E-07	1.80689E-03	6.16844E-02	6.16914E-02	1.64735E-04	2.81664E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.38025E-03	0.0	0.0	0.0	2.40662E 01	0.0
18	FP REF E	1.00000E-08	1.00000E-08	1.08329E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	9.20688E-04	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.09521E-04	1.08868E-04	1.17936E-03	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.27987E-11	8.22563E-11	2.23657E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.86679E-04	2.85201E-04	3.08940E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.09607E-09	3.08651E-09	2.69464E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.65819E-09	8.64673E-09	5.72433E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	1.70788E-02	3.74222E 04	3.74222E 04	9.89586E-02	0.0	0.0
2	PA-233	1.08572E-07	1.08452E-07	1.18081E-05	1.31739E 00	3.92122E 00	0.0	6.58693E-02	0.0
3	U-233	5.47472E-08	5.46863E-08	1.91965E-05	6.64287E-01	6.72591E-01	0.0	3.32143E-02	0.0
4	U-234	1.33157E-10	1.32691E-10	1.08249E-08	1.61874E-03	1.63898E-03	0.0	8.09372E-05	0.0
5	U-235	1.03743E-13	1.03199E-13	3.20950E-11	1.26435E-06	1.28015E-06	0.0	6.32173E-08	0.0
6	U-236	1.51152E-14	1.50345E-14	4.88618E-13	1.84979E-07	1.84987E-07	0.0	3.16746E-11	0.0
7	NP-237	8.40349E-16	8.33250E-16	1.89958E-13	1.02954E-08	1.02959E-08	0.0	1.76292E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	8.58694E-05	3.34285E 03	3.34285E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	1.89801E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	3.69217E-04	7.52868E 03	7.52868E 03	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	1.13576E-04	7.75754E-02	7.75754E-02	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	3.69393E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	4.84469E-09	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	6.58879E-05	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	3.95104E-06	3.92218E-06	1.90009E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	1.01219E-11	1.00798E-11	3.71067E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	5.06813E-11	5.04966E-11	1.39253E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
26	CHROME	7.11900E-03	7.11900E-03	1.21290E-03	0.0	0.0	0.0	0.0	0.0
27	IRON	4.74300E-03	4.74300E-03	6.64701E-04	0.0	0.0	0.0	0.0	0.0
28	NICKEL	6.40000E-02	6.40000E-02	1.63236E-02	0.0	0.0	0.0	0.0	0.0

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 29  MOLY        9.37500E-03   9.37500E-03   5.85200E-03   0.0           0.0           0.0           0.0           0.0

                                            MATERIAL  4
            /*********CENSITY**********/                /******INVENTORIES,KG******//**************RATES,KG/DAY***************/

NUCLIDE          INITIAL       FINAL        ABSORPTIONS    SYSTEM        TOTAL         FEED          PROCESS       PRODUCT
 23  GRAPHITE   9.53000E-02   9.53000E-02   2.66753E-02   0.0           0.0           0.0           0.0           0.0
ENTERED BTMOD
LEAVING BTMOD
LEAVING ERCOUT    1.9300  SEC
LEAVING ERCM   12.6000  SEC

BACK FROM ERC MATERIAL DENSITY

 MATERIAL    1
 93  5.3596E-05  94  2.4403E-05  95  6.1228E-06  96  7.5716E-06  97  9.7191E-07  98  4.5947E-06  79  6.3742E-08
 80  3.6575E-08  81  2.1984E-08  82  2.4739E-08   4  7.1150E-03  70  7.1150E-03   7  2.0630E-02   9  4.7610E-02
 90  3.0940E-03   6  1.7643E-07  91  1.3293E-06  99  1.0000E-08  33  2.8520E-04  77  1.0887E-04  54  8.2256E-11
 49  3.0865E-09  51  8.6467E-09

 MATERIAL    2
 93  5.4686E-08  94  1.3269E-10  95  1.0320E-13  96  1.5035E-14  97  8.3325E-16   4  7.1150E-03  70  7.1150E-03
  7  2.0630E-02   9  4.7610E-02  90  3.0940E-03   6  2.4800E-07  91  1.0845E-07  99  1.0000E-08  33  3.9222E-06
 77  1.3600E-04  49  1.0080E-11  51  5.0497E-11

 MATERIAL    3
 24  7.1190E-03  26  4.7430E-03  28  6.4000E-02  42  9.3750E-03

 MATERIAL    4
 12  9.5300E-02
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FISSION DENSITY(FD) AND AVERAGE FISSION POWER DENSITY(FPD) BY MESH POINT FOR DIMENSION 1

K	FD	FPD	K	FD	FPD	K	FD	FPD	K	FD	FPD
1	1.8855E 00	7.2179E 01	19	1.4404E 00	5.5140E 01	37	2.1008E-01	8.0422E 00	55	1.0720E-02	4.1039E-01
2	1.8840E 00	7.2125E 01	20	1.3916E 00	5.3272E 01	38	7.3284E-01	2.8055E 01	56	9.5372E-03	3.6510E-01
3	1.8798E 00	7.1962E 01	21	1.3406E 00	5.1320E 01	39	5.3431E-01	2.0455E 01	57	8.3989E-03	3.2153E-01
4	1.8727E 00	7.1690E 01	22	1.2875E 00	4.9289E 01	40	4.2685E-01	1.6341E 01	58	7.3066E-03	2.7971E-01
5	1.8628E 00	7.1311E 01	23	1.2325E 00	4.7181E 01	41	3.7405E-01	1.4319E 01	59	6.2578E-03	2.3956E-01
6	1.8501E 00	7.0823E 01	24	1.1755E 00	4.4999E 01	42	3.6429E-01	1.3946E 01	60	5.2478E-03	2.0089E-01
7	1.8345E 00	7.0229E 01	25	1.1166E 00	4.2747E 01	43	4.0471E-01	1.5493E 01	61	4.2706E-03	1.6349E-01
8	1.8162E 00	6.9528E 01	26	1.0561E 00	4.0429E 01	44	5.2765E-01	2.0199E 01	62	3.3193E-03	1.2707E-01
9	1.7951E 00	6.8722E 01	27	9.9391E-01	3.8049E 01	45	1.1058E-02	4.2331E-01	63	2.3861E-03	9.1345E-02
10	1.7713E 00	6.7811E 01	28	9.3018E-01	3.5609E 01	46	1.4763E-02	5.6517E-01	64	1.4608E-03	5.5922E-02
11	1.7448E 00	6.6796E 01	29	8.6502E-01	3.3115E 01	47	1.6701E-02	6.3935E-01	65	5.2581E-04	2.0129E-02
12	1.7157E 00	6.5679E 01	30	7.9854E-01	3.0570E 01	48	1.7393E-02	6.6583E-01	66	7.7268E-07	2.9580E-05
13	1.6839E 00	6.4461E 01	31	7.3084E-01	2.7978E 01	49	1.7245E-02	6.6017E-01	67	5.5001E-07	2.1055E-05
14	1.6495E 00	6.3144E 01	32	6.6198E-01	2.5342E 01	50	1.6565E-02	6.3413E-01	68	3.8679E-07	1.4807E-05
15	1.6125E 00	6.1730E 01	33	5.9181E-01	2.2656E 01	51	1.5571E-02	5.9609E-01	69	2.6537E-07	1.0159E-05
16	1.5731E 00	6.0220E 01	34	5.1934E-01	1.9881E 01	52	1.4412E-02	5.5172E-01	70	1.7264E-07	6.6089E-06
17	1.5312E 00	5.8617E 01	35	4.4102E-01	1.6883E 01	53	1.3183E-02	5.0466E-01	71	9.8563E-08	3.7732E-06
18	1.4869E 00	5.6923E 01	36	3.4643E-01	1.3262E 01	54	1.1941E-02	4.5713E-01			

FISSION DENSITY(FD) AND AVERAGE FISSION POWER DENSITY(FPD) BY MESH POINT FOR DIMENSION 2

K	FD	FPD	K	FD	FPD	K	FD	FPD	K	FD	FPD
1	2.5584E 00	7.2179E 01	19	1.9291E 00	5.4424E 01	37	4.9921E-01	1.4084E 01	55	1.0183E-0[illegible]	2.8728E-02
2	2.5563E 00	7.2121E 01	20	1.8625E 00	5.2545E 01	38	4.1618E-01	1.1741E 01	56	8.9398E-04	2.5221E-02
3	2.5501E 00	7.1945E 01	21	1.7934E 00	5.0596E 01	39	3.3362E-01	9.4123E 00	57	7.8510E-04	2.2150E-02
4	2.5398E 00	7.1653E 01	22	1.7220E 00	4.8583E 01	40	2.5102E-01	7.0818E 00	58	6.8948E-04	1.9452E-02
5	2.5253E 00	7.1246E 01	23	1.6485E 00	4.6509E 01	41	1.6684E-01	4.7069E 00	59	6.0528E-04	1.7077E-02
6	2.5068E 00	7.0723E 01	24	1.5731E 00	4.4380E 01	42	2.8033E-05	7.9087E-04	60	5.3093E-04	1.4979E-02
7	2.4843E 00	7.0087E 01	25	1.4958E 00	4.2200E 01	43	2.6599E-05	7.5041E-04	61	4.6508E-04	1.3121E-02
8	2.4578E 00	6.9339E 01	26	1.4169E 00	3.9976E 01	44	2.5219E-05	7.1150E-04	62	4.0654E-04	1.1469E-02
9	2.4273E 00	6.8481E 01	27	1.3367E 00	3.7711E 01	45	2.3892E-05	6.7405E-04	63	3.5432E-04	9.9962E-03
10	2.3931E 00	6.7515E 01	28	1.2552E 00	3.5412E 01	46	3.4103E-03	9.6213E-02	64	3.0755E-04	8.6768E-03
11	2.3551E 00	6.6443E 01	29	1.1727E 00	3.3084E 01	47	2.9696E-03	8.3780E-02	65	2.6549E-04	7.4901E-03
12	2.3135E 00	6.5269E 01	30	1.0893E 00	3.0732E 01	48	2.5886E-03	7.3031E-02	66	2.2749E-04	6.4179E-03
13	2.2683E 00	6.3993E 01	31	1.0053E 00	2.8362E 01	49	2.2589E-03	6.3729E-02	67	4.2162E-06	1.1895E-04
14	2.2196E 00	6.2621E 01	32	9.2086E-01	2.5980E 01	50	1.9732E-03	5.5670E-02	68	2.9881E-06	8.4301E-05
15	2.1676E 00	6.1155E 01	33	8.3620E-01	2.3591E 01	51	1.7255E-03	4.8681E-02	69	2.0925E-06	5.9034E-05
16	2.1125E 00	5.9598E 01	34	7.5150E-01	2.1202E 01	52	1.5104E-03	4.2612E-02	70	1.4299E-06	4.0342E-05
17	2.0542E 00	5.7954E 01	35	6.6698E-01	1.8817E 01	53	1.3233E-03	3.7335E-02	71	9.2709E-07	2.6155E-05
18	1.9930E 00	5.6228E 01	36	5.8284E-01	1.6443E 01	54	1.1604E-03	3.2738E-02	72	5.2838E-07	1.4907E-05

REAL POINT FLUXES FOR DIMENSION 1

K	RADIUS	GRP 1	GRP 2	GRP 3	GRP 4	GRP 5	GRP 6	GRP 7	GRP 8	GRP 9
1	0.0	1.2428E 14	2.6887E 14	2.6890E 14	2.4584E 14	2.1189E 14	6.7202E 13	3.8075E 14	4.0039E 14	1.2965E 14
2	1.000000E 01	1.2419E 14	2.6866E 14	2.6869E 14	2.4566E 14	2.1173E 14	6.7151E 13	3.8047E 14	4.0009E 14	1.2955E 14
3	2.000000E 01	1.2390E 14	2.6806E 14	2.6809E 14	2.4510E 14	2.1125E 14	6.6999E 13	3.7961E 14	3.9919E 14	1.2926E 14
4	3.000000E 01	1.2344E 14	2.6704E 14	2.6707E 14	2.4417E 14	2.1046E 14	6.6747E 13	3.7818E 14	3.9768E 14	1.2877E 14
5	4.000000E 01	1.2278E 14	2.6563E 14	2.6566E 14	2.4288E 14	2.0934E 14	6.6393E 13	3.7617E 14	3.9558E 14	1.2809E 14
6	5.000000E 01	1.2194E 14	2.6381E 14	2.6384E 14	2.4122E 14	2.0791E 14	6.5939E 13	3.7360E 14	3.9287E 14	1.2721E 14
7	6.000000E 01	1.2092E 14	2.6160E 14	2.6163E 14	2.3919E 14	2.0616E 14	6.5385E 13	3.7047E 14	3.8957E 14	1.2615E 14
8	7.000000E 01	1.1971E 14	2.5899E 14	2.5902E 14	2.3681E 14	2.0410E 14	6.4732E 13	3.6677E 14	3.8569E 14	1.2489E 14
9	8.000000E 01	1.1832E 14	2.5598E 14	2.5601E 14	2.3406E 14	2.0174E 14	6.3981E 13	3.6251E 14	3.8121E 14	1.2344E 14
10	9.000000E 01	1.1676E 14	2.5259E 14	2.5261E 14	2.3095E 14	1.9906E 14	6.3132E 13	3.5771E 14	3.7616E 14	1.2180E 14
11	1.000000E 02	1.1501E 14	2.4881E 14	2.4883E 14	2.2750E 14	1.9608E 14	6.2187E 13	3.5235E 14	3.7053E 14	1.1998E 14
12	1.100000E 02	1.1309E 14	2.4465E 14	2.4467E 14	2.2369E 14	1.9280E 14	6.1147E 13	3.4646E 14	3.6433E 14	1.1797E 14
13	1.200000E 02	1.1099E 14	2.4011E 14	2.4013E 14	2.1954E 14	1.8922E 14	6.0013E 13	3.4004E 14	3.5758E 14	1.1578E 14
14	1.300000E 02	1.0872E 14	2.3520E 14	2.3523E 14	2.1505E 14	1.8536E 14	5.8786E 13	3.3309E 14	3.5027E 14	1.1342E 14
15	1.400000E 02	1.0628E 14	2.2993E 14	2.2996E 14	2.1024E 14	1.8120E 14	5.7469E 13	3.2563E 14	3.4243E 14	1.1088E 14
16	1.500000E 02	1.0369E 14	2.2431E 14	2.2433E 14	2.0509E 14	1.7677E 14	5.6063E 13	3.1766E 14	3.3405E 14	1.0817E 14
17	1.600000E 02	1.0092E 14	2.1834E 14	2.1836E 14	1.9963E 14	1.7206E 14	5.4570E 13	3.0921E 14	3.2516E 14	1.0529E 14
18	1.700000E 02	9.8008E 13	2.1203E 14	2.1205E 14	1.9386E 14	1.6709E 14	5.2993E 13	3.0027E 14	3.1576E 14	1.0224E 14
19	1.800000E 02	9.4939E 13	2.0539E 14	2.0541E 14	1.8779E 14	1.6186E 14	5.1333E 13	2.9087E 14	3.0587E 14	9.9042E 13
20	1.900000E 02	9.1721E 13	1.9843E 14	1.9845E 14	1.8143E 14	1.5637E 14	4.9594E 13	2.8101E 14	2.9551E 14	9.5686E 13
21	2.000000E 02	8.8361E 13	1.9116E 14	1.9118E 14	1.7478E 14	1.5064E 14	4.7777E 13	2.7072E 14	2.8468E 14	9.2181E 13
22	2.100000E 02	8.4864E 13	1.8359E 14	1.8361E 14	1.6786E 14	1.4468E 14	4.5886E 13	2.6000E 14	2.7341E 14	8.8532E 13
23	2.200000E 02	8.1234E 13	1.7574E 14	1.7576E 14	1.6068E 14	1.3849E 14	4.3923E 13	2.4888E 14	2.6172E 14	8.4745E 13
24	2.300000E 02	7.7478E 13	1.6761E 14	1.6763E 14	1.5325E 14	1.3209E 14	4.1893E 13	2.3737E 14	2.4962E 14	8.0827E 13
25	2.400000E 02	7.3601E 13	1.5923E 14	1.5924E 14	1.4559E 14	1.2548E 14	3.9796E 13	2.2550E 14	2.3713E 14	7.6782E 13
26	2.500000E 02	6.9610E 13	1.5059E 14	1.5061E 14	1.3769E 14	1.1868E 14	3.7639E 13	2.1327E 14	2.2427E 14	7.2618E 13
27	2.600000E 02	6.5511E 13	1.4173E 14	1.4174E 14	1.2958E 14	1.1169E 14	3.5422E 13	2.0071E 14	2.1106E 14	6.8342E 13
28	2.700000E 02	6.1311E 13	1.3264E 14	1.3265E 14	1.2128E 14	1.0453E 14	3.3151E 13	1.8784E 14	1.9753E 14	6.3961E 13
29	2.800000E 02	5.7016E 13	1.2335E 14	1.2336E 14	1.1278E 14	9.7206E 13	3.0829E 13	1.7468E 14	1.8369E 14	5.9480E 13
30	2.900000E 02	5.2633E 13	1.1386E 14	1.1387E 14	1.0411E 14	8.9737E 13	2.8461E 13	1.6126E 14	1.6958E 14	5.4909E 13
31	3.000000E 02	4.8167E 13	1.0420E 14	1.0421E 14	9.5284E 13	8.2144E 13	2.6053E 13	1.4759E 14	1.5519E 14	5.0251E 13
32	3.100000E 02	4.3617E 13	9.4356E 13	9.4387E 13	8.6340E 13	7.4476E 13	2.3621E 13	1.3368E 14	1.4054E 14	4.5505E 13
33	3.200000E 02	3.8971E 13	8.4343E 13	8.4470E 13	7.7388E 13	6.6853E 13	2.1197E 13	1.1948E 14	1.2554E 14	4.0636E 13
34	3.300000E 02	3.4201E 13	7.4229E 13	7.4709E 13	6.8740E 13	5.9536E 13	1.8843E 13	1.0473E 14	1.0981E 14	3.5517E 13
35	3.400000E 02	2.9327E 13	6.4478E 13	6.5966E 13	6.1138E 13	5.2903E 13	1.6612E 13	8.8562E 13	9.2284E 13	2.9776E 13
36	3.500000E 02	2.4849E 13	5.7143E 13	6.0680E 13	5.5627E 13	4.6745E 13	1.4303E 13	6.8684E 13	7.0246E 13	2.2490E 13
37	3.600000E 02	2.3778E 13	5.9341E 13	6.3806E 13	5.0432E 13	3.7300E 13	1.0618E 13	4.1350E 13	3.7952E 13	1.1569E 13
38	3.600000E 02	2.3778E 13	5.9341E 13	6.3806E 13	5.0432E 13	3.7300E 13	1.0618E 13	4.1350E 13	3.7952E 13	1.1569E 13
39	3.650000E 02	2.3749E 13	6.2411E 13	6.5941E 13	4.5816E 13	3.1552E 13	8.5695E 12	3.0774E 13	2.4919E 13	7.1970E 12
40	3.700000E 02	2.1747E 13	6.0170E 13	6.4774E 13	4.2575E 13	2.7829E 13	7.3128E 12	2.4138E 13	1.8501E 13	5.1989E 12
41	3.750000E 02	1.9785E 13	5.5903E 13	6.0896E 13	3.9290E 13	2.5090E 13	6.5042E 12	2.0932E 13	1.5844E 13	4.4236E 12
42	3.800000E 02	1.8282E 13	5.0690E 13	5.4775E 13	3.5543E 13	2.2903E 13	5.9914E 12	2.0692E 13	1.6176E 13	4.5879E 12
43	3.850000E 02	1.6650E 13	4.3721E 13	4.6447E 13	3.1496E 13	2.1337E 13	5.7421E 12	2.3436E 13	2.0173E 13	5.9811E 12
44	3.900000E 02	1.2746E 13	3.2404E 13	3.5900E 13	2.7973E 13	2.0952E 13	5.7536E 12	2.8948E 13	3.0866E 13	9.8794E 12
45	3.900000E 02	1.2746E 13	3.2404E 13	3.5900E 13	2.7973E 13	2.0952E 13	5.7536E 12	2.8948E 13	3.0866E 13	9.8794E 12
46	3.950000E 02	7.4872E 12	2.0806E 13	2.4075E 13	2.2828E 13	1.9602E 13	5.4888E 12	3.6427E 13	4.6577E 13	1.5900E 13
47	4.000000E 02	4.6456E 12	1.3497E 13	1.6047E 13	1.7114E 13	1.6321E 13	4.7391E 12	4.1393E 13	5.5510E 13	1.9348E 13
48	4.050000E 02	3.0946E 12	8.5990E 12	1.0772E 13	1.2338E 13	1.2726E 13	3.8380E 12	4.3472E 13	5.9695E 13	2.1013E 13
49	4.100000E 02	2.2289E 12	6.2570E 12	7.3810E 12	8.7811E 12	9.5718E 12	2.9976E 12	4.3366E 13	6.0488E 13	2.1421E 13
50	4.150000E 02	1.7260E 12	4.5786E 12	5.2257E 12	6.2857E 12	7.0893E 12	2.3053E 12	4.1817E 13	5.8986E 13	2.0977E 13
51	4.200000E 02	1.4146E 12	3.5300E 12	3.8547E 12	4.5898E 12	5.2532E 12	1.7732E 12	3.9402E 13	5.6034E 13	1.9987E 13

52	4.2500C0E 02	1.2049E 12	2.8493E 12	2.9698E 12	3.4510E 12	3.9426E 12	1.3796E 12	3.6522E 13	5.2243E 13	1.8676E 13
53	4.300000E 02	1.0498E 12	2.3817E 12	2.3809E 12	2.6825E 12	3.0220E 12	1.0931E 12	3.3436E 13	4.8027E 13	1.7195E 13
54	4.3500C0E 02	9.2499E 11	2.0378E 12	1.9703E 12	2.1524E 12	2.3749E 12	8.8395E 11	3.0303E 13	4.3653E 13	1.5646E 13
55	4.400000E 02	8.1770E 11	1.7666E 12	1.6667E 12	1.7729E 12	1.9124E 12	7.2851E 11	2.7212E 13	3.9279E 13	1.4089E 13
56	4.450000E 02	7.2136E 11	1.5392E 12	1.4279E 12	1.4876E 12	1.5717E 12	6.0929E 11	2.4213E 13	3.4997E 13	1.2560E 13
57	4.500000E 02	6.3248E 11	1.3393E 12	1.2289E 12	1.2612E 12	1.3101E 12	5.1420E 11	2.1326E 13	3.0851E 13	1.1075E 13
58	4.5500C0E 02	5.4912E 11	1.1578E 12	1.0554E 12	1.0724E 12	1.0999E 12	4.3517E 11	1.8553E 13	2.6855E 13	9.6430E 12
59	4.600C0C0E 02	4.7012E 11	9.8953E 11	8.9915E 11	9.0846E 11	9.2363E 11	3.6698E 11	1.5890E 13	2.3008E 13	8.2625E 12
60	4.650000E 02	3.9481E 11	8.3162E 11	7.5578E 11	7.6200E 11	7.7052E 11	3.0629E 11	1.3325E 13	1.9296E 13	6.9298E 12
61	4.7000C0E 02	3.2280E 11	6.8289E 11	6.2328E 11	6.2915E 11	6.3389E 11	2.5097E 11	1.0844E 13	1.5700E 13	5.6380E 12
62	4.75C0C0E 02	2.5405E 11	5.4350E 11	5.0155E 11	5.0804E 11	5.0926E 11	1.9955E 11	8.4291E 12	1.2196E 13	4.3780E 12
63	4.8000C0E 02	1.8903E 11	4.1527E 11	3.9211E 11	3.9760E 11	3.9252E 11	1.5086E 11	6.0668E 12	8.7575E 12	3.1374E 12
64	4.8500C0E 02	1.2909E 11	3.0233E 11	2.9814E 11	2.9579E 11	2.7774E 11	1.0430E 11	3.7560E 12	5.3488E 12	1.8932E 12
65	4.9000C0E 02	7.7328E 10	2.1235E 11	2.2406E 11	1.9603E 11	1.5448E 11	6.2576E 10	1.5625E 12	1.9059E 12	5.8079E 11
66	4.90C0C0E 02	7.7328E 10	2.1235E 11	2.2406E 11	1.9602E 11	1.5448E 11	6.2576E 10	1.5625E 12	1.9059E 12	5.8079E 11
67	4.92C000E 02	5.5044E 10	1.7305E 11	1.5241E 11	1.0924E 11	6.1636E 10	2.9878E 10	4.3834E 11	4.1116E 11	9.9091E 10
68	4.9400C0E 02	3.8709E 10	1.3462E 11	1.0337E 11	6.2108E 10	2.6030E 10	1.2663E 10	1.1776E 11	9.2743E 10	1.9487E 10
69	4.9600C0E 02	2.6558E 10	9.7589E 10	6.6634E 10	3.4786E 10	1.1492E 10	5.0779E 09	3.1082E 10	2.1796E 10	4.2378E 09
70	4.980000E 02	1.7277E 10	6.1832E 10	3.5946E 10	1.7123E 10	4.8212E 09	1.8840E 09	8.0143E 09	5.2011E 09	9.6732E 08
71	5.0000C0E 02	9.8640E 09	2.6804E 10	6.9053E 09	3.6976E 09	9.5938E 08	3.7399E 08	1.3879E 09	8.5762E 08	1.5102E 08

REAL POINT FLUXES FOR DIMENSION 2

K	RADIUS	GRP 1	GRP 2	GRP 3	GRP 4	GRP 5	GRP 6	GRP 7	GRP 8	GRP 9
1	0.0	1.2428E 14	2.6887E 14	2.6890E 14	2.4584E 14	2.1189E 14	6.7202E 13	3.8075E 14	4.0039E 14	1.2965E 14
2	5.000000E 00	1.2418E 14	2.6865E 14	2.6868E 14	2.4564E 14	2.1172E 14	6.7148E 13	3.8045E 14	4.0007E 14	1.2954E 14
3	1.000000E 01	1.2388E 14	2.6799E 14	2.6803E 14	2.4504E 14	2.1121E 14	6.6984E 13	3.7952E 14	3.9910E 14	1.2923E 14
4	1.500000E 01	1.2337E 14	2.6691E 14	2.6694E 14	2.4405E 14	2.1035E 14	6.6712E 13	3.7798E 14	3.9748E 14	1.2870E 14
5	2.000000E 01	1.2267E 14	2.6539E 14	2.6542E 14	2.4266E 14	2.0915E 14	6.6333E 13	3.7583E 14	3.9522E 14	1.2797E 14
6	2.500000E 01	1.2177E 14	2.6344E 14	2.6347E 14	2.4088E 14	2.0762E 14	6.5846E 13	3.7307E 14	3.9232E 14	1.2703E 14
7	3.000000E 01	1.2068E 14	2.6107E 14	2.6110E 14	2.3872E 14	2.0575E 14	6.5254E 13	3.6972E 14	3.8879E 14	1.2589E 14
8	3.500000E 01	1.1939E 14	2.5829E 14	2.5832E 14	2.3617E 14	2.0356E 14	6.4558E 13	3.6577E 14	3.8464E 14	1.2455E 14
9	4.000000E 01	1.1791E 14	2.5509E 14	2.5512E 14	2.3325E 14	2.0104E 14	6.3759E 13	3.6125E 14	3.7988E 14	1.2301E 14
10	4.500000E 01	1.1625E 14	2.5149E 14	2.5152E 14	2.2995E 14	1.9820E 14	6.2860E 13	3.5615E 14	3.7452E 14	1.2127E 14
11	5.000000E 01	1.1440E 14	2.4750E 14	2.4753E 14	2.2630E 14	1.9505E 14	6.1862E 13	3.5050E 14	3.6858E 14	1.1935E 14
12	5.500000E 01	1.1238E 14	2.4312E 14	2.4315E 14	2.2230E 14	1.9160E 14	6.0768E 13	3.4430E 14	3.6206E 14	1.1724E 14
13	6.000000E 01	1.1018E 14	2.3837E 14	2.3840E 14	2.1796E 14	1.8786E 14	5.9580E 13	3.3757E 14	3.5498E 14	1.1495E 14
14	6.500000E 01	1.0782E 14	2.3326E 14	2.3329E 14	2.1328E 14	1.8383E 14	5.8303E 13	3.3033E 14	3.4737E 14	1.1248E 14
15	7.000000E 01	1.0530E 14	2.2780E 14	2.2782E 14	2.0829E 14	1.7953E 14	5.6937E 13	3.2260E 14	3.3924E 14	1.0985E 14
16	7.500000E 01	1.0262E 14	2.2200E 14	2.2202E 14	2.0299E 14	1.7496E 14	5.5488E 13	3.1439E 14	3.3060E 14	1.0705E 14
17	8.000000E 01	9.9787E 13	2.1588E 14	2.1590E 14	1.9739E 14	1.7013E 14	5.3958E 13	3.0572E 14	3.2149E 14	1.0410E 14
18	8.500000E 01	9.6815E 13	2.0945E 14	2.0947E 14	1.9151E 14	1.6507E 14	5.2351E 13	2.9661E 14	3.1191E 14	1.0100E 14
19	9.000000E 01	9.3708E 13	2.0273E 14	2.0275E 14	1.8537E 14	1.5977E 14	5.0671E 13	2.8709E 14	3.0190E 14	9.7756E 13
20	9.500000E 01	9.0473E 13	1.9573E 14	1.9575E 14	1.7897E 14	1.5425E 14	4.8921E 13	2.7718E 14	2.9148E 14	9.4381E 13
21	1.000000E 02	8.7118E 13	1.8847E 14	1.8849E 14	1.7233E 14	1.4853E 14	4.7107E 13	2.6690E 14	2.8067E 14	9.0882E 13
22	1.050000E 02	8.3651E 13	1.8097E 14	1.8099E 14	1.6547E 14	1.4262E 14	4.5232E 13	2.5628E 14	2.6950E 14	8.7265E 13
23	1.100000E 02	8.0080E 13	1.7324E 14	1.7326E 14	1.5841E 14	1.3653E 14	4.3301E 13	2.4534E 14	2.5800E 14	8.3540E 13
24	1.150000E 02	7.6414E 13	1.6531E 14	1.6533E 14	1.5116E 14	1.3028E 14	4.1319E 13	2.3411E 14	2.4618E 14	7.9715E 13
25	1.200000E 02	7.2661E 13	1.5719E 14	1.5721E 14	1.4373E 14	1.2388E 14	3.9290E 13	2.2261E 14	2.3409E 14	7.5800E 13
26	1.250000E 02	6.8830E 13	1.4891E 14	1.4892E 14	1.3615E 14	1.1735E 14	3.7218E 13	2.1088E 14	2.2175E 14	7.1804E 13
27	1.300000E 02	6.4931E 13	1.4047E 14	1.4049E 14	1.2844E 14	1.1070E 14	3.5110E 13	1.9893E 14	2.0919E 14	6.7737E 13
28	1.350000E 02	6.0973E 13	1.3191E 14	1.3192E 14	1.2061E 14	1.0395E 14	3.2969E 13	1.8680E 14	1.9644E 14	6.3607E 13
29	1.400000E 02	5.6964E 13	1.2323E 14	1.2325E 14	1.1268E 14	9.7116E 13	3.0801E 13	1.7452E 14	1.8352E 14	5.9426E 13
30	1.450000E 02	5.2914E 13	1.1447E 14	1.1448E 14	1.0466E 14	9.0209E 13	2.8610E 13	1.6211E 14	1.7048E 14	5.5202E 13
31	1.500000E 02	4.8833E 13	1.0564E 14	1.0565E 14	9.6585E 13	8.3247E 13	2.6403E 13	1.4961E 14	1.5733E 14	5.0946E 13
32	1.550000E 02	4.4729E 13	9.6760E 13	9.6761E 13	8.8461E 13	7.6248E 13	2.4184E 13	1.3705E 14	1.4412E 14	4.6668E 13
33	1.600000E 02	4.0612E 13	8.7846E 13	8.7843E 13	8.0310E 13	6.9230E 13	2.1959E 13	1.2445E 14	1.3087E 14	4.2378E 13
34	1.650000E 02	3.6489E 13	7.8917E 13	7.8911E 13	7.2153E 13	6.2213E 13	1.9735E 13	1.1185E 14	1.1762E 14	3.8086E 13
35	1.700000E 02	3.2365E 13	6.9985E 13	6.9986E 13	6.4014E 13	5.5222E 13	1.7519E 13	9.9273E 13	1.0439E 14	3.3802E 13
36	1.750000E 02	2.8242E 13	6.1061E 13	6.1091E 13	5.5925E 13	4.8288E 13	1.5321E 13	8.6751E 13	9.1210E 13	2.9532E 13
37	1.800000E 02	2.4116E 13	5.2152E 13	5.2264E 13	4.7933E 13	4.1451E 13	1.3153E 13	7.4303E 13	7.8090E 13	2.5279E 13
38	1.850000E 02	1.9970E 13	4.3271E 13	4.3574E 13	4.0105E 13	3.4760E 13	1.1027E 13	6.1941E 13	6.5024E 13	2.1037E 13
39	1.900000E 02	1.5766E 13	3.4453E 13	3.5153E 13	3.2529E 13	2.8264E 13	8.9597E 12	4.9666E 13	5.1967E 13	1.6779E 13
40	1.950000E 02	1.1437E 13	2.5809E 13	2.7250E 13	2.5301E 13	2.1996E 13	6.9707E 12	3.7511E 13	3.8785E 13	1.2422E 13
41	2.000000E 02	6.8628E 12	1.7645E 13	2.0311E 13	1.8427E 13	1.5941E 13	5.1117E 12	2.5744E 13	2.5095E 13	7.6957E 12
42	2.000000E 02	6.6628E 12	1.7645E 13	2.0311E 13	1.8427E 13	1.5941E 13	5.1117E 12	2.5744E 13	2.5095E 13	7.6957E 12
43	2.003333E 02	6.5116E 12	1.7107E 13	1.9545E 13	1.7692E 13	1.5284E 13	4.9403E 12	2.4642E 13	2.3594E 13	7.1420E 12
44	2.006667E 02	6.1740E 12	1.6585E 13	1.8807E 13	1.6982E 13	1.4690E 13	4.7854E 12	2.3728E 13	2.2342E 13	6.7249E 12
45	2.010000E 02	5.8491E 12	1.6078E 13	1.8095E 13	1.6295E 13	1.4156E 13	4.6470E 12	2.2999E 13	2.1322E 13	6.4346E 12
46	2.010000E 02	5.8491E 12	1.6078E 13	1.8095E 13	1.6295E 13	1.4156E 13	4.6470E 12	2.2999E 13	2.1322E 13	6.4346E 12
47	2.020000E 02	5.0235E 12	1.4685E 13	1.7187E 13	1.5225E 13	1.3423E 13	4.4361E 12	2.1983E 13	1.9986E 13	6.0903E 12
48	2.030000E 02	4.3147E 12	1.3370E 13	1.6273E 13	1.4230E 13	1.2708E 13	4.2248E 12	2.0941E 13	1.8755E 13	5.7509E 12
49	2.040000E 02	3.7063E 12	1.2140E 13	1.5364E 13	1.3302E 13	1.2012E 13	4.0144E 12	1.9888E 13	1.7606E 13	5.4192E 12
50	2.050000E 02	3.1840E 12	1.0996E 13	1.4467E 13	1.2434E 13	1.1338E 13	3.8059E 12	1.8833E 13	1.6522E 13	5.0968E 12
51	2.060000E 02	2.7356E 12	9.9380E 12	1.3590E 13	1.1620E 13	1.0684E 13	3.6002E 12	1.7783E 13	1.5490E 13	4.7838E 12

52	2.070000E 02	2.3507E 12	8.9648E 12	1.2739E 13	1.0856E 13	1.0052E 13	3.3978E 12	1.6744E 13	1.4501E 13	4.4801E 12
53	2.080000E 02	2.0204E 12	8.0734E 12	1.1920E 13	1.0138E 13	9.4419E 12	3.1993E 12	1.5718E 13	1.3548E 13	4.1852E 12
54	2.090000E 02	1.7369E 12	7.2600E 12	1.1136E 13	9.4626E 12	8.8526E 12	3.0048E 12	1.4706E 13	1.2625E 13	3.8983E 12
55	2.100000E 02	1.4936E 12	6.5206E 12	1.0389E 13	8.8268E 12	8.2838E 12	2.8146E 12	1.3709E 13	1.1728E 13	3.6186E 12
56	2.110000E 02	1.2850E 12	5.8507E 12	9.6819E 12	8.2280E 12	7.7347E 12	2.6288E 12	1.2729E 13	1.0854E 13	3.3453E 12
57	2.120000E 02	1.1060E 12	5.2457E 12	9.0163E 12	7.6637E 12	7.2042E 12	2.4473E 12	1.1764E 13	9.9990E 12	3.0774E 12
58	2.130000E 02	9.5258E 11	4.7010E 12	8.3928E 12	7.1316E 12	6.6911E 12	2.2700E 12	1.0814E 13	9.1609E 12	2.8142E 12
59	2.140000E 02	8.2117E 11	4.2120E 12	7.8118E 12	6.6295E 12	6.1940E 12	2.0969E 12	9.8789E 12	8.3373E 12	2.5546E 12
60	2.150000E 02	7.0871E 11	3.7746E 12	7.2734E 12	6.1551E 12	5.7115E 12	1.9276E 12	8.9572E 12	7.5260E 12	2.2977E 12
61	2.160000E 02	6.1258E 11	3.3846E 12	6.7772E 12	5.7061E 12	5.2419E 12	1.7620E 12	8.0481E 12	6.7251E 12	2.0422E 12
62	2.170000E 02	5.3057E 11	3.0380E 12	6.3227E 12	5.2803E 12	4.7835E 12	1.5998E 12	7.1508E 12	5.9330E 12	1.7870E 12
63	2.180000E 02	4.6076E 11	2.7314E 12	5.9093E 12	4.8752E 12	4.3342E 12	1.4407E 12	6.2642E 12	5.1478E 12	1.5305E 12
64	2.190000E 02	4.0155E 11	2.4614E 12	5.5361E 12	4.4881E 12	3.8922E 12	1.2847E 12	5.3876E 12	4.3682E 12	1.2707E 12
65	2.200000E 02	3.5156E 11	2.2250E 12	5.2024E 12	4.1162E 12	3.4552E 12	1.1314E 12	4.5201E 12	3.5932E 12	1.0051E 12
66	2.210000E 02	3.0965E 11	2.0194E 12	4.9072E 12	3.7565E 12	3.0210E 12	9.8085E 11	3.6613E 12	2.8220E 12	7.3069E 11
67	2.210000E 02	3.0965E 11	2.0194E 12	4.9075E 12	3.7566E 12	3.0210E 12	9.8086E 11	3.6613E 12	2.8221E 12	7.3069E 11
68	2.230000E 02	2.1946E 11	1.5647E 12	2.9643E 12	2.0777E 12	1.1953E 12	3.9384E 11	1.0106E 12	6.8334E 11	1.4348E 11
69	2.250000E 02	1.5368E 11	1.1701E 12	1.7915E 12	1.1536E 12	4.9842E 11	1.5753E 11	2.8398E 11	1.7297E 11	3.2623E 10
70	2.270000E 02	1.0502E 11	8.2294E 11	1.0449E 12	6.2469E 11	2.1600E 11	6.3116E 10	8.2460E 10	4.5994E 10	8.1801E 09
71	2.290000E 02	6.8089E 10	5.1017E 11	5.2287E 11	2.9777E 11	8.8791E 10	2.3934E 10	2.4133E 10	1.2495E 10	2.1408E 09
72	2.310000E 02	3.8806E 10	2.1904E 11	9.7401E 10	6.3713E 10	1.7538E 10	4.7743E 09	4.3679E 09	2.1520E 09	3.4942E 08

THICKNESSES AND OTHER REGION INFORMATION

DIMENSION 1

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	3.600000E 02	36	1	1	0.0	3.600000E 02
2	PLENA	3.000000E 01	6	2	1	3.600000E 02	3.900000E 02
3	REFLECT	1.000000E 02	20	3	1	3.900000E 02	4.900000E 02
4	VESSEL	1.000000E 01	5	1	0	4.900000E 02	5.000000E 02

DIMENSION 2

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	2.000000E 02	40	1	1	0.0	2.000000E 02
2	WALL	1.000000E 00	3	1	1	2.000000E 02	2.010000E 02
3	BLANKET	2.000000E 01	20	2	1	2.010000E 02	2.210000E 02
4	VESSEL	1.000000E 01	5	1	0	2.210000E 02	2.310000E 02

SUPER REGION VOLUMES AND MATERIAL VOLUMES IN CUBIC CENTIMETERS

```
TOTAL
  SUPER REGION  1,   CORE(1)     9.047784E 07
  SUPER REGION  2,   WALL        1.234558E 06
  SUPER REGION  3,   BLANKET     2.598472E 07
  SUPER REGION  4,   PLENA       7.535821E 06
  SUPER REGION  5,   AX REFL     2.513274E 07
  SUPER REGION  6,   VESSEL      1.726877E 07

MATERIAL  1,  FUELSALT
  SUPER REGION  1,   CORE(1)     1.266690E 07
  SUPER REGION  2,   WALL        0.0
  SUPER REGION  3,   BLANKET     0.0
  SUPER REGION  4,   PLENA       3.769910E 06
  SUPER REGION  5,   AX REFL     2.513273E 05
  SUPER REGION  6,   VESSEL      0.0
  INTERNAL                       1.668813E 07
  EXTERNAL                       1.840800E 07
  TOTAL                          3.509613E 07

MATERIAL  2,  FERTILE
  SUPER REGION  1,   CORE(1)     0.0
  SUPER REGION  2,   WALL        0.0
  SUPER REGION  3,   BLANKET     1.299236E 07
  SUPER REGION  4,   PLENA       0.0
  SUPER REGION  5,   AX REFL     0.0
  SUPER REGION  6,   VESSEL      0.0
  INTERNAL                       1.299236E 07
  EXTERNAL                       1.840800E 07
  TOTAL                          3.140035E 07

MATERIAL  3,  INCR
  SUPER REGION  1,   CORE(1)     0.0
  SUPER REGION  2,   WALL        3.703675E 05
  SUPER REGION  3,   BLANKET     0.0
  SUPER REGION  4,   PLENA       0.0
  SUPER REGION  5,   AX REFL     0.0
  SUPER REGION  6,   VESSEL      1.726877E 07
  INTERNAL                       1.763910E 07
  EXTERNAL                       0.0
  TOTAL                          1.763910E 07

MATERIAL  4,  GRAPHITE
  SUPER REGION  1,   CORE(1)     7.781093E 07
  SUPER REGION  2,   WALL        8.641512E 05
  SUPER REGION  3,   BLANKET     1.299236E 07
  SUPER REGION  4,   PLENA       3.769910E 06
  SUPER REGION  5,   AX REFL     2.488139E 07
  SUPER REGION  6,   VESSEL      0.0
  INTERNAL                       1.203187E 08
  EXTERNAL                       0.0
  TOTAL                          1.203187E 08
```

PROCESSING INFORMATION

MATERIAL 1, FUELSALT

TIME NO.	TIME	UNITS	PROC COST VCL BASIS
1	25.000	DAYS	1200.000
2	50.000	SECS	0.0
3	600.000	DAYS	0.0
4	50.000	SECS	0.0
5	200.000	DAYS	0.0
6	6.000	YEAR	0.0
7	16.000	YEAR	0.0
8	10.000	DAYS	600.000
9	300.000	DAYS	0.0

	PROCESSING GROUP	TIMES SPECIFIED	RELATIVE REMOVAL
1	RARE EARTH	1 0 0 0 0 0 0 0 0 0	1.00000E 00
2	DEP & SMOKE	0 2 0 0 0 0 0 0 0 0	4.32000E 04
3	EXTRACT HF	0 0 3 0 0 0 0 0 0 0	4.16667E-02
4	GAS STRIP	0 0 0 4 0 0 0 0 0 0	4.32000E 04
5	FLUORINATION	0 0 0 0 5 0 0 0 9 0	2.08333E-01
6	DISCARD	0 0 0 0 0 6 0 0 0 0	1.14155E-02
7	AVE/LIFETIME	0 0 0 0 0 0 7 0 0 0	4.28082E-03
8	PA-233	0 0 0 0 0 0 0 8 0 0	2.50000E 00

MATERIAL 2, FERTILE

TIME NO.	TIME	UNITS	PROC COST VCL BASIS
1	20.000	DAYS	400.000
2	50.000	SECS	0.0
3	16.000	YEAR	0.0
4	50.000	SECS	0.0

	PROCESSING GROUP	TIMES SPECIFIED	RELATIVE REMOVAL
1	RECYCLE	0 0 3 0 0 0 0 0 0 0	3.42466E-03
2	DEP & SMOKE	0 2 0 0 0 0 0 0 0 0	3.45600E 04
3	RECYCLE	0 0 3 0 0 0 0 0 0 0	3.42466E-03
4	GAS STRIP	0 0 0 4 0 0 0 0 0 0	3.45600E 04
5	RECYCLE	0 0 3 0 0 0 0 0 0 0	3.42466E-03
6	RECYCLE	0 0 3 0 0 0 0 0 0 0	3.42466E-03
7	RECYCLE	0 0 3 0 0 0 0 0 0 0	3.42466E-03
8	PA-233	1 0 0 0 0 0 0 0 0 0	1.00000E 00

NEUTRON BALANCE BY GROUP

GROUP	DIMENSION 1	DIMENSION 2
1	-4.5020749E-07	-5.6592603E-07
2	1.1324883E-06	4.7683716E-06
3	-1.3113022E-06	7.1525574E-06
4	-2.0861626E-06	2.4437904E-06
5	-1.5497208E-06	2.2649765E-06
6	2.0265579E-06	-1.3709068E-06
7	-1.9073486E-06	8.5830688E-06
8	2.8610229E-06	-4.7683716E-06
9	-1.7166138E-05	-5.7220459E-06

DIMENSICN 1

REGION TOTALS	ABSORPTICNS	NEUTRONS PRDD	FISSIONS	PROD/ABS
1	5.26389E-C1	5.52164E-01	2.21195E-01	1.04896
2	2.94032E-02	2.78978E-C2	1.11916E-C2	0.94880
3	2.70991E-C3	2.06569E-03	8.26928E-C4	0.76227
4	7.48606E-04	7.38878E-09	3.69439E-C9	0.00001
TOTAL	5.59251E-C1	5.82127E-C1	2.33213E-C1	

DIMENSICN 2

REGION TOTALS	ABSDRPTICNS	NEUTRONS PROD	FISSIONS	PROD/ABS
1	3.98190E-C1	4.17688E-01	1.67324E-01	1.04897
2	1.15701E-C2	2.10334E-07	1.05167E-07	0.00002
3	1.83277E-C2	1.98114E-04	9.11448E-05	0.01081
4	1.17594E-02	1.78197E-07	8.90986E-C8	0.00002
TOTAL	4.39848E-C1	4.17887E-01	1.67416E-01	
2 D SUM	9.99099E-C1	1.00001E C0	4.00629E-C1	

FNORM	ALPA	BETA	TLEAK	AVGNU
1.3625526E 00	2.3922806E 00	1.0000114E C0	9.2064403E-04	2.4961071E 00

HOMOGENIZED REGION DENSITIES FOR DIMENSION 1

REGION 1 DENSITIES

NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY
93	7.5020E-06	94	3.4136E-06	95	8.5933E-07	96	1.0586E-06	97	1.3642E-07	98	6.4319E-07	79	8.9776E-09
80	5.1296E-09	81	3.0961E-09	82	3.4713E-09	4	9.9610E-04	70	9.9610E-04	7	2.8882E-03	9	6.6654E-03
90	4.3316E-04	6	2.4797E-08	91	1.8603E-07	99	1.4000E-09	33	4.0135E-05	77	1.5333E-05	54	1.1592E-11
49	4.3345E-10	51	1.2121E-09	12	8.1958E-02								

REGION 2 DENSITIES

NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY
93	2.6793E-05	94	1.2191E-05	95	3.0690E-06	96	3.7807E-06	97	4.8721E-07	98	2.2971E-06	79	3.2063E-08
80	1.8320E-08	81	1.1057E-08	82	1.2397E-08	4	3.5575E-03	70	3.5575E-03	7	1.0315E-02	9	2.3805E-02
90	1.5470E-03	6	8.8559E-08	91	6.6440E-07	99	5.0000E-09	33	1.4334E-04	77	5.4760E-05	54	4.1399E-11
49	1.5480E-09	51	4.3291E-09	12	4.7650E-02								

REGION 3 DENSITIES

NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY
93	5.3586E-07	94	2.4383E-07	95	6.1381E-08	96	7.5614E-08	97	9.7441E-09	98	4.5942E-08	79	6.4126E-10
80	3.6640E-10	81	2.2115E-10	82	2.4795E-10	4	7.1150E-05	70	7.1150E-05	7	2.0630E-04	9	4.7610E-04
90	3.0940E-05	6	1.7712E-09	91	1.3288E-08	99	1.0000E-10	33	2.8668E-06	77	1.0952E-06	54	8.2799E-13
49	3.0961E-11	51	8.6582E-11	12	9.4347E-02								

REGION 4 DENSITIES

NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY
24	7.1190E-03	26	4.7430E-03	28	6.4000E-02	42	9.3750E-03						

HOMOGENIZED REGION DENSITIES FOR DIMENSION 2

REGION 1 DENSITIES

NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY
93	7.5020E-06	94	3.4136E-06	95	8.5933E-07	96	1.0586E-06	97	1.3642E-07	98	6.4319E-07	79	8.9776E-09
80	5.1296E-05	81	3.0961E-09	82	3.4713E-09	4	9.9610E-04	70	9.9610E-04	7	2.8882E-03	9	6.6654E-03
90	4.3316E-04	6	2.4797E-08	91	1.8603E-07	99	1.4000E-09	33	4.0135E-05	77	1.5333E-05	54	1.1592E-11
49	4.3345E-10	51	1.2121E-09	12	8.1958E-02								

REGION 2 DENSITIES

NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY
24	2.1357E-03	26	1.4229E-03	28	1.9200E-02	42	2.8125E-03	12	6.6710E-02				

REGION 3 DENSITIES

NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY
93	2.7374E-08	94	6.6578E-11	95	5.1872E-14	96	7.5576E-15	97	4.2017E-16	4	3.5575E-03	70	3.5575E-03
7	1.0315E-02	9	2.3805E-02	90	1.5470E-03	6	1.2400E-07	91	5.4286E-08	99	5.0000E-09	33	1.9755E-06
77	6.8000E-05	49	5.0609E-12	51	2.5341E-11	12	4.7650E-02						

REGION 4 DENSITIES

NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY	NUCLIDE	DENSITY
24	7.1190E-03	26	4.7430E-03	28	6.4000E-02	42	9.3750E-03						

**********STORE RHOT,FR,FLX**********

Table 8.3. Short Output for the Base Case

```
 ROD-18  P X4916  X1306  BLANKETED MSBR 1000 MWE  TF  S  10TH23BE      Q
         SINGLE-FLUID CORE, BARREN BLANKET  H=10M OP4 COR R,VF  BL R,CT
MICROSCOPIC CROSS-SECTIONS IN SET NO.    1  ORDER NO. CN TAPE    3
MSR  1  SET  3  10TH23BE (900K)  VF=.12  C/TH=226
MICROSCOPIC CROSS-SECTIONS IN SET NO.    2  ORDER NO. CN TAPE    5
MSR  1  SET  5  14TH17BE (900K)  VF=.20  C/TH= 91
MICROSCOPIC CROSS-SECTIONS IN SET NO.    3  ORDER NO. CN TAPE    9
MSR  1  SET  9  10TH23BE (900K)  VF=.01  C/TH=2517
THE READING OF THE CROSS-SECTION TAPE TOOK    3.0300  SEC
THE PRELIMINARY SETUP TOOK   18.5600  SEC
ITERATION LIMIT EXCEEDED IN DIFFUSION CALC.
ERC NUCLIDE   3 IN MATERIAL  1 HAS CONC. OPT. 2
NON CONVERGENCE  40  ITERATIONS
```

RAPID SEPTEMBER 1967 ROD-18 F X4916 X1306 BLANKETED MSBR 1000 MWE TF 9 10TH23BE Q

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	5.0000E-05
RESONANCE INTEGRAL FACTOR	1.8944E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.0863E 00
CONCENTRATION DAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR	1.01000

MATERIAL	VOLUME	TIME S	TIME P	TIME R	OPTION
1	1.2393E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	1.1088E 03	2.0000E 01	2.5000E-01	0.0	0
3	6.2285E 02	0.0	0.0	0.0	0
4	4.2485E 03	0.0	0.0	0.0	0

BO= 1.000019E 00 BS= 9.999524E-01 F1= 9.997725E-01 ETA= 2.235180E 00
IF= 9.295564E 02 PL= 7.769279E-04 Y = 6.883615E-01 FCC= 6.554781E-01
BR= 1.008421E 00 NO OF ITERS= 10 KI= 9.999943E-01 KC = 9.999991E-01

/**********RATES,KG PER DAY**********//*******FUEL CYCLE COSTS*******/

NUCLIDE		ABS	CAP	FIS	TOT INV,KG	FEED	PROCESS	LOSS	PRODUCT	INV.	REPL.	PROC	CREDIT
1	TH-232	0.9147	0.9124	0.0022	7.925E 04	2.147E 01	1.910E 01	1.910E 01	0.0	0.0283	0.0170	0.2170	0.0
2	PA-233	0.0058	0.0058	0.0000	9.331E 01	0.0	1.871E 00	1.805E-06	0.0	0.0228	0.0	0.0	0.0
3	U-233	0.8991	0.0940	0.8050	7.491E 02	0.0	7.280E 01	7.277E-05	1.922E-02	0.1832	0.0	0.0	0.0104
4	U-234	0.0964	0.0960	0.0004	3.411E 02	0.0	3.327E 01	3.327E-05	8.790E-03	0.0	0.0	0.0	0.0
5	U-235	0.0952	0.0169	0.0783	8.594E 01	0.0	8.384E 00	8.384E-06	2.215E-03	0.0181	0.0	0.0	0.0010
6	U-236	0.0101	0.0101	0.0000	1.041E 02	0.0	1.783E-02	1.783E-02	0.0	0.0	0.0	0.0	0.0
7	NP-237	0.0092	0.0092	0.0000	1.342E 01	0.0	2.298E-03	2.298E-03	0.0	0.0	0.0	0.0	0.0
8	U-238	0.0051	0.0051	0.0000	6.372E 01	0.0	1.091E-02	1.091E-02	0.0	0.0	0.0	0.1062	0.0
9	PU-239	0.0046	0.0017	0.0028	8.881E-01	0.0	1.480E-03	1.480E-03	0.0	0.0002	0.0	0.0	0.0
10	PU-240	0.0014	0.0014	0.0000	5.117E-01	0.0	8.525E-04	8.525E-04	0.0	0.0	0.0	0.0	0.0
11	PU-241	0.0012	0.0003	0.0009	3.088E-01	0.0	5.145E-04	5.145E-04	0.0	0.0001	0.0	0.0	0.0
12	PU-242	0.0001	0.0001	0.0000	3.490E-01	0.0	5.814E-04	5.814E-04	0.0	0.0	0.0	0.0	0.0
13	BE-9	0.0074	0.0017	0.0057	7.080E 03	1.707E 00	1.706E 00	1.706E 00	0.0	0.0115	0.0061	0.0	0.0
14	BE-9 NA	0.0020	0.0020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	LI-7	0.0193	0.0193	0.0	1.594E 04	3.844E 00	3.842E 00	3.842E 00	0.0	0.0368	0.0196	0.0	0.0
16	LI-6	0.0043	0.0043	0.0000	1.393E-01	1.647E-04	2.817E-05	2.817E-05	0.0	0.0	0.0	0.0	0.0
17	F	0.0218	0.0218	0.0	0.0	0.0	2.407E 01	2.407E 01	0.0	0.0	0.0	0.0	0.0
18	FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	0.0021	0.0021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	0.0028	0.0028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	GRAPHITE	0.0596	0.0596	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	0.0142	0.0142	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	CHROME	0.0027	0.0027	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	IRON	0.0015	0.0015	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	NICKEL	0.0365	0.0365	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	MOLY	0.0131	0.0131	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		2.2352								0.3009	0.0428	0.3233	0.0115

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	3.92146E-01	4.18268E 04	4.18315E 04	2.13712E 01	1.90990E 01	0.0
2	PA-233	1.32880E-06	1.32925E-06	2.58123E-03	1.80472E 01	8.93881E 01	0.0	1.80472E 00	0.0
3	U-233	5.35855E-05	5.35962E-05	4.02208E-01	7.27674E 02	7.48440E 02	0.0	7.27673E 01	1.92227E-02
4	U-234	2.43830E-05	2.44032E-05	4.31193E-02	3.32742E 02	3.41061E 02	0.0	3.32742E 01	8.78996E-03
5	U-235	6.13810E-06	6.12283E-06	4.25802E-02	8.38429E 01	8.59390E 01	0.0	8.38428E 00	2.21485E-03
6	U-236	7.56141E-06	7.57158E-06	4.54022E-03	1.04122E 02	1.04127E 02	0.0	1.78292E-02	0.0
7	NP-237	9.74414E-07	9.71909E-07	4.13271E-03	1.34221E 01	1.34227E 01	0.0	2.29830E-03	0.0
8	U-238	4.59421E-06	4.59470E-06	2.29023E-03	6.37207E 01	6.37234E 01	0.0	1.09111E-02	0.0
9	PU-239	6.41259E-08	6.37420E-08	2.03724E-03	8.87707E-01	8.88077E-01	0.0	1.47951E-03	0.0
10	PU-240	3.66399E-08	3.65751E-08	6.31927E-04	5.11498E-01	5.11711E-01	0.0	8.52495E-04	0.0
11	PU-241	2.21149E-08	2.19837E-08	5.46201E-04	3.08720E-01	3.08849E-01	0.0	5.14533E-04	0.0
12	PU-242	2.47948E-08	2.47395E-08	4.85348E-05	3.48861E-01	3.49006E-01	0.0	5.81435E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.24217E-03	3.73631E 03	3.73673E 03	1.70681E 00	1.70607E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	8.95527E-04	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	8.25854E-03	8.41480E 03	8.41575E 03	3.84382E 00	3.84237E 00	0.0
16	LI-6	1.77118E-07	1.76432E-07	1.80689E-03	6.16844E-02	6.16914E-02	1.64735E-04	2.81664E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.38025E-03	0.0	0.0	0.0	2.40662E 01	0.0
18	FP REF E	1.00000E-08	1.00000E-08	1.08329E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	9.20688E-04	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.09521E-04	1.08868E-04	1.17936E-03	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.27987E-11	8.22563E-11	2.23697E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.86679E-04	2.85201E-04	3.08940E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.09607E-09	3.08651E-09	2.69464E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.65819E-09	8.64673E-09	5.72433E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	1.70788E-02	3.74222E 04	3.74222E 04	9.89586E-02	0.0	0.0
2	PA-233	1.08572E-07	1.08452E-07	1.18081E-05	1.31739E 00	3.92122E 00	0.0	6.58693E-02	0.0
3	U-233	5.47472E-08	5.46863E-08	1.91965E-05	6.64287E-01	6.72591E-01	0.0	3.32143E-02	0.0
4	U-234	1.33157E-10	1.32691E-10	1.08249E-08	1.61874E-03	1.63898E-03	0.0	8.09372E-05	0.0
5	U-235	1.03743E-13	1.03199E-13	3.20950E-11	1.26435E-06	1.28015E-06	0.0	6.32173E-08	0.0
6	U-236	1.51152E-14	1.50345E-14	4.88618E-13	1.84979E-07	1.84987E-07	0.0	3.16746E-11	0.0
7	NP-237	8.40349E-16	8.33250E-16	1.89958E-13	1.02954E-08	1.02959E-08	0.0	1.76292E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	8.58694E-05	3.34285E 03	3.34285E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	1.89801E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	3.69217E-04	7.52868E 03	7.52868E 03	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	1.13576E-04	7.75754E-02	7.75754E-02	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	3.69393E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	4.84469E-09	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	6.58879E-05	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	3.95104E-06	3.92218E-06	1.90009E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	1.01219E-11	1.00798E-11	3.71067E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	5.06813E-11	5.04966E-11	1.39253E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
26 CHROME	7.11900E-03	7.11900E-03	1.21290E-03	0.0	0.0	0.0	0.0	0.0
27 IRON	4.74300E-03	4.74300E-03	6.64701E-04	0.0	0.0	0.0	0.0	0.0
28 NICKEL	6.40000E-02	6.40000E-02	1.63236E-02	0.0	0.0	0.0	0.0	0.0
29 MOLY	9.37500E-03	9.37500E-03	5.85200E-03	0.0	0.0	0.0	0.0	0.0

MATERIAL 4

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
23 GRAPHITE	9.53000E-02	9.53000E-02	2.66753E-02	0.0	0.0	0.0	0.0	0.0

Table 8.4. Short Output for the Optimization

```
ROD-18  P X4916  X1306  BLANKETED MSBR 1000 MWE  TF  9  10TH23BE        Q
        SINGLE-FLUID CORE, BARREN BLANKET  H=10M OP4 COR R.VF  BL R.CI
MICROSCOPIC CROSS-SECTIONS IN SET NO.    1  ORDER NO. CN TAPE    3
MSR  1  SET  3  10TH23BE (900K)  VF=.12  C/TH=226
MICROSCOPIC CROSS-SECTIONS IN SET NO.    2  ORDER NO. CN TAPE    5
MSR  1  SET  5  14TH178E (900K)  VF=.20  C/TH= 91
MICROSCOPIC CROSS-SECTIONS IN SET NO.    3  ORDER NO. CN TAPE    9
MSR  1  SET  9  10TH23BE (900K)  VF=.01  C/TH=25[illegible]
THE READING OF THE CROSS-SECTION TAPE TOOK   3.0700  SEC
THE PRELIMINARY SETUP TOOK  16.6600  SEC
ITERATION LIMIT EXCEEDED IN DIFFUSION CALC.
ERC NUCLIDE   3 IN MATERIAL  1 HAS CONC. OPT. 2
NON CONVERGENCE  40  ITERATIONS
```

RAPID SEPTEMBER 1967 ROD-18 F X4916 X1306 BLANKETED MSBR 1000 MWE TF 9 10TH23BE Q

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	5.0000E-05
RESONANCE INTEGRAL FACTOR	1.8944E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.0863E 00
CONCENTRATION DAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR	1.01000

MATERIAL	VOLUME	TIME S	TIME P	TIME R	OPTION
1	1.2393E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	1.1088E 03	2.0000E 01	2.5000E-01	0.0	0
3	6.2285E 02	0.0	0.0	0.0	0
4	4.2485E 03	0.0	0.0	0.0	0

BO= 1.000019E 00	BS= 9.999524E-01	F1= 9.997725E-01	ETA= 2.235180E 00
IF= 9.295564E 02	PL= 7.765279E-04	Y = 6.883615E-01	FCC= 6.554781E-01
BR= 1.008421E 00	NO OF ITERS= 10	KI= 9.999943E-01	KC = 9.999991E-01

/**********RATES,KG PER DAY**********//*******FUEL CYCLE COSTS*******/

NUCLIDE		ABS	CAP	FIS	TOT INV,KG	FEED	PROCESS	LOSS	PRODUCT	INV.	REPL.	PROC	CREDIT
1	TH-232	0.9147	0.9124	0.0022	7.925E 04	2.147E 01	1.910E 01	1.910E 01	0.0	0.0283	0.0170	0.2170	0.0
2	PA-233	0.0058	0.0058	0.0000	9.331E 01	0.0	1.871E 00	1.805E-06	0.0	0.0228	0.0	0.0	0.0
3	U-233	0.8991	0.0940	0.8050	7.491E 02	0.0	7.280E 01	7.277E-05	1.922E-02	0.1832	0.0	0.0	0.0104
4	U-234	0.0964	0.0960	0.0004	3.411E 02	0.0	3.327E 01	3.327E-05	8.790E-03	0.0	0.0	0.0	0.0
5	U-235	0.0952	0.0169	0.0783	8.594E 01	0.0	8.384E 00	8.384E-06	2.215E-03	0.0181	0.0	0.0	0.0010
6	U-236	0.0101	0.0101	0.0000	1.041E 02	0.0	1.783E-02	1.783E-02	0.0	0.0	0.0	0.0	0.0
7	NP-237	0.0092	0.0092	0.0000	1.342E 01	0.0	2.298E-03	2.298E-03	0.0	0.0	0.0	0.0	0.0
8	U-238	0.0051	0.0051	0.0000	6.372E 01	0.0	1.091E-02	1.091E-02	0.0	0.0	0.0	0.1062	0.0
9	PU-239	0.0046	0.0017	0.0028	8.881E-01	0.0	1.480E-03	1.480E-03	0.0	0.0002	0.0	0.0	0.0
10	PU-240	0.0014	0.0014	0.0000	5.117E-01	0.0	8.525E-04	8.525E-04	0.0	0.0	0.0	0.0	0.0
11	PU-241	0.0012	0.0003	0.0009	3.088E-01	0.0	5.145E-04	5.145E-04	0.0	0.0001	0.0	0.0	0.0
12	PU-242	0.0001	0.0001	0.0000	3.490E-01	0.0	5.814E-04	5.814E-04	0.0	0.0	0.0	0.0	0.0
13	BE-9	0.0074	0.0017	0.0057	7.080E 03	1.707E 00	1.706E 00	1.706E 00	0.0	0.0115	0.0061	0.0	0.0
14	BE-9 NA	0.0020	0.0020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	LI-7	0.0193	0.0193	0.0	1.594E 04	3.844E 00	3.842E 00	3.842E 00	0.0	0.0368	0.0196	0.0	0.0
16	LI-6	0.0043	0.0043	0.0000	1.393E-01	1.647E-04	2.817E-05	2.817E-05	0.0	0.0	0.0	0.0	0.0
17	F	0.0218	0.0218	0.0	0.0	0.0	2.407E 01	2.407E 01	0.0	0.0	0.0	0.0	0.0
18	FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	0.0021	0.0021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	0.0028	0.0028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	GRAPHITE	0.0596	0.0596	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	0.0142	0.0142	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	CHROME	0.0027	0.0027	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	IRON	0.0015	0.0015	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	NICKEL	0.0365	0.0365	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	MOLY	0.0131	0.0131	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		2.2352								0.3009	0.0428	0.3233	0.0115

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	3.92146E-01	4.18268E 04	4.18315E 04	2.13712E 01	1.90990E 01	0.0
2	PA-233	1.32880E-06	1.32925E-06	2.58123E-03	1.80472E 01	8.93881E 01	0.0	1.80472E 00	0.0
3	U-233	5.35855E-05	5.35962E-05	4.02208E-01	7.27674E 02	7.48440E 02	0.0	7.27673E 01	1.92227E-02
4	U-234	2.43830E-05	2.44032E-05	4.31193E-02	3.32742E 02	3.41061E 02	0.0	3.32742E 01	8.78996E-03
5	U-235	6.13810E-06	6.12283E-06	4.25802E-02	8.38429E 01	8.59390E 01	0.0	8.38428E 00	2.21485E-03
6	U-236	7.56141E-06	7.57158E-06	4.54022E-03	1.04122E 02	1.04127E 02	0.0	1.78292E-02	0.0
7	NP-237	9.74414E-07	9.71909E-07	4.13271E-03	1.34221E 01	1.34227E 01	0.0	2.29830E-03	0.0
8	U-238	4.59421E-06	4.5947CE-06	2.29023E-03	6.37207E 01	6.37234E 01	0.0	1.09111E-02	0.0
9	PU-239	6.41259E-08	6.37420E-08	2.03724E-03	8.87707E-01	8.88077E-01	0.0	1.47951E-03	0.0
10	PU-240	3.66399E-08	3.65751E-08	6.31927E-04	5.11498E-01	5.11711E-01	0.0	8.52495E-04	0.0
11	PU-241	2.21149E-08	2.19837E-08	5.46201E-04	3.08720E-01	3.08849E-01	0.0	5.14533E-04	0.0
12	PU-242	2.47948E-08	2.47395E-08	4.85348E-05	3.48861E-01	3.49006E-01	0.0	5.81435E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.24217E-03	3.73631E 03	3.73673E 03	1.70681E 00	1.70607E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	8.95527E-04	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	8.25854E-03	8.41480E 03	8.41575E 03	3.84382E 00	3.84237E 00	0.0
16	LI-6	1.77118E-07	1.76432E-07	1.80689E-03	6.16844E-02	6.16914E-02	1.64735E-04	2.81664E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.38025E-03	0.0	0.0	0.0	2.40662E 01	0.0
18	FP REF E	1.00000E-08	1.00000E-08	1.08329E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	9.20688E-04	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.09521E-04	1.08868E-04	1.17936E-03	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.27987E-11	8.22563E-11	2.23657E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.86679E-04	2.85201E-04	3.08940E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.09607E-09	3.08651E-09	2.69464E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.65819E-09	8.64673E-09	5.72433E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	1.70788E-02	3.74222E 04	3.74222E 04	9.89586E-02	0.0	0.0
2	PA-233	1.08572E-07	1.08452E-07	1.18081E-05	1.31739E 00	3.92122E 00	0.0	6.58693E-02	0.0
3	U-233	5.47472E-08	5.46863E-08	1.91965E-05	6.64287E-01	6.72591E-01	0.0	3.32143E-02	0.0
4	U-234	1.33157E-10	1.32691E-10	1.08249E-08	1.61874E-02	1.63898E-03	0.0	8.09372E-05	0.0
5	U-235	1.03743E-13	1.03199E-13	3.20950E-11	1.26435E-06	1.28015E-06	0.0	6.32173E-08	0.0
6	U-236	1.51152E-14	1.50345E-14	4.88618E-13	1.84979E-07	1.84987E-07	0.0	3.16746E-11	0.0
7	NP-237	8.40349E-16	8.33250E-16	1.89958E-13	1.02954E-08	1.02959E-08	0.0	1.76292E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	8.58694E-05	3.34285E 03	3.34285E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	1.89801E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	3.69217E-04	7.52868E 03	7.52868E 03	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	1.13576E-04	7.75754E-02	7.75754E-02	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	3.69393E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	4.84469E-09	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	6.58879E-05	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	3.95104E-06	3.92218E-06	1.90009E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	1.01219E-11	1.00798E-11	3.71067E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	5.06813E-11	5.04966E-11	1.39253E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	//**********RATES,KG/DAY**********/ SYSTEM	TOTAL	FEED	PROCESS	PRODUCT
26 CHROME	7.11900E-03	7.11900E-03	1.21290E-03	0.0	0.0	0.0	0.0	0.0
27 IRON	4.74300E-03	4.74300E-03	6.64701E-04	0.0	0.0	0.0	0.0	0.0
28 NICKEL	6.40000E-02	6.40000E-02	1.63236E-02	0.0	0.0	0.0	0.0	0.0
29 MOLY	9.37500E-03	9.37500E-03	5.85200E-03	0.0	0.0	0.0	0.0	0.0

MATERIAL 4

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	//**********RATES,KG/DAY**********/ SYSTEM	TOTAL	FEED	PROCESS	PRODUCT
23 GRAPHITE	9.53000E-02	9.53000E-02	2.66753E-02	0.0	0.0	0.0	0.0	0.0

ENTERED WLKEP 0

THE OBJECTIVE FUNCTION FOR THIS CALCULATION IS

T1= 0.0 *BR+ 0.0 *YIELD+ 1.000E 01/FCC+ 0.0 /SPINV+ 2.500E 02*FLXFAC+ 1.000E 02*XMERIT

ALLOWABLE FLUX= 1.210000E 14

MAXIMUM OPTI CYCLES= 10

THE REDUCED STEP OPTION HAS BEEN SPECIFIED
ALPHA AND BETA WILL BE REDUCED BY A FACTOR OF 2.000000E 00
UNTIL ALPHA REACHES THE LIMITING VALUE OF 2.000000E-02

RIDGE FACTOR WEIGHTING OPTION WAS SELECTED

THE OPTI VARIABLES ARE

I	ITYPE	INDX1	INDX2	INDX3	XL	XB	XH	ACC1	ACC2	FP1	SLEFAC	NAME
1	1	1	2	0	1.500000E 02	2.000000E 02	2.500000E 02	0.0	0.0	0.0	0.2000	CORE RAD
2	1	3	2	0	1.000000E 01	2.000000E 01	1.100000E 02	0.0	0.0	0.0	1.0000	THK R B
3	2	1	1	0	1.100000E-01	1.400000E-01	1.700000E-01	0.0	0.0	0.0	0.5000	VF S COR
4	10	2	1	0	1.000000E 01	2.000000E 01	3.100000E 02	0.0	0.0	0.0	1.0000	BLK CY T

RAPID SEPTEMBER 1967 ROD-18 F X4916 X1306 BLANKETED MSBR 1000 MWE TF 9 10TH23BE Q

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	1.0000E-04
RESONANCE INTEGRAL FACTOR	1.8942E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.0863E 00
CONCENTRATION DAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR	1.01000

MATERIAL	VOLUME	TIME S	TIME P	TIME R	OPTION
1	1.2393E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	1.1088E 03	2.0000E 01	2.5000E-01	0.0	0
3	6.2285E 02	0.0	0.0	0.0	0
4	4.2485E 03	0.0	0.0	0.0	0

BO= 1.000019E 00 BS= 1.000018E 00 FI= 9.997725E-01 ETA= 2.235164E 00
IF= 9.295520E 02 PL= 7.768972E-04 Y = 6.876695E-01 FCC= 6.554974E-01
BR= 1.008412E 00 NO OF ITERS= 2 KI= 1.000005E 00 KC = 1.000004E 00

/**********RATES,KG PER DAY**********//*******FUEL CYCLE COSTS*******/

NUCLIDE		ABS	CAP	FIS	TOT INV,KG	FEED	PROCESS	LOSS	PRODUCT	INV.	REPL.	PROC	CREDIT
1	TH-232	0.9147	0.9124	0.0022	7.925E 04	2.147E 01	1.910E 01	1.910E 01	0.0	0.0283	0.0170	0.2170	0.0
2	PA-233	0.0058	0.0058	0.0000	9.331E 01	0.0	1.871E 00	1.805E-06	0.0	0.0228	0.0	0.0	0.0
3	U-233	0.8990	0.0940	0.8051	7.491E 02	0.0	7.280E 01	7.277E-05	1.919E-02	0.1832	0.0	0.0	0.0104
4	U-234	0.0964	0.0960	0.0004	3.411E 02	0.0	3.328E 01	3.328E-05	8.776E-03	0.0	0.0	0.0	0.0
5	U-235	0.0952	0.0169	0.0783	8.595E 01	0.0	8.386E 00	8.386E-06	2.211E-03	0.0181	0.0	0.0	0.0010
6	U-236	0.0101	0.0101	0.0000	1.041E 02	0.0	1.783E-02	1.783E-02	0.0	0.0	0.0	0.0	0.0
7	NP-237	0.0092	0.0092	0.0000	1.342E 01	0.0	2.299E-03	2.299E-03	0.0	0.0	0.0	0.0	0.0
8	U-238	0.0051	0.0051	0.0000	6.373E 01	0.0	1.091E-02	1.091E-02	0.0	0.0	0.0	0.1062	0.0
9	PU-239	0.0046	0.0017	0.0028	8.881E-01	0.0	1.479E-03	1.479E-03	0.0	0.0002	0.0	0.0	0.0
10	PU-240	0.0014	0.0014	0.0000	5.117E-01	0.0	8.525E-04	8.525E-04	0.0	0.0	0.0	0.0	0.0
11	PU-241	0.0012	0.0003	0.0009	3.088E-01	0.0	5.145E-04	5.145E-04	0.0	0.0001	0.0	0.0	0.0
12	PU-242	0.0001	0.0001	0.0000	3.490E-01	0.0	5.814E-04	5.814E-04	0.0	0.0	0.0	0.0	0.0
13	BE-9	0.0074	0.0017	0.0057	7.080E 03	1.707E 00	1.706E 00	1.706E 00	0.0	0.0115	0.0061	0.0	0.0
14	BE-9 NA	0.0020	0.0020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	LI-7	0.0193	0.0193	0.0	1.594E 04	3.844E 00	3.842E 00	3.842E 00	0.0	0.0368	0.0196	0.0	0.0
16	LI-6	0.0043	0.0043	0.0000	1.393E-01	1.647E-04	2.816E-05	2.816E-05	0.0	0.0	0.0	0.0	0.0
17	F	0.0218	0.0218	0.0	0.0	0.0	2.407E 01	2.407E 01	0.0	0.0	0.0	0.0	0.0
18	FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	0.0021	0.0021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	0.0028	0.0028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	GRAPHITE	0.0596	0.0596	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	0.0142	0.0142	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	CHROME	0.0027	0.0027	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	IRON	0.0015	0.0015	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	NICKEL	0.0365	0.0365	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	MOLY	0.0131	0.0131	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		2.2352								0.3009	0.0428	0.3233	0.0114

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	3.92142E-01	4.18268E 04	4.18315E 04	2.13711E 01	1.90990E 01	0.0
2	PA-233	1.32924E-06	1.32922E-06	2.58106E-03	1.80469E 01	8.93869E 01	0.0	1.80469E 00	0.0
3	U-233	5.35954E-05	5.35951E-05	4.02204E-01	7.27658E 02	7.48424E 02	0.0	7.27657E 01	1.91876E-02
4	U-234	2.44063E-05	2.44072E-05	4.31253E-02	3.32798E 02	3.41117E 02	0.0	3.32797E 01	8.77555E-03
5	U-235	6.12350E-06	6.12379E-06	4.25879E-02	8.38560E 01	8.59524E 01	0.0	8.38559E 00	2.21120E-03
6	U-236	7.57283E-06	7.57318E-06	4.54084E-03	1.04145E 02	1.04149E 02	0.0	1.78330E-02	0.0
7	NP-237	9.71994E-07	9.72038E-07	4.13321E-03	1.34239E 01	1.34244E 01	0.0	2.29861E-03	0.0
8	U-238	4.59512E-06	4.59532E-06	2.29036E-03	6.37293E 01	6.37320E 01	0.0	1.09125E-02	0.0
9	PU-239	6.37387E-08	6.37415E-08	2.03728E-03	8.87700E-01	8.88070E-01	0.0	1.47950E-03	0.0
10	PU-240	3.65740E-08	3.65755E-08	6.31899E-04	5.11502E-01	5.11715E-01	0.0	8.52503E-04	0.0
11	PU-241	2.19803E-08	2.19812E-08	5.46153E-04	3.08685E-01	3.08813E-01	0.0	5.14474E-04	0.0
12	PU-242	2.47357E-08	2.47367E-08	4.85259E-05	3.48821E-01	3.48967E-01	0.0	5.81368E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.24203E-03	3.73631E 03	3.73673E 03	1.70681E 00	1.70607E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	8.95473E-04	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	8.25877E-03	8.41480E 03	8.41575E 03	3.84382E 00	3.84237E 00	0.0
16	LI-6	1.76423E-07	1.76423E-07	1.80685E-03	6.16813E-02	6.16883E-02	1.64735E-04	2.81650E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.38013E-03	0.0	0.0	0.0	2.40662E 01	0.0
18	FP REF E	1.00000E-08	1.00000E-08	1.08332E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	9.20407E-04	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.08860E-04	1.08861E-04	1.17931E-03	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.22482E-11	8.22482E-11	2.23683E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.85177E-04	2.85177E-04	3.08942E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.08649E-09	3.08649E-09	2.69490E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.64677E-09	8.64675E-09	5.72492E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	1.70760E-02	3.74222E 04	3.74222E 04	9.89422E-02	0.0	0.0
2	PA-233	1.08439E-07	1.08433E-07	1.18041E-05	1.31717E 00	3.92057E 00	0.0	6.58582E-02	0.0
3	U-233	5.46798E-08	5.46772E-08	1.91902E-05	6.64177E-01	6.72479E-01	0.0	3.32088E-02	0.0
4	U-234	1.32658E-10	1.32645E-10	1.08194E-08	1.61819E-03	1.63842E-03	0.0	8.09094E-05	0.0
5	U-235	1.03161E-13	1.03147E-13	3.20735E-11	1.26370E-06	1.27950E-06	0.0	6.31850E-08	0.0
6	U-236	1.50275E-14	1.50247E-14	4.88215E-13	1.84859E-07	1.84867E-07	0.0	3.16539E-11	0.0
7	NP-237	8.32795E-16	8.32621E-16	1.89784E-13	1.02877E-08	1.02881E-08	0.0	1.76159E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	8.58539E-05	3.34285E 03	3.34285E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	1.89764E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	3.69159E-04	7.52868E 03	7.52868E 03	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	1.13558E-04	7.75754E-02	7.75754E-02	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	3.69331E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	4.84393E-05	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	6.58775E-05	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	3.92119E-06	3.92098E-06	1.89933E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	1.00788E-11	1.00786E-11	3.70987E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	5.04892E-11	5.04868E-11	1.39213E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	//**********RATES,KG/DAY**********/ TOTAL	FEED	PROCESS	PRODUCT
26	CHROME	7.11900E-03	7.11900E-03	1.21276E-03	0.0	0.0	0.0	0.0	0.0
27	IRON	4.74300E-03	4.74300E-03	6.64625E-04	0.0	0.0	0.0	0.0	0.0
28	NICKEL	6.40000E-02	6.40000E-02	1.63218E-02	0.0	0.0	0.0	0.0	0.0
29	MOLY	9.37500E-03	9.37500E-03	5.85107E-03	0.0	0.0	0.0	0.0	0.0

MATERIAL 4

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	//**********RATES,KG/DAY**********/ TOTAL	FEED	PROCESS	PRODUCT
23	GRAPHITE	9.53000E-02	9.53000E-02	2.66761E-02	0.0	0.0	0.0	0.0	0.0

THICKNESSES AND OTHER REGION INFORMATION

DIMENSION 1

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	3.600000E 02	36	1	1	0.0	3.600000E 02
2	PLENA	3.000000E 01	6	2	1	3.600000E 02	3.900000E 02
3	REFLECT	1.000000E 02	20	3	1	3.900000E 02	4.900000E 02
4	VESSEL	1.000000E 01	5	1	0	4.900000E 02	5.000000E 02

DIMENSION 2

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	2.000000E 02	40	1	1	0.0	2.000000E 02
2	WALL	1.000000E 00	3	1	1	2.000000E 02	2.010000E 02
3	BLANKET	2.000000E 01	20	2	1	2.010000E 02	2.210000E 02
4	VESSEL	1.000000E 01	5	1	0	2.210000E 02	2.310000E 02

SUPER REGION VOLUME FRACTIONS

SUPER REGION		MATERIAL 1	2	3	4
1	CORE(1)	0.140000	0.0	0.0	0.860000
2	WALL	0.0	0.0	0.300000	0.700000
3	BLANKET	0.0	0.500000	0.0	0.500000
4	PLENA	0.500000	0.0	0.0	0.500000
5	AX REFL	0.010000	0.0	0.0	0.990000
6	VESSEL	0.0	0.0	1.000000	0.0

OBJECTIVE FUNCTION=	1.991096E 01	BALANCE=	1.000018E 00
BREEDING RATIO=	1.008412E 00	YIELD=	6.876695E-01
FUEL CYCLE COST=	6.554574E-01	SPECIFIC POWER=	2.420521E 00
SPECIFIC INVENTORY=	4.131342E-01	CONSERVATION COEFFICIENT=	4.928735E-02
FLUX FACTOR=	-1.093419E-03	ALLOWABLE FLUX=	1.210000E 14
MAXIMUM FLUX=	1.243067E 14		

	OPTI	USED
1 CORE RAD=	2.000000E 02	2.000000E 02
2 THK R B =	2.000000E 01	2.000000E 01
3 VF S CCR=	1.400000E-01	1.400000E-01
4 BLK CY T=	2.000000E 01	2.000000E 01

ENTERED WLKEP 1

OBJECTIVE FUNCTION=	2.035641E 01	BALANCE=	1.000052E 00
BREEDING RATIO=	1.008579E 00	YIELD=	7.318891E-01
FUEL CYCLE COST=	6.561881E-01	SPECIFIC POWER=	2.413736E 00
SPECIFIC INVENTORY=	4.142957E-01	CONSERVATION COEFFICIENT=	5.231176E-02
FLUX FACTOR=	-4.571634E-04	ALLOWABLE FLUX=	1.210000E 14
MAXIMUM FLUX=	1.231381E 14		

	OPTI	USED
1 CORE RAD=	2.010000E 02	2.010000E 02
2 THK R B =	2.000000E 01	2.000000E 01
3 VF S CCR=	1.400000E-01	1.400000E-01
4 BLK CY T=	2.000000E 01	2.000000E 01

ENTERED WLKEP 2

OBJECTIVE FUNCTION=	2.425150E 01	BALANCE=	9.999993E-01
BREEDING RATIO=	1.015514E 00	YIELD=	1.272220E 00
FUEL CYCLE COST=	6.508695E-01	SPECIFIC POWER=	2.429054E 00
SPECIFIC INVENTORY=	4.116828E-01	CONSERVATION COEFFICIENT=	9.153950E-02
FLUX FACTOR=	-1.066042E-03	ALLOWABLE FLUX=	1.210000E 14
MAXIMUM FLUX=	1.242650E 14		

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                                OPTI                    USED
                1  CORE RAD=  2.000000E 02          2.000000E 02
                2  THK R B =  2.499998E 01          2.499998E 01
                3  VF S CCR=  1.400000E-01          1.400000E-01
                4  BLK CY T=  2.000000E 01          2.000000E 01
ENTERED WLKEP    3

            OBJECTIVE FUNCTION=  2.049681E 01                BALANCE=  1.000027E 00
                BREEDING RATIO=  1.009484E 00                  YIELD=  7.715538E-01
            FUEL CYCLE COST=  6.557600E-01             SPECIFIC POWER=  2.408671E 00
            SPECIFIC INVENTORY=  4.151666E-01   CONSERVATION COEFFICIENT=  5.502499E-02
                  FLUX FACTOR= -1.020643E-03            ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.241948E 14

                                OPTI                    USED
                1  CORE RAD=  2.000000E 02          2.000000E 02
                2  THK R B =  2.000000E 01          2.000000E 01
                3  VF S CCR=  1.414999E-01          1.414999E-01
                4  BLK CY T=  2.000000E 01          2.000000E 01
ENTERED WLKEP    4

            OBJECTIVE FUNCTION=  2.007932E 01                BALANCE=  1.000032E 00
                BREEDING RATIO=  1.008385E 00                  YIELD=  6.847079E-01
            FUEL CYCLE COST=  6.471272E-01             SPECIFIC POWER=  2.418084E 00
            SPECIFIC INVENTORY=  4.135504E-01   CONSERVATION COEFFICIENT=  4.902646E-02
                  FLUX FACTOR= -1.104966E-03            ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.242241E 14

                                OPTI                    USED
                1  CORE RAD=  2.000000E 02          2.000000E 02
                2  THK R B =  2.000000E 01          2.000000E 01
                3  VF S CCR=  1.400000E-01          1.400000E-01
                4  BLK CY T=  3.499998E 01          3.499998E 01
ENTERED WLKEP    5

PARTIAL DERIVATIVES OF GRADIENT EVALUATION
  0.8908997E 01  0.8681061E 02  0.1171692E 02  0.3367004E 01

ALPHA =   0.500000E-01     BETA =   0.100000E 00
   0.250000E 00   0.100000E 01   0.625000E 00   0.100000E 01

            OBJECTIVE FUNCTION=  2.786505E 01                BALANCE=  9.999526E-01
                BREEDING RATIO=  1.021426E 00                  YIELD=  1.756378E 00
            FUEL CYCLE COST=  6.481743E-01             SPECIFIC POWER=  2.428849E 00
            SPECIFIC INVENTORY=  4.117175E-01   CONSERVATION COEFFICIENT=  1.263998E-01
                  FLUX FACTOR= -8.114444E-04            ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.238486E 14

                                OPTI                    USED
                1  CORE RAD=  2.002566E 02          2.002566E 02
                2  THK R B =  2.999998E 01          2.999998E 01
                3  VF S CCR=  1.405061E-01          1.405061E-01
                4  BLK CY T=  2.116356E 01          2.116356E 01
ENTERED WLKEP    6

SUCCESSFUL STEP NO. 1

            OBJECTIVE FUNCTION=  3.240923E 01                BALANCE=  9.999840E-01
                BREEDING RATIO=  1.029039E 00                  YIELD=  2.380450E 00
            FUEL CYCLE COST=  6.487859E-01             SPECIFIC POWER=  2.429595E 00
            SPECIFIC INVENTORY=  4.115911E-01   CONSERVATION COEFFICIENT=  1.714175E-01
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                    FLUX FACTOR= -5.836340E-04          ALLOWABLE FLUX=  1.210000E 14
                    MAXIMUM FLUX=  1.234159E 14

                                  OPTI                  USED
                 1  CORE RAD=  2.005131E 02          2.005131E 02
                 2  THK R B =  3.999997E 01          3.999997E 01
                 3  VF S CCR=  1.410122E-01          1.410122E-01
                 4  BLK CY T=  2.232712E 01          2.232712E 01
ENTERED WLKEP    7

SUCCESSFUL STEP NO. 2

            OBJECTIVE FUNCTION=  3.484474E 01                BALANCE=  1.000004E 00
                BREEDING RATIO=  1.023386E 00                  YIELD=  2.733196E 00
                 FUEL CYCLE COST=  6.542559E-01           SPECIFIC POWER=  2.426786E 00
            SPECIFIC INVENTORY=  4.120675E-01   CONSERVATION COEFFICIENT=  1.966212E-01
                    FLUX FACTOR= -4.075901E-04          ALLOWABLE FLUX=  1.210000E 14
                    MAXIMUM FLUX=  1.230189E 14

                                  OPTI                  USED
                 1  CORE RAD=  2.007697E 02          2.007697E 02
                 2  THK R B =  4.999995E 01          4.999995E 01
                 3  VF S CCR=  1.415183E-01          1.415183E-01
                 4  BLK CY T=  2.349068E 01          2.349068E 01
ENTERED WLKEP    8

SUCCESSFUL STEP NO. 3

            OBJECTIVE FUNCTION=  3.607570E 01                BALANCE=  1.000042E 00
                BREEDING RATIO=  1.035883E 00                  YIELD=  2.931957E 00
                 FUEL CYCLE COST=  6.625538E-01           SPECIFIC POWER=  2.422286E 00
            SPECIFIC INVENTORY=  4.128331E-01   CONSERVATION COEFFICIENT=  2.105421E-01
                    FLUX FACTOR= -2.704388E-04          ALLOWABLE FLUX=  1.210000E 14
                    MAXIMUM FLUX=  1.226445E 14

                                  OPTI                  USED
                 1  CORE RAD=  2.010262E 02          2.010262E 02
                 2  THK R B =  5.999994E 01          5.999994E 01
                 3  VF S CCR=  1.420244E-01          1.420244E-01
                 4  BLK CY T=  2.465424E 01          2.465424E 01
ENTERED WLKEP    9

SUCCESSFUL STEP NO. 4

            OBJECTIVE FUNCTION=  3.663438E 01                BALANCE=  1.000066E 00
                BREEDING RATIO=  1.037338E 00                  YIELD=  3.043736E 00
                 FUEL CYCLE COST=  6.725824E-01           SPECIFIC POWER=  2.416718E 00
            SPECIFIC INVENTORY=  4.137844E-01   CONSERVATION COEFFICIENT=  2.180749E-01
                    FLUX FACTOR= -1.646228E-04          ALLOWABLE FLUX=  1.210000E 14
                    MAXIMUM FLUX=  1.222831E 14

                                  OPTI                  USED
                 1  CORE RAD=  2.012828E 02          2.012828E 02
                 2  THK R B =  6.999992E 01          6.999992E 01
                 3  VF S CCR=  1.425305E-01          1.425305E-01
                 4  BLK CY T=  2.581779E 01          2.581779E 01
ENTERED WLKEP   10

SUCCESSFUL STEP NO. 5

            OBJECTIVE FUNCTION=  3.685289E 01                BALANCE=  1.000042E 00
                BREEDING RATIO=  1.038284E 00                  YIELD=  3.112947E 00
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                FUEL CYCLE COST=  6.836443E-01          SPECIFIC POWER=  2.410596E 00
             SPECIFIC INVENTORY=  4.148352E-01   CONSERVATION COEFFICIENT=  2.224690E-01
                   FLUX FACTOR= -8.591883E-05          ALLOWABLE FLUX=  1.210000E 14
                  MAXIMUM FLUX=  1.219269E 14

                                 OPTI                 USED
                1  CORE RAD=  2.015394E 02        2.015394E 02
                2  THK R B =  7.999991E 01        7.999991E 01
                3  VF S COR=  1.430366E-01        1.430366E-01
                4  BLK CY T=  2.698135E 01        2.698135E 01
ENTERED WLKEP   11

SUCCESSFUL STEP NO. 6

            OBJECTIVE FUNCTION=  3.684975E 01                BALANCE=  9.999359E-01
               BREEDING RATIO=  1.038899E 00                  YIELD=  3.154371E 00
              FUEL CYCLE COST=  6.955390E-01          SPECIFIC POWER=  2.403994E 00
             SPECIFIC INVENTORY=  4.159744E-01   CONSERVATION COEFFICIENT=  2.248069E-01
                   FLUX FACTOR= -3.204768E-05          ALLOWABLE FLUX=  1.210000E 14
                  MAXIMUM FLUX=  1.215749E 14

                                 OPTI                 USED
                1  CORE RAD=  2.017959E 02        2.017959E 02
                2  THK R B =  8.999989E 01        8.999989E 01
                3  VF S COR=  1.435427E-01        1.435427E-01
                4  BLK CY T=  2.814491E 01        2.814491E 01
ENTERED WLKEP   12

FIRST SEARCH FAILURE ALONG GRADIENT

FITTING PARABOLA TO LAST 3 POINTS TO DETERMINE AN INITIAL POINT FOR GRADIENT EVALUATION

MINMAX OF PARABOLA USED FOR GRADIENT EVALUATION
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RAPID SEPTEMBER 1967 ROD-18 F X4916 X1306 BLANKETED MSBR 1000 MWE TF 9 10TH238E 0

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	1.0000E-04
RESONANCE INTEGRAL FACTOR	1.9120E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.0871E 00
CONCENTRATION CAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR	1.01000

MATERIAL	VOLUME	TIME S	TIME P	TIME R	OPTION
1	1.2598E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	2.9111E 03	2.7547E 01	2.5000E-01	0.0	0
3	8.4561E 02	0.0	0.0	0.0	0
4	6.1033E 03	0.0	0.0	0.0	0

BO= 1.000016E 00 BS= 9.999591E-01 F1= 9.997214E-01 ETA= 2.238068E 00
IF= 9.346870E 02 PL= 6.912097E-04 Y = 3.132364E 00 FCC= 6.894249E-01
BR= 1.038576E 00 NO OF ITERS= 3 KI= 1.000078E 00 KC = 1.000016E 00

/**********RATES,KG PER DAY**********//*******FUEL CYCLE COSTS*******/

NUCLIDE	ABS	CAP	FIS	TOT INV,KG	FEED	PROCESS	LOSS	PRODUCT	INV.	REPL.	PROC	CREDIT
1 TH-232	0.9547	0.9524	0.0023	1.408E 05	2.189E 01	1.942E 01	1.942E 01	0.0	0.0503	0.0173	0.2297	0.0
2 PA-233	0.0059	0.0059	0.0000	9.729E 01	0.0	1.931E 00	1.835E-06	0.0	0.0238	0.0	0.0	0.0
3 U-233	0.9113	0.0952	0.8159	7.607E 02	0.0	7.385E 01	7.379E-05	8.916E-02	0.1860	0.0	0.0	0.0483
4 U-234	0.0873	0.0870	0.0003	3.083E 02	0.0	3.008E 01	3.008E-05	3.634E-02	0.0	0.0	0.0	0.0
5 U-235	0.0836	0.0149	0.0687	7.559E 01	0.0	7.375E 00	7.374E-06	8.911E-03	0.0159	0.0	0.0	0.0042
6 U-236	0.0089	0.0089	0.0000	9.119E 01	0.0	1.561E-02	1.561E-02	0.0	0.0	0.0	0.0	0.0
7 NP-237	0.0081	0.0081	0.0000	1.181E 01	0.0	2.022E-03	2.022E-03	0.0	0.0	0.0	0.0	0.0
8 U-238	0.0045	0.0045	0.0000	5.591E 01	0.0	9.573E-03	9.573E-03	0.0	0.0	0.0	0.1068	0.0
9 PU-239	0.0040	0.0015	0.0025	7.849E-01	0.0	1.308E-03	1.308E-03	0.0	0.0001	0.0	0.0	0.0
10 PU-240	0.0012	0.0012	0.0000	4.503E-01	0.0	7.502E-04	7.502E-04	0.0	0.0	0.0	0.0	0.0
11 PU-241	0.0011	0.0003	0.0008	2.730E-01	0.0	4.548E-04	4.548E-04	0.0	0.0000	0.0	0.0	0.0
12 PU-242	0.0001	0.0001	0.0000	3.072E-01	0.0	5.119E-04	5.119E-04	0.0	0.0	0.0	0.0	0.0
13 BE-9	0.0076	0.0018	0.0059	1.258E 04	1.735E 00	1.734E 00	1.734E 00	0.0	0.0204	0.0062	0.0	0.0
14 BE-9 NA	0.0021	0.0021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 LI-7	0.0203	0.0203	0.0	2.832E 04	3.907E 00	3.906E 00	3.906E 00	0.0	0.0653	0.0200	0.0	0.0
16 LI-6	0.0046	0.0046	0.0000	2.666E-01	1.675E-04	2.874E-05	2.874E-05	0.0	0.0	0.0	0.0	0.0
17 F	0.0227	0.0226	0.0	0.0	0.0	2.446E 01	2.446E 01	0.0	0.0	0.0	0.0	0.0
18 FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 LEAKAGE	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 DEL NEUT	0.0029	0.0029	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 FIX P FR	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 GRAPHITE	0.0593	0.0593	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 LUMP FP	0.0142	0.0142	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 CHROME	0.0016	0.0016	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 IRON	0.0009	0.0009	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 NICKEL	0.0211	0.0211	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 MOLY	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.2381								0.3619	0.0435	0.3365	0.0525

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY*********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	3.98760E-01	4.25190E 04	4.25239E 04	2.17259E 01	1.94151E 01	0.0
2	PA-233	1.32969E-06	1.32978E-06	2.63204E-03	1.83531E 01	9.09034E 01	0.0	1.83531E 00	0.0
3	U-233	5.34682E-05	5.34613E-05	4.07144E-01	7.37854E 02	7.58907E 02	0.0	7.37853E 01	8.91550E-02
4	U-234	2.17002E-05	2.16985E-05	3.90219E-02	3.00760E 02	3.08279E 02	0.0	3.00760E 01	3.63410E-02
5	U-235	5.29804E-06	5.29774E-06	3.73573E-02	7.37452E 01	7.55888E 01	0.0	7.37451E 00	8.91064E-03
6	U-236	6.52186E-06	6.52278E-06	3.99461E-03	9.11842E 01	9.11881E 01	0.0	1.56137E-02	0.0
7	NP-237	8.41098E-07	8.41516E-07	3.63599E-03	1.18109E 01	1.18114E 01	0.0	2.02241E-03	0.0
8	U-238	3.96350E-06	3.96541E-06	2.01954E-03	5.59036E 01	5.59060E 01	0.0	9.57254E-03	0.0
9	PU-239	5.53901E-08	5.54216E-08	1.79588E-03	7.84607E-01	7.84933E-01	0.0	1.30768E-03	0.0
10	PU-240	3.16396E-08	3.16631E-08	5.57293E-04	4.50130E-01	4.50318E-01	0.0	7.50217E-04	0.0
11	PU-241	1.90997E-08	1.91151E-08	4.81499E-04	2.72879E-01	2.72992E-01	0.0	4.54797E-04	0.0
12	PU-242	2.14036E-08	2.14245E-08	4.29073E-05	3.07115E-01	3.07243E-01	0.0	5.11858E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.30021E-03	3.79814E 03	3.79857E 03	1.73505E 00	1.73431E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	9.12685E-04	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	8.37079E-03	8.55406E 03	8.55503E 03	3.90743E 00	3.90596E 00	0.0
16	LI-6	1.77111E-07	1.77091E-07	1.83831E-03	6.29395E-02	6.29466E-02	1.67461E-04	2.87395E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.53917E-03	0.0	0.0	0.0	2.44645E 01	0.0
18	FP REF E	1.00000E-08	1.00000E-08	1.09802E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	1.87179E-05	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.06191E-04	1.06164E-04	1.16570E-03	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.11282E-11	8.11063E-11	2.23395E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.81170E-04	2.81121E-04	3.08665E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.03081E-09	3.03069E-09	2.68019E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.48840E-09	8.48824E-09	5.69308E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY*********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	2.78182E-02	9.82528E 04	9.82528E 04	1.61209E-01	0.0	0.0
2	PA-233	8.24427E-08	8.23021E-08	1.37808E-05	2.62484E 00	6.39154E 00	0.0	9.52863E-02	0.0
3	U-233	5.72705E-08	5.71735E-08	3.55199E-05	1.82342E 00	1.83997E 00	0.0	6.61933E-02	0.0
4	U-234	8.79459E-11	8.76893E-11	1.15009E-08	2.80866E-03	2.83415E-03	0.0	1.01959E-04	0.0
5	U-235	5.78178E-14	5.75692E-14	3.25718E-11	1.85180E-06	1.86861E-06	0.0	6.72235E-08	0.0
6	U-236	5.86071E-15	5.82431E-15	2.66241E-13	1.88145E-07	1.88153E-07	0.0	3.22167E-11	0.0
7	NP-237	2.01831E-16	2.00594E-16	7.76639E-14	6.50733E-09	6.50761E-09	0.0	1.11427E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	1.17873E-04	8.77673E 03	8.77673E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	2.04595E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	6.83566E-04	1.97667E 04	1.97667E 04	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	2.10154E-04	2.03676E-01	2.03676E-01	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	5.81540E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	8.96544E-09	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	1.21930E-04	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.15948E-06	2.15520E-06	1.93216E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	7.00906E-12	7.00878E-12	4.87007E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	3.42696E-11	3.42237E-11	1.76350E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	//**********RATES,KG/DAY**********/ SYSTEM	TOTAL	FEED	PROCESS	PRODUCT
26	CHROME	7.11900E-03	7.11900E-03	7.01872E-04	0.0	0.0	0.0	0.0	0.0
27	IRON	4.74300E-03	4.74300E-03	3.83168E-04	0.0	0.0	0.0	0.0	0.0
28	NICKEL	6.40000E-02	6.40000E-02	9.41695E-03	0.0	0.0	0.0	0.0	0.0
29	MOLY	9.37500E-03	9.37500E-03	2.22375E-03	0.0	0.0	0.0	0.0	0.0

MATERIAL 4

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	//**********RATES,KG/DAY**********/ SYSTEM	TOTAL	FEED	PROCESS	PRODUCT
23	GRAPHITE	9.53000E-02	9.53000E-02	2.65131E-02	0.0	0.0	0.0	0.0	0.0

THICKNESSES AND OTHER REGION INFORMATION

DIMENSION 1

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	3.600000E 02	36	1	1	0.0	3.600000E 02
2	PLENA	3.000000E 01	6	2	1	3.600000E 02	3.900000E 02
3	REFLECT	1.000000E 02	20	3	1	3.900000E 02	4.900000E 02
4	VESSEL	1.000000E 01	5	1	0	4.900000E 02	5.000000E 02

DIMENSION 2

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	2.016641E 02	40	1	1	0.0	2.016640E 02
2	WALL	1.000000E 00	3	1	1	2.016640E 02	2.026640E 02
3	BLANKET	8.486021E 01	20	2	1	2.026640E 02	2.875242E 02
4	VESSEL	1.000000E 01	5	1	0	2.875242E 02	2.975242E 02

SUPER REGION VOLUME FRACTIONS

SUPER REGION		MATERIAL 1	2	3	4
1	CORE(1)	0.143283	0.0	0.0	0.856717
2	WALL	0.0	0.0	0.300000	0.700000
3	BLANKET	0.0	0.500000	0.0	0.500000
4	PLENA	0.500000	0.0	0.0	0.500000
5	AX REFL	0.010000	0.0	0.0	0.990000
6	VESSEL	0.0	0.0	1.000000	0.0

OBJECTIVE FUNCTION=	3.684438E 01	BALANCE=	9.999591E-01
BREEDING RATIO=	1.038576E 00	YIELD=	3.132364E 00
FUEL CYCLE COST=	6.894249E-01	SPECIFIC POWER=	2.407223E 00
SPECIFIC INVENTORY=	4.154164E-01	CONSERVATION COEFFICIENT=	2.235379E-01
FLUX FACTOR=	-5.691254E-05	ALLOWABLE FLUX=	1.210000E 14
MAXIMUM FLUX=	1.217544E 14		

		OPTI	USED
1	CORE RAD=	2.016641E 02	2.016641E 02
2	THK R B =	8.486021E 01	8.486021E 01
3	VF S COR=	1.432828E-01	1.432828E-01
4	BLK CY T=	2.754692E 01	2.754692E 01

ENTERED WLKEP 13

END OPTI CYCLE 1

PARABOLIC FIT REJECTED. LOWEST PREVIOUS POINT USED.

PARABOLIC FIT WAS REJECTED-GO BACK TO MERC TO GET FULL OUTPUT FOR LAST SUCCESSFUL STEP

RAPID SEPTEMBER 1967 ROD-18 F X4916 X1306 BLANKETED MSBR 1000 MWE TF 9 10TH238E Q

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	1.0000E-04
RESONANCE INTEGRAL FACTOR	1.9079E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.0869E 00
CONCENTRATION DAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR	1.01000

MATERIAL	VOLUME	TIME S	TIME F	TIME R	OPTION
1	1.2582E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	2.7594E 03	2.6981E 01	2.5000E-01	0.0	0
3	8.2823E 02	0.0	0.0	0.0	0
4	5.5476E 03	0.0	0.0	0.0	0

BO= 1.001016E 00 BS= 1.000031E 00 FI= 5.597204E-01 ETA= 2.238113E 00
IF= 9.333630E 02 PL= 6.908244E-04 Y = 3.111497E 00 FCC= 6.836624E-01
BR= 1.038265E 00 NO OF ITERS= 3 KI= 1.000003E 00 KC = 1.000001E 00

/**********RATES,KG PER DAY**********//*******FUEL CYCLE COSTS*******/

NUCLIDE		ABS	CAP	FIS	TOT INV,KG	FEED	PROCESS	LOSS	PRODUCT	INV.	REPL.	PROC	CREDIT
1	TH-232	0.9543	0.9521	0.0023	1.356E 05	2.186E 01	1.939E 01	1.939E 01	0.0	0.0484	0.0173	0.2290	0.0
2	PA-233	0.0059	0.0059	0.0000	9.726E 01	0.0	1.931E 00	1.835E-06	0.0	0.0238	0.0	0.0	0.0
3	U-233	0.9112	0.0953	0.8159	7.595E 02	0.0	7.374E 01	7.367E-05	8.853E-02	0.1857	0.0	0.0	0.0480
4	U-234	0.0874	0.0871	0.0003	3.082E 02	0.0	3.007E 01	3.007E-05	3.613E-02	0.0	0.0	0.0	0.0
5	U-235	0.0837	0.0149	0.0688	7.553E 01	0.0	7.369E 00	7.369E-06	8.855E-03	0.0159	0.0	0.0	0.0041
6	U-236	0.0089	0.0089	0.0000	9.125E 01	0.0	1.562E-02	1.562E-02	0.0	0.0	0.0	0.0	0.0
7	NP-237	0.0081	0.0081	0.0000	1.181E 01	0.0	2.022E-03	2.022E-03	0.0	0.0	0.0	0.0	0.0
8	U-238	0.0045	0.0045	0.0000	5.595E 01	0.0	9.581E-03	9.581E-03	0.0	0.0	0.0	0.1067	0.0
9	PU-239	0.0040	0.0015	0.0025	7.844E-01	0.0	1.307E-03	1.307E-03	0.0	0.0001	0.0	0.0	0.0
10	PU-240	0.0012	0.0012	0.0000	4.506E-01	0.0	7.506E-04	7.506E-04	0.0	0.0	0.0	0.0	0.0
11	PU-241	0.0011	0.0003	0.0008	2.729E-01	0.0	4.547E-04	4.547E-04	0.0	0.0000	0.0	0.0	0.0
12	PU-242	0.0001	0.0001	0.0000	3.077E-01	0.0	5.125E-04	5.125E-04	0.0	0.0	0.0	0.0	0.0
13	BE-9	0.0076	0.0018	0.0058	1.211E 04	1.733E 00	1.732E 00	1.732E 00	0.0	0.0196	0.0062	0.0	0.0
14	BE-9 NA	0.0021	0.0021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	LI-7	0.0203	0.0203	0.0	2.728E 04	3.903E 00	3.901E 00	3.901E 00	0.0	0.0629	0.0199	0.0	0.0
16	LI-6	0.0046	0.0046	0.0000	2.558E-01	1.673E-04	2.866E-05	2.866E-05	0.0	0.0	0.0	0.0	0.0
17	F	0.0226	0.0226	0.0	0.0	0.0	2.443E 01	2.443E 01	0.0	0.0	0.0	0.0	0.0
18	FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	0.0029	0.0029	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	FIX P FP	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	GRAPHITE	0.0595	0.0595	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	0.0142	0.0142	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	CHROME	0.0016	0.0016	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	IRON	0.0009	0.0009	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	NICKEL	0.0212	0.0212	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	MOLY	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		2.2381								0.3566	0.0435	0.3357	0.0521

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	3.98633E-01	4.24666E 04	4.24714E 04	2.17012E 01	1.93511E 01	0.0
2	PA-233	1.33109E-06	1.33105E-06	2.63255E-03	1.83480E 01	9.08782E 01	0.0	1.83480E 00	0.0
3	U-233	5.34453E-05	5.34446E-05	4.07099E-01	7.36715E 02	7.57739E 02	0.0	7.36714E 01	8.85255E-02
4	U-234	2.17176E-05	2.17200E-05	3.90441E-02	3.00688E 02	3.08205E 02	0.0	3.00687E 01	3.61314E-02
5	U-235	5.29885E-06	5.30030E-06	3.73895E-02	7.36899E 01	7.55321E 01	0.0	7.36898E 00	8.85477E-03
6	U-236	6.53214E-06	6.53510E-06	3.99741E-03	9.12438E 01	9.12477E 01	0.0	1.56239E-02	0.0
7	NP-237	8.41610E-07	8.42104E-07	3.63895E-03	1.18074E 01	1.18079E 01	0.0	2.02181E-03	0.0
8	U-238	3.97095E-06	3.97373E-06	2.02122E-03	5.59518E 01	5.59542E 01	0.0	9.58079E-03	0.0
9	PU-239	5.54133E-08	5.54555E-08	1.79772E-03	7.84118E-01	7.84445E-01	0.0	1.30686E-03	0.0
10	PU-240	3.16933E-08	3.17197E-08	5.57925E-04	4.50379E-01	4.50567E-01	0.0	7.50632E-04	0.0
11	PU-241	1.91169E-08	1.91333E-08	4.82159E-04	2.72802E-01	2.72915E-01	0.0	4.54669E-04	0.0
12	PU-242	2.14609E-08	2.14798E-08	4.29719E-05	3.07528E-01	3.07656E-01	0.0	5.12546E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.29691E-03	3.79346E 03	3.79389E 03	1.73291E 00	1.73217E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	9.11381E-04	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	8.37472E-03	8.54351E 03	8.54448E 03	3.90261E 00	3.90115E 00	0.0
16	LI-6	1.76800E-07	1.76800E-07	1.83614E-03	6.27584E-02	6.27655E-02	1.67255E-04	2.86568E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.53475E-03	0.0	0.0	0.0	2.44343E 01	0.0
18	FP REF F	1.00000E-08	1.00000E-08	1.09854E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	1.94049E-05	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.06117E-04	1.06113E-04	1.16569E-03	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.10523E-11	8.10481E-11	2.23377E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.81235E-04	2.81232E-04	3.08953E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.02930E-09	3.02960E-09	2.68104E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.49253E-09	8.49302E-09	5.69998E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	2.77723E-02	9.31319E 04	9.31319E 04	1.60943E-01	0.0	0.0
2	PA-233	8.56405E-08	8.56284E-08	1.43247E-05	2.58859E 00	6.38113E 00	0.0	9.59401E-02	0.0
3	U-233	5.82658E-08	5.82582E-08	3.61204E-05	1.76118E 00	1.77750E 00	0.0	6.52738E-02	0.0
4	U-234	9.37890E-11	9.27648E-11	1.22811E-08	2.84673E-03	2.87310E-03	0.0	1.05507E-04	0.0
5	U-235	6.35454E-14	6.35219E-14	3.58593E-11	1.93679E-06	1.95473E-06	0.0	7.17823E-08	0.0
6	U-236	6.75291E-15	6.74969E-15	3.08445E-13	2.06674E-07	2.06683E-07	0.0	3.53894E-11	0.0
7	NP-237	2.41558E-16	2.41435E-16	9.33153E-14	7.42402E-09	7.42434E-09	0.0	1.27124E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	1.17653E-04	8.31929E 03	8.31929E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	2.04315E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	6.81972E-04	1.87365E 04	1.87365E 04	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	2.09665E-04	1.93060E-01	1.93060E-01	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	5.80489E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	8.94455E-09	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	1.21646E-04	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.27663E-06	2.27617E-06	2.03599E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	7.12956E-12	7.12936E-12	4.54188E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	3.54653E-11	3.54614E-11	1.82304E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
26	CHROME	7.11900E-03	7.11900E-03	7.07423E-04	0.0	0.0	0.0	0.0	0.0
27	IRON	4.74300E-03	4.74300E-03	3.86192E-04	0.0	0.0	0.0	0.0	0.0
28	NICKEL	6.40000E-02	6.40000E-02	9.49120E-03	0.0	0.0	0.0	0.0	0.0
29	MOLY	9.37500E-03	9.37500E-03	2.23698E-03	0.0	0.0	0.0	0.0	0.0

MATERIAL 4

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
23	GRAPHITE	9.53000E-02	9.53000E-02	2.65749E-02	0.0	0.0	0.0	0.0	0.0

THICKNESSES AND OTHER REGION INFORMATION

DIMENSION 1

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	3.600000E 02	36	1	1	0.0	3.600000E 02
2	PLENA	3.000000E 01	6	2	1	3.600000E 02	3.900000E 02
3	REFLECT	1.000000E 02	20	3	1	3.900000E 02	4.900000E 02
4	VESSEL	1.000000E 01	5	1	0	4.900000E 02	5.000000E 02

DIMENSION 2

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	2.015394E 02	40	1	1	0.0	2.015393E 02
2	WALL	1.000000E 00	3	1	1	2.015393E 02	2.025393E 02
3	BLANKET	7.999991E 01	20	2	1	2.025393E 02	2.825391E 02
4	VESSEL	1.000000E 01	5	1	0	2.825391E 02	2.925391E 02

SUPER REGION VOLUME FRACTIONS

SUPER REGION		MATERIAL 1	2	3	4
1	CORE(1)	0.143037	0.0	0.0	0.856963
2	WALL	0.0	0.0	0.300000	0.700000
3	BLANKET	0.0	0.500000	0.0	0.500000
4	PLENA	0.500000	0.0	0.0	0.500000
5	AX REFL	0.010000	0.0	0.0	0.990000
6	VESSEL	0.0	0.0	1.000000	0.0

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OBJECTIVE FUNCTION=  3.684213E 01                    BALANCE=  1.000031E 00
     BREEDING RATIO=  1.038265E 00                      YIELD=  3.111497E 00
   FUEL CYCLE COST=  6.826624E-01                SPECIFIC POWER=  2.410637E 00
SPECIFIC INVENTORY=  4.148280E-01    CONSERVATION COEFFICIENT=  2.223657E-01
       FLUX FACTOR= -8.608376E-05                ALLOWABLE FLUX=  1.210000E 14
     MAXIMUM FLUX=  1.219278E 14

                                 OPTI                  USED
                 1  CORE RAD=  2.015394E 02          2.015394E 02
                 2  THK R B =  7.999991E 01          7.999991E 01
                 3  VF S CCR=  1.430366E-01          1.430366E-01
                 4  BLK CY T=  2.698135E 01          2.698135E 01
ENTERED WLKEP  14

OBJECTIVE FUNCTION=  3.683676E 01                    BALANCE=  9.999604E-01
     BREEDING RATIO=  1.038599E 00                      YIELD=  3.125998E 00
   FUEL CYCLE COST=  6.856261E-01                SPECIFIC POWER=  2.401000E 00
SPECIFIC INVENTORY=  4.164930E-01    CONSERVATION COEFFICIENT=  2.225156E-01
       FLUX FACTOR=  0.0                         ALLOWABLE FLUX=  1.210000E 14
     MAXIMUM FLUX=  1.204638E 14

                                 OPTI                  USED
                 1  CORE RAD=  2.027894E 02          2.027894E 02
                 2  THK R B =  7.999997E 01          7.999997E 01
                 3  VF S CCR=  1.430368E-01          1.430368E-01
                 4  BLK CY T=  2.698140E 01          2.698140E 01
ENTERED WLKEP  15

OBJECTIVE FUNCTION=  3.678149E 01                    BALANCE=  9.999557E-01
     BREEDING RATIO=  1.038393E 00                      YIELD=  3.121535E 00
   FUEL CYCLE COST=  6.897578E-01                SPECIFIC POWER=  2.410327E 00
SPECIFIC INVENTORY=  4.148815E-01    CONSERVATION COEFFICIENT=  2.230510E-01
       FLUX FACTOR= -8.571681E-05                ALLOWABLE FLUX=  1.210000E 14
     MAXIMUM FLUX=  1.219258E 14
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                                OPTI                    USED
                    1  CORE RAD=  2.015394E 02          2.015394E 02
                    2  THK R B =  8.499995E 01          8.499995E 01
                    3  VF S COR=  1.430368E-01          1.430368E-01
                    4  BLK CY T=  2.698140E 01          2.698140E 01
ENTERED WLKEP   16

              OBJECTIVE FUNCTION=  3.720668E 01                BALANCE=  1.000011E 00
                  BREEDING RATIO=  1.039407E 00                  YIELD=  3.184034E 00
                 FUEL CYCLE COST=  6.843716E-01            SPECIFIC POWER=  2.395219E 00
              SPECIFIC INVENTORY=  4.174982E-01  CONSERVATION COEFFICIENT=  2.260795E-01
                     FLUX FACTOR= -5.278073E-05            ALLOWABLE FLUX=  1.210000E 14
                    MAXIMUM FLUX=  1.217265E 14

                                OPTI                    USED
                    1  CORE RAD=  2.015394E 02          2.015394E 02
                    2  THK R B =  7.999997E 01          7.999997E 01
                    3  VF S COR=  1.449118E-01          1.449118E-01
                    4  BLK CY T=  2.698140E 01          2.698140E 01
ENTERED WLKEP   17

              OBJECTIVE FUNCTION=  3.692700E 01                BALANCE=  1.000037E 00
                  BREEDING RATIO=  1.038258E 00                  YIELD=  3.105129E 00
                 FUEL CYCLE COST=  6.757975E-01            SPECIFIC POWER=  2.406215E 00
              SPECIFIC INVENTORY=  4.155905E-01  CONSERVATION COEFFICIENT=  2.215064E-01
                     FLUX FACTOR= -8.384454E-05            ALLOWABLE FLUX=  1.210000E 14
                    MAXIMUM FLUX=  1.219157E 14

                                OPTI                    USED
                    1  CORE RAD=  2.015394E 02          2.015394E 02
                    2  THK R B =  7.999997E 01          7.999997E 01
                    3  VF S COR=  1.430368E-01          1.430368E-01
                    4  BLK CY T=  4.198138E 01          4.198138E 01
ENTERED WLKEP   18

PARTIAL DERIVATIVES OF GRADIENT EVALUATION
 -0.1074219E 00 -0.1212769E 01  0.7290955E 01  0.1697388E 01

ALPHA =   0.500000E-01      BETA =   0.100000E 00
   0.102400E 00   0.409600E 00   0.976563E 00   0.100000E 01

              OBJECTIVE FUNCTION=  3.788400E 01                BALANCE=  1.000056E 00
                  BREEDING RATIO=  1.041643E 00                  YIELD=  3.316446E 00
                 FUEL CYCLE COST=  6.809700E-01            SPECIFIC POWER=  2.360393E 00
              SPECIFIC INVENTORY=  4.236583E-01  CONSERVATION COEFFICIENT=  2.320127E-01
                     FLUX FACTOR= -8.735819E-06            ALLOWABLE FLUX=  1.210000E 14
                    MAXIMUM FLUX=  1.212956E 14

                                OPTI                    USED
                    1  CORE RAD=  2.015243E 02          2.015243E 02
                    2  THK R B =  7.931863E 01          7.931863E 01
                    3  VF S COR=  1.488961E-01          1.488961E-01
                    4  BLK CY T=  3.396561E 01          3.396561E 01
ENTERED WLKEP   19

SUCCESSFUL STEP NO. 1

              OBJECTIVE FUNCTION=  3.853891E 01                BALANCE=  1.000051E 00
                  BREEDING RATIO=  1.044677E 00                  YIELD=  3.482639E 00
                 FUEL CYCLE COST=  6.800709E-01            SPECIFIC POWER=  2.309738E 00
              SPECIFIC INVENTORY=  4.329494E-01  CONSERVATION COEFFICIENT=  2.383457E-01
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                    FLUX FACTOR=  0.0                          ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.205958E 14

                                 OPTI                       USED
                  1  CORE RAD=  2.015092E 02              2.015092E 02
                  2  THK R B =  7.863730E 01              7.863730E 01
                  3  VF S CDR=  1.547554E-01              1.547554E-01
                  4  BLK CY T=  4.094981E 01              4.094981E 01
ENTERED WLKEP   20

SUCCESSFUL STEP NO. 2

              OBJECTIVE FUNCTION=  3.883035E 01                    BALANCE=  9.999641E-01
                  BREEDING RATIO=  1.047318E 00                      YIELD=  3.608315E 00
                 FUEL CYCLE COST=  6.807234E-01                SPECIFIC POWER=  2.258701E 00
              SPECIFIC INVENTORY=  4.427322E-01    CONSERVATION COEFFICIENT=  2.414012E-01
                    FLUX FACTOR=  0.0                          ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.198525E 14

                                 OPTI                       USED
                  1  CORE RAD=  2.014941E 02              2.014941E 02
                  2  THK R B =  7.795596E 01              7.795596E 01
                  3  VF S CDR=  1.606147E-01              1.606147E-01
                  4  BLK CY T=  4.793402E 01              4.793402E 01
ENTERED WLKEP   21

SUCCESSFUL STEP NO. 3

              OBJECTIVE FUNCTION=  3.897646E 01                    BALANCE=  1.000078E 00
                  BREEDING RATIO=  1.049838E 00                      YIELD=  3.717553E 00
                 FUEL CYCLE COST=  6.819490E-01                SPECIFIC POWER=  2.208693E 00
              SPECIFIC INVENTORY=  4.527565E-01    CONSERVATION COEFFICIENT=  2.431262E-01
                    FLUX FACTOR=  0.0                          ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.191590E 14

                                 OPTI                       USED
                  1  CORE RAD=  2.014790E 02              2.014790E 02
                  2  THK R B =  7.727463E 01              7.727463E 01
                  3  VF S CDR=  1.664740E-01              1.664740E-01
                  4  BLK CY T=  5.491823E 01              5.491823E 01
ENTERED WLKEP   22

SUCCESSFUL STEP NO. 4

              OBJECTIVE FUNCTION=  3.888649E 01                    BALANCE=  9.998289E-01
                  BREEDING RATIO=  1.051122E 00                      YIELD=  3.760030E 00
                 FUEL CYCLE COST=  6.825325E-01                SPECIFIC POWER=  2.177312E 00
              SPECIFIC INVENTORY=  4.592817E-01    CONSERVATION COEFFICIENT=  2.423519E-01
                    FLUX FACTOR=  0.0                          ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.186902E 14

                                 OPTI                       USED
                  1  CORE RAD=  2.014639E 02              2.014639E 02
                  2  THK R B =  7.659329E 01              7.659329E 01
                  3  VF S CDR=  1.700000E-01              1.700000E-01
                  4  BLK CY T=  6.190244E 01              6.190244E 01
ENTERED WLKEP   23

FIRST SEARCH FAILURE ALONG GRADIENT

FITTING PARABOLA TO LAST 3 POINTS TO DETERMINE AN INITIAL POINT FOR GRADIENT EVALUATION
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MINMAX OF PARABOLA USED FOR GRADIENT EVALUATION

RAPID SEPTEMBER 1967 ROD-18 P X4916 X1306 BLANKETED MSBR 1000 MWE TF 9 10TH238E Q

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	1.0000E-04
RESONANCE INTEGRAL FACTOR	2.3368E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.1064E 00
CONCENTRATION DAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR	1.01000

MATERIAL	VOLUME	TIME S	TIME P	TIME R	OPTION
1	1.3361E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	2.6731E 03	5.5751E 01	2.5000E-01	0.0	0
3	8.1829E 02	0.0	0.0	0.0	0
4	5.7807E 03	0.0	0.0	0.0	0

BD= 1.000015E 00 BS= 1.000031E 00 F1= 9.995831E-01 ETA= 2.234986E 00
IE= 1.021699E 03 PL= 7.829533E-04 Y = 3.721648E 00 FCC= 6.823838E-01
BR= 1.050037E 00 NO OF ITERS= 3 KI= 9.999817E-01 KC = 9.999971E-01

/**********RATES,KG PER DAY**********//*******FUEL CYCLE COSTS*******/

NUCLIDE	ABS	CAP	FIS	TOT INV,KG	FEED	PROCESS	LOSS	PRODUCT	INV.	REPL.	PROC	CREDIT
1 TH-232	0.9672	0.9647	0.0026	1.353E 05	2.310E 01	2.059E 01	2.059E 01	0.0	0.0483	0.0183	0.2184	0.0
2 PA-233	0.0060	0.0060	0.0000	9.867E 01	0.0	1.934E 00	1.871E-06	0.0	0.0241	0.0	0.0	0.0
3 U-233	0.9129	0.0575	0.8154	8.391E 02	0.0	8.122E 01	8.113E-05	1.162E-01	0.2052	0.0	0.0	0.0630
4 U-234	0.0867	0.0863	0.0004	2.161E 02	0.0	3.084E 01	3.084E-05	4.416E-02	0.0	0.0	0.0	0.0
5 U-235	0.0819	0.0149	0.0670	8.272E 01	0.0	8.070E 00	8.070E-06	1.156E-02	0.0174	0.0	0.0	0.0054
6 U-236	0.0091	0.0090	0.0000	8.929E 01	0.0	1.529E-02	1.529E-02	0.0	0.0	0.0	0.0	0.0
7 NP-237	0.0082	0.0082	0.0000	1.269E 01	0.0	2.173E-03	2.173E-03	0.0	0.0	0.0	0.0	0.0
8 U-238	0.0047	0.0046	0.0000	5.514E 01	0.0	9.442E-03	9.442E-03	0.0	0.0	0.0	0.1087	0.0
9 PU-239	0.0041	0.0016	0.0025	8.954E-01	0.0	1.492E-03	1.492E-03	0.0	0.0002	0.0	0.0	0.0
10 PU-240	0.0013	0.0013	0.0000	4.637E-01	0.0	7.724E-04	7.724E-04	0.0	0.0	0.0	0.0	0.0
11 PU-241	0.0011	0.0003	0.0008	3.063E-01	0.0	5.102E-04	5.102E-04	0.0	0.0001	0.0	0.0	0.0
12 PU-242	0.0001	0.0001	0.0000	3.048E-01	0.0	5.078E-04	5.078E-04	0.0	0.0	0.0	0.0	0.0
13 BE-9	0.0083	0.0017	0.0066	1.209E 04	1.840E 00	1.839E 00	1.839E 00	0.0	0.0196	0.0066	0.0	0.0
14 BE-9 NA	0.0024	0.0024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 LI-7	0.0190	0.0190	0.0	2.722E 04	4.144E 00	4.143E 00	4.143E 00	0.0	0.0628	0.0212	0.0	0.0
16 LI-6	0.0049	0.0049	0.0000	2.636E-01	1.776E-04	3.494E-05	3.494E-05	0.0	0.0	0.0	0.0	0.0
17 F	0.0233	0.0233	0.0	0.0	0.0	2.595E 01	2.595E 01	0.0	0.0	0.0	0.0	0.0
18 FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19 LEAKAGE	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20 DEL NEUT	0.0028	0.0028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21 FIX P FR	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 GRAPHITE	0.0470	0.0470	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25 LUMP FP	0.0137	0.0137	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26 CHROME	0.0014	0.0014	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 IRON	0.0008	0.0008	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28 NICKEL	0.0185	0.0185	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29 MOLY	0.0048	0.0048	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.2350								0.3777	0.0461	0.3270	0.0684

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	4.06632E-01	4.50951E 04	4.51002E 04	2.29476E 01	2.05914E 01	0.0
2	PA-233	1.27817E-06	1.27812E-06	2.68111E-03	1.87089E 01	9.26658E 01	0.0	1.87089E 00	0.0
3	U-233	5.54215E-05	5.54329E-05	4.08380E-01	8.11272E 02	8.34167E 02	0.0	8.11271E 01	1.16169E-01
4	U-234	2.09763E-05	2.09771E-05	3.87731E-02	3.08376E 02	3.16086E 02	0.0	3.08376E 01	4.41576E-02
5	U-235	5.46594E-06	5.46634E-06	3.66435E-02	8.07023E 01	8.27199E 01	0.0	8.07022E 00	1.15561E-02
6	U-236	6.02162E-06	6.02219E-06	4.06390E-03	8.92869E 01	8.92907E 01	0.0	1.52889E-02	0.0
7	NP-237	8.52211E-07	8.52381E-07	3.67907E-03	1.26912E 01	1.26918E 01	0.0	2.17315E-03	0.0
8	U-238	3.68653E-06	3.68772E-06	2.08362E-03	5.51386E 01	5.51410E 01	0.0	9.44154E-03	0.0
9	PU-239	5.95813E-08	5.96124E-08	1.82889E-03	8.95067E-01	8.95440E-01	0.0	1.49178E-03	0.0
10	PU-240	3.07172E-08	3.07385E-08	5.67081E-04	4.63463E-01	4.63656E-01	0.0	7.72438E-04	0.0
11	PU-241	2.02017E-08	2.02301E-08	4.82050E-04	3.06141E-01	3.06268E-01	0.0	5.10234E-04	0.0
12	PU-242	2.00181E-08	2.00395E-08	4.37723E-05	3.04665E-01	3.04792E-01	0.0	5.07775E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.59424E-03	4.02826E 03	4.02872E 03	1.84020E 00	1.83929E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	1.03300E-03	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	7.88212E-03	9.07232E 03	9.07336E 03	4.14399E 00	4.14261E 00	0.0
16	LI-6	2.03001E-07	2.03004E-07	1.98497E-03	7.65203E-02	7.65290E-02	1.77600E-04	3.49408E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.87917E-03	0.0	0.0	0.0	2.59467E 01	0.0
18	FP REF E	1.00000E-08	1.00000E-08	1.03418E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	1.99598E-05	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.12585E-04	1.12583E-04	1.16431E-02	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.76969E-11	8.76951E-11	2.23661E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.85685E-04	2.85666E-04	2.95441E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.21256E-09	3.21271E-09	2.63954E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.39488E-09	8.39506E-09	5.24743E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	2.61326E-02	9.02193E 04	9.02193E 04	1.51422E-01	0.0	0.0
2	PA-233	1.19887E-07	1.19918E-07	1.95021E-05	3.51182E 00	6.00189E 00	0.0	6.29914E-02	0.0
3	U-233	1.68018E-07	1.68061E-07	5.60109E-05	4.92168E 00	4.94375E 00	0.0	8.82801E-02	0.0
4	U-234	3.26997E-10	3.27155E-10	4.08018E-08	9.62201E-03	9.66516E-03	0.0	1.72590E-04	0.0
5	U-235	4.48477E-13	4.48805E-13	2.31035E-10	1.32561E-05	1.33155E-05	0.0	2.37774E-07	0.0
6	U-236	4.53218E-14	4.53653E-14	2.07312E-12	1.34563E-06	1.34569E-06	0.0	2.30417E-10	0.0
7	NP-237	1.69059E-15	1.69247E-15	6.12017E-13	5.04150E-08	5.04172E-08	0.0	8.63271E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	1.13121E-04	8.05911E 03	8.05911E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	2.08116E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	6.18793E-04	1.81505E 04	1.81505E 04	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	1.90272E-04	1.87022E-01	1.87022E-01	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	5.46131E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	8.11702E-09	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	1.10391E-04	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	4.60991E-06	4.61178E-06	3.74351E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	1.49874E-11	1.49915E-11	9.35477E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.16260E-11	8.16553E-11	3.79280E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
26 CHROME	7.11900E-03	7.11900E-03	6.14874E-04	0.0	0.0	0.0	0.0	0.0
27 IRON	4.74300E-03	4.74300E-03	3.35892E-04	0.0	0.0	0.0	0.0	0.0
28 NICKEL	6.40000E-02	6.40000E-02	8.25731E-03	0.0	0.0	0.0	0.0	0.0
29 MOLY	9.37500E-03	9.37500E-03	2.14122E-03	0.0	0.0	0.0	0.0	0.0

MATERIAL 4

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******/ SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
23 GRAPHITE	9.53000E-02	9.53000E-02	2.10315E-02	0.0	0.0	0.0	0.0	0.0

THICKNESSES AND OTHER REGION INFORMATION

DIMENSION 1

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	3.600000E 02	36	1	1	0.0	3.600000E 02
2	PLENA	3.000000E 01	6	2	1	3.600000E 02	3.900000E 02
3	REFLECT	1.000000E 02	20	3	1	3.900000E 02	4.900000E 02
4	VESSEL	1.000000E 01	5	1	0	4.900000E 02	5.000000E 02

DIMENSION 2

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	2.014772E 02	40	1	1	0.0	2.014772E 02
2	WALL	1.000000E 00	3	1	1	2.014772E 02	2.024772E 02
3	BLANKET	7.719347E 01	20	2	1	2.024772E 02	2.796704E 02
4	VESSEL	1.000000E 01	5	1	0	2.796704E 02	2.896704E 02

SUPER REGION VOLUME FRACTIONS

SUPER REGION		MATERIAL 1	2	3	4
1	CORE(1)	0.167173	0.0	0.0	0.832827
2	WALL	0.0	0.0	0.300000	0.700000
3	BLANKET	0.0	0.500000	0.0	0.500000
4	PLENA	0.500000	0.0	0.0	0.500000
5	AX REFL	0.010000	0.0	0.0	0.990000
6	VESSEL	0.0	0.0	1.000000	0.0

OBJECTIVE FUNCTION=	3.892133E 01	BALANCE=	1.000031E 00
BREEDING RATIO=	1.050037E 00	YIELD=	3.721648E 00
FUEL CYCLE COST=	6.823838E-01	SPECIFIC POWER=	2.202213E 00
SPECIFIC INVENTORY=	4.540885E-01	CONSERVATION COEFFICIENT=	2.426684E-01
FLUX FACTOR=	0.0	ALLOWABLE FLUX=	1.210000E 14
MAXIMUM FLUX=	1.185885E 14		

		OPTI	USED
1	CORE RAD=	2.014772E 02	2.014772E 02
2	THK R B =	7.719347E 01	7.719347E 01
3	VF S COR=	1.671726E-01	1.671726E-01
4	BLK CY T=	5.575070E 01	5.575070E 01

ENTERED WLKEP 24

END OPTI CYCLE 2

PARABOLIC FIT REJECTED. LOWEST PREVIOUS POINT USED.

PARABOLIC FIT WAS REJECTED-GO BACK TO MERC TO GET FULL OUTPUT FOR LAST SUCCESSFUL STEP

RAPID SEPTEMBER 1967 ROD-18 P X4916 X1306 BLANKETED MSBR 1000 MWE TF 9 10TH23BE 0

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	1.0000E-04
RESONANCE INTEGRAL FACTOR	2.3232E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.1058E 00
CONCENTRATION DAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR	1.01000

MATERIAL	VOLUME	TIME S	TIME P	TIME R	OPTION
1	1.3339E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	2.6756E 03	5.4918E 01	2.5000E-01	0.0	0
3	8.1857E 02	0.0	0.0	0.0	0
4	5.7655E 03	0.0	0.0	0.0	0

BO= 1.000014E 00 BS= 1.000053E 00 F1= 9.995869E-01 ETA= 2.235109E 00
IF= 1.018837E 03 PL= 7.796583E-04 Y = 3.713556E 00 FCC= 6.820619E-01
BR= 1.049791E 00 NO OF ITERS= 3 K1= 9.999588E-01 KC = 9.999933E-01

/**********RATES,KG PER DAY**********//*******FUEL CYCLE COSTS*******/

NUCLIDE		ABS	CAP	FIS	TOT INV,KG	FEED	PROCESS	LOSS	PRODUCT	INV.	REPL.	PROC	CREDIT
1	TH-232	0.9670	0.9645	0.0026	1.353E 05	2.306E 01	2.056E 01	2.056E 01	0.0	0.0483	0.0183	0.2185	0.0
2	PA-233	0.0060	0.0060	0.0000	9.864E 01	0.0	1.934E 00	1.870E-06	0.0	0.0241	0.0	0.0	0.0
3	U-233	0.9129	0.0975	0.8155	8.366E 02	0.0	8.098E 01	8.089E-05	1.156E-01	0.2046	0.0	0.0	0.0627
4	U-234	0.0866	0.0863	0.0004	2.156E 02	0.0	3.079E 01	3.079E-05	4.402E-02	0.0	0.0	0.0	0.0
5	U-235	0.0819	0.0149	0.0670	8.243E 01	0.0	8.042E 00	8.042E-06	1.150E-02	0.0174	0.0	0.0	0.0054
6	U-236	0.0091	0.0090	0.0000	8.927E 01	0.0	1.529E-02	1.529E-02	0.0	0.0	0.0	0.0	0.0
7	NP-237	0.0082	0.0082	0.0000	1.266E 01	0.0	2.167E-03	2.167E-03	0.0	0.0	0.0	0.0	0.0
8	U-238	0.0047	0.0046	0.0000	5.513E 01	0.0	9.439E-03	9.439E-03	0.0	0.0	0.0	0.1086	0.0
9	PU-239	0.0041	0.0016	0.0025	8.914E-01	0.0	1.485E-03	1.485E-03	0.0	0.0002	0.0	0.0	0.0
10	PU-240	0.0013	0.0013	0.0000	4.630E-01	0.0	7.714E-04	7.714E-04	0.0	0.0	0.0	0.0	0.0
11	PU-241	0.0011	0.0003	0.0008	3.051E-01	0.0	5.083E-04	5.083E-04	0.0	0.0001	0.0	0.0	0.0
12	PU-242	0.0001	0.0001	0.0000	3.048E-01	0.0	5.077E-04	5.077E-04	0.0	0.0	0.0	0.0	0.0
13	BE-9	0.0083	0.0017	0.0066	1.209E 04	1.837E 00	1.836E 00	1.836E 00	0.0	0.0196	0.0066	0.0	0.0
14	BE-9 NA	0.0023	0.0023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	LI-7	0.0190	0.0190	0.0	2.723E 04	4.137E 00	4.136E 00	4.136E 00	0.0	0.0628	0.0211	0.0	0.0
16	LI-6	0.0049	0.0049	0.0000	2.633E-01	1.773E-04	3.474E-05	3.474E-05	0.0	0.0	0.0	0.0	0.0
17	F	0.0233	0.0233	0.0	0.0	0.0	2.590E 01	2.590E 01	0.0	0.0	0.0	0.0	0.0
18	FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	0.0028	0.0028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	GRAPHITE	0.0473	0.0473	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	0.0137	0.0137	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	CHROME	0.0014	0.0014	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	IRON	0.0008	0.0008	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	NICKEL	0.0185	0.0185	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	MOLY	0.0048	0.0048	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		2.2351								0.3770	0.0460	0.3271	0.0681

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	4.06465E-01	4.50191E 04	4.50242E 04	2.29119E 01	2.05567E 01	0.0
2	PA-233	1.27984E-06	1.27978E-06	2.68070E-03	1.87017E 01	9.26299E 01	0.0	1.87017E 00	0.0
3	U-233	5.53499E-05	5.53532E-05	4.08361E-01	8.08888E 02	8.31724E 02	0.0	8.08887E 01	1.15635E-01
4	U-234	2.09798E-05	2.09827E-05	3.87604E-02	3.07939E 02	3.15638E 02	0.0	3.07939E 01	4.40216E-02
5	U-235	5.45515E-06	5.45630E-06	3.66404E-02	8.04182E 01	8.24287E 01	0.0	8.04181E 00	1.14962E-02
6	U-236	6.03019E-06	6.03115E-06	4.05951E-03	8.92690E 01	8.92728E 01	0.0	1.52858E-02	0.0
7	NP-237	8.51227E-07	8.51405E-07	3.67577E-03	1.26553E 01	1.26559E 01	0.0	2.16700E-03	0.0
8	U-238	3.69233E-06	3.69292E-06	2.08083E-03	5.51233E 01	5.51256E 01	0.0	9.43892E-03	0.0
9	PU-239	5.94318E-08	5.94459E-08	1.82723E-03	8.91062E-01	8.91434E-01	0.0	1.48510E-03	0.0
10	PU-240	3.07412E-08	3.07471E-08	5.66611E-04	4.62811E-01	4.63003E-01	0.0	7.71350E-04	0.0
11	PU-241	2.01713E-08	2.01756E-08	4.81911E-04	3.04955E-01	3.05082E-01	0.0	5.08259E-04	0.0
12	PU-242	2.00687E-08	2.00716E-08	4.37428E-05	3.04640E-01	3.04767E-01	0.0	5.07732E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.58587E-03	4.02147E 03	4.02192E 03	1.83709E 00	1.83629E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	1.02950E-03	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	7.89837E-03	9.05703E 03	9.05806E 03	4.13701E 00	4.13563E 00	0.0
16	LI-6	2.02146E-07	2.02164E-07	1.98081E-03	7.60753E-02	7.60840E-02	1.77300E-04	3.47376E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.87024E-03	0.0	0.0	0.0	2.59030E 01	0.0
18	FP REF E	1.00000E-08	1.00000E-08	1.03631E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	1.98694E-05	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.12337E-04	1.12347E-04	1.16426E-03	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.74545E-11	8.74622E-11	2.23645E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.85486E-04	2.85494E-04	2.95876E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.20600E-09	3.20631E-09	2.64091E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.39659E-09	8.39698E-09	5.26126E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	2.61737E-02	9.03031E 04	9.03031E 04	1.51661E-01	0.0	0.0
2	PA-233	1.19229E-07	1.19248E-07	1.94063E-05	3.49544E 00	6.01147E 00	0.0	6.36481E-02	0.0
3	U-233	1.64615E-07	1.64642E-07	9.42633E-05	4.82603E 00	4.84800E 00	0.0	8.78765E-02	0.0
4	U-234	3.18808E-10	3.18910E-10	3.98227E-08	9.38812E-03	9.43086E-03	0.0	1.70947E-04	0.0
5	U-235	4.30932E-13	4.31138E-13	2.22494E-10	1.27461E-05	1.28042E-05	0.0	2.32093E-07	0.0
6	U-236	4.36077E-14	4.36356E-14	1.99388E-12	1.29553E-06	1.29558E-06	0.0	2.21838E-10	0.0
7	NP-237	1.62470E-15	1.62591E-15	5.88978E-13	4.84775E-08	4.84796E-08	0.0	8.30094E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	1.13230E-04	8.06660E 03	8.06660E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	2.07985E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	6.20425E-04	1.81674E 04	1.81674E 04	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	1.90773E-04	1.87196E-01	1.87196E-01	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	5.46989E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	8.13839E-09	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	1.10682E-04	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	4.53692E-06	4.53816E-06	3.69353E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	1.47399E-11	1.47421E-11	9.22574E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.01896E-11	8.02067E-11	3.73588E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

		/*********DENSITY**********/		/******INVENTORIES,KG******/			/**********RATES,KG/DAY**********/		
NUCLIDE		INITIAL	FINAL	ABSORPTIONS	SYSTEM	TOTAL	FEED	PROCESS	PRODUCT
26	CHROME	7.11900E-03	7.11900E-03	6.17048E-04	0.0	0.0	0.0	0.0	0.0
27	IRON	4.74300E-03	4.74300E-03	3.37073E-04	0.0	0.0	0.0	0.0	0.0
28	NICKEL	6.40000E-02	6.40000E-02	8.28629E-03	0.0	0.0	0.0	0.0	0.0
29	MOLY	9.37500E-03	9.37500E-03	2.14316E-03	0.0	0.0	0.0	0.0	0.0

MATERIAL 4

		/*********DENSITY**********/		/******INVENTORIES,KG******/			/**********RATES,KG/DAY**********/		
NUCLIDE		INITIAL	FINAL	ABSORPTIONS	SYSTEM	TOTAL	FEED	PROCESS	PRODUCT
23	GRAPHITE	9.53000E-02	9.53000E-02	2.11712E-02	0.0	0.0	0.0	0.0	0.0

THICKNESSES AND OTHER REGION INFORMATION

DIMENSION 1

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	3.600000E 02	36	1	1	0.0	3.600000E 02
2	PLENA	3.000000E 01	6	2	1	3.600000E 02	3.900000E 02
3	REFLECT	1.000000E 02	20	3	1	3.900000E 02	4.900000E 02
4	VESSEL	1.000000E 01	5	1	0	4.900000E 02	5.000000E 02

DIMENSION 2

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	2.014790E 02	40	1	1	0.0	2.014790E 02
2	WALL	1.000000E 00	3	1	1	2.014790E 02	2.024790E 02
3	BLANKET	7.727463E 01	20	2	1	2.024790E 02	2.797534E 02
4	VESSEL	1.000000E 01	5	1	0	2.797534E 02	2.897534E 02

SUPER REGION VOLUME FRACTIONS

SUPER REGION		MATERIAL 1	2	3	4
1	CORE(1)	0.166474	0.0	0.0	0.833526
2	WALL	0.0	0.0	0.300000	0.700000
3	BLANKET	0.0	0.500000	0.0	0.500000
4	PLENA	0.500000	0.0	0.0	0.500000
5	AX REFL	0.010000	0.0	0.0	0.990000
6	VESSEL	0.0	0.0	1.000000	0.0

OBJECTIVE FUNCTION=	3.894479E 01	BALANCE=	1.000053E 00
BREEDING RATIO=	1.049791E 00	YIELD=	3.713596E 00
FUEL CYCLE COST=	6.820619E-01	SPECIFIC POWER=	2.208400E 00
SPECIFIC INVENTORY=	4.528165E-01	CONSERVATION COEFFICIENT=	2.428338E-01
FLUX FACTOR=	0.0	ALLOWABLE FLUX=	1.210000E 14
MAXIMUM FLUX=	1.190576E 14		

		OPTI	USED
1	CORE RAD=	2.014790E 02	2.014790E 02
2	THK R B =	7.727463E 01	7.727463E 01
3	VF S COR=	1.664740E-01	1.664740E-01
4	BLK CY T=	5.491823E 01	5.491823E 01

ENTERED WLKEP 25

OBJECTIVE FUNCTION=	3.867399E 01	BALANCE=	1.000060E 00
BREEDING RATIO=	1.049878E 00	YIELD=	3.713045E 00
FUEL CYCLE COST=	6.830601E-01	SPECIFIC POWER=	2.204233E 00
SPECIFIC INVENTORY=	4.536725E-01	CONSERVATION COEFFICIENT=	2.423400E-01
FLUX FACTOR=	0.0	ALLOWABLE FLUX=	1.210000E 14
MAXIMUM FLUX=	1.184470E 14		

		OPTI	USED
1	CORE RAD=	2.019910E 02	2.019910E 02
2	THK R B =	7.727467E 01	7.727467E 01
3	VF S COR=	1.664742E-01	1.664742E-01
4	BLK CY T=	5.491826E 01	5.491826E 01

ENTERED WLKEP 26

OBJECTIVE FUNCTION=	3.886334E 01	BALANCE=	9.999756E-01
BREEDING RATIO=	1.049768E 00	YIELD=	3.710899E 00
FUEL CYCLE COST=	6.846583E-01	SPECIFIC POWER=	2.207731E 00
SPECIFIC INVENTORY=	4.529535E-01	CONSERVATION COEFFICIENT=	2.425752E-01
FLUX FACTOR=	0.0	ALLOWABLE FLUX=	1.210000E 14
MAXIMUM FLUX=	1.190254E 14		

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                                  OPTI                    USED
                1  CORE RAD=  2.014790E 02          2.014790E 02
                2  THK R B =  7.932266E 01          7.932266E 01
                3  VF S CCR=  1.664742E-01          1.664742E-01
                4  BLK CY T=  5.491826E 01          5.491826E 01
ENTERED WLKEP   27

          OBJECTIVE FUNCTION=  3.889902E 01                BALANCE=  1.000033E 00
              BREEDING RATIO=  1.050921E 00                  YIELD=  3.756650E 00
            FUEL CYCLE COST=  6.844615E-01            SPECIFIC POWER=  2.184011E 00
         SPECIFIC INVENTORY=  4.578731E-01  CONSERVATION COEFFICIENT=  2.428902E-01
                FLUX FACTOR=  0.0                     ALLOWABLE FLUX=  1.210000E 14
               MAXIMUM FLUX=  1.187000E 14

                                  OPTI                    USED
                1  CORE RAD=  2.014790E 02          2.014790E 02
                2  THK R B =  7.727467E 01          7.727467E 01
                3  VF S CCR=  1.694039E-01          1.694039E-01
                4  BLK CY T=  5.491826E 01          5.491826E 01
ENTERED WLKEP   28

          OBJECTIVE FUNCTION=  3.889500E 01                BALANCE=  1.000059E 00
              BREEDING RATIO=  1.049746E 00                  YIELD=  3.702782E 00
            FUEL CYCLE COST=  6.788756E-01            SPECIFIC POWER=  2.204014E 00
         SPECIFIC INVENTORY=  4.537175E-01  CONSERVATION COEFFICIENT=  2.416478E-01
                FLUX FACTOR=  0.0                     ALLOWABLE FLUX=  1.210000E 14
               MAXIMUM FLUX=  1.190289E 14

                                  OPTI                    USED
                1  CORE RAD=  2.014790E 02          2.014790E 02
                2  THK R B =  7.727467E 01          7.727467E 01
                3  VF S CCR=  1.664742E-01          1.664742E-01
                4  BLK CY T=  6.991824E 01          6.991824E 01
ENTERED WLKEP   29

PARTIAL DERIVATIVES OF GRADIENT EVALUATION
 -0.1416016E 01 -0.1629028E 01 -0.9152222E 00 -0.9957886E 00

ALPHA =   0.500000E-01      BETA =   0.100000E 00
   0.819198E-01   0.327680E 00   0.400000E 00   0.409600E 00

          OBJECTIVE FUNCTION=  3.889954E 01                BALANCE=  1.000161E 00
              BREEDING RATIO=  1.048756E 00                  YIELD=  3.665741E 00
            FUEL CYCLE COST=  6.786969E-01            SPECIFIC POWER=  2.226306E 00
         SPECIFIC INVENTORY=  4.491745E-01  CONSERVATION COEFFICIENT=  2.416543E-01
                FLUX FACTOR=  0.0                     ALLOWABLE FLUX=  1.210000E 14
               MAXIMUM FLUX=  1.199643E 14

                                  OPTI                    USED
                1  CORE RAD=  2.007669E 02          2.007669E 02
                2  THK R B =  7.399786E 01          7.399786E 01
                3  VF S CCR=  1.651258E-01          1.651258E-01
                4  BLK CY T=  4.740688E 01          4.740688E 01
ENTERED WLKEP   30

FIRST SEARCH FAILURE ALONG GRADIENT

NOW SCANNING INTERVAL

          OBJECTIVE FUNCTION=  3.889124E 01                BALANCE=  9.999958E-01
              BREEDING RATIO=  1.049467E 00                  YIELD=  3.696278E 00
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                    FUEL CYCLE COST=  6.813381E-01          SPECIFIC POWER=  2.212470E 00
                SPECIFIC INVENTORY=  4.519834E-01   CONSERVATION COEFFICIENT=  2.421425E-01
                         FLUX FACTOR=  0.0                  ALLOWABLE FLUX=  1.210000E 14
                       MAXIMUM FLUX=  1.192599E 14

                                  OPTI                    USED
                     1  CORE RAD=  2.013010E 02          2.013010E 02
                     2  THK R B =  7.645547E 01          7.645547E 01
                     3  VF S CCR=  1.661371E-01          1.661371E-01
                     4  BLK CY T=  5.304041E 01          5.304041E 01
ENTERED WLKEP   31

UNSUCCESSFUL FIRST STEP WHILE SCANNING WITH REDUCED SF AFTER UNSUCCESSFUL FIRST STEP WHILE SCANNING WITH ENLARGED SF
REDUCE ALPHA,BETA,RE EVALUATE ELSE OPTIMUM IS OBTAINED
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RAPID SEPTEMBER 1967 ROD-18 F X4916 Y1306 BLANKETED MSBR 1000 MWE TF 9 10TH23BE Q

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	1.0000E-04
RESONANCE INTEGRAL FACTOR	2.3236E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.1058E 00
CONCENTRATION DAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR	1.01000

MATERIAL	VOLUME	TIME S	TIME P	TIME R	OPTION
1	1.3339E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	2.6756E 03	5.4918E 01	2.5000E-01	0.0	0
3	8.1857E 02	0.0	0.0	0.0	0
4	5.7855E 03	0.0	0.0	0.0	0

BO= 1.000015E 00 BS= 1.000019E 00 F1= 9.995868E-01 ETA= 2.235097E 00
IF= 1.018975E 03 PL= 7.800625E-04 Y = 3.709950E 00 FCC= 6.821967E-01
BR= 1.049749E 00 NO OF ITERS= 3 KI= 9.999638E-01 KC = 9.999924E-01

/*********RATES,KG PER DAY*****************//*******FUEL CYCLE COSTS********/

NUCLIDE		ABS	CAP	FIS	TOT INV,KG	FEED	PROCESS	LOSS	PRODUCT	INV.	REPL.	PROC	CREDIT
1	TH-232	0.9669	0.9644	0.0026	1.353E 05	2.306E 01	2.056E 01	2.056E 01	0.0	0.0483	0.0183	0.2185	0.0
2	PA-233	0.0060	0.0060	0.0000	9.863E 01	0.0	1.934E 00	1.870E-06	0.0	0.0241	0.0	0.0	0.0
3	U-233	0.9129	0.0975	0.8155	8.367E 02	0.0	8.099E 01	8.090E-05	1.155E-01	0.2046	0.0	0.0	0.0626
4	U-234	0.0867	0.0863	0.0004	3.158E 02	0.0	3.081E 01	3.081E-05	4.397E-02	0.0	0.0	0.0	0.0
5	U-235	0.0819	0.0149	0.0671	8.248E 01	0.0	8.046E 00	8.046E-06	1.148E-02	0.0174	0.0	0.0	0.0054
6	U-236	0.0091	0.0090	0.0000	8.931E 01	0.0	1.529E-02	1.529E-02	0.0	0.0	0.0	0.0	0.0
7	NP-237	0.0082	0.0082	0.0000	1.266E 01	0.0	2.168E-03	2.168E-03	0.0	0.0	0.0	0.0	0.0
8	U-238	0.0047	0.0046	0.0000	5.515E 01	0.0	9.443E-03	9.443E-03	0.0	0.0	0.0	0.1086	0.0
9	PU-239	0.0041	0.0016	0.0025	8.919E-01	0.0	1.486E-03	1.486E-03	0.0	0.0002	0.0	0.0	0.0
10	PU-240	0.0013	0.0013	0.0000	4.622E-01	0.0	7.717E-04	7.717E-04	0.0	0.0	0.0	0.0	0.0
11	PU-241	0.0011	0.0003	0.0008	3.052E-01	0.0	5.085E-04	5.085E-04	0.0	0.0001	0.0	0.0	0.0
12	PU-242	0.0001	0.0001	0.0000	3.049E-01	0.0	5.079E-04	5.079E-04	0.0	0.0	0.0	0.0	0.0
13	BE-9	0.0083	0.0017	0.0066	1.209E 04	1.837E 00	1.836E 00	1.836E 00	0.0	0.0196	0.0066	0.0	0.0
14	BE-9 NA	0.0023	0.0023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	LI-7	0.0190	0.0190	0.0	2.723E 04	4.137E 00	4.136E 00	4.136E 00	0.0	0.0628	0.0211	0.0	0.0
16	LI-6	0.0049	0.0049	0.0000	2.633E-01	1.773E-04	3.475E-05	3.475E-05	0.0	0.0	0.0	0.0	0.0
17	F	0.0233	0.0233	0.0	0.0	0.0	2.590E 01	2.590E 01	0.0	0.0	0.0	0.0	0.0
18	FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	0.0028	0.0028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	GRAPHITE	0.0473	0.0473	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	0.0137	0.0137	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	CHROME	0.0014	0.0014	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	IRON	0.0008	0.0008	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	NICKEL	0.0185	0.0185	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	MOLY	0.0048	0.0048	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		2.2351								0.3770	0.0460	0.3271	0.0680

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******//**********RATES,KG/DAY**********/ SYSTEM	TOTAL	FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	4.06430E-01	4.50191E 04	4.50242E 04	2.29117E 01	2.05567E 01	0.0
2	PA-233	1.27963E-06	1.27965E-06	2.68029E-03	1.86997E 01	9.26202E 01	0.0	1.86997E 00	0.0
3	U-233	5.53569E-05	5.53599E-05	4.08349E-01	8.08984E 02	8.31822E 02	0.0	8.08983E 01	1.15456E-01
4	U-234	2.09926E-05	2.09909E-05	3.87721E-02	3.08060E 02	3.15761E 02	0.0	3.08059E 01	4.39654E-02
5	U-235	5.46045E-06	5.45941E-06	3.66550E-02	8.04641E 01	8.24757E 01	0.0	8.04640E 00	1.14836E-02
6	U-236	6.03613E-06	6.03369E-06	4.06123E-03	8.93066E 01	8.93105E 01	0.0	1.52922E-02	0.0
7	NP-237	8.52257E-07	8.51845E-07	3.67729E-03	1.26619E 01	1.26624E 01	0.0	2.16812E-03	0.0
8	U-238	3.69672E-06	3.69437E-06	2.08167E-03	5.51451E 01	5.51474E 01	0.0	9.44264E-03	0.0
9	PU-239	5.95156E-08	5.94788E-08	1.82791E-03	8.91556E-01	8.91928E-01	0.0	1.48592E-03	0.0
10	PU-240	3.07831E-08	3.07604E-08	5.66813E-04	4.63011E-01	4.63204E-01	0.0	7.71684E-04	0.0
11	PU-241	2.02008E-08	2.01860E-08	4.82067E-04	3.05109E-01	3.05236E-01	0.0	5.08514E-04	0.0
12	PU-242	2.00946E-08	2.00780E-08	4.37558E-05	3.04736E-01	3.04863E-01	0.0	5.07893E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.58600E-03	4.02147E 03	4.02193E 03	1.83709E 00	1.83629E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	1.02959E-03	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	7.89692E-03	9.05703E 03	9.05806E 03	4.13701E 00	4.13563E 00	0.0
16	LI-6	2.02189E-07	2.02207E-07	1.98087E-03	7.60916E-02	7.61002E-02	1.77300E-04	3.47450E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.66588E-03	0.0	0.0	0.0	2.59030E 01	0.0
18	FP REF E	1.00000E-08	1.00000E-08	1.03612E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	1.98535E-05	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.12361E-04	1.12375E-04	1.16434E-03	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.74698E-11	8.74836E-11	2.23654E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.85497E-04	2.85518E-04	2.95836E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.20698E-09	3.20687E-09	2.64074E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.39776E-09	8.39750E-09	5.26036E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	ABSORPTIONS	/******INVENTORIES,KG******//**********RATES,KG/DAY**********/ SYSTEM	TOTAL	FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	2.61792E-02	9.03031E 04	9.03031E 04	1.51693E-01	0.0	0.0
2	PA-233	1.19255E-07	1.19271E-07	1.94144E-05	3.49612E 00	6.01263E 00	0.0	6.36604E-02	0.0
3	U-233	1.64652E-07	1.64672E-07	9.42995E-05	4.82691E 00	4.84889E 00	0.0	8.78926E-02	0.0
4	U-234	3.18949E-10	3.19032E-10	3.98465E-08	9.39171E-03	9.43446E-03	0.0	1.71012E-04	0.0
5	U-235	4.31224E-13	4.31382E-13	2.22663E-10	1.27534E-05	1.28114E-05	0.0	2.32224E-07	0.0
6	U-236	4.36479E-14	4.36672E-14	1.99580E-12	1.29647E-06	1.29652E-06	0.0	2.21998E-10	0.0
7	NP-237	1.62651E-15	1.62733E-15	5.89612E-13	4.85196E-08	4.85217E-08	0.0	8.30814E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	1.13256E-04	8.06660E 03	8.06660E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	2.08041E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	6.20546E-04	1.81674E 04	1.81674E 04	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	1.90810E-04	1.87196E-01	1.87196E-01	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	5.47107E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	8.13997E-05	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	1.10704E-04	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	4.53870E-06	4.53986E-06	3.69551E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	1.47438E-11	1.47447E-11	9.22880E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.02170E-11	8.02264E-11	3.73739E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	//**********RATES,KG/DAY**********/ TOTAL	FEED	PROCESS	PRODUCT
26 CHROME	7.11900E-03	7.11900E-03	6.17630E-04	0.0	0.0	0.0	0.0	0.0
27 IRON	4.74300E-03	4.74300E-03	3.37390E-04	0.0	0.0	0.0	0.0	0.0
28 NICKEL	6.40000E-02	6.40000E-02	8.29407E-03	0.0	0.0	0.0	0.0	0.0
29 MOLY	9.37500E-03	9.37500E-03	2.14445E-03	0.0	0.0	0.0	0.0	0.0

MATERIAL 4

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	//**********RATES,KG/DAY**********/ TOTAL	FEED	PROCESS	PRODUCT
23 GRAPHITE	9.53000E-02	9.53000E-02	2.11737E-02	0.0	0.0	0.0	0.0	0.0

THICKNESSES AND OTHER REGION INFORMATION

DIMENSION 1

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	3.600000E 02	36	1	1	0.0	3.600000E 02
2	PLENA	3.000000E 01	6	2	1	3.600000E 02	3.900000E 02
3	REFLECT	1.000000E 02	20	3	1	3.900000E 02	4.900000E 02
4	VESSEL	1.000000E 01	5	1	0	4.900000E 02	5.000000E 02

DIMENSION 2

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	2.014790E 02	40	1	1	0.0	2.014790E 02
2	WALL	1.000000E 00	3	1	1	2.014790E 02	2.024790E 02
3	BLANKET	7.727467E 01	20	2	1	2.024790E 02	2.797534E 02
4	VESSEL	1.000000E 01	5	1	0	2.797534E 02	2.897534E 02

SUPER REGION VOLUME FRACTIONS

SUPER REGION		MATERIAL 1	2	3	4
1	CORE(1)	0.166474	0.0	0.0	0.833526
2	WALL	0.0	0.0	0.300000	0.700000
3	BLANKET	0.0	0.500000	0.0	0.500000
4	PLENA	0.500000	0.0	0.0	0.500000
5	AX REFL	0.010000	0.0	0.0	0.990000
6	VESSEL	0.0	0.0	1.000000	0.0

OBJECTIVE FUNCTION= 3.891484E 01 BALANCE= 1.000019E 00
BREEDING RATIO= 1.049749E 00 YIELD= 3.709950E 00
FUEL CYCLE COST= 6.821967E-01 SPECIFIC POWER= 2.208100E 00
SPECIFIC INVENTORY= 4.528779E-01 CONSERVATION COEFFICIENT= 2.425633E-01
FLUX FACTOR= 0.0 ALLOWABLE FLUX= 1.210000E 14
MAXIMUM FLUX= 1.190444E 14

		OPTI	USED
1	CORE RAD=	2.014790E 02	2.014790E 02
2	THK R B =	7.727467E 01	7.727467E 01
3	VF S CCR=	1.664742E-01	1.664742E-01
4	BLK CY T=	5.491826E 01	5.491826E 01

ENTERED WLKEP 32

END OPTI CYCLE 3

OBJECTIVE FUNCTION= 3.886336E 01 BALANCE= 1.000015E 00
BREEDING RATIO= 1.049747E 00 YIELD= 3.706688E 00
FUEL CYCLE COST= 6.826489E-01 SPECIFIC POWER= 2.206262E 00
SPECIFIC INVENTORY= 4.532553E-01 CONSERVATION COEFFICIENT= 2.421456E-01
FLUX FACTOR= 0.0 ALLOWABLE FLUX= 1.210000E 14
MAXIMUM FLUX= 1.187642E 14

		OPTI	USED
1	CORE RAD=	2.016838E 02	2.016838E 02
2	THK R B =	7.727467E 01	7.727467E 01
3	VF S CCR=	1.664742E-01	1.664742E-01
4	BLK CY T=	5.491826E 01	5.491826E 01

ENTERED WLKEP 33

OBJECTIVE FUNCTION= 3.888464E 01 BALANCE= 1.000008E 00
BREEDING RATIO= 1.049743E 00 YIELD= 3.709064E 00
FUEL CYCLE COST= 6.832016E-01 SPECIFIC POWER= 2.207855E 00
SPECIFIC INVENTORY= 4.529282E-01 CONSERVATION COEFFICIENT= 2.424769E-01

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                    FLUX FACTOR=  0.0                          ALLOWABLE FLUX=  1.210000E 14
                   MAXIMUM FLUX=  1.189968E 14

                                   OPTI                       USED
                 1  CORE RAD=  2.014790E 02              2.014790E 02
                 2  THK R B =  7.809387E 01              7.809387E 01
                 3  VF S COR=  1.664742E-01              1.664742E-01
                 4  BLK CY T=  5.491826E 01              5.491826E 01
ENTERED WLKEP   34

            OBJECTIVE FUNCTION=  3.887395E 01                     BALANCE=  1.000011E 00
               BREEDING RATIO=  1.049930E 00                       YIELD=  3.714740E 00
            FUEL CYCLE COST=  6.827835E-01                  SPECIFIC POWER=  2.202826E 00
          SPECIFIC INVENTORY=  4.539623E-01     CONSERVATION COEFFICIENT=  2.422804E-01
                 FLUX FACTOR=  0.0                          ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.185201E 14

                                   OPTI                       USED
                 1  CORE RAD=  2.014790E 02              2.014790E 02
                 2  THK R B =  7.727467E 01              7.727467E 01
                 3  VF S COR=  1.670742E-01              1.670742E-01
                 4  BLK CY T=  5.491826E 01              5.491826E 01
ENTERED WLKEP   35

            OBJECTIVE FUNCTION=  3.889247E 01                     BALANCE=  1.000043E 00
               BREEDING RATIO=  1.049714E 00                       YIELD=  3.705715E 00
            FUEL CYCLE COST=  6.814561E-01                  SPECIFIC POWER=  2.207139E 00
          SPECIFIC INVENTORY=  4.530751E-01     CONSERVATION COEFFICIENT=  2.421802E-01
                 FLUX FACTOR=  0.0                          ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.190001E 14

                                   OPTI                       USED
                 1  CORE RAD=  2.014790E 02              2.014790E 02
                 2  THK R B =  7.727467E 01              7.727467E 01
                 3  VF S COR=  1.664742E-01              1.664742E-01
                 4  BLK CY T=  5.799025E 01              5.799025E 01
ENTERED WLKEP   36

PARTIAL DERIVATIVES OF GRADIENT EVALUATION
 -0.2059326E 01 -0.1207886E 01 -0.1635742E 01 -0.8947754E 00

ALPHA =   0.250000E-01      BETA =   0.500000E-01
   0.655358E-01   0.262144E 00   0.320000E 00   0.327680E 00

            OBJECTIVE FUNCTION=  3.890448E 01                     BALANCE=  1.000078E 00
               BREEDING RATIO=  1.049257E 00                       YIELD=  3.688437E 00
            FUEL CYCLE COST=  6.808203E-01                  SPECIFIC POWER=  2.217272E 00
          SPECIFIC INVENTORY=  4.510046E-01     CONSERVATION COEFFICIENT=  2.421632E-01
                 FLUX FACTOR=  0.0                          ALLOWABLE FLUX=  1.210000E 14
                 MAXIMUM FLUX=  1.194404E 14

                                   OPTI                       USED
                 1  CORE RAD=  2.011513E 02              2.011513E 02
                 2  THK R B =  7.650587E 01              7.650587E 01
                 3  VF S COR=  1.657116E-01              1.657116E-01
                 4  BLK CY T=  5.278261E 01              5.278261E 01
ENTERED WLKEP   37

FIRST SEARCH FAILURE ALONG GRADIENT

NOW SCANNING INTERVAL
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OBJECTIVE FUNCTION=  3.890312E 01                    BALANCE=  1.000041E 00
     BREEDING RATIO=  1.049612E 00                      YIELD=  3.703377E 00
   FUEL CYCLE COST=  6.818677E-01                 SPECIFIC POWER=  2.210298E 00
SPECIFIC INVENTORY=  4.524277E-01   CONSERVATION COEFFICIENT=  2.423754E-01
       FLUX FACTOR=  0.0                          ALLOWABLE FLUX=  1.210000E 14
      MAXIMUM FLUX=  1.191057E 14

                              OPTI                    USED
          1  CORE RAD=  2.013971E 02            2.013971E 02
          2  THK P B =  7.708247E 01            7.708247E 01
          3  VF S COR=  1.662835E-01            1.662835E-01
          4  BLK CY T=  5.438434E 01            5.438434E 01
ENTERED WLKEP   38

EXCELSIOR. YOU HAVE ARRIVED

BACK FROM ERC MATERIAL DENSITY

 MATERIAL    1
 93  5.5362E-05  94  2.0996E-05  95  5.4614E-06  96  6.0359E-06  97  8.5219E-07  98  3.6958E-06  79  5.9504E-08
 80  3.0773E-08  81  2.0195E-08  82  2.0086E-08   4  7.1150E-03  70  7.1150E-03   7  2.0630E-02   9  4.7610E-02
 90  3.0940E-03   6  2.0222E-07  91  1.2796E-06  99  1.0000E-08  33  2.8552E-04  77  1.1238E-04  54  8.7486E-11
 49  3.2072E-09  51  8.3980E-09

 MATERIAL    2
 93  1.6468E-07  94  3.1907E-10  95  4.3147E-13  96  4.3680E-14  97  1.6279E-15   4  7.1150E-03  70  7.1150E-03
  7  2.0630E-02   9  4.7610E-02  90  3.0940E-03   6  2.4800E-07  91  1.1928E-07  99  1.0000E-08  33  4.5403E-06
 77  1.3600E-04  49  1.4746E-11  51  8.0235E-11

 MATERIAL    3
 24  7.1190E-03  26  4.7430E-03  28  6.4000E-02  42  9.3750E-03

 MATERIAL    4
 12  9.5300E-02
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RAPID SEPTEMBER 1967 ROD-18 P X4916 X1306 BLANKETED MSBR 1000 MWE TF 9 10TH23BE 0

FISSION PRODUCT OPTION	2
FISSION PRODUCT REF NUCLIDE	18
CONVERGENCE CRITERION	5.0000E-05
RESONANCE INTEGRAL FACTOR	2.3238E-01
POWER	2.2500E 03
RESIDENCE TIME CORE	6.0000E 00
RESIDENCE TIME EXTERNAL	5.1000E 00
PLANT UTILIZATION FACTOR	8.0000E-01
THERMAL EFFICIENCY	4.4440E-01
SCALING FACTOR	3.0000E-01
ITERATION LIMIT	40
ALPHA	1.1059E 00
CONCENTRATION CAMPING,AVERAGING,OR FORCING FACTOR	0.50000
CONCENTRATION CHANGE LIMITING FACTOR	2.00000
RECYCLE FRACTION CHANGE LIMITING FACTOR	1.01000

MATERIAL	VOLUME	TIME S	TIME P	TIME R	OPTION
1	1.3339E 03	2.5000E 01	2.5000E-01	1.0000E 00	0
2	2.6756E 03	5.4918E 01	2.5000E-01	0.0	0
3	8.1857E 02	0.0	0.0	0.0	0
4	5.7855E 03	0.0	0.0	0.0	0

BO= 1.000014E 00 BS= 1.000023E 00 F1= 9.995868E-01 ETA= 2.235085E 00
IF= 1.019061E 03 PL= 7.802572E-04 Y = 3.706940E 00 FCC= 6.822557E-01
BR= 1.049712E 00 NO OF ITERS= 3 KI= 9.999737E-01 KC = 9.999943E-01

NUCLIDE		ABS	CAP	FIS	TOT INV,KG	/**********RATES,KG PER DAY**********/ FEED	PROCESS	LOSS	PRODUCT	/*******FUEL CYCLE COSTS*******/ INV.	REPL.	PROC	CREDIT
1	TH-232	0.9669	0.9643	0.0026	1.353E 05	2.306E 01	2.056E 01	2.056E 01	0.0	0.0483	0.0183	0.2185	0.0
2	PA-233	0.0060	0.0060	0.0000	9.863E 01	0.0	1.934E 00	1.870E-06	0.0	0.0241	0.0	0.0	0.0
3	U-233	0.9129	0.0575	0.8154	8.367E 02	0.0	8.099E 01	8.090E-05	1.154E-01	0.2046	0.0	0.0	0.0626
4	U-234	0.0867	0.0863	0.0004	3.158E 02	0.0	3.081E 01	3.081E-05	4.395E-02	0.0	0.0	0.0	0.0
5	U-235	0.0819	0.0149	0.0671	8.250E 01	0.0	8.049E 00	8.049E-06	1.148E-02	0.0174	0.0	0.0	0.0054
6	U-236	0.0091	0.0090	0.0000	8.933E 01	0.0	1.530E-02	1.530E-02	0.0	0.0	0.0	0.0	0.0
7	NP-237	0.0082	0.0082	0.0000	1.267E 01	0.0	2.169E-03	2.169E-03	0.0	0.0	0.0	0.0	0.0
8	U-238	0.0047	0.0046	0.0000	5.516E 01	0.0	9.444E-03	9.444E-03	0.0	0.0	0.0	0.1086	0.0
9	PU-239	0.0041	0.0016	0.0025	8.922E-01	0.0	1.486E-03	1.486E-03	0.0	0.0002	0.0	0.0	0.0
10	PU-240	0.0013	0.0013	0.0000	4.633E-01	0.0	7.718E-04	7.718E-04	0.0	0.0	0.0	0.0	0.0
11	PU-241	0.0011	0.0003	0.0008	3.053E-01	0.0	5.086E-04	5.086E-04	0.0	0.0001	0.0	0.0	0.0
12	PU-242	0.0001	0.0001	0.0000	3.049E-01	0.0	5.080E-04	5.080E-04	0.0	0.0	0.0	0.0	0.0
13	BE-9	0.0083	0.0017	0.0066	1.209E 04	1.837E 00	1.836E 00	1.836E 00	0.0	0.0196	0.0066	0.0	0.0
14	BE-9 NA	0.0023	0.0023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	LI-7	0.0190	0.0190	0.0	2.723E 04	4.137E 00	4.136E 00	4.136E 00	0.0	0.0628	0.0211	0.0	0.0
16	LI-6	0.0049	0.0049	0.0000	2.633E-01	1.773E-04	3.475E-05	3.475E-05	0.0	0.0	0.0	0.0	0.0
17	F	0.0233	0.0233	0.0	0.0	0.0	2.590E 01	2.590E 01	0.0	0.0	0.0	0.0	0.0
18	FP REF E	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	0.0000	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	0.0028	0.0028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	0.0050	0.0050	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	GRAPHITE	0.0473	0.0473	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	0.0137	0.0137	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	CHROME	0.0014	0.0014	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	IRON	0.0008	0.0008	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	NICKEL	0.0186	0.0186	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	MOLY	0.0048	0.0048	0.0000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		2.2351								0.3770	0.0460	0.3271	0.0679

IN THE PRECEDING TABLE THE LUMPED FISSION PRODUCT NUCLIDE CONTAINS ALL FISSION PRODUCTS
IN THE FOLLOWING TABLES IT CONTAINS ALL FISSION PRODUCTS EXCEPT THOSE TREATED EXPLICITLY IN MODRIC

MATERIAL 1

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	4.06406E-01	4.50191E 04	4.50242E 04	2.29115E 01	2.05567E 01	0.0
2	PA-233	1.27960E-06	1.27958E-06	2.68004E-03	1.86987E 01	9.26150E 01	0.0	1.86986E 00	0.0
3	U-233	5.53620E-05	5.53642E-05	4.08343E-01	8.09046E 02	8.31886E 02	0.0	8.09045E 01	1.15387E-01
4	U-234	2.09962E-05	2.09959E-05	3.87789E-02	3.08133E 02	3.15836E 02	0.0	3.08132E 01	4.39464E-02
5	U-235	5.46143E-06	5.46107E-06	3.66624E-02	8.04885E 01	8.25007E 01	0.0	8.04884E 00	1.14794E-02
6	U-236	6.03591E-06	6.03492E-06	4.06201E-03	8.93248E 01	8.93286E 01	0.0	1.52953E-02	0.0
7	NP-237	8.52189E-07	8.52054E-07	3.67794E-03	1.26650E 01	1.26655E 01	0.0	2.16865E-03	0.0
8	U-238	3.69581E-06	3.69504E-06	2.08204E-03	5.51549E 01	5.51573E 01	0.0	9.44433E-03	0.0
9	PU-239	5.95044E-08	5.94948E-08	1.82821E-03	8.91795E-01	8.92166E-01	0.0	1.48632E-03	0.0
10	PU-240	3.07731E-08	3.07667E-08	5.66858E-04	4.63106E-01	4.63299E-01	0.0	7.71842E-04	0.0
11	PU-241	2.01946E-08	2.01908E-08	4.82131E-04	3.05183E-01	3.05310E-01	0.0	5.08638E-04	0.0
12	PU-242	2.00858E-08	2.00808E-08	4.27612E-05	3.04779E-01	3.04906E-01	0.0	5.07965E-04	0.0
13	BE-9	7.11500E-03	7.11500E-03	3.58603E-03	4.02147E 03	4.02192E 03	1.83709E 00	1.83629E 00	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	1.02963E-03	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	7.89605E-03	9.05703E 03	9.05806E 03	4.13701E 00	4.13563E 00	0.0
16	LI-6	2.02217E-07	2.02230E-07	1.58088E-03	7.61002E-02	7.61089E-02	1.77300E-04	3.47450E-05	0.0
17	F	4.76100E-02	4.76100E-02	9.86961E-03	0.0	0.0	0.0	2.59030E 01	0.0
18	FP REF E	1.00000E-08	1.00000E-08	1.03600E-07	0.0	0.0	0.0	0.0	0.0
19	LEAKAGE	1.00000E 00	1.00000E 00	2.00602E-05	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.12381E-04	1.12389E-04	1.16436E-03	0.0	0.0	0.0	0.0	0.0
21	FIX P FR	8.74864E-11	8.74944E-11	2.23655E-03	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	2.85521E-04	2.85529E-04	2.95817E-03	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	3.20720E-09	3.20723E-09	2.64074E-03	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.39804E-09	8.39794E-09	5.26004E-04	0.0	0.0	0.0	0.0	0.0

MATERIAL 2

NUCLIDE		/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	TOTAL	//**********RATES,KG/DAY**********/ FEED	PROCESS	PRODUCT
1	TH-232	3.09400E-03	3.09400E-03	2.61823E-02	9.03031E 04	9.03031E 04	1.51711E-01	0.0	0.0
2	PA-233	1.19279E-07	1.19285E-07	1.94189E-05	3.49653E 00	6.01334E 00	0.0	6.36679E-02	0.0
3	U-233	1.64684E-07	1.64691E-07	9.43214E-05	4.82749E 00	4.84946E 00	0.0	8.79031E-02	0.0
4	U-234	3.19075E-10	3.19109E-10	3.98607E-08	9.39397E-03	9.43673E-03	0.0	1.71054E-04	0.0
5	U-235	4.31473E-13	4.31537E-13	2.22768E-10	1.27579E-05	1.28160E-05	0.0	2.32307E-07	0.0
6	U-236	4.36799E-14	4.36875E-14	1.99697E-12	1.29707E-06	1.29713E-06	0.0	2.22101E-10	0.0
7	NP-237	1.62789E-15	1.62823E-15	5.90009E-13	4.85466E-08	4.85487E-08	0.0	8.31278E-12	0.0
13	BE-9	7.11500E-03	7.11500E-03	1.13270E-04	8.06660E 03	8.06660E 03	0.0	0.0	0.0
14	BE-9 NA	7.11500E-03	7.11500E-03	2.08068E-05	0.0	0.0	0.0	0.0	0.0
15	LI-7	2.06300E-02	2.06300E-02	6.20615E-04	1.81674E 04	1.81674E 04	0.0	0.0	0.0
16	LI-6	2.48000E-07	2.48000E-07	1.90831E-04	1.87196E-01	1.87196E-01	0.0	0.0	0.0
17	F	4.76100E-02	4.76100E-02	5.47170E-04	0.0	0.0	0.0	0.0	0.0
18	FP REF E	1.00000E-08	1.00000E-08	8.14088E-05	0.0	0.0	0.0	0.0	0.0
20	DEL NEUT	1.36000E-04	1.36000E-04	1.10716E-04	0.0	0.0	0.0	0.0	0.0
25	LUMP FP	4.54029E-06	4.54081E-06	3.69670E-06	0.0	0.0	0.0	0.0	0.0
229	SM-149 1	1.47459E-11	1.47464E-11	9.23092E-07	0.0	0.0	0.0	0.0	0.0
231	SM-151 1	8.02352E-11	8.02393E-11	3.73841E-07	0.0	0.0	0.0	0.0	0.0

MATERIAL 3

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	//**********RATES,KG/DAY**********/ TOTAL	FEED	PROCESS	PRODUCT
26 CHROME	7.11900E-03	7.11900E-03	6.18113E-04	0.0	0.0	0.0	0.0	0.0
27 IRON	4.74300E-03	4.74300E-03	3.37654E-04	0.0	0.0	0.0	0.0	0.0
28 NICKEL	6.40000E-02	6.40000E-02	8.30055E-03	0.0	0.0	0.0	0.0	0.0
29 MOLY	9.37500E-03	9.37500E-03	2.14543E-03	0.0	0.0	0.0	0.0	0.0

MATERIAL 4

NUCLIDE	/*********DENSITY**********/ INITIAL	FINAL	/******INVENTORIES,KG******/ ABSORPTIONS	SYSTEM	//**********RATES,KG/DAY**********/ TOTAL	FEED	PROCESS	PRODUCT
23 GRAPHITE	9.53000E-02	9.53000E-02	2.11765E-02	0.0	0.0	0.0	0.0	0.0

FISSION PRODUCT CONCENTRATIONS AND ABSORPTIONS IN MATERIAL ONE

ERC =	NUCLIDE	MOD =	CONC	ABSORPTIONS	ERC =	NUCLIDE	MOD =	CONC	ABSORPTIONS
51	BR-81 5	0	8.180012E-08	1.339216E-05	176	I -135 5	0	2.176345E-09	0.0
52	BR-82 5	0	2.218346E-09	0.0	177	XE-128 4	0	1.139563E-21	2.914635E-20
53	BR-83 5	0	2.494847E-10	0.0	178	XE-129 4	0	6.716873E-30	1.321480E-27
54	KR-82 4	0	5.948479E-13	5.046057E-10	179	XE-130 4	0	4.440210E-19	1.135663E-17
55	KR-83M 4	0	9.524395E-13	2.283323E-09	180	XE-131 4	0	1.445964E-14	4.143978E-11
56	KR-84 4	0	1.685521E-12	2.270899E-11	181	XE-132 4	0	1.490137E-16	8.631558E-16
57	KR-85M 4	0	2.166329E-12	2.788398E-10	182	XE-133 4	0	2.797011E-14	5.435469E-11
58	KR-86 4	0	2.647414E-12	1.848536E-12	183	XE-134 4	0	1.252620E-20	3.983289E-20
59	KR-87 4	0	3.920495E-12	1.836474E-08	184	XE-135 4	0	3.105373E-12	8.149099E-05
60	KR-88 4	0	4.279040E-12	0.0	185	XE-136 4	0	6.119856E-12	9.932498E-12
61	KR-89 4	0	4.293973E-12	0.0	186	XE-137 4	0	5.004432E-12	0.0
62	KR-90 4	0	2.328725E-12	0.0	187	XE-138 4	0	5.889327E-12	0.0
63	KR-91 4	0	7.995480E-13	0.0	188	XE-139 4	0	2.623983E-12	0.0
64	RB-85 6	0	1.774505E-08	2.157999E-07	189	XE-140 4	0	1.162163E-12	0.0
65	RB-86 6	0	2.278737E-12	0.0	190	CS-133 6	0	3.959451E-12	4.696155E-09
66	RB-87 6	0	1.096378E-07	1.733829E-07	191	CS-134 6	0	1.023254E-12	1.402652E-09
67	SR-86 6	0	1.832255E-10	3.091612E-09	192	CS-135 6	0	1.034605E-08	2.239771E-06
68	SR-87 6	0	2.696217E-12	0.0	193	CS-136 6	0	1.658658E-11	0.0
69	SR-88 6	0	1.820312E-06	3.230463E-07	194	CS-137 6	0	3.450397E-06	5.809320E-06
70	SR-89 6	0	1.633146E-07	8.361234E-07	195	BA-134 6	0	1.816621E-12	3.716272E-11
71	SR-90 6	0	1.073570E-05	1.426487E-04	196	BA-135 6	0	3.113785E-14	1.458588E-12
72	SR-91 6	0	5.224351E-09	0.0	197	BA-136 6	0	1.884074E-09	6.038351E-08
73	SR-92 6	0	1.519804E-09	0.0	198	BA-137 6	0	4.665960E-07	2.432549E-05
74	Y -89 1	0	5.601033E-08	7.825186E-07	199	BA-138 6	0	1.246819E-06	9.533868E-06
75	Y -90 1	0	2.438762E-09	8.740028E-08	200	BA-140 6	0	1.568987E-07	1.924447E-05
76	Y -91 1	0	1.724618E-07	1.886518E-06	201	LA-139 1	0	1.479170E-07	1.587567E-05
77	Y -92 1	0	2.231490E-09	0.0	202	LA-140 1	0	1.873503E-08	5.930592E-07
78	Y -93 1	0	6.325681E-09	0.0	203	LA-141 1	0	2.243117E-09	0.0
79	ZR-90 3	0	3.784249E-07	3.874848E-07	204	CE-140 1	0	1.938261E-07	1.409466E-06
80	ZR-91 3	0	1.226472E-06	4.218580E-05	205	CE-141 1	0	1.609523E-07	0.0
81	ZR-92 3	0	6.190269E-06	2.191070E-05	206	CE-142 1	0	2.661887E-07	3.247181E-06
82	ZR-93 3	0	6.355378E-06	4.529073E-04	207	CE-143 1	0	1.722053E-08	1.057969E-06
83	ZR-94 3	0	6.434711E-06	7.383364E-06	208	CE-144 1	0	1.713059E-07	1.059903E-05
84	ZR-95 3	0	7.980111E-07	0.0	209	PR-141 1	0	8.438013E-08	1.357891E-05
85	ZR-96 3	0	5.399333E-06	3.503792E-06	210	PR-142 1	0	5.994943E-12	1.103620E-09
86	ZR-97 3	0	8.915787E-09	0.0	211	PR-143 1	0	9.530527E-08	1.188885E-04
87	ZR-98 3	0	8.349008E-12	0.0	212	PR-145 1	0	1.920508E-09	0.0
88	ZR-99 3	0	4.396644E-12	0.0	213	ND-142 1	0	1.289438E-10	2.373750E-08
89	NB-95 2	0	4.923657E-12	0.0	214	ND-143 1	0	1.166961E-07	3.872493E-04
90	NB-97 2	0	5.011142E-12	0.0	215	ND-144 1	0	5.035236E-09	3.674106E-07
91	NB-99 2	0	3.721004E-12	0.0	216	ND-145 1	0	1.325888E-07	1.452509E-04
92	NB-100 2	0	3.552433E-12	0.0	217	ND-146 1	0	1.051603E-07	1.557560E-05
93	NB-101 2	0	1.746616E-12	0.0	218	ND-147 1	0	3.046481E-08	0.0
94	MO-95 2	0	5.642502E-17	2.036907E-14	219	ND-148 1	0	5.196960E-08	7.086210E-06
95	MO-96 2	0	4.694115E-24	3.184785E-22	220	ND-149 1	0	1.517649E-10	0.0
96	MO-97 2	0	3.963809E-14	2.197699E-12	221	ND-150 1	0	2.214718E-08	1.297490E-06
97	MO-98 2	0	5.064662E-22	8.594529E-21	222	PM-147 1	0	4.286453E-08	3.948598E-04
98	MO-99 2	0	8.953287E-13	0.0	223	PM-148M1	0	3.983025E-10	1.284997E-04
99	MO-100 2	0	6.838417E-13	1.258260E-11	224	PM-148 1	0	3.925389E-10	4.311815E-05
100	MO-101 2	0	9.702881E-13	0.0	225	PM-149 1	0	3.765827E-09	0.0
101	MO-102 2	0	2.019323E-12	0.0	226	PM-151 1	0	9.055761E-10	0.0
102	MO-104 2	0	7.460257E-13	0.0	227	SM-147 1	0	7.498644E-10	1.767010E-06
103	TC-99 2	0	1.295987E-16	6.621196E-14	228	SM-148 1	0	1.446462E-09	2.794148E-07
104	TC-101 2	0	3.685925E-14	0.0	229	SM-149 1	49	3.207232E-09	2.640737E-03
105	TC-103 2	0	1.061626E-12	0.0	230	SM-150 1	0	2.591241E-08	3.793338E-05
106	TC-104 2	0	1.669740E-13	0.0	231	SM-151 1	51	8.397937E-09	5.260045E-04
107	TC-105 2	0	4.715360E-13	0.0	232	SM-152 1	0	1.317152E-08	9.834259E-05
108	RU-100 2	0	1.525874E-23	1.171805E-21	233	SM-153 1	0	7.090579E-10	0.0
109	RU-101 2	0	1.520443E-15	3.261016E-13	234	SM-154 1	0	2.088257E-09	2.212596E-07
110	RU-102 2	0	7.515113E-23	2.813555E-21	235	SM-156 1	0	8.617876E-12	0.0

111	RU-103	2	C	5.109007E-13	0.0	236	EU-151	1	0	5.448336E-12	4.456075E-07
112	RU-104	2	C	5.357351E-15	1.284404E-13	237	EU-152	1	0	7.778769E-12	3.643806E-07
113	RU-105	2	C	3.018365E-14	6.181259E-14	238	EU-153	1	0	3.652782E-08	2.637394E-04
114	RU-106	2	C	2.275758E-13	2.711578E-11	239	EU-154	1	0	1.026681E-08	1.575552E-04
115	RU-107	2	C	1.133943E-13	0.0	240	EU-155	1	0	1.784369E-09	2.555596E-04
116	RU-108	2	C	6.634325E-14	0.0	241	EU-156	1	0	2.401682E-09	0.0
117	RH-103	2	C	5.160083E-18	1.877398E-14	242	EU-157	1	0	1.394253E-12	0.0
118	RH-104	2	C	2.370696E-24	8.884025E-22	243	GD-152	1	0	3.027329E-14	5.105126E-11
119	RH-105	2	C	6.528215E-17	1.122318E-11	244	GD-153	1	0	5.082445E-16	0.0
120	RH-107	2	C	1.387246E-14	0.0	245	GD-154	1	0	3.038285E-11	6.546824E-09
121	PD-104	2	C	1.955824E-24	1.908415E-22	246	GD-155	1	0	7.742525E-12	4.234596E-06
122	PD-105	2	C	1.745643E-20	4.687264E-18	247	GD-156	1	0	2.740761E-09	3.652498E-07
123	PD-106	2	C	2.586417E-21	2.129566E-19	248	GD-157	1	0	1.750129E-12	3.970709E-06
124	PD-107	2	C	3.642513E-16	6.582723E-14	249	GD-158	1	0	4.400670E-11	4.386269E-09
125	PD-108	2	C	1.517009E-23	6.564140E-21	250	GD-159	1	0	9.553556E-14	0.0

BACK FROM ERC MATERIAL DENSITY

MATERIAL 1

93	5.5364E-05	94	2.0996E-05	95	5.4611E-06	96	6.0349E-06	97	8.5205E-07	98	3.6950E-06	79	5.9495E-08
80	3.0767E-08	81	2.0191E-08	82	2.0081E-08	4	7.1150E-03	70	7.1150E-03	7	2.0630E-02	9	4.7610E-02
90	3.0940E-03	6	2.0223E-07	91	1.2796E-06	99	1.0000E-08	33	2.9553E-04	77	1.1239E-04	54	8.7494E-11
49	3.2072E-09	51	8.3979E-09										

MATERIAL 2

93	1.6469E-07	94	3.1911E-10	95	4.3154E-13	96	4.3688E-14	97	1.6282E-15	4	7.1150E-03	70	7.1150E-03
7	2.0630E-02	9	4.7610E-02	90	3.0940E-03	6	2.4800E-07	91	1.1929E-07	99	1.0000E-08	33	4.5408E-06
77	1.3600E-04	49	1.4746E-11	51	8.0239E-11								

MATERIAL 3

24	7.1190E-03	26	4.7430E-03	28	6.4000E-02	42	9.3750E-03

MATERIAL 4

12	9.5300E-02

FISSION DENSITY(FD) AND AVERAGE FISSION POWER DENSITY(FPD) BY MESH POINT FOR DIMENSION 1

K	FD	FPD	K	FD	FPD	K	FD	FPD	K	FD	FPD
1	1.9863E 00	7.0759E 01	19	1.4350E 00	5.3582E 01	37	2.2667E-01	8.5029E 00	55	1.0607E-02	3.9790E-01
2	1.8849E 00	7.0705E 01	20	1.3904E 00	5.2156E 01	38	6.6537E-01	2.4960E 01	56	9.4315E-03	3.5380E-01
3	1.9805E 00	7.0543E 01	21	1.3356E 00	5.0252E 01	39	4.9784E-01	1.8675E 01	57	8.3015E-03	3.1141E-01
4	1.8733E 00	7.0274E 01	22	1.2868E 00	4.8272E 01	40	4.0671E-01	1.5257E 01	58	7.2184E-03	2.7078E-01
5	1.8633E 00	6.9897E 01	23	1.2321E 00	4.6219E 01	41	3.6262E-01	1.3603E 01	59	6.1795E-03	2.3181E-01
6	1.8504E 00	6.9413E 01	24	1.1755E 00	4.4097E 01	42	3.5738E-01	1.3406E 01	60	5.1801E-03	1.9432E-01
7	1.8347E 00	6.8824E 01	25	1.1172E 00	4.1908E 01	43	3.9980E-01	1.4998E 01	61	4.2142E-03	1.5808E-01
8	1.8162E 00	6.8130E 01	26	1.0572E 00	3.9658E 01	44	5.2297E-01	1.9618E 01	62	3.2747E-03	1.2284E-01
9	1.7949E 00	6.7331E 01	27	9.9561E-01	3.7348E 01	45	1.0955E-02	4.1096E-01	63	2.3537E-03	8.8292E-02
10	1.7709E 00	6.6430E 01	28	9.3257E-01	3.4983E 01	46	1.4649E-02	5.4953E-01	64	1.4409E-03	5.4052E-02
11	1.7442E 00	6.5428E 01	29	8.6816E-01	3.2567E 01	47	1.6579E-02	6.2191E-01	65	5.1881E-04	1.9462E-02
12	1.7148E 00	6.4326E 01	30	8.0248E-01	3.0103E 01	48	1.7265E-02	6.4765E-01	66	7.6154E-07	2.8567E-05
13	1.6828E 00	6.3125E 01	31	7.3565E-01	2.7596E 01	49	1.7114E-02	6.4199E-01	67	5.4208E-07	2.0335E-05
14	1.6482E 00	6.1829E 01	32	6.6775E-01	2.5049E 01	50	1.6433E-02	6.1643E-01	68	3.8121E-07	1.4300E-05
15	1.6112E 00	6.0439E 01	33	5.9867E-01	2.2458E 01	51	1.5440E-02	5.7919E-01	69	2.6155E-07	9.8112E-06
16	1.5716E 00	5.8956E 01	34	5.2759E-01	1.9791E 01	52	1.4284E-02	5.3581E-01	70	1.7015E-07	6.3827E-06
17	1.5297E 00	5.7384E 01	35	4.5123E-01	1.6927E 01	53	1.3058E-02	4.8985E-01	71	9.7141E-08	3.6440E-06
18	1.4855E 00	5.5725E 01	36	3.5953E-01	1.3487E 01	54	1.1822E-02	4.4347E-01			

FISSION DENSITY(FD) AND AVERAGE FISSION POWER DENSITY(FPD) BY MESH POINT FOR DIMENSION 2

K	FD	FPD	K	FD	FPD	K	FD	FPD	K	FD	FPD
1	4.0172E 00	7.0759E 01	19	3.0340E 00	5.3442E 01	37	7.9886E-01	1.4071E 01	55	3.4405E-04	6.0602E-03
2	4.0139E 00	7.0702E 01	20	2.9299E 00	5.1609E 01	38	6.6967E-01	1.1796E 01	56	2.6416E-04	4.6530E-03
3	4.0042E 00	7.0531E 01	21	2.8220E 00	4.9708E 01	39	5.4177E-01	9.5429E 00	57	2.0279E-04	3.5720E-03
4	3.9881E 00	7.0247E 01	22	2.7105E 00	4.7743E 01	40	4.1457E-01	7.3023E 00	58	1.5539E-04	2.7370E-03
5	3.9655E 00	6.9849E 01	23	2.5956E 00	4.5720E 01	41	2.8585E-01	5.0350E 00	59	1.1865E-04	2.0899E-03
6	3.9366E 00	6.9340E 01	24	2.4776E 00	4.3642E 01	42	4.4140E-05	7.7749E-04	60	9.0104E-05	1.5871E-03
7	3.9014E 00	6.8720E 01	25	2.3569E 00	4.1515E 01	43	4.1818E-05	7.3660E-04	61	6.7845E-05	1.1950E-03
8	3.8599E 00	6.7990E 01	26	2.2336E 00	3.9344E 01	44	3.9583E-05	6.9723E-04	62	5.0387E-05	8.8752E-04
9	3.8124E 00	6.7153E 01	27	2.1081E 00	3.7133E 01	45	3.7430E-05	6.5931E-04	63	3.6543E-05	6.4367E-04
10	3.7589E 00	6.6211E 01	28	1.9807E 00	3.4889E 01	46	6.6356E-02	1.1688E-01	64	2.5352E-05	4.4655E-04
11	3.6996E 00	6.5166E 01	29	1.8517E 00	3.2616E 01	47	4.2888E-02	7.5544E-02	65	1.6006E-05	2.8194E-04
12	3.6345E 00	6.4020E 01	30	1.7213E 00	3.0320E 01	48	2.8726E-02	5.0599E-02	66	7.7814E-06	1.3706E-04
13	3.5639E 00	6.2776E 01	31	1.5899E 00	2.8005E 01	49	1.9914E-02	3.5076E-02	67	8.5306E-09	1.5026E-07
14	3.4879E 00	6.1438E 01	32	1.4579E 00	2.5679E 01	50	1.4231E-02	2.5067E-02	68	6.0513E-09	1.0659E-07
15	3.4067E 00	6.0007E 01	33	1.3254E 00	2.3346E 01	51	1.0426E-02	1.8365E-02	69	4.2412E-09	7.4707E-08
16	3.3205E 00	5.8489E 01	34	1.1929E 00	2.1013E 01	52	7.7829E-04	1.3709E-02	70	2.9007E-09	5.1094E-08
17	3.2295E 00	5.6886E 01	35	1.0608E 00	1.8685E 01	53	5.8865E-04	1.0369E-02	71	1.8820E-09	3.3150E-08
18	3.1339E 00	5.5202E 01	36	9.2932E-01	1.6369E 01	54	4.4897E-04	7.9083E-03	72	1.0730E-09	1.8900E-08

REAL POINT FLUXES FOR DIMENSION 1

K	RADIUS	GRP 1	GRP 2	GRP 3	GRP 4	GRP 5	GRP 6	GRP 7	GRP 8	GRP 9
1	0.0	1.1900E 14	2.6538E 14	2.6725E 14	2.3774E 14	2.0012E 14	6.1345E 13	3.0334E 14	3.1111E 14	9.9255E 13
2	1.000000E 01	1.1891E 14	2.6518E 14	2.6705E 14	2.3756E 14	1.9997E 14	6.1298E 13	3.0311E 14	3.1087E 14	9.9180E 13
3	2.000000E 01	1.1864E 14	2.6457E 14	2.6643E 14	2.3702E 14	1.9951E 14	6.1158E 13	3.0242E 14	3.1016E 14	9.8952E 13
4	3.000000E 01	1.1818E 14	2.6356E 14	2.6542E 14	2.3611E 14	1.9875E 14	6.0924E 13	3.0126E 14	3.0897E 14	9.8574E 13
5	4.000000E 01	1.1755E 14	2.6215E 14	2.6399E 14	2.3484E 14	1.9768E 14	6.0597E 13	2.9965E 14	3.0731E 14	9.8046E 13
6	5.000000E 01	1.1674E 14	2.6034E 14	2.6217E 14	2.3322E 14	1.9632E 14	6.0178E 13	2.9757E 14	3.0519E 14	9.7367E 13
7	6.000000E 01	1.1575E 14	2.5813E 14	2.5994E 14	2.3124E 14	1.9465E 14	5.9667E 13	2.9505E 14	3.0260E 14	9.6541E 13
8	7.000000E 01	1.1458E 14	2.5552E 14	2.5732E 14	2.2891E 14	1.9269E 14	5.9065E 13	2.9207E 14	2.9954E 14	9.5567E 13
9	8.000000E 01	1.1323E 14	2.5253E 14	2.5430E 14	2.2622E 14	1.9043E 14	5.8373E 13	2.8865E 14	2.9603E 14	9.4447E 13
10	9.000000E 01	1.1172E 14	2.4915E 14	2.5090E 14	2.2320E 14	1.8788E 14	5.7592E 13	2.8479E 14	2.9207E 14	9.3183E 13
11	1.000000E 02	1.1003E 14	2.4539E 14	2.4711E 14	2.1983E 14	1.8504E 14	5.6723E 13	2.8049E 14	2.8766E 14	9.1777E 13
12	1.100000E 02	1.0818E 14	2.4125E 14	2.4295E 14	2.1613E 14	1.8193E 14	5.5768E 13	2.7576E 14	2.8282E 14	9.0231E 13
13	1.200000E 02	1.0616E 14	2.3675E 14	2.3842E 14	2.1209E 14	1.7853E 14	5.4727E 13	2.7062E 14	2.7754E 14	8.8547E 13
14	1.300000E 02	1.0398E 14	2.3189E 14	2.3352E 14	2.0774E 14	1.7487E 14	5.3603E 13	2.6506E 14	2.7184E 14	8.6729E 13
15	1.400000E 02	1.0164E 14	2.2668E 14	2.2827E 14	2.0307E 14	1.7094E 14	5.2398E 13	2.5910E 14	2.6573E 14	8.4778E 13
16	1.500000E 02	9.9150E 13	2.2112E 14	2.2267E 14	1.9809E 14	1.6674E 14	5.1113E 13	2.5275E 14	2.5921E 14	8.2699E 13
17	1.600000E 02	9.6507E 13	2.1522E 14	2.1674E 14	1.9281E 14	1.6230E 14	4.9750E 13	2.4601E 14	2.5230E 14	8.0494E 13
18	1.700000E 02	9.3717E 13	2.0900E 14	2.1047E 14	1.8723E 14	1.5761E 14	4.8312E 13	2.3889E 14	2.4501E 14	7.8167E 13
19	1.800000E 02	9.0784E 13	2.0246E 14	2.0388E 14	1.8137E 14	1.5268E 14	4.6801E 13	2.3142E 14	2.3734E 14	7.5721E 13
20	1.900000E 02	8.7714E 13	1.9561E 14	1.9699E 14	1.7524E 14	1.4751E 14	4.5218E 13	2.2359E 14	2.2931E 14	7.3161E 13
21	2.000000E 02	8.4512E 13	1.8847E 14	1.8980E 14	1.6884E 14	1.4213E 14	4.3567E 13	2.1543E 14	2.2094E 14	7.0489E 13
22	2.100000E 02	8.1182E 13	1.8105E 14	1.8232E 14	1.6219E 14	1.3653E 14	4.1851E 13	2.0694E 14	2.1224E 14	6.7712E 13
23	2.200000E 02	7.7730E 13	1.7335E 14	1.7457E 14	1.5530E 14	1.3072E 14	4.0072E 13	1.9814E 14	2.0321E 14	6.4832E 13
24	2.300000E 02	7.4161E 13	1.6539E 14	1.6655E 14	1.4817E 14	1.2472E 14	3.8232E 13	1.8904E 14	1.9388E 14	6.1856E 13
25	2.400000E 02	7.0481E 13	1.5718E 14	1.5829E 14	1.4081E 14	1.1853E 14	3.6335E 13	1.7966E 14	1.8426E 14	5.8786E 13
26	2.500000E 02	6.6696E 13	1.4874E 14	1.4979E 14	1.3325E 14	1.1217E 14	3.4384E 13	1.7001E 14	1.7436E 14	5.5629E 13
27	2.600000E 02	6.2812E 13	1.4008E 14	1.4107E 14	1.2549E 14	1.0564E 14	3.2382E 13	1.6011E 14	1.6421E 14	5.2389E 13
28	2.700000E 02	5.8835E 13	1.3121E 14	1.3214E 14	1.1755E 14	9.8950E 13	3.0332E 13	1.4997E 14	1.5381E 14	4.9072E 13
29	2.800000E 02	5.4771E 13	1.2215E 14	1.2301E 14	1.0943E 14	9.2117E 13	2.8237E 13	1.3962E 14	1.4319E 14	4.5683E 13
30	2.900000E 02	5.0627E 13	1.1291E 14	1.1370E 14	1.0115E 14	8.5151E 13	2.6102E 13	1.2905E 14	1.3236E 14	4.2227E 13
31	3.000000E 02	4.6408E 13	1.0349E 14	1.0422E 14	9.2727E 13	7.8070E 13	2.3932E 13	1.1831E 14	1.2133E 14	3.8709E 13
32	3.100000E 02	4.2114E 13	9.3916E 13	9.4565E 13	8.4188E 13	7.0914E 13	2.1739E 13	1.0738E 14	1.1011E 14	3.5128E 13
33	3.200000E 02	3.7735E 13	8.4175E 13	8.4864E 13	7.5621E 13	6.3774E 13	1.9547E 13	9.6254E 13	9.8644E 13	3.1463E 13
34	3.300000E 02	3.3240E 13	7.4310E 13	7.5229E 13	6.7274E 13	5.6853E 13	1.7405E 13	8.4732E 13	8.6669E 13	2.7622E 13
35	3.400000E 02	2.8616E 13	6.4665E 13	6.6403E 13	5.9748E 13	5.0444E 13	1.5351E 13	7.2162E 13	7.3372E 13	2.3330E 13
36	3.500000E 02	2.4212E 13	5.6909E 13	6.0469E 13	5.3909E 13	4.4359E 13	1.3215E 13	5.6745E 13	5.6648E 13	1.7875E 13
37	3.600000E 02	2.2464E 13	5.7130E 13	6.1833E 13	4.8298E 13	3.5485E 13	9.9043E 12	3.5414E 13	3.1790E 13	9.5732E 12
38	3.600000E 02	2.2464E 13	5.7130E 13	6.1833E 13	4.8298E 13	3.5485E 13	9.9043E 12	3.5414E 13	3.1790E 13	9.5732E 12
39	3.650000E 02	2.2192E 13	5.9171E 13	6.3262E 13	4.3905E 13	3.0248E 13	8.0677E 12	2.6980E 13	2.1444E 13	6.1417E 12
40	3.700000E 02	2.0416E 13	5.6932E 13	6.1850E 13	4.0760E 13	2.6785E 13	6.9385E 12	2.1685E 13	1.6390E 13	4.5790E 12
41	3.750000E 02	1.8741E 13	5.3074E 13	5.8090E 13	3.7596E 13	2.4195E 13	6.2041E 12	1.9225E 13	1.4421E 13	4.0120E 12
42	3.800000E 02	1.7470E 13	4.8368E 13	5.2307E 13	3.4022E 13	2.2106E 13	5.7334E 12	1.9330E 13	1.5039E 13	4.2583E 12
43	3.850000E 02	1.6015E 13	4.1911E 13	4.4435E 13	3.0173E 13	2.0596E 13	5.5048E 12	2.2133E 13	1.9012E 13	5.6332E 12
44	3.900000E 02	1.2300E 13	3.1151E 13	3.4402E 13	2.6819E 13	2.0192E 13	5.5260E 12	2.7507E 13	2.9296E 13	9.3747E 12
45	3.900000E 02	1.2300E 13	3.1151E 13	3.4402E 13	2.6819E 13	2.0192E 13	5.5260E 12	2.7507E 13	2.9296E 13	9.3747E 12
46	3.950000E 02	7.2279E 12	2.0022E 13	2.3106E 13	2.1905E 13	1.8857E 13	5.2761E 12	3.4724E 13	4.4364E 13	1.5142E 13
47	4.000000E 02	4.4881E 12	1.3003E 13	1.5423E 13	1.6438E 13	1.5697E 13	4.5557E 12	3.9496E 13	5.2935E 13	1.8448E 13
48	4.050000E 02	2.9927E 12	8.6802E 12	1.0367E 13	1.1864E 13	1.2244E 13	3.6901E 12	4.1492E 13	5.6949E 13	2.0044E 13
49	4.100000E 02	2.1579E 12	6.0432E 12	7.1139E 12	8.4535E 12	9.2152E 12	2.8832E 12	4.1388E 13	5.7708E 13	2.0436E 13
50	4.150000E 02	1.6725E 12	4.4276E 12	5.0436E 12	6.0589E 12	6.8315E 12	2.2184E 12	3.9900E 13	5.6265E 13	2.0009E 13
51	4.200000E 02	1.3717E 12	3.4171E 12	3.7251E 12	4.4297E 12	5.0675E 12	1.7073E 12	3.7583E 13	5.3433E 13	1.9059E 13

52	4.250000E 02	1.1686E 12	2.7602E 12	2.8730E 12	3.3346E 12	3.8073E 12	1.3289E 12	3.4821E 13	4.9798E 13	1.7802E 13
53	4.300000E 02	1.0182E 12	2.3081E 12	2.3050E 12	2.5945E 12	2.9212E 12	1.0533E 12	3.1863E 13	4.5759E 13	1.6383E 13
54	4.350000E 02	8.5691E 11	1.9750E 12	1.9083E 12	2.0833E 12	2.2976E 12	8.5192E 11	2.8862E 13	4.1570E 13	1.4900E 13
55	4.400000E 02	7.9261E 11	1.7120E 12	1.6146E 12	1.7168E 12	1.8514E 12	7.0214E 11	2.5905E 13	3.7386E 13	1.3411E 13
56	4.450000E 02	6.9896E 11	1.4912E 12	1.3831E 12	1.4407E 12	1.5221E 12	5.8719E 11	2.3038E 13	3.3294E 13	1.1949E 13
57	4.500000E 02	6.1259E 11	1.2972E 12	1.1902E 12	1.2215E 12	1.2690E 12	4.9546E 11	2.0280E 13	2.9335E 13	1.0532E 13
58	4.550000E 02	5.3162E 11	1.1210E 12	1.0219E 12	1.0385E 12	1.0654E 12	4.1921E 11	1.7635E 13	2.5523E 13	9.1654E 12
59	4.600000E 02	4.5496E 11	9.5773E 11	8.7036E 11	8.7958E 11	8.9463E 11	3.5343E 11	1.5098E 13	2.1857E 13	7.8500E 12
60	4.650000E 02	3.8195E 11	8.0464E 11	7.3137E 11	7.3761E 11	7.4622E 11	2.9491E 11	1.2656E 13	1.8324E 13	6.5814E 12
61	4.700000E 02	3.1219E 11	6.6054E 11	6.0300E 11	6.0888E 11	6.1379E 11	2.4161E 11	1.0296E 13	1.4905E 13	5.3528E 12
62	4.750000E 02	2.4564E 11	5.2559E 11	4.8511E 11	4.9157E 11	4.9303E 11	1.9209E 11	8.0011E 12	1.1576E 13	4.1555E 12
63	4.800000E 02	1.8273E 11	4.0150E 11	3.7919E 11	3.8464E 11	3.7995E 11	1.4523E 11	5.7578E 12	8.3103E 12	2.9775E 12
64	4.850000E 02	1.2478E 11	2.9227E 11	2.8827E 11	2.8611E 11	2.6881E 11	1.0041E 11	3.5644E 12	5.0751E 12	1.7965E 12
65	4.900000E 02	7.4746E 10	2.0528E 11	2.1663E 11	1.8960E 11	1.4950E 11	6.0147E 10	1.4827E 12	1.8083E 12	5.5107E 11
66	4.900000E 02	7.4744E 10	2.0528E 11	2.1663E 11	1.8960E 11	1.4950E 11	6.0147E 10	1.4827E 12	1.8083E 12	5.5108E 11
67	4.920000E 02	5.3205E 10	1.6728E 11	1.4735E 11	1.0565E 11	5.9644E 10	2.8663E 10	4.1595E 11	3.9009E 11	9.4017E 10
68	4.940000E 02	3.7416E 10	1.3013E 11	9.9935E 10	6.0066E 10	2.5186E 10	1.2144E 10	1.1175E 11	8.7990E 10	1.8489E 10
69	4.960000E 02	2.5671E 10	9.4337E 10	6.4421E 10	3.3641E 10	1.1118E 10	4.8713E 09	2.9502E 10	2.0680E 10	4.0208E 09
70	4.980000E 02	1.6700E 10	5.9771E 10	3.4751E 10	1.6559E 10	4.6640E 09	1.8085E 09	7.6095E 09	4.9357E 09	9.1788E 08
71	5.000000E 02	9.5343E 09	2.5911E 10	6.6758E 09	3.5758E 09	9.2807E 08	3.5906E 08	1.3180E 09	8.1392E 08	1.4331E 08

REAL POINT FLUXES FOR DIMENSION 2

K	RADIUS	GRP 1	GRP 2	GRP 3	GRP 4	GRP 5	GRP 6	GRP 7	GRP 8	GRP 9
1	0.0	1.1900E 14	2.6538E 14	2.6725E 14	2.3774E 14	2.0012E 14	6.1345E 13	3.0335E 14	3.1111E 14	9.9255E 13
2	5.036975E 00	1.1890E 14	2.6517E 14	2.6703E 14	2.3755E 14	1.9996E 14	6.1296E 13	3.0310E 14	3.1086E 14	9.9175E 13
3	1.007395E 01	1.1862E 14	2.6453E 14	2.6639E 14	2.3698E 14	1.9948E 14	6.1147E 13	3.0237E 14	3.1010E 14	9.8935E 13
4	1.511092E 01	1.1814E 14	2.6346E 14	2.6531E 14	2.3602E 14	1.9867E 14	6.0901E 13	3.0115E 14	3.0885E 14	9.8536E 13
5	2.014789E 01	1.1747E 14	2.6197E 14	2.6381E 14	2.3468E 14	1.9755E 14	6.0556E 13	2.9944E 14	3.0710E 14	9.7979E 13
6	2.518486E 01	1.1661E 14	2.6006E 14	2.6189E 14	2.3297E 14	1.9611E 14	6.0114E 13	2.9726E 14	3.0486E 14	9.7264E 13
7	3.022185E 01	1.1557E 14	2.5773E 14	2.5955E 14	2.3089E 14	1.9435E 14	5.9577E 13	2.9460E 14	3.0214E 14	9.6394E 13
8	3.525882E 01	1.1434E 14	2.5500E 14	2.5679E 14	2.2844E 14	1.9229E 14	5.8945E 13	2.9147E 14	2.9893E 14	9.5371E 13
9	4.029579E 01	1.1294E 14	2.5186E 14	2.5363E 14	2.2563E 14	1.8992E 14	5.8219E 13	2.8789E 14	2.9525E 14	9.4197E 13
10	4.533276E 01	1.1135E 14	2.4833E 14	2.5007E 14	2.2246E 14	1.8726E 14	5.7402E 13	2.8385E 14	2.9111E 14	9.2876E 13
11	5.036974E 01	1.0959E 14	2.4441E 14	2.4612E 14	2.1895E 14	1.8430E 14	5.6496E 13	2.7937E 14	2.8651E 14	9.1409E 13
12	5.540672E 01	1.0767E 14	2.4011E 14	2.4180E 14	2.1510E 14	1.8106E 14	5.5503E 13	2.7445E 14	2.8147E 14	8.9802E 13
13	6.044370E 01	1.0557E 14	2.3544E 14	2.3710E 14	2.1092E 14	1.7755E 14	5.4424E 13	2.6912E 14	2.7601E 14	8.8057E 13
14	6.548067E 01	1.0332E 14	2.3042E 14	2.3204E 14	2.0642E 14	1.7376E 14	5.3264E 13	2.6338E 14	2.7012E 14	8.6179E 13
15	7.051764E 01	1.0092E 14	2.2506E 14	2.2664E 14	2.0162E 14	1.6971E 14	5.2024E 13	2.5725E 14	2.6383E 14	8.4173E 13
16	7.555461E 01	9.8364E 13	2.1936E 14	2.2091E 14	1.9652E 14	1.6542E 14	5.0708E 13	2.5074E 14	2.5716E 14	8.2043E 13
17	8.059160E 01	9.5668E 13	2.1335E 14	2.1485E 14	1.9113E 14	1.6089E 14	4.9318E 13	2.4387E 14	2.5011E 14	7.9795E 13
18	8.562857E 01	9.2837E 13	2.0704E 14	2.0849E 14	1.8547E 14	1.5613E 14	4.7858E 13	2.3665E 14	2.4271E 14	7.7433E 13
19	9.066554E 01	8.9876E 13	2.0044E 14	2.0185E 14	1.7956E 14	1.5115E 14	4.6332E 13	2.2911E 14	2.3497E 14	7.4964E 13
20	9.570251E 01	8.6794E 13	1.9356E 14	1.9492E 14	1.7340E 14	1.4596E 14	4.4743E 13	2.2125E 14	2.2691E 14	7.2393E 13
21	1.007395E 02	8.3597E 13	1.8643E 14	1.8774E 14	1.6701E 14	1.4059E 14	4.3095E 13	2.1310E 14	2.1855E 14	6.9726E 13
22	1.057765E 02	8.0293E 13	1.7906E 14	1.8032E 14	1.6041E 14	1.3503E 14	4.1392E 13	2.0468E 14	2.0991E 14	6.6970E 13
23	1.108134E 02	7.6890E 13	1.7147E 14	1.7268E 14	1.5361E 14	1.2931E 14	3.9638E 13	1.9600E 14	2.0101E 14	6.4132E 13
24	1.158504E 02	7.3395E 13	1.6368E 14	1.6483E 14	1.4663E 14	1.2343E 14	3.7836E 13	1.8709E 14	1.9188E 14	6.1217E 13
25	1.208874E 02	6.9818E 13	1.5570E 14	1.5680E 14	1.3949E 14	1.1742E 14	3.5992E 13	1.7797E 14	1.8253E 14	5.8234E 13
26	1.259244E 02	6.6167E 13	1.4756E 14	1.4860E 14	1.3219E 14	1.1127E 14	3.4110E 13	1.6867E 14	1.7298E 14	5.5188E 13
27	1.309613E 02	6.2450E 13	1.3927E 14	1.4025E 14	1.2477E 14	1.0502E 14	3.2193E 13	1.5919E 14	1.6326E 14	5.2088E 13
28	1.359983E 02	5.8676E 13	1.3085E 14	1.3177E 14	1.1722E 14	9.8675E 13	3.0247E 13	1.4957E 14	1.5340E 14	4.8940E 13
29	1.410353E 02	5.4853E 13	1.2233E 14	1.2319E 14	1.0959E 14	9.2244E 13	2.8276E 13	1.3983E 14	1.4340E 14	4.5752E 13
30	1.460723E 02	5.0991E 13	1.1372E 14	1.1451E 14	1.0187E 14	8.5747E 13	2.6285E 13	1.2998E 14	1.3331E 14	4.2531E 13
31	1.511092E 02	4.7099E 13	1.0503E 14	1.0577E 14	9.4086E 13	7.9196E 13	2.4277E 13	1.2006E 14	1.2314E 14	3.9286E 13
32	1.561462E 02	4.3185E 13	9.6302E 13	9.6970E 13	8.6258E 13	7.2609E 13	2.2258E 13	1.1009E 14	1.1291E 14	3.6024E 13
33	1.611832E 02	3.9259E 13	8.7539E 13	8.8139E 13	7.8402E 13	6.5999E 13	2.0233E 13	1.0009E 14	1.0266E 14	3.2753E 13
34	1.662202E 02	3.5327E 13	7.8758E 13	7.9291E 13	7.0535E 13	5.9386E 13	1.8207E 13	9.0091E 13	9.2405E 13	2.9482E 13
35	1.712571E 02	3.1394E 13	6.9973E 13	7.0443E 13	6.2677E 13	5.2790E 13	1.6187E 13	8.0118E 13	8.2178E 13	2.6219E 13
36	1.762941E 02	2.7464E 13	6.1190E 13	6.1615E 13	5.4856E 13	4.6237E 13	1.4182E 13	7.0196E 13	7.1999E 13	2.2971E 13
37	1.813311E 02	2.3528E 13	5.2409E 13	5.2835E 13	4.7109E 13	3.9763E 13	1.2200E 13	6.0352E 13	6.1890E 13	1.9743E 13
38	1.863681E 02	1.9565E 13	4.3628E 13	4.4162E 13	3.9495E 13	3.3412E 13	1.0256E 13	5.0606E 13	5.1856E 13	1.6535E 13
39	1.914050E 02	1.5526E 13	3.4858E 13	3.5711E 13	3.2097E 13	2.7236E 13	8.3657E 12	4.0977E 13	4.1874E 13	1.3328E 13
40	1.964420E 02	1.1214E 13	2.6170E 13	2.7720E 13	2.5006E 13	2.1279E 13	6.5543E 12	3.1520E 13	3.1849E 13	1.0060E 13
41	2.014790E 02	6.7474E 12	1.7829E 13	2.0639E 13	1.8242E 13	1.5559E 13	4.8822E 12	2.2507E 13	2.1448E 13	6.5065E 12
42	2.014790E 02	6.7474E 12	1.7829E 13	2.0639E 13	1.8242E 13	1.5559E 13	4.8822E 12	2.2507E 13	2.1448E 13	6.5065E 12
43	2.018123E 02	6.3925E 12	1.7280E 13	1.9850E 13	1.7520E 13	1.4942E 13	4.7311E 12	2.1692E 13	2.0302E 13	6.0920E 12
44	2.021456E 02	6.0508E 12	1.6747E 13	1.9091E 13	1.6819E 13	1.4386E 13	4.5954E 12	2.1043E 13	1.9365E 13	5.7918E 12
45	2.024790E 02	5.7217E 12	1.6230E 13	1.8359E 13	1.6139E 13	1.3887E 13	4.4751E 12	2.0560E 13	1.8622E 13	5.5992E 12
46	2.024790E 02	5.7217E 12	1.6230E 13	1.8359E 13	1.6139E 13	1.3887E 13	4.4751E 12	2.0560E 13	1.8622E 13	5.5992E 12
47	2.063427E 02	3.2114E 12	1.1194E 13	1.4662E 13	1.2457E 13	1.1319E 13	3.7612E 12	1.7835E 13	1.5489E 13	4.7569E 12
48	2.102064E 02	1.8067E 12	7.4832E 12	1.1258E 13	9.5542E 12	9.0576E 12	3.0902E 12	1.5138E 13	1.2981E 13	4.0043E 12
49	2.140702E 02	1.0197E 12	4.8947E 12	8.3874E 12	7.2458E 12	7.1341E 12	2.4941E 12	1.2670E 13	1.0846E 13	3.3496E 12
50	2.179339E 02	5.7804E 11	3.1515E 12	6.1027E 12	5.4235E 12	5.5389E 12	1.9836E 12	1.0488E 13	9.0008E 12	2.7828E 12
51	2.217976E 02	3.2966E 11	2.0059E 12	4.3570E 12	4.0055E 12	4.2435E 12	1.5577E 12	8.5996E 12	7.4121E 12	2.2947E 12

52	2.256614E 02	1.8954E 11	1.2663E 12	3.0633E 12	2.9205E 12	3.2110E 12	1.2096E 12	6.9901E 12	6.0556E 12	1.8778E 12
53	2.295251E 02	1.1013E 11	7.5483E 11	2.1268E 12	2.1041E 12	2.4018E 12	9.2978E 11	5.6362E 12	4.9091E 12	1.5249E 12
54	2.333888E 02	6.4860E 10	4.5725E 11	1.4615E 12	1.4996E 12	1.7773E 12	7.0824E 11	4.5105E 12	3.9501E 12	1.2292E 12
55	2.372525E 02	3.8842E 10	3.1071E 11	9.5587E 11	1.0585E 12	1.3022E 12	5.3508E 11	3.5842E 12	3.1558E 12	9.8376E 11
56	2.411163E 02	2.3725E 10	1.9431E 11	6.7392E 11	7.4063E 11	9.4548E 11	4.0128E 11	2.8290E 12	2.5040E 12	7.8191E 11
57	2.449800E 02	1.4820E 10	1.2186E 11	4.5354E 11	5.1431E 11	6.8071E 11	2.9893E 11	2.2184E 12	1.9734E 12	6.1725E 11
58	2.488438E 02	9.4819E 09	7.6791E 10	3.0391E 11	3.5479E 11	4.8634E 11	2.2133E 11	1.7281E 12	1.5447E 12	4.8391E 11
59	2.527075E 02	6.2132E 09	4.8711E 10	2.0301E 11	2.4337E 11	3.4504E 11	1.6293E 11	1.3368E 12	1.2002E 12	3.7654E 11
60	2.565710E 02	4.1616E 09	3.1149E 10	1.3535E 11	1.6617E 11	2.4320E 11	1.1922E 11	1.0256E 12	9.2458E 11	2.9045E 11
61	2.604348E 02	2.8376E 09	2.0098E 10	9.0196E 10	1.1305E 11	1.7035E 11	8.6636E 10	7.7852E 11	7.0429E 11	2.2149E 11
62	2.642986E 02	1.9568E 09	1.3086E 10	6.0210E 10	7.6754E 10	1.1854E 11	6.2365E 10	5.8178E 11	5.2777E 11	1.6611E 11
63	2.681624E 02	1.3522E 09	8.5912E 09	4.0431E 10	5.2094E 10	8.1782E 10	4.4223E 10	4.2391E 11	3.8508E 11	1.2119E 11
64	2.720261E 02	9.2456E 08	5.6826E 09	2.7550E 10	3.5426E 10	5.5608E 10	3.0537E 10	2.9523E 11	2.6764E 11	8.3977E 10
65	2.758896E 02	6.1500E 08	3.7945E 09	1.9404E 10	2.4177E 10	3.6640E 10	2.0048E 10	1.8774E 11	1.6793E 11	5.1766E 10
66	2.797534E 02	3.9120E 08	2.5935E 09	1.4636E 10	1.6489E 10	2.2262E 10	1.1882E 10	9.5119E 10	7.9220E 10	2.1276E 10
67	2.797534E 02	3.9120E 08	2.5935E 09	1.4633E 10	1.6489E 10	2.2262E 10	1.1882E 10	9.5119E 10	7.9221E 10	2.1276E 10
68	2.817534E 02	2.7751E 08	2.0102E 09	8.4289E 09	8.6223E 09	8.2597E 09	4.5576E 09	2.5404E 10	1.8541E 10	4.0223E 09
69	2.837534E 02	1.9450E 08	1.5040E 09	4.8369E 09	4.5184E 09	3.1649E 09	1.7026E 09	6.7491E 09	4.4784E 09	8.7173E 08
70	2.857534E 02	1.3302E 08	1.0583E 09	2.6831E 09	2.3173E 09	1.2454E 09	6.2577E 08	1.8031E 09	1.1156E 09	2.0545E 08
71	2.877534E 02	8.6306E 07	6.5642E 08	1.2889E 09	1.0597E 09	4.7003E 08	2.1770E 08	4.7680E 08	2.7970E 08	4.9935E 07
72	2.897534E 02	4.9206E 07	2.8194E 08	2.3619E 08	2.2499E 08	9.0876E 07	4.2450E 07	8.3331E 07	4.6835E 07	7.9439E 06

THICKNESSES AND OTHER REGION INFORMATION

DIMENSION 1

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	3.600000E 02	36	1	1	0.0	3.600000E 02
2	PLENA	3.000000E 01	6	2	1	3.600000E 02	3.900000E 02
3	REFLECT	1.000000E 02	20	3	1	3.900000E 02	4.900000E 02
4	VESSEL	1.000000E 01	5	1	0	4.900000E 02	5.000000E 02

DIMENSION 2

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	2.014790E 02	40	1	1	0.0	2.014790E 02
2	WALL	1.000000E 00	3	1	1	2.014790E 02	2.024790E 02
3	BLANKET	7.727463E 01	20	2	1	2.024790E 02	2.797534E 02
4	VESSEL	1.000000E 01	5	1	0	2.797534E 02	2.897534E 02

SUPER REGION VOLUMES AND MATERIAL VOLUMES IN CUBIC CENTIMETERS

TOTAL

SUPER REGION 1,	CORE(1)	9.182096E 07
SUPER REGION 2,	WALL	1.243674E 06
SUPER REGION 3,	BLANKET	1.147275E 08
SUPER REGION 4,	PLENA	7.651747E 06
SUPER REGION 5,	AX REFL	2.550582E 07
SUPER REGION 6,	VESSEL	2.280888E 07

MATERIAL 1, FUELSALT

SUPER REGION 1,	CORE(1)	1.528581E 07
SUPER REGION 2,	WALL	0.0
SUPER REGION 3,	BLANKET	0.0
SUPER REGION 4,	PLENA	3.825873E 06
SUPER REGION 5,	AX REFL	2.550581E 05
SUPER REGION 6,	VESSEL	0.0
INTERNAL		1.936672E 07
EXTERNAL		1.840800E 07
TOTAL		3.777472E 07

MATERIAL 2, FERTILE

SUPER REGION 1,	CORE(1)	0.0
SUPER REGION 2,	WALL	0.0
SUPER REGION 3,	BLANKET	5.736376E 07
SUPER REGION 4,	PLENA	0.0
SUPER REGION 5,	AX REFL	0.0
SUPER REGION 6,	VESSEL	0.0
INTERNAL		5.736376E 07
EXTERNAL		1.840800E 07
TOTAL		7.577176E 07

MATERIAL 3, INCR

SUPER REGION 1,	CORE(1)	0.0
SUPER REGION 2,	WALL	3.731023E 05
SUPER REGION 3,	BLANKET	0.0
SUPER REGION 4,	PLENA	0.0
SUPER REGION 5,	AX REFL	0.0
SUPER REGION 6,	VESSEL	2.280888E 07
INTERNAL		2.318198E 07
EXTERNAL		0.0
TOTAL		2.318198E 07

MATERIAL 4, GRAPHITE

SUPER REGION 1,	CORE(1)	7.653515E 07
SUPER REGION 2,	WALL	8.705724E 05
SUPER REGION 3,	BLANKET	5.736376E 07
SUPER REGION 4,	PLENA	3.825873E 06
SUPER REGION 5,	AX REFL	2.525075E 07
SUPER REGION 6,	VESSEL	0.0
INTERNAL		1.638461E 08
EXTERNAL		0.0
TOTAL		1.638461E 08

PROCESSING INFORMATION

MATERIAL 1, FUELSALT

TIME NO.	TIME	UNITS	PROC COST VOL BASIS
1	25.000	DAYS	1200.000
2	50.000	SECS	0.0
3	600.000	DAYS	0.0
4	50.000	SECS	0.0
5	200.000	DAYS	0.0
6	6.000	YEAR	0.0
7	16.000	YEAR	0.0
8	10.000	DAYS	600.000
9	300.000	DAYS	0.0

	PROCESSING GROUP	TIMES SPECIFIED	RELATIVE REMOVAL
1	RARE EARTH	1 0 0 0 0 0 0 0 0 0	1.00000E 00
2	DEP & SMOKE	0 2 0 0 0 0 0 0 0 0	4.32000E 04
3	EXTRACT HF	0 0 3 0 0 0 0 0 0 0	4.16667E-02
4	GAS STRIP	0 0 0 4 0 0 0 0 0 0	4.32000E 04
5	FLUORINATION	0 0 0 0 5 0 0 0 9 0	2.08333E-01
6	DISCARD	0 0 0 0 0 6 0 0 0 0	1.14155E-02
7	AVE/LIFETIME	0 0 0 0 0 0 7 0 0 0	4.28082E-03
8	PA-233	0 0 0 0 0 0 0 8 0 0	2.50000E 00

MATERIAL 2, FERTILE

TIME NO.	TIME	UNITS	PROC COST VOL BASIS
1	54.918	DAYS	400.000
2	50.000	SECS	0.0
3	16.000	YEAR	0.0
4	50.000	SECS	0.0

	PROCESSING GROUP	TIMES SPECIFIED	RELATIVE REMOVAL
1	RECYCLE	0 0 3 0 0 0 0 0 0 0	9.40382E-03
2	DEP & SMOKE	0 2 0 0 0 0 0 0 0 0	9.48987E 04
3	RECYCLE	0 0 3 0 0 0 0 0 0 0	9.40382E-03
4	GAS STRIP	0 0 0 4 0 0 0 0 0 0	9.48987E 04
5	RECYCLE	0 0 3 0 0 0 0 0 0 0	9.40382E-03
6	RECYCLE	0 0 3 0 0 0 0 0 0 0	9.40382E-03
7	RECYCLE	0 0 3 0 0 0 0 0 0 0	9.40382E-03
8	PA-233	1 0 0 0 0 0 0 0 0 0	1.00000E 00

NEUTRON BALANCE BY GROUP

GROUP	DIMENSION 1	DIMENSION 2
1	-1.5126125E-06	-6.8681557E-06
2	1.5497208E-06	-9.5367432E-07
3	-1.9073486E-06	6.0200691E-06
4	-1.6093254E-06	-7.1525574E-07
5	-1.6093254E-06	-2.9802322E-07
6	3.2186508E-06	1.0728836E-06
7	-2.0980835E-05	-9.5367432E-07
8	-9.5367432E-06	-9.5367432E-07
9	-1.5258789E-05	-5.7220459E-06

DIMENSION 1

REGION TOTALS	ABSORPTIONS	NEUTRONS PROD	FISSIONS	PROD/ABS
1	6.27781E-01	6.55453E-01	2.62565E-01	1.04408
2	2.78364E-02	2.67134E-02	1.07148E-02	0.95966
3	2.64183E-03	2.04676E-03	8.19163E-04	0.77475
4	7.25518E-04	7.28452E-09	3.64226E-09	0.00001
TOTAL	6.58984E-01	6.84213E-01	2.74099E-01	

DIMENSION 2

REGION TOTALS	ABSORPTIONS	NEUTRONS PROD	FISSIONS	PROD/ABS
1	3.02081E-01	3.15394E-01	1.26342E-01	1.04407
2	1.04169E-02	2.08921E-07	1.04461E-07	0.00002
3	2.82303E-02	3.81434E-04	1.65539E-04	0.01351
4	2.82647E-04	2.85956E-10	1.42978E-10	0.00000
TOTAL	3.41011E-01	3.15776E-01	1.26508E-01	
2 D SUM	9.99995E-01	9.99989E-01	4.00607E-01	

FNORM	ALPA	BETA	TLEAK	AVGNU
2.1388531E 00	3.1677561E 00	9.9998784E-01	2.0060674E-05	2.4961834E 00

THICKNESSES AND OTHER REGION INFORMATION

DIMENSION 1

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	3.600000E 02	36	1	1	0.0	3.600000E 02
2	PLENA	3.000000E 01	6	2	1	3.600000E 02	3.900000E 02
3	REFLECT	1.000000E 02	20	3	1	3.900000E 02	4.900000E 02
4	VESSEL	1.000000E 01	5	1	0	4.900000E 02	5.000000E 02

DIMENSION 2

REGION		THICKNESS	MESH POINTS	XSECT SET	FISSIONABLE	REG START	REG END
1	CORE(1)	2.014790E 02	40	1	1	0.0	2.014790E 02
2	WALL	1.000000E 00	3	1	1	2.014790E 02	2.024790E 02
3	BLANKET	7.727463E 01	20	2	1	2.024790E 02	2.797534E 02
4	VESSEL	1.000000E 01	5	1	0	2.797534E 02	2.897534E 02

SUPER REGION VOLUME FRACTIONS

SUPER REGION		MATERIAL 1	2	3	4
1	CORE(1)	0.166474	0.0	0.0	0.833526
2	WALL	0.0	0.0	0.300000	0.700000
3	BLANKET	0.0	0.500000	0.0	0.500000
4	PLENA	0.500000	0.0	0.0	0.500000
5	AX REFL	0.010000	0.0	0.0	0.990000
6	VESSEL	0.0	0.0	1.000000	0.0

OBJECTIVE FUNCTION=	3.889139E 01	BALANCE=	1.000023E 00
BREEDING RATIO=	1.049712E 00	YIELD=	3.706940E 00
FUEL CYCLE COST=	6.822557E-01	SPECIFIC POWER=	2.207915E 00
SPECIFIC INVENTORY=	4.529159E-01	CONSERVATION COEFFICIENT=	2.423413E-01
FLUX FACTOR=	0.0	ALLOWABLE FLUX=	1.210000E 14
MAXIMUM FLUX=	1.189999E 14		

		OPTI	USED
1	CORE RAD=	2.014790E 02	2.014790E 02
2	THK R B =	7.727463E 01	7.727463E 01
3	VF S CCR=	1.664740E-01	1.664740E-01
4	BLK CY T=	5.491823E 01	5.491823E 01

OPTIMIZATION SUMMARY

I	OBJ. FUNCTION	1 CORE RAD	2 THK R B	3 VF S CCR	4 BLK CY T
1	1.991096E 01	2.000000E 02	2.000000E 01	1.400000E-01	2.000000E 01
2	2.035641E 01	2.010000E 02	2.000000E 01	1.400000E-01	2.000000E 01
3	2.425150E 01	2.000000E 02	2.499998E 01	1.400000E-01	2.000000E 01
4	2.049681E 01	2.000000E 02	2.000000E 01	1.414999E-01	2.000000E 01
5	2.007932E 01	2.000000E 02	2.000000E 01	1.400000E-01	3.499998E 01
6	2.786505E 01	2.002566E 02	2.999998E 01	1.405061E-01	2.116356E 01
7	3.240923E 01	2.005131E 02	3.999997E 01	1.410122E-01	2.232712E 01
8	3.484474E 01	2.007697E 02	4.999995E 01	1.415183E-01	2.349068E 01
9	3.607970E 01	2.010262E 02	5.999994E 01	1.420244E-01	2.465424E 01
10	3.663438E 01	2.012828E 02	6.999992E 01	1.425305E-01	2.581779E 01
11	3.685289E 01	2.015394E 02	7.999991E 01	1.430366E-01	2.698135E 01
12	3.684975E 01	2.017959E 02	8.999989E 01	1.435427E-01	2.814491E 01
13	3.684438E 01	2.016641E 02	8.486021E 01	1.432828E-01	2.754692E 01
14	3.684213E 01	2.015394E 02	7.999991E 01	1.430366E-01	2.698135E 01
15	3.683676E 01	2.027894E 02	7.999997E 01	1.430368E-01	2.698140E 01
16	3.678149E 01	2.015394E 02	8.499995E 01	1.430368E-01	2.698140E 01
17	3.720668E 01	2.015394E 02	7.999997E 01	1.449118E-01	2.698140E 01
18	3.692700E 01	2.015394E 02	7.999997E 01	1.430368E-01	4.198138E 01
19	3.788400E 01	2.015243E 02	7.931863E 01	1.488961E-01	3.396561E 01
20	3.853891E 01	2.015092E 02	7.863730E 01	1.547554E-01	4.094981E 01
21	3.883035E 01	2.014941E 02	7.795596E 01	1.606147E-01	4.793402E 01
22	3.897646E 01	2.014790E 02	7.727463E 01	1.664740E-01	5.491823E 01
23	3.888649E 01	2.014639E 02	7.659329E 01	1.700000E-01	6.190244E 01
24	3.892133E 01	2.014772E 02	7.719347E 01	1.671726E-01	5.575070E 01
25	3.894479E 01	2.014790E 02	7.727463E 01	1.664740E-01	5.491823E 01
26	3.887399E 01	2.019910E 02	7.727467E 01	1.664742E-01	5.491826E 01
27	3.886334E 01	2.014790E 02	7.932266E 01	1.664742E-01	5.491826E 01
28	3.889903E 01	2.014790E 02	7.727467E 01	1.694039E-01	5.491826E 01
29	3.889500E 01	2.014790E 02	7.727467E 01	1.664742E-01	6.991824E 01
30	3.889954E 01	2.007669E 02	7.399786E 01	1.651258E-01	4.740688E 01

31	3.889124E 01	2.013010E 02	7.645547E 01	1.661371E-01	5.304041E 01
32	3.891484E 01	2.014790E 02	7.727467E 01	1.664742E-01	5.491826E 01
33	3.886336E 01	2.016838E 02	7.727467E 01	1.664742E-01	5.491826E 01
34	3.888464E 01	2.014790E 02	7.809387E 01	1.664742E-01	5.491826E 01
35	3.887395E 01	2.014790E 02	7.727467E 01	1.670742E-01	5.491826E 01
36	3.889247E 01	2.014790E 02	7.727467E 01	1.664742E-01	5.799025E 01
37	3.890448E 01	2.011513E 02	7.650587E 01	1.657116E-01	5.278261E 01
38	3.890312E 01	2.013571E 02	7.708247E 01	1.662835E-01	5.438434E 01

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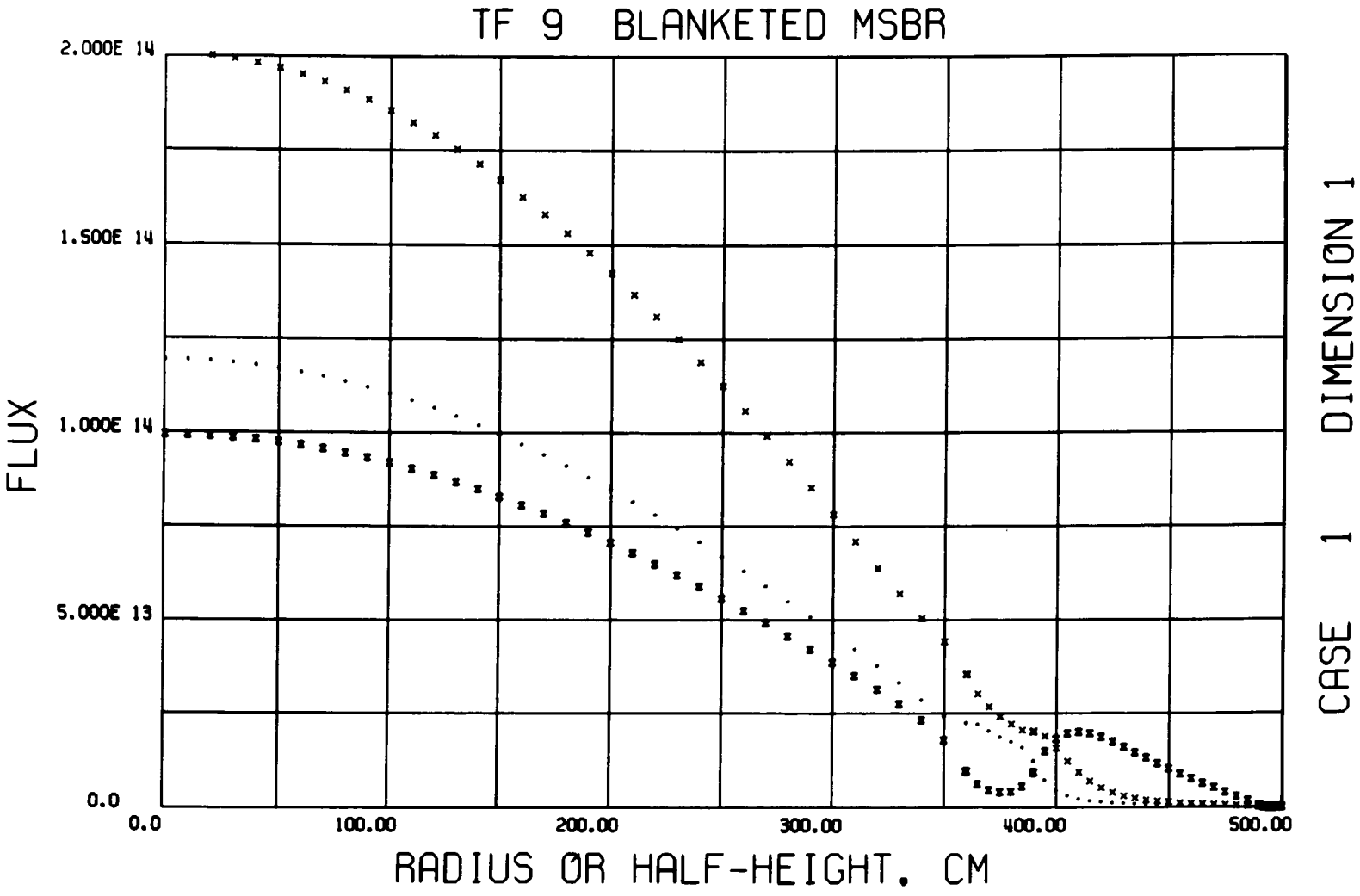

Fig. 8.1. Axial Flux Distribution for Neutron Energy Groups 1, 5, and 9.

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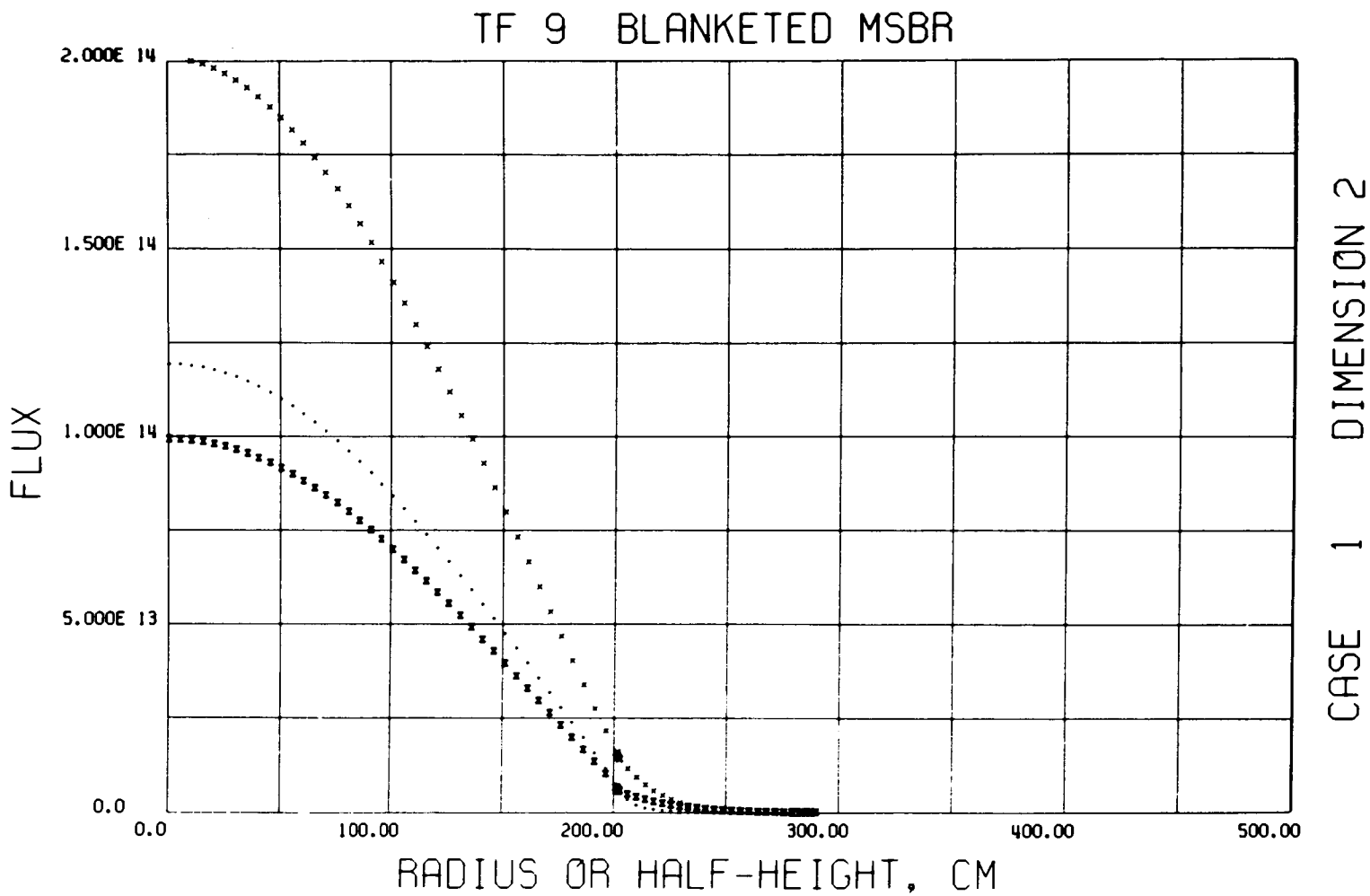

Fig. 8.2. Radial Flux Distribution for Neutron Energy Groups 1, 5, and 9.

CHAPTER 9

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APPENDICES

Appendix A

THE ERC EQUATIONS

Subscripts

Name	Description
I	Nuclide number
J	Material number
JD	Number of material from which recycled
IP	Nuclide number, processing source
IT	Nuclide number, transmutation source
ID	Nuclide number, decay source
ISTAR	Nuclide number of reference feed nuclide
L	Delayed neutron group number

Input Variables (in order of appearance in equations)

Name	Description
P	Power, MW(th)
CIMI	Initial atom density in material stream, atoms/barn cm
MATS	Number of materials
E	Fraction processed
SCE	Fraction removed or lost in processing
GPTIME	Processing cycle time
Y	Fission product yield
M655	Feed option
Q	Feed rate, kg/day
AMASS	Atomic weight
AMBA	Decay constant
N	Atom-density option
BETA	Delayed neutron fraction
AMA3	Delayed neutron decay constant
B55	Residence time, in core, sec
B56	Residence time, out of core, sec
XE21	Fixed poison fraction

Name	Description
L22N1	Array, nuclide numbers of fertile nuclides
L22N2	Array, nuclide numbers of fissile precursor nuclides
L22D	Array, nuclide numbers of fissile nuclides
L23D	Array, nuclide numbers of fissile nuclides
L29N	Array, nuclide numbers of fissile nuclides
L30N	Array, nuclide numbers of fissile and fissile precursor nuclides
L30D	Array, nuclide numbers of fissile nuclides
N21L	Array, nuclide numbers of fissile nuclides
TP	Holdup time in processing plant, days
TR	Operating time on reserve fuel, days
F36	Plant factor
E36	Thermal efficiency
W1	Value, in system, $/kg
W2	Interest rate, fraction per year
W3	Unit processing cost, weight basis, $/kg
W4	Processing plant unit cost, $
WNEW	Processing cost, reference, volume basis
B57	Scaling factor
W5	Value of feed, $/kg

Computed Variables

Name	Defining Equation	Description
F	1	Fission rate, fissions/sec $\times 10^{24}$
CIM	2,25,26, 29-35	Atom density in material stream, atoms/barn-cm
CAP	3	Neutron capture rate
CA		Neutron absorption rate
CF		Neutron fission rate
B	4	Total neutron absorptions
VM	5	Mean nu
CN		Neutron production rate

Name	Defining Equation	Description
FVB	6	Neutron balance, neutrons produced per absorption
S16	7	Total neutrons produced
R	8	External recycle rate (recycle to material from other materials)
V		Material volume, cm^3
SDC		Discharge concentration (SDC = CIM for fluid-fuel reactors)
RCF		Recycle fraction
TS		= GPTIME(1). Reference processing cycle time, days
FISS	9	Fission product source
CR94	10,12,13, 27,28	Processing source (internal recycle)
FRATE	11,14-16	Feed rate, atoms/sec
TRSK	24	Capture sink
BDS	17	Decay sink
PRS	18	Processing sink
D	19	Decay source
TRAS	20-23	Transmutation source
FFFS	36	Fraction of fissions in material 1
BR	37	Breeding ratio
ETA	38	Mean eta
SI	39	Inventory in reactor system, kg
PI	40,41	Inventory in processing plant, kg
RSI	42,43	Inventory in reserve, kg
TØTI	44	Inventory total, kg
FISSI	45	Total fissile inventory, kg
PL	46	Fissile loss in processing as fraction of burnup
YIELD	47	Fissile yield, percent of fissile inventory per year
FRTE	48	Feed rate, by material, kg/day
FRTEI	49	Feed rate, total, kg/day
PDRTE	50	Production rate, by material, kg/day
PDRAI	51	Production rate, total, kg/day
PCRTE	52	Processing rate, by material, kg/day

Name	Defining Equation	Description
FCRTEI	53	Processing rate, total, kg/day
PE36	54	Power, electrical, MW
FCIC	55	Inventory charges, by material, mills/kwhr(e)
FCICI	56	Inventory charges, total, mills/kwhr(e)
RC	51,58	Replacement charges, by material, mills/kwhr(e)
RCI	59	Replacement charges, total, mills/kwhr(e)
PC	60	Processing charges, by material, mills/kwhr(e)
PCI	61	Processing charges, total, mills/kwhr(e)
SV		Material volume, ft^3
STS		Processing cycle time, days
PCR	62	Production credit, by material, mills/kwhr(e)
PCRI	63	Production credit, total, mills/kwhr(e)
FCC	64	Fuel-cycle cost, mills/kwhr(e)
ANDX	65	Neutron absorptions, by material
ANDI	66	Neutron absorptions, total, normalized to ETA
RPIV	67	Neutron captures, total, normalized to ETA
CPIV	68	Fissions, total, normalized to ETA
TØTALI	69	Total inventory, kg
RSIV	70	Processing removal rate, kg/day
CALC	71-74	Calculated value for recycle fraction
BCD	75	Processing source (external recycle)
A1	76	Decay source
A2	77	Decay and removal sink
A3	78	Burnup
A4	79	Transmutation source
A	80	Net sink

Equations in ERCM

Fission rate

$$F = P*3.1E-8 \qquad (A.1)$$

Atom density

$$CIM(I,J) = CIMI(I,J) \quad \text{all } I,J \tag{A.2}$$

Capture rate

$$CAP(I,J) = CA(I,J) - CF(I,J) \quad I \leq 50 \tag{A.3}$$

Total neutron absorptions

$$B = \sum_{J=1}^{MATS} \sum_{I=1}^{N200} CIM(I,J)*CA(I,J) \tag{A.4}$$

Mean nu

$$VM = \frac{\sum_{J=1}^{MATS} \sum_{I=1}^{20} CIM(I,J)*CN(I,J)}{\sum_{J=1}^{MATS} \sum_{I=1}^{20} CIM(I,J)*CF(I,J)} \tag{A.5}$$

Neutron balance

$$FVB = F*VM/B \tag{A.6}$$

Total neutrons produced

$$S16 = \sum_{J=1}^{MATS} \sum_{I=1}^{50} CIM(I,J)*CN(I,J) \tag{A.7}$$

External recycle rate

$$R[I,J] = \sum_{JP=1}^{MATS} \sum_{\substack{IPC=IP(I,1) \\ IPC\neq 0}}^{IP(I,2)} ((V(JP)*SDC(IPC,JP)*E(IPC,JP)*(1.0-SCE(IPC,JP))$$

$$*RCF(IPC,JP,J))/TS(JP)) \tag{A.8}$$

for $IPC \neq I$

$IPC=I$ and $JP \neq J$

Fission product source

$$FISS(I,J) = FVB* \sum_{IJ=1}^{13} CIM(IJ,J)*CF(IJ,J)*Y(I,J) \qquad I > 21 \text{ except } 24 \tag{A.9}$$

Feed rate and processing source equations:

For M655(I,J) = 0

$$CR94(I,J) = 0.0 \tag{A.10}$$

$$FRATE(I,J) = 0.0 \tag{A.11}$$

For M655(I,J) = 1

If IP(I+1,1) = I

or

If IP(I+1,2) = I CR94(I,J) = 0.0 (A.12)

If IP(I+1,1)≠I and IP(I+1,2)≠I

$$CR94(I,J) = V(J)*E(I,J)*(1.0-SCE(I,J))*RCF(I,J,J)/TS(J) \tag{A.13}$$

$$FRATE(I,J) = CIM(I,J)*(TRSK(I,J)+BDS(I,J)+PRS(I,J) - CR94(I,J)) - (R(I,J) + FISS(I,J) + TRAS(I,J) + D(I,J)) \tag{A.14}$$

For M655(I,J) = 2

$$FRATE(I,J) = (Q(I,J)/AMASS(I))*6.9710648\ E\text{-}3 \tag{A.15}$$

For M655(I,J) = 3

$$FRATE(I,J) = Q(I,J)*FRATE(ISTAR(I,J),J) \tag{A.16}$$

Beta decay sink coefficient

$$BDS(I,J) = V(J)*AMBA(I) \tag{A.17}$$

Processing removal sink coefficient

$$PRS(I,J) = V(J)*E(I,J)/TS(J) \tag{A.18}$$

Beta decay source rate

$$D(I,J) = V(J) * \sum_{\substack{ID1=ID(I,1) \\ ID1\neq 0}}^{ID(I,2)} CIM(ID1,J)*AMBA(ID1) \qquad (A.19)$$

Transmutation source rate

$$TRAS(I,J) = FVB * \sum_{\substack{IT1=IT(I,1) \\ IT1\neq 0}}^{IT(I,2)} CIM(IT1,J)*CAP(IT1,J) \qquad (A.20)$$

$$I \leq 50$$

$$TRAS(I,J) = FVB * \sum_{\substack{IT1=IT(I,1) \\ IT1\neq 0}}^{IT(I,2)} CIM(IT1,J)*CA(IT1,J) \qquad (A.21)$$

$$I > 50$$

$$TRAS(223,J) = FVB*CIM(222,J)*CA(222,J)*0.47 \qquad (A.22)$$

$$TRAS(224,J) = FVB*CIM(222,J)*CA(222,J)*0.53 \qquad (A.23)$$

Transmutation sink coefficient

$$TRSK(I,J) = FVB*CA(I,J) \qquad (A.24)$$

Atom-density equations:

For $N(I,J) = 0$

$$CIM(I,J) = CIMI(I,J) \qquad (A.25)$$

For $N(I,J) = 1$

If $M655(I,J) = 1$

$$CIM(I,J) = \frac{FRATE(I,J)+R(I,J)+FISS(I,J)+TRAS(I,J)+D(I,J)}{TRSK(I,J)+BDS(I,J)+PRS(I,J)-CR94(I,J)} \qquad (A.26)$$

If $M655(I,J) \neq 1$

If $IP(I+1,1) = I$

or

If $IP(I+1,2) = I \quad CR94(I,J) = 0.0$ (A.27)

If $IP(I+1,1) \neq I$ and $IP(I+1,2) \neq I$

$$CR94(I,J) = \frac{V(J)*E(I,J)*(1.0 - SCE(I,J))*RCF(I,J,J)}{TS(J)} \qquad (A.28)$$

$$CIM(I,J) = \frac{FRATE(I,J)+R(I,J)+FISS(I,J)+TRAS(I,J)+D(I,J)}{TRSK(I,J)+BDS(I,J)+PRS(I,J)-CR94(I,J)} \qquad (A.29)$$

For $N(I,J) = 2$

$$CIM(I,J) = CIM(I,J) + \frac{\sum_{JJ=1}^{MATS} \sum_{II=1}^{N200} CIM(II,JJ)*CA(II,JJ) - \sum_{JJ=1}^{MATS} \sum_{II=1}^{50} CIM(II,JJ)*CN(II,JJ)}{CN(I,J)} \qquad (A.30)$$

For $N(I,J) = 3$

$$CIM(I,J) = B*CIMI(I,J) \qquad (A.31)$$

For $N(I,J) = 4$
(Option for ^{235}U only)

$A31 = CIM(3,J)*CA(3,J)$

$A51 = CIM(5,J)*CA(5,J)$

$A11 = CIM(1,J)*CA(1,J)$

$A41 = CIM(4,J)*CA(4,J)$

$A21 = CIM(2,J)*CA(2,J)$

$F31 = CIM(3,J)*CF(3,J)$

$F51 = CIM(5,J)*CF(5,J)$

$$FA\emptyset16 = \frac{A31 + A51 - A11 - A41 + A21 + A21}{(F31 + F51)*V(J)}$$

$UA1 = 3.452E\text{-}5*P*F36*Q(I,J)*FA\emptyset16$

$$UB2 = \frac{0.863E\text{-}4*P*F36*CA(I,J)}{V(J)}$$

$TAR = ISTAR(I,J)$

$BT1 = UB2*TAR$

$$EX1 = \frac{1.0 - EXP(-BT1)}{BT1}$$

$$UAB = \frac{UA1}{UB2}$$

$$EIB = UAB - (Q(I,J)*(CIMI(3,J) + CIMI(5,J))$$

$$CIM(I,J) = UAB - (EX1*EIB) \qquad (A.32)$$

For N(I,J) = 5
(delayed neutron nuclide)

$$CIM(I,J) = \frac{1}{B*CA(I,J)} * \sum_{M=1}^{MATS} \left[\sum_{K=1}^{13} CIM(K,M)*CN(K,M) \right.$$

$$\left. * \sum_{L=1}^{6} \frac{BETA(K,L)*(1.0-EXP(-AMA3(L)*B55))*(1.0 - EXP(-AMA3(L)*B56))}{AMA3(L)*B55*(1.0-EXP(-AMA3(L)*(B55 + B56)} \right] \qquad (A.33)$$

For N(I,J) = 6
(fixed poison fraction)

$$CIM(I,J) = \frac{XE21(J) * \sum_{K=N21L(1)}^{N21L(N21K)} CIM(K,J)*CA(K,J)}{B*CA(I,J)} \qquad (A.34)$$

For N(I,J) = 7
(lumped fission product)

$$CIM(I,J) = \frac{\sum_{\substack{II=51 \\ INE(II,J)=0}}^{250} CIM(II,J)*CA(II,J)}{B*CA(I,J)} \qquad (A.35)$$

INE(II,J)≠0 for fission products treated specifically in MODRIC.

Equations in ERCØUT

Fraction of fission in material 1 (fuel)

$$FFFS = \frac{\sum_{I=1}^{N50} CIM(I,1)*CF(I,1)}{\sum_{J=1}^{MATS} \sum_{I=1}^{N50} CIM(I,J)*CF(I,J)} \qquad (A.36)$$

Breeding ratio

$$BR = \frac{\sum_{J=1}^{MATS} \left[\sum_{K=L22N1(1)}^{L22N1(K22N1)} CIM(K,J)*CAP(K,J) - \sum_{K=L22N2(1)}^{L22N2(K22N2)} CIM(K,J)*CA(K,J) \right]}{\sum_{J=1}^{MATS} \sum_{K=L22D(1)}^{L22D(K22D)} CIM(K,J)*CA(K,J)} \qquad (A.37)$$

Mean eta

$$ETA = \frac{B}{\sum_{J=1}^{MATS} \sum_{K=L23D(1)}^{L23D(K23D)} CIM(K,J)*CA(K,J)} \qquad (A.38)$$

Material inventory in kg

$$SI(I,J) = \frac{CIM(I,J)*V(J)*AMASS(I)}{602.3} \qquad \begin{array}{l} I = 1,16 \\ J = 1,MATS \end{array} \qquad (A.39)$$

Processing inventory in kg

$$PI(I,J) = \frac{SDC(I,J)*V(J)*E(I,J)*TP(J)*AMASS(I)}{TS(J)*602.3} \qquad \begin{array}{l} I = 1,16 \\ J = 1,MATS \end{array} \qquad (A.40)$$

Exception:

If $I = 2$ and $IP(3,1) = 2$ or $IP(3,2) = 2$

$$PI(2,J) = \frac{SDC(2,J)*V(J)*E(2,J)*AMASS(2)}{AMBA(2)*TS(J)*602.3} \qquad (A.41)$$

$$\left.\begin{array}{l} SI(I,J) = 0.0 \\ PI(I,J) = 0.0 \end{array}\right\} \quad \begin{array}{l} I = 17,N200 \\ J = 1,MATS \end{array}$$

Reserve inventory in kg

$$RSI(I,J) = 0.0 \quad \begin{array}{l} I = 1,N200 \\ J = 1,MATS \end{array} \quad \text{if } N(I,J) \neq 2 \tag{A.42}$$

If $N(I,J) = 2$

$$RSI(I,J) = \frac{F*VM * \left[CIM(I,J)*CA(I,J) - \sum_{IX=IT(I,1)}^{IX \neq 0 \; IT(I,2)} CIM(IX,J)*CAP(IX,J) \right]}{B*602.3}$$

$$* \; AMAS*1.1*TR(J) \tag{A.43}$$

Total inventory in kg

$$TØTI(I,J) = SI(I,J) + PI(I,J) + RSI(I,J) \tag{A.44}$$

Fissionable inventory in kg

$$FISSI = \sum_{J=1}^{MATS} \sum_{K=L29N(1)}^{L29N(K29N)} SI(K,J) + PI(K,J) + RSI(K,J) \tag{A.45}$$

Processing losses

$$PL = \frac{\sum_{J=1}^{MATS} \frac{V(J)}{TS(J)} * \sum_{K=L30N(1)}^{L30N(K30N)} SDC(K,J)*E(K,J)*SCE(K,J)}{\frac{F*VM}{B} * \sum_{J=1}^{MATS} \sum_{K=L30D(1)}^{L30D(K30D)} CIM(K,J)*CA(K,J)} \tag{A.46}$$

Yield

$$YIELD = \frac{37.8*VM*P*F36*(BR-1.0-PL)}{ETA*FISSI} \tag{A.47}$$

Feed rate in kg/day

$$FRTE(I,J) = FRATE(I,J)*AMASS(I)*143.4501 \quad \begin{array}{l} I = 1,N50 \\ J = 1,MATS \end{array} \tag{A.48}$$

$$FRTEI(I) = \sum_{J=1}^{MATS} FRTE(I,J) \qquad I = 1,N50 \qquad (A.49)$$

Production rate in kg/day

$$PDRTE(I,J) = \frac{SDC(I,J)*V(J)*E(I,J)*(1.0 - SCE(I,J))*AMASS(I)*143.4501}{TS(J)} * \prod_{JP=1}^{3} (1.0 - RCF(I,J,JP)) \qquad \begin{matrix} I = 1,N50 \\ J = 1,MATS \end{matrix} \qquad (A.50)$$

$$PDRAI(I) = \sum_{J=1}^{MATS} PDRTE(I,J) \qquad I = 1,N50 \qquad (A.51)$$

Processing rate in kg/day

$$PCRTE(I,J) = \frac{SDC(I,J)*V(J)*E(I,J)*AMASS(I)*143.4501}{TS(J)} \qquad (A.52)$$

$$\begin{matrix} I = 1,N50 \\ J = 1,MATS \end{matrix}$$

$$FCRTEI(I) = \sum_{J=1}^{MATS} PCRTE(I,J) \qquad I = 1,50 \qquad (A.53)$$

Power, electrical

$$PE36 = P*E36 \qquad (A.54)$$

Inventory charges in mills/kwhr(e)

$$FCIC(I,J) = \frac{0.114E\text{-}3*TØTI(I,J)*W1(I,J)*W2(I)}{PE36*F36} \qquad (A.55)$$

$$\begin{matrix} I = 1,N50 \\ J = 1,MATS \end{matrix}$$

$$FCICI(I) = \sum_{J=1}^{MATS} FCIC(I,J) \qquad I = 1,N50 \qquad (A.56)$$

Replacement charges in mills/kwhr(e)

$$RC(I,J) = \frac{0.0417*FRTE(I,J)*W5(I,J)}{PE36} \quad \text{if } M655(I,J) \neq 0 \tag{A.57}$$

$$RC(I,J) = 0.0 \quad \text{if } M655(I,J) = 0 \quad \begin{array}{l} I = 1,N50 \\ J = 1,MATS \end{array} \tag{A.58}$$

$$RCI(I) = \sum_{J=1}^{MATS} RC(I,J) \qquad I = 1,N50 \tag{A.59}$$

Processing costs in mills/kwhr

$$PC(I,J) = \frac{PCRTE(I,J)*W3(I,J)*0.0417}{PE36}$$

$$+ \frac{W4(I,J)*(PCRTE(I,J)*F36)**B57*0.114E-3}{PE36*F36}$$

$$+ \frac{WNEW(I,J)*0.0417}{PE36} * \left[\frac{SV(J)*E(I,J)}{STS(J)}\right]**B57 \tag{A.60}$$

$$\begin{array}{l} I = 1,N50 \\ J = 1,MATS \end{array}$$

$$PCI(I) = \sum_{J=1}^{MATS} PC(I,J) \qquad I = 1,N50 \tag{A.61}$$

Production credits in mills/kwhr(e)

$$PCR(I,J) = \frac{0.0417*PDRTE(I,J)*W1(I,J)}{PE36} \quad \begin{array}{l} I = 1,N50 \\ J = 1,MATS \end{array} \tag{A.62}$$

$$PCRI(I) = \sum_{J=1}^{MATS} PCR(I,J) \qquad I = 1,N50 \tag{A.63}$$

Fuel-cycle costs in mills/kwhr(e)

$$FCC = \sum_{J=1}^{MATS} \sum_{I=1}^{N50} FCIC(I,J) + RC(I,J) + PC(I,J) - PCR(I,J) \qquad (A.64)$$

Neutron absorptions

$$ANDX(I,J) = CIM(I,J)*CA(I,J) \qquad (A.65)$$

$$ANDI(I) = ETA * \sum_{J=1}^{MATS} ANDX(I,J) \qquad (A.66)$$

Neutron captures

$$RPIV(I) = ETA * \sum_{J=1}^{MATS} CIM(I,J)*CAP(I,J) \qquad (A.67)$$

Fissions

$$CPIV(I) = ETA * \sum_{J=1}^{MATS} CIM(I,J)*CF(I,J) \qquad (A.68)$$

Total inventory

$$T\emptyset TALI(I) = \sum_{J=1}^{MATS} SI(I,J) + PI(I,J) + RSI(I,J) \qquad (A.69)$$

Processing removal rate, kg/day

$$RSIV(I) = \sum_{J=1}^{MATS} SDC(I,J)*V(J)*E(I,J)*SCE(I,J)*AMASS(I)*143.4501/TS(J) \qquad (A.70)$$

<u>Equations in CYCI8</u>

Recycle fractions

If CALC $\geqslant$ 1.0

RCF(I,1,1) = 1.0

RCF(I,1,2) = 0.0

RCF(I,1,3) = 0.0

RCF(I,2,1) = 1.0

RCF(I,2,2) = 0.0

RCF(I,2,3) = 0.0

RCF(I,3,1) = 1.0

RCF(I,3,2) = 0.0

RCF(I,3,3) = 0.0

If CALC < 1.0

M655(I,J) = 0

If J655(I,J) = 1

RCF(I,1,1) = CALC

$$CALC = \frac{A(I,1) - BCD(I,2) - BCD(I,3)}{BCD(I,1)} \tag{A.71}$$

If J655(I,J) = 2

RCF(I,1,1) = CALC

RCF(I,2,1) = CALC

RCF(I,3,1) = CALC

$$CALC = \frac{A(I,1)}{(BCD(I,1) + BCD(I,2) + BCD(I,3)} \tag{A.72}$$

If J655(I,J) = 3

RCF(I,3,1) = CALC

$$CALC = \frac{A(I,1) - BCD(I,1) - BCD(I,2)}{BCD(I,3)} \tag{A.73}$$

If J655(I,J) = 4

RCF(I,2,1) = CALC

RCF(I,3,1) = CALC

$$CALC = \frac{A(I,1) - BCD(I,1)}{BCD(I,2) - BCD(I,3)} \tag{A.74}$$

Processing source

$$BCD(I,J) = \sum_{\substack{LA1=IP(I,1) \\ LA1 \neq 0}}^{IP(I,2)} \frac{SDC(LA1,J)*V(J)*E(LA1,J)*(1.0 - SCE(LA1,J))}{TS(J)} \tag{A.75}$$

Decay source

$$A1(I,1) = \sum_{\substack{ID1=ID(I,1) \\ ID1 \neq 0}}^{ID(I,2)} CIM(ID1,1)*V(1)*AMBA(ID1) \qquad (A.76)$$

Decay and removal sink

$$A2(I,1) = V(1)*\left[CIM(I,1)*AMBA(I) + \frac{SDC(I,1)*E(I,1)}{TS(1)}\right] \qquad (A.77)$$

Burnup

$$A3(I,1) = CA(I,1)*CIM(I,1) \qquad (A.78)$$

Transmutation source

$$A4(I,1) = \sum_{\substack{IT1=IT(I,1) \\ IT1 \neq 0}}^{IT(I,2)} CIM(IT1,1)*CAP(IT1,1) \qquad (A.79)$$

Net sink

$$A(I,1) = FVB*(A3 - A4) - A1 + A2 \qquad (A.80)$$

Appendix B

BASIC MODRIC EQUATIONS

The following description of the basic MODRIC equations is taken from Ref. 1.

The diffusion equation which describes the neutron flux $\phi(r,g)$ at a point r in the reactor within the energy group g has the form:

$$\nabla^2\phi(r,g) + R(r,g)\ \phi(r,g) + S(r,g) = 0\ , \tag{B.1}$$

where

$$R(r,g) = \frac{\Sigma_a^g + \sum_{i=g+1}^{g+10} U_i^g}{-D} - B^2, \tag{B.2}$$

$$S(r,g) = \frac{\chi_g f(r) + \sum_{i=g-10}^{g-1} \Delta u_i U_g^i\ \phi(r,i)}{D(\Delta u_g)}\ . \tag{ .3}$$

For the geometries here $\nabla^2\phi \equiv \phi'' + \frac{\rho}{r}\phi'$, where

$\rho = 0$ for a slab,
$= 1$ for a cylinder,
$= 2$ for a sphere.

In order to state the problem in its entirety, it is convenient to change the notation so that the dependence of the variables and parameters on a particular energy group is omitted. Thus, the diffusion equation can be written:

$$\phi''(r) + \frac{\rho}{r}\phi'(r) + R(r)\ \phi(r) + S(r) = 0\ . \tag{B.4}$$

The boundary conditions at the origin ($r = 0$) and the outer boundary* ($r = R_N$) are:

---

*May include the extrapolated distance.

$$a\phi(0) + 2bD\phi'(0) = c \ , \tag{B.5}$$

$$d\phi(R_N) + 2eD\phi'(R_N) = f \ , \tag{B.6}$$

where a., b, c, d, e, and f are parameters which can vary with the energy group.

Another type of boundary condition occurs between regions at radius R_I. This takes the following form for an interface with no shell:

$$[\phi(R_I) - 2D\phi'(R_I)]_- = [\phi(R_I) - 2D\phi'(R_I)]_+ \ , \tag{B.7}$$

$$[\phi(R_I) + 2D\phi'(R_I)]_- = [\phi(R_I) + 2D\phi'(R_I)]_+ \ , \tag{B.8}$$

where the - and + signs refer to values at the left and right of the interface respectively. An interface with a shell is a subregion from R_I to R_J with attenuation of the neutron currents given by the following:

$$GR_I^\rho[\phi(R_I) - 2D\phi'(R_I)]_- = R_J^\rho[\phi(R_J) - 2D\phi'(R_I)]_+ \ , \tag{B.9}$$

$$R_I^\rho[\phi(R_I) + 2D\phi'(R_I)]_- = HR_J^\rho[\phi(R_J) + 2D\phi'(R_J)]_+ \ . \tag{B.10}$$

Again, G and H can vary with energy group. The - and + signs refer to values to the left of R_I and the right of R_J respectively. We can use Eqs. (B.9) and (B.10) for the special case of no shell by setting $R_I = R_J$. For continuity of the flux and current across the interface, $G = H = 1$, but this is not necessary if desired otherwise.

Nomenclature

r	=	Radial distance for a cylinder or sphere, longitudinal distance through a slab
g	=	Lethargy group index
$\phi(r,g)$	=	Neutron flux per unit lethargy at distance r in group g
Σ_a^g	=	Macroscopic absorption cross section* for group g
U_i^g	=	Macroscopic scattering cross section* for heavy elements from group g to group i
Σ_f^g	=	Macroscopic fission cross section* in group g multiplied by the neutrons/fission
B^2	=	Transverse buckling
D	=	Diffusion coefficient*
Δu_g	=	Lethargy width of group g
χ_g	=	Fraction of fission neutrons emitted in group g
$f(r)$	=	Fission density at distance r
$R(r,g)$	=	Removal term in diffusion equation
$S(r,g)$	=	Source term in diffusion equation

*Assumed to be constant over a region, but can vary with g.

Appendix C

FISSION PRODUCT TREATMENT*

The fission-product reaction rate coefficient is obtained by reference to a specified standard absorber:

$$C^{FP} = C^{R} \frac{\bar{\sigma}^{FP}}{\bar{\sigma}^{R}} , \tag{C.1}$$

where

C^{FP} = fission-product reaction rate coefficient,

C^{R} = reference material reaction rate coefficient,

$\bar{\sigma}^{FP}$ = effective fission-product absorption cross section,

$\bar{\sigma}^{R}$ = effective reference material absorption cross section.

The effective cross section ratio is obtained from a two-group formulation:

$$\frac{\bar{\sigma}^{FP}}{\bar{\sigma}^{R}} = \frac{(\sigma_1\phi_1/\phi_2 + \sigma_2)^{FP}}{(\sigma_1\phi_1/\phi_2 + \sigma_2)^{R}} , \tag{C.2}$$

where

σ_1 = fast absorption cross section = $\dfrac{\int_0^{u_{th}} \sigma_a(u)\, du}{u_{th}} = \dfrac{(RI)_a}{u_{th}}$,

$\bar{\sigma}_2$ = absorption cross section averaged over the thermal flux,

ϕ_1 = fast flux,

ϕ_2 = average thermal flux.

For a two-group treatment, all neutrons removed from the fast group must either be absorbed or leak from the reactor while thermal:

$$\Sigma_{R_1}\phi_1 = \Sigma_{a_2}\phi_2 + DB^2\phi_2 . \tag{C.3}$$

Ignoring leakage,

---

*This section has been revised from Ref. 2.

$$\frac{\phi_1}{\phi_2} = \Sigma_{a_2}/\Sigma_{R_1} \ . \tag{C.4}$$

Also,

$$\sigma_2 = f\ \sigma_a^{2200} \ , \tag{C.5}$$

where

f = thermal spectrum factor = $\sqrt{(\frac{\pi}{4})\ (\frac{298}{T + 273})}$ for a Maxwell-Boltzmann distribution,

σ_a^{2200} = 2200 m/s absorption cross section.

Substituting Eqs. (C.2), (C.4), and (C.5) into (C.1) gives

$$C^{FP} = C^R \left[\frac{(K(RI) + \sigma_a^{2200})^{FP}}{\alpha} \right] \ , \tag{C.6}$$

where

$$K = \frac{\Sigma_{a_2}}{\Sigma_{R_1}\ f\ \Delta u} \ ,$$

$$\alpha = (K(RI) + \sigma_a^{2200})^R .$$

K is calculated as follows:

$K = WS$,

$W = \frac{1}{f\ \Delta u}$ = input

$S = \Sigma_{a_2}/\Sigma_{R_1}$ = value automatically calculated by MODRIC for the composition being studied.

The nuclear constants for a 1/v absorber with a 2200 m/s cross section of 1.0 barns are built into the code. Therefore, the reference element must correspond to an artificial element in MODRIC which has cross sections for a 1/v absorber with $\sigma_a^{2200} = 1.0$.

Certain important fission products may be calculated explicitly by the multigroup diffusion calculation in MODRIC, using fission product option 2. Cross sections for such nuclides must be provided in the usual format on the cross section tape.

Appendix D

THE PROCESSING STUDY OPTION

An Alternative Calculation of Fission-Product Poisoning

For some applications it is necessary to compute the fission-product poisoning using a model other than the first-order removal process considered in the ERC calculations. An option has been provided in ROD with which it is possible to call a subroutine, named BELL, to be supplied by the user, to perform an alternative calculation of the lumped fission-product poisoning (refer to card B-1). If this option is designated, equilibrium concentrations will be computed in the ERC calculation for only those nuclides treated explicitly in the MODRIC diffusion calculation. When both the diffusion and equilibrium calculations have converged to within the specified limits for a given value of the lumped fission-product concentration, the program will call subroutine BELL to obtain a new estimate of the lumped fission-product concentration. This subroutine is called with the following argument list: SUBRØUTINE BELL (CØNC, ABSRC, BR, Y, BAL, P8, SV, RIFAC, ALPHA, FCC, CØNCFP, ETA). The variables CØNC and ABSRC are each dimensioned for fifty values in the calling program and contain, using the ERC numbering system, the atom densities, in atoms/barn-cm, and the relative absorption rates per unit atom density, absorption/(fissile absorption-atom/barn-cm), for the ERC principle nuclides. The definitions of the remaining variables are:

BR = breeding ratio,

Y = fuel yield, percent per annum,

BAL = ratio of two previous iterations of the converged equilibrium calculation,

P8 = reactor thermal power, MW,

SV = fuel salt volume, ft^3,

RIFAC = resonance integral factor, flux per unit lethargy/thermal flux,

ALPHA = spectrum-averaged neutron cross section for a 1/v absorber whose 2200 m/sec cross section is 1.0 barn, barns,

FCC = fuel-cycle cost, mills/kwhr(e),

CØNCFP = new value of lumped fission-product concentration computed by subroutine BELL, atoms/barn-cm,

ETA = effective value of $\eta\epsilon$, neutrons produced/fissile absorption.

With the exception of the variable CØNCFP, the values of all the arguments are computed by ROD for use by subroutine BELL. BELL uses the information in the argument list, and an independent set of fission yields, decay schemes, thermal neutron cross sections, and resonance integrals to compute the fission-product inventories and poisoning for a given set of processing conditions. The individual fission-product poisonings are summed, and this lumped fission-product poisoning is used to compute the concentration of the reference 1/v absorber which would produce the same poisoning. This concentration is the value of the variable CØNCFP which is returned to the calling program in ROD. The diffusion and equilibrium calculations are repeated using the new value of the lumped fission-product concentration, and the process is continued until the lumped fission-product concentration from two successive iterations converges to within a predtermined relative error. At this point the entire process may be repeated for another set of processing conditions, or the calculations may be terminated. When using this option to calculate the poisoning by the lumped fission products it is necessary to remove the permanent fission product data from the ERC input and to specify atom-density option 0 on ERC input card B-22 for the lumped fission-product nuclide. This specifies that the value of the lumped fission-product concentration is not to be changed in the equilibrium calculation.

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