DATE ISSUED MAR 1 1979

ORNL-5180

760611

202 pages

ORNL
MASTER COPY

# Exposure Calculation Code Module for Reactor Core Analysis: BURNER

D. R. Vondy
G. W. Cunningham

OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION • FOR THE DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY LIBRARIES
3 4456 0536803 6

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy $9.25; Microfiche $3.00

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, contractors, subcontractors, or their employees, makes any warranty, express or implied, nor assumes any legal liability or responsibility for any third party's use or the results of such use of any information, apparatus, product or process disclosed in this report, nor represents that its use by such third party would not infringe privately owned rights.

ORNL-5180
Distribution Category
UC-79d-LMFBR Physics

Contract No. W-7405-eng-26

Engineering Physics Division

# EXPOSURE CALCULATION CODE MODULE FOR REACTOR CORE ANALYSIS: BURNER

D. R. Vondy and G. W. Cunningham*

*UCC-ND Computer Sciences Division.

Date Published: February 1979

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

TABLE OF CONTENTS


| Section | Section Headings | Page |
|---|---|---|
| | ABSTRACT | v |
| | COMPUTER CODE ABSTRACT | vii |
| 01 | GENERAL DISCUSSION | 01-1 |
| | Introduction | 01-2 |
| | Method of Solving Problems | 01-2 |
| 02 | USER INFORMATION | 02-1 |
| 03 | PROGRAMMER INFORMATION | 03-1 |
| | Conversion. | 03-1 |
| 04 | DATA INTERFACING | 04-1 |
| | Information About the Exposure Data | 04-44 |
| 05 | DATA HANDLING STRATEGY | 05-1 |
| 06 | SAMPLE PROBLEMS | 06-1 |
| 07 | VERIFICATION TESTING | 07-1 |
| 08 | MATHEMATICAL EQUATIONS | 08-1 |
| | The Average Generation Rate Formulation | 08-2 |
| | The Explicit Chain Solution | 08-4 |
| | The Matrix Exponential Scheme | 08-6 |
| | Example Problem | 08-13 |
| | Shutdown and Negative Exposure Step | 08-18 |
| | Computation Time | 08-19 |
| | Power Level Renormalization | 08-19 |
| | Use of Flux Values at Two Points in Time | 08-20 |
| | Exposure of Materials in Zones | 08-21 |
| | Subzones. | 08-23 |

Local Detail Exposure . . . . . 08-25

The Steady State, Continuous Fueling Model . . . . . 08-27

Averaging the Exposure Results . . . . . 08-34

Integrals . . . . . 08-35

Significance . . . . . 08-38

Manuscript prepared by: Bonnie McCarter
Virginia Glidewell
Ann Houston

## ABSTRACT

This report documents the code module BURNER for nuclear reactor exposure calculations. The computer requirements are shown, as are the reference data and interface data file requirements, and the programmed equations and procedure of calculation are described. The operating history of a reactor is followed over the period between solutions of the space, energy neutronics problem. The end-of-period nuclide concentrations are determined given the necessary information. A steady state, continuous fueling model is treated in addition to the usual fixed fuel model. The control options provide flexibility to select among an unusually wide variety of programmed procedures. The code also provides user option to make a number of auxiliary calculations and print such information as the local gamma source, cumulative exposure, and a fine scale power density distribution in a selected zone. The code is used locally in a system for computation which contains the VENTURE diffusion theory neutronics code and other modules.

## COMPUTER CODE ABSTRACT

1. Identification: BURNER is a code module for exposure calculations.

2. Function: This code is designed to solve the nuclide chain equations to estimate the nuclide concentrations at the end of an exposure time and also after a shutdown period in a compatible code system.

3. Method of Solution: The explicit chain equation solution is cast in a general form for application. Alternatively, by user option, either a difference formulation using average generation rates or the matrix exponential approach may be applied with selected chains also treated explicitly. Given the necessary cross sections, (n,gamma), (n,$\alpha$), (n,2n), (n,p), (n,d), (n,t), and (n,f), transmutation products may be determined, and fission product yield fractions may be incident-energy dependent. Nuclides at both a zone and a subzone level are exposed to the zone-average flux. The usual fixed fuel model is treated and also a steady state, continuous fueling model. There is a provision for a fine-scale exposure to be calculated within selected zones, and the gamma source and cumulated exposure information may be obtained.

4. Related Material: Code blocks satisfying the basic requirements of the DOE reactor physics code coordination effort will interface with this module by way of defined external data files.

5. Restrictions: Data arrays are variably dimensioned and allocated disc space only as necessary for effective application to a wide range of problems, with a reasonable use of memory.

6. Computer: This code has been run on IBM computer models 360/75, 91, and 195.

7. Running Time: The computation time varies approximately as the number of depleting zones and as the square of the number of nuclides in a zone. For typical production type problems for which each zone contains a number of mesh points, the exposure calculation for a modest number of nuclides is trivial compared with that required for solution of the neutron flux problem.

8. Programming Languages: FORTRAN language is used with a few extensions to the ASA 1966 Std., especially in the service routines. The source deck contains approximately 24,000 cards.

9. Operating System: The OS-360 IBM operating system is used under HASP with a FORTRAN IV, H level compiler version 21.8, not extended.

10. Machine Requirements: A 64,000 word core is needed, and preferably considerably more for usual application (total requirements are usually governed by the neutronics code used). Auxiliary disk storage is required for up to 10 sequential scratch files and 4 direct access scratch files.

11. Authors: G. W. Cunningham and D. R. Vondy, Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tennessee 37830.

12. References:

a. D. R. Vondy and G. W. Cunningham, "Exposure Calculation Code Module for Reactor Core Analysis: BURNER," DOE Report ORNL-5180 (1979).

b. D. R. Vondy *et al.*, "A Computation System for Nuclear Reactor Core Analysis," ERDA Report ORNL-5158 (1976).

c. G. E. Bosler *et al.*, "LASIP-III, A Generalized Processor for Standard Interface Files," ERDA Report LA-6280-MS (April 1976).

13. Material Available: FORTRAN source deck card images are included in the package submitted to the Argonne Code Center.

# SECTION 01: GENERAL DISCUSSION

## Introduction

This report documents the code module BURNER which calculates the effects of exposure. Given neutron flux values as dependent on material location and energy, the nuclide concentrations at the end of an exposure step are predicted from those at the start. BURNER has been developed to serve in a computation system with other compatible codes developed in the DOE reactor physics area, especially those such as VENTURE[a] or SYN3D[b] which solve the neutron flux problems. This module is in operation on the local computers at ORNL in the system[c] which contains the VENTURE code.

In the local computation system there are a number of modules, each designed to perform specific tasks. They are accessed in accordance with user instructions along a prescribed path of calculation, under the direction of a control module. As the development effort continues, the capability is being enhanced to treat more sophisticated and complicated situations. For example, a relatively simple control module is in use at the time this is written. We expect to add to the system another control module which will effect a desired calculational path and automatically

---

[a] D. R. Vondy, T. B. Fowler, G. W. Cunningham, "VENTURE: A Code Block for Solving Multigroup Neutronics Problems Applying the Finite-Difference Diffusion-Theory Approximation to Neutron Transport, Version II, "Oak Ridge National Laboratory report ORNL-5062/R1 (1977).

[b] C. H. Adams, "SYN3D, A Single-Channel, Spatial Flux Synthesis Code for Diffusion Theory Calculations," ERDA Report ANL-76-21 (July 1976).

[c] D. R. Vondy, T. B. Fowler, G. W. Cunningham and L. M. Petrie, " A Computation System for Nuclear Reactor Core Analysis," Oak Ridge National Laboratory report ORNL-5158 (April 1977).

exercise control over instructions to the calculational modules from simple, global instructions by the user for reactor history calculations. A neutronics module is of course essential for solving usual depletion problems. Other modules are necessary to perform specific tasks as allocated in this system. Certain modules process user input data to generate interfacing data files, including an input data processor that originated at LASL[a] which has been modified and extended to serve local requirements. A particular advantage of a truly modularized computation system is its flexibility; given the necessary data files already in existence or generated from user input data, the exposure module may be used without access of other calculational modules. Thus given flux data, the changes in an initial set of nuclide concentrations may be determined for a period of exposure. A disadvantage of a modular system for routine application to simple situations involves the calculational path: a viable calculational procedure must be specified as defined by the path through the modules. The processing of user input data and computations must be properly sequenced. Normally the user input data must be processed first to supply data, and then a neutronics module must be executed before executing the exposure module, in order to supply it with neutron flux values.

## Method of Solving Problems

This exposure module was designed for application to the longtime reactor exposure problem, with emphasis on those aspects associated with assessment of reactor performance. Typically a neutronics module is executed to determine the neutron flux distribution at some point in

---

[a]G. E. Bosler et al., "LASIP-III, A Generalized Processor for Standard Interface Files," ERDA Report LA-6280-MS (April 1976).

time for the reactor model, given nuclide concentrations or a state condition to be satisfied. Exposure to this flux over an interval of time causes the nuclide concentrations to change. The periods between successive reactor fuelings are treated by alternating between neutronics and exposure calculations. This separability assumption is necessary when large, time consuming neutronics problems are involved. To hold down computation cost, a relatively long exposure period is required between neutronics problems. Techniques are used to make a reliable calculation over a long exposure period. The flux level may be readjusted to effect the desired average power level, and reexposure may be done to use average flux values over periods during which shifts can occur, as due to control rod positioning. The objective is reliable analysis under the severe burden of high computation cost forcing relatively coarse approximations. The analyst must choose from among the large number of alternatives available to describe a problem in detail so as to satisfy the primary objectives of the calculation. The primary considerations often include the requirements to predict power density peaking, reactivity effects of changes in the concentrations of those nuclides contributing significantly to the neutron balance, and fuel nuclide accounting in the mass balance sense.

If 20 nuclides are considered in 1,000 zones, there are 20,000 nuclide concentrations to follow; if 1,000 nuclides were considered in 10,000 zones, there would be the burden of following 10,000,000 nuclide concentrations, unreasonable in the present state of the art of computation. Problems must be tailored to emphasize the more important aspects and methods implemented which utilize the available computation capability effectively.

Selection of appropriate methods must be based on a number of considerations. We see the need in application over the range from a very simple treatment to a sophisticated one. There has been wide use of the elementary finite-difference solution. Given the linear chain equation

$$\frac{dN_n(t)}{dt} = - a_n N_n(t) + P_n(t)$$

for a very short time interval $\Delta$,

$$N_n(\Delta) = N_n(o)(1-a_n\Delta) + \frac{\Delta}{2}[P_n(o)+P_n(\Delta)]$$

where $N_n$ is the concentration of a nuclide, $a_n$ is its specific loss rate (neutron absorption plus decay), and $P_n$ is its generation rate from all possible sources. This formulation allows for complicated chain relationships, but unfortunately there are many situations where it is quite inaccurate. Since $1 - a_n\Delta$ is an approximation of exp $(-a_n\Delta)$, the next term of an expansion would be $+ (a_n\Delta)^2/2$, so the error of the expansion decreases in proportion to $\Delta$. It is often inadequate to take many short steps, so we implement a precise solution of this differential equation using average generation rates.

Alternatively, the conventional matrix exponential technique is offered on demand. Also, there is provision to solve the nuclide chain equations exclusively with an explicit solution, or with only special designated ones to supplement the application of one of the other schemes. Each scheme has advantages and disadvantages, and cost of computation bears consideration. We only hope that the analyst will not become bogged down testing all of the possible alternatives!

In usual application for reactor core analysis, only a few energy groups are treated to make the multidimensional neutronics problems tractable. Typically each nuclide has several sets of microscopic cross sections to account for spatial dependence of neutron reaction and transport. The data requirements for exposure calculations are compacted significantly by associating the chain equations and data such as fission yield with absolute nuclide names.

The analyst is given full flexibility over the problem definition, which does place the burden on him to make certain that those aspects of importance in a specific application are treated. A reasonable amount of experience is essential for reliable application; some of this necessary background can be established by application of the methods to simple models at reasonable computation cost. Such calculations are usually essential as backup to costly three-dimensional calculations in order to assess modeling and aspects of importance including power density peaking, reactivity behavior, and the estimates of the fuel enrichment required to satisfy criticality and physical design constraints.

In this report we discuss a number of aspects to support application, present information needed for efficient implementation and verification at other installations, show the mathematical equations programmed, and document input requirements.

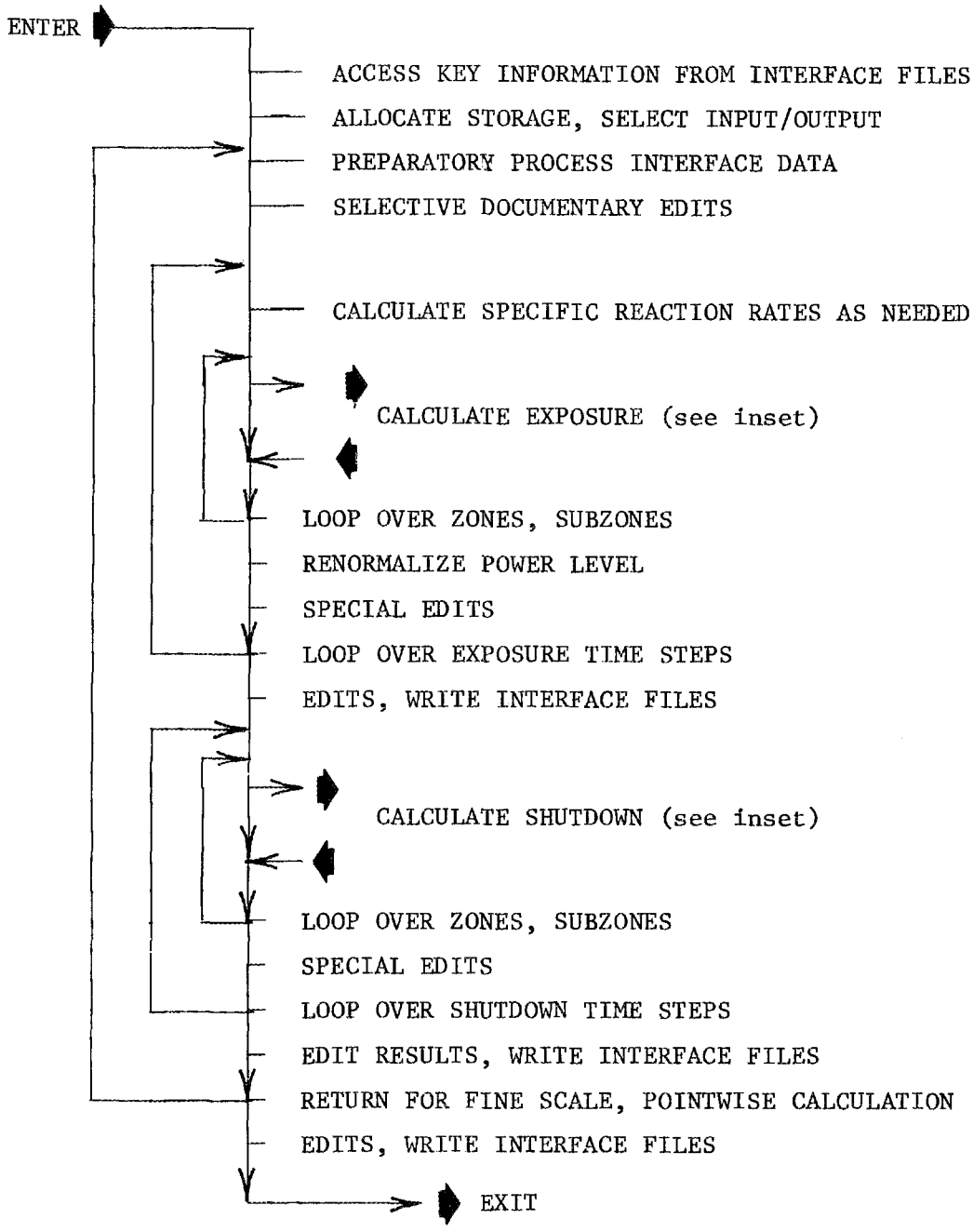
END OF SECTION

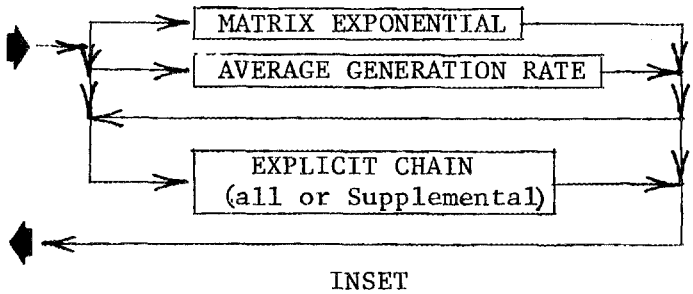
# SECTION 02: USER INFORMATION

The user is reminded that exposure calculations are done on a microscopic scale. Only changes in those nuclides identified in the chain specifications will be calculated. It is possible to lump together nuclides and data for treatment in the macroscopic sense only if associated exposure effects are not to be treated. Thus, structural material may be represented by a mixture of the isotopes. Take care, however, that such lumping does not cause the loss of the ability to produce the desired results. Care must also be taken to effect true neutron absorption rates, integral $\sigma\phi$, so usually pseudo nuclide concentrations can not be used (deplete $B^{10}$, not natural Boron). It is the integral $\sigma\phi$ which must be correct; smeared nuclide concentrations can be used to eliminate fine geometric detail.

A diagram of the flow of an exposure calculation is shown in Figure 02-1, hopefully self-explanatory. The three implemented methods of solution are in parallel for selective application per user instructions. As shown, a supplemental explicit chain solution is available for application when this method is not applied exclusively. Instructions for a calculation are contained in the record for this module (EXPINS) in the file CONTRL, and special data, including chain descriptions, are in file EXPOSE (see Section 04).

This module is designed to perform a task which may be very simple or rather complicated. The nuclide concentrations are estimated for the end of an exposure period, a shutdown period, or both. The results (final concentrations and exposure data) depend on the instructions for the calculations, the reference data supplied, and the neutron flux and nuclide




INSET

Figure 2.1. User Flow Diagram of BURNER Module.

concentrations accessed. It is of special importance and concern to an analyst to make certain that the details under his control are consistent and adequately present the problem he desires to be solved. Some verification testing, including the solution of a simplified version of the problem, is usually desirable. The same interpretation of external interface data files must be made by all modules used and by any other codes involved as to generate data files or to process results.

It is not intended that some weird combination of the procedures be applied to a single problem. Rather, a procedure should be selected from those available. The user should resist the temptation to produce edits of all possible results and should carefully select only those really needed; more elaborate results may be obtained at any point in a calculation by supplying special instructions for that step of the calculation.

The provision for treating an exposure period in more than one step is made primarily to allow the flux level to be renormalized at the end of each step to effect the desired average power level.

If a single exposure period is to be considered, then the BURNER module need be accessed only once. Usually a neutronics problem must be solved first. If several exposure periods are to be treated, then usually a neutronics module and this module are accessed one after the other. A single set of instructions for BURNER may be used, or a new record of instructions can be made available in the file CONTRL when desired. The system admits access of other modules along the calculational route as desired. For example, a final neutronics calculation may be required to establish end-of-cycle conditions, and may be desired for special results

such as to solve the adjoint flux problem. Quite generally, nuclide concentrations can not be changed arbitrarily during the period between fuelings. However, a separate module could be used to alter specific nuclide concentrations to simulate control rod positioning and also perhaps to account for temperature and coolant density changes; similarly the concentrations may be changed with new input data in order to effect refueling or control rod positioning.

There is provision to do an auxiliary exposure calculation on a fine scale within selected zones which impacts the data requirements and places additional demands on the neutronics code.

The user is reminded that the exposure calculation is done without accessing the geometric description of the problem. End-of-exposure step nuclide concentrations are obtained for each zone and subzone, without reference to geometric details. However, the calculation may depend on the zone volumes provided (when the flux level is renormalized), and edits of results depend on volumes, so they should be consistent. User beware!

Recommendations on Chain Equation Solution Method

Generally for simple nuclide chains we recommend the explicit solution method. This method is not recommended for treating situations where there is significant feed-back (that cannot be represented simply), nor for elaborate, complicated coupling situations (reliable elaborate descriptions are difficult to write).

For elaborate, complicated coupling situations, the matrix exponential method with intermediate nuclides having large loss coefficients assumed to be at equilibrium, is recommended.

The average generation rate method can be used to produce reliable

solutions, but it is deemed to be cost ineffective and is recommended against generally.

The full matrix exponential method implemented is rather expensive to apply, and so its use should be limited to testing specific situations, benchmarking, or possibly the situation where the concentrations of the nuclides far up the chains must be determined accurately or at least spot checked.

Quite generally it is desirable to treat a long exposure period (between neutron, flux solutions) in two steps rather than one to effect the desired power level on the average. Alternatively, as when control rods must be considered, it may be necessary to repeat the exposure calculation using a weighting between start-and-end-of-exposure-period neutron flux estimates to produce accurate results.

For the reverse exposure problem, exposure with a negative time, we find that an exposure period should be short and that only simple nuclide coupling should be treated avoiding intermediate nuclides, limiting the value of the largest loss coefficient $(t\int\sigma_a(E)\phi(E)dE)$ to less than 1.0. It may be necessary to discard false values of nuclide concentrations which can lead to unrealistic results (not programmed).

END OF SECTION

# SECTION 03: PROGRAMMER INFORMATION

We consider basic documentation to be the FORTRAN source deck listing, available elsewhere. Coarse documentation of the program routines is presented here. Table 03-1 identifies the roles of the subroutines and call references; service routines are identified. For documentation of the service routines, see ORNL-5062. Table 03-2 identifies a recommended overlay structure.

Basic information about the use of scratch files is shown in Table 03-3.

## Conversion

For conversion to other computers, care must be taken to avoid loss of integrity. Conversion to a long-word machine is best done with a FORTRAN source deck processor to eliminate the double precision and references to double precision library routines, and also to convert the use of apostrophe to delineate Hollerith strings (limited to service routines). Detailed conversion recommendations will be provided with the code package.

TABLE 03-1 INFORMATION ABOUT SUBROUTINES

```
C*********************************************************************-
C                                                                     -
C     BURNER SUBROUTINE DESCRIPTION                                   -
C     -----------------------------                                   -
C                                                                     -
C     ANOR    DETERMINE NORM OF MATRIX                                -
C     ARRI    SUM INVENTORY AND REACTION RATES (ABSORPTION, FISSION,  -
C              PRODUCTION, AND CAPTURE(N,G) ) BY ABSOLUTE NUCLIDE     -
C     AUXE    WRITE CONDENSED EDIT                                    -
C     BFIX    NORMAL EXPOSURE CALCULATION                             -
C     BGXS    PROCESS NEXT-TO-LATEST GRUPXS                           -
C     BINP    INITIAL INTERFACE PROCESSING (NDYSRF, GEODST, GRUPXS,   -
C              AND EXPOSE) AND DATA PREPARATION                       -
C     BMOV    CONTINUOUS FUELING EXPOSURE CALCULATION                 -
C     BPIA    CONTROL GEOMETRY (GEODST) AND POINT FLUX (RTFLUX)       -
C              PROCESSING FOR POINT CALCULATION (METHOD 1)            -
C     BPIB    CONTROL POINT FLUX (RZFLUX-MODIFIED) PROCESSING         -
C              FOR POINT CALCULATION (METHOD 2)                       -
C     BPIC    INITIAL DENSITY PREPARATION, COMPUTE REACTION RATES AND -
C              SETUP STORAGE FOR POINT EXPOSURE AND SHUTDOWN          -
C              CALCULATION                                            -
C     PPIN    CONTROL SETUP FOR POINT EXPOSURE AND SHUTDOWN           -
C     BRCI    OBTAIN EXPOSURE CONTROL INFORMATION FROM INTERFACE CONTRL -
C     BRDS    SETUP DYNAMIC DATA STORAGE SPACE                        -
C     BRNA    COMPUTE SPECIFIC REACTION RATES FOR ABSORPTION, FISSION, -
C              NU*FISSION, (N,G), (N,A), (N,P), (N,2N), (N,D), AND (N,T)-
C     BRND    EDIT SPECIFIC REACTION RATES                            -
C     BRNF    SETUP INTERNAL CROSS-REFERENCING INFORMATION FOR ABSOLUTE -
C              NUCLIDE, NUCLIDE CLASS, AND ZONE CLASS                 -
C     BRNO    PREPARE AND EDIT FINAL SUMMARY TABLE                    -
C     BRNS    DETERMINE STORAGE REQUIRED AND MODE OF SOLUTION AND     -
C              INITIALIZE DIRECT ACCESS UNITS IF NEEDED               -
C     BRNT    PRE-WRITE DIRECT ACCESS UNITS IF NEEDED                 -
C     BRNW    EDIT CONTENTS OF EXPOSE FILE - CHECKS DECAY, YIELD, AND -
C              MATRIX DATA FOR ERRORS                                 -
C     BRNX    SETUP DECAY CONSTANTS AND CORRESPONDENCE BETWEEN DENSITY -
C              AND EXPOSURE DATA                                      -
C     BRNY    EDIT ATOM DENSITIES                                     -
C     BRNZ    PROCESS ZNATDN AND WRITE INITIAL DENSITIES ON SCRATCH   -
C              ONE ZONE/SUBZONE AT A TIME                             -
C     BRN1    OVERALL CALCULATION CONTROL                             -
C     BRN3    PROCESS RZFLUX AND WRITE ZONE AVERAGE FLUX ON SCRATCH   -
C              ONE GROUP AT A TIME - PERFORM INITIAL POWER ADJUSTMENT -
C     BRN4    CHECK NUCLIDE NAMES AND CLASSES FROM 2 SOURCES          -
C     BRN7    COPY PRINCIPAL CROSS SECTIONS FROM GRUPXS TO SCRATCH    -
C     BRPF    COMPUTE SPECIFIC REACTION RATE FOR FISSION IN ENERGY    -
C              RANGES OF YIELD DATA FOR POINT CALCULATION             -
C     BRRF    COMPUTE SPECIFIC REACTION RATE FOR FISSION IN ENERGY    -
C              RANGES OF YIELD DATA                                   -
C     BURN    CONTROLS EXPOSURE AND SHUTDOWN CALCULATION              -
```

(CONT)

```
C     BZIN    ADDITIONAL INTERFACE PROCESSING (RZFLUX AND ZNATDN) AND   -
C              COMPUTE REACTION RATES AND SETUP STORAGE FOR             -
C              EXPOSURE AND SHUTDOWN CALCULATION                        -
C     BZT1    DETERMINE IF ZNTEMP EXISTS AND CHECK INPUT DATA           -
C     BZT2    PROCESS TEMPERATURES FROM ZNTEMP                          -
C     CHEK    DEBUG FLUX CHECK FOR POINT CALCULATION (METHOD 1)         -
C     CMOV    CHECK NUCLIDE SET REFERENCES FOR CONTINUOUS FUELING MODEL -
C     CMPH    COMPARE 2 HOLLERITH ARRAYS                                -
C     CMPI    COMPARE 2 INTEGER ARRAYS                                  -
C     CPH1    COPY ONE SET OF EXPOHT DATA FROM ONE UNIT TO ANOTHER      -
C     CPH2    EDIT ONE SET OF EXPOHT DATA                               -
C     DEEF    SETUP AND CHECK INPUT PARAMETERS FOR CONTINUOUS FUELING   -
C              MODEL                                                    -
C     DOEX    EXPOSURE BY VARIOUS METHODS                               -
C     DOPC    SCRATCH FILE DATA TRANSFER MANAGEMENT FOR SPECIAL ACCESS  -
C              METHODS (NOT SEQUENTIAL)                                 -
C     DOSH    SHUTDOWN BY VARIOUS METHODS                               -
C     DOWN    SHUTDOWN CALCULATION                                      -
C     ECHK    CHECK NEUTRON ENERGY GROUP STRUCTURE                      -
C     EDED    EDIT SECONDARY ENERGY DEPOSITION DATA FROM EXPOSE         -
C     EDEP    SETUP FOR SECONDARY ENERGY DEPOSITION EDITS               -
C     EPFD    SET DEFAULT VALUE FOR ENERGY/FISSION AND ENERGY/CAPTURE   -
C              IF NECESSARY                                             -
C     EPH2    EDIT MAXIMUMS AND SYSTEM TOTALS OF EXPOHT DATA            -
C     ESET    DETERMINE WHICH ENERGY GROUP NUMBER IS CUTOFF AND         -
C              FRACTIONAL PART FOR FLUENCE CALCULATION                  -
C     ETAB    CALCULATE AND EDIT SECONDARY ENERGY DEPOSITION            -
C     EXPH    SETUP AND CONTROL FOR WRITING INTERFACE EXPOHT            -
C     FERR    WRITE FATAL ERROR MESSAGE AND STOP                        -
C     FLUC    FUNCTION TO DETERMINE (FLUX)*(EXPOSURE TIME) CONSTANT     -
C     FLUE    SUM ZONE FLUX OVER RANGE OF GROUPS SPECIFIED              -
C     FOUL    EDIT MONITERING INFORMATION                               -
C     GCHK    CHECK FOR IMPLEMENTED GEOMETRY FOR POINT CALCULATION      -
C              (METHOD 1)                                               -
C     GNZC    OBTAIN ZONE CLASSES FROM GEODST                           -
C     HQUE    CHECK FOR UNIQUENESS IN LIST OF HOLLERITH NAMES           -
C     ISTR    FUNCTION TO ASSIGN A REAL VARIABLE TO AN INTEGER VARIABLE -
C              LOCATION WITHOUT TYPE CONVERSION                         -
C     IX2D    FUNCTION TO DETERMINE SUBSCRIPTS OF A TWO-DIMENSIONAL     -
C              ARRAY, GIVEN DIMENSIONS AND POSITION IN ARRAY            -
C     IX3D    FUNCTION TO DETERMINE SUBSCRIPTS OF A THREE-DIMENSIONAL   -
C              ARRAY, GIVEN DIMENSIONS AND POSITION IN ARRAY            -
C     JAGY    AVERAGE GENERATION RATE SOLUTION FOR EXPOSURE             -
C     JAOD    SETUP OFF-DIAGONAL MATRIX ELEMENTS FOR MATRIX EXPONENTIAL -
C              AND AVERAGE GENERATION RATE SOLUTIONS (EXPOSURE)         -
C     JEMY    SETUP MATRIX EXPONENTIAL SOLUTION FOR EXPOSURE            -
C     JUCY    EXPLICIT CHAIN SOLUTION FOR EXPOSURE                      -
C     LAGY    AVERAGE GENERATION RATE SOLUTION FOR SHUTDOWN             -
C     LAOD    SETUP OFF-DIAGONAL MATRIX ELEMENTS FOR MATRIX EXPONENTIAL -
C              AND AVERAGE GENERATION RATE SOLUTIONS (SHUTDOWN)         -
```

(CONT)

```
C     LEGF    FUNCTION TO COMPARE (LT,EQ,GT) TWO REAL NUMBERS          -
C              WITHIN EPSILON                                          -
C     LEMY    SETUP MATRIX EXPONENTIAL SOLUTION FOR SHUTDOWN          -
C     LUCY    EXPLICIT CHAIN SOLUTION FOR SHUTDOWN                    -
C     MAIN    INITIALIZE INPUT/OUTPUT UNITS                           -
C     MEIT    MATRIX EXPONENTIAL SOLUTION                             -
C     MEMA    MATRIX EXPONENTIAL - ELIMINATE NUCLIDES ASSUMED TO BE IN -
C              EQUILIBRIUM                                            -
C     MEPA    MATRIX EXPONENTIAL - COMPUTE DENSITIES FOR NUCLIDES IN  -
C              EQUILIBRIUM                                            -
C     MESA    MATRIX EXPONENTIAL 1 TERM METHOD                        -
C     MESB    MATRIX EXPONENTIAL 2 TERM METHOD                        -
C     METS    MATRIX EXPONENTIAL - TRANSPOSE MATRIX ELEMENTS          -
C     MNRP    LOCATE SMALLEST POSITIVE VALUE IN AN ARRAY              -
C     MSHK    CHECK COARSE MESH DATA FROM GEODST FOR POINT            -
C              CALCULATION (METHOD 1)                                 -
C     MSH0    SETUP COARSE MESH PARAMETERS FOR 1-D AND 2-D GEOMETRIES -
C              FOR POINT CALCULATION (METHOD 1)                       -
C     MSH1    CALCULATE FINE MESH DISTANCES FOR POINT CALCULATION     -
C              (METHOD 1)                                             -
C     MSH3    EDIT FINE MESH SPACING FOR POINT CALCULATION (METHOD 1) -
C     MXRP    LOCATE LARGEST POSITIVE VALUE IN AN ARRAY               -
C     NRCF    CONVERT REGION ASSIGNMENTS FOR COARSE MESH INTERVALS    -
C              TO REGION ASSIGNMENTS FOR FINE MESH INTERVALS FOR POINT -
C              CALCULATION (METHOD 1)                                 -
C     OEXP    EXPOSURE CALCULATIONS (FOR OVERLAY CONVENIENCE)         -
C     OFIX    NORMAL EXPOSURE CALCULATION (FOR OVERLAY CONVENIENCE)   -
C     OMOV    CONTINUOUS FUELING EXPOSURE (FOR OVERLAY CONVENIENCE)   -
C     OOWN    SHUTDOWN CALCULATION (FOR OVERLAY CONVENIENCE)          -
C     PARI    EDIT START AND END OF STEP INVENTORY AND REACTION RATES -
C              BY ABSOLUTE NUCLIDE                                    -
C     PDPT    CALCULATE POWER DENSITY                                 -
C     PDST    POWER DENSITY STATISTICS FOR POINT CALCULATION          -
C     PFIX    POINT EXPOSURE CALCULATION                              -
C     PGEO    PROCESS GEODST GEOMETRY FILE FOR POINT CALCULATION      -
C              (METHOD 1)                                             -
C     PLOC    LOCATE POINTS WITHIN SELECTED ZONES AND COMPUTE         -
C              POINT VOLUMES FOR POINT CALCULATION (METHOD 1)         -
C     PNAW    WRITE POINT NUCLIDE DENSITIES ON INTERFACE FILE PTATDN  -
C              FOR POINT CALCULATION                                  -
C     PONI    EDIT FEED AND DISCHARGE RATES IN KG/DAY                 -
C     POWL    ACCUMULATE POWER AND LOCATE MAXIMUM POWER DENSITY       -
C     POWN    POINT SHUTDOWN CALCULATION                              -
C     POWP    ACCUMULATE POWER ALONG PATH FOR CONTINUOUS FUELING MODEL -
C     PPOE    EDIT POWER, ACTINIDE FEED RATE, AND EXPOSURE BY ZONE PATH -
C              AND SUBZONE PATH FOR CONTINUOUS FUELING MODEL          -
C     PRNA    COMPUTE SPECIFIC REACTION RATES FOR ABSORPTION, FISSION, -
C              NU*FISSION, (N,G), (N,A), (N,P), (N,2N), (N,D), AND (N,T)-
C              FOR POINT CALCULATION                                  -
C     PRND    EDIT SPECIFIC REACTION RATES FOR POINT CALCULATION      -
```

(CONT)

```
C     PRNS    DETERMINE STORAGE REQUIRED AND MODE OF SOLUTION AND        -
C              INITIALIZE DIRECT ACCESS UNITS IF NEEDED  FOR POINT       -
C              CALCULATION                                               -
C     PRNT    PRE-WRITE DIRECT ACCESS UNITS IF NEEDED FOR POINT          -
C              CALCULATION                                               -
C     PRNY    EDIT ATOM DENSITIES FOR POINT CALCULATION                  -
C     PRNZ    SETUP INITIAL DENSITIES FOR POINT CALCULATION              -
C     PRN3    PROCESS RTFLUX AND WRITE SELECTED POINT FLUXES ON SCRATCH -
C              ONE GROUP AT A TIME FOR POINT CALCULATION (METHOD 1)      -
C     PRPF    EDIT SPECIFIC REACTION RATE FOR FISSION IN ENERGY RANGES  -
C              OF YIELD DATA FOR POINT CALCULATION                       -
C     PRRF    EDIT SPECIFIC REACTION RATE FOR FISSION IN ENERGY RANGES  -
C              OF YIELD DATA                                             -
C     PRTD    PRINT DOUBLE PRECISION ARRAY                               -
C     PRTH    PRINT HOLLERITH ARRAY                                      -
C     PRTI    PRINT INTEGER ARRAY                                        -
C     PRTR    PRINT REAL ARRAY                                           -
C     PRTT    PRINT HOLLERITH TITLE                                      -
C     PTAT    OBTAIN REFERENCE ZONE NUMBERS FROM PTATDN IF IT EXISTS     -
C              FOR POINT CALCULATION (METHOD 1)                          -
C     PTNS    DETERMINE NUCLIDE SET AND INITIAL DENSITY INDEX (ZONE OR  -
C              SUBZONE) FOR POINT CALCULATION                            -
C     PURN    CONTROLS POINT EXPOSURE AND SHUTDOWN CALCULATION           -
C     PZT2    PROCESS TEMPERATURES FROM ZNTEMP (POINT CALCULATION)       -
C     QNAT    WRITE INTERFACE FILE QNATDN                                -
C     QNAW    WRITE INTERFACE FILE ZNATDN (CONTINUOUS FUELING EXPOSURE) -
C     REED    ENTRY IN RITE - DATA TRANSFER (EXTERNAL DEVICE TO MEMORY) -
C     REHT    CALCULATE REACTION RATE TYPE DATA FOR EXPOHT               -
C     REOR    CHANGE VOLUME AND LOCATION DATA ORDER FOR POINT            -
C              CALCULATION (METHOD 1)                                    -
C     RITE    DATA TRANSFER (MEMORY TO EXTERNAL DEVICE)                  -
C     ROXX    ENTRY IN RITE - SPECIAL ADDRESS INITIALIZATION             -
C     ROXY    ENTRY IN DOPC - SPECIAL ADDRESS INITIALIZATION             -
C     RSTI    FUNCTION TO ASSIGN AN INTEGER VARIABLE TO A REAL VARIABLE -
C              LOCATION WITHOUT TYPE CONVERSION                          -
C     SEEK    INTERFACE FILE MANAGEMENT                                  -
C     SERM    WRITE INTERFACE FILE PROCESSING ERROR MESSAGE              -
C     SKER    WRITE SEEK RELATED ERROR MESSAGE AND STOP                  -
C     SKNU    DETERMINE NUCLIDES IN SUPPLEMENTAL EXPLICIT CHAINS         -
C              NOT TO BE TREATED WITH MATRIX EXPONENTIAL OR AVERAGE      -
C              GENERATION RATE METHODS                                   -
C     STOR    MOVE ARRAY Y TO ARRAY X                                    -
C     TIMER   MULTI-PURPOSE ROUTINE TO PROVIDE CPU TIME, CLOCK TIME,     -
C              CPU TIME REMAINING, I/O COUNT REMAINING, COMPUTER MODEL, -
C              JOB NAME, DATE AND TIME INFORMATION                       -
C     TPNE    EDIT POWER NORMALIZATION FACTORS, EXPOSURE SUBSTEP TIMES, -
C              AND SHUTDOWN SUBSTEP TIMES                                -
C     VOLP    COMPUTE REGION VOLUMES AND ZONE VOLUMES FROM POINT         -
C              VOLUMES FOR POINT CALCULATION (METHOD 1) (DEBUG ONLY)     -
C     XEQC    INITIALIZE AN ARRAY WITH A CONSTANT                        -
```

(CONT)

```
C     XEXC    MULTIPLY ARRAY X BY A CONSTANT                                -
C     XEYC    MOVE DATA FROM ARRAY Y TO ARRAY X AND MULTIPLY BY A           -
C              CONSTANT                                                     -
C     XPYC    ADD ARRAY Y MULTIPLIED BY A CONSTANT TO ARRAY X               -
C     ZCRI    SUM BY ZONE CLASS ABSORPTIONS BY NUCLIDE CLASS,               -
C              FISSILE ABSORPTIONS, FERTILE CAPTURES, FISSILE               -
C              DESTRUCTION RATE, AND FISSILE INVENTORY                      -
C     ZFMP    PROCESS RZFLUX (MODIFIED) FOR ZONE NUMBERS AND POINTS         -
C              PER ZONE FOR POINT CALCULATION (METHOD 2)                    -
C     ZFMV    DUMMY VOLUME AND LOCATION DATA FOR POINT CALCULATION          -
C              (METHOD 2)                                                   -
C     ZFM3    PROCESS RZFLUX (MODIFIED) AND WRITE POINT FLUXES ON           -
C              SCRATCH ONE GROUP AT A TIME FOR POINT CALCULATION            -
C              (METHOD 2)                                                   -
C     ZIGY    SETUP INTEGRATION RANGE FOR FISSION REACTION RATE             -
C     ZNAW    WRITE INTERFACE FILE ZNATDN                                   -
C     ZOND    EDIT ATOM DENSITIES FOR ONE ZONE/SUBZONE                      -
C     ZONI    ACCUMULATE MASS RATES IN KG/SEC                               -
C     ZUCY    CHECK AND EDIT EXPLICIT CHAIN DATA                            -
C     ZUCZ    DETERMINE MAXIMUM EXPLICIT CHAIN LENGTH                       -
C     ZZPD    EDIT ZONE POWER DENSITY AND WRITE INTERFACE FILE ZNPOWD       -
C     ZZPF    CALCULATE ACTINIDE FEED RATE (KG/SEC) BY PATH FOR             -
C              CONTINUOUS FUELING MODEL                                     -
C                                                                           -
```

(CONT)

```
C      BURNER SUBROUTINE DESCRIPTION (SPECIAL)                          -
C      ---------------------------------------                          -
C                                                                       -
C   A  CLOSDA  CLOSE DIRECT ACCESS SCRATCH FILE (OPENED WITH DEFILE)    -
C      CRED    ENTRY IN CRIT - DUMMY - DATA TRANSFER EXTENDED CORE TO   -
C                                      FAST CORE                        -
C      CRIT    DUMMY - DATA TRANSFER FAST CORE TO EXTENDED CORE         -
C   A  DEFILE  OPEN DIRECT ACCESS SCRATCH FILE  (REPLACES IBM           -
C               DEFINE FILE STATEMENT)                                  -
C   $  EXIT    IBM FORTRAN H LIBRARY                                    -
C      FBSAM   DUMMY - LOCAL I/O PACKAGE                                -
C      FCHECK  ENTRY IN FBSAM - DUMMY - LOCAL I/O PACKAGE               -
C      FDISP   ENTRY IN FBSAM - DUMMY - LOCAL I/O PACKAGE               -
C      FPNTR   ENTRY IN FBSAM - DUMMY - LOCAL I/O PACKAGE               -
C      FPOINT  ENTRY IN FBSAM - DUMMY - LOCAL I/O PACKAGE               -
C      FREAD   ENTRY IN FBSAM - DUMMY - LOCAL I/O PACKAGE               -
C   A  FRECOR  RELEASE DYNAMICALLY ALLOCATED STORAGE                    -
C      FREW    ENTRY IN FBSAM - DUMMY - LOCAL I/O PACKAGE               -
C      FWRITE  ENTRY IN FBSAM - DUMMY - LOCAL I/O PACKAGE               -
C   A  GETCOR  DYNAMIC STORAGE ALLOCATION                               -
C   $  ICLOCK  FUNCTION RETURNS CPU TIME IN HUNDREDTHS OF SECONDS       -
C               (INTEGER*4)                                             -
C   $  IDAY    SUBROUTINE RETURNS THE DATE MM-DD-YY (REAL*8)            -
C   $  IHCEDIOS IBM FORTRAN H LIBRARY (DIFFERENT FOR H EXTENDED)        -
C   $  IHCUATBL IBM FORTRAN H LIBRARY (DIFFERENT FOR H EXTENDED)        -
C   $  IOLEFT  SUBROUTINE RETURNS THE I/O COUNT REMAINING FROM AN       -
C               INITIAL ESTIMATE (INTEGER*4)                            -
C   A  ITTIME  FUNCTION RETURNS THE CLOCK TIME IN HUNDREDTHS OF SECONDS -
C               (INTEGER*4)                                             -
C   $  JOBNUM  SUBROUTINE RETURNS THE JOB NAME (REAL*8)                 -
C   $  JSTIME  FUNCTION OR SUBROUTINE RETURNS THE REMAINING JOB STEP    -
C               CPU TIME FROM AN INITIAL ESTIMATE (INTEGER*4)           -
C   $  MODEL   FUNCTION RETURNS THE COMPUTER MODEL NUMBER (75,91,155,195)-
C               (INTEGER*4)                                             -
C   $  TIME    SUBROUTINE RETURNS TIME OF DAY HH.MM.SS (REAL*8)         -
C                                                                       -
C   $  NOT SUPPLIED IN PROGRAM PACKAGE                                  -
C   A  ASSEMBLER LANGUAGE                                               -
C                                                                       -
C***********************************************************************-
```

(CONT)

```
C*********************************************************************-
C                                                                     -
C     BURNER SUBROUTINE CROSS-REFERENCE                               -
C     ---------------------------------                               -
C                                                                     -
C  SUBROUTINE ****************  CALLS SUBROUTINE  **********************-
C                                                                     -
C     ANOR                                                            -
C     ARRI                                                            -
C     AUXE                                                            -
C     BFIX     ARRI     BRNO     BRNY     DOEX     PARI     PDPT     POWL     -
C              REED     STOR     XEQC     XEXC     XEYC     ZCRI     ZNAW     -
C              ZZPD                                                    -
C     BGXS     BRN4     CMPI     PRTI     PRTT     REED     RITE     SEEK     -
C              SERM                                                    -
C     BINP     BGXS     BRNF     BRNW     BRNX     BRN4     BRN7     BZT1     -
C              EPFD     FERR     GNZC     PRTT     REED     SEEK     SKER     -
C              SKNU     STOR     ZIGY                                    -
C     BMOV     ARRI     BRNO     BRNY     DOEX     IX2D     PARI     PDPT     -
C              PONI     POWL     POWP     PPOE     QNAT     QNAW     REED     -
C              RITE     STOR     XEQC     XEXC     XEYC     ZCRI     ZOND     -
C              ZONI     ZZPD     ZZPF                                    -
C     BPIA     CHEK     PGEO     PRN3     PRTI     PRTR     PTAT     PTNS     -
C              REOR     STOR                                            -
C     BPIB     PRTI     PRTR     PTNS     ZFMP     ZFMV     ZFM3          -
C     BPIC     BRPF     PRNA     PRND     PRNS     PRNT     PRNZ     PRPF     -
C              PZT2                                                    -
C     BPIN     BPIA     BPIB     BPIC                                    -
C     BRCI     FERR     REED     SEEK     SKER                            -
C     BRDS     BRN1     DOPC     ROXX     ROXY     FRECOR   GETCOR          -
C     BRNA     REED     RITE                                            -
C     BRND     REED                                                     -
C     BRNF                                                              -
C     BRNO                                                              -
C     BRNS     DOPC     FERR                                            -
C     BRNT     RITE                                                     -
C     BRNW     ZUCY     ZUCZ                                            -
C     BRNX     HQUE                                                     -
C     BRNY                                                              -
C     BRNZ     LEGF     REED     RITE     SEEK     SKER                  -
C     BRN1     BINP     BPIN     BURN     BZIN     FERR     FOUL     PURN     -
C     BRN3     ISTR     REED     RITE     SEEK     SKER     XEXC          -
C     BRN4     CMPH     CMPI     PRTH     PRTI                            -
C     BRN7     REED     RITE                                            -
C     BRPF     REED     RITE                                            -
C     BRRF     REED     RITE                                            -
C     BURN     AUXE     BRNY     EDEP     EXPH     OEXP     OCWN     TPNE     -
C              XEQC                                                    -
C     BZIN     BRNA     BRND     BRNS     BRNT     BRNZ     BRN3     BRRF     -
C              BZT2     CMOV     DEEF     FERR     PRRF                    -
C     BZT1     REED     SEEK     SERM                                    -
C     BZT2     PRTR     REED                                            -
C     CHEK     IX3D     PRTI     PRTR     REED                            -
```

(CONT)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| C | CMOV | IX2D | | | | | | | - |
| C | CMPH | | | | | | | | - |
| C | CMPI | | | | | | | | - |
| C | CPH1 | REED | RITE | | | | | | - |
| C | CPH2 | PRTR | REED | RSTI | | | | | - |
| C | DEEF | | | | | | | | - |
| C | DOEX | JAGY | JEMY | JUCY | | | | | - |
| C | DOPC | FERR | FREW | REED | RITE | SEEK | FESAM | FDISP | - |
| C | | CLOSDA | DEFILE | FCHECK | | | | | - |
| C | DOSH | LAGY | LEMY | LUCY | | | | | - |
| C | DOWN | BRNY | DOSH | STOR | ZNAW | | | | - |
| C | ECHK | | | | | | | | - |
| C | EDED | | | | | | | | - |
| C | EDEP | EDED | ETAB | REED | SEEK | SKER | | | - |
| C | EPFD | | | | | | | | - |
| C | EPH2 | | | | | | | | - |
| C | ESET | | | | | | | | - |
| C | ETAB | REED | XEQC | XEYC | | | | | - |
| C | EXPH | CPH1 | CPH2 | ECHK | EPH2 | ESET | FLUC | FLUE | - |
| C | | LEGF | MXRP | REED | REHT | RITE | SEEK | SKER | - |
| C | | STOR | XEYC | XPYC | | | | | - |
| C | FERR | SEEK | | | | | | | - |
| C | FLUC | | | | | | | | - |
| C | FLUE | REED | | | | | | | - |
| C | FOUL | | | | | | | | - |
| C | GCHK | | | | | | | | - |
| C | GNZC | FEPR | REED | SEEK | SKER | STOR | | | - |
| C | HQUE | | | | | | | | - |
| C | ISTR | | | | | | | | - |
| C | IX2D | | | | | | | | - |
| C | IX3D | | | | | | | | - |
| C | JAGY | JAOD | | | | | | | - |
| C | JAOD | | | | | | | | - |
| C | JEMY | JAOD | MEIT | | | | | | - |
| C | JUCY | | | | | | | | - |
| C | LAGY | LAOD | | | | | | | - |
| C | LAOD | | | | | | | | - |
| C | LEGF | | | | | | | | - |
| C | LEMY | LAOD | MEIT | | | | | | - |
| C | LUCY | | | | | | | | - |
| C | MAIN | BRCI | BRDS | DOPC | TIMER | | | | - |
| C | MEIT | ANOR | MEMA | MEPA | MESA | MESB | METS | PRTD | - |
| C | MEMA | | | | | | | | - |
| C | MEPA | | | | | | | | - |
| C | MESA | | | | | | | | - |
| C | MESB | | | | | | | | - |
| C | METS | | | | | | | | - |
| C | MNRP | | | | | | | | - |
| C | MSHK | PRTD | PRTI | | | | | | - |
| C | MSH0 | | | | | | | | - |
| C | MSH1 | PRTD | | | | | | | - |
| C | MSH3 | | | | | | | | - |

(CONT)

```
C     MXRP
C     NRCF    REED    RITE
C     OEXP    OFIX    OMOV    XEQC
C     OFIX    BFIX
C     OMOV    BMOV
C     OOWN    DOWN
C     PARI
C     PDPT
C     PDST    MNRP    MXRP    PRTR
C     PFIX    DOEX    PDPT    PDST    PNAW    PRNY    REED    STOR
C             XEQC    XEXC    XEYC
C     PGEO    GCHK    MSHK    MSH0    MSH1    MSH3    NRCF    PLOC
C             PRTI    PRTR    REED    RITE    SEEK    SERM    STOR
C             VOLP
C     PLOC    REED
C     PNAW    REED    RITE    SEEK    SERM    STOR
C     PONI
C     POWL
C     POWN    DOSH    PNAW    PRNY    STOR
C     POWP
C     PPOE    PRTR
C     PRNA    REED    RITE
C     PRND    REED
C     PRNS    DOPC
C     PRNT    RITE
C     PRNY
C     PRNZ    CMPI    LEGF    PRTI    REED    RITE    SEEK    SERM
C     PRN3    PRTR    REED    RITE    SEEK    SERM    XEXC
C     PRPF    REED
C     PRRF    REED
C     PRTD
C     PRTH
C     PRTI
C     PRTR
C     PRTT
C     PTAT    PRTI    REED    SEEK    SERM
C     PTNS
C     PURN    PFIX    POWN    PRNY
C     PZT2    PRTR    REED
C     QNAT    REED    RITE    SEEK
C     QNAW    REED    RITE    SEEK    SKER
C     REHT    PRTR    REED    XEYC
C     REOR
C     RITE    CRED    CRIT    FERR    FREW    FPNTR   FREAD   FCHECK
C             FPOINT  FWRITE
C     RSTI
C     SEEK    REED    RITE
C     SERM
C     SKER    SEEK
C     SKNU
C     STOR
C     TIMER   IDAY    TIME    MODEL   ICLOCK  IOLEFT  ITTIME  JOBNUM
C             JSTIME
```

(CONT)

```
C     TPNE                                                              -
C     VOLP    REED                                                      -
C     XEQC                                                              -
C     XEXC                                                              -
C     XEYC                                                              -
C     XPYC                                                              -
C     ZCRI                                                              -
C     ZFMP    PRTI    PRTR    REED                                      -
C     ZFMV                                                              -
C     ZFM3    PRTR    REED    RITE    XEXC                              -
C     ZIGY                                                              -
C     ZNAW    REED    RITE    SEEK    SKER                              -
C     ZOND                                                              -
C     ZONI                                                              -
C     ZUCY                                                              -
C     ZUCZ                                                              -
C     ZZPD    PRTR    RITE    SEEK                                      -
C     ZZPF                                                              -
C                                                                       -
C     BURNER SUBROUTINE CROSS-REFERENCE (SPECIAL)                       -
C     -------------------------------------------                       -
C                                                                       -
C  SUBROUTINE ****************  CALLS SUBROUTINE  **********************-
C                                                                       -
C     CLOSDA                                                            -
C     CRIT    (S)                                                       -
C     DEFILE  IHCEDIOS IHCUATBL                                         -
C     EXIT    (S)                                                       -
C     FBSAM   (S)                                                       -
C     FCHECK  (S)                                                       -
C     FDISP   (S)                                                       -
C     FPNTR   (S)                                                       -
C     FPOINT  (S)                                                       -
C     FREAD   (S)                                                       -
C     FRECOR  EXIT                                                      -
C     FREW    (S)                                                       -
C     FWRITE  (S)                                                       -
C     GETCOR  EXIT                                                      -
C     ICLOCK                                                            -
C     IDAY                                                              -
C     IHCEDIOS                                                          -
C     IHCUATBL                                                          -
C     IOLEFT                                                            -
C     ITTIME                                                            -
C     JOBNUM                                                            -
C     JSTIME                                                            -
C     MODEL                                                             -
C     TIME                                                              -
C                                                                       -
C             (S)  DENOTES STOP                                         -
C                                                                       -
C***********************************************************************-
```

(CONT)

```
C*********************************************************************-
C                                                                     -
C     BURNER SUBROUTINE CROSS-REFERENCE                               -
C     ---------------------------------                               -
C                                                                     -
C  SUBROUTINE **************  CALLED FROM SUBROUTINE  ******************-
C                                                                     -
C     ANOR    MEIT                                                    -
C     ARRI    BFIX    BMOV                                            -
C     AUXE    BURN                                                    -
C     BFIX    OFIX                                                    -
C     BGXS    BINP                                                    -
C     BINP    BRN1                                                    -
C     BMOV    OMOV                                                    -
C     BPIA    BPIN                                                    -
C     BPIB    BPIN                                                    -
C     BPIC    BPIN                                                    -
C     BPIN    BRN1                                                    -
C     BRCI    MAIN                                                    -
C     BRDS    MAIN                                                    -
C     BRNA    BZIN                                                    -
C     BRND    BZIN                                                    -
C     BRNF    BINP                                                    -
C     BRNO    BFIX    BMOV                                            -
C     BRNS    BZIN                                                    -
C     BRNT    BZIN                                                    -
C     BRNW    BINP                                                    -
C     BRNX    BINP                                                    -
C     BRNY    BFIX    BMOV    BURN    DOWN                            -
C     BRNZ    BZIN                                                    -
C     BRN1    BRDS                                                    -
C     BRN3    BZIN                                                    -
C     BRN4    BGXS    BINP                                            -
C     BRN7    BINP                                                    -
C     BRPF    BPIC                                                    -
C     BRRF    BZIN                                                    -
C     BURN    BRN1                                                    -
C     BZIN    BRN1                                                    -
C     BZT1    BINP                                                    -
C     BZT2    BZIN                                                    -
C     CHEK    BPIA                                                    -
C     CMOV    BZIN                                                    -
C     CMPH    BRN4                                                    -
C     CMPI    BGXS    BRN4    PRNZ                                    -
C     CPH1    EXPH                                                    -
C     CPH2    EXPH                                                    -
C     DEEF    BZIN                                                    -
C     DOEX    BFIX    BMOV    PFIX                                    -
C     DOPC    BRDS    BRNS    MAIN    PRNS                            -
C     DOSH    DOWN    POWN                                            -
C     DOWN    OOWN                                                    -
C     ECHK    EXPH                                                    -
C     EDED    EDEP                                                    -
```

(CONT)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| C | EDEP | BURN | | | | | | | - |
| C | EPFD | BINP | | | | | | | - |
| C | EPH2 | EXPH | | | | | | | - |
| C | ESET | EXPH | | | | | | | - |
| C | ETAB | EDEP | | | | | | | - |
| C | EXPH | BURN | | | | | | | - |
| C | FERR | BINP | BRCI | BRMS | BRN1 | BZIN | DOPC | GNZC | - |
| C | | RITE | | | | | | | - |
| C | FLUC | EXPH | | | | | | | - |
| C | FLUE | EXPH | | | | | | | - |
| C | FOUL | BRN1 | | | | | | | - |
| C | FRFCOR | BRDS | | | | | | | - |
| C | GCHK | PGEO | | | | | | | - |
| C | GETCOR | BRDS | | | | | | | - |
| C | GNZC | BINP | | | | | | | - |
| C | HQUE | BRNX | | | | | | | - |
| C | ISTR | BRN3 | | | | | | | - |
| C | IX2D | BMOV | CMOV | | | | | | - |
| C | IX3D | CHEK | | | | | | | - |
| C | JAGY | DOEX | | | | | | | - |
| C | JAOD | JAGY | JEMY | | | | | | - |
| C | JEMY | DOEX | | | | | | | - |
| C | JUCY | DOEX | | | | | | | - |
| C | LAGY | DOSH | | | | | | | - |
| C | LAOD | LAGY | LEMY | | | | | | - |
| C | LEGF | BRNZ | EXPH | PRNZ | | | | | - |
| C | LEMY | DOSH | | | | | | | - |
| C | LUCY | DOSH | | | | | | | - |
| C | MAIN | | | | | | | | - |
| C | MEIT | JEMY | LEMY | | | | | | - |
| C | MEMA | MEIT | | | | | | | - |
| C | MEPA | MEIT | | | | | | | - |
| C | MESA | MEIT | | | | | | | - |
| C | MESB | MEIT | | | | | | | - |
| C | METS | MEIT | | | | | | | - |
| C | MNRP | PDST | | | | | | | - |
| C | MSHK | PGEO | | | | | | | - |
| C | MSH0 | PGEO | | | | | | | - |
| C | MSH1 | PGEO | | | | | | | - |
| C | MSH3 | PGEO | | | | | | | - |
| C | MXRP | EXPH | PDST | | | | | | - |
| C | NRCF | PGEO | | | | | | | - |
| C | OEXP | BURN | | | | | | | - |
| C | OFIX | OEXP | | | | | | | - |
| C | OMOV | OEXP | | | | | | | - |
| C | OOWN | BURN | | | | | | | - |
| C | PARI | BFIX | BMOV | | | | | | - |
| C | PDPT | BFIX | BMOV | PFIX | | | | | - |
| C | PDST | PFIX | | | | | | | - |
| C | PFIX | PURN | | | | | | | - |
| C | PGEO | BPIA | | | | | | | - |
| C | PLOC | PGEO | | | | | | | - |

(CONT)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| C | PNAW | PFIX | POWN | | | | | | - |
| C | PONI | BMOV | | | | | | | - |
| C | POWL | BFIX | BMOV | | | | | | - |
| C | POWN | PURN | | | | | | | - |
| C | POWP | BMOV | | | | | | | - |
| C | PPOE | BMOV | | | | | | | - |
| C | PRNA | BPIC | | | | | | | - |
| C | PRND | BPIC | | | | | | | - |
| C | PRNS | BPIC | | | | | | | - |
| C | PRNT | BPIC | | | | | | | - |
| C | PRNY | PFIX | POWN | PURN | | | | | - |
| C | PRNZ | BPIC | | | | | | | - |
| C | PRN3 | BPIA | | | | | | | - |
| C | PRPF | BPIC | | | | | | | - |
| C | PRRF | BZIN | | | | | | | - |
| C | PRTD | MEIT | MSHK | MSH1 | | | | | - |
| C | PRTH | BRN4 | | | | | | | - |
| C | PRTI | BGXS | BPIA | BPIB | BRN4 | CHEK | MSHK | PGEO | - |
| C | | PRNZ | PTAT | ZFMP | | | | | - |
| C | PRTR | BPIA | BPIB | BZT2 | CHEK | CPH2 | PDST | PGEO | - |
| C | | PPOE | PRN3 | PZT2 | REHT | ZFMP | ZFM3 | ZZPD | - |
| C | PRTT | BGXS | BINP | | | | | | - |
| C | PTAT | BPIA | | | | | | | - |
| C | PTNS | BPIA | BPIB | | | | | | - |
| C | PURN | BRN1 | | | | | | | - |
| C | PZT2 | BPIC | | | | | | | - |
| C | QNAT | BMOV | | | | | | | - |
| C | QNAW | BMOV | | | | | | | - |
| C | REED | BFIX | BGXS | BINP | BMOV | BRCI | BRNA | BRND | - |
| C | | BRNZ | BRN3 | BRN7 | BRPF | BRRF | BZT1 | BZT2 | - |
| C | | CHEK | CPH1 | CPH2 | DOPC | EDEP | ETAB | EXPH | - |
| C | | FLUE | GNZC | NRCF | PFIX | PGEO | PLOC | PNAW | - |
| C | | PRNA | PRND | PRNZ | PRN3 | PRPF | PRRF | PTAT | - |
| C | | PZT2 | QNAT | QNAW | REHT | SEEK | VOLP | ZFMP | - |
| C | | ZFM3 | ZNAW | | | | | | - |
| C | REHT | EXPH | | | | | | | - |
| C | REOR | BPIA | | | | | | | - |
| C | RITE | BGXS | BMOV | BRNA | BRNT | BRNZ | BRN3 | BRN7 | - |
| C | | BRPF | BRRF | CPH1 | DOPC | EXPH | NRCF | PGEO | - |
| C | | PNAW | PRNA | PRNT | PRNZ | PRN3 | QNAT | QNAW | - |
| C | | SEEK | ZFM3 | ZNAW | ZZPD | | | | - |
| C | ROXX | BRDS | | | | | | | - |
| C | ROXY | BRDS | | | | | | | - |
| C | RSTI | CPH2 | | | | | | | - |
| C | SEEK | BGXS | BINP | BRCI | BRNZ | BRN3 | BZT1 | DOPC | - |
| C | | EDEP | EXPH | FERR | GNZC | PGEO | PNAW | PRNZ | - |
| C | | PRN3 | PTAT | QNAT | QNAW | SKER | ZNAW | ZZPD | - |
| C | SERM | BGXS | BZT1 | PGEO | PNAW | PRNZ | PRN3 | PTAT | - |
| C | SKER | BINP | BRCI | BRNZ | BRN3 | EDEP | EXPH | GNZC | - |
| C | | QNAW | ZNAW | | | | | | - |
| C | SKNU | BINP | | | | | | | - |
| C | STOR | BFIX | BINP | BMOV | BPIA | DOWN | EXPH | GNZC | - |
| C | | PFIX | PGEO | PNAW | POWN | | | | - |

(CONT)

```
C     TIMER   MAIN                                                    -
C     TPNE    BURN                                                    -
C     VOLP    PGEO                                                    -
C     XEQC    BFIX    BMOV    BURN    ETAB    OEXP    PFIX            -
C     XEXC    BFIX    BMOV    BRN3    PFIX    PRN3    ZFM3            -
C     XEYC    BFIX    BMOV    ETAB    EXPH    PFIX    REHT            -
C     XPYC    EXPH                                                    -
C     ZCRI    BFIX    BMOV                                            -
C     ZFMP    BPIB                                                    -
C     ZFMV    BPIB                                                    -
C     ZFM3    BPIB                                                    -
C     ZIGY    BINP                                                    -
C     ZNAW    BFIX    DOWN                                            -
C     ZOND    BMOV                                                    -
C     ZONI    BMOV                                                    -
C     ZUCY    BRNW                                                    -
C     ZUCZ    BRNW                                                    -
C     ZZPD    BFIX    BMOV                                            -
C     ZZPF    BMOV                                                    -
C                                                                     -
C     BURNER SUBROUTINE CROSS-REFERENCE (SPECIAL)                     -
C     -------------------------------------------                     -
C                                                                     -
C  SUBROUTINE **************  CALLED FROM SUBROUTINE  ******************-
C                                                                     -
C     CLOSDA  DOPC                                                    -
C     CRED    RITE                                                    -
C     CRIT    RITE                                                    -
C     DEFILE  DOPC                                                    -
C     EXIT    FRECOR  GETCOR                                          -
C     FBSAM   DOPC                                                    -
C     FCHECK  DOPC    RITE                                            -
C     FDISP   DOPC                                                    -
C     FPNTR   RITE                                                    -
C     FPOINT  RITE                                                    -
C     FREAD   RITE                                                    -
C     FREW    DOPC    RITE                                            -
C     FWRITE  RITE                                                    -
C     ICLOCK  TIMER                                                   -
C     IDAY    TIMER                                                   -
C     IHCEDIOS DEFILE                                                 -
C     IHCUATBL DEFILE                                                 -
C     IOLEFT  TIMER                                                   -
C     ITTIME  TIMER                                                   -
C     JOBNUM  TIMER                                                   -
C     JSTIME  TIMER                                                   -
C     MODEL   TIMER                                                   -
C     TIME    TIMER                                                   -
C                                                                     -
C*********************************************************************-
```

(CONT)

```
C*********************************************************************-
C                                                                     -
C     BURNER COMMON                                                   -
C     -------------                                                   -
C                                                                     -
C     COMMON   ********* REFERENCED IN SUBROUTINE ***********************-
C                                                                     -
C     ACES1    BZIN     EDEP     EXPH     OFIX     OMOV                -
C     ACES2    BPIC     PURN                                          -
C     CFEED    BMOV     BRNS     BZIN     CMOV     DEEF     QNAW       -
C     FACES    BGXS     BINP     BPIA     BPIB     BPIC     BRNS     BURN -
C              BZIN     EDEP     EXPH     OFIX     OMOV     OCWN     PRNS -
C              PURN                                                   -
C     GEODS    BPIA     BPIP     BPIC     PGEO     PURN                -
C     GLOBE    AUXE     BFIX     BGXS     BINP     BMOV     BPIA     BPIB -
C              BPIC     BPIN     BRNO     BRNS     BRNW     BRNX     BRNZ -
C              BRN1     BRN3     BURN     BZIN     BZT1     BZT2     DEEF -
C              DOEX     DOSH     DOWN     EDEP     ETAB     EXPH     FOUL -
C              JAGY     JEMY     JUCY     LAGY     LEMY     LUCY     MEIT -
C              PARI     PFIX     PGEO     PNAW     PONI     PCWN     PPOE -
C              PRNS     PRNZ     PRN3     PURN     PZT2     QNAT     QNAW -
C              REHT     ZFMP     ZFM3     ZNAW     ZONI     ZZPD     ZZPF -
C     PARMS    BINP     BPIC     BRNS     BURN     BZIN     EDEP     EXPH -
C              OEXP     OFIX     OMOV     OOWN     PRNS     PURN        -
C     PARMY    BFIX     BINP     BMOV     BPIA     BPIB     BPIC     BZIN -
C              DOWN     EDEP     ETAB     EXPH     MAIN     PFIX     PNAW -
C              POWN     PURN     QNAT     QNAW     REHT     ZNAW     ZZPD -
C     PBURN    BPIA     BPIB     BPIC     PRNS     PURN                -
C     POINT    BFIX     BINP     BMOV     BPIA     BPIB     BPIC     BRN1 -
C              BURN     BZIN     DOEX     DOSH     DOWN     EDEP     EXPH -
C              OEXP     OFIX     OMOV     OOWN     PFIX     PCWN     PURN -
C     REACX    BFIX     BINP     BMOV     BPIC     BZIN     DOEX     PFIX -
C              PURN                                                   -
C     RRTCL    AUXE     BFIX     BGXS     BINP     BMOV     BPIA     BPIB -
C              BPIC     BPIN     BRCI     BRNS     BRNW     BRNX     BRNY -
C              BRNZ     BRN1     BRN3     BURN     BZIN     BZT1     BZT2 -
C              DEEF     DOEX     DOSH     DOWN     EDEP     ETAB     EXPH -
C              JAGY     JEMY     JUCY     LAGY     LEMY     LUCY     MEIT -
C              OEXP     PDST     PFIX     PGEO     PNAW     POWN     PRNS -
C              PRNZ     PRN3     PURN     PZT2     QNAT     QNAW     REHT -
C              ZFMP     ZFM3     ZIGY     ZNAW     ZZPD                -
C     UNITS    BFIX     BINP     BMOV     BPIA     BPIB     BPIC     BPIN -
C              BRN1     BURN     BZIN     DOWN     EDEP     ETAB     EXPH -
C              FOUL     MAIN     PFIX     PNAW     POWN     PURN     QNAT -
C              QNAW     REHT     ZNAW     ZZPD                          -
C     USRID    BRCI     EXPH     PNAW     QNAT     QNAW     ZNAW     ZZPD -
C     VCTRL    BRCI                                                   -
```

(CONT)

```
C                                                                      -
C     BURNER COMMON (SPECIAL)                                          -
C     -----------------------                                          -
C                                                                      -
C     COMMON  ********* REFERENCED IN SUBROUTINE ***********************-
C                                                                      -
C     COMSAM  DOPC    RITE                                             -
C     CTABLE  FRECOR  GETCOR                                           -
C     DEFILCOM DEFILE  CLOSDA                                          -
C     MGMTIO  DOPC    RITE    SEEK                                     -
C                                                                      -
C**********************************************************************-
```

TABLE 03-1 END

TABLE 03-2 OVERLAY STRUCTURE

```
C*****************************************************************-
C                                                                 -
C     BURNER OVERLAY STRUCTURE                                    -
C     ------------------------                                    -
C                                                                 -
C     PROGRAM SIZE (DOES NOT INCLUDE DATA ARRAY OR I/O BUFFERS)   -
C        WITH OVERLAY       40500 WORDS                           -
C        WITHOUT OVERLAY    92500 WORDS                           -
C        INCLUDES            7100 WORDS IBM FORTRAN LIBRARY       -
C                                                                 -
C                              MAIN                               -
C                              BRCI                               -
C                              BRDS                               -
C                              BRN1                               -
C                              DOEX                               -
C                              DOSH                               -
C                              JEMY                               -
C                              LEMY                               -
C                              JAOD                               -
C                              LAOD                               -
C                              MEIT                               -
C                              ANOR                               -
C                              MESA                               -
C                              MESB                               -
C                              MEMA                               -
C                              MEPA                               -
C                              METS                               -
C                              JUCY                               -
C                              LUCY                               -
C                              JAGY                               -
C                              LAGY                               -
C                              PDPT                               -
C                              DOPC(ROXY)        LIBRARY          -
C                              RITE(REED,ROXX)   LIBRARY          -
C                              SEEK              LIBRARY          -
C                              PRTD              LIBRARY          -
C                              PRTH              LIBRARY          -
C                              PRTI              LIBRARY          -
C                              PRTR              LIBRARY          -
C                              PRTT              LIBRARY          -
C                              IX2D              LIBRARY          -
C                              IX3D              LIBRARY          -
C                              MNRP              LIBRARY          -
C                              MXRP              LIBRARY          -
C                              XEQC              LIBRARY          -
C                              XEXC              LIBRARY          -
C                              XEYC              LIBRARY          -
C                              XPYC              LIBRARY          -
C                              STOR              LIBRARY          -
C                              LEGF              LIBRARY          -
```

(CONT)

```
C                                CMPH              LIBRARY                    -
C                                CMPI              LIBRARY                    -
C                                ISTR              LIBRARY                    -
C                                RSTI              LIBRARY                    -
C                                FERR              LIBRARY                    -
C                                SERM              LIBRARY                    -
C                                SKER              LIBRARY                    -
C                                TIMER             LIBRARY                    -
C                                GETCOR            LIBRARY                    -
C                                FRECOR            LIBRARY                    -
C                                DEFILE            LIBRARY                    -
C                                CLOSDA            LIBRARY                    -
C                                ITTIME            LIBRARY                    -
C                                CRIT(CRED)        LIBRARY DUMMY              -
C                                FBSAM(ENTRIES)    LIBRARY DUMMY              -
C                                ICLOCK            SYSTEM LIBRARY             -
C                                IDAY              SYSTEM LIBRARY             -
C                                IOLEFT            SYSTEM LIBRARY             -
C                                JOBNUM            SYSTEM LIBRARY             -
C                                JSTIME            SYSTEM LIBRARY             -
C                                MODEL             SYSTEM LIBRARY             -
C                                TIME              SYSTEM LIBRARY             -
C                                (OTHERS)          IBM FORTRAN LIBRARY        -
C                                ACES1             COMMON                     -
C                                ACES2             COMMON                     -
C                                CFEED             COMMON                     -
C                                FACES             COMMON                     -
C                                GEODS             COMMON                     -
C                                GLOBE             COMMON                     -
C                                PARMS             COMMON                     -
C                                PARMY             COMMON                     -
C                                PBURN             COMMON                     -
C                                POINT             COMMON                     -
C                                REACX             COMMON                     -
C                                RRTCL             COMMON                     -
C                                UNITS             COMMON                     -
C                                USRID             COMMON                     -
C                                VCTRL             COMMON                     -
C                                COMSAM            COMMON                     -
C                                CTABLE            COMMON                     -
C                                DEFILCOM          COMMON                     -
C                                MGMTIO            COMMON                     -
C                                 *                                            -
C      ***********************************************************            -
C      *       *       *       *                *                *            -
C      BINP    BZIN    BURN    FOUL             BPIN             PURN         -
C      GNZC    DEEF    BRNY                     PTNS             PRNY         -
C      BRN7    CMOV    ZNAW                     *                PFIX         -
C      BRN4    BRNS    ZZPD             *****************        POWN         -
C      BGXS    BRN3    AUXE             *       *       *        PNAW         -
C      BZT1    BRNZ    TPNE            BPIA    BPIB    BPIC      PDST         -
C      BRNF    BRNT     *              PTAT    ZFMP    PRNS                   -
```

(CONT)

```
C      BRNW     BZT2      *                PGEO     ZFM3     PRNZ                -
C      ZUCZ     BRNA      *                GCHK     ZFMV     PRNT                -
C      ZUCY     BRND      *                MSHO              PZT2                -
C      ZIGY     BRRF      *                MSHK              PRNA                -
C      EPFD     PRRF      *                MSH1              PRND                -
C      BRNX               *                MSH3              BRPF                -
C      HQUE               *                NRCF              PRPF                -
C      SKNU               *                VOLP                                  -
C                         *                PLOC                                  -
C                         *                PRN3                                  -
C                         *                REOR                                  -
C                         *                CHEK                                  -
C                         *                                                      -
C                         *                                                      -
C                 *************************                                    -
C                 *       *       *       *                                    -
C                OEXP    EXPH    EDEP    OOWN                                  -
C                POWL    CPH1    EDED    DOWN                                  -
C                ARRI    ECHK    ETAB                                          -
C                ZCRI    ESET                                                  -
C                PARI    FLUC                                                  -
C                BRNO    FLUE                                                  -
C                 *      REHT                                                  -
C                 *      CPH2                                                  -
C                 *      EPH2                                                  -
C                 *                                                            -
C                 *                                                            -
C        ****************                                                      -
C        *               *                                                     -
C       OFIX            OMOV                                                   -
C       BFIX            BMOV                                                   -
C                        *                                                     -
C                        *                                                     -
C                 ****************                                             -
C                 *               *                                            -
C                ZOND            PONI                                          -
C                ZZPF            PPOE                                          -
C                ZONI            QNAW                                          -
C                POWP            QNAT                                          -
C                                                                              -
C*****************************************************************************-
```

TABLE 03-2 END

TABLE 03-3 SCRATCH INPUT/OUTPUT

```
C*********************************************************************-
C                                                                     -
C     BURNER SCRATCH INPUT/OUTPUT                                     -
C     ---------------------------                                     -
C                                                                     -
C          DIRECT ACCESS                                              -
C          -------------                                              -
C                                                                     -
C     LOGICAL UNIT 24 (IDA2)   SPECIFIC REACTION RATES BY ZONE AND    -
C                                SUBZONE                              -
C       NUMBER OF RECORDS    NZONE + NSZ                              -
C       LENGTH OF RECORD     NACT*NNS        WORDS                    -
C       OPTIONAL DEPENDING ON MEMORY STORAGE AVAILABLE                -
C                                                                     -
C     LOGICAL UNIT 27 (IDA3)   SPECIFIC REACTION RATE FOR FISSION     -
C                               IN ENERGY RANGES OF YIELD DATA        -
C                               BY ZONE AND SUBZONE                   -
C       NUMBER OF RECORDS    NZONE + NSZ                              -
C       LENGTH OF RECORD     NYER*NNS        WORDS                    -
C       OPTIONAL DEPENDING ON MEMORY STORAGE AVAILABLE                -
C        AND PRESENCE OF ENERGY DEPENDENT YIELD DATA                  -
C                                                                     -
C     LOGICAL UNIT 40 (IDA4)   SPECIFIC REACTION RATES BY POINT       -
C       NUMBER OF RECORDS    NPT                                      -
C       LENGTH OF RECORD     NACT*NNS        WORDS                    -
C       OPTIONAL DEPENDING ON MEMORY STORAGE AVAILABLE                -
C        FOR POINT CALCULATION                                        -
C                                                                     -
C     LOGICAL UNIT 28 (IDA5)   SPECIFIC REACTION RATE FOR FISSION     -
C                               IN ENERGY RANGES OF YIELD DATA        -
C                               BY POINT                              -
C       NUMBER OF RECORDS    NPT                                      -
C       LENGTH OF RECORD     NYER*NNS        WORDS                    -
C       OPTIONAL DEPENDING ON MEMORY STORAGE AVAILABLE                -
C        AND PRESENCE OF ENERGY DEPENDENT YIELD DATA                  -
C        FOR POINT CALCULATION                                        -
C                                                                     -
C          SEQUENTIAL                                                 -
C          ----------                                                 -
C                                                                     -
C     LOGICAL UNIT 52 (ISR1)   ZONE AVERAGE FLUX                      -
C       NUMBER OF RECORDS    NGROUP                                   -
C       LENGTH OF RECORD     NZONE           WORDS                    -
C       ALWAYS USED                                                   -
C                                                                     -
C     LOGICAL UNIT 46 (ISR2)   INITIAL DENSITIES                      -
C       NUMBER OF RECORDS    NZONE + NSZ                              -
C       LENGTH OF RECORD     NNS             WORDS                    -
C       ALWAYS USED                                                   -
C                                                                     -
```

(CONT)

```
C     LOGICAL UNIT 48 (ISR3)   PRINCIPAL CROSS SECTIONS                 -
C                               (LATEST VERSION)                        -
C       NUMBER OF RECORDS    NGROUP                                     -
C       LENGTH OF RECORD     NPSCS           WORDS                      -
C       ALWAYS USED                                                     -
C                                                                       -
C     LOGICAL UNIT 49 (ISR4)   ZONE AVERAGE FLUX                        -
C       NUMBER OF RECORDS    NGROUP                                     -
C       LENGTH OF RECORD     NZONE           WORDS                      -
C       USED WHEN TWO RZFLUX FILES ARE READ                             -
C                                                                       -
C     LOGICAL UNIT 47 (ISR5)   INITIAL POINT DENSITIES                  -
C       NUMBER OF RECORDS    NPT                                        -
C       LENGTH OF RECORD     NNS             WORDS                      -
C       ALWAYS USED FOR POINT CALCULATION                               -
C                                                                       -
C     LOGICAL UNIT 54 (ISR6)   PRINCIPAL CROSS SECTIONS                 -
C                               (NEXT-TO-LATEST VERSION)                -
C       NUMBER OF RECORDS    NGROUP                                     -
C       LENGTH OF RECORD     NPSCS           WORDS                      -
C       USED WHEN TEMPERATURE CORRELATION IS TO BE DONE                 -
C                                                                       -
C     LOGICAL UNIT 45 (ISR7)   EXPOSURE HISTORY DATA                    -
C       NUMBER OF RECORDS    1                                          -
C       LENGTH OF RECORD     40              WORDS                      -
C       PLUS                                                            -
C       NUMBER OF RECORDS    3                                          -
C       LENGTH OF RECORD     NZONE           WORDS                      -
C       PLUS                                                            -
C       NUMBER OF RECORDS    4                                          -
C       LENGTH OF RECORD     NZONE + NSZ     WORDS                      -
C       IF DATA FROM ALL EXPOSURE CALCULATIONS IS TO BE SAVED           -
C        MULTIPLY THIS REQUIREMENT BY THE NUMBER OF EXPOSURES TO        -
C        BE DONE                                                        -
C       USED WHEN EXPOHT INTERFACE IS WRITTEN                           -
C                                                                       -
C     LOGICAL UNIT 45 (ISR7)   REGION ASSIGNMENTS TO FINE MESH          -
C       NUMBER OF RECORDS    NINTK                                      -
C       LENGTH OF RECORD     NINTI*NINTJ     WORDS                      -
C       USED FOR POINT CALCULATION WHEN DATA IS TAKEN FROM GEODST       -
C        AND RTFLUX (3-D ONLY)                                          -
C                                                                       -
C     LOGICAL UNIT 45 (ISR7)   POINT FLUX                               -
C       NUMBER OF RECORDS    NGROUP                                     -
C       LENGTH OF RECORD     NPT             WORDS                      -
C       ALWAYS USED FOR POINT CALCULATION                               -
C                                                                       -
```

(CONT)

```
C     LOGICAL UNIT 53 (ISR8)   EXPOSURE HISTORY DATA                    -
C       NUMBER OF RECORDS     3                                         -
C       LENGTH OF RECORD      NZONE          WORDS                      -
C       PLUS                                                            -
C       NUMBER OF RECORDS     4                                         -
C       LENGTH OF RECORD      NZONE + NSZ    WORDS                      -
C       USED WHEN EXPCHT INTERFACE IS WRITTEN                           -
C                                                                       -
C     LOGICAL UNIT 53 (ISR8)   POINT FLUX                               -
C       NUMBER OF RECORDS     NGROUP                                    -
C       LENGTH OF RECORD      NPT            WORDS                      -
C       USED FOR POINT CALCULATION WHEN TWO FLUX FILES ARE READ         -
C                                                                       -
C     LOGICAL UNIT 51 (ISR9)   SAVE CURRENT DENSITY ARRAY               -
C       NUMBER OF RECORDS     1                                         -
C       LENGTH OF RECORD      NNS*(NZONE + NSZ)  WORDS                  -
C       USED WHEN WEIGHTED AVERAGE EXPOSURE DENSITIES ARE TO BE         -
C        WRITTEN ON ZNATDN INTERFACE                                    -
C       USED WHEN MULTIPLE PASSES ARE DONE FOR CONTINUOUS FUELING OPTION-
C                                                                       -
C     LOGICAL UNIT 50 (ISR10)  DENSITIES TO BE WRITTEN ON QNATDN        -
C                               INTERFACE                               -
C       NUMBER OF RECORDS     NZONE + NSZ                               -
C       LENGTH OF RECORD      NNS            WORDS                      -
C       USED WHEN CONTINUOUS FUELING OPTION IS SPECIFIED                -
C                                                                       -
C          DEFINITIONS                                                  -
C          -----------                                                  -
C                                                                       -
C     IRSUM = IALF + INP + IN2N + IND + INT                             -
C     NACT  = 4 + IRSUM                                                 -
C     NPSCS = (4 + IRSUM + 2*(MAXORD + 1) + NSTRPD)*NISO                -
C                                                                       -
C     NGROUP  NUMBER OF ENERGY GROUPS                                   -
C     NISO    NUMBER OF NUCLIDES IN CROSS SECTION DATA                  -
C     MAXORD  MAXIMUM SCATTERING ORDER                                  -
C     NPSCS   LENGTH OF PRINCIPAL CROSS SECTION RECORD                  -
C     NSTRPD  NUMBER OF COORDINATE DIRECTIONS FOR WHICH TRANSPORT       -
C              CROSS SECTIONS ARE GIVEN                                 -
C     IALF    (N,A)  CROSS SECTION FLAG 0,1                             -
C     INP     (N,P)  CROSS SECTION FLAG 0,1                             -
C     IN2N    (N,2N) CROSS SECTION FLAG 0,1                             -
C     IND     (N,D)  CROSS SECTION FLAG 0,1                             -
C     INT     (N,T)  CROSS SECTION FLAG 0,1                             -
C     NZONE   NUMBER OF ZONES                                           -
C     NSZ     NUMBER OF SUBZONES                                        -
C     NNS     MAXIMUM NUMBER OF NUCLIDES IN ANY SET                     -
C     NYER    NUMBER OF ENERGY RANGES FOR YIELD DATA                    -
C     NPT     NUMBER OF POINTS TREATED IN POINT CALCULATION             -
C     NINTI   NUMBER OF FIRST DIMENSION FINE MESH INTERVALS             -
C     NINTJ   NUMBER OF SECOND DIMENSION FINE MESH INTERVALS            -
C     NINTK   NUMBER OF THIRD DIMENSION FINE MESH INTERVALS             -
C                                                                       -
C***********************************************************************-
```

TABLE 03-3 END

END OF SECTION

# SECTION 04: DATA INTERFACING

The external data files addressed in BURNER are:

| | |
|---|---|
| CONTRL (read only) | Instruction records EXPINS, DVRINS, and PROINS |
| NDXSRF (read only) | Nuclide referencing data and nuclide concentration assignment data |
| GRUPXS (read only) | Microscopic cross section data - group ordered |
| EXPOSE (read only) | Basic exposure data |
| RZFLUX (read only) | Zone average flux - also flux values at selected points for a geometry independent calculation (if modified) |
| ZNATDN (read/write) | Nuclide concentrations (zone and subzone) |
| PTATDN (read/write) | Nuclide concentrations (at selected points) |
| EXPOHT (read/write) | Continuously updated integrals of exposure conditions |
| ZNTEMP (read only) | Temperature data (zone and subzone) |
| QNATDN (write only) | Nuclide concentrations leaving the zones and subzones for the continuous fueling model (same format as ZNATDN) |
| ZNPOWD (write only) | Power density data (zone and subzone) |
| GEODST (read only) | Zone class data - also complete geometry processing for a geometry dependent calculation at selected points |
| RTFLUX (read only) | Regular total flux - for a geometry dependent calculation at selected points |

The primary zone exposure calculation requires that at least one version of the files CONTRL, NDXSRF, GRUPXS, EXPOSE, RZFLUX, and ZNATDN be available.

Generally, and if not specified otherwise in the control record EXPINS, the latest version of any file is used for reading. Also for files written, the latest existing version of a file is rewritten unless specified otherwise.

Table 04-1 documents the BURNER control record EXPINS in file CONTRL (page 04-3), and the special files EXPOSE (page 04-17), EXPOHT (page 04-24), PTATDN (page 04-30), QNATDN (page 04-33), ZNTEMP (page 04-38), and ZNPOWD (page 04-40), and the modified standard file RZFLUX (page 04-35).

TABLE 04-1 INTERFACE FILE SPECIFICATIONS

SPECIFICATIONS FOR EXPINS RECORD IN INTERFACE FILE CONTRL

```
C-----------------------------------------------------------------------------
CR          EXPOSURE MODULE INSTRUCTIONS                                    -
C                                                                           -
CL    EXPINS, (XX(I),I=1,100),(IX(I),I=1,100)                               -
C                                                                           -
CW          101*MULT + 100                                                  -
C                                                                           -
CD    EXPINS        EXPOSURE MODULE DATA IDENTIFIER (6HEXPINS)              -
C                                                                           -
CN*           OPTION NOT IMPLEMENTED                                        -
CN**          OPTION NOT RECOMMENDED                                        -
C                                                                           -
CD    XX(1)         EXPOSURE TIME STEP (DAYS)                               -
CD**                   (A NEGATIVE TIME IS USED FOR SPECIAL SITUATIONS)     -
C                                                                           -
CD    XX(2)         SHUTDOWN TIME STEP AFTER EXPOSURE (DAYS AT ZERO         -
CD                   FLUX)                                                  -
C                                                                           -
CD    XX(3)         THE RATIO OF EACH SHUTDOWN SUBSTEP TIME INTERVAL        -
CD                   TO THAT OF THE PREVIOUS SUBSTEP (APPLICABLE            -
CD                   ONLY IF IX(7) .GT. 1)                                  -
CD                   (DEFAULT TO 1.0)                                       -
C                                                                           -
CD    XX(4)         RESERVED                                                -
C                                                                           -
CD    XX(5)         RESERVED                                                -
C                                                                           -
CD    XX(6)         RELATIVE POWER LEVEL (ALL REACTION RATES ARE            -
CD                   MULTIPLIED BY THIS FACTOR IF NONZERO - PROPER          -
CD                   NORMALIZATION OF THE FLUX LEVEL BY THE NEUTRONICS      -
CD                   CODE TO EFFECT SOME POWER LEVEL IS PRESUMED)           -
C                                                                           -
CD    XX(7)         RESERVED                                                -
C                                                                           -
CD    XX(8)         RESERVED                                                -
C                                                                           -
CD    XX(9)         RESERVED                                                -
C                                                                           -
CD    XX(10)        WEIGHTING FACTOR FOR USE WITH TWO FLUX INTERFACE        -
CD                   FILES (IF IX(13) .EQ. -2)                              -
C                                                                           -
CD                   PHI(USED) = PHI(LV) + XX(10)*(PHI(NTLV) - PHI(LV))     -
CD                    WHERE PHI(LV) IS LATEST VERSION (IN TIME) FLUX        -
CD                    WHERE PHI(NTLV) IS NEXT-TO-LATEST VERSION (IN         -
CD                     TIME) FLUX                                           -
CD                   (DEFAULT TO 0.5)                                       -
C                                                                           -
CD    XX(11)        FLUENCE LOWER BOUND FOR FIRST ENERGY RANGE (EV)         -
C                                                                           -
CD    XX(12)        FLUENCE LOWER BOUND FOR SECOND ENERGY RANGE (EV)        -
```

(CONT)

```
C                                                                       -
CD     XX(13)          CONVERGENCE LEVEL FOR MATRIX EXPONENTIAL METHOD  -
CD                      (DEFAULT TO 1.0E-8)                             -
C                                                                       -
CD     XX(14)          LIMITING VALUE OF DIAGONAL TERM FOR MATRIX       -
CD                      EXPONENTIAL METHOD (EACH SUBSTEP IS SUBDIVIDED  -
CD                      INTO AS MANY TIME INCREMENTS AS NEEDED TO REDUCE -
CD                      THE LARGEST DIAGONAL TERM TO THIS LEVEL)        -
CD                      (DEFAULT TO 12.0)                               -
C                                                                       -
CD     XX(15)          MATRIX EXPONENTIAL TRANSFORM, FRACTION OF LARGEST -
CD                      DIAGONAL TERM                                   -
CD                      (DEFAULT TO 0.5)                                -
C                                                                       -
CD     XX(16)          MINIMUM NUCLIDE DENSITY ALLOWED                  -
CD                      (DEFAULT TO 1.0E-50)                            -
C                                                                       -
CD     XX(17)          MAGNITUDE OF DIAGONAL TERM USED AS CRITERIA FOR  -
CD                      APPLYING THE EQUILIBRIUM APPROXIMATION TO A     -
CD                      NUCLIDE WITH THE MATRIX EXPONENTIAL METHOD      -
CD                      (DEFAULT TO 10.0*XX(14))                        -
C                                                                       -
CD     XX(18)          WEIGHTING FACTOR FOR EXPOSURE NUCLIDE DENSITIES  -
CD                      WRITTEN ON INTERFACE FILE (IF IX(31) .NE. 0)    -
CD                      'ZNATDN' FOR ZONE CALCULATION                   -
CD                      'PTATDN' FOR POINT CALCULATION                  -
C                                                                       -
CD                       N(WRITTEN) = N(E) + XX(18)*(N(S) - N(E))       -
CD                       WHERE N(E) ARE DENSITIES AT END OF EXPOSURE    -
CD                       WHERE N(S) ARE DENSITIES AT START OF EXPOSURE  -
CD                      (DEFAULT TO 0.5)                                -
C                                                                       -
CD     XX(19)          AVERAGE GENERATION RATE WEIGHTING FACTOR FOR     -
CD                      SOURCE TERM                                     -
C                                                                       -
CD                      PRECURSOR DENSITY IS                            -
CD                      XX(19)*N(T) + (1.0 - XX(19))*N(T+DT)            -
CD                      (DEFAULT TO 0.5)                                -
C                                                                       -
CD     XX(20)          CONVERGENCE CRITERIA ON POWER LEVEL FOR CONTINUOUS -
CD                      FUELING MODEL TO DISCONTINUE POWER LEVEL        -
CD                      INITIALIZATION PASSES (APPLICABLE IF IX(51) .GT. 0 -
CD                      AND/OR IX(52) .GT. 0 AND IX(61) .GT. 1)         -
CD                      (DEFAULT TO 0.005)                              -
C                                                                       -
CD     XX(21)          RESERVED                                         -
C                                                                       -
CD     XX(22)          RESERVED                                         -
C                                                                       -
CD     XX(23)          RESERVED                                         -
```

(CONT)

```
C                                                                       -
CD     XX(24)          RESERVED                                         -
C                                                                       -
CD     XX(25)          REFERENCE TEMPERATURE (DEGREES C) OF THE         -
CD                      NEXT-TO-LATEST VERSION 'GRUPXS' CROSS SECTION   -
CD                      INTERFACE FILE                                  -
C                                                                       -
CD     XX(26)          REFERENCE TEMPERATURE (DEGREES C) OF THE         -
CD                      LATEST VERSION 'GRUPXS' CROSS SECTION INTERFACE -
CD                      FILE                                            -
C                                                                       -
CD     XX(27)          CORRELATION PARAMETER FOR THE ARCTANGENT         -
CD                      DEPENDENCE OF CROSS SECTIONS ON ZONE            -
CD                      TEMPERATURES (LINEAR CORRELATION IF 0.0)        -
C                                                                       -
CD     XX(28)          RESERVED                                         -
C                                                                       -
CD     XX(29)          RESERVED                                         -
C                                                                       -
CD     XX(30)          RESERVED                                         -
C                                                                       -
CD     XX(31-100)      CORE RESIDENCE TIME (DAYS) FOR EACH ZONE PATH    -
CD                      FOLLOWED BY THE CORE RESIDENCE TIME (DAYS) FOR  -
CD                      EACH SUBZONE PATH (IF ANY) - SEE IX(51)         -
CD                      (DEFAULT TO XX(1))                              -
C                                                                       -
CN            USUAL VALUES OF SOME OF THE PARAMETERS ARE SHOWN HERE IN ( )-
C                                                                       -
CD     IX(1)           RESERVED                                         -
C                                                                       -
CD     IX(2)           CONDENSED EDIT OPTION                            -
CD                      0- YES                                          -
CD                      1- NO                                           -
C                                                                       -
CD     IX(3)           DEBUG EDIT OPTION (0)                            -
CD                      0- NO SPECIAL EDITS                             -
CD                      1- CROSS REFERENCE TABLES, EXPOSURE DATA,       -
CD                         CHECK AND EDIT DATA FROM 'EXPOSE' INTERFACE  -
CD                         FILE, AND EDIT INTERFACE FILE PARAMETERS     -
CD                      2- HIGHER LEVEL DATA EDIT                       -
CD                      3- PLUS STARTING NUCLIDE DENSITIES              -
CD                      4- PLUS INTERMEDIATE LEVEL DATA                 -
CD                      5- PLUS STARTING REACTION RATES                 -
CD                      6- PLUS ALL EDIT OPTIONS ARE TURNED ON          -
CD                      7- PLUS MATRIX EXPONENTIAL AND AVERAGE GENERATION -
CD                         RATE DEBUG EDITS                             -
CD                      8- PLUS ADDITIONAL MATRIX EXPONENTIAL DEBUG EDITS -
C                                                                       -
CN              NOTE- USE OF 6,7, OR 8 WILL PRODUCE REAMS OF PAPER      -
C                                                                       -
```

(CONT)

```
CD     IX(4)          RESERVED                                          -
C                                                                       -
CD     IX(5)          OPTION ON BASIC CHAIN EQUATION SOLUTION METHOD    -
CD                     (CONSISTENT CHAIN DATA MUST BE PRESENT ON        -
CD                     INTERFACE FILE 'EXPOSE')                         -
CD                     0- MATRIX EXPONENTIAL                            -
CD                     1- EXPLICIT CHAIN                                -
CD                     2- AVERAGE GENERATION RATE                       -
C                                                                       -
CN                    (IF IX(5) .EQ. 0 AND NMATXE('EXPOSE') .EQ. 0 AND  -
CN                    LBEXCH('EXPOSE') .GT. 0, DEFAULT TO 1)            -
C                                                                       -
CD     IX(6)          NUMBER OF SUBSTEP EXPOSURE INTERVALS              -
CD                     IX(6) .GT. 1 IS NORMALLY USED ONLY WHEN THE FLUX -
CD                      LEVEL IS TO BE ADJUSTED (SEE IX(12))            -
CD                     (DEFAULT TO 1 IF XX(1) .NE. 0.0)                 -
C                                                                       -
CN                    EXPOSURE NOT CALCULATED IF XX(1) .EQ. 0.0         -
C                                                                       -
CN                    FOR CONTINUOUS FUELING MODEL SET IX(6) .EQ. 1     -
C                                                                       -
CD     IX(7)          NUMBER OF SUBSTEP SHUTDOWN INTERVALS              -
CD                     IX(7) .GT. 1 IS NORMALLY USED ONLY TO PRODUCE    -
CD                      EDITS AT POINTS ALONG SHUTDOWN STEP             -
CD                     (DEFAULT TO 1 IF XX(2) .GT. 0.0)                 -
C                                                                       -
CN                    SHUTDOWN NOT CALCULATED IF XX(2) .LE. 0.0         -
C                                                                       -
CD     IX(8)          OPTION ON VERSION OF NUCLIDE DENSITIES AT START   -
CD                     'ZNATDN' FOR ZONE CALCULATION                    -
CD                     'PTATDN' FOR POINT CALCULATION (IF NOT AVAILABLE -
CD                      DENSITIES WILL BE EXTRACTED FROM INITIAL ZONE   -
CD                      DENSITIES)                                      -
CD                    -1- USE VERSION WITH THE SAME TIME AS THE ZONE    -
CD                        FLUX FILE                                     -
CD                     0- USE LATEST VERSION (USUAL)                    -
CD                     1- USE NEXT-TO-LATEST VERSION IF IT EXISTS       -
C                                                                       -
CD     IX(9)          OPTION TO ACCOUNT FOR THE DEPENDENCE OF THE       -
CD                     CROSS SECTIONS ON THE LOCAL TEMPERATURE, REQUIRES -
CD                     TWO 'GRUPXS' FILES, A 'ZNTEMP' FILE, AND REFERENCE -
CD                     TEMPERATURES (SEE XX(25),XX(26), AND XX(27))     -
CD                     0- NO                                            -
CD                     1- YES                                           -
C                                                                       -
CD     IX(10)         RESERVED                                          -
C                                                                       -
CD     IX(11)         NUMBER OF SUBDIVISIONS OF EACH SUBSTEP FOR THE    -
CD                     AVERAGE GENERATION RATE METHOD (IF ZERO, THE     -
CD                     CHOICE IS AUTOMATED)                             -
C                                                                       -
```

(CONT)

```
CD     IX(12)        OPTION ON POWER RENORMALIZATION (SUBSTEPS)          -
CD                    0- ATTEMPT TO SATISIFY DESIRED POWER LEVEL BY      -
CD                       ADJUSTING FLUX LEVEL AT THE START OF EACH       -
CD                       SUBSTEP AFTER THE FIRST                         -
CD                    1- DO NOT ADJUST THE FLUX LEVEL                    -
CD                    2- NORMALIZE TO THE INITIAL POWER LEVEL AT THE     -
CD                       START OF EACH SUBSTEP                           -
C                                                                        -
CD     IX(13)        OPTION ON FLUX VALUES                               -
CD                    'RZFLUX' FOR ZONE CALCULATION                      -
CD                    'RTFLUX' FOR POINT CALCULATION (IF IX(73) .EQ. 1)  -
CD                    'RZFLUX' (MODIFIED) FOR POINT CALCULATION          -
CD                     (IF IX(73) .EQ. 2)                                -
CD                   -2- WEIGHT LATEST VERSION AND NEXT-TO-LATEST        -
CD                       VERSION (SEE XX(10))                            -
CD                   -1- USE A LINEAR FLUX APPROXIMATION WITH TIME FROM  -
CD                       THE NEXT-TO-LATEST VERSION FILE TO THE LATEST   -
CD                       VERSION FILE (IF ONLY ONE EXISTS, USE IT)       -
CD                    0- USE LATEST VERSION (USUAL)                      -
CD                    1- USE NEXT-TO-LATEST VERSION IF IT EXISTS         -
C                                                                        -
CD     IX(14)        OPTION ON ZONE(SUBZONE) NUCLIDE DENSITY EDITS       -
CD                    (EXPOSURE)                                         -
CD                    0- NONE                                            -
CD                    1- END OF EXPOSURE STEP                            -
CD                    2- END OF EACH EXPOSURE SUBSTEP                    -
C                                                                        -
CD     IX(15)        RESERVED                                            -
C                                                                        -
CD     IX(16)        RESERVED                                            -
C                                                                        -
CD     IX(17)        RESERVED                                            -
C                                                                        -
CD     IX(18)        OPTION ON SECONDARY ENERGY DEPOSITION EDITS         -
CD                    0- NONE                                            -
CD                    1- DECAY ENERGY RELEASE ONLY                       -
CD                    2- FISSION ENERGY RELEASE ONLY                     -
CD                    3- CAPTURE ENERGY RELEASE ONLY                     -
CD                    4- DECAY + FISSION + CAPTURE ENERGY RELEASE        -
C                                                                        -
CN                   IF .GT. 0, EDITS BY ZONE AND SUBZONE                -
CN                   IF .LT. 0, EDIT TOTALS ONLY                         -
C                                                                        -
CD     IX(19)        RESERVED                                            -
C                                                                        -
CD     IX(20)        OPTION ON ZONE(SUBZONE) NUCLIDE DENSITY EDITS       -
CD                    (SHUTDOWN)                                         -
CD                    0- NONE                                            -
CD                    1- END OF SHUTDOWN STEP                            -
CD                    2- END OF EACH SHUTDOWN SUBSTEP                    -
C                                                                        -
```

(CONT)

```
CD     IX(21)        SPECIAL NUCLIDE DENSITY EDIT OPTION FOR A SINGLE    -
CD                    ZONE PROBLEM                                       -
CD                   -1- COLUMN EDIT IN 0PE15.6 FORMAT                   -
CD                    0- NORMAL EDIT                                     -
CD                    1- COLUMN EDIT IN 1PE15.6 FORMAT                   -
C                                                                        -
CD     IX(22)        RESERVED                                            -
C                                                                        -
CD     IX(23)        RESERVED                                            -
C                                                                        -
CD     IX(24)        RESERVED                                            -
C                                                                        -
CD     IX(25)        OPTION ON WRITING INTERFACE FILE 'EXPOHT'           -
CD                    (FLUENCE AND REACTION RATE TYPE DATA)              -
CD                    0- DO NOT WRITE                                    -
CD                    1- YES - SAVE LATEST AND NEXT-TO-LATEST DATA       -
CD                    2- YES - SAVE ALL DATA                             -
CD                    3- YES - SAVE LATEST DATA ONLY                     -
CD                    4- YES - START OVER AGAIN                          -
C                                                                        -
CN                   IF .GT. 0, NO EDIT                                  -
CN                   IF .LT. 0, EDITS OF CUMULATIVE DATA BY ZONE AND     -
CN                              SUBZONE                                  -
C                                                                        -
CN                   OPTIONS IX(26),IX(27),XX(11), AND XX(12) APPLY ONLY -
CN                    WHEN 'EXPOHT' FILE IS INITIALLY WRITTEN            -
CN                   IF THE FILE EXISTS THE OPTIONS SPECIFIED            -
CN                    ON THE FILE ARE USED                               -
C                                                                        -
CD     IX(26)        FLUENCE DATA TO BE SAVED ON 'EXPOHT' FILE           -
CD                    0- NONE                                            -
CD                    1- TOTAL FLUENCE (AND FIRST AND SECOND             -
CD                        FLUENCE RANGES IF XX(11) AND XX(12) ARE        -
CD                        PROPERLY DEFINED)                              -
C                                                                        -
CD     IX(27)        REACTION RATE TYPE DATA TO BE SAVED ON 'EXPOHT'     -
CD                    FILE                                               -
CD                    0- NONE                                            -
CD                    1- FISSIONS AND EXPOSURE                           -
CD                    2- PLUS ENERGY                                     -
CD                    3- PLUS UNDEFINED                                  -
C                                                                        -
CD     IX(28)        OPTION TO EDIT EXPOSURE STEP AVERAGE ZONE(SUBZONE)  -
CD                    POWER DENSITIES                                    -
CD                    0- NO                                              -
CD                    1- YES                                             -
C                                                                        -
```

```
CD     IX(29)        OPTION TO WRITE INTERFACE FILE 'ZNPOWD' WITH        -
CD                    EXPOSURE STEP AVERAGE ZONE(SUBZONE) POWER          -
CD                    DENSITIES                                          -
CD                    0- DO NOT WRITE                                    -
CD                    1- REPLACE THE LATEST VERSION OF AN OLD FILE,      -
CD                       IF NONE EXISTS WRITE NEW FILE                   -
CD                    2- WRITE NEW FILE                                  -
C                                                                        -
CD     IX(30)        OPTION ON NUCLIDE DENSITY FILE WRITING              -
CD                    'ZNATDN' FOR ZONE CALCULATION                      -
CD                    'PTATDN' FOR POINT CALCULATION                     -
CD                    0- WRITE OVER LATEST EXISTING FILE WITH END OF     -
CD                       EXPOSURE DENSITIES                              -
CD                    1- WRITE NEW FILE WITH END OF EXPOSURE DENSITIES   -
CD                    2- WRITE OVER LATEST EXISTING FILE WITH END OF     -
CD                       SHUTDOWN DENSITIES                              -
CD                    3- WRITE NEW FILE WITH END OF SHUTDOWN DENSITIES   -
CD                    4- WRITE OVER LATEST EXISTING FILE WITH END OF     -
CD                       EXPOSURE DENSITIES AND WRITE NEW FILE WITH      -
CD                       END OF SHUTDOWN DENSITIES                       -
CD                    5- WRITE NEW FILE WITH END OF EXPOSURE DENSITIES   -
CD                       AND WRITE NEW FILE WITH END OF SHUTDOWN         -
CD                       DENSITIES                                       -
C                                                                        -
CD     IX(31)        OPTION TO WRITE WEIGHTED AVERAGE EXPOSURE DENSITIES -
CD                    (SEE XX(18))                                       -
CD                    'ZNATDN' FOR ZONE CALCULATION                      -
CD                    'PTATDN' FOR POINT CALCULATION                     -
CD                   -1- REPORT NORMAL END OF EXPOSURE TIME              -
CD                    0- NO                                              -
CD                    1- REPORT WEIGHTED TIME                            -
C                                                                        -
CD     IX(32)        OPTION TO CHECK AND EDIT DATA FROM INTERFACE FILE   -
CD                    'EXPOSE'                                           -
CD                    0- NO                                              -
CD                    1- YES                                             -
C                                                                        -
CD     IX(33)        OPTION TO EDIT INITIAL ZONE(SUBZONE) SPECIFIC       -
CD                    REACTION RATES                                     -
CD                    0- NO                                              -
CD                    1- YES                                             -
C                                                                        -
CD     IX(34)        OPTION TO EDIT INITIAL ZONE(SUBZONE) SPECIFIC       -
CD                    REACTION RATE FOR FISSION IN YIELD DATA            -
CD                    ENERGY RANGES                                      -
CD                    0- NO                                              -
CD                    1- YES                                             -
C                                                                        -
CD     IX(35)        OPTION TO EDIT INITIAL ZONE(SUBZONE) NUCLIDE        -
CD                    DENSITIES                                          -
CD                    0- NO                                              -
CD                    1- YES                                             -
C                                                                        -
```

(CONT)

```
CD     IX(36)        OPTION TO FORCE CALCULATION INTO I/O MODE (NORMALLY -
CD                    DETERMINED BY CODE BASED ON MEMORY AVAILABLE)       -
CD                    0- NO (AUTOMATED)                                   -
CD                    1- YES                                              -
C                                                                         -
CD     IX(37)        OPTION TO INCREASE STORAGE FOR COUPLING TERMS       -
CD                    FOR MATRIX EXPONENTIAL METHOD (IN THE EVENT         -
CD                    STOP 4321 OCCURS)                                   -
CD                    (DEFAULT - NUMBER OF NUCLIDES IN EXPOSURE DATA)     -
C                                                                         -
CD**   IX(38)        OPTION TO SOLVE THE TRANSPOSE OF THE MATRIX FOR     -
CD**                   THE MATRIX EXPONENTIAL METHOD (THIS IS A SPECIAL  -
CD**                   FEATURE - NOT APPLICABLE TO A REACTOR CALCULATION)-
CD**                  0- NO                                               -
CD**                  1- YES                                              -
C                                                                         -
CD     IX(39)        MATRIX EXPONENTIAL EQUILIBRIUM OPTION               -
CD                    0- DEFAULT, SAME AS 1                               -
CD                    1- APPLY EQUILIBRIUM ASSUMPTION TO HIGH LOSS        -
CD                       NUCLIDES                                         -
CD                    2- DO NOT APPLY EQUILIBRIUM ASSUMPTION (REQUIRED    -
CD                       FOR HIGH ACCURACY (BENCHMARKING) BUT IS          -
CD                       EXPENSIVE IN TERMS OF RUNNING TIME)              -
C                                                                         -
CD     IX(40)        MATRIX EXPONENTIAL FORMULATION OPTION               -
CD                    0- DEFAULT, SAME AS 4                               -
CD                    1- NO TRANSFORMATION, ONE TERM                      -
CD                    2-    TRANSFORMATION, ONE TERM                      -
CD                    3- NO TRANSFORMATION, TWO TERM                      -
CD                    4-    TRANSFORMATION, TWO TERM                      -
C                                                                         -
CD     IX(41)        MATRIX EXPONENTIAL REFERENCE NUMBER OF TERMS        -
CD                    IN EXPANSION                                        -
CD                    (DEFAULT TO 60)                                     -
C                                                                         -
CD     IX(42)        NUMBER OF SUBDIVISIONS OF EACH SUBSTEP FOR THE      -
CD                    MATRIX EXPONENTIAL METHOD (IF ZERO, THE CHOICE      -
CD                    IS AUTOMATED)                                       -
C                                                                         -
CD     IX(43)        UPPER BOUND ON NUMBER OF SUBDIVISIONS OF EACH       -
CD                    SUBSTEP FOR THE MATRIX EXPONENTIAL METHOD.          -
CD                    (IF IX(39) .EQ. 2 AND THE NUMBER OF SUBDIVISIONS    -
C                     COMPUTED BY THE CODE EXCEEDS IX(43) THEN THE        -
CD                    EQUILIBRIUM ASSUMPTION WILL BE USED)                -
CD                    (DEFAULT TO 10000)                                  -
C                                                                         -
CD     IX(44)        RESERVED                                            -
C                                                                         -
```

(CONT)

```
CD     IX(45)        EXPLICIT CHAIN MISSING NUCLIDE OPTION (0)          -
CD                    0- TREAT SUBCHAINS                                -
CD                    1- TREAT FIRST SUBCHAIN ONLY                      -
CD                    2- SKIP CHAIN                                     -
C                                                                       -
CD     IX(46)        RESERVED                                           -
C                                                                       -
CD     IX(47)        RESERVED                                           -
C                                                                       -
CD     IX(48)        RESERVED                                           -
C                                                                       -
CD     IX(49)        OPTION TO ALLOW EXPOSURE WITH ZERO FLUX AND/OR     -
CD                    ZERO ZONE VOLUME                                  -
CD                    0- DO NOT TREAT THE ZONE(SUBZONE)                 -
CD                    1- ALLOW (FOR TREATING OUT-OF-CORE DECAY IN       -
CD                       FALSE ZONES(SUBZONES))                         -
C                                                                       -
CD     IX(50)        RESERVED                                           -
C                                                                       -
CD     IX(51)        FALSE ZONE NUMBER CONTAINING FEED MATERIAL         -
CD                    COMPOSITION FOR ZONE PATHS (OR THE FIRST IN A     -
CD                    SEQUENCE OF FALSE ZONE NUMBERS IF IX(57) .EQ. 1)  -
C                                                                       -
CN             IF IX(51) .GT. 0 AND/OR IX(52) .GT. 0 THE STEADY STATE,  -
CN             CONTINUOUS FUELING MODEL IS TO BE APPLIED.               -
C                                                                       -
CN             THIS ZONE IS THE FEED BOX (OR THE FIRST OF A SET OF BOXES)-
CN             WHERE FEED MATERIAL FOR EACH FLOW PATH ORIGINATES.       -
CN             THESE ARE FALSE ZONES WHICH MUST BE WITHIN THE DATA      -
CN             DESCRIPTION OF THE PROBLEM, THAT ARE NOT ASSIGNED        -
CN             TO GEOMETRIC LOCATIONS FOR THE NEUTRONICS CALCULATION (THE-
CN             FLUX WILL NOT BE CALCULATED), AND HAVE ASSIGNED NUMBERS  -
CN             LESS THAN THE MAXIMUM ZONE NUMBER IN THE PROBLEM IF      -
CN             THE 'DVENTR' SPECIAL INPUT PROCESSOR IS USED.            -
CN             THE NUCLIDE DENSITIES ALONG A FLOW PATH CALCULATED IN    -
CN             THIS MODEL DEPEND ONLY ON THE FEED MATERIAL, THE         -
CN             NEUTRON FLUX, AND THE RESIDENCE TIME, SO ALL MATERIALS   -
CN             IN THESE ZONES INCLUDING STRUCTURE, MODERATOR, ETC.      -
CN             MUST BE GIVEN IN THE FEED BOX ZONE (ZONES). IF THE       -
CN             DENSITIES OF THE NUCLIDES REPRESENTING STRUCTURAL        -
CN             MATERIAL WERE NOT SPECIFIED FOR THE FEED BOX (OR BOXES), -
CN             NONE WOULD APPEAR IN THE REACTOR AFTER THE EXPOSURE      -
CN             CALCULATION EVEN THOUGH VALUES WERE ASSIGNED INITIALLY.  -
CN             FOR SOME SIMPLE SITUATIONS IT IS POSSIBLE TO SEPARATE    -
CN             OUT SELECTED MATERIALS USING THE SUBZONE REPRESENTATION  -
CN             (THOSE MATERIALS ACCOUNTED FOR WOULD NOT BE ASSIGNED     -
CN             CONCENTRATIONS IN THE FEED BOX(ES)). IT IS DESIRABLE     -
CN             TO CARRY AT LEAST ONE NON-DEPLETING NUCLIDE CONCENTRATION -
CN             ALONG THE PATHS TO PROVIDE A MASS BALANCE CHECK.         -
CN             MATERIAL ENTERING A ZONE IS THAT LEAVING THE PREVIOUS    -
CN             ZONE ALONG A PATH, WHILE THE AVERAGE BETWEEN ENTERING    -
CN             AND LEAVING NUCLIDE DENSITIES IN EACH ZONE ARE WRITTEN   -
CN             IN THE NEW NUCLIDE DENSITY FILE 'ZNATDN' FOR USE BY      -
CN             THE NEUTRONICS CODE TO ESTIMATE THE FLUX DISTRIBUTION.   -
```

(CONT)

```
CN            THE SPECIAL INPUT DATA FOR THIS MODEL ARE THE RESIDENCE   -
CN            TIMES ALONG FLOW PATHS (XX(31) UP TO XX(100)),            -
CN            XX(20), IX(49), IX(51), IX(52), IX(53), IX(54), IX(55),   -
CN            IX(56), IX(57), IX(58), IX(59), IX(60), IX(61),           -
CN            AND IX(62). THE EXPOSURE TIME XX(1) MUST BE               -
CN            SPECIFIED - IT WILL BE USED FOR RECORD KEEPING AND IT     -
CN            WILL BE USED FOR EXPOSURE OF ANY ZONES NOT IN THE FLOW    -
CN            PATHS, EXCLUDING THE FEED BOX ZONE(S), AS MIGHT BE USED   -
CN            TO REPRESENT A FIXED BLANKET, AND THE FINAL NUCLIDE       -
CN            DENSITIES IN THESE ZONES WILL BE PLACED IN THE NEW        -
CN            NUCLIDE DENSITY FILE (WHICH REQUIRES ACTION TO BE TAKEN   -
CN            TO PREVENT CONTINUING BUILDUP FROM EXPOSURE IN AN         -
CN            ITERATION PROCESS.                                        -
CN            QUITE GENERALLY AN ITERATION PROCESS IS NECESSARY         -
CN            (NEUTRONICS, EXPOSURE) TO ESTABLISH A NEUTRON FLUX        -
CN            DISTRIBUTION WHICH DEPENDS ON THE NUCLIDE DENSITIES       -
CN            AFTER EXPOSURE, THE COMPOSITION IN THE FEED BOX(ES) MUST  -
CN            BE ALTERED TO EFFECT A CRITICAL STATE, AND THE ITERATIVE  -
CN            PROCESS MUST CONVERGE TO A SOLUTION FOR RELIABLE          -
CN            ANALYSIS. IF THE FEED BOX COMPOSITIONS ARE NOT ALTERED,   -
CN            A PSEUDO STEADY STATE CONDITION RESULTS FOR A REACTOR     -
CN            WHICH IS NOT JUST CRITICAL. A CAPABILITY EXISTS TO        -
CN            EFFECT THE CRITICAL STATE BY APPLYING THE CRITICALITY     -
CN            SEARCH OPTION WHEN THE NEUTRONICS PROBLEM IS SOLVED.      -
CN            MATERIALS IN THE REACTOR MUST BE CHANGED AS WELL AS THE   -
CN            CONTENTS OF THE FEED BOXES. AFTER EXPOSURE THE REACTOR    -
CN            CONTENTS DEPEND ON THE FEED, SO THE FEED MUST BE          -
CN            DETERMINED (CHANGING ONLY THE FEED DURING A               -
CN            NEUTRONICS CALCULATION WILL NOT CHANGE THE CURRENT        -
CN            ESTIMATE OF THE REACTOR CONTENTS SINCE THE FEED BOX       -
CN            LIES OUTSIDE OF THE REACTOR AND THE NEUTRONICS SEARCH     -
CN            PROBLEM COULD NOT CONVERGE).                              -
CN            MORE THAN ONE PASS MAY BE MADE THROUGH THE REACTOR.       -
CN            HOLD-UP OUT-OF-CORE MAY BE ALLOWED WITH FALSE ZONES       -
CN            NOT IN THE ACTUAL GEOMETRY (IX(49) MUST BE SET .EQ. 1).   -
CN            NOTE THAT THE ASSIGNMENT OF ZONES AND SUBZONES TO THE     -
CN            GEOMETRY MUST START WITH 1 FOR LOCATIONS RECEIVING        -
CN            FEED AND INDEX UP ALONG FLOW PATHS.                       -
CN            ONLY ONE EXPOSURE SUBSTEP MAY BE REQUESTED FOR THIS       -
CN            OPTION.                                                   -
C                                                                       -
CN            CONSTRAINTS ON INPUT:                                     -
C                                                                       -
CN                 IX(51) .LE. NUMBER OF ZONES                          -
CN                 IX(51)+IX(53)-1 .LE. NUMBER OF ZONES IF IX(57) .EQ. 1-
CN                 IX(52) .LE. NUMBER OF ZONES                          -
CN                 IX(52)+IX(54)-1 .LE. NUMBER OF ZONES IF IX(58) .EQ. 1-
CN                 IX(55)*IX(53) .LE. MIN(IX(51),IX(52).NE.0) - 1       -
CN                 IX(56)*IX(54) .LE. NUMBER OF SUBZONES                -
CN                 IX(53)+IX(54) .LE. 70                                -
CN                STOP WILL OCCUR IF CONSTRAINTS ARE EXCEEDED           -
C                                                                       -
```

(CONT)

```
CD     IX(52)        FALSE ZONE NUMBER CONTAINING FEED MATERIAL          -
CD                    COMPOSITION FOR SUBZONE PATHS (OR THE FIRST IN A   -
CD                    SEQUENCE OF FALSE ZONE NUMBERS IF IX(58) .EQ. 1)   -
C                                                                        -
CD     IX(53)        NUMBER OF ZONE PATHS THROUGH THE REACTOR            -
C                                                                        -
CN                    THE FIRST ZONE IN THE FIRST ZONE PATH IS ZONE      -
CN                    NUMBER 1, AND THE PATH FOLLOWS UP THE NUMBERS      -
C                                                                        -
CD     IX(54)        NUMBER OF SUBZONE PATHS THROUGH THE REACTOR         -
C                                                                        -
CN                    THE FIRST SUBZONE IN THE FIRST SUBZONE PATH IS     -
CN                    SUBZONE NUMBER 1, AND THE PATH FOLLOWS UP THE      -
CN                    NUMBERS                                            -
C                                                                        -
CD     IX(55)        NUMBER OF ZONES ALONG EACH ZONE PATH                -
C                                                                        -
CD     IX(56)        NUMBER OF SUBZONES ALONG EACH SUBZONE PATH          -
C                                                                        -
CD     IX(57)        OPTION ON ZONE FEED MATERIAL                        -
CD                    0- USE ZONE IX(51) AS FEED FOR ALL ZONE PATHS      -
CD                    1- USE ZONES IX(51) THROUGH IX(51)+IX(53)-1        -
CD                        AS FEED FOR EACH ZONE PATH (A DIFFERENT ZONE   -
CD                        FOR EACH ZONE PATH)                            -
C                                                                        -
CD     IX(58)        OPTION ON SUBZONE FEED MATERIAL                     -
CD                    0- USE ZONE IX(52) AS FEED FOR ALL SUBZONE PATHS   -
CD                    1- USE ZONES IX(52) THROUGH IX(52)+IX(54)-1        -
CD                        AS FEED FOR EACH SUBZONE PATH (A DIFFERENT     -
CD                        ZONE FOR EACH SUBZONE PATH)                    -
C                                                                        -
CD     IX(59)        RESERVED                                            -
C                                                                        -
CD     IX(60)        RESERVED                                            -
C                                                                        -
CD     IX(61)        NUMBER OF PASSES TO ESTABLISH POWER LEVEL REPORTED  -
CD                    BY THE NEUTRONICS CALCULATION                      -
CD                    (DEFAULT TO 1)                                     -
C                                                                        -
CN             THE CALCULATION IS DONE THIS MANY TIMES (OR UNTIL THE     -
CN             CONVERGENCE CRITERIA (SEE XX(20)) IS SATISFIED) WITH      -
CN             THE FLUX LEVEL ADJUSTED AFTER EACH PASS WHICH IMPROVES    -
CN             THE POWER LEVEL AND MAY ACCELERATE THE CONVERGENCE RATE   -
CN             OF A USUAL FEED SEARCH ITERATION PROCEDURE.               -
C                                                                        -
```

(CONT)

```
CD*     IX(62)          OPTION TO WRITE INTERFACE FILE 'QNATDN' WITH        -
CD*                      DISCHARGE DENSITIES (FOR CONTINUOUS FUELING MODEL  -
CD*                      ONLY)                                              -
CD*                      0- DO NOT WRITE                                    -
CD*                      1- REPLACE THE LATEST VERSION OF AN OLD FILE,      -
CD*                          IF NONE EXISTS WRITE NEW FILE                  -
CD*                      2- WRITE NEW FILE                                  -
C                                                                           -
CD      IX(63)          RESERVED                                            -
C                                                                           -
CD      IX(64)          RESERVED                                            -
C                                                                           -
CD      IX(65)          RESERVED                                            -
C                                                                           -
CD      IX(66)          RESERVED                                            -
C                                                                           -
CD      IX(67)          RESERVED                                            -
C                                                                           -
CD      IX(68)          RESERVED                                            -
C                                                                           -
CD      IX(69)          RESERVED                                            -
C                                                                           -
CD      IX(70)          RESERVED                                            -
C                                                                           -
CD      IX(71)          RESERVED                                            -
C                                                                           -
CD      IX(72)          RESERVED                                            -
C                                                                           -
CD      IX(73)          OPTION TO PERFORM AUXILIARY POINT CALCULATION       -
CD                       OVER SELECTED ZONES                                -
CD                       0- NO                                              -
CD                       1- YES - THE ZONE NUMBERS SPECIFIED IN             -
CD                           IX(84)-IX(93), MAXIMUM OF 10, ARE TREATED IF   -
CD                           THE POINT NUCLIDE DENSITY FILE 'PTATDN' DOES   -
CD                           NOT EXIST; IF THIS FILE EXISTS THE REFERENCE   -
CD                           DATA IN THE FILE IS USED TO CONTINUE THE       -
CD                           CALCULATION FOR THE SAME ZONES TREATED         -
CD                           PREVIOUSLY. FILE 'GEODST' IS ACCESSED FOR      -
CD                           IDENTIFYING LOCATIONS OF POINTS IN THE ZONES   -
CD                           AND POINT FLUX VALUES ARE OBTAINED FROM FILE   -
CD                           'RTFLUX'.                                      -
CD                       2- YES - THE REFERENCE DATA IS INITIALLY TAKEN     -
CD                           FROM THE FILE 'RZFLUX' (MODIFIED) AND THE      -
CD                           POINT FLUX VALUES ARE ALWAYS USED FROM THIS    -
CD                           FILE (AS MADE AVAILABLE FROM A COMPATIBLE      -
CD                           NEUTRONICS CODE). IF THE POINTS DO NOT         -
CD                           AGREE WITH AN EXISTING 'PTATDN' FILE THE       -
CD                           CALCULATION WILL NOT BE DONE.                  -
C                                                                           -
```

(CONT)

```
CN                    IN AN ATTEMPT TO PARALLEL THE ZONE CALCULATION      -
CN                     OPTIONS XX(6), XX(10), XX(18), IX(8), IX(12),      -
CN                     IX(13), IX(30), AND IX(31) APPLY TO BOTH ZONE      -
CN                     AND POINT CALCULATIONS                             -
C                                                                         -
CN                    THE PROCEDURE SHOULD MAINTAIN A SET OF POINT        -
CN                     DENSITIES CONSISTENT WITH THE ZONE DENSITIES       -
CN                     BUT CAN NOT ACCOUNT FOR EXTERNAL CHANGES IN        -
CN                     THE ZONE DENSITIES (FROM A NEUTRONICS SEARCH,      -
CN                     OR AFTER REFUELING, OR REPOSITIONING, FOR EXAMPLE) -
C                                                                         -
CN                    NOT DONE IF IX(51) .GT. 0 OR IX(52) .GT. 0          -
C                                                                         -
CD    IX(74)          OPTION ON POINT NUCLIDE DENSITY EDITS (EXPOSURE)    -
CD                     0- NONE                                            -
CD                     1- END OF EXPOSURE STEP                            -
CD                     2- END OF EACH EXPOSURE SUBSTEP                    -
C                                                                         -
CD    IX(75)          OPTION ON POINT NUCLIDE DENSITY EDITS (SHUTDOWN)    -
CD                     0- NONE                                            -
CD                     1- END OF SHUTDOWN STEP                            -
CD                     2- END OF EACH SHUTDOWN SUBSTEP                    -
C                                                                         -
CD    IX(76)          OPTION TO EDIT INITIAL POINT SPECIFIC REACTION      -
CD                     RATES                                              -
CD                     0- NO                                              -
CD                     1- YES                                             -
C                                                                         -
CD    IX(77)          OPTION TO EDIT INITIAL POINT SPECIFIC REACTION      -
CD                     RATE FOR FISSION IN YIELD DATA ENERGY RANGES       -
CD                     0- NO                                              -
CD                     1- YES                                             -
C                                                                         -
CD    IX(78)          OPTION TO EDIT INITIAL POINT NUCLIDE DENSITIES      -
CD                     0- NO                                              -
CD                     1- YES                                             -
C                                                                         -
CD    IX(79)          DEBUG EDIT OPTION FOR POINT CALCULATION             -
CD                     (IN ADDITION TO THOSE REQUESTED WITH IX(3))        -
CD                     0- NONE                                            -
CD                     1- MINIMAL EDITS                                   -
CD                     2- PLUS FLUX INFORMATION                           -
CD                     3- PLUS VOLUME INFORMATION                         -
C                                                                         -
CN                     2,3 MAY INCREASE STORAGE REQUIREMENTS FOR          -
CN                         IX(73) .EQ. 1                                  -
C                                                                         -
CD    IX(80)          RESERVED                                            -
C                                                                         -
CD    IX(81)          RESERVED                                            -
C                                                                         -
```

(CONT)

```
CD     IX(82)         RESERVED                                          -
C                                                                       -
CD     IX(83)         RESERVED                                          -
C                                                                       -
CD     IX(84-93)      UP TO 10 ZONE NUMBERS SPECIFYING THE LOCATIONS WHERE-
CD                     THE POINT CALCULATION IS TO BE DONE              -
CD                     (IF IX(73) .EQ. 1)                               -
CD                     IF THERE ARE LESS THAN 10 ENTRIES , THE FIRST 0  -
CD                     TERMINATES THE LIST OF ZONE NUMBERS              -
C                                                                       -
CD     IX(94-100)     RESERVED                                          -
C                                                                       -
C-----------------------------------------------------------------------
```

(CONT)

SPECIFICATIONS FOR INTERFACE FILE EXPOSE

```
C*********************************************************************-
C                                                                     -
CF          EXPOSE                                                    -
C                                                                     -
CE          DATA FOR EXPOSURE CALCULATIONS                            -
C                                                                     -
CN          THE BASIC DATA REQUIRED FOR SOLVING THE CHAIN             -
CN          EQUATIONS IDENTIFIES NUCLIDES, FISSIONING                 -
CN          NUCLIDES, FISSION PRODUCTS, AND GIVES DECAY, YIELD, ENERGY, -
CN          AND COUPLING DATA                                         -
C                                                                     -
C*********************************************************************-

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


C---------------------------------------------------------------------
CR    1D    FILE REFERENCE INFORMATION                                -
C                                                                     -
CL    NEXP1,NISOE,NAMOPT,NYER,NGER,NFSLR,NFPR,NDCYR,NEXP9,NEXP10,     -
CL    NEXP11,NMATXE,LSEXCH,LBEXCH,NEXP15,NOEDCY,NOEFIS,NOECAP,        -
CL    NEXP19,NEXP20                                                   -
C                                                                     -
CW          20                                                        -
C                                                                     -
CN    UNDEFINED DATA IS RESERVED FOR FUTURE USE                       -
C                                                                     -
CD    NEXP1          DOCUMENTING FILE REFERENCE NUMBER                -
CD    NISOE          REFERENCE NUMBER OF NUCLIDES                     -
CD                    MUST BE NON-ZERO                                -
CD    NAMOPT         OPTION ON NUCLIDE NAMES                          -
CD                   IF 0 - THEY ARE ABSOLUTE NAMES                   -
CD                   IF 1 - THEY ARE USER LABELS                      -
C                                                                     -
CN                   IN FILE ISOTXS, ABSOLUTE NAMES ARE               -
CN                   HABSID, WHILE USER LABELS ARE HISONM             -
C                                                                     -
CN                   UNIQUE NAMES ARE REQUIRED HERE                   -
C                                                                     -
```

(CONT)

```
CD     NYER          NUMBER OF ENERGY RANGES FOR YIELD DATA                -
CD                    (GENERALLY NON-ZERO)                                 -
CD     NGER          NUMBER OF ENERGY RANGES FOR GAMMA RAYS               -
CD     NFSLR         NUMBER OF IDENTIFIED FISSILE NUCLIDES WHICH YIELD    -
CD                    FISSION PRODUCTS                                     -
CD     NFPR          NUMBER OF FISSION PRODUCTS HAVING YIELD              -
CD     NDCYR         NUMBER OF NUCLIDES WHICH DECAY                       -
CD     NEXP9         RESERVED                                             -
CD     NEXP10        RESERVED                                             -
CD     NEXP11        RESERVED                                             -
CD     NMATXE        OPTION IF .GT. 0 INDICATING THE NUMBER               -
CD                   OF MATRIX EXPONENTIAL DATA ENTRIES                   -
CD     LSEXCH        OPTION IF .GT.0 INDICATING THE NUMBER                -
CD                   OF ENTRIES IN THE SUPPLEMENTING TABLE OF EXPLICIT    -
CD                   CHAIN DATA (USED WITH MATRIX DATA)                   -
CD     LBEXCH        OPTION IF .GT.0 INDICATING THE NUMBER                -
CD                   OF ENTRIES IN THE BASIC TABLE OF EXPLICIT            -
CD                   CHAIN DATA (USED ONLY ALONE)                         -
CD     NEXP15        RESERVED                                             -
CD     NOEDCY        OPTION INDICATING DATA FOR THE DECAY PROCESS         -
CD                   IS INCLUDED FOR GAMMA RAYS AND BETA PARTICLES        -
CD     NOEFIS        OPTION INDICATING DATA FOR THE FISSION PROCESS       -
CD                   IS INCLUDED FOR GAMMA RAYS AND BETA PARTICLES        -
CD     NOECAP        OPTION INDICATING DATA FOR THE CAPTURE PROCESS       -
CD                   IS INCLUDED FOR GAMMA RAYS AND BETA PARTICLES        -
CD     NEXP19        RESERVED                                             -
CD     NEXP20        RESERVED                                             -
C                                                                         -
C-------------------------------------------------------------------------

C-------------------------------------------------------------------------
CR     2D     TITLE AND NUCLIDE NAMES                                     -
C                                                                         -
CC            ALWAYS PRESENT                                              -
C                                                                         -
CN            HEREAFTER ALL REFERENCES TO NUCLIDES IN THIS FILE ARE       -
CN            BY THE ORDER NUMBER IN THIS TABLE OF NAMES                  -
C                                                                         -
CL     (HTL(J),J=1,12),(HNUC(I),I=1,NISOE)                                -
C                                                                         -
CW            MULT*(12+NISOE)                                             -
C                                                                         -
CD     HTL           DOCUMENTING TITLE   (12A6)                          -
CD     HNUC(I)       NAME OF NUCLIDE ORDERED I (A6) SEE NAMOPT OPTION    -
C                                                                         -
CN            ALL NUCLIDES TO BE TREATED (EXPOSURE CALCULATED) MUST BE    -
CN            NAMED IN THIS LIST (NORMALLY EXCLUDE COOLANT, STRUCTURE).   -
```

(CONT)

```
C                                                                       -
CN          WHEN THE AVERAGE GENERATION RATE METHOD IS USED, THESE      -
CN          SPECIFICATIONS ARE PROCESSED IN THE ORDER IN THIS LIST, SO  -
CN          THEY SHOULD BE ORDERED ALONG CHAINS, DOMINATING ROUTES FIRST-
CN          (EXAMPLE,  U....PU, I..XE, XE..CS), FISSION PRODUCTS LAST.  -
C                                                                       -
CN          NUCLIDES SPECIFIED HERE BUT ABSENT IN THE SYSTEM OF COURSE  -
CN          ARE NOT TREATED - IMPACTS ARE DOCUMENTED ELSEWHERE.         -
C                                                                       -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR    3D    REFERENCE DATA                                              -
C                                                                       -
CC          PRESENT IF NYER+NGER+NFSLR+NFPR+NDCYR .GT. 0                -
C                                                                       -
CL    (YER(N),N=1,NYER),(GER(J),J=1,NGER),(IFSLR(K),K=1,NFSLR),         -
CL    (IFPR(L),L=1,NFPR),(IDCYR(I),I=1,NDCYR)                           -
C                                                                       -
CW          NYER+NGER+NFSLR+NFPR+NDCYR                                  -
C                                                                       -
CD    YER           LOWER ENERGY OF RANGE OF INCIDENT                   -
CD                  NEUTRON ENERGY (EV), DECREASING ORDER               -
CD                  (LAST NUMBER TYPICALLY ZERO, SINGLE VALUE USUALLY 0)-
CD    GER           MEAN OR EFFECTIVE ENERGY OF EACH RANGE              -
CD                   OF DATA FOR GAMMA RAY ENERGY DATA, ORDERED BY      -
CD                   DECREASING ENERGY, FOR DOCUMENTATION (EV PER PART.)-
CD    IFSLR         REFERENCE ORDER NUMBER OF IDENTIFIED                -
CD                  NUCLIDES WHICH FISSION                              -
CD    IFPR          REFERENCE ORDER NUMBER OF FISSION PRODUCTS          -
CD                   (NUCLIDES FOR WHICH FISSION YIELD DATA IS GIVEN)   -
CD    IDCYR         REFERENCE ORDER NUMBER OF NUCLIDES WHICH DECAY      -
C                                                                       -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR    4D    DECAY DATA                                                  -
C                                                                       -
CC          PRESENT IF NDCYR .GT. 0                                     -
C                                                                       -
CL    (ALMDA(I),I=1,NDCYR)                                              -
C                                                                       -
CW          NDCYR                                                       -
C                                                                       -
CD    ALMDA         TOTAL DECAY CONSTANT FOR NUCLIDE ORDERED I IN THE   -
CD                  REFERENCE SET IDCYR(I)    (SEC-1)                   -
C                                                                       -
C-----------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     5D     FISSION PRODUCT YIELD DATA                                -
C                                                                       -
CC            PRESENT IF NFSLR*NFPR*NYER .GT. 0                         -
C                                                                       -
CL     (((YFFP(K,L,N),K=1,NFSLR),L=1,NFPR),N=1,NYER)                    -
C                                                                       -
CW            NFSLR*NFPR*NYER                                           -
C                                                                       -
CD     YFFP(K,L,N)    YIELD OF FISSION PRODUCT IFPR(L) FRCM             -
CD                    FISSION OF NUCLIDE IFSLR(K) DUE TO FISSIONING     -
CD                    NEUTRON IN ENERGY RANGE N                         -
CD                    (ATOMS PER SECOND PER FISSION PER SECOND)         -
C                                                                       -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR     6D     CHAIN DATA FOR MATRIX EXPONENTIAL OR AVERAGE GENERATION RATE-
C                                                                       -
CC            PRESENT IF NMATXE .GT. 0                                  -
C                                                                       -
CL     ((MATXE(J,I),J=1,3),I=1,NMATXE)                                  -
C                                                                       -
CW            3*NMATXE                                                  -
C                                                                       -
CD     MATXE(1,I)     SOURCE NUCLIDE                                    -
CD     MATXE(2,I)     PRODUCT NUCLIDE                                   -
CD     MATXE(3,I)     SPECIFIES THE TRANSMUTATION PROCESS,              -
CD                     0- NOT ALLOWED                                   -
CD                     1- DECAY                                         -
CD                     2- (N,GAMMA), USUAL CAPTURE UP THE CHAIN         -
CD                     3- (N,ALPHA)                                     -
CD                     4- (N,P)                                         -
CD                     5- (N,2N), DOWN THE CHAIN                        -
CD                     6- (N,D)                                         -
CD                     7- (N,T)                                         -
CD                     8- FISSION (DO NOT SPECIFY FOR A FISSION PRODUCT -
CD                        FOR WHICH YIELD DATA IS GIVEN, THIS IS TREATED -
CD                      DIRECTLY)                                       -
CD                     9- TOTAL CAPTURE, TOTAL ABSORPTION LESS FISSION  -
C                                                                       -
CN            PARTIAL RATES OF PRODUCT GENERATION CAN BE CONSIDERED.  THE -
CN            PARTS PER MILLION IS EXPRESSED AS AN INTEGER (500000 IS THE -
CN            FRACTION 0.5), ROUNDED TO THE NEAREST TEN (LAST DIGIT ZERO),-
CN            ADDED TO THE NUMBER FROM THE ABOVE TABLE TO SPECIFY THE   -
CN            TRANSMUTATION PROCESS.  FOR EXAMPLE, IF THE PARTIAL CAPTURE -
CN            ROUTES OF PM-147 TO PM-148 AND TO PM-148M ARE BOTH TO BE  -
CN            CONSIDERED, THE FIRST AT FRACTION 0.53, THE APPROPRIATE   -
CN            ENTRIES TO INDICATE (N,GAMMA) REACTION PRODUCTS ARE 530002 -
CN            FOR THE PRODUCT PM-148 AND 470002 FOR PM-148M.  LESS THAN -
CN            A TOTAL FRACTION OF UNITY MAY BE SPECIFIED, BUT TAKE CARE. -
C                                                                       -
C-----------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     7D     CHAIN DATA, SUPPLEMENTAL EXPLICIT                         -
C                                                                       -
CC            PRESENT IF LSEXCH .GT. 0                                  -
C                                                                       -
CL     (NSXCH(I),I=1,LSEXCH)                                            -
C                                                                       -
CW            LSEXCH                                                    -
C                                                                       -
CD     NSXCH          ENTRY IN THE SUPPLEMENTAL EXPLICIT CHAIN          -
CD                    DATA TABLE (SEE DESCRIPTION BELOW)                -
C                                                                       -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR     8D     CHAIN DATA, COMPLETE BASIC DATA TO APPLY EXPLICIT SOLUTION -
C                                                                       -
CC            PRESENT IF LBEXCH .GT. 0                                  -
C                                                                       -
CL     (NBXCH(I),I=1,LBEXCH)                                            -
C                                                                       -
CW            LBEXCH                                                    -
C                                                                       -
CD     NBXCH          ENTRY IN THE BASIC EXPLICIT CHAIN DATA TABLE,     -
CD                    OUTLINED HERE                                     -
C                                                                       -
CN            THE FIRST ENTRY IS THE FIRST NUCLIDE IN THE FIRST         -
CN            CHAIN.  THE NEXT ENTRY IS THE TRANSMUTATION PROCESS FOR   -
CN            GENERATION OF THE PRODUCT (SEE THE VALUES OF MATXE(3,I) IN -
CN            THE TABLE ABOVE).  THE NEXT ENTRY IN THE LIST IS THE FIRST -
CN            PRODUCT IN THE FIRST CHAIN.  THUS FOR N NUCLIDES IN A CHAIN,-
CN            THERE ARE 2*(N-1)+1 ENTRIES FOR THE CHAIN.  THEN THERE IS A -
CN            ZERO ENTRY.  DATA FOLLOWS FOR THE NEXT CHAIN.  A FINAL    -
CN            EXTRA ZERO IS PLACED AT THE END AFTER THE LAST CHAIN WHICH -
CN            FLAGS THE END OF CHAINS.  TWO ZERO ENTRIES AT THE END.    -
CN            ENTER ACTINIDE CHAINS FIRST.                              -
C                                                                       -
CN            REPEAT OF A NUCLIDE REFERENCE IN A CHAIN IS NOT ALLOWED.  -
CN            GIVEN A FIRST APPEARANCE IN ONE CHAIN, SUBSEQUENT ENTRIES OF-
CN            A NUCLIDE REFERENCE INDICATE OTHER GENERATION ROUTES WHICH -
CN            CONTRIBUTE INDEPENDENTLY.  CARE MUST BE TAKEN TO SUPPLY   -
CN            REASONABLE SPECIFICATIONS - ONLY THE ACTUAL CHAINS SHOWN  -
CN            WILL BE TREATED, SO FULL SPECIFICATIONS REQUIRING REPEATS -
CN            ARE REQUIRED, AND ONLY LIMITED BRANCHING IS ALLOWED.      -
CN            THE CONTRIBUTIONS ALONG A ROUTE THROUGH THE CHAINS ARE ONLY -
CN            THOSE FOR THE NUCLIDES ACTUALLY GIVEN FOR THAT CHAIN.     -
CN            AS AN EXAMPLE, THE TABLE                                  -
CN            1 +02 2 +02 3 +01 4 +02 5 0 1 +02 2 +01 6 +02 -4 +02 -5 0 0 -
CN            ALLOWS TWO ROUTES TO BE TREATED FOR GENERATION OF NUCLIDES -
CN            REFERENCED 4 AND 5.  THE -4 AND -5 IN THE SECOND CHAIN    -
CN            INDICATE THESE CONTRIBUTIONS ARE ADDITIONAL.              -
```

(CONT)

```
C                                                                       -
CN          ONLY NUCLIDES GIVEN IN THESE CHAINS WILL BE TREATED         -
CN          (EXPOSED).                                                  -
C                                                                       -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR    9D    DECAY ENERGY RELEASE DATA                                   -
C                                                                       -
CC          PRESENT IF NOEDCY .GT. 0 .AND. NDCYR*(NGER+2) .GT. 0        -
C                                                                       -
CL    ((EGAMA(I,J),I=1,NDCYR),J=1,NGER),(EBETA(I),I=1,NDCYR),           -
CL    (EDCY(I),I=1,NDCYR)                                               -
C                                                                       -
CW          NDCYR*(NGER+2)                                              -
C                                                                       -
CD    EGAMA(I,J)     THE AMOUNT OF ENERGY RELEASED PER ATOMIC           -
CD                   DECAY OF PARENT NUCLIDE IDCYR(I)                   -
CD                   AS GAMMA RAYS IN ENERGY RANGE J (EV)               -
CD    EBETA(I)       THE AMOUNT OF ENERGY RELEASED PER                  -
CD                   ATOMIC DECAY OF PARENT NUCLIDE IDCYR(I)            -
CD                   AS BETA PARTICLES (EV)                             -
CD    EDCY(I)        THE AMOUNT OF ENERGY RELEASED PER ATOMIC DECAY OF  -
CD                   PARENT NUCLIDE IDCYR(I), (EV)                      -
C                                                                       -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR    10D   SECONDARY ENERGY FROM FISSION                               -
C                                                                       -
CC          PRESENT IF NOEFIS .GT. 0 .AND. NFSLR*(NGER+1) .GT. 0        -
C                                                                       -
CL    ((EFGAM(I,J),I=1,NFSLR),J=1,NGER),(EFBAT(I),I=1,NFSLR)            -
C                                                                       -
CW          NFSLR*(NGER+1)                                              -
C                                                                       -
CD    EFGAM(I,J)     THE AMOUNT OF ENERGY RELEASED PER                  -
CD                   ATOMIC FISSION OF NUCLIDE IFSLR(I)                 -
CD                   AS GAMMA RAYS IN ENERGY RANGE J (EV)               -
CD    EFBAT(I)       THE AMOUNT OF ENERGY RELEASED PER ATOMIC           -
CD                   FISSION OF NUCLIDE IFSLR(I) AS BETA PARTICLES (EV) -
C                                                                       -
C-----------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     11D    ENERGY RELEASE FRCM CAPTURE                                -
C                                                                        -
CC            PRESENT IF NOECAP .GT. 0 .AND. NISOE*(NGER+1) .GT. 0       -
C                                                                        -
CL     ((ECGAM(I,J),I=1,NISOE),J=1,NGER),(ECBAT(I),I=1,NISOE)            -
C                                                                        -
CW            NISOE*(NGER+1)                                             -
C                                                                        -
CD     ECGAM(I,J)     THE AMOUNT OF ENERGY RELEASED PER                  -
CD                    ATOMIC CAPTURE OF NUCLIDE I AS GAMMA RAYS          -
CD                    IN ENERGY RANGE J (EV)                             -
CD     ECBAT(I)       THE AMOUNT OF ENERGY RELEASED PER ATOMIC           -
CD                     CAPTURE OF NUCLIDE I AS BETA PARTICLES (EV)       -
C                                                                        -
C-----------------------------------------------------------------------

C***********************************************************************-
C                                                                        -
CEOF          EXPOSE                                                     -
C                                                                        -
C***********************************************************************-
```

(CONT)

SPECIFICATIONS FOR INTERFACE FILE EXPOHT

```
C*********************************************************************-
C                                                                     -
CF          EXPOHT                                                    -
C                                                                     -
CE          RECORD OF EXPOSURE HISTORY                                -
C                                                                     -
C*********************************************************************-

C---------------------------------------------------------------------
CS          FILE STRUCTURE                                            -
CS                                                                    -
CS             RECORD TYPE                          PRESENT IF        -
CS          ================================      ===============   -
CS             FILE IDENTIFICATION                  ALWAYS            -
CS          1D FILE REFERENCE INFORMATION           ALWAYS            -
CS       **********(REPEAT FROM 1 TO IHIST)                           -
CS       *  2D GENERAL INFORMATION                  ALWAYS            -
CS       *  3D TOTAL FLUENCE                        NFLUT = 1         -
CS       *  4D FLUENCE RANGE 1                      NFLU1 = 1         -
CS       *  5D FLUENCE RANGE 2                      NFLU2 = 1         -
CS       *  8D FISSIONS                             NRR1 = 1          -
CS       *  9D EXPOSURE                             NRR2 = 1          -
CS       * 10D ENERGY                               NRR3 = 1          -
CS       * 11D UNDEFINED                            NRR4 = 1          -
CS       **********                                                   -
CS                                                                    -
C---------------------------------------------------------------------

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


C---------------------------------------------------------------------
CR    1D    FILE REFERENCE INFORMATION                                -
C                                                                     -
CL    EXPH1,EXPH2,EXPH3,EFLU1,EFLU2,IHIST,IZONE,ISZ,                  -
CL    NFLUT,NFLU1,NFLU2,IXPH12,IXPH13,NRR1,NRR2,NRR3,                 -
CL    NRR4,IXPH18,IXPH19,IXPH20                                       -
C                                                                     -
CW          20                                                        -
C                                                                     -
```

(CONT)

```
CD     EXPH1          END OF EXPOSURE TIME (DAYS) FROM LAST SET OF DATA   -
CD     EXPH2          RESERVED                                            -
CD     EXPH3          RESERVED                                            -
CD     EFLU1          CUTOFF ENERGY (EV) FOR FIRST FLUENCE                -
CD     EFLU2          CUTOFF ENERGY (EV) FOR SECOND FLUENCE               -
CD     IHIST          NUMBER OF SETS OF DATA                              -
CD     IZONE          NUMBER OF ZONES                                     -
CD     ISZ            NUMBER OF SUBZONES                                  -
CD     NFLUT          OPTION FOR TOTAL FLUENCE                            -
CD                     0 - NOT PRESENT                                    -
CD                     1 - PRESENT                                        -
CD     NFLU1          OPTION FOR FLUENCE IN FIRST RANGE                   -
CD                     0 - NOT PRESENT                                    -
CD                     1 - PRESENT                                        -
C                                                                         -
CN                    WHEN NFLU1 = 1, EFLU1 MUST BE GREATER THAN 0 AND    -
CN                     LIE IN THE ENERGY RANGE SPECIFIED IN THE           -
CN                     CROSS SECTION DATA                                 -
C                                                                         -
CD     NFLU2          OPTION FOR FLUENCE IN SECOND RANGE                  -
CD                     0 - NOT PRESENT                                    -
CD                     1 - PRESENT                                        -
C                                                                         -
CN                    WHEN NFLU2 = 1, EFLU2 MUST BE GREATER THAN 0 AND    -
CN                     LIE IN THE ENERGY RANGE SPECIFIED IN THE           -
CN                     CROSS SECTION DATA                                 -
C                                                                         -
CD     IXPH12         RESERVED                                            -
CD     IXPH13         RESERVED                                            -
CD     NRR1           OPTION FOR FISSIONS                                 -
CD                     0 - NOT PRESENT                                    -
CD                     1 - PRESENT                                        -
CD     NRR2           OPTION FOR EXPOSURE                                 -
CD                     0 - NOT PRESENT                                    -
CD                     1 - PRESENT                                        -
CD     NRR3           OPTION FOR ENERGY                                   -
CD                     0 - NOT PRESENT                                    -
CD                     1 - PRESENT                                        -
CD     NRR4           OPTION FOR UNDEFINED                                -
CD                     0 - NOT PRESENT                                    -
CD                     1 - PRESENT                                        -
CD     IXPH18         RESERVED                                            -
CD     IXPH19         RESERVED                                            -
CD     IXPH20         INDICATOR NORMALLY = 0, BUT IS SET = 1 IF           -
CD                     A DISCONTINUITY EXISTS IN EXPOSURE TIMES           -
C                                                                         -
C-------------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     2D     GENERAL INFORMATION                                      -
C                                                                       -
CL     (EPHT(I),I=1,40)                                                 -
C                                                                       -
CW           40                                                         -
C                                                                       -
CD     EPHT(1)          END OF EXPOSURE TIME (DAYS)                     -
CD     EPHT(2)          START OF EXPOSURE TIME (DAYS)                   -
CD     EPHT(3-10)       RESERVED                                        -
CD     EPHT(11)         CURRENT TOTAL SYSTEM FISSIONS                   -
CD                       (FISSIONS)                                     -
C                                                                       -
CN                      DEFINED WHEN NRR1 = 1                           -
C                                                                       -
CD     EPHT(12)         CURRENT TOTAL SYSTEM EXPOSURE                   -
CD                       (MEGAWATT(THERMAL)-DAYS/KG)                    -
C                                                                       -
CN                      DEFINED WHEN NRR2 = 1                           -
C                                                                       -
CD     EPHT(13)         CURRENT TOTAL SYSTEM ENERGY                     -
CD                       (MEGAWATT(THERMAL)-DAYS)                       -
C                                                                       -
CN                      DEFINED WHEN NRR3 = 1                           -
C                                                                       -
CD     EPHT(14)         CURRENT TOTAL SYSTEM UNDEFINED                  -
C                                                                       -
CN                      DEFINED WHEN NRR4 = 1                           -
C                                                                       -
CD     EPHT(15-20)      RESERVED                                        -
CD     EPHT(21)         CUMULATIVE TOTAL SYSTEM FISSIONS                -
CD                       (FISSIONS)                                     -
C                                                                       -
CN                      DEFINED WHEN NRR1 = 1                           -
C                                                                       -
CD     EPHT(22)         CUMULATIVE TOTAL SYSTEM EXPOSURE                -
CD                       (MEGAWATT(THERMAL)-DAYS/KG)                    -
C                                                                       -
CN                      DEFINED WHEN NRR2 = 1                           -
C                                                                       -
CD     EPHT(23)         CUMULATIVE TOTAL SYSTEM ENERGY                  -
CD                       (MEGAWATT(THERMAL)-DAYS)                       -
C                                                                       -
CN                      DEFINED WHEN NRR3 = 1                           -
C                                                                       -
CD     EPHT(24)         CUMULATIVE TOTAL SYSTEM UNDEFINED               -
C                                                                       -
CN                      DEFINED WHEN NRR4 = 1                           -
C                                                                       -
CD     EPHT(25-40)      RESERVED                                        -
C                                                                       -
C-----------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     3D     TOTAL FLUENCE                                            -
C                                                                      -
CC            PRESENT IF NFLUT = 1                                     -
C                                                                      -
CL     (FLUT(M),M=1,IZONE)                                             -
C                                                                      -
CW            IZONE                                                    -
C                                                                      -
CD     FLUT            CUMULATIVE TOTAL FLUENCE BY ZONE                -
CD                      (NEUTRONS/CM**2)                               -
C                                                                      -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR     4D     FLUENCE TO FIRST CUTOFF ENERGY EFLU1                     -
C                                                                      -
CC            PRESENT IF NFLU1 = 1                                     -
C                                                                      -
CL     (FLU1(M),M=1,IZONE)                                             -
C                                                                      -
CW            IZONE                                                    -
C                                                                      -
CD     FLU1            CUMULATIVE FLUENCE IN FIRST RANGE BY ZONE       -
CD                      (NEUTRONS/CM**2)                               -
C                                                                      -
C-----------------------------------------------------------------------
```

```
C-----------------------------------------------------------------------
CR     5D     FLUENCE TO SECOND CUTOFF ENERGY EFLU2                    -
C                                                                      -
CC            PRESENT IF NFLU2 = 1                                     -
C                                                                      -
CL     (FLU2(M),M=1,IZONE)                                             -
C                                                                      -
CW            IZONE                                                    -
C                                                                      -
CD     FLU2            CUMULATIVE FLUENCE IN SECOND RANGE BY ZONE      -
CD                      (NEUTRONS/CM**2)                               -
C                                                                      -
C-----------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     6D     RESERVED                                                  -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     7D     RESERVED                                                  -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     8D     FISSIONS                                                  -
C                                                                       -
CC            PRESENT IF NRR1 = 1                                       -
C                                                                       -
CL     (RR1(MM),MM=1,ITZSZ)                                             -
C                                                                       -
CW            ITZSZ = IZONE + ISZ                                       -
C                                                                       -
CD     RR1            CUMULATIVE FISSIONS BY ZONE AND SUBZONE          -
CD                     (FISSIONS/CM**3)                                 -
C                                                                       -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     9D     EXPOSURE                                                  -
C                                                                       -
CC            PRESENT IF NRR2 = 1                                       -
C                                                                       -
CL     (RR2(MM),MM=1,ITZSZ)                                             -
C                                                                       -
CW            ITZSZ = IZONE + ISZ                                       -
C                                                                       -
CD     RR2            CUMULATIVE EXPOSURE BY ZONE AND SUBZONE          -
CD                     (MEGAWATT(THERMAL)-DAYS/KG)                      -
C                                                                       -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     10D    ENERGY                                                    -
C                                                                       -
CC            PRESENT IF NRR3 = 1                                       -
C                                                                       -
CL     (RR3(MM),MM=1,ITZSZ)                                             -
C                                                                       -
CW            ITZSZ = IZONE + ISZ                                       -
C                                                                       -
CD     RR3            CUMULATIVE ENERGY BY ZONE AND SUBZONE            -
CD                     (MEGAWATT(THERMAL)-DAYS/CM**3)                   -
C                                                                       -
C-----------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     11D   UNDEFINED                                                 -
C                                                                      -
CC           PRESENT IF NRR4 = 1                                       -
C                                                                      -
CL     (RR4(MM),MM=1,ITZSZ)                                            -
C                                                                      -
CW           ITZSZ = IZONE + ISZ                                       -
C                                                                      -
CD     RR4            UNDEFINED                                       -
C                                                                      -
C-----------------------------------------------------------------------

C***********************************************************************-
C                                                                      -
CEOF         EXPOHT                                                    -
C                                                                      -
C***********************************************************************-
```

(CONT)

SPECIFICATIONS FOR INTERFACE FILE PTATDN

```
C*********************************************************************-
C                                                                     -
CF          PTATDN                                                    -
C                                                                     -
CE          POINT NUCLIDE DENSITIES                                   -
C                                                                     -
C*********************************************************************-

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


C---------------------------------------------------------------------
CR    1D    FILE REFERENCE INFORMATION                                -
C                                                                     -
CL    TIME,XPTD2,XPTD3,NCY,NZPT,NPT,NNS,NBLKPT,IPTD9,IPTD10,          -
CL    NZONE,NSZ,NINTI,NINTJ,NINTK,IPTD16,IPTD17,IPTD18,IPTD19,IPTD20  -
C                                                                     -
CW          20                                                        -
C                                                                     -
CD    TIME           REFERENCE REAL TIME, DAYS                        -
CD    XPTD2          RESERVED                                         -
CD    XPTD3          RESERVED                                         -
CD    NCY            REFERENCE CYCLE NUMBER                           -
CD    NZPT           NUMBER OF ZONES FOR WHICH POINT DATA IS PRESENT  -
CD    NPT            NUMBER OF POINTS                                 -
C                                                                     -
CN                   NPT = NZPNT(1) + NZPNT(2) + ... + NZPNT(NZPT)    -
C                                                                     -
CD    NNS            MAXIMUM NUMBER OF NUCLIDES IN ANY SET            -
CD    NBLKPT         NUMBER OF BLOCKS OF ATOM DENSITY DATA            -
CD                   (MUST DIVIDE EVENLY INTO NPT)                    -
CD    IPTD9          RESERVED                                         -
CD    IPTD10         OPTION TO INCLUDE VOLUME INFORMATION IF .EQ. 1   -
CD    NZONE          NUMBER OF ZONES                                  -
CD                   FOR DOCUMENTATION (IF NONZERO MUST AGREE WITH OTHER -
CD                   PARAMETERS)                                      -
CD    NSZ            NUMBER OF SUBZONES                               -
CD                   FOR DOCUMENTATION (IF NONZERO MUST AGREE WITH OTHER -
CD                   PARAMETERS)                                      -
CD    NINTI          NUMBER OF FIRST DIMENSION FINE MESH INTERVALS    -
CD                   FOR DOCUMENTATION (IF NONZERO MUST AGREE WITH OTHER -
CD                   PARAMETERS)                                      -
```

(CONT)

```
CD     NINTJ          NUMBER OF SECOND DIMENSION FINE MESH INTERVALS      -
CD                    FOR DOCUMENTATION (IF NONZERO MUST AGREE WITH OTHER -
CD                    PARAMETERS)                                         -
CD     NINTK          NUMBER OF THIRD DIMENSION FINE MESH INTERVALS       -
CD                    FOR DOCUMENTATION (IF NONZERO MUST AGREE WITH OTHER -
CD                    PARAMETERS)                                         -
CD     IPTD16         RESERVED                                            -
CD     IPTD17         RESERVED                                            -
CD     IPTD18         RESERVED                                            -
CD     IPTD19         RESERVED                                            -
CD     IPTD20         RESERVED                                            -
C                                                                         -
C-------------------------------------------------------------------------


C-------------------------------------------------------------------------
CR     2D     GENERAL INFORMATION                                         -
C                                                                         -
CL     (MZPNT(NZ),NZ=1,NZPT),(NZPNT(NZ),NZ=1,NZPT),                       -
CL     (LZPNT(NZ),NZ=1,NZPT),(LOCPT(NP),NP=1,NPT)                         -
C                                                                         -
CW           3*NZPT+NPT                                                   -
C                                                                         -
CD     MZPNT(NZ)      ZONE NUMBERS                                        -
CD     NZPNT(NZ)      NUMBER OF POINTS IN EACH ZONE                       -
CD     LZPNT(NZ)      NUCLIDE SET REFERENCE                               -
CD                    FOR DOCUMENTATION                                   -
CD     LOCPT(NP)      POINT LOCATIONS IN THE RANGE 1 TO NINTI*NINTJ*NINTK -
CD                    FOR DOCUMENTATION                                   -
CD                    (MAY BE ZERO IF NINTI,NINTJ AND NINTK ARE ZERO)     -
C                                                                         -
CN                    LOCPT = (K-1)*NINTI*NINTJ + (J-1)*NINTI + I         -
CN                    WHERE I IS FIRST DIMENSION INDEX                    -
CN                          J IS SECOND DIMENSION INDEX                   -
CN                          K IS THIRD DIMENSION INDEX                    -
C                                                                         -
CN                    GIVEN NINTI,NINTJ,NINTK AND LOCPT THE INDICES       -
CN                    I,J,K MAY BE DETERMINED                             -
C                                                                         -
C-------------------------------------------------------------------------


C-------------------------------------------------------------------------
CR     3D     VOLUME INFORMATION                                          -
C                                                                         -
CC           PRESENT IF IPTD10 .EQ. 1                                     -
C                                                                         -
CL     (VZPNT(NZ),NZ=1,NZPT),(VOLPT(NP),NP=1,NPT)                         -
C                                                                         -
CW           NZPT+NPT                                                     -
C                                                                         -
CD     VZPNT(NZ)      ZONE VOLUME (CM**3)                                 -
CD     VOLPT(NP)      POINT VOLUME (CM**3)                                -
C                                                                         -
C-------------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     4D     POINT NUCLIDE DENSITIES                                   -
C                                                                       -
CL     ((PDEN(N,J),N=1,NNS),J=JL,JU)----SEE STRUCTURE BELOW----         -
C                                                                       -
CW            NNS*((NPT-1)/NBLKPT+1)                                    -
C                                                                       -
CC     DO 1 M=1,NBLKPT                                                  -
CC   1 READ(I) *LIST AS ABOVE*                                          -
C                                                                       -
CC         WITH M AS THE BLOCK INDEX, JL=(M-1)*((NPT-1)/NBLKPT+1)+1     -
CC         AND JU=M*((NPT-1)/NBLKPT+1)                                  -
C                                                                       -
CD     PDEN(N,J)      ATOMIC DENSITY OF NUCLIDE ORDERED N IN THE        -
CD                    ASSOCIATED SET GIVEN IN ORDER FOR EACH POINT      -
C                                                                       -
C-----------------------------------------------------------------------

C***********************************************************************-
C                                                                       -
CEOF          PTATDN                                                    -
C                                                                       -
C***********************************************************************-
```

(CONT)

SPECIFICATIONS FOR INTERFACE FILE QNATDN

```
C*********************************************************************-
C                                                                     -
CF          QNATDN                                                    -
C                                                                     -
CE          ZONE(SUBZONE) NUCLIDE DENSITIES (DISCHARGE)               -
C                                                                     -
C*********************************************************************-

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


C---------------------------------------------------------------------
CR    1D    FILE REFERENCE INFORMATION                                -
C                                                                     -
CL    TIME,NCY,NTZSZ,NNS,NBLKAD                                       -
C                                                                     -
CW          5                                                         -
C                                                                     -
CD    TIME           REFERENCE REAL TIME, DAYS                        -
CD    NCY            REFERENCE CYCLE NUMBER                           -
CD    NTZSZ          NUMBER OF ZONES PLUS NUMBER OF SUBZONES          -
CD    NNS            MAXIMUM NUMBER OF NUCLIDES IN ANY SET            -
CD    NBLKAD         NUMBER OF BLOCKS OF ATOM DENSITY DATA            -
CD                   (MUST DIVIDE EVENLY INTO NTZSZ)                  -
C                                                                     -
C---------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CP     2D     ZONE(SUBZONE) NUCLIDE DENSITIES (DISCHARGE)                -
C                                                                        -
CL     ((ADEN(N,J),N=1,NNS),J=JL,JU) ----SEE STRUCTURE BELOW----         -
C                                                                        -
CW            NNS*((NTZSZ-1)/NBLKAD+1)                                   -
C                                                                        -
CC     DO 1 M=1,NBLKAD                                                   -
CC   1 READ(I) *LIST AS ABOVE*                                           -
C                                                                        -
CC         WITH M AS THE BLOCK INDEX, JL=(M-1)*((NTZSZ-1)/NBLKAD+1)+1    -
CC         AND JU=M*((NTZSZ-1)/NBLKAD+1)                                 -
C                                                                        -
CD     ADEN(N,J)      ATOMIC DENSITY OF NUCLIDE ORDERED N IN THE         -
CD                    ASSOCIATED SET GIVEN IN ORDER FOR EACH ZONE        -
CD                    FOLLOWED IN ORDER FOR EACH SUBZONE                 -
C                                                                        -
C-----------------------------------------------------------------------

C***********************************************************************-
C                                                                        -
CEOF          QNATDN                                                     -
C                                                                        -
C***********************************************************************-
```

(CONT)

SPECIFICATIONS FOR INTERFACE FILE RZFLUX

```
C*********************************************************************
C                                                                    -
CF          RZFLUX                                                   -
C                                                                    -
CE          REGULAR ZONE FLUX BY GROUP, AVERAGED OVER EACH ZONE      -
C                                                                    -
CN          AN ASTERISK IN COLUMN 72 INDICATES LOCAL MODIFICATION    -
C                                                                    -
C*********************************************************************

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


C--------------------------------------------------------------------
CR    1D    FILE REFERENCE INFORMATION                               -
C                                                                    -
CL    TIME,POWER,VOL,EFFK,EIVS,DKDS,TNL,TNA,TNSL,TNBL,TNBAL,TNCRA,   -
CL    CF,CE,CR,CC,ITPS,NZONE,NGROUP,NPV                              -
C                                                                    -
CW          20                                                       -
C                                                                    -
CD    TIME           REFERENCE REAL TIME, DAYS                       -
CD    POWER          POWER LEVEL FOR ACTUAL NEUTRONICS PROBLEM, WATTS -
CD                       THERMAL                                     -
CD    VOL            VOLUME OVER WHICH POWER WAS DETERMINED, CC      -
CD    EFFK           MULTIPLICATION FACTOR                           -
CD    EIVS           EIGENVALUE OF SEARCH OF SEARCH PROBLEM          -
CD    DKDS           DERIVATIVE OF SEARCH PROBLEM                    -
CD    TNL            TOTAL NEUTRON LOSSES                            -
CD    TNA            TOTAL NEUTRON ABSORPTIONS                       -
CD    TNSL           TOTAL NEUTRON SURFACE LEAKAGE                   -
CD    TNBL           TOTAL NEUTRON BUCKLING LOSS                     -
CD    TNBAL          TOTAL NEUTRON BLACK ABSORBER LOSS               -
CD    TNCRA          TOTAL NEUTRON CONTROL ROD ABSORPTIONS           -
```

(CONT)

```
CD     CF            FRACTION OF CORE TREATED IN PROBLEM                 *-
CD     CE            CONVERSION FACTOR, RATIO OF THERMAL ENERGY TO       *-
CD                   FISSION + CAPTURE ENERGY AVAILABLE WITH             *-
CD                   THE CROSS SECTIONS                                  *-
CD     CR            ADDITIONAL DATA FLAG IF .GT.0 (TWO RECORDS)         *-
CD     CC            RESERVED                                             -
CD     ITPS          ITERATIVE PROCESS STATE                              -
CD                       =0, NO ITERATIONS DONE                           -
CD                       =1, CONVERGENCE SATISFIED                        -
CD                       =2, NOT CONVERGED, BUT CONVERGING                -
CD                       =3, NOT CONVERGED, NOT CONVERGING                -
CD     NZONE         NUMBER OF GEOMETRIC ZONES                            -
CD     NGROUP        NUMBER OF NEUTRON ENERGY GROUPS                      -
CD     NPV           NUMBER OF BLOCKS OF LOCAL, FINE-SCALE FLUX VALUES   *-
C                                                                         -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR     2D     FLUX VALUES                                                 -
C                                                                         -
CL     ((ZGF(K,M),K=1,NGROUP),M=1,NZONE)                                  -
C                                                                         -
CW            NGROUP*NZONE                                                -
C                                                                         -
CD     ZGF           REGULAR ZONE FLUX BY GROUP, AVERAGED OVER ZONE      -
CD                   NEUTRONS/SEC-CM**2                                  -
C                                                                         -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR     3D     ADDITIONAL DATA, FIRST OF TWO RECORDS                      *-
C                                                                        *-
CC            PRESENT IF CR .GT.0                                        *-
C                                                                        *-
CL     (SHARE8(I),I=1,100),(SHARE(I),I=1,100),(LX(I),I=1,200)            *-
C                                                                        *-
CW            100*MULT + 300                                             *-
C                                                                        *-
CD     SHARE8        NEUTRONICS DATA FOR REFERENCE                       *-
C                      DOUBLE PRECISION ON A SHORT WORD MACHINE          *-
CD     SHARE         NEUTRONICS DATA FOR REFERENCE                       *-
CD     LX            NEUTRONICS FLAGS FOR REFERENCE                      *-
C                                                                        *-
C-----------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     4D     ADDITIONAL DATA, SECOND OF TWO RECORDS                    *-
C                                                                       *-
CC            PRESENT IF CR .GT.0                                       *-
C                                                                       *-
CL     (INRS(I),I=1,NGROUP),(RHO(I),I=1,NGROUP),(BATA(I),I=1,NGROUP)    *-
C                                                                       *-
CW            3*NGROUP                                                  *-
C                                                                       *-
CD     INRS           NEUTRONICS ITERATION FLAGS                       *-
CD     RHO            NEUTRONICS ITERATION DATA                        *-
CD     BATA           NEUTRONICS ITERATION DATA                        *-
C                                                                       *-
CN            NOTE NONSTANDARD DATA TYPE ORDER                          *-
C                                                                       *-
C-----------------------------------------------------------------------
                                                                        *
      THERE ARE NPV SETS OF THE FOLLOWING TWO RECORDS                   *
                                                                        *
C-----------------------------------------------------------------------
CR     5D     LOCAL FLUX RECORD REFERENCE DATA                          *-
C                                                                       *-
CL     (XFV(I),I=1,10),NLP,NRZ,(IFV(J),J=1,8)                           *-
C                                                                       *-
CW            20                                                        *-
C                                                                       *-
CD     XFV(1)         REFERENCE VOLUME, CC                             *-
CD     XFV(2)         REFERENCE POWER LEVEL, WATTS                     *-
CD     NLP            NUMBER OF LOCATIONS FOR WHICH DATA IS GIVEN      *-
CD     NRZ            REFERENCE ZONE NUMBER                            *-
C                                                                       *-
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR     6D     LOCAL NEUTRON FLUX VALUES                                 *-
C                                                                       *-
CL     ((FLF(K,M),K=1,NGROUP),M=1,NLP)                                  *-
C                                                                       *-
CW            NGROUP*NLP                                                *-
C                                                                       *-
CD     FLF            LOCAL VALUE OF THE NEUTRON TOTAL FLUX,           *-
CD                     AS ASSOCIATED WITH A SUB-VOLUME WITHIN THE       *-
CD                     REFERENCE ZONE NRZ                               *-
C                                                                       *-
C-----------------------------------------------------------------------

C***********************************************************************-
C                                                                       -
CEOF          RZFLUX                                                    -
C                                                                       -
C***********************************************************************-
```

(CONT)

SPECIFICATIONS FOR INTERFACE FILE ZNTEMP

```
C*********************************************************************-
C                                                                     -
CN          ORIGINAL SPECS REVISED TO INCLUDE SUBZONE DATA WHEN NEEDED -
C                                                                     -
CF          ZNTEMP                                                    -
C                                                                     -
CE          ZONE TEMPERATURE DATA                                     -
C                                                                     -
C*********************************************************************-

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


C---------------------------------------------------------------------
CR          FILE REFERENCE INFORMATION                                -
C                                                                     -
CL    NRZ,NZT,NSZ,(NA(I),I=1,17)                                      -
C                                                                     -
CW          20                                                        -
C                                                                     -
CD    NRZ            NUMBER OF REACTOR ZONES , NOT ZERO               -
CD    NZT            NUMBER OF TEMPERATURES FOR EACH ZONE  .LE. 5     -
CD    NSZ            NUMBER OF REACTOR SUBZONES                       -
CD    NA             RESERVED                                         -
C                                                                     -
CN        OFTEN A SINGLE TEMPERATURE WILL BE CARRIED WHICH SERVES AS A -
CN        REFERENCE, AS TO EXPRESS THE EFFECTIVE TEMPERATURE OF THE ZONE-
CN        WHICH MAY BE USED SIMPLY FOR SUCH PURPOSE AS CROSS SECTION  -
CN        CORRELATION.  EVEN IF TWO TEMPERATURES ARE CARRIED TO INCLUDE -
CN        THE COOLANT TEMPERATURE, THE FIRST IS INTENDED TO ADMIT SUCH -
CN        SIMPLE APPLICATION  (LINEAR INTERPOLATION OF CROSS SECTIONS  -
CN        IS ADMITTED WHICH MAY BE DONE AT THE MACROSCOPIC LEVEL USING -
CN        TWO MICROSCOPIC CROSS SECTION SETS).                         -
C                                                                     -
C                                                                     -
C---------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR          ZONE TEMPERATURES                                          -
C                                                                      -
CC          ALWAYS PRESENT                                             -
C                                                                      -
CL     ((ZTEMP(I,M),I=1,NZT),M=1,NRZ)                                  -
C                                                                      -
CW          NZT*NRZ                                                    -
C                                                                      -
CD     ZTEMP          TEMPERATURE OF REFERENCE I IN ZONE M (DEGREES C) -
CD                            I     REFERENCE                          -
CD                            -     ---------                          -
CD                            1     ACTINIDES (FUEL) --- REFERENCE     -
CD                            2     COOLANT                            -
CD                            3     MODERATOR                          -
CD                            4     STRUCTURAL                         -
CD                            5     SPECIAL                            -
C                                                                      -
C-----------------------------------------------------------------------


C-----------------------------------------------------------------------
CR          SUBZONE TEMPERATURES                                       -
C                                                                      -
CC          PRESENT IF NSZ .NE. 0                                      -
C                                                                      -
CL     ((SZTEMP(I,M),I=1,NZT),M=1,NSZ)                                 -
C                                                                      -
CW          NZT*NSZ                                                    -
C                                                                      -
CD     SZTEMP         TEMPERATURE OF REFERENCE I IN SUBZONE M (DEGREES C) -
C                                                                      -
CN                    SEE NOTES ABOUT ZONE TEMPERATURE DATA            -
C                                                                      -
C-----------------------------------------------------------------------

C***********************************************************************-
C                                                                      -
CEOF        ZNTEMP                                                     -
C                                                                      -
C***********************************************************************-
```

(CONT)

SPECIFICATIONS FOR INTERFACE FILE ZNPOWD

```
C*********************************************************************-
C                                                                     -
CN          ORIGINAL SPECS REVISED TO INCLUDE SUBZONE DATA WHEN NEEDED -
C                                                                     -
CF          ZNPOWD                                                    -
C                                                                     -
CE          ZONE AVERAGE AND PEAK POWER DENSITY                       -
C                                                                     -
C*********************************************************************-

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


C---------------------------------------------------------------------
CR    1D    FILE REFERENCE INFORMATION                                -
C                                                                     -
CL    POW,TIME,XZPD3,XZPD4,XZPD5,XZPD6,XZPD7,XZPD8,                   -
CL    NZONE,IZPD10,IZPD11,NSZ,IZPD13,IZPD14,IZPD15,                   -
CL    IZPD16,IZPD17,IZPD18,IZPD19,IZPD20                              -
C                                                                     -
CW          20                                                        -
C                                                                     -
CD    POW            REFERENCE REACTOR POWER LEVEL, WATTS             -
CD    TIME           REFERENCE TIME IN THE HISTORY, DAYS              -
CD    XZPD3          RESERVED                                         -
CD    XZPD4          RESERVED                                         -
CD    XZPD5          RESERVED                                         -
CD    XZPD6          RESERVED                                         -
CD    XZPD7          RESERVED                                         -
CD    XZPD8          RESERVED                                         -
CD    NZONE          NUMBER OF REACTOR ZONES                          -
CD    IZPD10         OPTION FOR PEAK ZONE DATA                        -
CD    IZPD11         OPTION ON FILE CONTENTS                          -
CD                   0- ZONE POWER DENSITY INCLUDES ANY SUBZONE       -
CD                      CONTRIBUTION (ALTHOUGH NSZ MAY BE ZERO)       -
CD                   1- ZONE POWER DENSITY AND SUBZONE POWER DENSITY  -
CD                      CARRIED SEPARATELY                            -
CD    NSZ            NUMBER OF REACTOR SUBZONES                       -
CD    IZPD13         OPTION FOR REFERENCE INFORMATION                 -
```

(CONT)

```
CD     IZPD14          RESERVED                                          -
CD     IZPD15          RESERVED                                          -
CD     IZPD16          RESERVED                                          -
CD     IZPD17          RESERVED                                          -
CD     IZPD18          RESERVED                                          -
CD     IZPD19          RESERVED                                          -
CD     IZPD20          RESERVED                                          -
C                                                                        -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     2D     ZONE AVERAGE POWER DENSITIES (TOTAL)                      -
C                                                                        -
CC            PRESENT IF IZPD11 .EQ. 0                                  -
C                                                                        -
CL     (ZPOW(M),M=1,NZONE)                                               -
C                                                                        -
CW            NZONE                                                     -
C                                                                        -
CD     ZPOW            ZONE AVERAGE POWER DENSITY, WATTS/CC              -
C                                                                        -
CN            ZPOW(M) = VFPA(M)*ZPD(M) + SUM(OVER J FOR NZSZ(J) = M) OF  -
CN                      VRSZ(J)*SZPD(J)                                  -
C                                                                        -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     3D     PEAK ZONE POWER DENSITIES                                 -
C                                                                        -
CC            PRESENT IF IZPD11 .EQ. 0 AND IZPD10 .EQ. 1                -
C                                                                        -
CL     (PZPOW(M),M=1,NZONE)                                              -
C                                                                        -
CW            NZONE                                                     -
C                                                                        -
CD     PZPOW           PEAK ZONE POWER DENSITY AT THE MESH POINT LEVEL,  -
CD                     WATTS/CC                                          -
C                                                                        -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     4D     ZONE AVERAGE POWER DENSITIES                              -
C                                                                        -
CC            PRESENT IF IZPD11 .EQ. 1                                  -
C                                                                        -
CL     (ZPD(M),M=1,NZONE)                                                -
C                                                                        -
CW            NZONE                                                     -
C                                                                        -
CD     ZPD             ZONE AVERAGE POWER DENSITY, WATTS/CC              -
C                                                                        -
C-----------------------------------------------------------------------
```

(CONT)

```
C-----------------------------------------------------------------------
CR     5D     SUBZONE AVERAGE POWER DENSITIES                          -
C                                                                      -
CC            PRESENT IF IZPD11 .EQ. 1 AND NSZ .GT. 0                  -
C                                                                      -
CL     (SZPD(J),J=1,NSZ)                                               -
C                                                                      -
CW            NSZ                                                      -
C                                                                      -
CD     SZPD            SUBZONE AVERAGE POWER DENSITY, WATTS/CC        -
C                                                                      -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     6D     SUBZONE TO ZONE CORRESPONDENCE                           -
C                                                                      -
CC            PRESENT IF IZPD13 .EQ. 1 AND NSZ .GT. 0                  -
C                                                                      -
CL     (NZSZ(J),J=1,NSZ)                                               -
C                                                                      -
CW            NSZ                                                      -
C                                                                      -
CD     NZSZ            ZONE CONTAINING SUBZONE                        -
C                                                                      -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     7D     ZONE VOLUME INFORMATION                                  -
C                                                                      -
CC            PRESENT IF IZPD13 .EQ. 1                                 -
C                                                                      -
CL     (VOLZ(M),M=1,NZONE)                                             -
C                                                                      -
CW            NZONE                                                    -
C                                                                      -
CD     VOLZ            ZONE VOLUMES, CC                               -
C                                                                      -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
CR     8D     VOLUME FRACTION INFORMATION                              -
C                                                                      -
CC            PRESENT IF IZPD13 .EQ. 1                                 -
C                                                                      -
CL     (VFPA(M),M=1,NZONE),(VRSZ(J),J=1,NSZ)                           -
C                                                                      -
CW            NZONE + NSZ                                              -
C                                                                      -
CD     VFPA            VOLUME FRACTIONS FOR PRIMARY ZONE ASSIGNMENTS  -
CD     VRSZ            VOLUME FRACTIONS FOR SUBZONE ASSIGNMENTS       -
C                                                                      -
C-----------------------------------------------------------------------
```

(CONT)

```
C*********************************************************************-
C                                                                     -
CEOF        ZNPOWD                                                    -
C                                                                     -
C*********************************************************************-
```

TABLE 04-1 END

Information About the Exposure Data

The data which must be supplied for the exposure calculation in file EXPOSE documented on page 04-17 is discussed here. The primary data required for reactor calculations are the decay constants, the yield of products from fission, and the chain coupling information. Data to produce auxiliary information includes the energy produced from the various reactions or decay.

The nuclides involved are identified and the order number in this list is then used for further identification. These nuclides include the actinides and the fission products and any others to be considered, such as control rod or burnable poison components. The nuclides for which the generation of products from fission are to be considered are also identified. The fission products are identified. The decay constants and the fission products are specified for the identified nuclides. Note that fission product yield values are fractions (atoms produced per fission); these often sum to 2.0 or near about, but may not under schemes of representing several nuclides as one or more lumped pseudo nuclides.

Data for the matrix exponential or average generation rate methods of solution describe individual parent-product couplings. The program automatically couples defined fission products with the defined nuclides which produce them through fission, so these relationships are not to be specified. All nuclides in the supplied list of those having exposure data will be depleted, so leave out any not to be changed. Only specified parent-product couplings will be treated, so all of these which are deemed significant must be specified. Thus it is usual to include $Np^{239}$

in the chain starting with $U^{238}$, but usually $U^{239}$ is ignored. (In the procedures, special action must often be taken to treat nuclides having large loss coefficients leading to some degree of approximation anyway.)

For an explicit chain representation, consider the example

$$\begin{array}{ccccc} U^{238} & \searrow & & & \\ & & Np^{239} & \rightarrow & Np^{240} \\ & & \downarrow & & \downarrow \\ & & Pu^{239} & \rightarrow & Pu^{240} \end{array}$$

Here $U^{239}$ has been omitted. If $Np^{239}$ were left out, the loss of $Pu^{239}$ generation due to capture in $Np^{239}$ would be ignored, which would cause an overestimate of the fissile $Pu^{239}$ generation. Since there are two routes to $Pu^{240}$, two chain specifications are required:

$U^{238}$ capture $Np^{239}$ decay $Pu^{239}$ capture $Pu^{240}$

$U^{238}$ capture $Np^{239}$ capture $Np^{240}$ decay (-) $Pu^{240}$

The dominant route to $Pu^{240}$ is shown first. The secondary route brings in $Np^{240}$ and a (-) is shown before the $Pu^{240}$, indicating that this is an additional contribution.

Additional contributions are described in the specifications by a negative product nuclide number. When this contribution to the nuclide concentration is calculated, it is added to that previously calculated. Further, no contributions down the chains are calculated from the initial concentrations of those nuclides having negative identification numbers; they should have been accounted for in some previous chain specification. This is not true if the first nuclide number in the chain is made negative. For those nuclides having negative numbers to the first positive one, no contributions to them are calculated; but contributions from them to the first positive number nuclide and all those beyond are

calculated. This allows treatment of the primary actinides in one way with short chains,

$$U^{238} \rightarrow Np^{239} \rightarrow Pu^{239} \rightarrow Pu^{240} \rightarrow Pu^{241} \rightarrow Pu^{242},$$

while a supplemental treatment could be used for the effects of down-chain contributions, avoiding long chains (useful for actinide recycle),

$$(-)Pu^{240} \rightarrow (-)Pu^{241} \rightarrow (-)Pu^{242} \rightarrow Am^{243} \rightarrow \text{etc.}$$

It should be noted that when explicit chains are treated, the average between start and end of step fissioning nuclide concentrations is used to calculate yield rates. This reduces the amount of calculation required compared with that for full chain representations, and is a reasonable approximation for fixed power generation. Still, the actinide chains should be specified before the fission product chains in order to account for the effect of change in fissioning nuclide concentrations as the chains are processed in the order presented.

The reader should refer to the second sample problem for a reasonable treatment of the actinides.

END OF SECTION

# SECTION 05: DATA HANDLING STRATEGY

A rather involved procedure has been implemented for processing the data. This procedure is described here in some detail to convey sufficient information to an interested reader for assessment; it is possible to make changes to incorporate extensions, but they may seriously impact the code and integrity will be assured only after careful verification testing. Reference may be made to the user flow diagram, Fig. 2.1, page 02-2, and to the documentation of scratch input/output data files, Table 03-3 on page 03-21.

The key data needed for allocating storage, defining the range of the calculation, and major option selections is obtained from the data files initially and stored in memory. The nuclide referencing data are obtained from the NDXSRF file and the exposure data from the file EXPOSE and are stored in memory. The zone average neutron flux values are obtained from the RZFLUX file and stored on a sequential scratch data file blocked over all zones, one group at a time. The principal microscopic cross sections are obtained from the GRUPXS file and restored in a sequential data file, one record for all data at one group.

When an interpolation is to be made between the data on two flux files, this is done by a subsequent access of the data in the second file and a new scratch data file is written.

The initial nuclide concentrations are obtained from the ZNATDN file and stored in memory and also placed on a sequential scratch data file blocked one record for each zone and each subzone for later recovery.

Specific reaction rates (cross section times flux, summed over groups) can be a large amount of data. These specific reaction rates

are placed in a direct access scratch data file for use during the primary calculation, blocked one zone and one subzone to a record. A separate direct access file is used to store the fission rates when the fission product yield data has an incident energy dependence. When space is adequate, the specific reaction rates are kept in memory.

The latest nuclide concentrations are always stored in memory for all zones and subzones.

The nuclide concentrations are determined for all zones after one exposure interval of the time. Specific reaction rates are adjusted by a running account of the factor which must be applied to the initial flux to approximate the fixed power level condition. Thus the reaction rate data must be reaccessed at each step when stored on a scratch file.

The shutdown calculation is done with data contained in memory. Auxiliary calculations of cumulative exposure information and the beta and gamma source are done with separate accesses of the necessary data. The auxiliary calculation of local exposure is done on the fine scale for the selected zones as a subsequent pass through the basic procedure using the flux level information produced by the primary calculation.

END OF SECTION

# SECTION 06: SAMPLE PROBLEMS

The first sample problem was originated at SRL by M. V. Gregory in a contribution to the ANS Mathematics and Computation Division benchmark problem effort.[a] Given an initial concentration of $U^{235}$ and $U^{238}$, 24 actinides and 9 fission products are considered for an exposure of 50 days to a fixed fast flux of $6.1 \times 10^{14}$ and a thermal flux of $2.5 \times 10^{14}$ $n/cm^2$-sec. The chain relationships are shown in Figure 06-1. Note that as described there are a number of couplings which cause feedback in the problem. Shown in Table 06-1 is a computer listing that includes the input data cards showing all data,[b] computation instructions, condensed results, and selected edits. The $(n,\gamma)$ capture routes to the excited state of the product nuclide have been mocked up as equivalent (n,t) reactions testing this provision in the code [alternatively these could have been equivalent fractional $(n,\gamma)$ capture]. The specifications for the explicit chain treatment include only the principle chain routes, excluding feedback mechanisms of $\alpha$ decay.

Primary results of benchmark quality are shown for the matrix exponential and the average generation rate methods of solution in Table 06-2. It may be noted that a considerable amount of calculation is required to produce benchmark quality solutions. Results for other schemes, including the explicit chain solution method, are shown in Table 06-3. With the explicit chain method, the generation rate of fission products is taken as the average between start and end step values, which is often quite good for usual reactor evaluations but

---

[a] "Argonne Code Center: Benchmark Problem Book," ANL-7416 Supplement 2 (June 1977).

[b] See ORNL-5158 for user instructions.

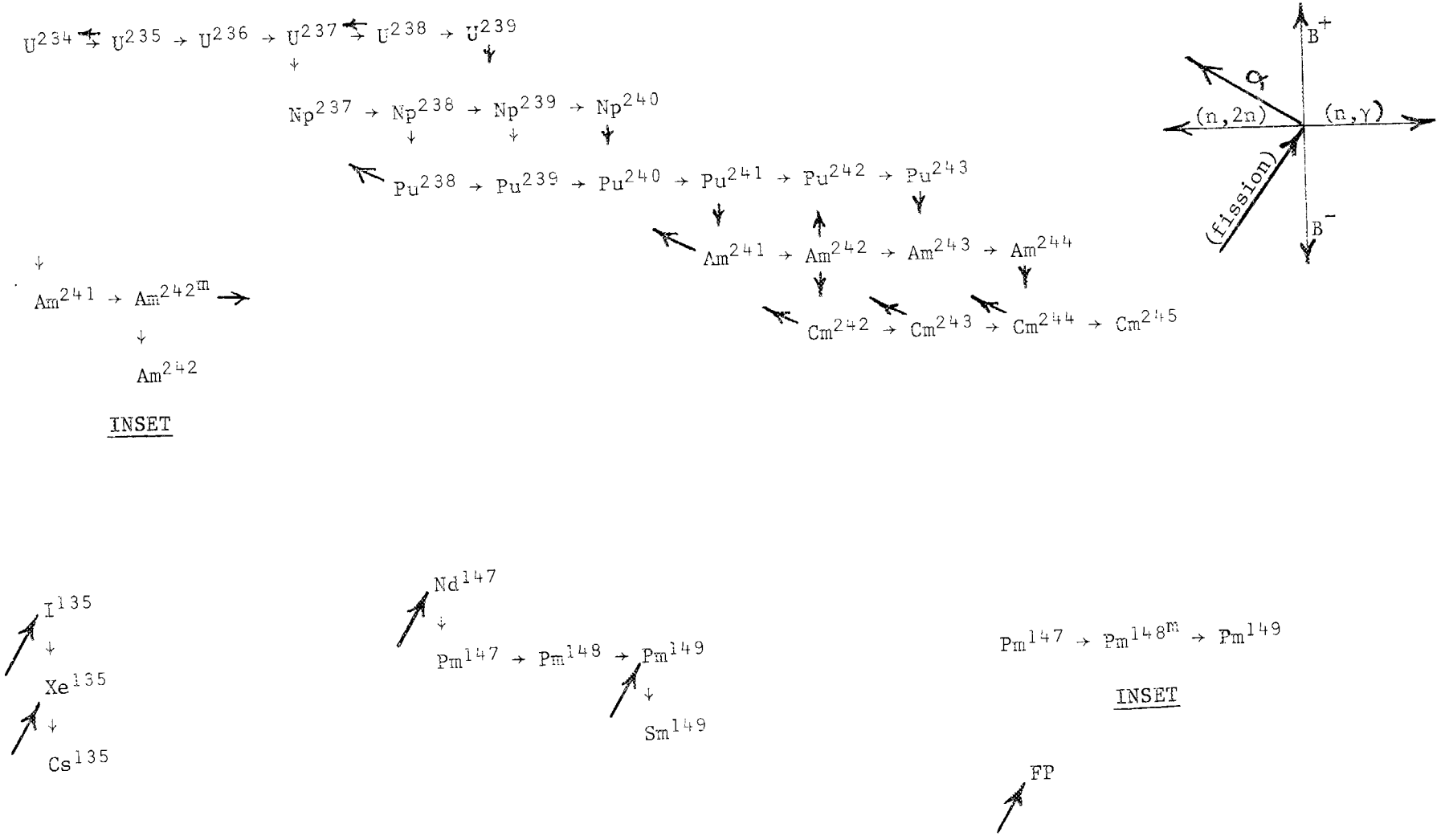



Figure 06-1. Nuclide chains for the First Sample Problem

Table 06-1. Selected Output for the Three Sample Problems

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

MODULE CONTROL1 WILL BE CALLED  TIME OF DAY  1.49.41  DATE 78.336

  DEPLETION BENCHMARK COMPARING VARIOUS SOLUTION METHODS                    CONTRLT
  10000                        0            0                   1           CONTRLM
   1 13   1 13   1 13   1 13   0                                            CONTRLP
 END                                                                        DRIVERE

 LASLIN                                                                     DRIVERS
 OV GRUPXS      THIS DATA CAN NOT BE USED FOR A FLUX CALCULATION
 1D  2 35 0 0 0 1 280 0 0 0 1 1 0 0
 2D /
 * TWO-GROUP DEPLETION PROBLEM (BENCHMARK FROM SRL)  (N,D) IS (N,G)M     *
 *U234  U235  U236  U237  U238  U239  NP237 NP238 NP239 NP240 PU238 *
 *PU239 PU240 PU241 PU242 PU243 AM241 AM242 AM242MAM243 AM244 CM242 *
 *CM243 CM244 CM245 I135  XE135 CS135 ND147 PM147 PM148 PM148MPM149 *
 *SM149 FPLL  *
   1.0 0.0   0.0 0.0   1.492+7 8.65244 0.0
 4D /
 *U234  U235  U236  U237  U238  U239  NP237 NP238 NP239 NP240 PU238 *
 *PU239 PU240 PU241 PU242 PU243 AM241 AM242 AM242MAM243 AM244 CM242 *
 *CM243 CM244 CM245 I135  XE135 CS135 ND147 PM147 PM148 PM148MPM149 *
 *SM149 FPLL  *
   (*SRL   *) 35R  (*SIGMAS*) 35R
   234.0 235.0 236.0 237.0 238.0 239.0 237.0 238.0 239.0 240.0 238.0
   239.0 240.0 241.0 242.0 243.0 241.0 242.0 242.0 243.0 244.0 242.0
   243.0 244.0 245.0 135.0 135.0 135.0 147.0 147.0 148.0 148.0 149.0
   149.0 100.0  / AMASS
   0.0 35R  0.0 35R  / EFISS,ECAPT
    0.0 35R    0.0 35R    0.0 35R  / XN,TEMP,SIGPOT
   0.0 35R  / ADENS
   3 1 3 3 2 3 3 3 3 3 3 1 2 1 3 3 3 3 3 3 3 3 3 3
   4 4 4 4 4 4 4 4 4 4  / K8R
    0 1          0 35R              / IDSCT,LORD,ICHI
    0 0 1 0 1 0 0
 5D 0.0 35R    0.0 35R  / GROUP 1
    33.575  5.9872  16.859  16.991  0.53258  0.40015  24.072  5.2648      SIGC1
    26.341  0.0  7.3125  9.8658  366.09  8.0305  51.820  11.030           SIGC1
   43.8844  2.3381  20.016  91.056  0.0  3.1202  9.9059  32.129           SIGC1
    4.8993  0.0  243.47  0.0  0.0  131.34  3368.4  2921.0                 SIGC1
    0.0  105.85  10.376                                                    SIGC1
    0.42744  12.370  0.16664  0.17139  0.081338  0.27283  0.41867         SIGF1
    47.412  0.0  0.0  1.5815  14.403  0.54033  29.986  0.43460            SIGF1
    28.382  1.1130  31.137  108.79  0.30784  26.192  0.0  92.299          SIGF1
    1.5663  37.165  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0      SIGF1
    0.0 35R    0.0 35R
    0.0  0.002603  0.0 2R  0.0043972  0.0  0.00020144  0.0 28R             SIGN2N1
    0.0 16R  6.7486   0.0 12R  117.44   0.0 5R                            SIGCM1
 5D 0.0 35R    0.0 35R  / GROUP 2
    26.368  26.420  1.4399  132.12  0.73141  6.1613  71.864  55.512       SIGC2
    16.654  0.0  119.91  196.77  96.479  152.24  5.1903  21.649           SIGC2
   353.137  0.0  444.09  24.980  0.0  4.7185  69.389  3.6915  82.972      SIGC2
    0.0  1064780.0  0.0  0.0  34.727  420.09  7561.6  0.0  23387.4         SIGC2
    19.429                                                                 SIGC2
    0.0  148.18  0.0  0.55512  0.0  4.2009  0.0094250  555.12  0.0         SIGF2
    0.0  3.5496  348.89  0.016744  352.73  0.0  49.960  2.3817  693.90    SIGF2
    1776.4  0.0  403.29  0.83267  194.29  0.33307  537.15  0.0  0.0       SIGF2
    0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0                               SIGF2
    0.0 35R    0.0 35R
    0.0 35R                                                               SIGN2N2
    0.0 16R  39.543   0.0 12R  31.087   0.0 5R                            SIGCM2
 7D  1 35R   1 35R  / GROUP 1
```

```
8D  0.0 35R
7D  1 35R   1 35R  / GROUP 2
8D  0.0 35R
0V GEODST
1D  1 10R 0 17R
2D  0.0  1.0  1
5D  1.0  1  1
6D  1
0V NDXSRF
1D  35 1 35 35 1 0
2D /
*U234  U235  U236  U237  U238  U239  NP237 NP238 NP239 NP240 PU238 *
*PU239 PU240 PU241 PU242 PU243 AM241 AM242 AM242MAM243 AM244 CM242 *
*CM243 CM244 CM245 I135  XE135 CS135 ND147 PM147 PM148 PM148MPM149 *
*SM149 FPLL  *
*U234  U235  U236  U237  U238  U239  NP237 NP238 NP239 NP240 PU238 *
*PU239 PU240 PU241 PU242 PU243 AM241 AM242 AM242MAM243 AM244 CM242 *
*CM243 CM244 CM245 I135  XE135 CS135 ND147 PM147 PM148 PM148MPM149 *
*SM149 FPLL  *
  0.0 35R  / WPF
  234.0 235.0 236.0 237.0 238.0 239.0 237.0 238.0 239.0 240.0 238.0
  239.0 240.0 241.0 242.0 243.0 241.0 242.0 242.0 243.0 244.0 242.0
  243.0 244.0 245.0 135.0 135.0 135.0 147.0 147.0 148.0 148.0 149.0
  149.0 100.0  / ATWT
  3 1 3 3 2 3 3 3 3 3 3 1 2 1 3 3 3 3 3 3 3 3 3 3 3
  4 4 4 4 4 4 4 4 4 4  / NCLN
   35 0 0 0  /  NDXS
   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
   26 27 28 29 30 31 32 33 34 35  / NOS
   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
   26 27 28 29 30 31 32 33 34 35  / NOR
3D  1.0 1.0 1  / VOLZ,VFPA,NSPA
0V ZNATDN
1D  0.0 0  1 35 1
2D  0.0  0.74003-4  0.0  0.0  0.69360-2  0.0 30R
0V RZFLUX
1D  0.0 1.0+6  1.0  1.0  0.0  0.0  1.0  1.0  0.0 4R
    1.0  1.0  0.0  0.0  0  1  2  0
2D  6.1374+14  2.5078+14
0V EXPOSE
1D  0 35 0 1 0 4 5 21 0 0 0  46   0 229  0 0 0 0 0 0
2D  /
* TWO-GROUP DEPLETION PROBLEM (BENCHMARK FROM SRL)  (N,T) IS (N,G) M    *
*U234  U235  U236  U237  U238  U239  NP237 NP238 NP239 NP240 PU238 *
*PU239 PU240 PU241 PU242 PU243 AM241 AM242 AM242MAM243 AM244 CM242 *
*CM243 CM244 CM245 I135  XE135 CS135 ND147 PM147 PM148 PM148MPM149 *
*SM149 FPLL  *
3D   0.0  /  YFR
     2 5 12 14  /  IFSLR
     26 27 33 29 35  /  IFPR
     26 27 29 30 31 32 33 4 6 8 9 10 14 16 18 21  /  IDCYR
     11 17 22 23 24  / IDCYR ADDED
4D   2.874-5  2.093-5  7.228-7  8.289-9  1.488-6  1.976-7
     3.626-6  1.190-6  4.915-4  3.820-6  3.410-6  1.583-3
     1.680-9  3.886-5  1.196-5  4.440-4  /  ALMDA
     2.550-10  5.090-11  4.910-8  6.860-10  1.250-9  /  ALMDA ADDED
5D   0.0617   0.0578   0.0693   0.0626   /  I135  YIELD
     0.0024   0.0022   0.0027   0.0024   /  XE135 YIELD
     0.0113   0.0210   0.0130   0.0120   /  PM149 YIELD
     0.0236   0.0280   0.0205   0.0220   /  ND149 YIELD
     0.9010   0.8910   0.8945   0.9010   /  FPLL  YIELD
6D  / FULL MATRIX DATA FOR FEEDBACK PROCESSES
     1 2 2   2 3 2   3 4 2   4 5 2   4 7 1   5 6 2   6 9 1
     7 8 2   8 9 2   8 11 1   9 10 2   9 12 1   10 13 1
     11 12 2   12 13 2   13 14 2   14 15 2   14 17 1   15 16 2
     16 20 1   17 18 2         17 19 7         18 20 2
```

```
     19 20 2   20 21 2   21 24 1   22 23 2   23 24 2   24 25 2
     2 1 5   5 4 5   / (N,2N)
     18 22 830271   18 15 169731   /  BETA-,BETA+
     11 1 1   17 7 1   22 11 1   23 12 1   24 13 1   /  ALPHA
     26 27 1   27 28 1   29 30 1   30 31 2         30 32 7
     31 33 2   32 33 2   33 34 1
 8D /  PRIMARY EXPLICIT CHAINS (15 CHAINS, 229 ENTRIES)
  5  2  6  1  9  1  12  2  13  2  14  2  15  2  16  1  20  2  21  1  24
  2  25  0
  5  2  6  1  9  2  10  1  -13  2  -14  2  -15  2  -16  1  -20  2  -21
  1  -24  2  -25  0
  5  2  6  1  9  1  12  2  13  2  14  1  17  2  18  830271  22  2  23
  2  -24  2  -25  0
  5  2  6  1  9  2  10  1 -13  2 -14  1 -17  2 -18  830271 -22  2 -23
  2  -24  2  -25  0
  2  2  3  2  4  1  7  2  8  2  -9  1  -12  2  -13  2  -14  0
  5  5  4  1  7  2  8  2  -9  1  -12  0
  2  2  3  2  4  1  7  2  8  1  11  2  -12  2  -13  2  -14  0
  2  2  3  2  4  1  7  2  8  1  11  1  1  0
  5  5  -4  1  -7  2  -8  1  -11  1 -1  0
  2  5  -1  2  -2  0
 -5  2 -6  1 -9  1 -12  2 -13  2 -14  1 -17  7  19  2 -20  2 -21  1 -24
  2 -25  0
 29   1   30   2   31   2   33   1   34   0
 29   1   30   7   32   2  -33   1  -34   0
  26   1   27   1   28   0   35   0   0
0V CONTRL
1D *PROINS*  /
* MATRIX EXPONENTIAL SOLUTION  (ASSUMING EQUILIBRIUM)                    *
* ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)                       *
*USER  * *IDENT *   0.0 74R  0 100R
1D *DVRINS*  0.0 100R  10000  0 99R
1D *EXPINS*    50.0  0.0 99R
  $1$ 0  $2$ 0  $3 DEBUG$ 1  $4$ 0  $5 METHOD$ 0  $6 SUBSTEPE$ 1
  $7 SUBSTEPS$ 0  $8$ 0  $9$ 0  $10$ 0  $11 AGRINC$  0    $12 POWER$ 0
  $13$ 0  $14$  1  $15$ 0  $16$ 0  $17$ 0  $18$ 0  $19$ 0  $20$ 0
  $21$ 1  $22-29$ 0  8R  $30$ 0  $31$ 0  $32$ 1  $33$ 1  $34$ 0  $35$ 1
  $36$ 0  $37$ 0  $38$ 0  $39$ 0  $40$ 0  $41$ 0  $42$ 0  $43$ 0
  $44$ 0  $45$ 0  $46-100$ 0 55R
1D *      *  0.0 100R  0 100R
   STOP
END                                                                    DRIVERE

LASLIN                                                                 DRIVERS
0V ZNATDN
1D  0.0 0  1 35 1
2D  0.0  0.74003-4  0.0  0.0  0.69360-2  0.0 30R
0V CONTRL
1D *PROINS*  /
* EXPLICIT CHAIN SOLUTION                                               *
* ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)                       *
*USER  * *IDENT *   0.0 74R  0 100R
1D *DVRINS*  0.0 100R  10000  0 99R
1D *EXPINS*    50.0  0.0 99R
  $1$ 0  $2$ 0  $3 DEBUG$ 1  $4$ 0  $5 METHOD$ 1  $6 SUBSTEPE$ 1
  $7 SUBSTEPS$ 0  $8$ 0  $9$ 0  $10$ 0  $11 AGRINC$  0    $12 POWER$ 0
  $13$ 0  $14$  1  $15$ 0  $16$ 0  $17$ 0  $18$ 0  $19$ 0  $20$ 0
  $21$ 1  $22-29$ 0  8R  $30$ 0  $31$ 0  $32$ 1  $33$ 1  $34$ 0  $35$ 1
  $36$ 0  $37$ 0  $38$ 0  $39$ 0  $40$ 0  $41$ 0  $42$ 0  $43$ 0
  $44$ 0  $45$ 0  $46-100$ 0 55R
1D *      *  0.0 100R  0 100R
   STOP
END                                                                    DRIVERE

LASLIN                                                                 DRIVERS
0V ZNATDN
```

```
1D  0.0 0  1 35 1
2D  0.0  0.74003-4  0.0  0.0  0.69360-2  0.0 30R
0V CONTRL
1D *PROINS*  /
* AVERAGE GENERATION RATE SOLUTION                                    *
* ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)                    *
*USER  * *IDENT *   0.0 74R  0 100R
1D *DVRINS*  0.0 100R  10000  0 99R
1D *EXPINS*    50.0  0.0 99R
  $1$ 0  $2$ 0  $3 DEBUG$ 1  $4$ 0  $5 METHOD$ 2  $6 SUBSTEPE$ 1
  $7 SUBSTEPS$ 0  $8$ 0  $9$ 0  $10$ 0  $11 AGRINC$  0    $12 POWER$ 0
  $13$ 0  $14$  1  $15$ 0  $16$ 0  $17$ 0  $18$ 0  $19$ 0  $20$ 0
  $21$ 1  $22-29$ 0  8R  $30$ 0  $31$ 0  $32$ 1  $33$ 1  $34$ 0  $35$ 1
  $36$ 0  $37$ 0  $38$ 0  $39$ 0  $40$ 0  $41$ 0  $42$ 0  $43$ 0
  $44$ 0  $45$ 0  $46-100$ 0 55R
1D *      *  0.0 100R  0 100R
   STOP
END                                                                   DRIVERE

LASLIN                                                                DRIVERS
0V ZNATDN
1D  0.0 0  1 35 1
2D  0.0  0.74003-4  0.0  0.0  0.69360-2  0.0 30R
0V CONTRL
1D *PROINS*  /
* MATRIX EXPONENTIAL SOLUTION                                        *
* ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)                    *
*USER  * *IDENT *   0.0 74R  0 100R
1D *DVRINS*  0.0 100R  10000  0 99R
1D *EXPINS*    50.0  0.0 99R
  $1$ 0  $2$ 0  $3 DEBUG$ 1  $4$ 0  $5 METHOD$ 0  $6 SUBSTEPE$ 1
  $7 SUBSTEPS$ 0  $8$ 0  $9$ 0  $10$ 0  $11 AGRINC$  0    $12 POWER$ 0
  $13$ 0  $14$  1  $15$ 0  $16$ 0  $17$ 0  $18$ 0  $19$ 0  $20$ 0
  $21$ 1  $22-29$ 0  8R  $30$ 0  $31$ 0  $32$ 1  $33$ 1  $34$ 0  $35$ 1
  $36$ 0  $37$ 0  $38$ 0  $39$ 2  $40$ 0  $41$ 0  $42$ 0  $43$ 0
  $44$ 0  $45$ 0  $46-100$ 0 55R
1D *      *  0.0 100R  0 100R
   STOP
END                                                                   DRIVERE

MODULE CONTROL1 IS FINISHED.  USER COMPLETION CODE  0000. CPU TIME USED    25.56 (SECONDS). I/O'S USED    2804

MODULE CONTROL1 WILL BE CALLED  TIME OF DAY  1.52.24  DATE 78.336

  BREEDER REACTOR SAMPLE PROBLEM FOR THE BURNER CODE                  CONTRLT
  10000                    0          0                  1           CONTRLM
   1  2  7  2 13  7  2 13  7 13  7  0                                 CONTRLP
END                                                                   DRIVERE

LASLIN                                                                DRIVERS
 0V GRUPXS
 1D       3      45       0       2       0       1     270       0      3R
      1      2R       0      2R
  2D /
     * BREEDER REACTOR CROSS SECTION DATA (3 GROUP)                  *
     *            U235A U236A U238A PU239APU240APU241APU242AO16A  *
     *NA23A CR-A  MN55A FE-A  NI-A  XE135APM147APM48MAPM148ASM149A*
     *NSFPA SSFPA TA181ACR-RA FE-RA NI-RA U235B U236B U238B PU239B*
     *PU240BPU241BPU242BO16B  NA23B CR-B  MN55B FE-B  NI-B  XE135B*
     *PM147BPM48MBPM148BSM149BNSFPB SSFPB TA181B*
 6.17000E-01 3.73000E-01 1.00000E-02 2.03625E 09 6.89180E 08 1.50038E 08
 1.49200E 07 1.22500E 06 8.65200E 04 5.00045E-03
  4D /
     *U235  U236  U238  PU239 PU240 PU241 PU242 O16   NA23  CR    *
     *MN55  FE    NI    XE135 PM147 PM148MPM148 SM149 NSFP  SSFP  *
     *TA181 CR    FE    NI    U235  U236  U238  PU239 PU240 PU241 *
```

```
    *PU242 016    NA23  CR     MN55  FE     NI     XE135 PM147 PM148M*
    *PM148 SM149 NSFP  SSFP  TA181 CITNXSCITNXSCITNXSCITNXSCITNXS*
    *CITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXS*
    *CITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXS*
    *CITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXS*
    *CITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXSCITNXS*
    *10     11     12     14     15     16     17     23     25     31     *
    *32     33     35     58     63     64     65     67     76     77     *
    *81     131    133    135    10     11     12     14     15     16     *
    *17     23     25     31     32     33     35     58     63     64     *
    *65     67     76     77     81     *
2.35000E 02 2.36000E 02 2.38000E 02 2.39000E 02 2.40000E 02 2.41000E 02
2.42000E 02 1.58600E 01 2.27900E 01 5.15500E 01 5.44700E 01 5.53600E 01
5.82100E 01 1.35000E 02 1.47000E 02 1.48000E 02     2R   1.49000E 02
0.0             2R   1.81000E 02 5.15500E 01 5.53600E 01 5.82100E 01
2.35000E 02 2.36000E 02 2.38000E 02 2.39000E 02 2.40000E 02 2.41000E 02
2.42000E 02 1.58600E 01 2.27900E 01 5.15500E 01 5.44700E 01 5.53600E 01
5.82100E 01 1.35000E 02 1.47000E 02 1.48000E 02     2R   1.49000E 02
0.0             2R   1.81000E 02 3.23000E-11 3.24000E-11 3.31000E-11
3.34000E-11 3.36000E-11 3.37000E-11 3.38000E-11 0.0              17R
3.23000E-11 3.24000E-11 3.31000E-11 3.34000E-11 3.36000E-11 3.37000E-11
3.38000E-11 0.0            239R
     1      3      2      1      2      1      3      0      6
     5     4R      4     7R      7     4R      1      3      2      1
     2      1      3      0      6      5     4R      4     7R      7
     0      1     8R      0      1     5R      0      1      0     2R
     1      0     3R      1    10R      0      1     5R      0      1
     0     2R      1      0    10R
5D  4.65000E 00 4.79000E 00 4.74000E 00 4.89000E 00 4.76000E 00
4.60000E 00 4.40000E 00 1.52000E 00 1.83000E 00 2.31400E 00 2.49000E 00
2.39000E 00 2.54000E 00 2.00000E-04 6.42000E 00 2.92000E 00 7.56000E-02
3.94000E 00 3.00000E-02 2.00000E-01 4.00000E 00 2.31400E 00 2.39000E 00
2.54000E 00 4.70000E 00 4.84000E 00 4.77000E 00 4.91500E 00 4.77800E 00
4.61000E 00 4.41000E 00 1.58000E 00 1.86000E 00 2.29000E 00 2.51000E 00
2.39000E 00 2.59000E 00 4.00000E-04 6.47000E 00 3.00000E 00 7.77000E-02
4.03000E 00 4.00000E-02 3.00000E-01 4.00000E 00 0.0              45R
4.69999E-02 1.07500E-01 5.40000E-02 9.00078E-03 4.99992E-02 8.39996E-02
3.19996E-02 8.37000E-03 2.40776E-03 4.37440E-03 4.70800E-03 8.96019E-03
1.02898E-01 2.00000E-04 1.50540E-01 2.92000E 00 7.56000E-02 3.96000E-02
3.00000E-02 2.00000E-01 3.00000E-02 4.37440E-03 8.96019E-03 1.02898E-01
4.89998E-02 1.18200E-01 5.88000E-02 9.00078E-03 5.20000E-02 8.60004E-02
3.19996E-02 7.54000E-03 2.40583E-03 4.39950E-03 4.67100E-03 8.34160E-03
9.33974E-02 4.00000E-04 1.56726E-01 3.00000E 00 7.77000E-02 4.28000E-02
4.00000E-02 3.00000E-01 3.00000E-02 1.23500E 00 8.12200E-01 4.38000E-01
1.86600E 00 1.53500E 00 1.67600E 00 1.51800E 00 0.0          2.24000E-06
2.26000E-05 1.52000E-04 5.98000E-05 1.83000E-06 0.0          1.46000E-03
0.0             2R   1.23000E-02 0.0            3R   2.26000E-05
5.98000E-05 1.83000E-06 1.23800E 00 8.00400E-01 4.14300E-01 1.86600E 00
1.52900E 00 1.68400E 00 1.50900E 00 0.0          3.16500E-06 3.05000E-05
1.89000E-04 7.84000E-05 2.52000E-06 0.0          1.67400E-03
0.0             2R   1.28000E-02 0.0            3R   2.71000E 00
2.73000E 00     2R   3.22000E 00 3.14000E 00 3.27000E 00 3.18000E 00
0.0         2.00000E 00     5R   0.0          2.00000E 00
0.0             2R   2.00000E 00 0.0            3R
2.00000E 00     3R   2.71000E 00     2R   2.74000E 00 3.21000E 00
3.13000E 00 3.26000E 00 3.16000E 00 0.0          2.00000E 00     5R
0.0         2.00000E 00 0.0             2R   2.00000E 00
0.0             3R   6.17000E-01     7R   0.0
6.17000E-01     5R   0.0          6.17000E-01 0.0              2R
6.17000E-01 0.0             3R   6.17000E-01     10R   0.0
6.17000E-01     5R   0.0          6.17000E-01 0.0              2R
6.17000E-01 0.0             3R
5D  7.78000E 00 8.76000E 00 8.13000E 00 7.78000E 00 7.54000E 00
8.17700E 00 7.29000E 00 3.61000E 00 3.46000E 00 3.81900E 00 4.83000E 00
2.90000E 00 4.60000E 00 1.00000E-03 6.28000E 00 8.58000E 00 2.22000E-01
8.26000E 00 5.00000E-02 4.00000E-01 6.00000E 00 3.81900E 00 2.90000E 00
```

```
4.60000E 00 8.10000E 00 9.12000E 00 8.47000E 00 8.07800E 00 7.83600E 00
8.50000E 00 7.58000E 00 3.77000E 00 3.43000E 00 4.04000E 00 5.04000E 00
3.02000E 00 4.78000E 00 3.00000E-03 6.25000E 00 9.10000E 00 2.36000E-01
8.51000E 00 7.00000E-02 5.00000E-01 6.00000E 00 0.0          45R
2.64000E-01 3.04600E-01 1.57300E-01 1.46000E-01 1.85000E-01 1.90000E-01
1.23000E-01 0.0         5.11000E-04 5.48000E-03 9.60000E-03 7.05000E-03
1.05500E-02 1.00000E-03 3.81000E-01 8.58000E 00 2.22000E-01 4.83000E-01
5.00000E-02 4.00000E-01 3.00000E-01 5.48000E-03 7.05000E-03 1.05500E-02
2.83999E-01 3.04950E-01 1.59650E-01 1.60000E-01 1.92700E-01 2.04000E-01
1.28400E-01 0.0         5.26200E-04 5.80000E-03 1.04000E-02 7.62000E-03
1.09000E-02 3.00000E-03 3.95100E-01 9.10000E 00 2.36000E-01 5.27000E-01
7.00000E-02 5.00000E-01 3.00000E-01 1.35100E 00 3.65000E-02 1.70000E-03
1.53700E 00 3.40000E-01 1.79000E 00 2.49000E-01 0.0          17R
1.37500E 00 1.85500E-02 8.50000E-04 1.52200E 00 2.52300E-01 1.82400E 00
1.69300E-01 0.0          14R   2.46000E 00 2.51000E 00 2.49000E 00
2.93000E 00 2.96000E 00 2.98000E 00 2.92000E 00 0.0          17R
2.46000E 00 2.50000E 00 2.49000E 00 2.92000E 00 2.95000E 00 2.98000E 00
2.90000E 00 0.0          14R   3.73000E-01     7R   0.0
3.73000E-01     5R   0.0          3.73000E-01 0.0          2R
3.73000E-01 0.0          3R   3.73000E-01    10R   0.0
3.73000E-01     5R   0.0          3.73000E-01 0.0          2R
3.73000E-01 0.0          3R
5D  1.48000E 01 1.44000E 01 1.42000E 01 1.43000E 01 1.41000E 01
1.56400E 01 1.61000E 01 3.56000E 00 6.76000E 00 6.01000E 00 2.66000E 01
8.07000E 00 1.68000E 01 6.10000E-02 1.51000E 01 1.97700E 02 3.40000E 02
1.67000E 01 3.00000E-01 2.50000E 00 1.50000E 01 6.01000E 00 8.07000E 00
1.68000E 01 1.51000E 01 1.47800E 01 1.41100E 01 1.47300E 01 1.44700E 01
1.61600E 01 1.60600E 01 3.57000E 00 5.92000E 00 5.28000E 00 2.56000E 01
8.48000E 00 1.50000E 01 2.70000E-01 1.53000E 01 3.01000E 02 5.44000E 02
1.90000E 01 5.00000E-01 5.00000E 00 1.50000E 01 0.0          45R
1.13800E 00 9.90300E-01 5.55000E-01 1.01200E 00 7.86000E-01 8.79999E-01
7.40800E-01 1.06000E-07 1.73000E-04 3.62500E-02 1.82000E-01 3.03000E-02
5.33000E-02 6.10000E-02 3.45000E 00 1.97700E 02 3.40000E 02 2.95000E 00
3.00000E-01 2.50000E 00 2.00000E 00 3.62500E-02 3.03000E-02 5.33000E-02
1.27500E 00 1.19600E 00 5.28400E-01 1.18500E 00 1.23910E 00 9.66000E-01
9.71899E-01 2.33900E-07 1.70000E-03 3.22000E-02 2.39000E-01 2.95000E-02
4.86000E-02 2.70000E-01 4.61600E 00 3.01000E 02 5.44000E 02 4.30000E 00
5.00000E-01 5.00000E 00 2.00000E 00 3.09000E 00 0.0          2R
2.15900E 00 1.06000E-01 3.79000E 00 3.52000E-02 0.0          17R
3.30200E 00 0.0          2R   2.51100E 00 1.02900E-01 4.27800E 00
3.61000E-02 0.0          14R   2.43000E 00 0.0          2R
2.88000E 00 2.89000E 00 2.94000E 00 2.81000E 00 0.0          17R
2.43000E 00 0.0          2R   2.88000E 00 2.89000E 00 2.94000E 00
2.81000E 00 0.0          14R   1.00000E-02     7R   0.0
1.00000E-02     5R   0.0          1.00000E-02 0.0          2R
1.00000E-02 0.0          3R   1.00000E-02    10R   0.0
1.00000E-02     5R   0.0          1.00000E-02 0.0          2R
1.00000E-02 0.0          3R
7D      1    90R
8D  4.80000E 00 4.70000E 00 4.48000E 00 4.36000E 00 4.78000E 00
4.68000E 00 4.81000E 00 1.63500E 00 2.27000E 00 2.66000E 00 2.85000E 00
2.72000E 00 2.80000E 00 0.0          4.70000E 00 0.0          2R
5.09000E 00 0.0          2R   3.00000E 00 2.66000E 00 2.72000E 00
2.80000E 00 4.71000E 00 4.68500E 00 4.43000E 00 4.29400E 00 4.71500E 00
4.67000E 00 4.78500E 00 1.65700E 00 2.23300E 00 2.61000E 00 2.80000E 00
2.65000E 00 2.84000E 00 0.0          4.76000E 00 0.0          2R
5.11000E 00 0.0          2R   3.00000E 00
7D      2    13R      1      2      1      2R      2      1      2R
     2    17R      1      2      1      2R      2      1      2R      2
     1    45R
8D  7.60000E 00 9.98000E-01 9.80000E 00 1.83000E 00 9.53000E 00
2.28000E 00 8.02000E 00 1.14200E 00 9.04000E 00 1.04000E 00 8.62000E 00
1.02300E 00 8.79000E 00 7.53000E-01 3.69000E 00 3.22000E-01 3.76000E 00
4.14000E-01 4.79000E 00 6.05000E-01 4.91000E 00 6.46000E-01 3.18000E 00
5.32000E-01 4.85000E 00 4.90000E-01 0.0          5.89000E 00 1.57300E 00
0.0          2R   7.38000E 00 1.50000E 00 0.0          2R
```

```
 5.00000E 00 1.00000E 00 4.79000E 00 6.05000E-01 3.18000E 00 5.32000E-01
 4.85000E 00 4.90000E-01 7.79000E 00 1.03800E 00 1.04900E 01 1.83800E 00
 9.79000E 00 2.31000E 00 8.27000E 00 1.16400E 00 9.35800E 00 1.06200E 00
 8.83000E 00 1.01400E 00 9.08000E 00 7.64500E-01 3.82000E 00 4.17900E-01
 3.62000E 00 4.89200E-01 5.06000E 00 6.01500E-01 5.11000E 00 6.76000E-01
 3.28000E 00 5.81000E-01 5.00000E 00 5.10000E-01 0.0         5.84000E 00
 1.57000E 00 0.0             2R   7.40000E 00 1.55000E 00
 0.0             2R   5.00000E 00 1.00000E 00
 7D        3     13R       1       3       1      2R       3       1      2R
      3    17R       1       3       1      2R       3       1      2R       3
      1    45R
 8D  1.08000E 01 1.40000E-01 1.90000E-02 1.38000E 01 1.69000E-01
 6.05000E-02 1.39000E 01 1.72000E-01 5.17000E-02 1.16500E 01 1.10000E-01
 2.99000E-02 1.38300E 01 1.85000E-01 1.37000E-02 1.17400E 01 2.11000E-01
 2.60000E-02 1.59000E 01 1.38000E-01 2.15000E-02 3.59000E 00 1.90000E-01
 2.78000E-05 6.87000E 00 1.40000E-01 5.37900E-03 6.32200E 00 2.88200E-02
 1.48600E-02 2.68000E 01 1.50000E-01 2.46000E-02 8.12000E 00 8.94000E-02
 6.83000E-03 1.70000E 01 9.10000E-02 2.20000E-02 0.0         1.17000E 01
 4.18000E-02 3.94000E-02 0.0             2R   1.36400E 01 2.55000E-01
 1.53000E-02 0.0             2R   1.00000E 01 2.00000E-01 1.00000E-01
 6.32200E 00 2.88200E-02 1.48600E-02 8.12000E 00 8.94000E-02 6.83000E-03
 1.70000E 01 9.10000E-02 2.20000E-02 1.07500E 01 1.67600E-01 1.82000E-02
 1.39300E 01 2.03000E-01 5.80000E-02 1.39100E 01 2.00000E-01 5.15000E-02
 1.15800E 01 1.30500E-01 2.97000E-02 1.38300E 01 2.25000E-01 1.22800E-02
 1.17500E 01 2.45000E-01 2.30000E-02 1.56900E 01 1.68500E-01 2.13500E-02
 3.58500E 00 2.42200E-01 2.71000E-05 6.00000E 00 1.78000E-01 4.77000E-03
 5.60000E 00 3.67500E-02 1.46000E-02 2.57000E 01 1.71000E-01 2.70000E-02
 8.53000E 00 1.10000E-01 6.07000E-03 1.52000E 01 1.16000E-01 2.32000E-02
 0.0         1.07600E 01 5.06000E-02 4.00000E-02 0.0             2R
 1.46000E 01 2.94000E-01 1.33000E-02 0.0             2R   1.00000E 01
 2.00000E-01 1.00000E-01
0V EXPOSE
1D  0 14 0 2 2 7 5 5 0 0 0 10 0 33 0 1 1 1 0 0
2D /
* BREEDER REACTOR EXPOSURE DATA                                          *
*U235  * *U236  * *U238  * *PU239 * *PU240 * *PU241 * *PU242 * *XE135 *
*PM147 * *SM149 * *NSFP  * *SSFP  * *PM148M* *PM148 *
3D  1.0+5  0.0 / YER
  3.0+6  0.5+6  / GER
   1 2 3 4 5 6 7 /   IFSLP
   8 9 10 11 12 /    IFPR
   6 8 9 13 14 /     IDCYR
4D  1.689-9  2.093-5  8.289-9  1.976-7  1.488-6  / DECAY CONSTANTS
5D (0.0715  0.06  0.06  0.0715  0.06  0.0715  0.06  / XE135 YIELD
    0.027   0.03  0.03  0.027   0.03  0.027   0.03  / PM147 YIELD
    0.013   0.02  0.02  0.013   0.02  0.013   0.02  / SM149 YIELD
    1.5011 1.5466 1.5466 1.5011 1.5466 1.5011 1.5466  / NSFP YIELD
    0.0134  7R )  2R  / SSFP YIELD
6D  / MATRIX EXPONENTIAL OR AVERAGE GENERATION RATE
    3 4 2    4 5 2    5 6 2    6 7 2    1 2 2  /
    9 13 900002    13 10 2    9 14 100002    14 10 2    12 11 2  /
8D  / BASIC EXPLICIT CHAINS
    3 2 4 2 5 2 6 2 7 0  /
    1 2 2 0  /
    9 900002 13 2 10 0  /
    9 100002 14 2 -10 0  /
    8 0  /
    12 2 11 0  0  /
 $ THE DATA IN 9D, 10D, 11D RECORDS IS FICTITIOUS $
9D    0.0  5R   5.8   0.5+6 0.1+6 0.8+6 1.0+6
      7.0+3  0.4+6 0.1+6 1.0+6 1.0+6  9.0+3 1.0+6 0.2+6 1.8+6 2.0+6
10D   7.0+6 6.0+6 5.0+6 4.0+6 3.0+6 2.0+6 1.0+6
      0.1+6 0.2+6 0.3+6 0.4+6 0.5+6 0.6+6 0.7+6    2.0+6  7R
11D   6.5+6 5.0+6 4.8+6 6.5+6 5.4+6 6.2+6 5.0+6 7.9+6 5.0+6  6R
      0.0 14R   1.0+6  14R
     STOP
```

```
END                                                                                    DRIVERE

DVENDS                                                                                 DRIVERS
001                                                                                       1-1
                                                  2500.0+5        0.97         0.5        1-2
                                                                                          1-3
                                                                                          1-4
  1  2        0                    50                                                     1-5
  1  1  1  1                    0  0        1     1        0  1                           1-6
002                                                                                       2-1
                                                                                          2-2
  0  1  3                                                                                 2-3
                                                                                          2-4
                                                                                          2-5
                                                                                          2-6
003                                                                                       3-1
  7  1  2  2  1  0  0  1  0  0  0  0  0                                                    3-2
        0.0                                                                               3-3
004                                                                                       4-1
  2  91.2213  2  37.7847  2  28.9940  2  13.4934  2  12.5066  2  30.0000                  4-2
  0                                                                                       4-2
  2  30.0000  1  18.0000  1  18.0000  2  22.0000  2  22.0000                              4-2
005                                                                                       5-1
 22 22 22 22 22 22                                                                        5-2
  8 10 12 16 20 21                                                                        5-2
  7  9 11 15 19 21                                                                        5-2
  2  4  6 14 18 21                                                                        5-2
  1  3  5 13 17 21                                                                        5-2
012                                                                                      12-1
  0                                                                                      12-2
  1  2  1101          1.0                                                                12-3
  3  4  1102          1.0                                                                12-3
  5  6  1103          1.0                                                                12-3
  7  8  2104          1.0                                                                12-3
  9 10  2105          1.0                                                                12-3
 11 12  2106          1.0                                                                12-3
 13 16  2107          1.0                                                                12-3
 17 20  2108          1.0                                                                12-3
 21 21  4109          1.0                                                                12-3
 22 22  4110          1.0                                                                12-3
  0                                                                                      12-3
013                                                                                      13-1
 21                                                                                      13-2
 21                                                                                      13-3
U235A U236A U238A PU239APU240APU241APU242AO16A  NA23A CR-A  MN55A FE-A                  13-4
NI-A  XE135APM147APM48MAPM148ASM149ANSFPA SSFPA TA181A                                   13-4
 21                                                                                      13-3
U235B U236B U238B PU239BPU240BPU241BPU242BO16B  NA23B CR-B  MN55B FE-B                  13-4
NI-B  XE135BPM147BPM48MBPM148BSM149BNSFPB SSFPB TA181B                                   13-4
  4                                                                                      13-3
NA23A FE-A  CR-A  NI-A                                                                   13-4
  4                                                                                      13-3
NA23B FE-B  CR-B  NI-B                                                                   13-4
020                                                                                      20-1
  1  2                                                                                   20-2
U235A      2.2870-5U238A      7.5043-3PU239A     8.6771-4PU240A     3.3536-4             20-3
PU241A     6.4215-5PU242A     2.5591-5O16A       1.7640-2NA23A      9.0585-3             20-3
FE-A       9.7856-3CR-A       2.6187-3NI-A       1.3783-3TA181A     1.000-10             20-3
                                                                                          20-3
  3  4                                                                                   20-2
U235A      2.3915-5U238A      7.8475-3PU239A     9.9061-4PU240A     3.8268-4             20-3
PU241A     7.3271-5PU242A     2.9201-5O16A       1.8693-2NA23A      8.4032-3             20-3
FE-A      10.0866-3CR-A       2.6993-3NI-A       1.4206-3TA181A     1.000-10             20-3
                                                                                          20-3
  5  6                                                                                   20-2
U235A      2.3573-5U238A      7.7355-3PU239A     1.1587-3PU240A     4.4788-4             20-3
```

```
PU241A     8.5748-5PU242A     3.4168-5016A       1.8553-2NA23A      8.2275-3     20-3
FE-A      10.1726-3CR-A       2.7223-3NI-A       1.4328-3TA181A     1.000-10     20-3
                                                                                  20-3
  7  8                                                                            20-2
U235B      2.8395-5U238B      9.3176-3NA23B      9.0585-3FE-B       9.7856-3     20-3
CR-B       2.6187-3NI-B       1.3783-3016B       1.8692-2                        20-3
  9 10                                                                            20-2
U235B      3.0092-5U238B      9.8747-3NA23B      8.4032-3FE-B      10.0866-3     20-3
CR-B       2.6993-3NI-B       1.4206-3016B       1.9810-2                        20-3
 11 12                                                                            20-2
U235B      3.0542-5U238B     10.0222-3NA23B      8.2275-3FE-B      10.1726-3     20-3
CR-B       2.7223-3NI-B       1.4328-3016B       2.0105-2                        20-3
 13 20                                                                            20-2
U235B      4.3183-5U238B      1.4170-2NA23B      4.2244-3FE-B       9.9333-3     20-3
CR-B       2.6582-3NI-B       1.3991-3016B       2.8426-2                        20-3
 21 22                                                                            20-2
NA23B      1.0847-2FE-B       3.0715-2CR-B       8.2196-3NI-B       4.3261-3     20-3
                                                                                  20-3
  0                                                                               20-2
END                                                                          DRIVERE

DUTLIN                                                                       DRIVERS
EXPINS          0 12  0 96
         75.0          0.0          0.0          0.0          0.0          0.0
          0.0          0.0          0.0          0.0       1.0+3        1.0+5
  0  0  1  0  1  2  0  0  0  0  0  0  1  0  0  0  4  0  0  0  0  0  0  1-24
 -1  1  1  1  1  1  0  1  0  0  1  0  0  0  0  0  0  0  0  0  0  0  0 25-48
                                                                          49-72
  1  1  0  0  0  1  0  0  0  0  0  1  3  0  0  0  0  0  0  0  0  0  0  0 73-96
BLANK
END                                                                          DRIVERE

DUTLIN                                                                       DRIVERS
EXPINS          0 12  0 96
         75.0          0.0          0.0          0.0          0.0          0.0
          0.0          0.0          0.0          0.0          0.0          0.0
  0  0  0  0  1  2  0  0  0  0  0  0  0  0  0  0  0 -4  0  0  0  0  0  0  1-24
  1  1  1  0  1  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 25-48
                                                                          49-72
  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 73-96
BLANK
END                                                                          DRIVERE

MODULE CONTROL1 IS FINISHED.  USER COMPLETION CODE  0000. CPU TIME USED    33.79 (SECONDS). I/O'S USED    6721

MODULE CONTROL1 WILL BE CALLED  TIME OF DAY  1.57.42  DATE 78.336

  GAS COOLED REACTOR PROBLEM, (1-D MODELED AS 2-D) BURNER CODE TEST CASE
  10                                  1                          1
  1  2  2  6  2  7 13 -2  3  3  2  7 13  7 -2  3  0

 END

 INPUT PROCESSOR
  CV ISOTXS
  1D       4      20       0       3      2R       1       4       1
   2D /
      * FOUR GROUP MICROSCOPIC GAS COOLED REACTOR CROSS SECTIONS   *
      *BURNER CODE   C    I-135XE-135PM-147PM148MPM-148SM-149 U-236*
                  *  FP2   FP1 TH-232THX232PA-233 U-233 U-234 U-235*
            *PM-149ND-143  HE  RECVEL*
 9.67250E-01 3.27516E-02 5.46603E-09 9.85424E-13 1.14347E 09 1.04943E 08
 6.19099E 06 5.09968E 05 1.49183E 07 1.83155E 05 5.82947E 02 1.85540E 00
 5.00000E-03
  0 6 12 14 20 22 24 30 36 38 40 46 52 58 64 70 76 82 88 94
  4D /
```

```
    *00000 AMPX  0000  *
0.0                 3R   9.00000E 02 0.0                 2R
     0      3R       1       0      4R       1      2R       0      2R       1
     2       3       1      5R       2       3       4       1       2      3R
     1       2      3R       1       2      3R       1     16R
5D  2.46495E 00 4.35172E 00 4.49984E 00 5.24907E 00 2.80576E 00
4.63323E 00 4.75415E 00 4.76155E 00 7.71149E-07 8.40718E-06 1.42501E-04
1.72627E-03 1.57589E-04 0.0                 3R
7D  2.61137E 00 4.50929E 00 1.94211E-01 4.63977E 00 1.23899E-01
2.55481E-07 4.75962E 00 1.14203E-01 0.0          6.33724E-10
7D  1.02244E 00 9.47622E-01-1.61143E-01 8.98736E-01-1.09701E-01
0.0          -1.01162E-01
7D  4.55984E-01 5.68312E-02-3.07351E-02 4.59477E-02-1.36361E-02
0.0          -1.24564E-02
7D  6.22074E-02 9.43820E-04-2.04589E-03 1.49141E-04-6.12344E-04
0.0          -7.56086E-04
 4D /
    *00000 AMPX  0000  *
0.0                 3R   9.00000E 02 0.0                 2R
     0      3R       1      2R       0      3R       1      2R       0      2R
     1       2       3       1      5R       2       3       4       1
     2      3R       1       2      3R       1       2      3R       1     16R
5D  3.13209E 00 3.49211E 00 3.56222E 00 4.26628E 00 3.57817E 00
3.59211E 00 3.71071E 00 3.85076E 00-1.31012E-10 1.85304E-07 9.47002E-06
7.81381E-05 2.36170E-03 0.0                 3R   4.13948E-06
0.0                 3R
7D  3.43969E 00 3.51929E 00 1.36078E-01 3.64207E 00 7.28106E-02
8.00963E-08 3.85044E 00 6.86274E-02 0.0          7.08408E-11
7D  1.33822E 00 3.94203E-01-1.47233E-01 5.27982E-01-6.66327E-02
0.0          -6.27515E-02
7D  2.00541E 00 8.83380E-03 1.06699E-02 2.28815E-02-5.96633E-03
0.0          -5.67032E-03
7D  3.48841E-01-3.38483E-03 6.08060E-04-3.32863E-03-3.00659E-04
0.0          -3.75276E-04
 4D /
    *00000 AMPX  0000  *
0.0                 3R   9.00000E 02 0.0                 2R
     0      8R       1      2R       0     41R
5D  0.0          1.57024E-05 3.63947E 01 1.11992E 06 0.0
1.57025E-05 3.63948E 01 1.11993E 06 0.0          1.57025E-05 3.63948E 01
1.11993E 06
 4D /
    *00003 AMPX  0000  *
8.28900E-09 0.0                 2R   9.00000E 02 0.0                 2R
     0      5R       1       0      2R       1      2R       0      2R       1
     2       3       1      5R       2       3       2       1       2      3R
     1       2      3R       1       2      3R       1     16R
5D  6.33956E 00 2.24317E 01 4.59573E 02 1.02065E 02 6.37194E 00
2.25075E 01 4.60094E 02 1.01844E 02 2.64414E-01 6.34250E 00 3.45114E 02
1.01844E 02 3.09018E-04 0.0                 3R
7D  6.00819E 00 1.61376E 01 9.95159E-02 1.14969E 02 2.73572E-02
1.05621E-06 0.0          1.11237E-02
7D  9.71400E-02 2.42431E-01-2.38279E-02 1.58928E 00-2.02812E-02
0.0          -1.12029E-02
7D  5.70030E-02 1.93196E-01 9.48644E-04 1.38464E 00 8.67579E-04
0.0           2.44644E-04
7D -2.07583E-03-1.93186E-02 3.58152E-04-5.87924E-02 1.18708E-02
0.0          -5.02103E-04
 4D /
    *00003 AMPX  0000  *
1.97600E-07 0.0                 2R   9.00000E 02 0.0                 2R
     0      8R       1      2R       0     41R
5D  5.20293E 00 4.35190E 02 4.52295E 03 1.16523E 04 5.20293E 00
4.35190E 02 4.52296E 03 1.16523E 04 5.20293E 00 4.35190E 02 4.52296E 03
1.16523E 04
 4D /
```

```
    *00003 AMPX  0000  *
1.48800E-06 0.0              2R   9.00000E 02 0.0              2R
     0      8R      1      2R      0     41R
5D  1.34886E-01 8.03715E 02 7.41200E 03 6.47351E 02 1.34886E-01
8.03715E 02 7.41201E 03 6.47352E 02 1.34886E-01 8.03715E 02 7.41201E 03
6.47352E 02
 4D /
    *00000 AMPX  0000  *
0.0                 3R   9.00000E 02 0.0              2R
     0      3R      1      3R      0      2R      1      2R      0      2R
     1      2       3      1      5R      2      3      2R      1
     2      3R      1      2      3R      1      2      3R      1     16R
5D  6.19874E 00 2.17341E 01 2.20188E 02 3.55981E 04 7.29491E 00
2.17218E 01 2.20580E 02 3.55977E 04 2.04199E-01 4.72308E 00 1.48346E 02
3.53984E 04 4.13242E-05 0.0                 3R   4.13242E-05
0.0                 3R   2.86179E-03 0.0              3R
7D  6.75315E 00 1.69162E 01 3.39961E-01 7.22107E 01 8.25309E-02
3.66847E-05 1.99308E 02 2.30498E-02 9.60831E-09
7D  3.28851E 00-1.29284E-02-3.75093E-02 1.27754E 00-8.16336E-02
0.0          -2.28129E-02
7D  7.91628E 00 2.20639E-01 1.47068E-02-7.73363E-02-8.65960E-04
0.0          -1.07144E-04
7D  4.38087E 00-2.91009E-02-7.15515E-03-2.11063E-01 9.98253E-06
0.0          -2.81597E-04
 4D /
    *00009 AMPX  0000  *
0.0                 3R   9.00000E 02 0.0              2R
     0      1      2R      0      2R      1      0      2R      1      2R
     0      2R      1      2      3      1      5R      2      3      2
     1      2      3R      1      2      3R      1      2      3R
     1     16R
5D  6.45392E 00 1.61302E 01 7.31880E 01 1.22898E 01 8.59539E 00
1.64366E 01 7.34190E 01 1.20661E 01 2.33142E-01 1.58154E 00 4.82720E 01
2.69134E 00 3.35581E-01 0.0                 3R   2.67199E 00
0.0                 3R   9.67491E-01 3.25084E-02 0.0              2R
1.90903E-03 0.0                 3R
7D  7.80229E 00 1.48090E 01 2.25622E-01 2.51356E 01 4.60062E-02
6.63545E-08 9.37473E 00 1.13733E-02
7D  6.42438E 00 9.30622E-01-1.79708E-02 7.49588E-01-4.57083E-02
0.0          -1.13259E-02
7D  5.81333E 00 1.70217E-01-3.24541E-03-1.39539E-01-2.87688E-04
0.0           3.10092E-05
7D  5.46002E 00 6.92364E-02-7.52168E-04 1.35115E 00-1.32073E-05
0.0          -1.45689E-04
 4D /
    *00000 AMPX  0000  *
0.0                 3R   9.00000E 02 0.0              2R
     0      8R      1      2R      0     41R
5D  1.96967E-02 2.43616E-01 1.01253E 00 4.79472E-01 1.96967E-02
2.43616E-01 1.01253E 00 4.79472E-01 1.96967E-02 2.43616E-01 1.01253E 00
4.79472E-01
 4D /
    *00000 AMPX  0000  *
0.0                 3R   9.00000E 02 0.0              2R
     0      8R      1      2R      0     41R
5D  6.86115E-02 7.08814E-01 1.13373E 01 6.19355E 00 6.86116E-02
7.08814E-01 1.13373E 01 6.19355E 00 6.86116E-02 7.08814E-01 1.13373E 01
6.19355E 00
 4D /
    *00012 AMPX  0000  *
0.0                 3R   9.00000E 02 0.0              2R
     0      1      2R      0      2R      1      0      2R      1      2R
     0      2R      1      2      3      1      5R      2      3      2
     1      2      3R      1      2      3R      1      2      3R
     1     16R
5D  6.74676E 00 1.47389E 01 2.61214E 01 1.58802E 01 7.78197E 00
```

```
1.48870E 01 2.61660E 01 1.55648E 01 1.32916E-01 1.07400E 00 7.08836E 00
3.04295E 00 3.66095E-02 0.0              3R   2.38770E 00
0.0              3R   9.66726E-01 3.32735E-02 0.0              2R
4.92270E-03 0.0              3R
7D  7.39790E 00 1.37752E 01 2.19124E-01 1.90617E 01 3.78033E-02
3.46449E-06 1.25215E 01 1.58786E-02
7D  3.10561E 00 4.57992E-01-2.15081E-02 1.78208E-01-3.58880E-02
0.0         -1.59732E-02
7D  2.87912E 00 1.37820E-01-1.11800E-03 2.67811E-02 2.57116E-03
0.0          3.31132E-04
7D  2.08431E 00 3.99083E-02 1.19941E-04-4.66264E-03 2.86149E-03
0.0         -7.15179E-04
 4D /
    *00012 AMPX  0000  *
0.0              3R   9.00000E 02 0.0              2R
     0      1      2R      0      2R      1      0      2R      1      2R
     0     2R      1       2      3      1     5R      2      3      2
     1      2      3R      1      2     3R      1      2     3R
     1    16R
5D  6.74677E 00 1.47187E 01 2.50846E 01 1.58802E 01 7.78199E 00
1.48667E 01 2.51292E 01 1.55648E 01 1.32916E-01 1.05374E 00 6.05146E 00
3.04294E 00 3.66096E-02 0.0              3R   2.38770E 00
0.0              3R   9.66726E-01 3.32735E-02 0.0              2R
4.92272E-03 0.0              3R
7D  7.39772E 00 1.37751E 01 2.19137E-01 1.90618E 01 3.78032E-02
3.46452E-06 1.25217E 01 1.58786E-02
7D  3.10563E 00 4.57987E-01-2.15082E-02 1.78209E-01-3.58879E-02
0.0         -1.59732E-02
7D  2.87914E 00 1.37820E-01-1.11800E-03 2.67809E-02 2.57115E-03
0.0          3.31132E-04
7D  2.08432E 00 3.99080E-02 1.19941E-04-4.66270E-03 2.86148E-03
0.0         -7.15179E-04
 4D /
    *00010 AMPX  0000  *
2.92700E-07 0.0              2R   9.00000E 02 0.0              2R
     0      1      2R      0      2R      1      0      2R      1      2R
     0     2R      1       2      3      1     5R      2      3      2
     1      2      3R      1      2     3R      1      2     3R
     1    16R
5D  5.71454E 00 1.31765E 01 7.27738E 01 6.54323E 01 7.96116E 00
1.33241E 01 7.28092E 01 6.49819E 01 2.20474E-01 2.41445E 00 6.00936E 01
5.49616E 01 5.57755E-01 0.0              3R   2.71657E 00
0.0              3R   9.66726E-01 3.32735E-02 0.0              2R
2.12826E-03 0.0              3R
7D  6.82956E 00 1.08919E 01 3.54730E-01 1.26928E 01 1.76091E-02
6.86099E-06 1.00202E 01 2.27684E-02
7D  6.73987E 00 4.50553E-01-1.18768E-02 1.22837E-01-1.35560E-02
0.0         -2.28105E-02
7D  6.88456E 00 5.81156E-02-8.34375E-03 6.79732E-02 2.24736E-03
0.0          3.85785E-04
7D  4.86297E 00-7.44348E-03 5.77399E-04-9.71469E-03 7.57816E-03
0.0         -1.00426E-03
 4D /
    *00012 AMPX  0000  *
0.0              3R   9.00000E 02 0.0              2R
     0      1      2R      0      2R      1      0      2R      1      2R
     0     2R      1       2      3      1     5R      2      3      2
     1      2      3R      1      2     3R      1      2     3R
     1    16R
5D  5.74891E 00 1.61665E 01 9.52141E 01 2.81781E 02 7.58709E 00
1.66390E 01 9.52474E 01 2.81463E 02 9.98576E-02 7.26233E-01 1.55603E 01
2.48434E 01 1.99326E 00 5.88113E 00 6.77771E 01 2.44094E 02 2.60408E 00
2.50295E 00 2.50290E 00 2.50300E 00 9.66726E-01 3.32735E-02
0.0              2R   2.21612E-03 0.0              3R
7D  5.34374E 00 1.00147E 01 1.51938E-01 1.18940E 01 1.68491E-02
3.48918E-06 1.25250E 01 1.60449E-02
```

```
7D  5.51455E 00 1.42199E 00-7.13662E-03 1.18676E-01-1.53256E-02
0.0          -1.61553E-02
7D  4.77171E 00 3.54786E-01-2.97483E-03 3.32699E-02 3.34567E-03
0.0           3.54131E-04
7D  4.32062E 00 5.68678E-02-1.73648E-03-2.98625E-03 1.15353E-03
0.0          -7.17038E-04
 4D /
    *00000 AMPX  0000  *
0.0                3R   9.00000E 02 0.0                2R
     0       1      2R       0      2R       1       0      2R       1      2R
     0      2R       1       2       3       1      5R       2       3       2
     1       2      3R       1       2      3R       1       2      3R
     1     16R
5D  5.47845E 00 1.22946E 01 1.36486E 02 4.52315E 01 7.79960E 00
1.26958E 01 1.36586E 02 4.49679E 01 1.45039E-01 1.44377E 00 1.00146E 02
3.59523E 01 8.84482E-01 6.23145E-03 0.0                2R   2.68881E 00
2.51198E 00 0.0                2R   9.67491E-01 3.25084E-02
0.0                2R   7.16235E-04 0.0                3R
7D  6.60050E 00 1.12266E 01 1.70022E-01 3.64263E 01 1.91352E-02
2.67831E-06 9.01538E 00 1.32778E-02
7D  6.96345E 00 1.21134E 00-1.22277E-02 3.20812E-01-1.70869E-02
0.0          -1.33494E-02
7D  7.08678E 00 3.16224E-02-8.60607E-03 7.38894E-02 4.40680E-04
0.0           2.70231E-04
7D  5.02343E 00 1.47891E-03 6.28570E-04-8.58055E-03 3.53058E-03
0.0          -5.96207E-04
 4D /
    *00000 AMPX  0000  *
0.0                3R   9.00000E 02 0.0                2R
     0       1      2R       0      2R       1       0      2R       1      2R
     0      2R       1       2       3       1      5R       2       3       4
     1       2      3R       1       2      3R       1       2      3R
     1     16R
5D  5.72374E 00 1.62874E 01 6.26451E 01 2.50376E 02 7.75611E 00
1.68015E 01 6.26768E 01 2.50031E 02 1.34206E-01 1.84088E 00 2.02046E 01
3.75663E 01 1.23611E 00 4.12570E 00 3.07044E 01 1.99946E 02 2.57170E 00
2.44356E 00 2.44199E 00 2.43018E 00 9.67491E-01 3.25084E-02
0.0                2R   2.72482E-03 0.0                3R
7D  6.22609E 00 1.08180E 01 1.61886E-01 1.17514E 01 1.67659E-02
3.03703E-05 1.25184E 01 1.62969E-02 1.19922E-09 1.98360E-07
7D  6.09709E 00 1.54708E 00-7.72057E-03 1.12332E-01-1.29448E-02
0.0          -1.63925E-02
7D  5.32340E 00 4.33794E-01-3.07464E-03 6.20566E-02 2.35181E-03
0.0           3.30067E-04
7D  4.85681E 00 7.03195E-02-7.05941E-04-9.03989E-03 7.16228E-03
0.0          -7.27819E-04
 4D /
    *00003 AMPX  0000  *
0.0                3R   9.00000E 02 0.0                2R
     0      3R       1      2R       0      3R       1      2R       0      2R
     1       2       3       1      5R       2      3R       1       2      3R
     1       2      3R       1       2      3R       1     16R
5D  2.93676E 00 3.39650E 00 3.55382E 00 4.06817E 00 3.71922E 00
3.57522E 00 3.70058E 00 3.66156E 00 5.02683E-09 0.0                2R
7.68191E-05 3.16126E-03 0.0                3R   4.46651E-06
0.0                3R
7D  3.59811E 00 3.50237E 00 1.17933E-01 3.63357E 00 7.28413E-02
3.66125E 00 6.70116E-02
7D  2.34738E 00 5.95135E-01-9.21809E-02 5.22542E-01-6.64347E-02
0.0          -6.14059E-02
7D  2.05082E 00 7.87079E-02-2.17789E-02 4.27036E-02-5.40829E-03
0.0          -5.19853E-03
7D  6.49248E-01 2.78619E-02 5.70894E-04-3.61752E-03-4.68773E-04
0.0          -1.55357E-03
 4D /
    *00049 AMPX  0000  *
```

```
0.0                3R   9.00000E 02 0.0                2R
     0      5R       1       0      2R       1      2R       0      2R       1
     2       3       1      5R       2       3       2       1       2      3R
     1       2      3R       1       2      3R       1     16R
5D  6.40211E 00 6.62002E 00 2.20608E 01 1.35224E 02 6.43713E 00
6.64410E 00 2.21275E 01 1.33725E 02 4.54604E-02 9.83074E-01 1.07289E 01
1.33725E 02 1.02827E-03 0.0                3R
7D  6.30398E 00 5.64837E 00 8.83873E-02 1.13227E 01 1.26315E-02
8.74441E-07 0.0          7.58904E-02
7D  1.05035E-01 8.82550E-02-2.50681E-02 2.11496E-01-9.29727E-03
0.0          -7.59188E-02
7D  6.10851E-02 6.73230E-02 1.03147E-03 1.36321E-01 1.64413E-04
0.0           1.14611E-03
7D -2.12290E-03-8.09928E-03 3.03158E-04-3.63844E-02 5.45286E-03
0.0          -3.36437E-03
 4D /
    *00000 AMPX  0000  *
0.0                3R   9.00000E 02 0.0                2R
     0      4R       1       0      3R       1      2R       0      2R       1
     2       3       1      5R       2      3R       1       2      3R       1
     2      3R       1       2      3R       1     16R
5D  2.57987E 00 6.67602E-01 6.06275E-01 8.38091E-01 3.14836E 00
7.25981E-01 7.24264E-01 7.91167E-01 0.0                2R   2.83813E-05
2.99248E-03 1.19322E-06 1.33478E-05 2.16784E-04 0.0
7D  2.97878E 00 6.74810E-01 1.69568E-01 6.77026E-01 5.11521E-02
7.88157E-01 4.69873E-02
7D  1.70546E 00 3.13085E-01-2.15620E-01 3.94420E-01-3.26720E-02
0.0          -2.98945E-02
7D  2.49352E 00 2.37621E-02 4.47553E-02 6.14010E-02-1.65605E-02
0.0          -1.52547E-02
7D  1.45560E 00-4.19358E-03 7.42280E-04 1.73844E-03-1.98518E-03
0.0          -1.88735E-03
 4D /
    *00000 AMPX  0000  *
0.0                3R   9.00000E 02 0.0                2R
     0      9R       1      2R       0     41R
5D  1.92801E-04 2.10190E-03 3.56295E-02 4.31568E-01 1.92801E-04
2.10190E-03 3.56295E-02 4.31568E-01 1.92801E-04 2.10190E-03 3.56295E-02
4.31568E-01
0V EXPOSE /      C EXPOSURE DATA FOR GAS COOLED REACTOR
1D   20101  16  C  1  0  3  7  7  0  0  0 0 0 49 0 0 0 0 0 0
2D  60H TH-232, U-233 U-235 FUEL (NO U-238) CHAIN EXPOSURE DATA
  12H
          54HTH-232PA-233 U-233 U-234 U-235 U-236 I-135XE-135PM-147
   42HPM-148PM148MEM-149SM-149ND-143   FP1    FP2
3D  0.   1  3  5  7  8  9  12  14  15  16  2  7  8  9  10  11  12  /
4D  2.93E-7  2.87E-5  2.09E-5  8.29E-9  1.49E-6  1.98E-7  3.63E-6  /
5D   .0539   .0562   .0617  /
     .0021    .0022    .0024  /
     .0382    .0193   .0236   /
     .00945   .0077   .0113  /
     .08     .0591    .0603  /
    .98  .99  1.11 /
   3.6    3.6    3.8  /
8D  1  +2  2  +1  3  +2  4  +2  5  +2  6  0 /
  1  +2  2  +2  -4  +2  -5  +2  -6  0
  7  +1  8  0  /
  9  +530002  10  +2  12  +1  13  0
  9  +470002  11  +2  -12  +1  -13  0
  14  0    15  +2  16  0  0  /
0V PPRINT
1D  2  0  0  0
2D 6HZNATDN   0  1  0
2D 6HNDXSRF   0  1  0
 0V ZNATDN
 1D  1.20000E 04
```

```
     0      57      17       1
2D  2.48846E-04 3.38806E-07 7.07687E-07 3.08030E-08 5.56563E-05
1.24614E-06 8.00000E-02 9.97988E-10 3.06370E-10 9.52996E-08 7.45213E-10
1.02164E-09 1.89860E-09 2.82328E-09 2.86995E-07 5.52321E-06 1.90906E-05
2.45959E-04 8.52594E-07 2.39450E-06 1.71825E-07 4.22371E-05 3.84687E-06
8.00000E-02 2.23964E-09 5.70169E-10 2.54384E-07 2.41384E-09 2.86217E-09
5.04630E-09 5.82613E-09 8.77427E-07 1.77647E-05 6.20754E-05 2.42426E-04
1.05228E-06 4.08094E-06 4.35983E-07 2.93572E-05 6.13188E-06 8.00000E-02
2.31545E-09 4.64472E-10 3.33099E-07 3.58213E-09 3.77864E-09 6.28080E-09
5.58582E-09 1.37598E-06 3.00984E-05 1.06819E-04 2.39064E-04 1.01092E-06
5.18179E-06 7.29945E-07 2.01131E-05 7.56296E-06 8.00000E-02 1.85099E-09
3.51468E-10 3.38445E-07 3.60333E-09 3.66562E-09 5.50735E-09 4.63037E-09
1.65817E-06 3.96124E-05 1.42915E-04 2.36296E-04 8.42891E-07 5.77966E-06
9.70963E-07 1.44160E-05 8.29993E-06 8.00000E-02 1.29552E-09 2.68325E-10
3.13443E-07 3.00148E-09 3.19892E-09 3.93507E-09 3.66484E-09 1.77130E-06
4.60030E-05 1.68430E-04 2.34247E-04 6.33597E-07 6.10051E-06 1.13468E-06
1.11471E-05 8.63928E-06 8.00000E-02 8.44999E-10 2.12863E-10 2.83735E-07
2.23608E-09 2.71248E-09 2.48895E-09 2.92716E-09 1.79907E-06 5.00100E-05
1.85221E-04 2.32897E-04 4.24650E-07 6.30217E-06 1.23047E-06 9.37550E-06
8.78350E-06 8.00000E-02 5.11284E-10 1.72620E-10 2.57534E-07 1.48886E-09
2.26004E-09 1.40175E-09 2.39009E-09 1.79673E-06 5.23593E-05 1.95450E-04
2.32197E-04 2.26162E-07 6.47323E-06 1.27458E-06 8.56486E-06 8.83650E-06
8.00000E-02 2.52848E-10 1.27892E-10 2.35367E-07 7.83990E-10 1.70896E-09
6.16920E-10 1.93741E-09 1.79047E-06 5.34983E-05 2.00530E-04 2.48616E-04
3.44656E-07 8.80622E-07 4.12719E-08 7.22306E-05 1.92766E-06 8.00000E-02
1.29362E-09 3.97279E-10 1.42267E-07 1.12051E-09 1.54366E-09 2.56209E-09
3.81568E-09 4.41669E-07 8.57895E-06 2.97019E-05 2.45162E-04 8.59435E-07
2.84832E-06 2.24773E-07 5.19858E-05 5.80270E-06 8.00000E-02 2.81782E-09
7.21202E-10 3.59964E-07 3.41190E-09 4.07393E-09 6.63409E-09 7.70538E-09
1.30663E-06 2.69861E-05 9.46425E-05 2.40942E-04 1.04976E-06 4.62279E-06
5.56556E-07 3.36391E-05 8.94282E-06 8.00000E-02 2.75221E-09 5.53457E-10
4.35166E-07 4.68798E-09 4.95879E-09 7.83735E-09 6.99677E-09 1.95334E-06
4.43803E-05 1.58581E-04 2.36938E-04 1.00149E-06 5.63451E-06 9.09743E-07
2.13732E-05 1.06789E-05 8.00000E-02 2.05833E-09 3.90651E-10 4.07235E-07
4.34983E-09 4.42593E-09 6.41765E-09 5.39577E-09 2.23718E-06 5.67627E-05
2.06945E-04 2.33650E-04 8.30554E-07 6.09892E-06 1.18549E-06 1.43390E-05
1.14200E-05 8.00000E-02 1.35606E-09 2.80338E-10 3.51440E-07 3.37787E-09
3.59613E-09 4.29639E-09 3.99335E-09 2.28500E-06 6.44361E-05 2.39223E-04
2.31220E-04 6.21540E-07 6.31060E-06 1.36400E-06 1.05467E-05 1.16711E-05
8.00000E-02 8.46255E-10 2.12759E-10 3.01530E-07 2.38496E-09 2.88853E-09
2.58153E-09 3.02806E-09 2.24270E-06 6.89365E-05 2.59610E-04 2.29622E-04
4.14625E-07 6.44073E-06 1.46395E-06 8.58517E-06 1.17295E-05 8.00000E-02
4.98313E-10 1.67978E-10 2.63554E-07 1.52902E-09 2.31695E-09 1.40245E-09
2.38453E-09 2.18952E-06 7.14545E-05 2.71725E-04 2.28794E-04 2.18845E-07
6.57437E-06 1.50829E-06 7.71326E-06 1.17319E-05 8.00000E-02 2.42987E-10
1.22782E-10 2.34716E-07 7.85283E-10 1.70687E-09 6.02871E-10 1.88415E-09
2.15646E-06 7.26428E-05 2.77666E-04 2.50000E-04 0.0          3R
6.18411E-05 0.0          8.00000E-02 0.0          10R    2.50000E-04
0.0          3R    8.18411E-05 0.0          8.00000E-02
0.0         10R    2.50000E-02 0.0          50R    5.00000E-04
0.0          5R    6.99999E-02 0.0          10R    1.00000E-02
0.0         16R    4.99179E-04 2.45048E-07 5.39136E-07 9.78134E-09
1.48305E-10 8.04292E-13 6.99999E-02 5.81168E-12 2.93514E-12 5.87728E-10
2.19492E-12 4.29795E-12 7.15876E-12 2.12907E-11 1.89001E-09 3.17006E-08
1.15740E-07 4.96267E-04 8.68091E-07 2.41832E-06 9.93647E-08 4.68893E-09
7.86009E-11 6.99999E-02 6.02140E-11 1.96398E-11 5.75040E-09 4.27298E-11
6.00116E-11 9.15993E-11 1.46773E-10 2.05561E-08 3.58084E-07 1.31430E-06
4.91033E-04 1.55583E-06 5.33479E-06 3.95592E-07 3.51669E-08 1.21288E-09
6.99999E-02 2.38618E-10 5.58514E-11 2.26040E-09 2.21960E-10 2.55396E-10
4.33783E-10 4.57929E-10 8.98993E-08 1.64092E-06 6.06700E-06 4.84606E-04
1.91430E-06 8.05328E-06 8.99851E-07 1.17101E-07 6.48581E-09 6.99999E-02
4.97955E-10 9.77905E-11 5.10727E-08 5.47381E-10 5.69772E-10 1.00114E-09
8.68199E-10 2.23033E-07 4.29232E-06 1.59968E-05 4.78463E-04 1.84632E-06
9.83562E-06 1.44336E-06 2.39937E-07 1.87482E-08 6.99999E-02 6.73597E-10
1.28478E-10 8.14018E-08 8.51845E-10 8.66004E-10 1.42012E-09 1.19628E-09
3.85272E-07 7.83958E-06 2.94493E-05 4.73388E-04 1.54524E-06 1.08132E-05
```

```
1.88290E-06 3.64930E-07 3.66240E-08 6.99999E-02 6.85695E-10 1.43729E-10
1.05074E-07 9.85716E-10 1.05524E-09 1.45466E-09 1.36965E-09 5.32429E-07
1.14100E-05 4.31650E-05 4.69620E-04 1.16496E-06 1.13485E-05 2.17942E-06
4.64125E-07 5.53758E-08 6.99999E-02 5.75649E-10 1.46807E-10 1.19565E-07
9.23915E-10 1.12649E-09 1.18903E-09 1.41642E-09 6.43341E-07 1.43776E-05
5.46953E-05 4.67132E-04 7.82319E-07 1.16966E-05 2.35217E-06 5.29621E-07
7.04849E-08 6.99999E-02 4.08770E-10 1.39468E-10 1.25527E-07 7.13338E-10
1.09650E-09 7.97383E-10 1.37759E-09 7.15840E-07 1.64692E-05 6.28916E-05
4.65840E-04 4.17091E-07 1.20033E-05 2.43145E-06 5.63047E-07 7.91755E-08
6.99999E-02 2.21553E-10 1.12982E-10 1.23790E-07 4.07024E-10 8.87089E-10
3.93418E-10 1.25833E-09 7.53330E-07 1.75978E-05 6.73367E-05 4.99015E-04
2.49839E-07 6.80629E-07 1.32846E-08 2.42129E-10 1.58600E-12 6.99999E-02
7.24889E-12 3.66040E-12 8.50563E-10 3.20672E-12 6.37198E-12 9.08536E-12
2.70307E-11 2.80091E-09 4.74028E-08 1.73166E-07 4.95525E-04 8.78735E-07
2.94998E-06 1.32100E-07 7.43417E-09 1.50257E-10 6.99999E-02 7.33332E-11
2.39600E-11 8.01636E-09 5.98342E-11 9.45472E-11 1.16410E-10 1.86796E-10
2.96953E-08 5.23534E-07 1.92492E-06 4.89263E-04 1.56302E-06 6.24472E-06
5.15583E-07 5.38853E-08 2.24604E-09 6.99999E-02 2.81687E-10 6.61295E-11
3.00146E-08 2.95394E-10 3.41342E-10 5.38721E-10 5.70909E-10 1.25443E-07
2.33456E-06 8.66046E-06 4.81589E-04 1.90932E-06 9.03120E-06 1.14393E-06
1.73196E-07 1.16464E-08 6.99999E-02 5.68452E-10 1.11796E-10 6.45362E-08
6.93938E-10 7.23771E-10 1.20288E-09 1.04596E-09 2.99932E-07 5.94588E-06
2.22742E-05 4.74274E-04 1.82942E-06 1.06220E-05 1.79085E-06 3.42869E-07
3.27399E-08 6.99999E-02 7.43769E-10 1.41835E-10 9.82597E-08 1.03208E-09
1.04970E-09 1.64579E-09 1.38707E-09 5.00057E-07 1.06050E-05 4.01209E-05
4.68244E-04 1.52322E-06 1.13553E-05 2.28876E-06 5.06036E-07 6.24549E-08
6.99999E-02 7.35970E-10 1.54126E-10 1.22147E-07 1.14996E-09 1.23074E-09
1.63162E-09 1.53519E-09 6.70670E-07 1.51482E-05 5.78159E-05 4.63773E-04
1.14340E-06 1.16973E-05 2.60873E-06 6.28834E-07 9.27218E-08 6.99999E-02
6.05151E-10 1.54175E-10 1.35071E-07 1.04705E-09 1.27602E-09 1.29945E-09
1.54615E-09 7.92459E-07 1.88353E-05 7.23915E-05 4.60826E-04 7.64322E-07
1.19202E-05 2.78695E-06 7.06477E-07 1.16574E-07 6.99999E-02 4.23889E-10
1.44499E-10 1.38816E-07 7.91164E-10 1.20435E-09 8.54527E-10 1.47404E-09
8.68918E-07 2.13928E-05 8.26149E-05 4.59298E-04 4.03861E-07 1.21616E-05
2.86563E-06 7.44990E-07 1.30105E-07 6.99999E-02 2.27931E-10 1.16154E-10
1.34573E-07 4.44181E-10 9.66253E-10 4.15382E-10 1.32363E-09 9.07551E-07
2.27601E-05 8.81164E-05 0.0          2.10000E-04 5.00000E-05
0.0            15R   2.10000E-04 5.00000E-05 0.0            15R
2.10000E-04 5.00000E-05 0.0            15R   2.10000E-04 5.00000E-05
0.0            15R   2.10000E-04 5.00000E-05 0.0            15R
2.10000E-04 5.00000E-05 0.0            15R   2.10000E-04 5.00000E-05
0.0            15R   2.10000E-04 5.00000E-05 0.0            15R
2.10000E-04 5.40000E-05 0.0            15R   2.10000E-04 5.40000E-05
0.0            15R   2.10000E-04 5.40000E-05 0.0            15R
2.10000E-04 5.40000E-05 0.0            15R   2.10000E-04 5.40000E-05
0.0            15R   2.10000E-04 5.40000E-05 0.0            15R
2.10000E-04 5.40000E-05 0.0            15R   2.10000E-04 5.40000E-05
0.0            14R
STOP
END

DCRSPR      CROSS SECTION PROCESSING
        1  1        1  1                                                1
          20            1
CH-232TH-232            232.        3.18   -11            2
THX232TH-232            232.        3.18   -11            2
PA-233PA-233            233.        3.19   -11            1
 U-233 U-233            233.        3.19   -11            1
 U-234 U-234            234.        3.19   -11            2
 U-235 U-235            235.        3.21   -11            1
 U-236 U-236            236.        3.26   -11            3
  C     C                12.                               5
  HE    HE                4.                               5
RECVELRECVEL               1.                               5
 I-135 I-135            135.                               4
XE-135XE-135            135.                               4
```

```
ND-143ND-143              143.                                    4
PM-147PM-147              147.                                    4
PM-148PM-148              148.                                    4
PM148MPM148M              148.                                    4
PM-149PM-149              149.                                    4
SM-149SM-149              149.                                    4
  FP1    FP1              116.                                    4
  FP2    FP2              116.                                    4
END

DUTLIN       MODULE CONTROL INSTRUCTIONS
EXPINS         0 36  0 72
  1000.


  1000.       1200.         1125.       1350.
  0  0  1  0  1  1
             1  1
  0  0 17 22  2  2  8  9  1  0         2

END

DVENTR    ONE DIMENSIONAL AXIAL TRAVERSE TREATED IN TWO DIMENSIONS
001
                                        1500.   +6   .98         5.       -6
0
  3.       -5
  1  1  1       -1               8 40
             1
003
  6  2  2  1  1
004
  1     5.      3   22.5    4   44.274  3   45.     3   45.75   3   46.525
  3   46.525    3   47.328  3   47.328  3  47.328   2  10.
  1   1.        1   1.5
005
 19 20  1  2  3  4  5  6  7  8 23
 19 21  9 10 11 12 13 14 15 16 23
012
 34
  1  1  1  1      0.31
  2  2  1  1      0.305
  3  3  1  1      0.3
  4  5  1  1      0.295
  6  8  1  1      0.29
  9  9  1  1      0.2795
 10 10  1  1      0.275
 11 11  1  1      0.2705
 12 13  1  1      0.266
 14 16  1  1      0.2615
 17 17  1  1      0.31
 18 18  1  1      0.2795
 19 20  3  2      1.
 21 21  3  3      1.
 22 22  2  1      1.
 23 23  3  3      1.
  0
  1  1  2 20          .61
  2  2  2  1        .31    1
  3  3  2  2        .305   1
  4  4  2  3        .3     1
  5  6  2  4        .295   1
  7  9  2  6        .29    1
 10 10  2 21          .67
```

```
 11 11  2  9        .3405  1
 12 12  2 10        .335   1
 13 13  2 11        .3295  1
 14 15  2 12        .324   1
 16 18  2 14        .3185  1
 19 19  3  1        .62    1
 20 20  3  2        .61    1
 21 21  3  3        .6     1
 22 23  3  4        .59    1
 24 26  3  6        .58    1
 27 27  3  9        .62    1
 28 28  3 10        .61    1
 29 29  3 11        .6     1
 30 31  3 12        .59    1
 32 34  3 14        .58    1
  0
013
 17
 17
TH-232PA-233 U-233 U-234 U-235 U-236  C     I-135XE-135PM-147PM-148PM148M
PM-149SM-149ND-143  FP1   FP2
 17
THX232PA-233 U-233 U-234 U-235 U-236  C     I-135XE-135PM-147PM-148PM148M
PM-149SM-149ND-143  FP1   FP2
  3
  C      HE  RECVRL
020     -1
028
  1

  9                   1  3
  1  3
 U-235   2.      -5
  9 11
 U-235   2.      -5
 17 18
 U-235   1.      -5

END

DUTLIN       MODULE CONTROL INSTRUCTIONS
DTNINS         0 13  0 72
                                        1500.   +6   .98        5.      -6
0
  3.       -5
0                          2                    1                8
                        1                    1

FXPINS         0  6  0 48
     0.        0.4
        0  0  1  0  1
                 2

END
```

MODULE CONTROL1 IS FINISHED.  USER COMPLETION CODE  0000. CPU TIME USED  71.68 (SECONDS). I/O'S USED  12897

```
BOLD VENTURE VERS-2 RUN AT X-10 ON 360/ 91. CONTROL MOD=CONTROL1, DATE=12-02-78, TIME=01.49.43, JOBNAME=GWCSAMP .

INITILIZATION, REFERENCE - REMAINING I/O=  29.94, CPU MIN=   5.00

RUN TITLE AND CONTROL MODULE DATA
 DEPLETION BENCHMARK COMPARING VARIOUS SOLUTION METHODS
 10000     0     0     0     0     0     0     0     0  0  0  1  0  0  0
  1 13  1 13  1 13  1 13


                        INITIAL I/O FILE MANAGEMENT TABLES
                    FILE NAME SUPPLIED BY
                 ------------------------------                                  USER
FILE NUMBER       SEEK   USER-EXIST   USER-STACK      VERSION      WRITTEN    IDENTIFICATION
    10           CONTRL                                  1            1      GWCSAMP   12-02-78


MODULES TO BE ACCESSED IN ORDER
     1    13     1    13     1    13     1    13

READ DATA AND ACCESS MODULE  1    - REMAINING I/O=  29.86, CPU MIN=   4.99

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  29.03, CPU MIN=   4.94

ACCESS MODULES 13  0  0  0  0     - REMAINING I/O=  28.99, CPU MIN=   4.93
     TIME AFTER EXPOSURE   50.000 DAYS, ESTIMATED K  0.0     , FISSILE INVENTORY 2.709593E-05 KG, CONVERSION RATIO(MB)    0.76453

ACCESS INPUT MODULE  1            - REMAINING I/O=  28.77, CPU MIN=   4.91

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  28.51, CPU MIN=   4.90

ACCESS MODULES 13  0  0  0  0     - REMAINING I/O=  28.46, CPU MIN=   4.89
     TIME AFTER EXPOSURE   50.000 DAYS, ESTIMATED K  0.0     , FISSILE INVENTORY 2.709414E-05 KG, CONVERSION RATIO(MB)    0.76428

ACCESS INPUT MODULE  1            - REMAINING I/O=  28.25, CPU MIN=   4.87

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  27.98, CPU MIN=   4.85

ACCESS MODULES 13  0  0  0  0     - REMAINING I/O=  27.94, CPU MIN=   4.85
     TIME AFTER EXPOSURE   50.000 DAYS, ESTIMATED K  0.0     , FISSILE INVENTORY 2.709548E-05 KG, CONVERSION RATIO(MB)    0.76447

ACCESS INPUT MODULE  1            - REMAINING I/O=  27.72, CPU MIN=   4.82

ACCESS MODULES 13  0  0  0  0     - REMAINING I/O=  27.46, CPU MIN=   4.80
     TIME AFTER EXPOSURE   50.000 DAYS, ESTIMATED K  0.0     , FISSILE INVENTORY 2.709424E-05 KG, CONVERSION RATIO(MB)    0.76429

                        FINAL I/O FILE MANAGEMENT TABLES
                    FILE NAME SUPPLIED BY
                 ------------------------------                                  USER
FILE NUMBER       SEEK   USER-EXIST   USER-STACK      VERSION      WRITTEN    IDENTIFICATION
    10           CONTRL                                  1            1      LASL I    NPUT P
    11           GRUPXS                                  1            1      LASL I    NPUT P
    12           GEODST                                  1            1      LASL I    NPUT P
    13           NDXSRF                                  1            1      LASL I    NPUT P
    14           ZNATDN                                  1            1      USER      IDENT
    15           RZFLUX                                  1            1      LASL I    NPUT P
    16           EXPOSE                                  1            1      LASL I    NPUT P

WRAP-UP NOW COMPLETE. -- DRIVER TO SEEK NEW CASE - REMAINING I/O=  27.19, CPU MIN=   4.57 - TIME=01.52.24
```

```
BOLD VENTURE VERS-2 RUN AT X-10 ON 360/ 91. CONTROL MOD=CONTROL1, DATE=12-02-78, TIME=01.52.26, JOBNAME=GWCSAMP .

INITILIZATION, REFERENCE - REMAINING I/O=  27.14, CPU MIN=   4.57

RUN TITLE AND CONTROL MODULE DATA
 BREEDER REACTOR SAMPLE PROBLEM FOR THE BURNER CODE
 10000    0    0    0    0    0    0    0    0  0  0  1  0  0  0
  1  2  7  2 13  7  2 13  7 13  7


                        INITIAL I/O FILE MANAGEMENT TABLES
                     FILE NAME SUPPLIED BY
                 ------------------------------                                  USER
FILE NUMBER       SEEK   USER-EXIST   USER-STACK       VERSION       WRITTEN    IDENTIFICATION
    10           CONTRL                                   1             1      GWCSAMP   12-02-78


MODULES TO BE ACCESSED IN ORDER
     1    2    7    2   13    7    2   13    7   13    7

READ DATA AND ACCESS MODULE  1    - REMAINING I/O=  27.06, CPU MIN=   4.57

READ DATA FOR A SPECIAL PROCESSOR - REMAINING I/O=  26.52, CPU MIN=   4.51

ACCESS PROCESSOR 'DVENTR'         - REMAINING I/O=  26.47, CPU MIN=   4.51

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  26.28, CPU MIN=   4.50

ACCESS MODULES  7  0  0  0  0     - REMAINING I/O=  26.21, CPU MIN=   4.49
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    35  -4.46210D-05   0.0          5.27530E 02    1.0123475
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   1.42317   1.45807   3.13082E 10

ACCESS PROCESSOR 'DUTLIN'         - REMAINING I/O=  25.20, CPU MIN=   4.39

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  25.09, CPU MIN=   4.39

ACCESS MODULES 13  0  0  0  0     - REMAINING I/O=  25.04, CPU MIN=   4.38
     TIME AFTER EXPOSURE   75.000 DAYS, ESTIMATED K  1.015330, FISSILE INVENTORY 3.244736E 03 KG, CONVERSION RATIO(MB)    1.40186

ACCESS MODULES  7  0  0  0  0     - REMAINING I/O=  24.56, CPU MIN=   4.33
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    21   4.54113D-05   0.0          5.20281E 02    1.0139118
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   1.40633   1.44555   3.13484E 10

ACCESS PROCESSOR 'DUTLIN'         - REMAINING I/O=  23.56, CPU MIN=   4.25

ACCESS MODULES 13  0  0  0  0     - REMAINING I/O=  23.45, CPU MIN=   4.25
     TIME AFTER EXPOSURE  150.000 DAYS, ESTIMATED K  1.016664, FISSILE INVENTORY 3.322609E 03 KG, CONVERSION RATIO(MB)    1.38589

ACCESS MODULES  7 13  0  0  0     - REMAINING I/O=  23.01, CPU MIN=   4.21
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    19   4.43645D-05   0.0          5.12912E 02    1.0152505
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   1.39038   1.43328   3.13853E 10
     TIME AFTER EXPOSURE  225.000 DAYS, ESTIMATED K  1.017835, FISSILE INVENTORY 3.397509E 03 KG, CONVERSION RATIO(MB)    1.37074

ACCESS MODULES  7  0  0  0  0     - REMAINING I/O=  21.59, CPU MIN=   4.10
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    19   4.40682D-05   0.0          5.05562E 02    1.0163992
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   1.37532   1.42136   3.14197E 10

                        FINAL I/O FILE MANAGEMENT TABLES
                     FILE NAME SUPPLIED BY
                 ------------------------------                                  USER
FILE NUMBER       SEEK   USER-EXIST   USER-STACK       VERSION       WRITTEN    IDENTIFICATION
    10           CONTRL                                   1             1      GWCSAMP   12-02-78
    11           GRUPXS                                   1             1      LASL I    NPUT P
```

| | | | | | |
|---|---|---|---|---|---|
| 12 | EXPOSE | 1 | 1 | LASL I | NPUT P |
| 13 | GEODST | 1 | 1 | DVENTR | INPUT |
| 14 | NDXSRP | 1 | 1 | DVENTR | INPUT |
| 15 | ZNATDN | 1 | 1 | DVENTR | INPUT |
| 16 | RZFLUX | 1 | 1 | GWCSAMP | 12-02-78 |
| 17 | RTFLUX | 1 | 1 | GWCSAMP | 12-02-78 |
| 18 | ZNATDN | 2 | 1 | GWCSAMP | 12-02-78 |
| 19 | ZNPOWD | 1 | 1 | GWCSAMP | 12-02-78 |
| 20 | EXPOHT | 1 | 1 | GWCSAMP | 12-02-78 |
| 30 | PTATDN | 1 | 1 | GWCSAMP | 12-02-78 |
| 31 | ZNATDN | 3 | 1 | GWCSAMP | 12-02-78 |
| 32 | PTATDN | 2 | 1 | GWCSAMP | 12-02-78 |
| 33 | ZNATDN | 4 | 1 | GWCSAMP | 12-02-78 |
| 34 | PTATDN | 3 | 1 | GWCSAMP | 12-02-78 |

WRAP-UP NOW COMPLETE. -- DRIVER TO SEEK NEW CASE - REMAINING I/O= 20.47, CPU MIN= 4.01 - TIME=01.57.42

```
BOLD VENTURE VERS-2 RUN AT X-10 ON 360/ 91. CONTROL MOD=CONTROL1, DATE=12-02-78, TIME=01.57.44, JOBNAME=GWCSAMP .

INITILIZATION, REFERENCE - REMAINING I/O=  20.41, CPU MIN=   4.01

RUN TITLE AND CONTROL MODULE DATA
 GAS COOLED REACTOR PROBLEM, (1-D MODELED AS 2-D) BURNER CODE TEST CASE
 10000     0     0     0     0     0     1     0     0  0  0  1  0  0  0
  1  2  2  6  2  7 13 -2  3  3  2  7 13  7 -2  3
  0        0        0        0        0        0        0        0        0


                    INITIAL I/O FILE MANAGEMENT TABLES
                 FILE NAME SUPPLIED BY
              ------------------------------                                  USER
FILE NUMBER     SEEK   USER-EXIST   USER-STACK      VERSION      WRITTEN   IDENTIFICATION
    10         CONTRL                                  1            1     GWCSAMP   12-02-78


MODULES TO BE ACCESSED IN ORDER
     1     2     2     6     2     7    13     7    13     7    13     3     2     7    13     7    13     7    13     7

READ DATA AND ACCESS MODULE  1    - REMAINING I/O=  20.33, CPU MIN=   4.00

READ DATA FOR A SPECIAL PROCESSOR - REMAINING I/O=  19.61, CPU MIN=   3.91

ACCESS PROCESSOR 'DCRSPR'         - REMAINING I/O=  19.56, CPU MIN=   3.91

READ DATA FOR A SPECIAL PROCESSOR - REMAINING I/O=  19.42, CPU MIN=   3.90

ACCESS PROCESSOR 'DUTLIN'         - REMAINING I/O=  19.38, CPU MIN=   3.90

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  19.27, CPU MIN=   3.89

ACCESS MODULES  6  0  0  0  0     - REMAINING I/O=  19.22, CPU MIN=   3.89

ACCESS PROCESSOR 'DVENTR'         - REMAINING I/O=  17.79, CPU MIN=   3.85

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  17.60, CPU MIN=   3.84

ACCESS MODULES  7 13  0  0  0     - REMAINING I/O=  17.50, CPU MIN=   3.83
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    41  -3.81815D-05   2.50331E-04   1.60327E 01    1.0000008
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59666   0.59666   3.89521E 10
     TIME AFTER EXPOSURE12999.996 DAYS, ESTIMATED K  0.999704, FISSILE INVENTORY 8.806904E 02 KG, CONVERSION RATIO(MB)    0.59794
     EXPOSURE TIME STEP 1000.000 DAYS,                TOTAL POWER 1.499983E 09 W(TH)
     ZONE    - PEAK POWER DENSITY 4.579884E 01 W(TH)/CC, PATH POWER 1.080818E 09 W(TH), FISSILE FEED RATE 1.320279E 00 KG/DAY
     SUBZONE - PEAK POWER DENSITY 1.271862E 01 W(TH)/CC, PATH POWER 4.191695E 08 W(TH), FISSILE FEED RATE 0.0          KG/DAY

ACCESS MODULES  7 13  0  0  0     - REMAINING I/O=  15.65, CPU MIN=   3.62
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    27   6.91401D-07   4.90232E-04   1.60300E 01    0.9999999
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59666   0.59666   3.89519E 10
     TIME AFTER EXPOSURE13999.996 DAYS, ESTIMATED K  0.999730, FISSILE INVENTORY 8.807720E 02 KG, CONVERSION RATIO(MB)    0.59790
     EXPOSURE TIME STEP 1000.000 DAYS,                TOTAL POWER 1.499998E 09 W(TH)
     ZONE    - PEAK POWER DENSITY 4.579337E 01 W(TH)/CC, PATH POWER 1.080858E 09 W(TH), FISSILE FEED RATE 1.320368E 00 KG/DAY
     SUBZONE - PEAK POWER DENSITY 1.271731E 01 W(TH)/CC, PATH POWER 4.191432E 08 W(TH), FISSILE FEED RATE 0.0          KG/DAY

ACCESS MODULES  7 13  0  0  0     - REMAINING I/O=  13.89, CPU MIN=   3.45
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -     2  -4.28486D-05  -1.80996E-06   1.60298E 01    1.0000034
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59665   0.59666   3.89519E 10
     TIME AFTER EXPOSURE14999.996 DAYS, ESTIMATED K  0.999729, FISSILE INVENTORY 8.807710E 02 KG, CONVERSION RATIO(MB)    0.59791
     EXPOSURE TIME STEP 1000.000 DAYS,                TOTAL POWER 1.499993E 09 W(TH)
     ZONE    - PEAK POWER DENSITY 4.579395E 01 W(TH)/CC, PATH POWER 1.080858E 09 W(TH), FISSILE FEED RATE 1.320367E 00 KG/DAY
     SUBZONE - PEAK POWER DENSITY 1.271698E 01 W(TH)/CC, PATH POWER 4.191419E 08 W(TH), FISSILE FEED RATE 0.0          KG/DAY
```

```
ACCESS MODULES  3  0  0  0  0     - REMAINING I/O=  12.14, CPU MIN=   3.31

ACCESS PROCESSOR 'DUTLIN'         - REMAINING I/O=  12.04, CPU MIN=   3.30

ACCESS MODULES  7 13  0  0  0     - REMAINING I/O=  11.92, CPU MIN=   3.30
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -     1  -1.11982D-05   0.0          1.60297E 01    1.0000022
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59665   0.59666   3.89519E 10
     SHUTDOWN CALCULATION DONE FOR TIME    0.400 DAYS

ACCESS MODULES  7 13  0  0  0     - REMAINING I/O=  10.83, CPU MIN=   3.22
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    32   1.23060D-05   0.0          1.59971E 01    0.9581648
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.61099   0.52325   3.90202E 10
     SHUTDOWN CALCULATION DONE FOR TIME    0.400 DAYS

ACCESS MODULES  7 13  0  0  0     - REMAINING I/O=   9.73, CPU MIN=   3.08
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    34   1.15866D-05   0.0          1.60305E 01    0.9723847
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.60583   0.54871   3.89859E 10
     SHUTDOWN CALCULATION DONE FOR TIME    0.400 DAYS

ACCESS MODULES  7  0  0  0  0     - REMAINING I/O=   8.62, CPU MIN=   2.94
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    31  -2.04223D-05   0.0          1.60641E 01    0.9925759
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59881   0.58375   3.89416E 10
```

FINAL I/O FILE MANAGEMENT TABLES

| FILE NUMBER | FILE NAME SUPPLIED BY: SEEK | USER-EXIST | USER-STACK | VERSION | WRITTEN | USER IDENTIFICATION | |
|---|---|---|---|---|---|---|---|
| 10 | CONTRL | | | 1 | 1 | GWCSAMP | 12-02-78 |
| 11 | ISOTXS | | | 1 | 1 | LASL I | NPUT P |
| 12 | EXPOSE | | | 1 | 1 | LASL I | NPUT P |
| 14 | ZNATDN | | | 3 | 1 | GWCSAMP | 12-02-78 |
| 15 | CXSPRR | | | 1 | 1 | CONSTI | PATION |
| 16 | ISOTXS | | | 2 | 1 | LASL I | NPUT P |
| 17 | GRUPXS | | | 1 | 1 | ORNL M | ADE |
| 18 | GEODST | | | 1 | 1 | DVENTR | INPUT |
| 19 | NDXSRF | | | 1 | 1 | DVENTR | INPUT |
| 20 | SEARCH | | | 1 | 1 | DVENTR | INPUT |
| 30 | ZNATDN | | | 4 | 1 | GWCSAMP | 12-02-78 |
| 31 | RZFLUX | | | 1 | 1 | GWCSAMP | 12-02-78 |
| 32 | RTFLUX | | | 1 | 1 | GWCSAMP | 12-02-78 |
| 33 | ZNPOWD | | | 1 | 1 | GWCSAMP | 12-02-78 |
| 34 | QNATDN | | | 1 | 1 | GWCSAMP | 12-02-78 |

```
WRAP-UP NOW COMPLETE. -- DRIVER TO SEEK NEW CASE - REMAINING I/O=   7.57, CPU MIN=   2.82 - TIME=02.07.28
```

CASE TITLE - MATRIX EXPONENTIAL SOLUTION
ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)

RITE CONTAINER ARRAYS, CONTROL 6 DATA 1

GRUPXS TITLE
TWO-GROUP DEPLETION PROBLEM (BENCHMARK FROM SRL) (N,T) IS (N,G)M

NISOU - THE NUMBER OF DIFFERENT UNIQUE ISOTOPES IN SYSTEM IS 35
NISOA - THE NUMBER OF DIFFERENT ABSOLUTE ISOTOPES IN SYSTEM IS 35
NUCLAS - THE NUMBER OF DIFFERENT ISOTOPE CLASSES IN SYSTEM IS 4

| NO. | NORR | NOSS | NABSOL | HABSOL | MCLAS | ICLAS |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | U234 | 3 | 1 |
| 2 | 2 | 2 | 2 | U235 | 1 | 2 |
| 3 | 3 | 3 | 3 | U236 | 3 | 3 |
| 4 | 4 | 4 | 4 | U237 | 3 | 4 |
| 5 | 5 | 5 | 5 | U238 | 2 | 0 |
| 6 | 6 | 6 | 6 | U239 | 3 | 0 |
| 7 | 7 | 7 | 7 | NP237 | 3 | 0 |
| 8 | 8 | 8 | 8 | NP238 | 3 | 0 |
| 9 | 9 | 9 | 9 | NP239 | 3 | 0 |
| 10 | 10 | 10 | 10 | NP240 | 3 | 0 |
| 11 | 11 | 11 | 11 | PU238 | 3 | 0 |
| 12 | 12 | 12 | 12 | PU239 | 1 | 0 |
| 13 | 13 | 13 | 13 | PU240 | 2 | 0 |
| 14 | 14 | 14 | 14 | PU241 | 3 | 0 |
| 15 | 15 | 15 | 15 | PU242 | 3 | 0 |
| 16 | 16 | 16 | 16 | PU243 | 3 | 0 |
| 17 | 17 | 17 | 17 | AM241 | 3 | 0 |
| 18 | 18 | 18 | 18 | AM242 | 3 | 0 |
| 19 | 19 | 19 | 19 | AM242M | 3 | 0 |
| 20 | 20 | 20 | 20 | AM243 | 3 | 0 |
| 21 | 21 | 21 | 21 | AM244 | 3 | 0 |
| 22 | 22 | 22 | 22 | CM242 | 3 | 0 |
| 23 | 23 | 23 | 23 | CM243 | 3 | 0 |
| 24 | 24 | 24 | 24 | CM244 | 3 | 0 |
| 25 | 25 | 25 | 25 | CM245 | 3 | 0 |
| 26 | 26 | 26 | 26 | I135 | 4 | 0 |
| 27 | 27 | 27 | 27 | XE135 | 4 | 0 |
| 28 | 28 | 28 | 28 | CS135 | 4 | 0 |
| 29 | 29 | 29 | 29 | ND147 | 4 | 0 |
| 30 | 30 | 30 | 30 | PM147 | 4 | 0 |
| 31 | 31 | 31 | 31 | PM148 | 4 | 0 |
| 32 | 32 | 32 | 32 | PM148M | 4 | 0 |
| 33 | 33 | 33 | 33 | PM149 | 4 | 0 |
| 34 | 34 | 34 | 34 | SM149 | 4 | 0 |
| 35 | 35 | 35 | 35 | FPLL | 4 | 0 |

NZCLAS - THE NUMBER OF DIFFERENT ZONE CLASSES IS 1

| NO. | NZCLS | IZCLS |
|---|---|---|

```
     1       1       1

METHOD OF SOLUTION - MATRIX EXPONENTIAL

      * TWO-GROUP DEPLETION PROBLEM (BENCHMARK FROM SRL)  (N,T) IS (N,G)M      *

            EXPOSURE NUCLIDES
            NUCLIDE NAMES ARE ABSOLUTE
         1)  U234
         2)  U235
         3)  U236
         4)  U237
         5)  U238
         6)  U239
         7)  NP237
         8)  NP238
         9)  NP239
        10)  NP240
        11)  PU238
        12)  PU239
        13)  PU240
        14)  PU241
        15)  PU242
        16)  PU243
        17)  AM241
        18)  AM242
        19)  AM242M
        20)  AM243
        21)  AM244
        22)  CM242
        23)  CM243
        24)  CM244
        25)  CM245
        26)  I135
        27)  XE135
        28)  CS135
        29)  ND147
        30)  PM147
        31)  PM148
        32)  PM148M
        33)  PM149
        34)  SM149
        35)  FPLL

                                 DECAY CONSTANTS (1/SEC)

         1)  I135        26      2.873999E-05
         2)  XE135       27      2.092999E-05
         3)  ND147       29      7.227997E-07
         4)  PM147       30      8.288996E-09
         5)  PM148       31      1.487999E-06
         6)  PM148M      32      1.975999E-07
         7)  PM149       33      3.625997E-06
         8)  U237         4      1.189998E-06
         9)  U239         6      4.914999E-04
        10)  NP238        8      3.819997E-06
        11)  NP239        9      3.409998E-06
        12)  NP240       10      1.582999E-03
        13)  PU241       14      1.679999E-09
        14)  PU243       16      3.885999E-05
        15)  AM242       18      1.195999E-05
        16)  AM244       21      4.439999E-04
        17)  PU238       11      2.549998E-10
        18)  AM241       17      5.090001E-11
        19)  CM242       22      4.909998E-08
        20)  CM243       23      6.859999E-10
```

21) CM244 24 1.250000E-09

FISSION PRODUCT YIELD DATA

ENERGY RANGE 1 CUTOFF AT 0.0 EV

| FISSION PRODUCT | | | FISSIONING NUCLIDE 1) U235 2 | 2) U238 5 | 3) PU239 12 | 4) PU241 14 |
|---|---|---|---|---|---|---|
| 1) | I135 | 26 | 0.061700 | 0.057800 | 0.069300 | 0.062600 |
| 2) | XE135 | 27 | 0.002400 | 0.002200 | 0.002700 | 0.002400 |
| 3) | PM149 | 33 | 0.011300 | 0.021000 | 0.013000 | 0.012000 |
| 4) | ND147 | 29 | 0.023600 | 0.028000 | 0.020500 | 0.022000 |
| 5) | FPLL | 35 | 0.901000 | 0.891000 | 0.894500 | 0.901000 |

TRANSMUTATIONS SPECIFIED

| | PARENT | DAUGHTER | PROCESS | FRACTION | | | |
|---|---|---|---|---|---|---|---|
| 1) | U234 | U235 | (N,G) | 1.000000 | 1 | 2 | 2 |
| 2) | U235 | U236 | (N,G) | 1.000000 | 2 | 3 | 2 |
| 3) | U236 | U237 | (N,G) | 1.000000 | 3 | 4 | 2 |
| 4) | U237 | U238 | (N,G) | 1.000000 | 4 | 5 | 2 |
| 5) | U237 | NP237 | DECAY | 1.000000 | 4 | 7 | 1 |
| 6) | U238 | U239 | (N,G) | 1.000000 | 5 | 6 | 2 |
| 7) | U239 | NP239 | DECAY | 1.000000 | 6 | 9 | 1 |
| 8) | NP237 | NP238 | (N,G) | 1.000000 | 7 | 8 | 2 |
| 9) | NP238 | NP239 | (N,G) | 1.000000 | 8 | 9 | 2 |
| 10) | NP238 | PU238 | DECAY | 1.000000 | 8 | 11 | 1 |
| 11) | NP239 | NP240 | (N,G) | 1.000000 | 9 | 10 | 2 |
| 12) | NP239 | PU239 | DECAY | 1.000000 | 9 | 12 | 1 |
| 13) | NP240 | PU240 | DECAY | 1.000000 | 10 | 13 | 1 |
| 14) | PU238 | PU239 | (N,G) | 1.000000 | 11 | 12 | 2 |
| 15) | PU239 | PU240 | (N,G) | 1.000000 | 12 | 13 | 2 |
| 16) | PU240 | PU241 | (N,G) | 1.000000 | 13 | 14 | 2 |
| 17) | PU241 | PU242 | (N,G) | 1.000000 | 14 | 15 | 2 |
| 18) | PU241 | AM241 | DECAY | 1.000000 | 14 | 17 | 1 |
| 19) | PU242 | PU243 | (N,G) | 1.000000 | 15 | 16 | 2 |
| 20) | PU243 | AM243 | DECAY | 1.000000 | 16 | 20 | 1 |
| 21) | AM241 | AM242 | (N,G) | 1.000000 | 17 | 18 | 2 |
| 22) | AM241 | AM242M | (N,T) | 1.000000 | 17 | 19 | 7 |
| 23) | AM242 | AM243 | (N,G) | 1.000000 | 18 | 20 | 2 |
| 24) | AM242M | AM243 | (N,G) | 1.000000 | 19 | 20 | 2 |
| 25) | AM243 | AM244 | (N,G) | 1.000000 | 20 | 21 | 2 |
| 26) | AM244 | CM244 | DECAY | 1.000000 | 21 | 24 | 1 |
| 27) | CM242 | CM243 | (N,G) | 1.000000 | 22 | 23 | 2 |
| 28) | CM243 | CM244 | (N,G) | 1.000000 | 23 | 24 | 2 |
| 29) | CM244 | CM245 | (N,G) | 1.000000 | 24 | 25 | 2 |
| 30) | U235 | U234 | (N,2N) | 1.000000 | 2 | 1 | 5 |
| 31) | U238 | U237 | (N,2N) | 1.000000 | 5 | 4 | 5 |
| 32) | AM242 | CM242 | DECAY | 0.830270 | 18 | 22 | 830271 |
| 33) | AM242 | PU242 | DECAY | 0.169730 | 18 | 15 | 169731 |
| 34) | PU238 | U234 | DECAY | 1.000000 | 11 | 1 | 1 |
| 35) | AM241 | NP237 | DECAY | 1.000000 | 17 | 7 | 1 |
| 36) | CM242 | PU238 | DECAY | 1.000000 | 22 | 11 | 1 |
| 37) | CM243 | PU239 | DECAY | 1.000000 | 23 | 12 | 1 |
| 38) | CM244 | PU240 | DECAY | 1.000000 | 24 | 13 | 1 |
| 39) | I135 | XE135 | DECAY | 1.000000 | 26 | 27 | 1 |
| 40) | XE135 | CS135 | DECAY | 1.000000 | 27 | 28 | 1 |
| 41) | ND147 | PM147 | DECAY | 1.000000 | 29 | 30 | 1 |
| 42) | PM147 | PM148 | (N,G) | 1.000000 | 30 | 31 | 2 |
| 43) | PM147 | PM148M | (N,T) | 1.000000 | 30 | 32 | 7 |
| 44) | PM148 | PM149 | (N,G) | 1.000000 | 31 | 33 | 2 |
| 45) | PM148M | PM149 | (N,G) | 1.000000 | 32 | 33 | 2 |
| 46) | PM149 | SM149 | DECAY | 1.000000 | 33 | 34 | 1 |

```
NOTE - ENERGY PER FISSION NOT DEFINED IN CROSS SECTIONS, DEFAULTED TO  3.20E-11 AND ENERGY PER CAPTURE DEFAULTED TO  0.0

POSITION IN DENSITY ARRAY FOR EACH NUCLIDE IN EXPOSURE DATA
SET       1  NUCLIDES INCLUDED   35
IHNUC     1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20
IHNUC    21   22   23   24   25   26   27   28   29   30   31   32   33   34   35

MAXIMUM ARRAY SIZE USED FOR INITIAL PROCESSING IS    1379

STORAGE REQUIRED FOR BASIC DATA IS    1379

        STORAGE SUPPLIED IS    10000
MAXIMUM STORAGE REQUIRED IS     3239
MINIMUM STORAGE REQUIRED IS     3239

 MODRR  =  0 MODRRF = -1

MEMORY ACTUALLY USED WILL BE    3239

INTERFACE FILE RZFLUX VERSION   1 UNIT  15
 TIME  =  0.0           POWER =  1.000000E 06
 VOL   =  1.000000E 00  EFFK  =  1.000000E 00
 FIVS  =  0.0           DKDS  =  0.0
 TNL   =  1.000000E 00  TNA   =  1.000000E 00
 TNSL  =  0.0           TNBL  =  0.0
 TNBAL =  0.0           TNCRA =  0.0
 FC    =  1.000000E 00  CRTF  =  1.000000E 00
 X3    =  0.0           X4    =  0.0
 ITPS  =      0         NZONE =      1
 NGROUP=      2         NCY   =      0

RZFLUX REFERENCE TIME         0.0    DAYS INDICATOR       1

INTERFACE FILE INATDN VERSION   1 UNIT  14
 TIME  =  0.0
 NCY   =      0         NTZSZ =      1
 NNS   =     35         NBLKAD=      1
```

SPECIFIC REACTION RATES (B/(CM**2-SEC))

| ZONE 1 | | | SET 1 | | | | | |
|---|---|---|---|---|---|---|---|---|
| POS. DEN. | POS. SIG. | IDENTIFIER UNIQUE | ABSORPTION | FISSION | PRODUCTION | CAPTURE(NG) | (N,2N) | (N,T) |
| 1 | 1 | U234 | 2.74812E 16 | 2.62337E 14 | 0.0 | 2.72189E 16 | 0.0 | 0.0 |
| 2 | 2 | U235 | 5.50543E 16 | 4.47525E 16 | 0.0 | 1.03002E 16 | 1.59756E 12 | 0.0 |
| 3 | 3 | U236 | 1.08104E 16 | 1.02274E 14 | 0.0 | 1.07081E 16 | 0.0 | 0.0 |
| 4 | 4 | U237 | 4.38055E 16 | 2.44402E 14 | 0.0 | 4.35611E 16 | 0.0 | 0.0 |
| 5 | 5 | U238 | 5.62907E 14 | 4.99204E 13 | 0.0 | 5.10288E 14 | 2.69874E 12 | 0.0 |
| 6 | 6 | U239 | 3.01167E 15 | 1.22095E 15 | 0.0 | 1.79072E 15 | 0.0 | 0.0 |
| 7 | 7 | NP237 | 3.30554E 16 | 2.59318E 14 | 0.0 | 3.27960E 16 | 1.23632E 11 | 0.0 |
| 8 | 8 | NP238 | 1.85464E 17 | 1.68311E 17 | 0.0 | 1.71525E 16 | 0.0 | 0.0 |
| 9 | 9 | NP239 | 2.03430E 16 | 0.0 | 0.0 | 2.03430E 16 | 0.0 | 0.0 |
| 10 | 10 | NP240 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 11 | PU238 | 3.64198E 16 | 1.86080E 15 | 0.0 | 3.45590E 16 | 0.0 | 0.0 |
| 12 | 12 | PU239 | 1.51735E 17 | 9.63342E 16 | 0.0 | 5.54010E 16 | 0.0 | 0.0 |
| 13 | 13 | PU240 | 2.49215E 17 | 3.35821E 14 | 0.0 | 2.48879E 17 | 0.0 | 0.0 |
| 14 | 14 | PU241 | 1.49968E 17 | 1.06861E 17 | 0.0 | 4.31074E 16 | 0.0 | 0.0 |
| 15 | 15 | PU242 | 3.33723E 16 | 2.66731E 14 | 0.0 | 3.33056E 16 | 0.0 | 0.0 |
| 16 | 16 | PU243 | 4.21468E 16 | 2.99481E 16 | 0.0 | 1.21987E 16 | 0.0 | 0.0 |
| 17 | 17 | AM241 | 1.30832E 17 | 1.28037E 15 | 0.0 | 1.15493E 17 | 0.0 | 1.40585E 16 |
| 18 | 18 | AM242 | 1.94561E 17 | 1.93126E 17 | 0.0 | 1.43498E 15 | 0.0 | 0.0 |
| 19 | 19 | AM242M | 6.35907E 17 | 5.12254E 17 | 0.0 | 1.23653E 17 | 0.0 | 0.0 |
| 20 | 20 | AM243 | 6.23381E 16 | 1.88934E 14 | 0.0 | 6.21492E 16 | 0.0 | 0.0 |
| 21 | 21 | AM244 | 1.17212E 17 | 1.17212E 17 | 0.0 | 0.0 | 0.0 | 0.0 |
| 22 | 22 | CM242 | 3.30711E 15 | 2.08817E 14 | 0.0 | 3.09829E 15 | 0.0 | 0.0 |
| 23 | 23 | CM243 | 1.28853E 17 | 1.05372E 17 | 0.0 | 2.34810E 16 | 0.0 | 0.0 |
| 24 | 24 | CM244 | 2.16894E 16 | 1.04483E 15 | 0.0 | 2.06446E 16 | 0.0 | 0.0 |
| 25 | 25 | CM245 | 1.81330E 17 | 1.57516E 17 | 0.0 | 2.38146E 16 | 0.0 | 0.0 |
| 26 | 26 | I135 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 27 | 27 | XE135 | 2.67175E 20 | 0.0 | 0.0 | 2.67175E 20 | 0.0 | 0.0 |
| 28 | 28 | CS135 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | 29 | ND147 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30 | 30 | PM147 | 1.69191E 17 | 0.0 | 0.0 | 8.93174E 16 | 0.0 | 7.98735E 16 |
| 31 | 31 | PM148 | 2.17267E 18 | 0.0 | 0.0 | 2.17267E 18 | 0.0 | 0.0 |
| 32 | 32 | PM148M | 3.68903E 18 | 0.0 | 0.0 | 3.68903E 18 | 0.0 | 0.0 |
| 33 | 33 | PM149 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 34 | 34 | SM149 | 5.93005E 18 | 0.0 | 0.0 | 5.93005E 18 | 0.0 | 0.0 |
| 35 | 35 | FPLL | 1.12406E 16 | 0.0 | 0.0 | 1.12406E 16 | 0.0 | 0.0 |

START OF STEP ATOM DENSITIES AT TIME 0.0 DAYS

ZONE NUMBER 1

| | |
|---|---|
| U235 | 7.400298E-05 |
| U238 | 6.935995E-03 |

EXPOSURE TIME STEP STARTS AT 0.0 DAYS

EXPOSURE TIME STEP IS 5.000000E 01 DAYS ( 4.320000E 06 SECONDS ) THE NUMBER OF SUBSTEPS IS 1

MATRIX EXPONENTIAL OPTIONS
EXPAND MATRIX SERIES TWO TERMS AT A TIME
DIAGONAL TRANSFORMATION
NO EQUILIBRIUM ASSUMPTION

SUBTRACT 5.998731D 00 FROM DIAGONAL TERMS AND MULTIPLY DENSITIES BY 2.481899D-03

POWER 1.170581E 02 WATTS, MAXIMUM POWER DENSITY 1.170581E 02 WATTS/CC IN ZONE 1 AT START OF SUBSTEP 1
POWER 1.283667E 02 WATTS, MAXIMUM POWER DENSITY 1.283667E 02 WATTS/CC IN ZONE 1 AT END OF SUBSTEP 1

AVERAGE POWER AT END OF SUBSTEP 1.227124E 02 WATTS

END OF EXPOSURE STEP ATOM DENSITIES AT TIME 5.000000E 01 DAYS

ZONE NUMBER 1

| | |
|---|---|
| U234 | 4.288214E-10 |
| U235 | 5.833902E-05 |
| U236 | 2.860568E-06 |
| U237 | 3.567799E-08 |
| U238 | 6.919149E-03 |
| U239 | 7.183601E-09 |
| NP237 | 1.047389E-07 |
| NP238 | 7.805148E-10 |
| NP239 | 1.029440E-06 |
| NP240 | 1.322925E-11 |
| PU238 | 4.418691E-09 |
| PU239 | 1.057472E-05 |
| PU240 | 9.959249E-07 |
| PU241 | 3.342037E-07 |
| PU242 | 1.637433E-08 |
| PU243 | 1.363557E-11 |
| AM241 | 5.864038E-10 |
| AM242 | 5.209982E-12 |
| AM242M | 5.048311E-12 |
| AM243 | 4.570633E-10 |
| AM244 | 6.380291E-14 |
| CM242 | 4.496810E-11 |
| CM243 | 9.509781E-14 |
| CM244 | 2.067478E-11 |
| CM245 | 2.433333E-13 |
| I135 | 8.827520E-09 |
| XE135 | 9.147587E-10 |
| CS135 | 7.716926E-08 |
| ND147 | 1.211565E-07 |
| PM147 | 2.018138E-07 |
| PM148 | 4.570417E-09 |
| PM148M | 3.867218E-09 |
| PM149 | 1.996816E-08 |
| SM149 | 1.197764E-08 |
| FPLL | 1.452273E-05 |

INVENTORY AND REACTION RATES BY ABSOLUTE NUCLIDE

| NO. | NAME | ********** START OF STEP TIME 0.0 DAYS ********** INVENTORY (KG) | ABSORPTION | FISSION | PRODUCTION | CAPTURE (N,G) | ********** END OF STEP TIME 50.000 DAYS ********** INVENTORY (KG) | ABSORPTION | FISSION | PRODUCTION | CAPTURE (N,G) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | U234 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.66615E-10 | 1.22699E-06 | 1.17129E-08 | 0.0 | 1.21528E-06 |
| 2 | U235 | 2.88761E-05 | 5.10645E-01 | 4.15093E-01 | 0.0 | 9.55372E-02 | 2.27640E-05 | 3.34410E-01 | 2.71835E-01 | 0.0 | 6.25652E-02 |
| 3 | U236 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.12095E-06 | 3.21976E-03 | 3.04610E-05 | 0.0 | 3.18930E-03 |
| 4 | U237 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.40401E-08 | 1.62725E-04 | 9.07891E-07 | 0.0 | 1.61818E-04 |
| 5 | U238 | 2.74099E-03 | 4.89355E-01 | 4.33975E-02 | 0.0 | 4.43611E-01 | 2.73433E-03 | 4.05526E-01 | 3.59633E-02 | 0.0 | 3.67618E-01 |
| 6 | U239 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.85077E-09 | 2.25257E-06 | 9.13205E-07 | 0.0 | 1.33936E-06 |
| 7 | NP237 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.12172E-08 | 3.60479E-04 | 2.82794E-06 | 0.0 | 3.57650E-04 |
| 8 | NP238 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.08446E-10 | 1.50720E-05 | 1.36780E-05 | 0.0 | 1.39392E-06 |
| 9 | NP239 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.08527E-07 | 2.18044E-03 | 0.0 | 0.0 | 2.18044E-03 |
| 10 | NP240 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.27191E-12 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | PU238 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.74619E-09 | 1.67556E-05 | 8.56094E-07 | 0.0 | 1.58995E-05 |
| 12 | PU239 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.19651E-06 | 1.67064E-01 | 1.06066E-01 | 0.0 | 6.09980E-02 |
| 13 | PU240 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.96880E-07 | 2.58422E-02 | 3.48227E-05 | 0.0 | 2.58074E-02 |
| 14 | PU241 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.33736E-07 | 5.21843E-03 | 3.71843E-03 | 0.0 | 1.50000E-03 |
| 15 | PU242 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.57962E-09 | 5.68956E-05 | 4.54743E-07 | 0.0 | 5.64409E-05 |
| 16 | PU243 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.50175E-12 | 5.98365E-08 | 4.25179E-08 | 0.0 | 1.73187E-08 |
| 17 | AM241 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.34658E-10 | 7.98803E-06 | 7.81741E-08 | 0.0 | 7.05151E-06 |
| 18 | AM242 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.09350E-12 | 1.05541E-07 | 1.04763E-07 | 0.0 | 7.78417E-10 |
| 19 | AM242M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.02854E-12 | 3.34248E-07 | 2.69253E-07 | 0.0 | 6.49951E-08 |
| 20 | AM243 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.84418E-10 | 2.95660E-06 | 8.99113E-09 | 0.0 | 2.95761E-06 |
| 21 | AM244 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.58495E-14 | 7.78648E-10 | 7.78648E-10 | 0.0 | 0.0 |
| 22 | CM242 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.80693E-11 | 1.54840E-08 | 9.77685E-10 | 0.0 | 1.45063E-08 |
| 23 | CM243 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.83706E-14 | 1.27583E-09 | 1.04333E-09 | 0.0 | 2.32496E-10 |
| 24 | CM244 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.37630E-12 | 4.65894E-08 | 2.24913E-09 | 0.0 | 4.44402E-08 |
| 25 | CM245 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.89895E-14 | 4.59411E-09 | 3.99075E-09 | 0.0 | 6.03356E-10 |
| 26 | I135 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.97876E-09 | 0.0 | 0.0 | 0.0 | 0.0 |
| 27 | XE135 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.05051E-10 | 2.54467E-02 | 0.0 | 0.0 | 2.54467E-02 |
| 28 | CS135 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.72982E-08 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | ND147 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.95723E-08 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30 | PM147 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.92595E-08 | 3.55514E-03 | 0.0 | 0.0 | 1.87679E-03 |
| 31 | PM148 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.12315E-09 | 1.03393E-03 | 0.0 | 0.0 | 1.03390E-03 |
| 32 | PM148M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.50346E-10 | 1.48539E-03 | 0.0 | 0.0 | 1.48539E-03 |
| 33 | PM149 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.94022E-09 | 0.0 | 0.0 | 0.0 | 0.0 |
| 34 | SM149 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.96333E-09 | 7.39535E-03 | 0.0 | 0.0 | 7.39535E-03 |
| 35 | FPIL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.41140E-06 | 1.69967E-02 | 0.0 | 0.0 | 1.69967E-02 |
| | TOTALS | 2.76987E-03 | 1.00000E 00 | 4.58490E-01 | 0.0 | 5.39148E-01 | 2.76594E-03 | 1.00000E 00 | 4.17668E-01 | 0.0 | 5.78698E-01 |
| OTHER LOSS RATE | | | 2.38419E-07 | | | | | 1.19209E-07 | | | |
| TOTAL LOSS RATE | | | 1.00000E 00 | | | | | 1.00000E 00 | | | |
| SYSTEM LOSS RATE (N/SEC) | | | 7.97850E 12 | | | | | 9.60441E 12 | | | |
| RELATIVE FLUX LEVEL | | | 1.00000E 00 | | | | | 1.00000E 00 | | | |

```
SUMMARY TABLES FOR EXPOSURE ENDING AT TIME    5.000000E 01  DAYS
FOR CASE            MATRIX EXPONENTIAL SOLUTION
                    ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)

AVERAGE NEUTRON LOSSES BY NUCLIDE CLASS AND ZONE CLASS - SYSTEM LOSS RATE   8.791460E 12  N/SEC

ZONE CLASS  FISSILE      FERTILE      O. ACTINIDE  FISSION PROD
   ID.        1            2            3            4
    1      0.5084859    0.4576802    0.0032922    0.0305417
          ----------   ----------   ----------   ----------
      SUM  0.5084859    0.4576802    0.0032922    0.0305417


ZONE CLASS   ABSORPTION          FISSILE INVENTORY (KG)          EFFECTIVE CONVERSION RATIO       POWER (WATTS)
   ID.        LOSSES              0.0   DAYS    50.000 DAYS     REACTION RATE   MASS BALANCE
    1        0.9999999          2.887611E-05  2.709424E-05          0.81850        0.76429        1.227124E 02
            ----------         ------------  ------------         ----------     ----------     ------------
     OVERALL 0.9999999          2.887611E-05  2.709424E-05          0.81850        0.76429        1.227124E 02
OTHER LOSSES 0.0000001
            ----------
TOTAL LOSSES 1.0000000

    FISSILE CONSUMPTION PER UNIT ENERGY GENERATION IS   1.426026E-14 KG/WATT-SEC
                         FISSILE CONSUMPTION RATE IS   1.749910E-12 KG/SEC

INTERFACE FILE ZNATDN VERSION  1 (OLD) HAS BEEN WRITTEN ON UNIT  14  WITH DENSITIES AT TIME   5.000000E 01  DAYS


PNSTE    9.999995E-25
TNSTE    0.0            5.000000E 01
TNSTS    0.0


        SUMMARY OF CALCULATION

    MATRIX EXPONENTIAL - EXPOSURE
      MAX. STEPS (INTERVALS) USED                    570
      MIN. STEPS (INTERVALS) USED                    570


     MAX ARRAY SIZE USED     3237 WORDS - FOR ZONE CALCULATION


     MAX ARRAY SIZE USED     3237 WORDS

     TOTAL CPU TIME USED    0.220 MINUTES     TOTAL CLOCK TIME USED    0.438 MINUTES     TOTAL I/O USED     152

NORMAL END OF EXPOSURE MODULE
```

CASE TITLE - BREEDER REACTOR SAMPLE PROBLEM FOR THE BURNER CODE

RITE CONTAINER ARRAYS, CONTROL 6 DATA 1

GRUPXS TITLE
BREEDER REACTOR CROSS SECTION DATA (3 GROUP)

NISOU - THE NUMBER OF DIFFERENT UNIQUE ISOTOPES IN SYSTEM IS 42
NISOA - THE NUMBER OF DIFFERENT ABSOLUTE ISOTOPES IN SYSTEM IS 21
NUCLAS - THE NUMBER OF DIFFERENT ISOTOPE CLASSES IN SYSTEM IS 8

| NO. | NORR | NOSS | NABSOL | HABSOL | NCLAS | ICLAS |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | U235 | 1 | 1 |
| 2 | 2 | 2 | 2 | U236 | 3 | 2 |
| 3 | 3 | 3 | 3 | U238 | 2 | 3 |
| 4 | 4 | 4 | 4 | PU239 | 1 | 4 |
| 5 | 5 | 5 | 5 | PU240 | 2 | 5 |
| 6 | 6 | 6 | 6 | PU241 | 1 | 6 |
| 7 | 7 | 7 | 7 | PU242 | 3 | 7 |
| 8 | 8 | 8 | 8 | O16 | 8 | 0 |
| 9 | 9 | 9 | 9 | NA23 | 6 | 0 |
| 10 | 10 | 10 | 10 | CR | 5 | 0 |
| 11 | 11 | 11 | 11 | MN55 | 5 | 0 |
| 12 | 12 | 12 | 12 | FE | 5 | 0 |
| 13 | 13 | 13 | 13 | NI | 5 | 0 |
| 14 | 14 | 14 | 14 | XE135 | 4 | 0 |
| 15 | 15 | 15 | 15 | PM147 | 4 | 0 |
| 16 | 16 | 16 | 16 | PM148M | 4 | 0 |
| 17 | 17 | 17 | 17 | PM148 | 4 | 0 |
| 18 | 18 | 18 | 18 | SM149 | 4 | 0 |
| 19 | 19 | 19 | 19 | NSFP | 4 | 0 |
| 20 | 20 | 20 | 20 | SSFP | 4 | 0 |
| 21 | 21 | 21 | 21 | TA181 | 7 | 0 |
| 22 | 0 | 25 | 0 | | 0 | 0 |
| 23 | 0 | 26 | 0 | | 0 | 0 |
| 24 | 0 | 27 | 0 | | 0 | 0 |
| 25 | 22 | 28 | 1 | | 1 | 0 |
| 26 | 23 | 29 | 2 | | 3 | 0 |
| 27 | 24 | 30 | 3 | | 2 | 0 |
| 28 | 25 | 31 | 4 | | 1 | 0 |
| 29 | 26 | 32 | 5 | | 2 | 0 |
| 30 | 27 | 33 | 6 | | 1 | 0 |
| 31 | 28 | 34 | 7 | | 3 | 0 |
| 32 | 29 | 35 | 8 | | 8 | 0 |
| 33 | 30 | 36 | 9 | | 6 | 0 |
| 34 | 31 | 37 | 10 | | 5 | 0 |
| 35 | 32 | 38 | 11 | | 5 | 0 |
| 36 | 33 | 39 | 12 | | 5 | 0 |
| 37 | 34 | 40 | 13 | | 5 | 0 |
| 38 | 35 | 41 | 14 | | 4 | 0 |
| 39 | 36 | 42 | 15 | | 4 | 0 |
| 40 | 37 | 43 | 16 | | 4 | 0 |
| 41 | 38 | 44 | 17 | | 4 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| 42 | 39 | 45 | 18 | 4 | 0 |
| 43 | 40 | 0 | 19 | 4 | 0 |
| 44 | 41 | 0 | 20 | 4 | 0 |
| 45 | 42 | 0 | 21 | 7 | 0 |

NZCLAS - THE NUMBER OF DIFFERENT ZONE CLASSES IS 10

| NO. | NZCLS | IZCLS |
|---|---|---|
| 1 | 1 | 101 |
| 2 | 1 | 102 |
| 3 | 2 | 103 |
| 4 | 2 | 104 |
| 5 | 3 | 105 |
| 6 | 3 | 106 |
| 7 | 4 | 107 |
| 8 | 4 | 108 |
| 9 | 5 | 109 |
| 10 | 5 | 110 |
| 11 | 6 | 0 |
| 12 | 6 | 0 |
| 13 | 7 | 0 |
| 14 | 7 | 0 |
| 15 | 7 | 0 |
| 16 | 7 | 0 |
| 17 | 8 | 0 |
| 18 | 8 | 0 |
| 19 | 8 | 0 |
| 20 | 8 | 0 |
| 21 | 9 | 0 |
| 22 | 10 | 0 |

METHOD OF SOLUTION - EXPLICIT CHAIN

THE LONGEST EXPLICIT CHAIN IS 10

* BREEDER REACTOR EXPOSURE DATA

EXPOSURE NUCLIDES
NUCLIDE NAMES ARE ABSOLUTE

1) U235
2) U236
3) U238
4) PU239
5) PU240
6) PU241
7) PU242
8) XE135
9) PM147
10) SM149
11) NSFP
12) SSFP
13) PM148M
14) PM148

DECAY CONSTANTS (1/SEC)

| | | | |
|---|---|---|---|
| 1) | PU241 | 6 | 1.688999E-09 |
| 2) | XE135 | 8 | 2.092999E-05 |
| 3) | PM147 | 9 | 8.288996E-09 |
| 4) | PM148M | 13 | 1.975999E-07 |
| 5) | PM148 | 14 | 1.487999E-06 |

FISSION PRODUCT YIELD DATA

ENERGY RANGE 1 CUTOFF AT 1.000000E 05 EV

FISSIONING NUCLIDE

| FISSION PRODUCT | | | 1) U235 1 | 2) U236 2 | 3) U238 3 | 4) PU239 4 | 5) PU240 5 | 6) PU241 6 | 7) PU242 7 |
|---|---|---|---|---|---|---|---|---|---|
| 1) | XE135 | 8 | 0.071500 | 0.060000 | 0.060000 | 0.071500 | 0.060000 | 0.071500 | 0.060000 |
| 2) | PM147 | 9 | 0.027000 | 0.030000 | 0.030000 | 0.027000 | 0.030000 | 0.027000 | 0.030000 |
| 3) | SM149 | 10 | 0.013000 | 0.020000 | 0.020000 | 0.013000 | 0.020000 | 0.013000 | 0.020000 |
| 4) | NSFP | 11 | 1.501100 | 1.546599 | 1.546599 | 1.501100 | 1.546599 | 1.501100 | 1.546599 |
| 5) | SSFP | 12 | 0.013400 | 0.013400 | 0.013400 | 0.013400 | 0.013400 | 0.013400 | 0.013400 |

ENERGY RANGE 2 CUTOFF AT 0.0 EV

FISSIONING NUCLIDE

| FISSION PRODUCT | | | 1) U235 1 | 2) U236 2 | 3) U238 3 | 4) PU239 4 | 5) PU240 5 | 6) PU241 6 | 7) PU242 7 |
|---|---|---|---|---|---|---|---|---|---|
| 1) | XE135 | 8 | 0.071500 | 0.060000 | 0.060000 | 0.071500 | 0.060000 | 0.071500 | 0.060000 |
| 2) | PM147 | 9 | 0.027000 | 0.030000 | 0.030000 | 0.027000 | 0.030000 | 0.027000 | 0.030000 |
| 3) | SM149 | 10 | 0.013000 | 0.020000 | 0.020000 | 0.013000 | 0.020000 | 0.013000 | 0.020000 |
| 4) | NSFP | 11 | 1.501100 | 1.546599 | 1.546599 | 1.501100 | 1.546599 | 1.501100 | 1.546599 |
| 5) | SSFP | 12 | 0.013400 | 0.013400 | 0.013400 | 0.013400 | 0.013400 | 0.013400 | 0.013400 |

BASIC EXPLICIT CHAINS SPECIFIED

```
    START CHAIN     1     LENGTH IS    10              1   10
 1) U238                                                          3
 2)             (N,G)        1.000000                             2
 3) PU239                                                         4
 4)             (N,G)        1.000000                             2
 5) PU240                                                         5
 6)             (N,G)        1.000000                             2
 7) PU241                                                         6
 8)             (N,G)        1.000000                             2
 9) PU242                                                         7
10)   END CHAIN     1                                             0
    START CHAIN     2     LENGTH IS     4              11   14
11) U235                                                          1
12)             (N,G)        1.000000                             2
13) U236                                                          2
14)   END CHAIN     2                                             0
    START CHAIN     3     LENGTH IS     6              15   20
15) PM147                                                         9
16)             (N,G)        0.900000                        900002
17) PM148M                                                       13
18)             (N,G)        1.000000                             2
19) SM149                                                        10
20)   END CHAIN     3                                             0
    START CHAIN     4     LENGTH IS     6              21   26
21) PM147                                                         9
22)             (N,G)        0.100000                        100002
23) PM148                                                        14
24)             (N,G)        1.000000                             2
25) SM149                              ADDED CONTRIBUTION       -10
26)   END CHAIN     4                                             0
    START CHAIN     5     LENGTH IS     2              27   28
27) XE135                                                         8
28)   END CHAIN     5                                             0
    START CHAIN     6     LENGTH IS     4              29   32
29) SSFP                                                         12
30)             (N,G)        1.000000                             2
31) NSFP                                                         11
32)   END CHAIN     6                                             0
33)   END OF CHAIN SPECIFICATIONS                                 0
```

```
ENERGY   1.492000E 07   1.224999E 06   8.651994E 04   5.000446E-03
YER      1.000000E 05   0.0

YIELD RANGE NUMBER FOR EACH NEUTRON ENERGY GROUP
IGY     1  1  2

POSITION IN DENSITY ARRAY FOR EACH NUCLIDE IN EXPOSURE DATA
SET       1  NUCLIDES INCLUDED   14
IHNUC     1    2    3    4    5    6    7   14   15   18   19   20   16   17
SET       2  NUCLIDES INCLUDED   14
IHNUC     1    2    3    4    5    6    7   14   15   18   19   20   16   17
SET       3  NUCIIDES INCLUDED    0
IHNUC     0    0    0    0    0    0    0    0    0    0    0    0    0    0
SET       4  NUCLIDES INCLUDED    0
IHNUC     0    0    0    0    0    0    0    0    0    0    0    0    0    0

MAXIMUM ARRAY SIZE USED FOR INITIAL PROCESSING IS    1780

STORAGE REQUIRED FOR BASIC DATA IS    1678

        STORAGE SUPPLIED IS    10000
MAXIMUM STORAGE REQUIRED IS     5811
MINIMUM STORAGE REQUIRED IS     3165

 MODRP  =  0 MODRRF =  0

MEMORY ACTUALLY USED WILL BE    5811

INTERFACE FILE RZFLUX VERSION   1 UNIT  16
 TIME  =  0.0          POWER =  1.250000E 09
 VOL   =  1.582595E 07 EFFK  =  1.012347E 00
 EIVS  =  0.0          DKDS  =  0.0
 TNL   =  1.106218E 20 TNA   =  1.092223E 20
 TNSL  =  1.399461E 18 TNBL  =  0.0
 TNBAL =  0.0          TNCRA =  0.0
 FC    =  5.000000E-01 CRTF  =  9.700000E-01
 X3    =  1.000000E 00 X4    =  0.0
 ITPS  =      1        NZONE =     22
 NGROUP=      3        NCY   =      2

RZFLUX REFERENCE TIME         0.0    DAYS INDICATOR       1

INTERFACE FILE ZNATDN VERSION   1 UNIT  15
 TIME  =  0.0
 NCY   =      0        NTZSZ =     22
 NNS   =     21        NBLKAD=      1


START OF STEP ATOM DENSITIES AT TIME   0.0          DAYS


ZONE NUMBER    1
U235A      2.286999E-05  U238A      7.504299E-03  PU239A     8.677100E-04  PU240A     3.353599E-04
PU241A     6.421500E-05  PU242A     2.559100E-05  O16A       1.764000E-02  NA23A      9.058498E-03
CR-A       2.618700E-03  FE-A       9.785596E-03  NI-A       1.378300E-03  TA181A     9.999999E-11

ZONE NUMBER    2
U235A      2.286999E-05  U238A      7.504299E-03  PU239A     8.677100E-04  PU240A     3.353599E-04
PU241A     6.421500E-05  PU242A     2.559100E-05  O16A       1.764000E-02  NA23A      9.058498E-03
CR-A       2.618700E-03  FE-A       9.785596E-03  NI-A       1.378300E-03  TA181A     9.999999E-11

ZONE NUMBER    3
U235A      2.391500E-05  U238A      7.847499E-03  PU239A     9.906099E-04  PU240A     3.826800E-04
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PU241A | 7.327099E-05 | PU242A | 2.920099E-05 | O16A | 1.869300E-02 | NA23A | 8.403197E-03 |
| CR-A | 2.699300E-03 | FE-A | 1.008660E-02 | NI-A | 1.420600E-03 | TA181A | 9.999999E-11 |

ZONE NUMBER 4

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235A | 2.391500E-05 | U238A | 7.847499E-03 | PU239A | 9.906099E-04 | PU240A | 3.826800E-04 |
| PU241A | 7.327099E-05 | PU242A | 2.920099E-05 | O16A | 1.869300E-02 | NA23A | 8.403197E-03 |
| CR-A | 2.699300E-03 | FE-A | 1.008660E-02 | NI-A | 1.420600E-03 | TA181A | 9.999999E-11 |

ZONE NUMBER 5

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235A | 2.357300E-05 | U238A | 7.735498E-03 | PU239A | 1.158700E-03 | PU240A | 4.478798E-04 |
| PU241A | 8.574799E-05 | PU242A | 3.416800E-05 | O16A | 1.855300E-02 | NA23A | 8.227497E-03 |
| CR-A | 2.722300E-03 | FE-A | 1.017260E-02 | NI-A | 1.432800E-03 | TA181A | 9.999999E-11 |

ZONE NUMBER 6

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235A | 2.357300E-05 | U238A | 7.735498E-03 | PU239A | 1.158700E-03 | PU240A | 4.478798E-04 |
| PU241A | 8.574799E-05 | PU242A | 3.416800E-05 | O16A | 1.855300E-02 | NA23A | 8.227497E-03 |
| CR-A | 2.722300E-03 | FE-A | 1.017260E-02 | NI-A | 1.432800E-03 | TA181A | 9.999999E-11 |

ZONE NUMBER 7

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 2.839499E-05 | U238B | 9.317599E-03 | O16B | 1.869200E-02 | NA23B | 9.058498E-03 |
| CR-B | 2.618700E-03 | FE-B | 9.785596E-03 | NI-B | 1.378300E-03 | | |

ZONE NUMBER 8

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 2.839499E-05 | U238B | 9.317599E-03 | O16B | 1.869200E-02 | NA23B | 9.058498E-03 |
| CR-B | 2.618700E-03 | FE-B | 9.785596E-03 | NI-B | 1.378300E-03 | | |

ZONE NUMBER 9

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 3.009199E-05 | U238B | 9.874698E-03 | O16B | 1.981000E-02 | NA23B | 8.403197E-03 |
| CR-B | 2.699300E-03 | FE-B | 1.008660E-02 | NI-B | 1.420600E-03 | | |

ZONE NUMBER 10

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 3.009199E-05 | U238B | 9.874698E-03 | O16B | 1.981000E-02 | NA23B | 8.403197E-03 |
| CR-B | 2.699300E-03 | FE-B | 1.008660E-02 | NI-B | 1.420600E-03 | | |

ZONE NUMBER 11

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 3.054200E-05 | U238B | 1.002220E-02 | O16B | 2.010500E-02 | NA23B | 8.227497E-03 |
| CR-B | 2.722300E-03 | FE-B | 1.017260E-02 | NI-B | 1.432800E-03 | | |

ZONE NUMBER 12

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 3.054200E-05 | U238B | 1.002220E-02 | O16B | 2.010500E-02 | NA23B | 8.227497E-03 |
| CR-B | 2.722300E-03 | FE-B | 1.017260E-02 | NI-B | 1.432800E-03 | | |

ZONE NUMBER 13

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.318300E-05 | U238B | 1.417000E-02 | O16B | 2.842600E-02 | NA23B | 4.224397E-03 |
| CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 | | |

ZONE NUMBER 14

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.318300E-05 | U238B | 1.417000E-02 | O16B | 2.842600E-02 | NA23B | 4.224397E-03 |
| CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 | | |

ZONE NUMBER 15

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.318300E-05 | U238B | 1.417000E-02 | O16B | 2.842600E-02 | NA23B | 4.224397E-03 |
| CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 | | |

ZONE NUMBER 16

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.318300E-05 | U238B | 1.417000E-02 | O16B | 2.842600E-02 | NA23B | 4.224397E-03 |
| CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 | | |

ZONE NUMBER 17

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.318300E-05 | U238B | 1.417000E-02 | O16B | 2.842600E-02 | NA23B | 4.224397E-03 |
| CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 | | |

ZONE NUMBER 18

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.318300E-05 | U238B | 1.417000E-02 | O16B | 2.842600E-02 | NA23B | 4.224397E-03 |
| CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 | | |

```
ZONE NUMBER   19
U235B      4.318300E-05  U238B      1.417000E-02  O16B       2.842600E-02  NA23B      4.224397E-03
CR-B       2.658200E-03  FE-B       9.933297E-03  NI-B       1.399100E-03

ZONE NUMBER   20
U235B      4.318300E-05  U238B      1.417000E-02  O16B       2.842600E-02  NA23B      4.224397E-03
CR-B       2.658200E-03  FE-B       9.933297E-03  NI-B       1.399100E-03

ZONE NUMBER   21
NA23B      1.084700E-02  FE-B       3.071500E-02  CR-B       8.219600E-03  NI-B       4.326098E-03

ZONE NUMBER   22
NA23B      1.084700E-02  FE-B       3.071500E-02  CR-B       8.219600E-03  NI-B       4.326098E-03


EXPOSURE TIME STEP STARTS AT   0.0          DAYS

EXPOSURE TIME STEP IS   7.500000E 01 DAYS (   6.480000E 06 SECONDS ) THE NUMBER OF SUBSTEPS IS   2

POWER   2.499994E 09 WATTS, MAXIMUM POWER DENSITY   4.801135E 02 WATTS/CC IN ZONE          3   AT START OF SUBSTEP     1
POWER   2.506527E 09 WATTS, MAXIMUM POWER DENSITY   4.795476E 02 WATTS/CC IN ZONE          3     AT END OF SUBSTEP     1

          AVERAGE POWER AT END OF SUBSTEP   2.503260E 09 WATTS

          INITIAL REACTION RATES WILL BE MULTIPLIED BY   9.947864E-01 FOR NEXT SUBSTEP          9.947871E-01   9.973869E-01

POWER   2.493459E 09 WATTS, MAXIMUM POWER DENSITY   4.770474E 02 WATTS/CC IN ZONE          3   AT START OF SUBSTEP     2
POWER   2.499557E 09 WATTS, MAXIMUM POWER DENSITY   4.764346E 02 WATTS/CC IN ZONE          3     AT END OF SUBSTEP     2

          AVERAGE POWER AT END OF SUBSTEP   2.499885E 09 WATTS


END OF EXPOSURE STEP ATOM DENSITIES AT TIME   7.500000E 01  DAYS


ZONE NUMBER    1
U235A      2.058735E-05  U236A      5.136085E-07  U238A      7.400621E-03  PU239A     8.800898E-04
PU240A     3.421307E-04  PU241A     6.156201E-05  PU242A     2.609445E-05  O16A       1.764000E-02
NA23A      9.058498E-03  CR-A       2.618700E-03  FE-A       9.785596E-03  NI-A       1.378300E-03
XE135A     4.458910E-08  PM147A     2.271438E-06  PM48MA     2.234346E-08  PM148A     9.017800E-10
SM149A     1.250482E-06  NSFPA      1.315323E-04  SSFPA      1.142208E-06  TA181A     9.999999E-11

ZONE NUMBER    2
U235A      2.120515E-05  U236A      3.784846E-07  U238A      7.429700E-03  PU239A     8.773983E-04
PU240A     3.404298E-04  PU241A     6.210948E-05  PU242A     2.596811E-05  O16A       1.764000E-02
NA23A      9.058498E-03  CR-A       2.618700E-03  FE-A       9.785596E-03  NI-A       1.378300E-03
XE135A     3.159982E-08  PM147A     1.621981E-06  PM48MA     1.356257E-08  PM148A     5.152616E-10
SM149A     8.809697E-07  NSFPA      9.322088E-05  SSFPA      8.144883E-07  TA181A     9.999999E-11

ZONE NUMBER    3
U235A      2.170130E-05  U236A      4.935033E-07  U238A      7.746894E-03  PU239A     9.947387E-04
PU240A     3.892647E-04  PU241A     7.032519E-05  PU242A     2.970784E-05  O16A       1.869300E-02
NA23A      8.403197E-03  CR-A       2.699300E-03  FE-A       1.008660E-02  NI-A       1.420600E-03
XE135A     4.730247E-08  PM147A     2.421608E-06  PM48MA     2.283125E-08  PM148A     9.039385E-10
SM149A     1.328123E-06  NSFPA      1.398469E-04  SSFPA      1.216691E-06  TA181A     9.999999E-11

ZONE NUMBER    4
U235A      2.231830E-05  U236A      3.594862E-07  U238A      7.775873E-03  PU239A     9.942211E-04
PU240A     3.875806E-04  PU241A     7.094321E-05  PU242A     2.957681E-05  O16A       1.869300E-02
NA23A      8.403197E-03  CR-A       2.699300E-03  FE-A       1.008660E-02  NI-A       1.420600E-03
XE135A     3.325605E-08  PM147A     1.713913E-06  PM48MA     1.352400E-08  PM148A     5.043075E-10
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SM149A | 9.286215E-07 | NSFPA | 9.828305E-05 | SSFPA | 8.600093E-07 | TA181A | 9.999999E-11 |

ZONE NUMBER 5

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235A | 2.216359E-05 | U236A | 3.134498E-07 | U238A | 7.672083E-03 | PU239A | 1.151331E-03 |
| PU240A | 4.524670E-04 | PU241A | 8.313591E-05 | PU242A | 3.453673E-05 | O16A | 1.855300E-02 |
| NA23A | 8.227497E-03 | CR-A | 2.722300E-03 | FE-A | 1.017260E-02 | NI-A | 1.432800E-03 |
| XE135A | 3.479463E-08 | PM147A | 1.799117E-06 | PM48MA | 1.312546E-08 | PM148A | 4.786822E-10 |
| SM149A | 9.702462E-07 | NSFPA | 1.029550E-04 | SSFPA | 9.025713E-07 | TA181A | 9.999999E-11 |

ZONE NUMBER 6

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235A | 2.256612E-05 | U236A | 2.258267E-07 | U238A | 7.690597E-03 | PU239A | 1.153839E-03 |
| PU240A | 4.512919E-04 | PU241A | 8.363278E-05 | PU242A | 3.443898E-05 | O16A | 1.855300E-02 |
| NA23A | 8.227497E-03 | CR-A | 2.722300E-03 | FE-A | 1.017260E-02 | NI-A | 1.432800E-03 |
| XE135A | 2.439545E-08 | PM147A | 1.265777E-06 | PM48MA | 7.388770E-09 | PM148A | 2.571743E-10 |
| SM149A | 6.779068E-07 | NSFPA | 7.211619E-05 | SSFPA | 6.345712E-07 | TA181A | 9.999999E-11 |

ZONE NUMBER 7

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 2.727723E-05 | U236B | 2.860580E-07 | U238B | 9.274539E-03 | PU239B | 4.085012E-05 |
| PU240B | 1.874816E-07 | PU241B | 5.998426E-10 | PU242B | 1.173829E-12 | O16B | 1.869200E-02 |
| NA23B | 9.058498E-03 | CR-B | 2.618700E-03 | FE-B | 9.785596E-03 | NI-B | 1.378300E-03 |
| XE135B | 1.499749E-09 | PM147B | 7.804584E-08 | PM48MB | 4.990823E-10 | PM148B | 1.846047E-11 |
| SM149B | 4.726498E-08 | NSFPB | 4.336024E-06 | SSFPB | 3.747619E-08 | | |

ZONE NUMBER 8

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 2.792086E-05 | U236B | 1.254173E-07 | U238B | 9.299640E-03 | PU239B | 1.757269E-05 |
| PU240B | 3.540682E-08 | PU241B | 4.977005E-11 | PU242B | 4.203518E-14 | O16B | 1.869200E-02 |
| NA23B | 9.058498E-03 | CR-B | 2.618700E-03 | FE-B | 9.785596E-03 | NI-B | 1.378300E-03 |
| XE135B | 3.678091E-10 | PM147B | 1.901870E-08 | PM48MB | 6.951301E-11 | PM148B | 2.335051E-12 |
| SM149B | 1.087706E-08 | NSFPB | 1.060644E-06 | SSFPB | 9.292791E-09 | | |

ZONE NUMBER 9

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 2.905575E-05 | U236B | 2.643765E-07 | U238B | 9.834833E-03 | PU239B | 3.780107E-05 |
| PU240B | 1.504305E-07 | PU241B | 4.181211E-10 | PU242B | 7.109398E-13 | O16B | 1.981000E-02 |
| NA23B | 8.403197E-03 | CR-B | 2.699300E-03 | FE-B | 1.008660E-02 | NI-B | 1.420600E-03 |
| XE135B | 1.386265E-09 | PM147B | 7.369596E-08 | PM48MB | 4.332485E-10 | PM148B | 1.567423E-11 |
| SM149B | 4.493243E-08 | NSFPB | 4.078612E-06 | SSFPB | 3.529572E-08 | | |

ZONE NUMBER 10

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 2.967722E-05 | U236B | 1.095282E-07 | U238B | 9.859003E-03 | PU239B | 1.535728E-05 |
| PU240B | 2.541463E-08 | PU241B | 2.937284E-11 | PU242B | 2.039872E-14 | O16B | 1.981000E-02 |
| NA23B | 8.403197E-03 | CR-B | 2.699300E-03 | FE-B | 1.008660E-02 | NI-B | 1.420600E-03 |
| XE135B | 3.170564E-10 | PM147B | 1.668346E-08 | PM48MB | 5.230844E-11 | PM148B | 1.726232E-12 |
| SM149B | 9.603667E-09 | NSFPB | 9.279490E-07 | SSFPB | 8.135483E-09 | | |

ZONE NUMBER 11

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 2.988821E-05 | U236B | 1.668225E-07 | U238B | 9.997170E-03 | PU239B | 2.382486E-05 |
| PU240B | 5.835807E-08 | PU241B | 1.001951E-10 | PU242B | 1.049281E-13 | O16B | 2.010500E-02 |
| NA23B | 8.227497E-03 | CR-B | 2.722300E-03 | FE-B | 1.017260E-02 | NI-B | 1.432800E-03 |
| XE135B | 8.129024E-10 | PM147B | 4.519074E-08 | PM48MB | 1.916463E-10 | PM148B | 6.522069E-12 |
| SM149B | 2.781273E-08 | NSFPB | 2.481560E-06 | SSFPB | 2.156215E-08 | | |

ZONE NUMBER 12

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 3.028789E-05 | U236B | 6.710900E-08 | U238B | 1.001260E-02 | PU239B | 9.404162E-06 |
| PU240B | 9.356615E-09 | PU241B | 6.510811E-12 | PU242B | 2.719012E-15 | O16B | 2.010500E-02 |
| NA23B | 8.227497E-03 | CR-B | 2.722300E-03 | FE-B | 1.017260E-02 | NI-B | 1.432800E-03 |
| XE135B | 1.836200E-10 | PM147B | 9.934265E-09 | PM48MB | 2.036107E-11 | PM148B | 6.494110E-13 |
| SM149B | 5.756579E-09 | NSFPB | 5.505461E-07 | SSFPB | 4.835012E-09 | | |

ZONE NUMBER 13

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.195412E-05 | U236B | 3.087540E-07 | U238B | 1.412266E-02 | PU239B | 4.447694E-05 |
| PU240B | 1.420743E-07 | PU241B | 3.183498E-10 | PU242B | 4.384977E-13 | O16B | 2.842600E-02 |
| NA23B | 4.224397E-03 | CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 |
| XE135B | 1.820544E-09 | PM147B | 1.011662E-07 | PM48MB | 5.170966E-10 | PM148B | 1.811419E-11 |
| SM149B | 6.299314E-08 | NSFPB | 5.554417E-06 | SSFPB | 4.808798E-08 | | |

ZONE NUMBER 14

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.231119E-05 | U236B | 2.199638E-07 | U238B | 1.413656E-02 | PU239B | 3.159675E-05 |
| PU240B | 7.162578E-08 | PU241B | 1.140688E-10 | PU242B | 1.112806E-13 | O16B | 2.842600E-02 |
| NA23B | 4.224397E-03 | CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 |
| XE135B | 1.192675E-09 | PM147B | 6.767323E-08 | PM48MB | 2.709704E-10 | PM148B | 9.136442E-12 |
| SM149B | 4.219634E-08 | NSFPB | 3.701856E-06 | SSFPB | 3.214319E-08 | | |

ZONE NUMBER 15

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.279405E-05 | U236B | 1.013992E-07 | U238B | 1.415531E-02 | PU239B | 1.430974E-05 |
| PU240B | 1.510341E-08 | PU241B | 1.117069E-11 | PU242B | 4.985070E-15 | O16B | 2.842600E-02 |
| NA23B | 4.224397E-03 | CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 |
| XE135B | 3.242826E-10 | PM147B | 1.795364E-08 | PM48MB | 3.866626E-11 | PM148B | 1.235665E-12 |
| SM149B | 1.067078E-08 | NSFPB | 9.893556E-07 | SSFPB | 8.666753E-09 | | |

ZONE NUMBER 16

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.303029E-05 | U236B | 4.067467E-08 | U238B | 1.416425E-02 | PU239B | 5.671818E-06 |
| PU240B | 2.422128E-09 | PU241B | 7.233524E-13 | PU242B | 1.290885E-16 | O16B | 2.842600E-02 |
| NA23B | 4.224397E-03 | CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 |
| XE135B | 9.155354E-11 | PM147B | 4.948880E-09 | PM48MB | 4.705717E-12 | PM148B | 1.455169E-13 |
| SM149B | 2.799954E-09 | NSFPB | 2.752519E-07 | SSFPB | 2.427413E-09 | | |

ZONE NUMBER 17

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.265596E-05 | U236B | 1.380268E-07 | U238B | 1.415009E-02 | PU239B | 1.943769E-05 |
| PU240B | 2.806829E-08 | PU241B | 2.835625E-11 | PU242B | 1.726620E-14 | O16B | 2.842600E-02 |
| NA23B | 4.224397E-03 | CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 |
| XE135B | 4.229284E-10 | PM147B | 2.274401E-08 | PM48MB | 6.381276E-11 | PM148B | 2.081940E-12 |
| SM149B | 1.329370E-08 | NSFPB | 1.259788E-06 | SSFPB | 1.103771E-08 | | |

ZONE NUMBER 18

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.280594E-05 | U236B | 9.898662E-08 | U238B | 1.415578E-02 | PU239B | 1.391757E-05 |
| PU240B | 1.439566E-08 | PU241B | 1.042303E-11 | PU242B | 4.540730E-15 | O16B | 2.842600E-02 |
| NA23B | 4.224397E-03 | CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 |
| XE135B | 2.854836E-10 | PM147B | 1.554309E-08 | PM48MB | 3.291099E-11 | PM148B | 1.051477E-12 |
| SM149B | 9.079226E-09 | NSFPB | 8.599079E-07 | SSFPB | 7.545395E-09 | | |

ZONE NUMBER 19

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.300353E-05 | U236B | 4.772472E-08 | U238B | 1.416324E-02 | PU239B | 6.661562E-06 |
| PU240B | 3.335831E-09 | PU241B | 1.168302E-12 | PU242B | 2.447095E-16 | O16B | 2.842600E-02 |
| NA23B | 4.224397E-03 | CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 |
| XE135B | 1.092912E-10 | PM147B | 5.894581E-09 | PM48MB | 6.501689E-12 | PM148B | 2.019154E-13 |
| SM149B | 3.338003E-09 | NSFPB | 3.278572E-07 | SSFPB | 2.890325E-09 | | |

ZONE NUMBER 20

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235B | 4.310599E-05 | U236B | 2.072131E-08 | U238B | 1.416710E-02 | PU239B | 2.872650E-06 |
| PU240B | 6.280705E-10 | PU241B | 9.591763E-14 | PU242B | 8.713967E-18 | O16B | 2.842600E-02 |
| NA23B | 4.224397E-03 | CR-B | 2.658200E-03 | FE-B | 9.933297E-03 | NI-B | 1.399100E-03 |
| XE135B | 3.984242E-11 | PM147B | 2.118848E-09 | PM48MB | 1.065457E-12 | PM148B | 3.255246E-14 |
| SM149B | 1.162319E-09 | NSFPB | 1.185710E-07 | SSFPB | 1.049215E-09 | | |

ZONE NUMBER 21

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NA23B | 1.084700E-02 | FE-B | 3.071500E-02 | CR-B | 8.219600E-03 | NI-B | 4.326098E-03 |

ZONE NUMBER 22

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NA23B | 1.084700E-02 | FE-B | 3.071500E-02 | CR-B | 8.219600E-03 | NI-B | 4.326098E-03 |

INVENTORY AND REACTION RATES BY ABSOLUTE NUCLIDE

********** START OF STEP TIME 0.0 DAYS ********** ********** END OF STEP TIME 75.000 DAYS **********

| NO. | NAME | INVENTORY (KG) | ABSORPTION | FISSION | PRODUCTION | CAPTURE (N,G) | INVENTORY (KG) | ABSORPTION | FISSION | PRODUCTION | CAPTURE (N,G) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | U235 | 2.03859E 02 | 1.27430E-02 | 9.72006E-03 | 2.38177E-02 | 3.02301E-03 | 1.96964E 02 | 1.19511E-02 | 9.11120E-03 | 2.23240E-02 | 2.83990E-03 |
| 2 | U236 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.63146E 00 | 4.34672E-05 | 5.44731E-06 | 1.46339E-05 | 3.80199E-05 |
| 3 | U238 | 6.77484E 04 | 5.30739E-01 | 4.89961E-02 | 1.33569E-01 | 4.81743E-01 | 6.74498E 04 | 5.25065E-01 | 4.83988E-02 | 1.31941E-01 | 4.76665E-01 |
| 4 | PU239 | 2.75438E 03 | 3.10585E-01 | 2.45010E-01 | 7.18752E-01 | 6.55757E-02 | 2.84906E 03 | 3.14404E-01 | 2.47837E-01 | 7.26965E-01 | 6.65669E-02 |
| 5 | PU240 | 1.06888E 03 | 4.02407E-02 | 1.85017E-02 | 5.59522E-02 | 2.17390E-02 | 1.08347E 03 | 4.07334E-02 | 1.87262E-02 | 5.66308E-02 | 2.20072E-02 |
| 6 | PU241 | 2.05506E 02 | 3.04464E-02 | 2.58448E-02 | 7.68530E-02 | 4.60161E-03 | 1.98713E 02 | 2.93199E-02 | 2.48886E-02 | 7.40097E-02 | 4.43128E-03 |
| 7 | PU242 | 8.22351E 01 | 2.56787E-03 | 1.11128E-03 | 3.38525E-03 | 1.45659E-03 | 8.33457E 01 | 2.59910E-03 | 1.12472E-03 | 3.42618E-03 | 1.47437E-03 |
| 8 | O16 | 9.57602E 03 | 2.13357E-03 | 0.0 | 0.0 | 2.13357E-03 | 9.57602E 03 | 2.12846E-03 | 0.0 | 0.0 | 2.12846E-03 |
| 9 | NA23 | 1.07873E 04 | 1.11334E-03 | 2.71857E-07 | 5.43715E-07 | 1.11307E-03 | 1.07873E 04 | 1.11068E-03 | 2.71206E-07 | 5.42413E-07 | 1.11041E-03 |
| 10 | CR | 1.41915E 04 | 1.03383E-02 | 8.68757E-07 | 1.73752E-06 | 1.03375E-02 | 1.41915E 04 | 1.03136E-02 | 8.66677E-07 | 1.73335E-06 | 1.03127E-02 |
| 11 | MN55 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | FE | 5.69502E 04 | 3.61986E-02 | 8.56230E-06 | 1.71246E-05 | 3.61900E-02 | 5.69502E 04 | 3.61119E-02 | 8.54180E-06 | 1.70835E-05 | 3.61034E-02 |
| 13 | NI | 8.43419E 03 | 1.02423E-02 | 3.71089E-08 | 7.42178E-08 | 1.02422E-02 | 8.43419E 03 | 1.02177E-02 | 3.70200E-08 | 7.40401E-08 | 1.02177E-02 |
| 14 | XE135 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.72171E-02 | 1.38816E-07 | 0.0 | 0.0 | 1.38816E-07 |
| 15 | PM147 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.20527E 00 | 4.37085E-04 | 3.62659E-08 | 7.25320E-08 | 4.37049E-04 |
| 16 | PM148M | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.66574E-02 | 2.00362E-04 | 0.0 | 0.0 | 2.00362E-04 |
| 17 | PM148 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.02190E-03 | 1.26783E-05 | 0.0 | 0.0 | 1.26783E-05 |
| 18 | SM149 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.77350E 00 | 2.14795E-04 | 1.66607E-07 | 3.33215E-07 | 2.14628E-04 |
| 19 | NSFP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.34796E-03 | 0.0 | 0.0 | 2.34796E-03 |
| 20 | SSFP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.69369E-04 | 0.0 | 0.0 | 1.69369E-04 |
| 21 | TA181 | 2.07418E-04 | 1.33243E-08 | 0.0 | 0.0 | 1.33243E-08 | 2.07418E-04 | 1.32924E-08 | 0.0 | 0.0 | 1.32924E-08 |
| | TOTALS | 1.72002E 05 | 9.87348E-01 | 3.49193E-01 | 1.01235E 00 | 6.38155E-01 | 1.71807E 05 | 9.87379E-01 | 3.50101E-01 | 1.01533E 00 | 6.37277E-01 |
| OTHER LOSS RATE | | | 1.26515E-02 | | | | | 1.26207E-02 | | | |
| TOTAL LOSS RATE | | | 1.00000E 00 | | | | | 1.00000E 00 | | | |
| SYSTEM LOSS RATE(N/SEC) | | | 2.21243E 20 | | | | | 2.20618E 20 | | | |
| RELATIVE FLUX LEVEL | | | 1.00000E 00 | | | | | 9.94786E-01 | | | |

SUMMARY TABLES FOR EXPOSURE ENDING AT TIME 7.500000E 01 DAYS
FOR CASE BREEDER REACTOR SAMPLE PROBLEM FOR THE BURNER CODE

AVERAGE NEUTRON LOSSES BY NUCLIDE CLASS AND ZONE CLASS - SYSTEM LOSS RATE 2.209308E 20 N/SEC

| ZONE CLASS ID. | FISSILE 1 | FERTILE 2 | O. ACTINIDE 3 | FISSION PROD 4 | STRUCTURAL 5 | COOLANT 6 | CONTROL ROD 7 | OTHER 0 |
|---|---|---|---|---|---|---|---|---|
| 101 | 0.1233919 | 0.1573420 | 0.0009080 | 0.0006939 | 0.0143537 | 0.0002605 | 0.0000000 | 0.0006988 |
| 102 | 0.1297044 | 0.1534486 | 0.0009687 | 0.0006659 | 0.0135565 | 0.0002345 | 0.0000000 | 0.0007441 |
| 103 | 0.0958793 | 0.0983354 | 0.0007251 | 0.0003033 | 0.0086557 | 0.0001514 | 0.0000000 | 0.0005045 |
| 104 | 0.0015851 | 0.0401112 | 0.0000011 | 0.0000086 | 0.0034403 | 0.0001284 | 0.0 | 0.0000415 |
| 105 | 0.0013827 | 0.0365153 | 0.0000009 | 0.0000069 | 0.0030379 | 0.0001024 | 0.0 | 0.0000407 |
| 106 | 0.0007627 | 0.0227529 | 0.0000003 | 0.0000026 | 0.0018777 | 0.0000616 | 0.0 | 0.0000265 |
| 107 | 0.0014695 | 0.0418508 | 0.0000008 | 0.0000069 | 0.0023604 | 0.0000414 | 0.0 | 0.0000644 |
| 108 | 0.0005478 | 0.0180368 | 0.0000001 | 0.0000007 | 0.0010426 | 0.0000175 | 0.0 | 0.0000106 |
| 109 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0029953 | 0.0000408 | 0.0 | 0.0 |
| 110 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0053913 | 0.0000734 | 0.0 | 0.0 |
| SUM | 0.3547232 | 0.5683929 | 0.0026052 | 0.0016888 | 0.0567114 | 0.0011120 | 0.0000000 | 0.0021310 |

| ZONE CLASS ID. | ABSORPTION LOSSES | FISSILE INVENTORY (KG) 0.0 DAYS | 75.000 DAYS | EFFECTIVE CONVERSION RATIO REACTION RATE | MASS BALANCE | POWER (WATTS) |
|---|---|---|---|---|---|---|
| 101 | 0.2976486 | 8.718159E 02 | 8.779272E 02 | 1.09613 | 1.08715 | 8.577050E 08 |
| 102 | 0.2993225 | 9.932793E 02 | 9.926743E 02 | 1.00149 | 0.99179 | 9.092792E 08 |
| 103 | 0.2045545 | 1.157943E 03 | 1.149101E 03 | 0.85315 | 0.83774 | 6.687063E 08 |
| 104 | 0.0453162 | 2.085480E 01 | 4.209000E 01 | 24.57222 | 24.84361 | 1.575746E 07 |
| 105 | 0.0410868 | 2.210088E 01 | 4.142136E 01 | 25.58640 | 25.88263 | 1.469022E 07 |
| 106 | 0.0254843 | 2.243201E 01 | 3.450909E 01 | 28.86142 | 29.24298 | 8.994285E 06 |
| 107 | 0.0457942 | 3.765649E 01 | 5.958716E 01 | 27.25711 | 27.59851 | 1.991576E 07 |
| 108 | 0.0196562 | 3.765674E 01 | 4.742706E 01 | 32.37958 | 32.85880 | 4.837678E 06 |
| 109 | 0.0030361 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 110 | 0.0054647 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OVERALL | 0.9873639 | 3.163738E 03 | 3.244736E 03 | 1.41260 | 1.40186 | 2.499885E 09 |
| OTHER LOSSES | 0.0126361 | | | | | |
| TOTAL LOSSES | 1.0000000 | | | | | |

FISSILE CONSUMPTION PER UNIT ENERGY GENERATION IS 1.244223E-14 KG/WATT-SEC
FISSILE CONSUMPTION RATE IS 3.110414E-05 KG/SEC

INTERFACE FILE ZNATDN VERSION 2 (NEW) HAS BEEN WRITTEN ON UNIT 18 WITH DENSITIES AT TIME 7.500000E 01 DAYS

ZONE POWER DENSITY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1) | 4.499385E 02 | 2) | 3.186902E 02 | 3) | 4.782856E 02 | 4) | 3.359417E 02 | 5) | 3.519414E 02 |
| 6) | 2.464430E 02 | 7) | 1.446836E 01 | 8) | 3.532372E 00 | 9) | 1.359318E 01 | 10) | 3.087408E 00 |
| 11) | 8.248502E 00 | 12) | 1.828635E 00 | 13) | 1.847278E 01 | 14) | 1.229480E 01 | 15) | 3.284383E 00 |
| 16) | 9.134049E-01 | 17) | 4.187669E 00 | 18) | 2.855874E 00 | 19) | 1.088182E 00 | 20) | 3.934439E-01 |
| 21) | 0.0 | 22) | 0.0 | | | | | | |

POWER COMPUTED FROM POWER DENSITY 2.499882E 09

INTERFACE FILE ZNPOWD VERSION 1 (NEW) HAS BEEN WRITTEN ON UNIT 19

```
CUMULATIVE EXPOSURE INFORMATION

          TR1
     1)   7.724766E 19

          TR2
     1)   0.0

          TR3
     1)   2.499775E 09

          TR4
     1)   7.196300E 04

INTERFACE FILE EXPOHT VERSION  1 (NEW) HAS BEEN WRITTEN ON UNIT  20

GENERAL INFORMATION
     1)   7.500000E 01      2)   0.0                3)   0.0                4)   0.0                5)   0.0
     6)   0.0               7)   0.0                8)   0.0                9)   0.0               10)   0.0
    11)   5.005646E 26     12)   2.685844E 00      13)   0.0               14)   0.0               15)   0.0
    16)   0.0              17)   0.0               18)   0.0               19)   0.0               20)   0.0
    21)   5.005646E 26     22)   2.685844E 00      23)   0.0               24)   0.0               25)   0.0
    26)   0.0              27)   0.0               28)   0.0               29)   0.0               30)   0.0
    31)   0.0              32)   0.0               33)   0.0               34)   0.0               35)   0.0
    36)   0.0              37)   0.0               38)   0.0               39)   0.0               40)   0.0

FLUENCE (TOTAL) BY ZONE (NEUTRONS/CM**2)
     1)   3.920224E 22      2)   2.781114E 22       3)   3.691674E 22       4)   2.594316E 22       5)   2.371080E 22
     6)   1.659327E 22      7)   1.169075E 22       8)   4.465400E 21       9)   1.031286E 22      10)   3.706918E 21
    11)   6.395175E 21     12)   2.235230E 21      13)   8.884206E 21      14)   6.222736E 21      15)   2.524482E 21
    16)   9.229494E 20     17)   3.373613E 21      18)   2.393824E 21      19)   1.091315E 21      20)   4.482061E 20
    21)   6.044923E 20     22)   7.493438E 20

FLUENCE (RANGE 1 - TO CUTOFF ENERGY   1.000000E 03 EV) BY ZONE (NEUTRONS/CM**2)
     1)   2.715056E 22      2)   1.899199E 22       3)   2.607470E 22       4)   1.809535E 22       5)   1.693974E 22
     6)   1.171662E 22      7)   6.443453E 21       8)   2.092397E 21       9)   5.778587E 21      10)   1.761611E 21
    11)   3.605675E 21     12)   1.065866E 21      13)   5.301556E 21      14)   3.670546E 21      15)   1.299875E 21
    16)   4.172149E 20     17)   1.690760E 21      18)   1.185708E 21      19)   4.993197E 20      20)   1.866808E 20
    21)   2.463072E 20     22)   2.994818E 20

FLUENCE (RANGE 2 - TO CUTOFF ENERGY   1.000000E 05 EV) BY ZONE (NEUTRONS/CM**2)
     1)   2.169450E 22      2)   1.503887E 22       3)   2.109670E 22       4)   1.452694E 22       5)   1.380643E 22
     6)   9.481392E 21      7)   4.299566E 21       8)   1.161890E 21       9)   3.915968E 21      10)   9.964684E 20
    11)   2.457621E 21     12)   6.055957E 20      13)   3.795313E 21      14)   2.602619E 21      15)   8.087198E 20
    16)   2.202764E 20     17)   1.020337E 21      18)   7.058272E 20      19)   2.682080E 20      20)   8.631719E 19
    21)   1.092766E 20     22)   1.279171E 20

FISSIONS BY ZONE (SUBZONE) (FISSIONS/CM**3)
     1)   8.736246E 19      2)   6.187972E 19       3)   9.286407E 19       4)   6.522618E 19       5)   6.832212E 19
     6)   4.784042E 19      7)   2.844604E 18       8)   6.988236E 17       9)   2.673618E 18      10)   6.110084E 17
    11)   1.624504E 18     12)   3.622481E 17      13)   3.632838E 18      14)   2.420067E 18      15)   6.494796E 17
    16)   1.814628E 17     17)   8.283341E 17      18)   5.653845E 17      19)   2.161294E 17      20)   7.836968E 16
    21)   8.165907E 12     22)   1.024213E 13

EXPOSURE BY ZONE (SUBZONE) (MEGAWATT(THERMAL)-DAYS/KG)
     1)   9.721290E 00      2)   6.875807E 00       3)   9.751050E 00       4)   6.838918E 00       5)   7.060204E 00
     6)   4.938419E 00      7)   2.934773E-01       8)   7.169485E-02       9)   2.602351E-01      10)   5.913597E-02
    11)   1.556627E-01     12)   3.451673E-02      13)   2.465370E-01      14)   1.641208E-01      15)   4.384855E-02
    16)   1.219584E-02     17)   5.590121E-02      18)   3.812705E-02      19)   1.452922E-02      20)   5.253505E-03
    21)   0.0              22)   0.0

                                                   CURRENT                    CUMULATIVE
MAXIMUM FLUENCE (TOTAL)       (NEUTRONS/CM**2)     3.920224E 22       1       3.920224E 22       1
```

| | | | | | |
|---|---|---|---|---|---|
| MAXIMUM FLUENCE (RANGE 1) (NEUTRONS/CM**2) | 2.715056E 22 | 1 | 2.715056E 22 | 1 |
| MAXIMUM FLUENCE (RANGE 2) (NEUTRONS/CM**2) | 2.169450E 22 | 1 | 2.169450E 22 | 1 |
| MAXIMUM FISSIONS (FISSIONS/CM**3) | 9.286407E 19 | 3 | 9.286407E 19 | 3 |
| MAXIMUM EXPOSURE (MEGAWATT(THERMAL)-DAYS/KG) | 9.751050E 00 | 3 | 9.751050E 00 | 3 |
| TOTAL SYSTEM FISSIONS (FISSIONS) | 5.005646E 26 | | 5.005646E 26 | |
| TOTAL SYSTEM EXPOSURE (MEGAWATT(THERMAL)-DAYS/KG) | 2.685844E 00 | | 2.685844E 00 | |

DECAY ENERGY RELEASE DATA AVAILABLE

SECONDARY ENERGY FROM FISSION DATA AVAILABLE

ENERGY RELEASE FROM CAPTURE DATA AVAILABLE

DATA FOR DECAY ENERGY RELEASE

| | | | DECAY CONSTANT | BETA ENERGY | TOTAL ENERGY | GAMMA ENERGY IN RANGES 1) 3.000000E 06 | 2) 5.000000E 05 |
|---|---|---|---|---|---|---|---|
| 1) | PU241 | 6 | 1.688999E-09 | 7.000000E 03 | 9.000000E 03 | 0.0 | 5.799999E 00 |
| 2) | XE135 | 8 | 2.092999E-05 | 3.999999E 05 | 1.000000E 06 | 0.0 | 5.000000E 05 |
| 3) | PM147 | 9 | 8.288996E-09 | 9.999994E 04 | 1.999999E 05 | 0.0 | 9.999994E 04 |
| 4) | PM148M | 13 | 1.975999E-07 | 1.000000E 06 | 1.799999E 06 | 0.0 | 7.999999E 05 |
| 5) | PM148 | 14 | 1.487999E-06 | 1.000000E 06 | 2.000000E 06 | 0.0 | 1.000000E 06 |

DATA FOR SECONDARY ENERGY FROM FISSION

| | | | BETA ENERGY | GAMMA ENERGY IN RANGES 1) 3.000000E 06 | 2) 5.000000E 05 |
|---|---|---|---|---|---|
| 1) | U235 | 1 | 2.000000E 06 | 7.000000E 06 | 9.999994E 04 |
| 2) | U236 | 2 | 2.000000E 06 | 6.000000E 06 | 1.999999E 05 |
| 3) | U238 | 3 | 2.000000E 06 | 5.000000E 06 | 2.999999E 05 |
| 4) | PU239 | 4 | 2.000000E 06 | 4.000000E 06 | 3.999999E 05 |
| 5) | PU240 | 5 | 2.000000E 06 | 3.000000E 06 | 5.000000E 05 |
| 6) | PU241 | 6 | 2.000000E 06 | 2.000000E 06 | 5.999999E 05 |
| 7) | PU242 | 7 | 2.000000E 06 | 1.000000E 06 | 6.999999E 05 |

DATA FOR ENERGY RELEASE FROM CAPTURE

| | | BETA ENERGY | GAMMA ENERGY IN RANGES 1) 3.000000E 06 | 2) 5.000000E 05 |
|---|---|---|---|---|
| 1) | U235 | 1.000000E 06 | 6.500000E 06 | 0.0 |
| 2) | U236 | 1.000000E 06 | 5.000000E 06 | 0.0 |
| 3) | U238 | 1.000000E 06 | 4.799999E 06 | 0.0 |
| 4) | PU239 | 1.000000E 06 | 6.500000E 06 | 0.0 |
| 5) | PU240 | 1.000000E 06 | 5.399999E 06 | 0.0 |
| 6) | PU241 | 1.000000E 06 | 6.199999E 06 | 0.0 |
| 7) | PU242 | 1.000000E 06 | 5.000000E 06 | 0.0 |
| 8) | XE135 | 1.000000E 06 | 7.899999E 06 | 0.0 |
| 9) | PM147 | 1.000000E 06 | 5.000000E 06 | 0.0 |
| 10) | SM149 | 1.000000E 06 | 5.000000E 06 | 0.0 |
| 11) | NSFP | 1.000000E 06 | 5.000000E 06 | 0.0 |
| 12) | SSFP | 1.000000E 06 | 5.000000E 06 | 0.0 |
| 13) | PM148M | 1.000000E 06 | 5.000000E 06 | 0.0 |
| 14) | PM148 | 1.000000E 06 | 5.000000E 06 | 0.0 |

INITIAL REACTION RATES WILL BE MULTIPLIED BY 9.947858E-01

SECONDARY ENERGY DEPOSITION

```
UNITS OF EV/(SEC-CM**3)
  1)        TOTAL
  2)        BETA
  3)        BETA + TOTAL GAMMA
  4)        TOTAL GAMMA
  5) -  6)  GAMMA RANGES 1 -  2

ZONE NUMBER     1     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   1.150257E 06 CM**3
DECAY      1)   9.485810E 17   2)   3.816669E 17   3)   8.550486E 17   4)   4.733817E 17   5)   0.0            6)   4.733817E 17
FISSION    1)   8.601881E 19   2)   2.694912E 19   3)   8.601881E 19   4)   5.906969E 19   5)   5.365560E 19   6)   5.414095E 18
CAPTURE    1)   1.102725E 20   2)   1.807502E 19   3)   1.102725E 20   4)   9.219750E 19   5)   9.219750E 19   6)   0.0
TOTAL      1)   1.972399E 20   2)   4.540578E 19   3)   1.971463E 20   4)   1.517406E 20   5)   1.458531E 20   6)   5.887477E 18

ZONE NUMBER     2     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   1.150257E 06 CM**3
DECAY      1)   6.713741E 17   2)   2.700788E 17   3)   6.050263E 17   4)   3.349475E 17   5)   0.0            6)   3.349475E 17
FISSION    1)   6.088476E 19   2)   1.908133E 19   3)   6.088476E 19   4)   4.180343E 19   5)   3.796767E 19   6)   3.835765E 18
CAPTURE    1)   7.966395E 19   2)   1.305736E 19   3)   7.966395E 19   4)   6.660660E 19   5)   6.660660E 19   6)   0.0
TOTAL      1)   1.412201E 20   2)   3.240875E 19   3)   1.411537E 20   4)   1.087450E 20   5)   1.045743E 20   6)   4.170713E 18

ZONE NUMBER     3     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   1.150243E 06 CM**3
DECAY      1)   1.005934E 18   2)   4.047109E 17   3)   9.066927E 17   4)   5.019818E 17   5)   0.0            6)   5.019818E 17
FISSION    1)   9.102245E 19   2)   2.855001E 19   3)   9.102245E 19   4)   6.247244E 19   5)   5.672493E 19   6)   5.747517E 18
CAPTURE    1)   1.078351E 20   2)   1.762859E 19   3)   1.078351E 20   4)   9.020650E 19   5)   9.020650E 19   6)   0.0
TOTAL      1)   1.998635E 20   2)   4.658330E 19   3)   1.997642E 20   4)   1.531809E 20   5)   1.469314E 20   6)   6.249498E 18

ZONE NUMBER     4     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   1.150243E 06 CM**3
DECAY      1)   7.062793E 17   2)   2.841014E 17   3)   6.364353E 17   4)   3.523339E 17   5)   0.0            6)   3.523339E 17
FISSION    1)   6.394401E 19   2)   2.006296E 19   3)   6.394401E 19   4)   4.388105E 19   5)   3.983986E 19   6)   4.041198E 18
CAPTURE    1)   7.710527E 19   2)   1.260324E 19   3)   7.710527E 19   4)   6.450203E 19   5)   6.450203E 19   6)   0.0
TOTAL      1)   1.417555E 20   2)   3.295029E 19   3)   1.416857E 20   4)   1.087354E 20   5)   1.043419E 20   6)   4.393531E 18

ZONE NUMBER     5     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   1.150274E 06 CM**3
DECAY      1)   7.385905E 17   2)   2.970804E 17   3)   6.654852E 17   4)   3.684048E 17   5)   0.0            6)   3.684048E 17
FISSION    1)   6.655483E 19   2)   2.094390E 19   3)   6.655483E 19   4)   4.561093E 19   5)   4.137040E 19   6)   4.240527E 18
CAPTURE    1)   7.019159E 19   2)   1.140325E 19   3)   7.019159E 19   4)   5.878835E 19   5)   5.878835E 19   6)   0.0
TOTAL      1)   1.374850E 20   2)   3.264422E 19   3)   1.374119E 20   4)   1.047677E 20   5)   1.001588E 20   6)   4.608932E 18

ZONE NUMBER     6     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   1.150274E 06 CM**3
DECAY      1)   5.173593E 17   2)   2.081190E 17   3)   4.660176E 17   4)   2.578986E 17   5)   0.0            6)   2.578986E 17
FISSION    1)   4.664443E 19   2)   1.468312E 19   3)   4.664443E 19   4)   3.196133E 19   5)   2.898677E 19   6)   2.974565E 18
CAPTURE    1)   4.997458E 19   2)   8.116528E 18   3)   4.997458E 19   4)   4.185806E 19   5)   4.185806E 19   6)   0.0
TOTAL      1)   9.713636E 19   2)   2.300776E 19   3)   9.708503E 19   4)   7.407726E 19   5)   7.084482E 19   6)   3.232463E 18

ZONE NUMBER     7     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   9.411198E 05 CM**3
DECAY      1)   3.175155E 16   2)   1.274666E 16   3)   2.861257E 16   4)   1.586591E 16   5)   0.0            6)   1.586591E 16
FISSION    1)   3.832693E 18   2)   1.027102E 18   3)   3.832693E 18   4)   2.805592E 18   5)   2.660836E 18   6)   1.447568E 17
CAPTURE    1)   3.779231E 19   2)   6.486169E 18   3)   3.779231E 19   4)   3.130614E 19   5)   3.130614E 19   6)   0.0
TOTAL      1)   4.165675E 19   2)   7.526016E 18   3)   4.165360E 19   4)   3.412759E 19   5)   3.396698E 19   6)   1.606226E 17

ZONE NUMBER     8     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   9.411198E 05 CM**3
DECAY      1)   7.761427E 15   2)   3.112268E 15   3)   6.991610E 15   4)   3.879345E 15   5)   0.0            6)   3.879345E 15
FISSION    1)   9.520968E 17   2)   2.413089E 17   3)   9.520968E 17   4)   7.107879E 17   5)   6.825159E 17   6)   2.827203E 16
CAPTURE    1)   1.601123E 19   2)   2.751722E 18   3)   1.601123E 19   4)   1.325951E 19   5)   1.325951E 19   6)   0.0
TOTAL      1)   1.697109E 19   2)   2.996143E 18   3)   1.697032E 19   4)   1.397418E 19   5)   1.394203E 19   6)   3.215137E 16

ZONE NUMBER     9     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   9.411080E 05 CM**3
DECAY      1)   2.933742E 16   2)   1.177582E 16   3)   2.643596E 16   4)   1.466015E 16   5)   0.0            6)   1.466015E 16
FISSION    1)   3.547359E 18   2)   9.459031E 17   3)   3.547359E 18   4)   2.601457E 18   5)   2.470107E 18   6)   1.313502E 17
CAPTURE    1)   3.485251E 19   2)   5.983623E 18   3)   3.485251E 19   4)   2.886890E 19   5)   2.886890E 19   6)   0.0
TOTAL      1)   3.842920E 19   2)   6.941300E 18   3)   3.842630E 19   4)   3.148502E 19   5)   3.133900E 19   6)   1.460103E 17

ZONE NUMBER    10     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   9.411080E 05 CM**3
DECAY      1)   6.687376E 15   2)   2.681126E 15   3)   6.023782E 15   4)   3.342657E 15   5)   0.0            6)   3.342657E 15
FISSION    1)   8.218726E 17   2)   2.070084E 17   3)   8.218726E 17   4)   6.148643E 17   5)   5.911788E 17   6)   2.368552E 16
CAPTURE    1)   1.396497E 19   2)   2.400531E 18   3)   1.396497E 19   4)   1.156444E 19   5)   1.156444E 19   6)   0.0
```

```
TOTAL       1)   1.479353E 19   2)   2.610220E 18   3)   1.479287E 19   4)   1.218265E 19   5)   1.215562E 19   6)   2.702818E 16

ZONE NUMBER    11     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   9.411340E 05 CM**3
DECAY       1)   1.717651E 16   2)   6.890639E 15   3)   1.547511E 16   4)   8.584467E 15   5)   0.0            6)   8.584467E 15
FISSION     1)   2.088548E 18   2)   5.479607E 17   3)   2.088548E 18   4)   1.540587E 18   5)   1.468226E 18   6)   7.236133E 16
CAPTURE     1)   2.177258E 19   2)   3.741122E 18   3)   2.177258E 19   4)   1.803147E 19   5)   1.803147E 19   6)   0.0
TOTAL       1)   2.387830E 19   2)   4.295973E 18   3)   2.387659E 19   4)   1.958063E 19   5)   1.949969E 19   6)   8.094577E 16

ZONE NUMBER    12     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   9.411340E 05 CM**3
DECAY       1)   3.868804E 15   2)   1.550488E 15   3)   3.484487E 15   4)   1.933999E 15   5)   0.0            6)   1.933999E 15
FISSION     1)   4.775395E 17   2)   1.184868E 17   3)   4.775395E 17   4)   3.590527E 17   5)   3.462867E 17   6)   1.276609E 16
CAPTURE     1)   8.520150E 18   2)   1.465121E 18   3)   8.520150E 18   4)   7.055028E 18   5)   7.055028E 18   6)   0.0
TOTAL       1)   9.001558E 18   2)   1.585158E 18   3)   9.001173E 18   4)   7.416015E 18   5)   7.401314E 18   6)   1.470009E 16

ZONE NUMBER    13     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   6.145690E 05 CM**3
DECAY       1)   3.850950E 16   2)   1.545456E 16   3)   3.469909E 16   4)   1.924452E 16   5)   0.0            6)   1.924452E 16
FISSION     1)   4.662637E 18   2)   1.239916E 18   3)   4.662637E 18   4)   3.422721E 18   5)   3.251951E 18   6)   1.707715E 17
CAPTURE     1)   4.083667E 19   2)   7.014100E 18   3)   4.083667E 19   4)   3.382258E 19   5)   3.382258E 19   6)   0.0
TOTAL       1)   4.553781E 19   2)   8.269470E 18   3)   4.553400E 19   4)   3.726454E 19   5)   3.707453E 19   6)   1.900160E 17

ZONE NUMBER    14     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   6.145690E 05 CM**3
DECAY       1)   2.519842E 16   2)   1.010829E 16   3)   2.270214E 16   4)   1.259385E 16   5)   0.0            6)   1.259385E 16
FISSION     1)   3.062596E 18   2)   8.057410E 17   3)   3.062596E 18   4)   2.256855E 18   5)   2.149511E 18   6)   1.073450E 17
CAPTURE     1)   2.884914E 19   2)   4.957640E 18   3)   2.884914E 19   4)   2.389151E 19   5)   2.389151E 19   6)   0.0
TOTAL       1)   3.193692E 19   2)   5.773488E 18   3)   3.193443E 19   4)   2.616095E 19   5)   2.604101E 19   6)   1.199388E 17

ZONE NUMBER    15     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   5.028291E 05 CM**3
DECAY       1)   6.834414E 15   2)   2.739251E 15   3)   6.155693E 15   4)   3.416446E 15   5)   0.0            6)   3.416446E 15
FISSION     1)   8.408420E 17   2)   2.116447E 17   3)   8.408420E 17   4)   6.291972E 17   5)   6.050437E 17   6)   2.415357E 16
CAPTURE     1)   1.296959E 19   2)   2.230204E 18   3)   1.296959E 19   4)   1.073939E 19   5)   1.073939E 19   6)   0.0
TOTAL       1)   1.381727E 19   2)   2.444588E 18   3)   1.381659E 19   4)   1.137200E 19   5)   1.134443E 19   6)   2.757002E 16

ZONE NUMBER    16     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   5.028291E 05 CM**3
DECAY       1)   1.926525E 15   2)   7.717334E 14   3)   1.734903E 15   4)   9.631692E 14   5)   0.0            6)   9.631692E 14
FISSION     1)   2.396575E 17   2)   5.762324E 16   3)   2.396575E 17   4)   1.820343E 17   5)   1.766501E 17   6)   5.384261E 15
CAPTURE     1)   5.122422E 18   2)   8.811253E 17   3)   5.122422E 18   4)   4.241298E 18   5)   4.241298E 18   6)   0.0
TOTAL       1)   5.364006E 18   2)   9.395202E 17   3)   5.363815E 18   4)   4.424295E 18   5)   4.417948E 18   6)   6.347429E 15

ZONE NUMBER    17     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   6.145728E 05 CM**3
DECAY       1)   8.918470E 15   2)   3.575311E 15   3)   8.033290E 15   4)   4.457978E 15   5)   0.0            6)   4.457978E 15
FISSION     1)   1.096064E 18   2)   2.764431E 17   3)   1.096064E 18   4)   8.196206E 17   5)   7.878259E 17   6)   3.179471E 16
CAPTURE     1)   1.765563E 19   2)   3.035327E 18   3)   1.765563E 19   4)   1.462030E 19   5)   1.462030E 19   6)   0.0
TOTAL       1)   1.876061E 19   2)   3.315345E 18   3)   1.875971E 19   4)   1.544438E 19   5)   1.540812E 19   6)   3.625269E 16

ZONE NUMBER    18     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   6.145728E 05 CM**3
DECAY       1)   6.015759E 15   2)   2.411016E 15   3)   5.418247E 15   4)   3.007232E 15   5)   0.0            6)   3.007232E 15
FISSION     1)   7.416490E 17   2)   1.849808E 17   3)   7.416490E 17   4)   5.566682E 17   5)   5.363066E 17   6)   2.036170E 16
CAPTURE     1)   1.261230E 19   2)   2.168777E 18   3)   1.261230E 19   4)   1.044352E 19   5)   1.044352E 19   6)   0.0
TOTAL       1)   1.335997E 19   2)   2.356168E 18   3)   1.335937E 19   4)   1.100320E 19   5)   1.097983E 19   6)   2.336893E 16

ZONE NUMBER    19     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   5.028323E 05 CM**3
DECAY       1)   2.300149E 15   2)   9.214560E 14   3)   2.071402E 15   4)   1.149946E 15   5)   0.0            6)   1.149946E 15
FISSION     1)   2.858910E 17   2)   6.897258E 16   3)   2.858910E 17   4)   2.169185E 17   5)   2.103661E 17   6)   6.552411E 15
CAPTURE     1)   6.018739E 18   2)   1.035263E 18   3)   6.018739E 18   4)   4.983477E 18   5)   4.983477E 18   6)   0.0
TOTAL       1)   6.306930E 18   2)   1.105157E 18   3)   6.306701E 18   4)   5.201545E 18   5)   5.193842E 18   6)   7.702354E 15

ZONE NUMBER    20     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   5.028323E 05 CM**3
DECAY       1)   8.378891E 14   2)   3.355752E 14   3)   7.544985E 14   4)   4.189233E 14   5)   0.0            6)   4.189233E 14
FISSION     1)   1.048311E 17   2)   2.456746E 16   3)   1.048311E 17   4)   8.026366E 16   5)   7.826303E 16   6)   2.000671E 15
CAPTURE     1)   2.591491E 18   2)   4.458184E 17   3)   2.591491E 18   4)   2.145673E 18   5)   2.145673E 18   6)   0.0
TOTAL       1)   2.697159E 18   2)   4.707214E 17   3)   2.697076E 18   4)   2.226355E 18   5)   2.223935E 18   6)   2.419595E 15

TOTAL VOLUME INTEGRALS OVER SYSTEM (EV/SEC)
DECAY       1)   5.422713E 24   2)   2.181346E 24   3)   4.886796E 24   4)   2.705439E 24   5)   0.0            6)   2.705439E 24
FISSION     1)   4.950808E 26   2)   1.544733E 26   3)   4.950808E 26   4)   3.406069E 26   5)   3.097996E 26   6)   3.080931E 25
CAPTURE     1)   7.693659E 26   2)   1.273862E 26   3)   7.693659E 26   4)   6.419803E 26   5)   6.419803E 26   6)   0.0
```

```
TOTAL      1)   1.269869E 27   2)   2.840409E 26   3)   1.269333E 27   4)   9.852925E 26   5)   9.517800E 26   6)   3.351475E 25

MAXIMUM DECAY     ENERGY DEPOSITION IS   1.005934E 18 EV/(SEC-CM**3) AT ZONE     3
MAXIMUM FISSION   ENERGY DEPOSITION IS   9.102245E 19 EV/(SEC-CM**3) AT ZONE     3
MAXIMUM CAPTURE   ENERGY DEPOSITION IS   1.102725E 20 EV/(SEC-CM**3) AT ZONE     1
MAXIMUM TOTAL     ENERGY DEPOSITION IS   1.998635E 20 EV/(SEC-CM**3) AT ZONE     3

PNSTE    9.999995E-25   9.947859E-25
TNSTE    0.0            3.750000E 01   7.500000E 01
TNSTS    0.0


        SUMMARY OF CALCULATION

    EXPLICIT CHAIN - EXPOSURE
      SIGNIFICANCE EVENTS ENCOUNTERED                    18


     MAX ARRAY SIZE USED      5810 WORDS - FOR ZONE CALCULATION
```

```
AUXILIARY POINT CALCULATION HAS BEEN REQUESTED

MEMORY AVAILABLE FOR GEODST PROCESSING    8310

INTERFACE FILE GEODST VERSION   1 UNIT  13
 IGOM  =      7        NZONE =     22
 NREG  =     30        NZCL  =    110
 NCINTI=      6        NCINTJ=      5
 NCINTK=      1        NINTI =     12
 NINTJ =      8        NINTK =      1
 IMB1  =      1        IMB2  =      2
 JMB1  =      2        JMB2  =      1
 KMB1  =      0        KMB2  =      0
 NBS   =      1        NBCS  =      6
 NIBCS =      1        NZWBB =      0
 NTRIAG=      0        NRASS =      1
 NGOP1 =      0        NGOP2 =      0
 NGOP3 =      0        NGOP4 =      0
 NGOP5 =      0

MEMORY SETUP FOR GEODST PROCESSING     600 ALLOWING FOR      96 POINTS (     348     295     216     600)

MEMORY USED FOR GEODST PROCESSING     348 ACTUAL POINTS       8 (     348     295     216     248)

INTERFACE FILE RTFLUX VERSION   1 UNIT  17
 NDIM  =      2        NGROUP=      3
 NINTI =     12        NINTJ =      8
 NINTK =      1        ITER  =     35
 EFFK  =  1.012347E 00 POWER =  2.500000E 09

MAXIMUM ARRAY SIZE USED FOR INITIAL PROCESSING IS    2038

STORAGE REQUIRED FOR BASIC DATA IS    1714

        STORAGE SUPPLIED IS    10000
MAXIMUM STORAGE REQUIRED IS     3213
MINIMUM STORAGE REQUIRED IS     2331

 MODRP  =  0 MODRPF =  0

MEMORY ACTUALLY USED WILL BE    3213

NO PTATDN FILE EXISTS - POINT DENSITIES WILL BE EXTRACTED FROM ZONE DENSITIES


START OF STEP ATOM DENSITIES AT TIME   0.0           DAYS


POINT NUMBER    1
U235A      2.286999E-05  U238A      7.504299E-03  PU239A     8.677100E-04  PU240A     3.353599E-04
PU241A     6.421500E-05  PU242A     2.559100E-05  O16A       1.764000E-02  NA23A      9.058498E-03
CR-A       2.618700E-03  FE-A       9.785596E-03  NI-A       1.378300E-03  TA181A     9.999999E-11

POINT NUMBER    2
U235A      2.286999E-05  U238A      7.504299E-03  PU239A     8.677100E-04  PU240A     3.353599E-04
PU241A     6.421500E-05  PU242A     2.559100E-05  O16A       1.764000E-02  NA23A      9.058498E-03
CR-A       2.618700E-03  FE-A       9.785596E-03  NI-A       1.378300E-03  TA181A     9.999999E-11

POINT NUMBER    3
U235A      2.286999E-05  U238A      7.504299E-03  PU239A     8.677100E-04  PU240A     3.353599E-04
PU241A     6.421500E-05  PU242A     2.559100E-05  O16A       1.764000E-02  NA23A      9.058498E-03
```

```
CR-A        2.618700E-03  FE-A        9.785596E-03  NI-A        1.378300E-03  TA181A      9.999999E-11

POINT NUMBER    4
U235A       2.286999E-05  U238A       7.504299E-03  PU239A      8.677100E-04  PU240A      3.353599E-04
PU241A      6.421500E-05  PU242A      2.559100E-05  O16A        1.764000E-02  NA23A       9.058498E-03
CR-A        2.618700E-03  FE-A        9.785596E-03  NI-A        1.378300E-03  TA181A      9.999999E-11

POINT NUMBER    5
U235A       2.391500E-05  U238A       7.847499E-03  PU239A      9.906099E-04  PU240A      3.826800E-04
PU241A      7.327099E-05  PU242A      2.920099E-05  O16A        1.869300E-02  NA23A       8.403197E-03
CR-A        2.699300E-03  FE-A        1.008660E-02  NI-A        1.420600E-03  TA181A      9.999999E-11

POINT NUMBER    6
U235A       2.391500E-05  U238A       7.847499E-03  PU239A      9.906099E-04  PU240A      3.826800E-04
PU241A      7.327099E-05  PU242A      2.920099E-05  O16A        1.869300E-02  NA23A       8.403197E-03
CR-A        2.699300E-03  FE-A        1.008660E-02  NI-A        1.420600E-03  TA181A      9.999999E-11

POINT NUMBER    7
U235A       2.391500E-05  U238A       7.847499E-03  PU239A      9.906099E-04  PU240A      3.826800E-04
PU241A      7.327099E-05  PU242A      2.920099E-05  O16A        1.869300E-02  NA23A       8.403197E-03
CR-A        2.699300E-03  FE-A        1.008660E-02  NI-A        1.420600E-03  TA181A      9.999999E-11

POINT NUMBER    8
U235A       2.391500E-05  U238A       7.847499E-03  PU239A      9.906099E-04  PU240A      3.826800E-04
PU241A      7.327099E-05  PU242A      2.920099E-05  O16A        1.869300E-02  NA23A       8.403197E-03
CR-A        2.699300E-03  FE-A        1.008660E-02  NI-A        1.420600E-03  TA181A      9.999999E-11


EXPOSURE TIME STEP STARTS AT   0.0            DAYS

EXPOSURE TIME STEP IS   7.500000E 01 DAYS (   6.480000E 06 SECONDS ) THE NUMBER OF SUBSTEPS IS   2


END OF EXPOSURE STEP ATOM DENSITIES AT TIME   7.500000E 01  DAYS


POINT NUMBER    1
U235A       2.067366E-05  U236A       4.948737E-07  U238A       7.404726E-03  PU239A      8.797359E-04
PU240A      3.418962E-04  PU241A      6.163890E-05  PU242A      2.607709E-05  O16A        1.764000E-02
NA23A       9.058498E-03  CR-A        2.618700E-03  FE-A        9.785596E-03  NI-A        1.378300E-03
XE135A      4.274040E-08  PM147A      2.179643E-06  PM48MA      2.104961E-08  PM148A      8.429359E-10
SM149A      1.197648E-06  NSFPA       1.260825E-04  SSFPA       1.095820E-06  TA181A      9.999999E-11

POINT NUMBER    2
U235A       2.066878E-05  U236A       4.953868E-07  U238A       7.404476E-03  PU239A      8.795344E-04
PU240A      3.418631E-04  PU241A      6.162714E-05  PU242A      2.607575E-05  O16A        1.764000E-02
NA23A       9.058498E-03  CR-A        2.618700E-03  FE-A        9.785596E-03  NI-A        1.378300E-03
XE135A      4.293673E-08  PM147A      2.190191E-06  PM48MA      2.116196E-08  PM148A      8.475007E-10
SM149A      1.203803E-06  NSFPA       1.266855E-04  SSFPA       1.101016E-06  TA181A      9.999999E-11

POINT NUMBER    3
U235A       2.050718E-05  U236A       5.315480E-07  U238A       7.396810E-03  PU239A      8.805413E-04
PU240A      3.423970E-04  PU241A      6.149839E-05  PU242A      2.611296E-05  O16A        1.764000E-02
NA23A       9.058498E-03  CR-A        2.618700E-03  FE-A        9.785596E-03  NI-A        1.378300E-03
XE135A      4.621886E-08  PM147A      2.351339E-06  PM48MA      2.351781E-08  PM148A      9.562997E-10
SM149A      1.296567E-06  NSFPA       1.363106E-04  SSFPA       1.182746E-06  TA181A      9.999999E-11

POINT NUMBER    4
U235A       2.050045E-05  U236A       5.324343E-07  U238A       7.396474E-03  PU239A      8.804409E-04
PU240A      3.423665E-04  PU241A      6.148459E-05  PU242A      2.611188E-05  O16A        1.764000E-02
NA23A       9.058498E-03  CR-A        2.618700E-03  FE-A        9.785596E-03  NI-A        1.378300E-03
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| XE135A | 4.646112E-08 | PM147A | 2.364186E-06 | PM48MA | 2.366553E-08 | PM148A | 9.625241E-10 |
| SM149A | 1.304079E-06 | NSFPA | 1.370506E-04 | SSFPA | 1.189098E-06 | TA181A | 9.999999E-11 |

POINT NUMBER 5

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235A | 2.166411E-05 | U236A | 5.023983E-07 | U238A | 7.745158E-03 | PU239A | 9.949647E-04 |
| PU240A | 3.894465E-04 | PU241A | 7.030077E-05 | PU242A | 2.971978E-05 | O16A | 1.869300E-02 |
| NA23A | 8.403197E-03 | CR-A | 2.699300E-03 | FE-A | 1.008660E-02 | NI-A | 1.420600E-03 |
| XE135A | 4.800278E-08 | PM147A | 2.455245E-06 | PM48MA | 2.336390E-08 | PM148A | 9.286327E-10 |
| SM149A | 1.347161E-05 | NSFPA | 1.418767E-04 | SSFPA | 1.233910E-06 | TA181A | 9.999999E-11 |

POINT NUMBER 6

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235A | 2.190622E-05 | U236A | 4.478702E-07 | U238A | 7.756531E-03 | PU239A | 9.942893E-04 |
| PU240A | 3.885862E-04 | PU241A | 7.051123E-05 | PU242A | 2.965846E-05 | O16A | 1.869300E-02 |
| NA23A | 8.403197E-03 | CR-A | 2.699300E-03 | FE-A | 1.008660E-02 | NI-A | 1.420600E-03 |
| XE135A | 4.282855E-08 | PM147A | 2.199334E-06 | PM48MA | 1.968808E-08 | PM148A | 7.642180E-10 |
| SM149A | 1.201967E-06 | NSFPA | 1.266728E-04 | SSFPA | 1.104193E-06 | TA181A | 9.999999E-11 |

POINT NUMBER 7

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235A | 2.148906E-05 | U236A | 5.406479E-07 | U238A | 7.736824E-03 | PU239A | 9.951955E-04 |
| PU240A | 3.899734E-04 | PU241A | 7.013400E-05 | PU242A | 2.975909E-05 | O16A | 1.869300E-02 |
| NA23A | 8.403197E-03 | CR-A | 2.699300E-03 | FE-A | 1.008660E-02 | NI-A | 1.420600E-03 |
| XE135A | 5.197767E-08 | PM147A | 2.652512E-06 | PM48MA | 2.618939E-08 | PM148A | 1.057237E-09 |
| SM149A | 1.460437E-06 | NSFPA | 1.536068E-04 | SSFPA | 1.333719E-06 | TA181A | 9.999999E-11 |

POINT NUMBER 8

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| U235A | 2.174788E-05 | U236A | 4.825040E-07 | U238A | 7.749062E-03 | PU239A | 9.944895E-04 |
| PU240A | 3.890505E-04 | PU241A | 7.035804E-05 | PU242A | 2.969359E-05 | O16A | 1.869300E-02 |
| NA23A | 8.403197E-03 | CR-A | 2.699300E-03 | FE-A | 1.008660E-02 | NI-A | 1.420600E-03 |
| XE135A | 4.640035E-08 | PM147A | 2.377943E-06 | PM48MA | 2.215556E-08 | PM148A | 8.729550E-10 |
| SM149A | 1.303429E-06 | NSFPA | 1.372236E-04 | SSFPA | 1.194397E-06 | TA181A | 9.999999E-11 |

```
POWER DENSITY STATISTICS FROM POINT CALCULATION

   1) ZONE      1 NUMBER OF POINTS      4 CALC. POINTS      1 TO      4

AVERAGE POWER DENSITY   4.499397E 02
MAXIMUM POWER DENSITY   4.688579E 02 AT POINT      4
MINIMUM POWER DENSITY   4.312568E 02 AT POINT      1

POWER DENSITY
     1)   4.312568E 02       2)   4.333071E 02       3)   4.663381E 02       4)   4.688579E 02

   2) ZONE      3 NUMBER OF POINTS      4 CALC. POINTS      5 TO      8

AVERAGE POWER DENSITY   4.782844E 02
MAXIMUM POWER DENSITY   5.255000E 02 AT POINT      3
MINIMUM POWER DENSITY   4.331047E 02 AT POINT      2

POWER DENSITY
     1)   4.852708E 02       2)   4.331047E 02       3)   5.255000E 02       4)   4.692642E 02

INTERFACE FILE PTATDN VERSION  1 (NEW) HAS BEEN WRITTEN ON UNIT  30  WITH DENSITIES AT TIME   7.500000E 01  DAYS


     MAX ARRAY SIZE USED     3213 WORDS - FOR POINT CALCULATION


     MAX ARRAY SIZE USED     5810 WORDS

     TOTAL CPU TIME USED    0.046 MINUTES     TOTAL CLOCK TIME USED    0.258 MINUTES     TOTAL I/O USED     365

NORMAL END OF EXPOSURE MODULE
```

```
BURNER - EXPOSURE MODULE - PRE-RELEASE VERSION 1E - NOVEMBER 14, 1978 - QUALITY ASSURANCE LEVEL 0
-------------------------------------------------------------------------------------------------

CASE TITLE -  BREEDER REACTOR SAMPLE PROBLEM FOR THE BURNER CODE

RITE CONTAINER ARRAYS, CONTROL       6 DATA       1

          GRUPXS TITLE
           BREEDER REACTOR CROSS SECTION DATA (3 GROUP)

METHOD OF SOLUTION - EXPLICIT CHAIN

          THE LONGEST EXPLICIT CHAIN IS    10


YIELD RANGE NUMBER FOR EACH NEUTRON ENERGY GROUP
IGY     1  1  2

MAXIMUM ARRAY SIZE USED FOR INITIAL PROCESSING IS    1780

STORAGE REQUIRED FOR BASIC DATA IS    1678

        STORAGE SUPPLIED IS    10000
MAXIMUM STORAGE REQUIRED IS     5811
MINIMUM STORAGE REQUIRED IS     3165

 MODRR  =  0 MODRRF =  0

MEMORY ACTUALLY USED WILL BE    5811

EXPOSURE TIME STEP STARTS AT   7.500000E 01  DAYS

EXPOSURE TIME STEP IS   7.500000E 01 DAYS (   6.480000E 06 SECONDS ) THE NUMBER OF SUBSTEPS IS   2

POWER   2.499994E 09 WATTS, MAXIMUM POWER DENSITY   4.714111E 02 WATTS/CC IN ZONE            3   AT START OF SUBSTEP     1
POWER   2.506054E 09 WATTS, MAXIMUM POWER DENSITY   4.707554E 02 WATTS/CC IN ZONE            3     AT END OF SUBSTEP     1

          AVERAGE POWER AT END OF SUBSTEP   2.503024E 09 WATTS

          INITIAL REACTION RATES WILL BE MULTIPLIED BY   9.951643E-01 FOR NEXT SUBSTEP            9.951645E-01   9.975767E-01

POWER   2.493935E 09 WATTS, MAXIMUM POWER DENSITY   4.684790E 02 WATTS/CC IN ZONE            3   AT START OF SUBSTEP     2
POWER   2.499578E 09 WATTS, MAXIMUM POWER DENSITY   4.677825E 02 WATTS/CC IN ZONE            3     AT END OF SUBSTEP     2

          AVERAGE POWER AT END OF SUBSTEP   2.499890E 09 WATTS
```

INVENTORY AND REACTION RATES BY ABSOLUTE NUCLIDE

| NO. | NAME | ********** START OF STEP TIME 75.000 DAYS ********** INVENTORY (KG) | ABSORPTION | FISSION | PRODUCTION | CAPTURE (N,G) | ********** END OF STEP TIME 150.000 DAYS ********** INVENTORY (KG) | ABSORPTION | FISSION | PRODUCTION | CAPTURE (N,G) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | U235 | 1.96964E 02 | 1.19611E-02 | 9.12009E-03 | 2.23456E-02 | 2.84099E-03 | 1.90497E 02 | 1.12315E-02 | 8.55935E-03 | 2.09709E-02 | 2.67219E-03 |
| 2 | U236 | 1.63146E 00 | 4.35668E-05 | 5.48041E-06 | 1.47234E-05 | 3.80864E-05 | 3.13981E 00 | 8.28111E-05 | 1.03725E-05 | 2.78659E-05 | 7.24387E-05 |
| 3 | U238 | 6.74498E 04 | 5.25614E-01 | 4.87300E-02 | 1.32847E-01 | 4.76884E-01 | 6.71543E 04 | 5.20089E-01 | 4.81459E-02 | 1.31256E-01 | 4.71943E-01 |
| 4 | PU239 | 2.84906E 03 | 3.13508E-01 | 2.47155E-01 | 7.24982E-01 | 6.63528E-02 | 2.93935E 03 | 3.16991E-01 | 2.49725E-01 | 7.32442E-01 | 6.72660E-02 |
| 5 | PU240 | 1.08347E 03 | 4.06193E-02 | 1.86852E-02 | 5.65086E-02 | 2.19340E-02 | 1.09826E 03 | 4.11146E-02 | 1.89091E-02 | 5.71853E-02 | 2.22055E-02 |
| 6 | PU241 | 1.98713E 02 | 2.92249E-02 | 2.48088E-02 | 7.37734E-02 | 4.41613E-03 | 1.92763E 02 | 2.82475E-02 | 2.39791E-02 | 7.13064E-02 | 4.26839E-03 |
| 7 | PU242 | 8.33457E 01 | 2.59188E-03 | 1.12250E-03 | 3.41953E-03 | 1.46938E-03 | 8.43423E 01 | 2.61947E-03 | 1.13438E-03 | 3.45573E-03 | 1.48508E-03 |
| 8 | O16 | 9.57602E 03 | 2.14057E-03 | 0.0 | 0.0 | 2.14057E-03 | 9.57602E 03 | 2.13578E-03 | 0.0 | 0.0 | 2.13578E-03 |
| 9 | NA23 | 1.07873E 04 | 1.11904E-03 | 2.73721E-07 | 5.47444E-07 | 1.11877E-03 | 1.07873E 04 | 1.11654E-03 | 2.73109E-07 | 5.46219E-07 | 1.11627E-03 |
| 10 | CR | 1.41915E 04 | 1.03466E-02 | 8.74113E-07 | 1.74823E-06 | 1.03457E-02 | 1.41915E 04 | 1.03235E-02 | 8.72157E-07 | 1.74431E-06 | 1.03226E-02 |
| 11 | MN55 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | FE | 5.69502E 04 | 3.62417E-02 | 8.61342E-06 | 1.72268E-05 | 3.62331E-02 | 5.69502E 04 | 3.61606E-02 | 8.59414E-06 | 1.71883E-05 | 3.61520E-02 |
| 13 | NI | 8.43419E 03 | 1.02570E-02 | 3.73428E-08 | 7.46857E-08 | 1.02570E-02 | 8.43419E 03 | 1.02340E-02 | 3.72593E-08 | 7.45187E-08 | 1.02340E-02 |
| 14 | XE135 | 5.72171E-02 | 1.38661E-07 | 0.0 | 0.0 | 1.38661E-07 | 5.72242E-02 | 1.39813E-07 | 0.0 | 0.0 | 1.39813E-07 |
| 15 | PM147 | 3.20527E 00 | 4.36565E-04 | 3.63504E-08 | 7.27008E-08 | 4.36528E-04 | 6.10237E 00 | 8.27993E-04 | 6.87842E-08 | 1.37568E-07 | 8.27925E-04 |
| 16 | PM148M | 2.66574E-02 | 2.00321E-04 | 0.0 | 0.0 | 2.00321E-04 | 5.91921E-02 | 4.40569E-04 | 0.0 | 0.0 | 4.40569E-04 |
| 17 | PM148 | 1.02190E-03 | 1.26785E-05 | 0.0 | 0.0 | 1.26785E-05 | 2.00972E-03 | 2.48970E-05 | 0.0 | 0.0 | 2.48970E-05 |
| 18 | SM149 | 1.77350E 00 | 2.14568E-04 | 1.67014E-07 | 3.34028E-07 | 2.14401E-04 | 3.55941E 00 | 4.30275E-04 | 3.34128E-07 | 6.68257E-07 | 4.29941E-04 |
| 19 | NSFP | 0.0 | 2.34557E-03 | 0.0 | 0.0 | 2.34557E-03 | 0.0 | 4.67325E-03 | 0.0 | 0.0 | 4.67325E-03 |
| 20 | SSFP | 0.0 | 1.69189E-04 | 0.0 | 0.0 | 1.69189E-04 | 0.0 | 3.31455E-04 | 0.0 | 0.0 | 3.31455E-04 |
| 21 | TA181 | 2.07418E-04 | 1.32705E-08 | 0.0 | 0.0 | 1.32705E-08 | 2.07418E-04 | 1.32408E-08 | 0.0 | 0.0 | 1.32408E-08 |
| | TOTALS | 1.71807E 05 | 9.87045E-01 | 3.49637E-01 | 1.01391E 00 | 6.37408E-01 | 1.71611E 05 | 9.87074E-01 | 3.50473E-01 | 1.01666E 00 | 6.36600E-01 |
| OTHER LOSS RATE | | | 1.29546E-02 | | | | | 1.29257E-02 | | | |
| TOTAL LOSS RATE | | | 1.00000E 00 | | | | | 1.00000E 00 | | | |
| SYSTEM LOSS RATE(N/SEC) | | | 2.20953E 20 | | | | | 2.20377E 20 | | | |
| RELATIVE FLUX LEVEL | | | 1.00000E 00 | | | | | 9.95164E-01 | | | |

SUMMARY TABLES FOR EXPOSURE ENDING AT TIME 1.500000E 02 DAYS
FOR CASE BREEDER REACTOR SAMPLE PROBLEM FOR THE BURNER CODE

AVERAGE NEUTRON LOSSES BY NUCLIDE CLASS AND ZONE CLASS - SYSTEM LOSS RATE 2.206654E 20 N/SEC

| ZONE CLASS ID. | FISSILE 1 | FERTILE 2 | O. ACTINIDE 3 | FISSION PROD 4 | STRUCTURAL 5 | COOLANT 6 | CONTROL ROD 7 | OTHER 0 |
|---|---|---|---|---|---|---|---|---|
| 101 | 0.1262376 | 0.1586086 | 0.0009564 | 0.0021281 | 0.0145973 | 0.0002663 | 0.0000000 | 0.0007174 |
| 102 | 0.1277906 | 0.1501803 | 0.0009839 | 0.0019593 | 0.0133804 | 0.0002318 | 0.0000000 | 0.0007364 |
| 103 | 0.0927221 | 0.0953811 | 0.0007186 | 0.0008793 | 0.0084433 | 0.0001473 | 0.0000000 | 0.0004904 |
| 104 | 0.0027242 | 0.0414753 | 0.0000035 | 0.0000303 | 0.0035642 | 0.0001335 | 0.0 | 0.0000467 |
| 105 | 0.0022160 | 0.0366619 | 0.0000027 | 0.0000230 | 0.0030557 | 0.0001033 | 0.0 | 0.0000436 |
| 106 | 0.0010701 | 0.0225311 | 0.0000010 | 0.0000081 | 0.0018616 | 0.0000612 | 0.0 | 0.0000272 |
| 107 | 0.0021462 | 0.0410372 | 0.0000022 | 0.0000214 | 0.0023181 | 0.0000408 | 0.0 | 0.0000652 |
| 108 | 0.0006744 | 0.0178460 | 0.0000004 | 0.0000022 | 0.0010316 | 0.0000174 | 0.0 | 0.0000113 |
| 109 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0029830 | 0.0000407 | 0.0 | 0.0 |
| 110 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0055467 | 0.0000756 | 0.0 | 0.0 |
| SUM | 0.3555809 | 0.5637214 | 0.0026688 | 0.0050516 | 0.0567818 | 0.0011178 | 0.0000000 | 0.0021382 |

| ZONE CLASS ID. | ABSORPTION LOSSES | FISSILE INVENTORY (KG) 75.000 DAYS | 150.000 DAYS | EFFECTIVE CONVERSION RATIO REACTION RATE | MASS BALANCE | POWER (WATTS) |
|---|---|---|---|---|---|---|
| 101 | 0.3035116 | 8.779272E 02 | 8.828882E 02 | 1.07770 | 1.06923 | 8.765327E 08 |
| 102 | 0.2952624 | 9.926743E 02 | 9.915166E 02 | 0.99354 | 0.98404 | 8.949230E 08 |
| 103 | 0.1987820 | 1.149101E 03 | 1.140681E 03 | 0.85557 | 0.84002 | 6.461614E 08 |
| 104 | 0.0479776 | 4.209000E 01 | 6.334897E 01 | 14.74775 | 14.84156 | 2.265726E 07 |
| 105 | 0.0421060 | 4.142136E 01 | 6.028589E 01 | 15.99673 | 16.10864 | 1.959589E 07 |
| 106 | 0.0255603 | 3.450909E 01 | 4.626129E 01 | 20.34496 | 20.53076 | 1.073147E 07 |
| 107 | 0.0456311 | 5.958716E 01 | 8.063489E 01 | 18.27583 | 18.42551 | 2.365822E 07 |
| 108 | 0.0195833 | 4.742706E 01 | 5.699405E 01 | 25.98819 | 26.29350 | 5.631444E 06 |
| 109 | 0.0030237 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 110 | 0.0056222 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| OVERALL | 0.9870601 | 3.244736E 03 | 3.322609E 03 | 1.39627 | 1.38589 | 2.499890E 09 |
| OTHER LOSSES | 0.0129399 | | | | | |
| TOTAL LOSSES | 1.0000000 | | | | | |

FISSILE CONSUMPTION PER UNIT ENERGY GENERATION IS 1.245740E-14 KG/WATT-SEC
FISSILE CONSUMPTION RATE IS 3.114215E-05 KG/SEC

INTERFACE FILE ZNATDN VERSION 3 (NEW) HAS BEEN WRITTEN ON UNIT 31 WITH DENSITIES AT TIME 1.500000E 02 DAYS

POWER COMPUTED FROM POWER DENSITY 2.499887E 09

INTERFACE FILE ZNPOWD VERSION 1 (OLD) HAS BEEN WRITTEN ON UNIT 19

```
CUMULATIVE EXPOSURE INFORMATION

EXPORT OPTION - SAVE LATEST AND NEXT-TO-LATEST DATA

INTERFACE FILE EXPORT VERSION  1 (OLD) HAS BEEN WRITTEN ON UNIT  20

                                                        CURRENT                      CUMULATIVE
MAXIMUM FLUENCE (TOTAL)        (NEUTRONS/CM**2)         3.981573E 22       1         7.901793E 22       1
MAXIMUM FLUENCE (RANGE 1)      (NEUTRONS/CM**2)         2.762220E 22       1         5.477276E 22       1
MAXIMUM FLUENCE (RANGE 2)      (NEUTRONS/CM**2)         2.209593E 22       1         4.379043E 22       1
MAXIMUM FISSIONS    (FISSIONS/CM**3)                    9.117501E 19       3         1.840391E 20       3
MAXIMUM EXPOSURE    (MEGAWATT(THERMAL)-DAYS/KG)         1.001963E 01       1         1.974091E 01       1
TOTAL SYSTEM FISSIONS    (FISSIONS)                     5.005472E 26                 1.001112E 27
TOTAL SYSTEM EXPOSURE    (MEGAWATT(THERMAL)-DAYS/KG)    2.693353E 00                 5.379197E 00

   DECAY ENERGY RELEASE DATA AVAILABLE

   SECONDARY ENERGY FROM FISSION DATA AVAILABLE

   ENERGY RELEASE FROM CAPTURE DATA AVAILABLE

SECONDARY ENERGY DEPOSITION

   UNITS OF EV/(SEC-CM**3)
     1)        TOTAL
     2)        BETA
     3)        BETA + TOTAL GAMMA
     4)        TOTAL GAMMA
     5) -  6)  GAMMA RANGES 1 -  2

TOTAL VOLUME INTEGRALS OVER SYSTEM (EV/SEC)
DECAY      1)   5.501869E 24   2)   2.223410E 24   3)   4.965937E 24   4)   2.742513E 24   5)   0.0            6)   2.742513E 24
FISSION    1)   4.950064E 26   2)   1.544686E 26   3)   4.950064E 26   4)   3.405378E 26   5)   3.097247E 26   6)   3.081486E 25
CAPTURE    1)   7.678736E 26   2)   1.270786E 26   3)   7.678736E 26   4)   6.407956E 26   5)   6.407956E 26   6)   0.0
TOTAL      1)   1.268382E 27   2)   2.837707E 26   3)   1.267846E 27   4)   9.840757E 26   5)   9.505203E 26   6)   3.355736E 25

MAXIMUM DECAY    ENERGY DEPOSITION IS   1.003200E 18 EV/(SEC-CM**3) AT ZONE     3
MAXIMUM FISSION  ENERGY DEPOSITION IS   8.933777E 19 EV/(SEC-CM**3) AT ZONE     3
MAXIMUM CAPTURE  ENERGY DEPOSITION IS   1.119292E 20 EV/(SEC-CM**3) AT ZONE     1
MAXIMUM TOTAL    ENERGY DEPOSITION IS   2.005958E 20 EV/(SEC-CM**3) AT ZONE     1


        SUMMARY OF CALCULATION

    EXPLICIT CHAIN - EXPOSURE
      SIGNIFICANCE EVENTS ENCOUNTERED                 18


     MAX ARRAY SIZE USED     5810 WORDS - FOR ZONE CALCULATION
```

```
AUXILIARY POINT CALCULATION HAS BEEN REQUESTED

REFERENCE ZONE NUMBERS FROM PTATDN
     1)        1        2)        3

MEMORY AVAILABLE FOR GEODST PROCESSING    8310

MEMORY SETUP FOR GEODST PROCESSING     600 ALLOWING FOR      96 POINTS (     348     295     216     600)

MEMORY USED FOR GEODST PROCESSING     348 ACTUAL POINTS       8 (     348     295     216     248)

MAXIMUM ARRAY SIZE USED FOR INITIAL PROCESSING IS    2038

STORAGE REQUIRED FOR BASIC DATA IS    1714

        STORAGE SUPPLIED IS    10000
MAXIMUM STORAGE REQUIRED IS     3213
MINIMUM STORAGE REQUIRED IS     2331

 MODRP  =  0 MODRPP =  0

MEMORY ACTUALLY USED WILL BE    3213

EXPOSURE TIME STEP STARTS AT   7.500000E 01  DAYS

EXPOSURE TIME STEP IS   7.500000E 01 DAYS (   6.480000E 06 SECONDS ) THE NUMBER OF SUBSTEPS IS   2
```

```
POWER DENSITY STATISTICS FROM POINT CALCULATION

   1) ZONE      1 NUMBER OF POINTS      4 CALC. POINTS      1 TO      4

AVERAGE POWER DENSITY   4.590356E 02
MAXIMUM POWER DENSITY   4.800054E 02 AT POINT      3
MINIMUM POWER DENSITY   4.381750E 02 AT POINT      2

POWER DENSITY
     1)   4.441904E 02       2)   4.381750E 02       3)   4.800054E 02       4)   4.737722E 02

   2) ZONE      3 NUMBER OF POINTS      4 CALC. POINTS      5 TO      8

AVERAGE POWER DENSITY   4.696011E 02
MAXIMUM POWER DENSITY   5.181877E 02 AT POINT      3
MINIMUM POWER DENSITY   4.231641E 02 AT POINT      2

POWER DENSITY
     1)   4.791335E 02       2)   4.231641E 02       3)   5.181877E 02       4)   4.579207E 02

INTERFACE FILE PTATDN VERSION  2 (NEW) HAS BEEN WRITTEN ON UNIT  32  WITH DENSITIES AT TIME   1.500000E 02  DAYS


     MAX ARRAY SIZE USED     3213 WORDS - FOR POINT CALCULATION


     MAX ARRAY SIZE USED     5810 WORDS

     TOTAL CPU TIME USED    0.030 MINUTES     TOTAL CLOCK TIME USED    0.264 MINUTES     TOTAL I/O USED     387

NORMAL END OF EXPOSURE MODULE
```

BURNER - EXPOSURE MODULE - PRE-RELEASE VERSION 1E - NOVEMBER 14, 1978 - QUALITY ASSURANCE LEVEL 0

CASE TITLE - GAS COOLED REACTOR PROBLEM, (1-D MODELED AS 2-D) BURNER CODE TEST CASE

RITE CONTAINER ARRAYS, CONTROL 6 DATA 1

GRUPXS TITLE
FOUR GROUP MICROSCOPIC GAS COOLED REACTOR CROSS SECTIONS BURNER CODE

NISOU - THE NUMBER OF DIFFERENT UNIQUE ISOTOPES IN SYSTEM IS 20
NISOA - THE NUMBER OF DIFFERENT ABSOLUTE ISOTOPES IN SYSTEM IS 19
NUCLAS - THE NUMBER OF DIFFERENT ISOTOPE CLASSES IN SYSTEM IS 5

| NO. | NORR | NOSS | NABSOL | HABSOL | NCLAS | ICLAS |
|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | C | 5 | 1 |
| 2 | 2 | 2 | 2 | I-135 | 4 | 2 |
| 3 | 3 | 3 | 3 | XE-135 | 4 | 3 |
| 4 | 4 | 4 | 4 | PM-147 | 4 | 4 |
| 5 | 5 | 5 | 5 | PM148M | 4 | 5 |
| 6 | 6 | 6 | 6 | PM-148 | 4 | 0 |
| 7 | 7 | 7 | 7 | SM-149 | 4 | 0 |
| 8 | 8 | 8 | 8 | U-236 | 3 | 0 |
| 9 | 9 | 9 | 9 | FP2 | 4 | 0 |
| 10 | 10 | 10 | 10 | FP1 | 4 | 0 |
| 11 | 11 | 11 | 11 | TH-232 | 2 | 0 |
| 12 | 12 | 12 | 11 | PA-233 | 2 | 0 |
| 13 | 13 | 13 | 12 | U-233 | 1 | 0 |
| 14 | 14 | 14 | 13 | U-234 | 1 | 0 |
| 15 | 15 | 15 | 14 | U-235 | 2 | 0 |
| 16 | 16 | 16 | 15 | PM-149 | 1 | 0 |
| 17 | 17 | 17 | 16 | ND-143 | 4 | 0 |
| 18 | 18 | 18 | 17 | HE | 4 | 0 |
| 19 | 19 | 19 | 18 | RECVEL | 5 | 0 |
| 20 | 20 | 20 | 19 | | 5 | 0 |

NZCLAS - THE NUMBER OF DIFFERENT ZONE CLASSES IS 3

| NO. | NZCLS | IZCLS |
|---|---|---|
| 1 | 1 | 1 |
| 2 | 1 | 2 |
| 3 | 1 | 3 |
| 4 | 1 | 0 |
| 5 | 1 | 0 |
| 6 | 1 | 0 |
| 7 | 1 | 0 |
| 8 | 1 | 0 |
| 9 | 1 | 0 |
| 10 | 1 | 0 |
| 11 | 1 | 0 |
| 12 | 1 | 0 |
| 13 | 1 | 0 |
| 14 | 1 | 0 |
| 15 | 1 | 0 |

```
16        1        0
17        1        0
18        1        0
19        2        0
20        2        0
21        3        0
22        1        0
23        3        0

METHOD OF SOLUTION - EXPLICIT CHAIN

          THE LONGEST EXPLICIT CHAIN IS     12

          * TH-232, U-233 U-235 FUEL (NO U-238) CHAIN EXPOSURE DATA                *

                EXPOSURE NUCLIDES
                NUCLIDE NAMES ARE ABSOLUTE
            1)  TH-232
            2)  PA-233
            3)   U-233
            4)   U-234
            5)   U-235
            6)   U-236
            7)   I-135
            8)  XE-135
            9)  PM-147
           10)  PM-148
           11)  PM148M
           12)  PM-149
           13)  SM-149
           14)  ND-143
           15)    FP1
           16)    FP2

                                DECAY CONSTANTS (1/SEC)

            1)  PA-233        2      2.929998E-07
            2)   I-135        7      2.869999E-05
            3)  XE-135        8      2.089998E-05
            4)  PM-147        9      8.289998E-09
            5)  PM-148       10      1.489999E-06
            6)  PM148M       11      1.979998E-07
            7)  PM-149       12      3.629997E-06

                                FISSION PRODUCT YIELD DATA

                                ENERGY RANGE   1 CUTOFF AT     0.0          EV

                                 FISSIONING NUCLIDE
                                     1)         2)         3)
                                 TH-232      U-233      U-235
            FISSION PRODUCT          1          3          5
            1)   I-135        7     0.053900  0.056200  0.061700
            2)  XE-135        8     0.002100  0.002200  0.002400
            3)  PM-147        9     0.038200  0.019300  0.023600
            4)  PM-149       12     0.009450  0.007700  0.011300
            5)  ND-143       14     0.080000  0.059100  0.060300
            6)    FP1        15     0.980000  0.990000  1.110000
            7)    FP2        16     3.599999  3.599999  3.799999

                  BASIC EXPLICIT CHAINS SPECIFIED

                START CHAIN      1      LENGTH IS     12                1    12
            1)  TH-232                                                                1
            2)              (N,G)          1.000000                                   2
            3)  PA-233                                                                2
```

```
 4)                DECAY        1.000000                                          1
 5)   U-233
 6)                (N,G)        1.000000                                          3
 7)   U-234                                                                        2
 8)                (N,G)        1.000000                                          4
 9)   U-235                                                                        2
10)                (N,G)        1.000000                                          5
11)   U-236                                                                        2
12)     END CHAIN      1                                                           6
      START CHAIN      2     LENGTH IS    10              13   22                  0
13)   TH-232
14)                (N,G)        1.000000                                          1
15)   PA-233                                                                       2
16)                (N,G)        1.000000                                          2
17)   U-234                                 ADDED CONTRIBUTION                    2
18)                (N,G)        1.000000                                         -4
19)   U-235                                 ADDED CONTRIBUTION                    2
20)                (N,G)        1.000000                                         -5
21)   U-236                                 ADDED CONTRIBUTION                    2
22)     END CHAIN      2                                                          -6
      START CHAIN      3     LENGTH IS     4              23   26                  0
23)   I-135
24)                DECAY        1.000000                                          7
25)   XE-135                                                                       1
26)     END CHAIN      3                                                           8
      START CHAIN      4     LENGTH IS     8              27   34                  0
27)   PM-147
28)                (N,G)        0.530000                                          9
29)   PM-148                                                                     530002
30)                (N,G)        1.000000                                         10
31)   PM-149                                                                       2
32)                DECAY        1.000000                                         12
33)   SM-149                                                                       1
34)     END CHAIN      4                                                          13
      START CHAIN      5     LENGTH IS     8              35   42                  0
35)   PM-147
36)                (N,G)        0.470000                                          9
37)   PM148M                                                                     470002
38)                (N,G)        1.000000                                         11
39)   PM-149                                                                       2
40)                DECAY        1.000000                                         -12
41)   SM-149                                 ADDED CONTRIBUTION                    1
42)     END CHAIN      5                                                          -13
      START CHAIN      6     LENGTH IS     2              43   44                  0
43)   ND-143
44)     END CHAIN      6                                                          14
      START CHAIN      7     LENGTH IS     4              45   48                  0
45)     FP1
46)                (N,G)        1.000000                                         15
47)     FP2                                                                        2
48)     END CHAIN      7                                                          16
49)     END OF CHAIN SPECIFICATIONS                                                0
                                                                                   0
```

```
POSITION IN DENSITY ARRAY FOR EACH NUCLIDE IN EXPOSURE DATA
SET       1  NUCLIDES INCLUDED   16
IHNUC     1    2    3    4    5    6    8    9   10   11   12   13   14   15   16   17
SET       2  NUCLIDES INCLUDED   16
IHNUC     1    2    3    4    5    6    8    9   10   11   12   13   14   15   16   17
SET       3  NUCLIDES INCLUDED    0
IHNUC     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

CONTINUOUS FUELING MODEL

FALSE ZONE NUMBER CONTAINING FEED MATERIAL COMPOSITION FOR ZONE PATHS        17
```

```
NUMBER OF ZONE PATHS THROUGH THE REACTOR                                    2
NUMBER OF ZONES ALONG EACH ZONE PATH                                        8
ZONE FEED OPTION                                                            1  ZONE     17 THROUGH ZONE     18

FALSE ZONE NUMBER CONTAINING FEED MATERIAL COMPOSITION FOR SUBZONE PATHS   22
NUMBER OF SUBZONE PATHS THROUGH THE REACTOR                                 2
NUMBER OF SUBZONES ALONG EACH SUBZONE PATH                                  9
SUBZONE FEED OPTION                                                         0  ZONE     22 THROUGH ZONE     22

MAXIMUM ARRAY SIZE USED FOR INITIAL PROCESSING IS    1070

STORAGE REQUIRED FOR BASIC DATA IS    1070

        STORAGE SUPPLIED IS    10000
MAXIMUM STORAGE REQUIRED IS     9594
MINIMUM STORAGE REQUIRED IS     2930

 MODRF  =  0 MODRRF = -1

MEMORY ACTUALLY USED WILL BE    9594

INTERFACE FILE RZFLUX VERSION   1 UNIT  31
 TIME  =  1.200000E 04 POWER =  7.499996E 03
 VOL   =  1.018894E 03 EFFK  =  1.000000E 00
 EIVS  = -8.410464E-06 DKDS  =  0.0
 TNL   =  5.881155E 14 TNA   =  5.347242E 14
 TNSL  =  3.657977E 13 TNBL  =  1.681155E 13
 TNBAL =  0.0          TNCRA =  0.0
 FC    =  5.000000E-06 CRTF  =  9.800000E-01
 X3    =  1.000000E 00 X4    =  0.0
 ITPS  =      1        NZONE =     23
 NGROUP=      4        NCY   =      0

RZFLUX REFERENCE TIME     11999.9961 DAYS INDICATOR       1

INTERFACE FILE ZNATDN VERSION   2 UNIT  30
 TIME  =  1.200000E 04
 NCY   =      0        NTZSZ =     57
 NNS   =     17        NBLKAD=      1

EXPOSURE TIME STEP STARTS AT   1.200000E 04  DAYS

EXPOSURE TIME STEP IS   1.000000E 03 DAYS (   8.640000E 07 SECONDS ) THE NUMBER OF PASSES IS     2

REFERENCE POWER   1.499998E 09 WATTS

                                AVERAGE POWER   1.499938E 09 WATTS FOR PASS     1
                   MAXIMUM AVERAGE POWER DENSITY   4.579768E 01 WATTS/CC IN ZONE          10
                   MAXIMUM AVERAGE POWER DENSITY   1.271795E 01 WATTS/CC IN SUBZONE        14

          INITIAL REACTION RATES WILL BE MULTIPLIED BY   1.000039E 00 FOR NEXT PASS                1.000040E 00

          REFERENCE POWER LEVEL HAS BEEN ATTAINED

     FEED DENSITIES FOR ZONE PATH   1


TH-232     2.499998E-04   U-235     6.184359E-05    C        7.999998E-02


DISCHARGE DENSITIES FOR ZONE PATH   1 EXPOSURE TIME FOR EACH ZONE IN PATH   125.0000 DAYS


TH-232     2.320042E-04  PA-233     1.292737E-07   U-233     6.559322E-06   U-234     1.285601E-06
 U-235     8.356485E-06   U-236     8.848609E-06    C        7.999998E-02   I-135     1.364332E-10
```

```
XE-135      1.011962E-10  PM-147      2.251089E-07  PM-148      4.389602E-10  PM148M      1.379773E-09
PM-149      2.864895E-10  SM-149      1.714079E-09  ND-143      1.788326E-06    FP1       5.380361E-05
  FP2       2.019066E-04


     FEED DENSITIES FOR ZONE PATH   2

TH-232      2.499998E-04   U-235      8.184359E-05    C         7.999998E-02


DISCHARGE DENSITIES FOR ZONE PATH   2 EXPOSURE TIME FOR EACH ZONE IN PATH   150.0000 DAYS

TH-232      2.285659E-04  PA-233      1.233818E-07   U-233      6.649680E-06   U-234      1.519055E-06
 U-235      7.492157E-06   U-236      1.172935E-05    C         7.999998E-02   I-135      1.303289E-10
XE-135      9.667088E-11  PM-147      2.220348E-07  PM-148      4.329999E-10  PM148M      1.359222E-09
PM-149      2.756013E-10  SM-149      1.646061E-09  ND-143      2.146997E-06    FP1       7.295753E-05
  FP2       2.792669E-04


     FEED DENSITIES FOR SUBZONE PATH   1

THX232      4.999998E-04    C         6.999987E-02


DISCHARGE DENSITIES FOR SUBZONE PATH   1 EXPOSURE TIME FOR EACH SUBZONE IN PATH   125.0000 DAYS

THX232      4.654839E-04  PA-233      2.384967E-07   U-233      1.216016E-05   U-234      2.451223E-06
 U-235      5.721726E-07   U-236      8.167831E-08    C         6.999987E-02   I-135      1.251422E-10
XE-135      9.283212E-11  PM-147      1.210409E-07  PM-148      2.354472E-10  PM148M      7.353620E-10
PM-149      1.973527E-10  SM-149      1.176041E-09  ND-143      7.637404E-07    FP1       1.791560E-05
  FP2       6.859080E-05


     FEED DENSITIES FOR SUBZONE PATH   2

THX232      4.999998E-04    C         6.999987E-02


DISCHARGE DENSITIES FOR SUBZONE PATH   2 EXPOSURE TIME FOR EACH SUBZONE IN PATH   150.0000 DAYS

THX232      4.588766E-04  PA-233      2.277776E-07   U-233      1.229953E-05   U-234      2.884681E-06
 U-235      7.553666E-07   U-236      1.339741E-07    C         6.999987E-02   I-135      1.282339E-10
XE-135      9.512703E-11  PM-147      1.304994E-07  PM-148      2.539102E-10  PM148M      7.923870E-10
PM-149      2.059040E-10  SM-149      1.225565E-09  ND-143      9.181878E-07    FP1       2.314328E-05
  FP2       8.966257E-05


                          AVERAGE POWER   1.499983E 09 WATTS FOR PASS     2
MAXIMUM AVERAGE POWER DENSITY   4.579884E 01 WATTS/CC IN ZONE            10
MAXIMUM AVERAGE POWER DENSITY   1.271862E 01 WATTS/CC IN SUBZONE         14
```

FEED AND DISCHARGE RATES (KILOGRAMS PER DAY) BY ABSOLUTE NUCLIDE

| NO. | NAME | MOVING ZONES/SUBZONES FEED ZONE | FEED SUBZONE | DISCHARGE ZONE | DISCHARGE SUBZONE | STATIONARY ZONES/SUBZONES FEED ZONE | FEED SUBZONE | DISCHARGE ZONE | DISCHARGE SUBZONE |
|---|---|---|---|---|---|---|---|---|---|
| 1 | C | 7.44537E 01 | 7.26797E 01 | 7.44595E 01 | 7.26771E 01 | 2.24155E 00 | 0.0 | 2.24155E 00 | 0.0 |
| 2 | I-135 | 0.0 | 0.0 | 1.39470E-06 | 1.48259E-06 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | XE-135 | 0.0 | 0.0 | 1.03450E-06 | 1.09981E-06 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | PM-147 | 0.0 | 0.0 | 2.54803E-03 | 1.60906E-03 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | PM148M | 0.0 | 0.0 | 1.57137E-05 | 9.83882E-06 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | PM-148 | 0.0 | 0.0 | 5.00265E-06 | 3.15169E-06 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | SM-149 | 0.0 | 0.0 | 1.93926E-05 | 1.55304E-05 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | U-236 | 0.0 | 0.0 | 1.89912E-01 | 2.28558E-03 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | FP2 | 0.0 | 0.0 | 2.18541E 00 | 8.10761E-01 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | FP1 | 0.0 | 0.0 | 5.75398E-01 | 2.10163E-01 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | TH-232 | 4.49824E 00 | 1.00367E 01 | 4.14199E 00 | 9.26682E 00 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | PA-233 | 0.0 | 0.0 | 2.27981E-03 | 4.68290E-03 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | U-233 | 0.0 | 0.0 | 1.19405E-01 | 2.46766E-01 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14 | U-234 | 0.0 | 0.0 | 2.55782E-02 | 5.47043E-02 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | U-235 | 1.32028E 00 | 0.0 | 1.43966E-01 | 1.37886E-02 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16 | PM-149 | 0.0 | 0.0 | 3.24421E-06 | 2.60797E-06 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17 | ND-143 | 0.0 | 0.0 | 2.19430E-02 | 1.05549E-02 | 0.0 | 0.0 | 0.0 | 0.0 |
| 18 | HE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.53142E-01 | 0.0 | 1.53142E-01 |
| 19 | RECVFL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.55316E-03 | 0.0 | 9.55316E-03 |
| | FISSILE | 1.32028E 00 | 0.0 | 2.65651E-01 | 2.65237E-01 | 0.0 | 0.0 | 0.0 | 0.0 |

POWER (WATTS) FOR EACH ZONE PATH
1) 4.232259E 08 2) 6.575926E 08

TOTAL POWER (WATTS) FOR ZONE PATHS 1.080818E 09

ACTINIDE FEED RATE (KILOGRAMS PER DAY) FOR EACH ZONE PATH
1) 2.644727E 00 2) 3.173792E 00

TOTAL ACTINIDE FEED RATE (KILOGRAMS PER DAY) FOR ZONE PATHS 5.818519E 00

EXPOSURE (MEGAWATT-DAYS PER KILOGRAM) FOR EACH ZONE PATH
1) 1.600262E 02 2) 2.071945E 02

TOTAL EXPOSURE (MEGAWATT-DAYS PER KILOGRAM) FOR ZONE PATHS 1.857548E 02

POWER (WATTS) FOR EACH SUBZONE PATH
1) 1.501758E 08 2) 2.689938E 08

TOTAL POWER (WATTS) FOR SUBZONE PATHS 4.191695E 08

ACTINIDE FEED RATE (KILOGRAMS PER DAY) FOR EACH SUBZONE PATH
1) 4.229645E 00 2) 5.807095E 00

TOTAL ACTINIDE FEED RATE (KILOGRAMS PER DAY) FOR SUBZONE PATHS 1.003674E 01

EXPOSURE (MEGAWATT-DAYS PER KILOGRAM) FOR EACH SUBZONE PATH
1) 3.550549E 01 2) 4.632153E 01

TOTAL EXPOSURE (MEGAWATT-DAYS PER KILOGRAM) FOR SUBZONE PATHS 4.176347E 01

INVENTORY AND REACTION RATES BY ABSOLUTE NUCLIDE

| NO. | NAME | INVENTORY (KG) | ABSORPTION | FISSION | PRODUCTION | CAPTURE (N,G) |
|---|---|---|---|---|---|---|
| 1 | C | 1.75816E 05 | 1.15822E-02 | 0.0 | 0.0 | 1.08290E-02 |
| 2 | I-135 | 2.20078E-02 | 1.70242E-10 | 0.0 | 0.0 | 7.07680E-12 |
| 3 | XE-135 | 5.34170E-03 | 2.06490E-02 | 0.0 | 0.0 | 2.06490E-02 |
| 4 | PM-147 | 4.91050E 00 | 5.75211E-03 | 0.0 | 0.0 | 5.75211E-03 |
| 5 | PM148M | 4.92195E-02 | 2.42200E-03 | 0.0 | 0.0 | 2.42200E-03 |
| 6 | PM-148 | 4.10933E-02 | 1.06690E-03 | 0.0 | 0.0 | 1.06690E-03 |
| 7 | SM-149 | 6.82514E-02 | 7.54910E-03 | 0.0 | 0.0 | 7.54910E-03 |
| 8 | U-236 | 1.66000E 02 | 1.24942E-02 | 7.28164E-05 | 1.94564E-04 | 1.24210E-02 |
| 9 | FP2 | 2.14577E 03 | 1.08792E-02 | 0.0 | 0.0 | 1.08792E-02 |
| 10 | FP1 | 5.76264E 02 | 3.01676E-02 | 0.0 | 0.0 | 3.01676E-02 |
| 11 | TH-232 | 1.67825E 04 | 2.87585E-01 | 8.66875E-04 | 2.06983E-03 | 2.86601E-01 |
| 12 | PA-233 | 4.23265E 01 | 9.73143E-03 | 4.06337E-05 | 1.10384E-04 | 9.69064E-03 |
| 13 | U-233 | 3.06579E 02 | 1.80766E-01 | 1.60682E-01 | 4.02265E-01 | 2.00836E-02 |
| 14 | U-234 | 5.41727E 01 | 9.76304E-03 | 5.47075E-05 | 1.46996E-04 | 9.70828E-03 |
| 15 | U-235 | 5.31791E 02 | 3.06095E-01 | 2.44558E-01 | 5.94918E-01 | 6.15341E-02 |
| 16 | PM-149 | 6.13971E-02 | 5.70082E-10 | 0.0 | 0.0 | 1.61116E-11 |
| 17 | ND-143 | 2.71623E 01 | 1.08132E-02 | 0.0 | 0.0 | 1.08131E-02 |
| 18 | HF | 1.53145E 02 | 5.13360E-05 | 0.0 | 0.0 | 4.80748E-05 |
| 19 | RFCVEL | 9.55331E 00 | 1.84923E-03 | 0.0 | 0.0 | 1.84923E-03 |
| | TOTALS | 1.96616E 05 | 9.09216E-01 | 4.06275E-01 | 9.99704E-01 | 5.02064E-01 |

| | |
|---|---|
| OTHER LOSS RATE | 9.07837E-02 |
| TOTAL LOSS RATE | 1.00000E 00 |
| SYSTEM LOSS RATE(N/SEC) | 1.17657E 20 |
| RELATIVE FLUX LEVEL | 1.00004E 00 |

SUMMARY TABLES FOR EXPOSURE ENDING AT TIME 1.300000E 04 DAYS
FOR CASE GAS COOLED REACTOR PROBLEM, (1-D MODELED AS 2-D) BURNER CODE TEST CASE

AVERAGE NEUTRON LOSSES BY NUCLIDE CLASS AND ZONE CLASS - SYSTEM LOSS RATE 1.176546E 20 N/SEC

| ZONE CLASS ID. | FISSILE 1 | FERTILE 2 | O. ACTINIDE 3 | FISSION PROD 4 | STRUCTURAL 5 |
|---|---|---|---|---|---|
| 1 | 0.4960831 | 0.2879552 | 0.0124942 | 0.0892851 | 0.0131850 |
| 2 | 0.0001670 | 0.0035488 | 0.0000000 | 0.0000042 | 0.0001179 |
| 3 | 0.0003393 | 0.0058461 | 0.0000000 | 0.0000091 | 0.0001799 |
| SUM | 0.4965892 | 0.2973500 | 0.0124942 | 0.0892983 | 0.0134829 |

| ZONE CLASS ID. | ABSORPTION LOSSES | EFFECTIVE CONVERSION RATIO REACTION RATE | POWER (WATTS) |
|---|---|---|---|
| 1 | 0.8990026 | 0.57842 | 1.498423E 09 |
| 2 | 0.0038379 | 21.19359 | 5.110206E 05 |
| 3 | 0.0063744 | 17.18544 | 1.049554E 06 |
| OVERALL | 0.9092149 | 0.59670 | 1.499983E 09 |
| OTHER LOSSES | 0.0907851 | | |
| TOTAL LOSSES | 1.0000000 | | |

EFFECTIVE CONVERSION RATIO FROM MASS BALANCE 0.59794

FISSILE INVENTORY IS 8.806904E 02 KG

FISSILE CONSUMPTION PER UNIT ENERGY GENERATION IS 1.514948E-14 KG/WATT-SEC
FISSILE CONSUMPTION RATE IS 2.272397E-05 KG/SEC

INTERFACE FILE ZNATDN VERSION 2 (OLD) HAS BEEN WRITTEN ON UNIT 30 WITH DENSITIES AT TIME 1.300000E 04 DAYS

ZONE POWER DENSITY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1) | 2.985609E 01 | 2) | 3.731664E 01 | 3) | 3.250659E 01 | 4) | 2.372375E 01 | 5) | 1.594561E 01 |
| 6) | 1.011266E 01 | 7) | 5.739485E 00 | 8) | 2.126983E 00 | 9) | 3.869702E 01 | 10) | 4.579884E 01 |
| 11) | 3.717091E 01 | 12) | 2.535669E 01 | 13) | 1.619487E 01 | 14) | 9.942492E 00 | 15) | 5.542222E 00 |
| 16) | 2.037612E 00 | 17) | 0.0 | 18) | 0.0 | 19) | 0.0 | 20) | 0.0 |
| 21) | 0.0 | 22) | 0.0 | 23) | 0.0 | | | | |

SUBZONE POWER DENSITY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1) | 1.899635E-01 | 2) | 1.775983E 00 | 3) | 6.007829E 00 | 4) | 1.022264E 01 | 5) | 1.171411E 01 |
| 6) | 1.059763E 01 | 7) | 8.119692E 00 | 8) | 5.164412E 00 | 9) | 2.033301E 00 | 10) | 2.368104E-01 |
| 11) | 2.156689E 00 | 12) | 7.029646E 00 | 13) | 1.149298E 01 | 14) | 1.271862E 01 | 15) | 1.121498E 01 |
| 16) | 8.447442E 00 | 17) | 5.316885E 00 | 18) | 2.081737E 00 | 19) | 0.0 | 20) | 0.0 |
| 21) | 0.0 | 22) | 0.0 | 23) | 0.0 | 24) | 0.0 | 25) | 0.0 |
| 26) | 0.0 | 27) | 0.0 | 28) | 0.0 | 29) | 0.0 | 30) | 0.0 |
| 31) | 0.0 | 32) | 0.0 | 33) | 0.0 | 34) | 0.0 | | |

POWER COMPUTED FROM POWER DENSITY 1.499981E 09

INTERFACE FILE ZNPOWD VERSION 1 (NEW) HAS BEEN WRITTEN ON UNIT 33

INTERFACE FILE QNATDN VERSION 1 (NEW) HAS BEEN WRITTEN ON UNIT 34

PNSTE 1.000039E-24
TNSTE 1.200000E 04 1.300000E 04
TNSTS 0.0

```
      SUMMARY OF CALCULATION

    EXPLICIT CHAIN - EXPOSURE
      SIGNIFICANCE EVENTS ENCOUNTERED                68


     MAX ARRAY SIZE USED     9592 WORDS - FOR ZONE CALCULATION


     MAX ARRAY SIZE USED     9592 WORDS

     TOTAL CPU TIME USED    0.029 MINUTES     TOTAL CLOCK TIME USED    0.177 MINUTES     TOTAL I/O USED     232

NORMAL END OF EXPOSURE MODULE
```

```
BURNER - EXPOSURE MODULE - PRE-RELEASE VERSION 1E - NOVEMBER 14, 1978 - QUALITY ASSURANCE LEVEL 0
-------------------------------------------------------------------------------------------------

CASE TITLE -  GAS COOLED REACTOR PROBLEM, (1-D MODELED AS 2-D) BURNER CODE TEST CASE

RITE CONTAINER ARRAYS, CONTROL       6 DATA       1

         GRUPXS TITLE
          FOUR GROUP MICROSCOPIC GAS COOLED REACTOR CROSS SECTIONS   BURNER CODE

METHOD OF SOLUTION - EXPLICIT CHAIN

         THE LONGEST EXPLICIT CHAIN IS    12


MAXIMUM ARRAY SIZE USED FOR INITIAL PROCESSING IS    1068

STORAGE REQUIRED FOR BASIC DATA IS    1068

        STORAGE SUPPLIED IS    10000
MAXIMUM STORAGE REQUIRED IS     9363
MINIMUM STORAGE REQUIRED IS     2699

 MODRR  =  0 MODRRP = -1

MEMORY ACTUALLY USED WILL BE    9363

SHUTDOWN TIME STEP STARTS AT   1.500000E 04  DAYS

SHUTDOWN TIME STEP IS   4.000000E-01 DAYS (   3.456000E 04 SECONDS ) THE NUMBER OF SUBSTEPS IS   1
THE SUBSTEP TIME RATIO IS   1.000000E 00

INTERFACE FILE ZNATDN VERSION  4 (OLD) HAS BEEN WRITTEN ON UNIT  30  WITH DENSITIES AT TIME   1.500039E 04  DAYS


     MAX ARRAY SIZE USED     9360 WORDS - FOR ZONE CALCULATION


     MAX ARRAY SIZE USED     9360 WORDS

     TOTAL CPU TIME USED    0.008 MINUTES     TOTAL CLOCK TIME USED    0.100 MINUTES     TOTAL I/O USED     154

NORMAL END OF EXPOSURE MODULE
```

TABLE 06-2. NUCLIDE CONCENTRATIONS FOR THE CONSTANT PARAMETER POINT DEPLETION PROBLEM WITH FEEDBACK

| NUCLIDE | MATRIX EXPONENTIAL | AVERAGE GENERATION RATE | | | |
|---|---|---|---|---|---|
| | (570 STEPS) | (24 STEPS) | (100 STEPS) | (768 STEPS) | (1536 STEPS) |
| U 234 | 0.428821-09 | 0.432797-09 | 0.429788-09 | 0.428948-09 | 0.428885-09 |
| U 235 | 0.583390-04 | 0.583390-04 | 0.583390-04 | 0.583390-04 | 0.583390-04 |
| U 236 | 0.286057-05 | 0.286060-05 | 0.286057-05 | 0.286057-05 | 0.286057-05 |
| U 237 | 0.356780-07 | 0.356615-07 | 0.356773-07 | 0.356780-07 | 0.356780-07 |
| U 238 | 0.691915-02 | 0.691915-02 | 0.691915-02 | 0.691915-02 | 0.691915-02 |
| U 239 | 0.718360-08 | 0.718396-08 | 0.718368-08 | 0.718361-08 | 0.718360-08 |
| NP237 | 0.104739-06 | 0.104623-06 | 0.104733-06 | 0.104739-06 | 0.104739-06 |
| NP238 | 0.780515-09 | 0.776410-09 | 0.780286-09 | 0.780513-09 | 0.780515-09 |
| NP239 | 0.102944-05 | 0.102944-05 | 0.102944-05 | 0.102944-05 | 0.102944-05 |
| NP240 | 0.132292-10 | 0.132300-10 | 0.132294-10 | 0.132293-10 | 0.132293-10 |
| PU238 | 0.441869-08 | 0.438590-08 | 0.441678-08 | 0.441867-08 | 0.441869-08 |
| PU239 | 0.105747-04 | 0.105603-04 | 0.105775-04 | 0.105779-04 | 0.105741-04 |
| PU240 | 0.995925-06 | 0.993025-06 | 0.996450-06 | 0.996522-06 | 0.995817-06 |
| PU241 | 0.334204-06 | 0.332829-06 | 0.334508-06 | 0.334535-06 | 0.334147-06 |
| PU242 | 0.163743-07 | 0.163166-07 | 0.163978-07 | 0.163978-07 | 0.163706-07 |
| PU243 | 0.136356-10 | 0.128797-10 | 0.135892-10 | 0.136541-10 | 0.136321-10 |
| AM241 | 0.586404-09 | 0.584223-09 | 0.587227-09 | 0.587227-09 | 0.586273-09 |
| AM242 | 0.520998-11 | 0.506562-11 | 0.520959-11 | 0.521732-11 | 0.520876-11 |
| AM242M | 0.504831-11 | 0.503334-11 | 0.505735-11 | 0.505691-11 | 0.504700-11 |
| AM243 | 0.457063-09 | 0.469838-09 | 0.455217-09 | 0.457874-09 | 0.456923-09 |
| AM244 | 0.638029-13 | 0.597730-13 | 0.622171-13 | 0.638416-13 | 0.637633-13 |
| CM242 | 0.449681-10 | 0.435962-10 | 0.449784-10 | 0.450514-10 | 0.449552-10 |
| CM243 | 0.950978-13 | 0.922981-13 | 0.951678-13 | 0.953147-13 | 0.950664-13 |
| CM244 | 0.206748-10 | 0.216066-10 | 0.206454-10 | 0.207691-10 | 0.206595-10 |
| CM245 | 0.243333-12 | 0.258532-12 | 0.243081-12 | 0.244637-12 | 0.243128-12 |
| I 135 | 0.882752-08 | 0.881344-08 | 0.882746-08 | 0.882832-08 | 0.882737-08 |
| XE135 | 0.914759-09 | 0.913341-09 | 0.914414-09 | 0.914828-09 | 0.914740-09 |
| CS135 | 0.771693-07 | 0.778203-07 | 0.771638-07 | 0.771630-07 | 0.771637-07 |
| ND147 | 0.121156-06 | 0.121106-06 | 0.121166-06 | 0.121167-06 | 0.121155-06 |
| PM147 | 0.201814-06 | 0.201612-06 | 0.201824-06 | 0.201833-06 | 0.201810-06 |
| PM148 | 0.457042-08 | 0.455253-08 | 0.456989-08 | 0.457084-08 | 0.457034-08 |
| PM148M | 0.386722-08 | 0.385151-08 | 0.386674-08 | 0.386757-08 | 0.386715-08 |
| PM149 | 0.199682-07 | 0.199135-07 | 0.199671-07 | 0.199700-07 | 0.199678-07 |
| SM149 | 0.119776-07 | 0.119219-07 | 0.119757-07 | 0.119787-07 | 0.119774-07 |
| FPLL | 0.145227-04 | 0.145164-04 | 0.145241-04 | 0.145243-04 | 0.145224-04 |
| IBM 360/91 CPU TIME (SEC) | 13.5 | 0.96 | 1.62 | 6.48 | 12.1 |

TABLE 06-3. RESULTS FROM OTHER SCHEMES OF SOLUTION

| NUCLIDE | EXPLICIT CHAIN | | | MATRIX EXPONENTIAL ASSUMING EQUILIBRIUM | |
|---|---|---|---|---|---|
| | ELABORATE CHAINS (33) (1 STEP) | PRIMARY CHAINS (15) (1 STEP) | PRIMARY CHAINS (15) (4 STEPS) | (8 NUCLIDES) (2 STEPS) | (6 NUCLIDES) (5 STEPS) |
| U 234 | 0.428821-09 | 0.428821-09 | 0.428820-09 | 0.428822-09 | 0.428822-09 |
| U 235 | 0.583389-04 | 0.583389-04 | 0.583388-04 | 0.583390-04 | 0.583390-04 |
| U 236 | 0.286057-05 | 0.286057-05 | 0.286056-05 | 0.286057-05 | 0.286057-05 |
| U 237 | 0.356780-07 | 0.356780-07 | 0.356780-07 | 0.356780-07 | 0.356780-07 |
| U 238 | 0.691915-02 | 0.691915-02 | 0.691914-02 | 0.691915-02 | 0.691915-02 |
| U 239 | 0.718360-08 | 0.718360-08 | 0.718359-08 | 0.718359-08 | 0.718359-08 |
| NP237 | 0.104739-06 | 0.104739-06 | 0.104739-06 | 0.104739-06 | 0.104739-06 |
| NP238 | 0.780515-09 | 0.780515-09 | 0.780515-09 | 0.780515-09 | 0.780515-09 |
| NP239 | 0.102944-05 | 0.102944-05 | 0.102944-05 | 0.102944-05 | 0.102944-05 |
| NP240 | 0.132292-10 | 0.132292-10 | 0.132292-10 | 0.132292-10 | 0.132292-10 |
| PU238 | 0.441710-08 | 0.441710-08 | 0.441710-08 | 0.441888-08 | 0.441870-08 |
| PU239 | 0.105746-04 | 0.105746-04 | 0.105747-04 | 0.105786-04 | 0.105786-04 |
| PU240 | 0.995920-06 | 0.995919-06 | 0.995924-06 | 0.996660-06 | 0.996660-06 |
| PU241 | 0.334203-06 | 0.334203-06 | 0.334204-06 | 0.334611-06 | 0.334611-06 |
| PU242 | 0.163743-07 | 0.163650-07 | 0.163650-07 | 0.164041-07 | 0.164032-07 |
| PU243 | 0.136356-10 | 0.136279-10 | 0.136279-10 | 0.139598-10 | 0.139591-10 |
| AM241 | 0.586403-09 | 0.586403-09 | 0.586404-09 | 0.587413-09 | 0.587413-09 |
| AM242 | 0.520998-11 | 0.520998-11 | 0.520998-11 | 0.558162-11 | 0.521915-11 |
| AM242M | 0.504831-11 | 0.448086-11 | 0.503844-11 | 0.505884-11 | 0.505884-11 |
| AM243 | 0.457063-09 | 0.456782-09 | 0.456844-09 | 0.471053-09 | 0.471028-09 |
| AM244 | 0.638028-13 | 0.637637-13 | 0.637722-13 | 0.659185-13 | 0.659150-13 |
| CM242 | 0.449681-10 | 0.449681-10 | 0.449681-10 | 0.491413-10 | 0.450717-10 |
| CM243 | 0.950979-13 | 0.950979-13 | 0.950979-13 | 0.105839-12 | 0.953659-13 |
| CM244 | 0.206748-10 | 0.206635-10 | 0.206663-10 | 0.215165-10 | 0.215151-10 |
| CM245 | 0.243334-12 | 0.243213-12 | 0.243223-12 | 0.254910-12 | 0.254894-12 |
| I 135 | 0.832002-08 | 0.832002-08 | 0.872511-08 | 0.883481-08 | 0.883481-08 |
| XE135 | 0.862199-09 | 0.862199-09 | 0.904186-09 | 0.915555-09 | 0.915555-09 |
| CS135 | 0.772908-07 | 0.772908-07 | 0.772677-07 | 0.778882-07 | 0.778882-07 |
| ND147 | 0.119566-06 | 0.119566-06 | 0.121042-06 | 0.121169-06 | 0.121169-06 |
| PM147 | 0.203043-06 | 0.203043-06 | 0.202102-06 | 0.201837-06 | 0.201837-06 |
| PM148 | 0.460801-08 | 0.460801-08 | 0.457801-08 | 0.457096-08 | 0.457096-08 |
| PM148M | 0.389858-08 | 0.389858-08 | 0.387359-08 | 0.386767-08 | 0.386767-08 |
| PM149 | 0.193223-07 | 0.193223-07 | 0.198854-07 | 0.199704-07 | 0.199704-07 |
| SM149 | 0.116169-07 | 0.116169-07 | 0.119519-07 | 0.122111-07 | 0.119790-07 |
| FPLL | 0.145394-04 | 0.145394-04 | 0.145376-04 | 0.145246-04 | 0.145246-04 |
| IBM 360/91 CPU TIME (SEC) | 2.52 | 1.38 | 1.62 | 1.08 | 1.14 |

rather poor when a desired power level is not maintained; the error caused by this approximation is shown to decrease when the exposure period is divided into substeps. The explicit chain treatments involve an elaborate representation involving 33 chains (799 chain entries) which includes the $B^+$ decay of $Am^{242}$ and only the $\alpha$ decay feedback of $^{238}Pu \rightarrow ^{234}U$, and a primary chain representation which requires 15 chains (229 chain entries) of which 4 are required to treat the fission products. The matrix exponential method results shown in Table 06-3 were obtained by setting the nuclide concentrations equal to equilibrium values at end of step for those nuclides having a specific loss rate times the time interval exceeding 24.0 and 120.0, respectively. For average generation rate results shown, the end of exposure step generation rates from a precursor were used (instead of the average of the start and end of step averages) when the specific loss rate times the time interval exceeds 2.3, $e^{-b} < 0.1$.

Processor times shown are for total BURNER module access.

The second sample problem is a two-dimensional mockup of a fast breeder reactor in (r-z) geometry. The VENTURE code[a] is used to solve an initial flux-eigenvalue problem. Then the period of the point of refueling is treated in three exposure steps, each followed by recalculation of the flux-eigenvalue problem. Prespecified control rod positioning in the sense of smeared nuclide concentrations is imposed with neglect of deviation from critical conditions. The nuclide chains which were considered are shown in Figure 06-2. The computer listing of the input data which documents the problem was shown in Table 06-1 along with the

---

[a]ORNL-5062.

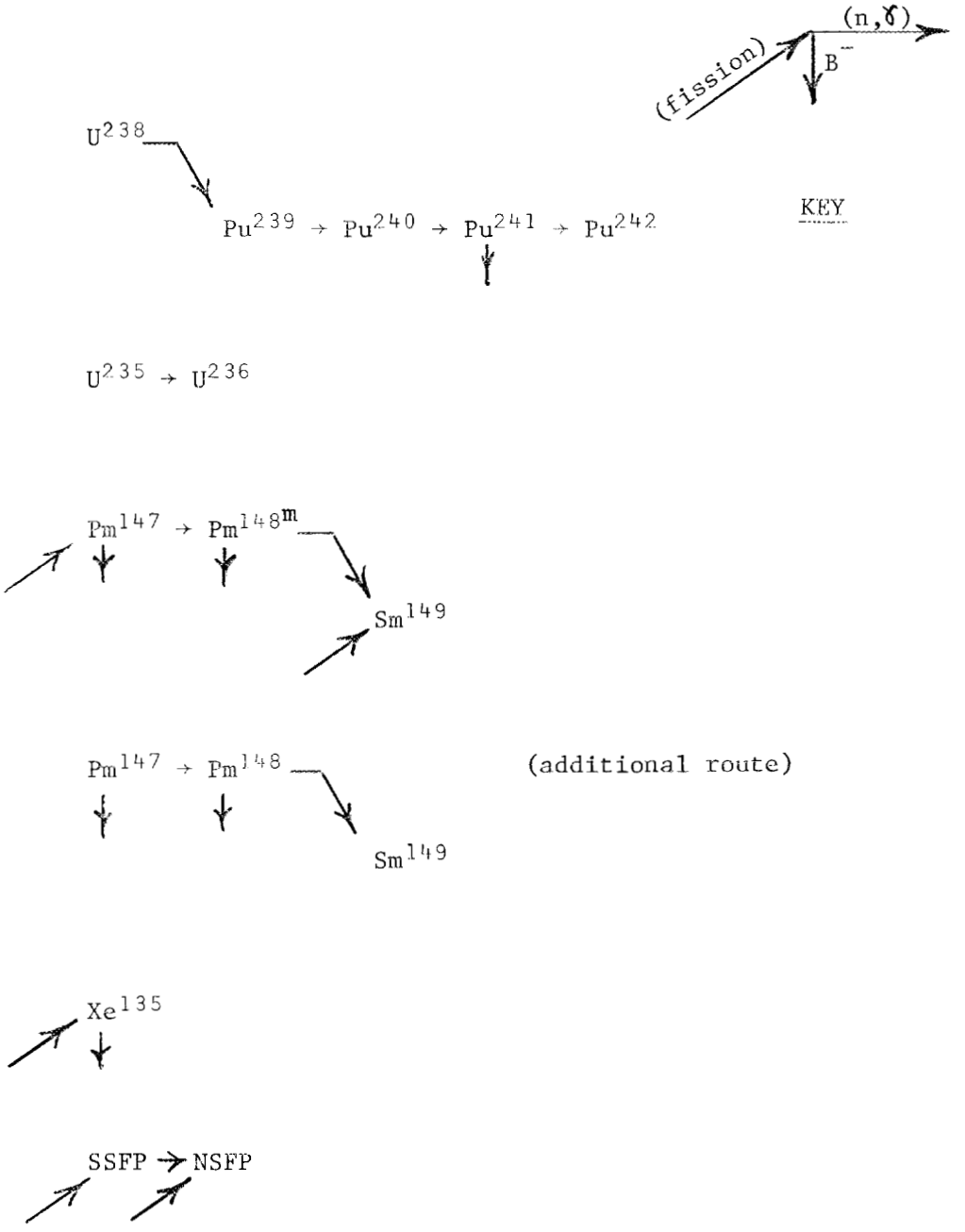



Figure 06-2. Nuclide Chains for the Second Sample Problem

condensed results and selected edits from the BURNER code.

Much of the capability of the BURNER code is applied in this sample problem. Gamma heating calculations are done, exposure data is cumulated, and local exposure is done at each of the points in a zone.

The third sample problem applies the steady state continuous fueling model. The computer listing of the input data, the condensed edit and selected edits from the BURNER code are in Table 06-1. The problem is a reactor which is at steady state, with two types of pebbles in four streams passing through the reactor at rates defined by residence times. The problem is solved by an iterative process: a neutronics calculation which involves a criticality search on the fuel in the reactor and in an external feed box, and the exposure calculation which follows the material passing through the reactor, applied successively in an iteration loop.

This problem was selected to demonstrate some of the capability implemented. The one-dimensional traverse is mocked up with a thin two-dimensional model. Fueled pebbles are introduced at the top of the core and fertile pebbles at the top of an inlet blanket. A density change occurs when the two streams come together, and change in the residence time (per unit height) of the fertile pebbles is accounted for by a change in the zone heights. The feed composition is fixed for the fertile pebbles while the fissile enrichment of the fueled pebbles must be determined in the calculation for the steady state condition.

After terminating the iteration process, the multiplication factor is followed over a period of shutdown.

END OF SECTION

## SECTION 07: VERIFICATION TESTING

This module has been subjected to extensive verification testing. All of the implemented options have been exercised, but not all combinations of them. A number of problems have been solved, and solved in different ways with BURNER to prove that the parallel procedures produce similar results. Only a limited amount of absolute testing has been done. The appropriate problems from ORNL-TM-3793 have been solved and acceptable results obtained.

A number of different situations have been described as input and results obtained over the range of the possible user options. These cases cover typical reactor problems, fast and thermal reactors, blankets, etc., and a variety of nuclide chain representations of the actinides and the fission products. Code modifications were made during this time as deemed desirable such as required to avoid machine underflow and to improve the reporting of results.

END OF SECTION

## SECTION 08: MATHEMATICAL EQUATIONS

The linear coupled first order nuclide chain equations are solved for a specific location in a reactor. We consider them here in the form

$$\frac{dN_n(t)}{dt} = - a_n N_n(t) + Y_n(t) + \sum_m b_{m \to n} M_m(t) \ , \qquad (08\text{-}1)$$

where $N_n(t)$ is the concentration of nuclide indexed n at time t,

$M_m(t)$ is the precursor nuclide along a chain route, m depending on n and the number of these depending on m, ,

$Y_n(t)$ is the production rate of nuclide n from fission as a fission product (which may be zero),

$$Y_n(t) = \sum_{\ell=1}^{L} N_\ell(t) \sum_{u=1}^{U} y(\ell,n,u) \sum_{g \varepsilon u} \sigma_{f,\ell,g} \phi_g \ , \qquad (08\text{-}2)$$

where $\ell$ refers to an identified fissile nuclide,

$\sigma_{f,\ell,g}$ is its microscopic fission cross section for energy group g,

$\phi_g$ is the local neutron flux, usually that for the start of a step, but can be a linear weighting in time,

$y(\ell,n,u)$ is the specific fission product yield fraction for a range in energy which may span one or more of the energy groups;

$$a_n = \sum_g \sigma_{x,n,g} \phi_g + \lambda_n \qquad (08\text{-}3)$$

where $\sigma_x$ refers to the sum over all reactions which cause loss of nuclide n (not scattering!) , including (n,γ), (n,α), (n,f), (n,p), (n,d), (n,t), and (n,2n) cross sections.

$$b_{m\to n} = z_{m\to n} \begin{bmatrix} \lambda_{m\to n}, \text{ or} \\ r_{m\to n} \end{bmatrix} , \qquad (08\text{-}4)$$

where

$$r_{m\to n} = \sum_g \sigma_{n,m,g}\phi_g , \qquad (08\text{-}5)$$

and $z_{m\to n}$ is the fraction of this reaction considered to produce nuclide n (often unity),

$\sigma_{n,m,g}$ is the microscopic cross section for generation of the product: (n,γ), (n,α), (n,p), (n,2n), (n,d), (n,t), (n,f), or total absorption less fission, for group g.

As presented, the nuclide concentrations are in units of atoms/bn-cm, specific rates are $sec^{-1}$ and the neutron flux having usual units of $n/sec\text{-}cm^2$ must be multiplied by $10^{-24}$ ($cm^2$/bn) to give units of n/sec-bn for use of cross sections having units of bn (barns). Time here is always in units of sec.

Not shown above is the provision to apply on demand the Bondarenko correlation.[a] Given start of step nuclide concentrations and temperature information, the specific reaction rates are determined. Considering that these specific rates are assumed to hold over the exposure period, it may well be appropriate to subdivide an exposure period to allow these rates to be calculated more than once.

## The Average Generation Rate Formulation

Simplifying equation 08-1 to the form

$$\frac{dN_n(t)}{dt} = -a_n N_n(t) + P_n , \qquad (08\text{-}6)$$

[a]Not implemented in the first release version.

where $P_n$ is an effective or average generation rate, the exposure period T is divided into a fine scale of L intervals of time $\Delta$ each, $\Delta = T/L$.

An elementary finite-difference solution of equation 07-6 is

$$\frac{dN_n(t)}{dt} \simeq \frac{N_n(\Delta) - N_n(0)}{\Delta} \simeq - a_n \left[ \frac{N_n(\Delta) + N_n(0)}{2} \right] + P_n ,$$

$$N_n(\Delta) = N_n(0) \left[ \frac{1 - \frac{a_n \Delta}{2}}{1 + \frac{a_n \Delta}{2}} \right] + \frac{\Delta P_n}{1 + \frac{a_n \Delta}{2}} ,$$

or

$$N_n(\Delta) = N_n(0) \left[ \frac{2 - a_n \Delta}{2 + a_n \Delta} \right] + \left[ \frac{2\Delta}{2 + a_n \Delta} \right] P_n . \qquad (08\text{-}7)$$

When appropriate, $a_n \Delta$ large, a higher order formulation is used which comes directly from integration of equation 08-6,

$$N_n(\Delta) = N_n(0) e^{-a_n \Delta} + \left( \frac{1 - e^{-a_n \Delta}}{a_n} \right) P_n . \qquad (08\text{-}8)$$

Use of the higher order form is especially desirable to avoid serious inaccuracy for nuclides which approach an equilibrium condition rapidly,

$$\frac{dN_n}{dt} = 0; \quad N_n = \frac{P_n}{a_n} .$$

To improve the estimate of the average generation rate, $N_n(\Delta)$ for the precursor is used to calculate $P_n$ if $e^{-a_n \Delta} < 0.1$ for exposure calculations or if 0.01 for shutdown calculations; otherwise the selected weighting is

$$\overline{N_n(0,\Delta)} = \alpha N_n(0) + (1-\alpha) N_n(\Delta), \qquad (08\text{-}9)$$

where the parameter $\alpha$ may be specified, defaulted to 0.5.

The equation coefficients do not change with time and therefore are calculated only once. Passing through the specifications, end of step concentrations will be the same as start of step concentrations except for those nuclides already treated, so the results depend on the order of processing. We expect the actinide nuclides to be treated first, then the fission products.

As programmed, the user may specify the number of intervals for an exposure period L. Unless otherwise specified, the largest specific nuclide reaction rate is selected, and L is set to

$$L = 500\ T\ \{\max(a_n)\}^{1/3},$$

except that it is restrained to

$$10 \leq L \leq 100,$$

and is always made an even integer when not specified. For $a_n$ small, the value of L = 10 may not be adequate, requiring that the user supply a larger value when application experience indicates this.

The Explicit Chain Solution

The general solution used for the chain equations allows simple chain coupling. It is assumed that the term $Y_n(t)$ in equation 08-1 is not time dependent; if the power level were constant, the fission product generation would be constant except as the fissioning nuclide concentrations shift and as these fission rates vary locally. The user is requested to specify the actinide chains first, and the fission product yield is determined from equation 08-2, except that $N_\ell(t)$ is replaced by

$$1/2\ [N_\ell(0) + N_\ell(T)] \quad .$$

The equation programmed for an exposure period T is

$$N_n(T) = N_n(0)e^{-a_nT} + Y_n\left(\frac{1-e^{-a_nT}}{a_n}\right) + \sum_j \sum_{i=1}^{n-1} [N_i(0)Q_{j,n,i}+Y_{j,i}U_{j,n,i}] , \tag{08-10}$$

where

$$Q_{j,n,i} = \sum_{m=i}^{n-1} \left[\frac{e^{-a_mT}-e^{-a_nT}}{(a_n-a_m)}\right] b_{j,m\to m+1} \prod_{\substack{k=i \\ k\neq m}}^{n-1} \frac{b_{j,k\to k+1}}{(a_k-a_m)} , \tag{08-11}$$

and

$$U_{j,n,i} = \left[\frac{1-e^{-a_nT}}{a_n}\right] \prod_{m=i}^{n-1} \frac{b_{j,m\to m+1}}{a_m} - \sum_{m=i}^{n-1} \left[\frac{e^{-a_mT}-e^{-a_nT}}{a_m(a_n-a_m)}\right] b_{j,m\to m+1} \prod_{\substack{k=i \\ k\neq m}}^{n-1} \frac{b_{j,k\to k+1}}{(a_k-a_m)} . \tag{08-12}$$

The calculations are done in double precision on a short word computer. Significance tests are made and extraneous contributions (hopefully) are discarded. When two specific loss rates are found to be identical, they are automatically separated by slight adjustments to prevent overflow of any contributions to the result of equations 08-11 or 08-12.

To achieve the necessary precision, terms are changed from the form

$$\frac{e^{-zt}-e^{-yt}}{y-z} \quad \text{to} \quad te^{-zt}\left[\frac{1-e^{-(y-z)t}}{(y-z)t}\right]$$

and the approximation of

$$\frac{1-e^{-x}}{x} = (1-\frac{x}{2}(1-\frac{x}{3}(1-\frac{x}{4}(1-\frac{x}{5}(1-\frac{x}{6}(\cdots)))))) \ , \qquad (08\text{-}13)$$

is used when $e^{-x}$ is near unity, $x < 0.01$.

The Matrix Exponential Scheme

Consider a simple situation where a set of nuclide concentrations are to be obtained. Without interchain coupling, the generation rates do not depend on the nuclide concentrations,

$$\frac{dN_n}{dt} = -a_n N_n + P_n \ .$$

After an exposure period $\Delta$, the nuclide concentrations are given by

$$N_n(\Delta) = N_n(0)e^{-a_n\Delta} + \frac{P_n}{a_n}(1-e^{-a_n\Delta}) \ .$$

Expansion of the exponential terms gives

$$N_n(\Delta) = N_n(0)[1-a_n\Delta+\frac{1}{2}(a_n\Delta)^2-\frac{1}{6}(a_n\Delta)^3+\ldots]$$

$$+\frac{P_n}{a_n}[a_n\Delta-\frac{1}{2}(a_n\Delta)^2+\frac{1}{6}(a_n\Delta)^3+\ldots] \ ;$$

$$N_n(\Delta) = N_n(0)\{1-a_n\Delta[1-\frac{1}{2}(a_n\Delta)[1-\frac{1}{3}(a_n\Delta)[1-\ldots]]]\}$$

$$+P_n\Delta[1-\frac{1}{2}(a_n\Delta)[1-\frac{1}{3}(a_n\Delta)[1-\ldots]]] \ .$$

Consider the meaning of $e^{-\Delta A}$, where A is a matrix;

$$e^{-\Delta A} = I - \Delta A + \frac{\Delta^2}{2} A^2 - \frac{\Delta^3}{6} A^3 + \ldots$$

$$= I - \Delta A[I - \frac{\Delta}{2} A[I - \frac{\Delta}{3} A[I - \ldots]]] \ . \tag{08-14}$$

If A is diagonal, the diagonal terms being $a_n$, then this operation produces the desired solution results. The operation AA simply squares the diagonal terms.

For the general problem, the off-diagonal terms in A are coupling terms between the equations.

Consider the set of linear equations,

$$a_{n,n} N_n(t) - \sum_m a_{m,n} N_m(t) = - \frac{dN_n(t)}{dt} \ .$$

This set of coupled, linear first order equations may be described in matrix notation as

$$AN = - \dot{N} \tag{08-15}$$

where A contains both the $a_{n,n}$ terms on the main diagonal (all positive), and the $-a_{m,n}$ terms, $m \neq n$, off the diagonal (all negative). This equation has the solution

$$N(\Delta) = e^{-\Delta A} N(0)$$

$$= \{I - \Delta A + \frac{\Delta^2}{2} A^2 - \frac{\Delta^3}{6} A^3 + \ldots\} N(0) \tag{08-16}$$

$$= \{I - \Delta A[I - \frac{\Delta}{2} A[I - \frac{\Delta}{3} A[I - \ldots]]]\} N(0) \ ,$$

for an exposure period $\Delta$ where I is the unit matrix. A single term $(I - \Delta A)$ can not be used because there is inadequate propagation through the coupling

terms. Indeed matrix A only contains near chain coupling. $A^2$ increases this by one nuclide, so if the coupling band is n+1 nuclides, n couplings, one needs the term $A^n$ to effect propagation through the whole chain, resulting in n terms containing A, a minimum.

The advantage of this technique is that it properly accounts for the full coupling between nuclides; alpha decay feedback along a chain and multiple routes can not be fully accounted for with explicit solutions for individual chains. It should be noted that the nuclide to nuclide coupling (transmutation) terms include the fissile nuclide, fission product nuclide coupling, so the calculation of fission products is direct.

The implemented procedure of calculation was selected to minimize both the amount of storage required and the amount of arithmetic involved. Consider the solution cast in the form

$$N(\Delta) = \sum_{j=0}^{\infty} (-1)^j \left(\frac{1}{j!}\right) (\Delta A)^j N(0) \quad . \tag{08-17}$$

Let $E = \Delta A$, $H_j$ be a working column vector, and $M_j$ be the estimate of the solution column vector, where j is a running index of the sweeps through the equations. Setting

$$\begin{aligned} M_o &= H_o = N(0) \ , \\ H_j &= -\left(\frac{1}{j}\right) E H_{j-1} \ , \\ M_j &= M_{j-1} + H_j \ . \end{aligned} \tag{08-18}$$

An acceptable solution is identified, $N(\Delta) = M_J$, and the calculation terminated at $j = J$ when the ratio of any term in $H_J$ to the associated solution estimate

(term in $M_J$) is $< 10^{-6}$. A minimum value of J is allowed which we have set by various ways, currently the solution of $J = \max(\Delta a_n)$ plus the square root of the number of actinide nuclides plus the square root of the number of fission product nuclides. The matrix $E = \Delta A$ is not set up as a square matrix, but its two major components are stored separately:

1) the diagonal entries $\Delta a_n$,
2) the set of coupling terms $\Delta b(m \to n)$ plus the fission product yield terms, the latter typically

$$\Delta b(\ell \to k) = \Delta \sum_{g=1}^{G} y(\ell,k,g) \sum_{u \in g} \sigma_{f,\ell,u} \phi_u \ .$$

Underflow is prevented by setting any entry in $H_j$ equal to zero if it is $< 10^{-50}$ after it has been used (summed into $M_j$).

The convergence rate of the calculational procedure can be accelerated a small amount for usual problems by a simple transformation. We consider

$$N = e^{-\alpha\Delta} Z \ ,$$

$$Ae^{-\alpha\Delta} Z = - \frac{d}{dt} [e^{-\alpha\Delta} Z] \ ,$$

$$BZ = -\dot{Z} \ ,$$

$$\text{where } B = (A - \alpha) \ ;$$

$$N(\Delta) = e^{-\alpha\Delta} [e^{-\Delta B}] N(0) \ . \qquad (08\text{-}19)$$

The procedure described above is used with $E = \Delta(A - \alpha)$, and the solution is $N(\Delta) = e^{-\alpha\Delta} M_J$. The main diagonal term $\alpha$ is a selected constant, currently chosen by

$$\alpha = \frac{1}{2} \max a_n \tag{08-20}$$

The use of $e^{-\alpha\Delta}$ evaluated precisely at the end causes a slight distortion of the results, but an expansion of $e^{\Delta\alpha}$ to the number of terms used in the calculation and use of its reciprocal instead of $e^{-\Delta\alpha}$ was less consistent.

Another procedure is of interest because of a slight gain in significance of the results for large coefficients at a slight increase in computation cost. Consider the expansion

$$e^{-x} = 1 - x + \frac{x^2}{2!} - \frac{x^3}{3!} + \frac{x^4}{4!} - \ldots$$

Grouping adjacent terms,

$$e^{-x} = 1 + \frac{x}{2!}(x - 2) + \frac{x^3}{4!}(x - 4) + \ldots$$

By such grouping the result is obtained by summing numbers which are not as near the same magnitude. The integer subtraction is done precisely. For small x, the approximation monotonically decreases from unity and for large x it increases monotonically to a peak and then monotonically decreases. The procedure is as follows with the transformation introduced above. Let

$$B = \Delta(A - \alpha) \ ,$$

$$M_o = N(0) \ ,$$

for $i = 1$, $\quad E_1 = \frac{1}{2} ZN(0)$ ;

for $i > 1$, $\quad Y_i = ZE_{i-1}$ , and

$$E_i = \left(\frac{1}{2i}\right)\left(\frac{1}{2i-1}\right) BY_i \ ;$$

Then

$$F_i = B - (2i)I \ ,$$

$$H_i = F_i E_i \ , \text{ and} \tag{08-21}$$

$$M_i = M_{i-1} + H_i \ .$$

The solution $N(\Delta) = M_I e^{-\alpha\Delta}$ is obtained upon truncation at required convergence, $I \simeq J/2 + 1$. An increase in the amount of calculation of about 15 percent is incurred by this procedure over the simpler one above. Early termination of the expansion must be avoided because the combination of successive terms may make a small if not zero contribution, so a minimum number of terms is required to avoid false convergence indication, $I > x/2$.

If an entry in A exceeds some value, the results from these procedures would not have adequate significance due to subtraction of numbers of nearly the same magnitude. The problem is illustrated by the expansion

$$e^{-x} = 1 - x + \frac{x^2}{2!} - \cdots$$

This expansion peaks when

$$\frac{x^n}{n!} \simeq \frac{x^{n-1}}{(n-1)!} \ ,$$

$$x \simeq n \ ,$$

and since the signs of the successive terms alternate, the largest value involved is $x^n/n!$, while the answer we seek is $e^{-x}$. For six-digit significance in $e^{-x}$, it is required that the number of machine significant digits used to store the largest value be six more than the desired remainder considering the difference $x^n/n!-e^{-x}$. If x is 12, the difference is 18614 - 0.0000061, a loss of 10 digits requiring 9 + 6 = 16 machine significant digits.

If the effect of coupling coefficients is considered and the largest term is nearly equal to the largest diagonal (loss) term, then x above is twice the largest diagonal loss coefficient, sum of the absolute values of the entries on columns of matrix A, or if x = 12, max $(a_n) = 6$. (The $e^{\alpha\Delta}$ transformation distorts the operator norm evaluation.)

In simple situations it is reasonable to assume that a nuclide having a large value of $a_n$ will take on the end-of-exposure steady state solution. The automated procedure is as follows. Given nuclide n having large $a_n$, for all m having coupling $(m \to n)$ and all $\ell$ having coupling $(n \to \ell)$, replace all $(n \to \ell)$ with coupling coefficients

$$a_{m,\ell} = a_{m,n} \left[ \frac{a_{n,\ell}}{a_{n,n}} \right] ,$$

drop nuclide n from the calculation, and finally set

$$\left. \frac{dN_n}{dt} \right|_{t=\Delta} = 0 = -a_n N_n(\Delta) + P_n(\Delta) ,$$

$$N_n(\Delta) = \max\left(\frac{1}{a_n} P_n(\Delta),\ e^{-a_n\Delta} N_n(0)\right) , \qquad (08\text{-}22)$$

where $P_n$ is the generation rate of nuclide n from all sources. It is possible to eliminate one through several nuclides in this manner. There is loss of conservation of mass in the amount of the final assigned concentrations, that introduced by Equation (08-22). The full implications of this procedure applied to complicated situations is yet under study. The procedure is most applicable to core behavior during operation, not the shutdown problem at zero flux exposure.

The user may override the automated procedure for subdivision of an exposure interval into substeps over which the max $(a_n \Delta)$ is small enough to produce accurate results; this option may well be needed in those situations involving only a few zones where the coefficients are large, but the calculation cost of this procedure may make it unattractive for certain applications. We expect use to be made of the supplemental explicit chain capability when the coefficients are large (as for the $I^{135} \rightarrow x_e^{135} \rightarrow$ chain).

Example Problem

As an example, a simple situation is treated, three nuclide equations,

$$\frac{dN_1(t)}{dt} = - a_1 N_1(t)$$

$$\frac{dN_2(t)}{dt} = - a_2 N_2(t) + a_1 N_1(t)$$

$$\frac{dN_3(t)}{dt} = a_2 N_2(t) \quad .$$

There is no loss of material because loss shows up as source to the next nuclide and the last nuclide has no loss. One measure of the accuracy of a calculation is the loss of material from the system. As initial conditions we set

$$N_1(0) = 0.7$$

$$N_2(0) = 0.3$$

$$N_3(0) = \underline{0.0}$$

$$1.0$$

the explicit results for an exposure step T are

$$N_1(T) = N_1(0)e^{-a_1T} ,$$

$$N_2(T) = N_2(0)e^{-a_2T} + N_1(0)\left[\frac{a_1e^{-a_2T}}{a_1-a_2}\right]\left[1-e^{-(a_1-a_2)T}\right] ,$$

$$N_3(T) = N_2(0)\left[1-e^{-a_2T}\right] + N_1(0)\left[1-\frac{a_2e^{-a_1T}-a_1e^{-a_2T}}{(a_2-a_1)}\right] .$$

We consider $T=1.0$, $a_1=0.4$, $a_2=0.3$. These data give specific reaction rates which are higher than those typical of application. An explicit solution of the equations yields the following results:

$$N_1(T) = 0.46922403$$

$$N_2(T) = 0.41964036$$

$$N_3(T) = 0.11113561$$

$$\text{sum} \quad 1.0$$

For the average generation rate method we first consider the lowest order finite difference approximation, $e^{-x} \simeq 1 - x$:

$$N_1(t+\Delta) = N_1(t)(1-a_1\Delta)$$

$$N_2(t+\Delta) = N_2(t)(1-a_2\Delta) + a_1\frac{\Delta}{2}[N_1(t) + N_1(t+\Delta)]$$

$$N_3(t+\Delta) = N_3(t) + \frac{a_2\Delta}{2}[N_2(t)+N_2(t+\Delta)]$$

The results as dependent on the number of steps taken over the exposure period are

| Intervals | 1 | 2 | 4 | 8 |
|---|---|---|---|---|
| $N_1(T)$ | 0.42 | 0.448 | 0.45927 | 0.464394 |
| $N_2(T)$ | 0.434 | 0.42465 | 0.421173 | 0.420604 |
| $N_3(T)$ | 0.1101 | 0.11150 | 0.111465 | 0.111349 |
| TOTAL | 0.9641 | 0.98415 | 0.991908 | 0.996347 |

Thus doubling the number of steps essentially halves the error in this example. This is a relatively slow rate of error reduction. Of critical importance for accurate results is that all $a_n\Delta << 1$.

Next we consider the use of average generation rates with a precise integration of the differential equations,

$$N_1(t+\Delta) = N_1(t)e^{-a_1\Delta} ,$$

$$N_2(t+\Delta) = N_2(t)e^{-a_2\Delta} + \frac{a_1}{2a_2}[1-e^{-a_2\Delta}][N_1(t)+N_1(t+\Delta)] ,$$

$$N_3(t+\Delta) = N_3(t) + \frac{a_2\Delta}{2}[N_2(t)+N_2(t+\Delta)] .$$

The results as dependent on the number of steps taken over the exposure period are

| Intervals | 1 | 2 | 4 | 8 |
|---|---|---|---|---|
| $N_1(T)$ | 0.4692 | 0.46922 | 0.469224 | 0.469224 |
| $N_2(T)$ | 0.4243 | 0.42079 | 0.419928 | 0.419795 |
| $N_3(T)$ | 0.1086 | 0.11053 | 0.110984 | 0.111117 |
| TOTAL | 1.0021 | 1.00054 | 1.000135 | 1.000136 |

Note the much smaller error than with the very low order formulation, and a relatively fast rate of error reduction associated with the individual nuclide concentrations calculated. Here doubling the number of steps essentially reduces the error by a factor larger than two.

For the matrix exponential approach, we consider the matrix

$$A = \begin{bmatrix} 0.4 & 0 & 0 \\ -0.4 & 0.3 & 0 \\ 0 & -0.3 & 0 \end{bmatrix},$$

$$I - \Delta A = \begin{bmatrix} 0.6 & 0 & 0 \\ 0.4 & 0.7 & 0 \\ 0 & 0.3 & 1.0 \end{bmatrix};$$

and the results as dependent on the number of terms taken in the expansion are

| Number of Terms | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| $N_1(T)$ | 0.7 | 0.42 | 0.476 | 0.468533 | 0.469280 |
| $N_2(T)$ | 0.3 | 0.49 | 0.4055 | 0.421417 | 0.419476 |
| $N_3(T)$ | 0 | 0.09 | 0.1185 | 0.11005 | 0.111244 |
| TOTAL | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |

Note that there is conservation of the total. Measuring error as the square root of the sum of the squares of the differences of the final nuclide concentrations from fact, the error goes down as 0.08843, 0.01732, 0.002194, and 0.000204 for increasing terms in the expansion; doubling the number of terms decreases the error by about a factor of ten after effecting full coupling.

The simple transformed matrix exponential method is now applied. Let $\alpha = \frac{1}{2} \max (a_n) = 0.2$,

$$B = \begin{bmatrix} 0.2 & 0 & 0 \\ -0.4 & 0.1 & 0 \\ 0 & -0.3 & -0.2 \end{bmatrix}$$

The results as dependent on the number of terms of the expansion are

| Number of Terms | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| $N_1(T)$ | 0.7 | 0.458489 | 0.469951 | 0.469187 | 0.469226 |
| $N_2(T)$ | 0.3 | 0.450302 | 0.417143 | 0.419777 | 0.419635 |
| $N_3(T)$ | 0 | 0.073686 | 0.111757 | 0.110979 | 0.111138 |
| TOTAL | 1.0 | 0.982477 | 0.998851 | 0.999943 | 0.999999 |

The expansion is more rapidly convergent, although conservation is lost (sum not unity). For $\alpha = 0.3$, the results obtained are

| Number of Terms | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| $N_1(T)$ | 0.7 | 0.4667 | 0.46931 | 0.469222 | 0.469224 |
| $N_2(T)$ | 0.3 | 0.4297 | 0.41930 | 0.419649 | 0.419640 |
| $N_3(T)$ | 0 | 0.0667 | 0.10779 | 0.110863 | 0.111120 |
| TOTAL | 1.0 | 0.9631 | 0.99640 | 0.999734 | 0.999984 |

Here 0.2 is judged superior to 0.3 for $\alpha$ although this may be obvious for this simple case; increasing the value of $\alpha$ tends to reduce a weighted error in the results with termination at a set number of terms up to some point where the error grows, the optimum depending on the coupling coefficients and the concentrations.

Shutdown and Negative Exposure Step

Special routines have been implemented to treat a period of shutdown. For this calculation all flux-dependent reaction rates, loss, and coupling terms are ignored. The user may specify that results are to be obtained at more than one point in time. The input data allows the time intervals for the substeps to be varied. Generally there is interest in short times immediately after shutdown, but in longer ones between results toward the end. The ratio of one substep to the previous one is specified, which means continuously increasing the time interval with time.[a] The nuclide concentrations calculated for the end of a shutdown period may or may not be used thereafter for subsequent calculations, depending on the selection of options for writing the interface data files.

The coding has been done to permit the treatment of a negative exposure time interval (not shutdown). This capability is not of interest for usual calculations, but does permit going backward from one fueling to the previous one given end-of-cycle nuclide concentrations. It appears that these end-of-cycle concentrations cannot readily be estimated unless produced from calculations for a rather simple nuclide chain treatment with adequate provision for spatial variation consistent with a desired refueling pattern. Special steps are taken in the procedures to handle large coefficients realistically without producing reasonably large nuclide concentrations. Still, assessment of results may be essential and application restricted to situations for which the procedures produce reasonable results.

---

[a]Unless the ratio is made less than unity.

Computation Time

The full matrix exponential method requires perhaps three or more times as much computation as the other methods, and hence its use should be limited to testing. A reasonable balance of computation was attempted in setting the default procedures for the other methods, and testing has shown that typically they have the order of increasing amount of computation: explicit, matrix exponential (equilibrium intermediate), average generation rate.

Power Level Renormalization

The programmed procedure attempts to maintain the initial power level by adjusting the reaction rates (flux level) at the start of each substep after the first one. Consider the initial power level to be $P_o$ as calculated from the data available (with provision for adjusting it). After the first substep, the power level is calculated to be $P_E(1)$. The power level at the start of the second substep will be set at $B(2)\ P_o$. Assuming a continuing linear change, the anticipated average over the two steps is set to the desired value,

$$P_o = \frac{1}{4}\left[P_o + P_E(1) + 2\ B(2)\ P_o + P_E(1) - P_o\right].$$

$$B(2) = 2 - \frac{P_E(1)}{P_o}\ .$$

The power level is calculated from integrated rate of fission times energy per fission plus capture times energy per capture. If the values

[a]Interval divided into 50 substeps.

of energy per fission are all zero, they are set to $3.2 \times 10^{-11}$ watt-sec/fission and energy per capture values are set to zero. Considering $\overline{P}_n$ to be the average over the past history, the general formulation used is to set B(1) = 1, and

$$B(n+1) = \frac{1}{2} B(n) + n+1 - \frac{1}{P_o} \left[ n \overline{P}_n + \frac{1}{2} P_E(n) \right] , \qquad (08\text{-}23)$$

where

$$\overline{P}_n = \left( \frac{n-1}{n} \right) \overline{P}_n + \frac{1}{2n} \left[ B(n) P_o + P_E(n) \right] .$$

The user may override this scheme, specifying no renormalization, or that the power level at the start of each substep be that at the start. Renormalization is done on the basic substep scale for all solution techniques, not during the fine scale calculation used for the average generation rate formulation; the total exposure period is divided into a specified number of substep exposure periods.

Use of Flux Values at Two Points in Time

By option, zone average neutron flux values for two points in time may be used for an exposure period. It is assumed here that both nuclide concentration and flux data files exist for the start of the step and that a second flux file is available for some later time. User options on adjusting the flux level to effect a desired power level are not impacted by this calculation, although the best choice from the possibilities may well be influenced.

Given nuclide concentrations and flux values at time t, N(t) and $\phi(t)$, and also flux values at time $t + \ell$, nuclide concentrations are to

be determined after exposure time $\Delta$. The flux values are initially weighted by the formulation

$$\phi(\Delta) = \phi(t) + A[\phi(t+\ell) - \phi(t)] \ , \tag{08-24}$$

where A is determined as[a]

$$A = \begin{cases} 1 & \text{if } t \geq t+\ell > 0, \text{ or if} \\ & \text{only one flux file exists,} \\ \frac{1}{2} & \text{if } t = t+\ell = 0, \text{ or otherwise.} \\ \dfrac{\Delta}{2[(t+\ell)-t]} & \end{cases} \tag{08-25}$$

where $t+\ell$ and t refer to reference time information in the flux files. If only one nuclide concentration data file is available, it is used; if more than one version exists, the latest version having reference time t is used, but if none is found for this time, the latest version is used. It is assumed that the flux file having the latest (highest) version number is for time $t+\ell$ and the next-to-latest version is for time t.

Generally the exposure period needs to be divided into substeps only if the flux values supplied will not effect a desired power level over the exposure period.

Exposure of Material in Zones

Generally the nuclide concentrations are processed for each zone of the reactor. These are smeared concentrations, averaged over the fine geometric detail of the fuel rods for the particular zone to make the problem tractable, both for the exposure calculation and the neutronics problem solution. A solution for the zone average nuclide concentrations does not account for the effects of local flux peaking in locations of

[a]Or a direct weighting factor may be used on option, factor B, and A = 1-B.

high moderation (rods near a reflector), nor flux suppression where absorption rates are high (as in the dramatic case in the neighborhood of a large resonance in a rod loaded with a fertile actinide). The calculation is of average behavior, hopefully representative of the average over local behavior. Care must be taken to properly represent these average conditions with appropriate nuclide concentrations and consistent cross sections which will allow realistic results to be obtained.

Consider that a control rod is depleted in accordance with the equation

$$\frac{dN}{dt} = - N \int \sigma\phi(E)dE \ ,$$

$$N(\Delta) = N(0)e^{-\Delta \int \sigma\phi(E)dE} \ . \qquad (08\text{-}26)$$

The change in concentration is dependent on the specific reaction rate integral over the energy range. For neutronics calculations, actual rates are determined as $N \int \sigma\phi(E)dE$, so it is adequate to constrain $N\sigma$; $B^{10}$ may be represented as natural boron, $\sigma$ decreased and N increased. The specific reaction rate would not be correct for the exposure calculation; the change in concentration of the pseudo material would be significantly underestimated in the illustrative case of $B^{10}$. If exposure effects are to be calculated properly, data for the important nuclides of interest must be made available in such form that $\sigma\phi$ truly expresses the nuclide loss rate at the individual isotope level. By smearing out fine detail, one requires $N_2V_2\sigma_2\phi_2 = N_1V_1\sigma_1\phi_1$; $N_2V_2 = N_1V_1$, requiring $\sigma_2\phi_2 = \sigma_1\phi_1$ in the integral sense.

Depletion by zone is usually desirable when the geometric description of the reactor includes an explicit representation of the fuel assemblies.

This is the case for most three-dimensional representations and those one- and two-dimensional ones which are simple traverses or cross sections through the reactor. Thus a problem may be a two-dimensional section normal to the axis (normal to the fuel pins); exposure would normally be done for average axial conditions to approximate average behavior, but there is no direct way to account for behavior of an axial blanket.

Many calculations are done which do not treat the full three-dimensional problem. A point model, one zone, is a gross approximation of average conditions which has been widely exploited. Indeed blanket behavior can be approximated with disadvantaged cross sections (not disadvantaged concentrations) to yield suitable specific reaction rates given a point flux spectrum appropriate for the core on the average. Of course, this is a very coarse approximation which will not produce results for assessment of power density peaking, etc.

BURNER does not access the detailed geometric description of the reactor. Only if the zone and subzone volume data is consistent with the detailed geometric description will renormalization of the flux and edits of integrals be correct.

Subzones

By subzone we mean that a zone is considered to be subdivided into component blocks of nuclide concentrations. Only the zone average flux is available, so exposure of the materials in each of the subzones in a zone is to the same flux. The use of subzones is a powerful tool of analysis. Application is to the situation where the fuel assemblies are not represented explicitly — generally the geometric description treats less than the full three dimensions. Common applications represent the full reactor with a point model or an R-Z model, or occasionally a one-dimensional spherical model.

Consider an R-Z model. The untreated azimuthal coordinate would pass through fuel assemblies containing varied nuclide concentrations, except in the unusual case where the representation is quite adequate, true azimuthal symmetry. Azimuthal symmetry is assumed for the calculation and there is no way for the calculation to produce unsymmetry. The use of subzones allows the accounting to be done for azimuthal variation. The neutronics problem solves for the neutron flux using smeared nuclide concentrations averaged over the subzones associated with each zone.

Sophisticated fuel management schemes may be treated with a subzone provision (fuel management is not done by BURNER). Consider that one-third of the fuel assemblies in a reactor core are to be replaced each refueling in a random or scattered sense. With subzones, accounting is accomplished by assigning three subzones to each zone and replacing the material sequentially in one of the three subzones at each refueling. At some refueling point in history, the three subzones in a zone will have been exposed for one, two, and three cycle periods, respectively. Thus the accounting of nuclide concentrations and mass balances is accurate within the approximation of exposure to the zone average flux. There may be a different number of subzones in one zone than in another, as may be necessary to account for a scheme of fuel management. Thus one-fourth of the assemblies in a radial blanket may be replaced each refueling, while one-third of those in the core are replaced. Such complexity as relocation of assemblies is accounted for by reassigning the proper subzones to new zones, hopefully consistently, but which is not done with the BURNER code.

There is a provision in BURNER for depletion at the subzone level. Blocks of nuclide concentrations (subzones) may be contained in a zone and exposed to the zone flux separately. Considering the general solution

$$N(\Delta) = BN(0) \tag{08-27}$$

where B is a solution matrix dependent on $\Delta$, when the flux and the cross sections are the same for blocks of nuclide concentrations (subzones within a zone), a single solution matrix is needed which would minimize the amount of calculation. However, for the more general situation, the microscopic cross sections may be subzone dependent, so this general capability is implemented rather than using Eq. 08-27.

The situation where the microscopic cross sections depend on the zone location and not the subzone contents is deemed usual. In the unusual situation, the microscopic cross sections depend on the subzone nuclide assignments (not on the zone location) and this situation can not be handled by the above procedure. The exposure calculation is seriously impacted because specific reaction rates must be calculated for each subzone and the solution matrix B determined independently for each; basically, the exposure calculation is increased by the factor of the average number of subzones per zone. This situation also results when specific reaction rates depend on the nuclide concentrations with application of the Bondarenko correlation.

Local Detail Exposure

BURNER has the provision to carry out exposure calculations on a fine scale for a limited number of zones. This calculation is auxiliary to the primary problem for the purpose of producing auxiliary information without affecting the primary results. (The neutronics code calculates macroscopic cross sections for zone-average nuclide concentrations.) The interface data file requirements are significantly impacted by this provision.

Consider that results are desired in detail for a zone. The objective may be to establish the maximum local power density in the zone. This zone

is subdivided into a number of small elemental volumes (or a selected location may be treated, such as when the sophisticated capability of the neutronics code is used to select the location of maximum initial local power density). A data file contains the current nuclide concentrations for each of these elemental volumes. The exposure calculation is done for each elemental volume and the nuclide concentration file is updated for the end of exposure step conditions. The burden of producing the appropriate elemental volume group neutron flux values is placed outside of BURNER; this data is best produced by the neutronics code since it has the necessary information, including macroscopic data and geometric detail, to produce a consistent mapping of the flux over a zone,

The selection of locations is done by the neutronics code under user control; values of the flux over energy and point are written on the zone average flux file.

The procedure used for the primary calculation is also applied in the local exposure calculation. In the absence of a local nuclide concentration file (initially), one is generated from the zone nuclide concentration file; identical concentrations by nuclide are assigned over a zone. Thereafter, the contents of the point nuclide concentration file are used, and the file is rewritten with the data for the end-of-exposure conditions, after a shutdown period if appropriate.

Key results are obtained and reported for each exposure period. These include peak power density information, and the time this peak occurs during this exposure period, and exposure data. A simple average power density result is reported,

$$\overline{P} = \frac{\sum_{n=1}^{N} V(n)\ P(n)}{\sum_{n=1}^{N} V(n)}, \qquad (08\text{-}28)$$

Where the point volumes V(n) are defaulted to unity if not calculated.

Statistical information about the power density distribution is edited at the time the peak occurs, given the maximum and minimum power density values. If there are less than ten points involved, the power density at each is edited. Otherwise, a power density range of 20 intervals is selected, each interval of width

$$\Delta P = \frac{1}{19.5} [\max P(n) - \min P(n)] , \qquad (08\text{-}29)$$

starting at the lowest value min P(n) - $\frac{1}{4}\Delta P$, and the number of power density values lying in each interval is printed, giving a visual distribution.

The Steady State, Continuous Fueling Model

The BURNER module contains an option to treat the steady state, continuous fueling exposure problem. The zones must have been numbered in ascending order along the individual paths (routes) through the reactor. Exposure for zones not in the flow path (higher numbers) is calculated normally. Recycle, once or more, is allowed, as are multiple streams.

Consider a one-dimensional model of a reactor core, an axial transverse. Feed material is introduced at the top, say, and moves down through the core. Dividing the core into zones of equal thickness, the residence time in any zone is the core residence time divided by the number of these zones. Feed material is taken from an "extra" zone of the problems; the number of this zone is specified in the control instructions and the zone should be inactive: have no volume and no flux (be unused in a neutronics problem).

The composition leaving the first zone is calculated by exposure of the external feed material to the average flux in this zone for the

time of residence in the zone. This is a direct application of the fixed material calculational procedure without any rate term additions and with no restrictions on the available options. The desired power level cannot be effected by breaking the exposure time into substeps, but the exposure calculations may be repeated with the flux level adjusted to effect the desired power level. Usual reaction rates are calculated for material entering a zone and material leaving, and the integrals of the sums of the averages are reported.

The material leaving the first zone, end of exposure concentrations, is used as feed material for the next zone along the path. The average between the concentrations of the material entering and that leaving for each zone is obtained to approximate the zone average concentrations (before the shutdown calculation is done), and these averages are written on the nuclide concentration interface file for further use such as for a neutronics calculation. Information about feed and discharge is made available in the edit, and the composition of the material leaving the last zone along each path may be obtained as an edit. The continuous fueling mode of calculation involves an estimate of the nuclide concentrations moving across the interface between zones and produces an estimate of the average concentrations in each zone.

It is noted that the overall flux, eigenvalue, and nuclide concentration distribution problem which must usually be solved involves iteration; successive neutronics and exposure calculations are performed with parameter changes made to drive the problem to a steady-state solution. A simple criticality search problem may be done at each neutronics calculation in order to adjust the primary fertile nuclide concentration in the reactor and in the feed. But, generally, some control external from the exposure and

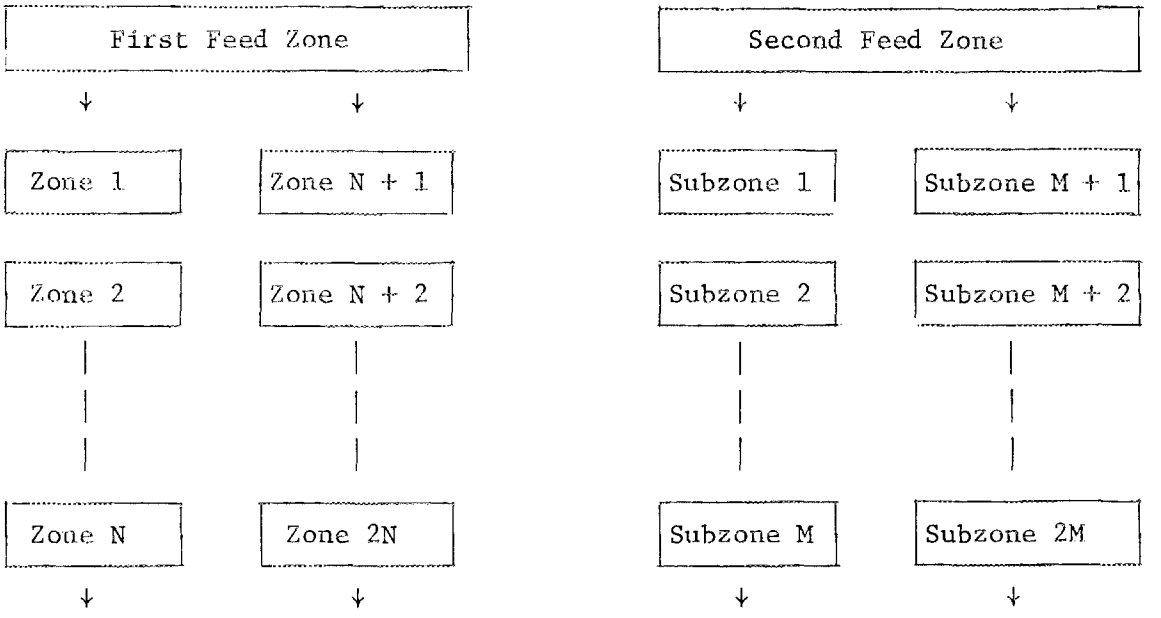
neutronics codes will likely have to be exercised to adjust the residence times or the fraction of fissile material in the feed. This can be done manually, and likely also automated, given a limited number of alternatives.

Bidirectional feed in the one-dimensional sense can be treated by parallel flow paths. The neutronics model can be extended from one-dimensional to two using two meshpoints in the second coordinate and a small thickness to cause the same flux to be generated for adjacent zones for the average composition. Alternatively, one could use the subzone option discussed below.

The multi-dimensional problem is a direct extension of the one-dimensional problem with provision for more than one path of material passing through the core. Residence time along each path may be specified.

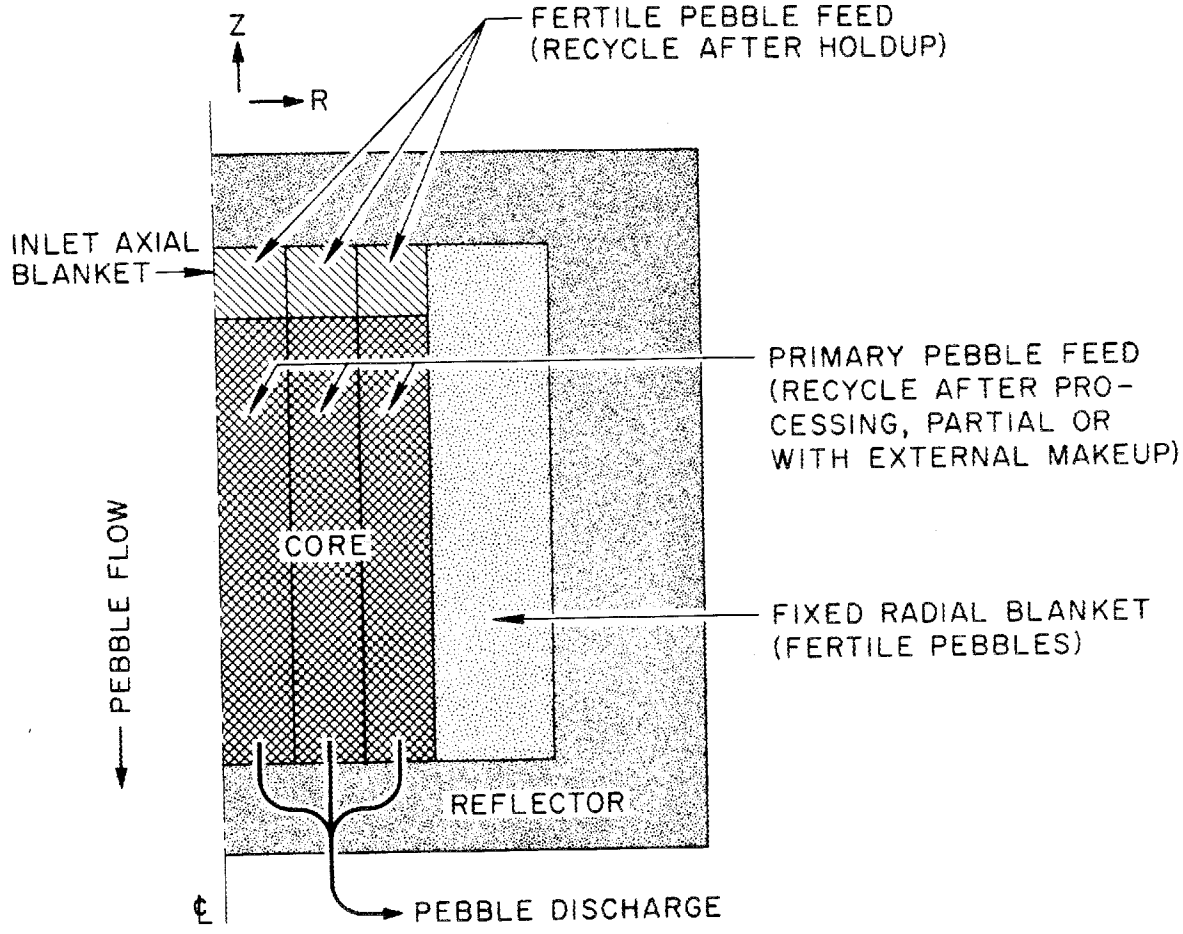
The subzone option allows the specification of separate feed material. Residence times along the paths are defined by the ordering of the subzone numbers and association with zone numbers. This provision expands the class of problem which can be treated. For example, the flow of two different particles at different rates along a path may be treated, possibly flowing in opposite directions.

The block diagram presented on the next page illustrates the exposure model. Not shown is the implemented capability to assign a separate feed zone to each of the flow paths which allows variation in the fissile enrichment, for example, to effect reduction in the peak radial power density peak.




The flexibility of the programmed treatment may be exploited. One example is a change in the zone average density (volume fraction) from one zone to another. The residence time is constant in each zone and is the core residence time divided by the number of zones along the path. If the material in a zone is twice as dense as in the other zones, this zone can be made half as thick as the other zones and the density change accounted for by the core volume fraction specifications. Making a zone half as thick causes the set residence time to apply to half the distance of travel, compensating for the increased density. Thus pebbles could be introduced into an axial blanket where they have one density and associated flow rate and then pass into the core where the available flow volume is smaller and the traverse rate per unit height is faster. Such an example is illustrated in Fig. 08-1, where one stream of pebbles is introduced at the top of the core directly and a second stream of pebbles is introduced

ORNL-DWG 77-13629




NOTE:

THIS IS AN ILLUSTRATION OF ONE OF THE MANY POSSIBILITIES.

THREE FLOW PATHS THROUGH AXIAL BLANKET AND CORE ARE SHOWN.

Fig. 08-1. The Once Through, Continuous Fueling Model

at the top of an inlet blanket. By using relatively small fertile pellets it is postulated that within the core they can flow through the interstices between larger pellets at a controlled rate faster than the controlled flow rate of larger primary particles. Calculations have been done for this situation treating the primary pebbles as zone material and the fertile pebbles as subzone material, with different core residence times, higher density of the fertile pebbles in the blanket than in the core, and spatial variation in core residence times. Some care is necessary to effect a wholly consistent set of specifications for the zone thicknesses, densities (volume fractions), and residence times. When zone thicknesses must be varied to account for variation in zone densities (volume fraction), care must be taken in selection of consistent zone heights to approximate region boundaries.

Also indicated in Fig. 08-1 is a fixed radial blanket. After the exposure calculation, zones containing fixed material (zones outside of the continuous fueling specifications) contain the material produced by exposure. Exposure time is additive when exposure continues through subsequent accesses of the BURNER code. If an iteration procedure is used to drive the conditions to a steady state, this additive exposure must be prevented. The computation system allows the nuclide concentrations to be selectively changed prior to subsequent accesses of the exposure code. Care must be taken to effect proper initial nuclide concentrations, as of fertile material, and zero values for the exposure products, including fission products (see the use of the special processor DENMAN, report ORNL-5229).

The implemented procedure admits the use of position dependent microscopic cross sections. Correspondences between nuclide densities and cross

sections are contained in the referencing file NDXSRF by unique nuclide names which have a fixed association with zones and subzones. Nuclide concentrations are accessed in the order contained in the nuclide concentration file ZNATDN. Material is moved from one zone to the next by order. Therefore the identifying sets of nuclides must be consistent: blocking must be done the same way and the same number of nuclides must be contained in each blocked set over the zones along the flow paths and in the feed box zone, and likewise for the subzones and their feed box. Further exposure calculations are usually done by absolute nuclide identification name, so these must also be consistent. Don't move the concentration of $U^{235}$ from one zone to another where it will be identified as $U^{238}$, or structural material, or anything else!

It is noteworthy that in parameter studies, converged solutions can be obtained to the continuous fueling model much quicker given the nuclide concentrations for similar conditions than by starting with uniform concentrations. Keep in mind that the neutron flux solution satisfies the nuclide concentrations presented to the neutronics code; a search can be done by the neutronics code to effect a critical condition, as by adjusting the nuclide concentrations in the reactor zones, but the feed zone material must also be altered to effect a change in the exposure results. Along the flow paths, the nuclide concentrations depend only on the residence time, the zone neutron flux values, and the feed material.

Under certain conditions it was found that successive estimates of the reactor state oscillated between two approximations. This was found to be driven by the successive estimates of the average zone nuclide concentrations and the associated distribution of the flux (dampening the search did

not help and the problems oscillated even when the neutronics code simply solved for the multiplication factor). Stability should be effected by averaging results as discussed below.

Averaging the Exposure Results

Under very special conditions it is practical to produce as the primary product of the exposure calculation a file of the nuclide densities which lie between those at the start and the after exposure values. Consider that a fixed fuel reactor is to be treated for some period of time. Given initial concentrations and an estimate of the flux distribution for these, end of exposure nuclide concentrations are obtained. If a simple average is taken of the initial and final concentrations, mid-exposure conditions should be well approximated, and a more applicable neutron flux distribution is associated with these concentrations. Then the original start of exposure concentrations can be exposed to this improved flux estimate to improve the results. To use this option, special instructions must be presented to the exposure module prior to each access to effect the proper control of access of the desired nuclide concentration file and of generation of the new file. The calculation above would require alternately producing an average concentration file using the latest version concentrations and then producing an end of exposure file (turning off the option under discussion) using the next-to-latest nuclide concentrations.

This option may be useful for stabilizing the oscillation of problems applying the once through, continuous fueling model discussed above.[a] It

---

[a]See also the capability for averaging successive iterate flux estimates and note the repeat capability to effect the desired power level.

should be exercised selectively, only for that class of problems which require it, because the rate of convergence of a problem which moves monotonically toward a solution would likely be significantly decreased. The products of fission approach an asymptote slowly with dampening.

The equation applied on this option is for each nuclide concentration in the system, over all zones and subzones, to be weighted as

$$N_n(\psi) = N_n(T) + F\,[N_n(0) - N_n(T)]\ , \qquad (08\text{-}30)$$

is after exposure, and $N_n(\psi)$ is the weighted value. F is a weighting is after exposure, and $N_n(\psi)$ is the weighted value. F is a weighting factor supplied by the user which is defaulted to 0.5 if outside of the range $0 < F < 1$, and the documenting reference time is incremented by the amount (1-F)T. Note that as $F \to 0$, end exposure concentrations are used, not those at the start.

Integrals

Basic mass balance data and gross absorption and power generation integrals are always edited for the exposure period. Integrated reaction rates are quite straightforward sume of the local contributions times volumes using zone average flux values.

Mass balances are reported in kgms,

$$Q_n = \frac{A_n}{602.25} \sum_z V_z \left\{N_{n,z} + \sum_{sz} \frac{V_{sz}}{V_z} N_{n,sz}\right\} \qquad (08\text{-}31)$$

where A is the nuclide atomic weight, the constant converts the results to kgms,

V is the volume in $cm^3$,

N is the nuclide concentration in atoms/barn-cm, and

z and sz refer to zone and subzone respectively.

The integrated reaction rate of a specific type is given by

$$R_{n,x} = \sum_z \{N_{n,z} + \sum_{sz} \frac{V_{sz}}{V_z} N_{n,sz}\} \sum_g \overline{\phi}_{g,z} \sigma_{x,n,g}$$

where the requirement for proper correspondence between nuclide concentration, zone, or subzone, and cross section referencing has been ignored but hopefully not in the code, where

$\overline{\phi}_{g,z}$ is the zone average flux in group g, and

$\sigma_{x,n,g}$ is the microscopic cross section for the reaction of interest.

Estimates of the multiplication factor with exposure are based on a simple interpretation of reaction rates and other loss rates given in the zone average flux file,

$$k(\Delta) = \frac{P(\Delta)}{A(\Delta) + L(0) \frac{\phi(\Delta)}{\phi(0)}} \qquad (08\text{-}32)$$

where $P(\Delta)$ is the rate of neutron production, $\Sigma N \nu \sigma_f \phi V$,

$A(\Delta)$ is the rate of neutron loss, $\Sigma N[\sigma_a - \sigma(n,2n)]\phi V$,

$L(0)$ is the start of step rate of losses other than due to reaction rates, and $\frac{\phi(\Delta)}{\phi(0)}$ is the ratio of the flux level for maintaining power level.

Estimates of conversion (breeding) ratio are made in the primitive sense,

$$CR = \frac{\text{Rate of neutron capture in fertile}}{\text{Rate of neutron absorption in fissile}}, \qquad (08\text{-}33)$$

which requires adjustment to represent realism (as to account for any desired nuclide importance weighting, decay, capture in intermediate

material, and out of core losses), where fertile and fissile material identifications are taken from the cross section file. Similarly, the rate of fissile consumption per unit energy generation is calculated.

Fluence exposure is determined directly for a specific energy range,

$$F(z,i,T) = \sum_{\Delta \varepsilon T} \Delta \sum_{g \varepsilon i} \overline{\phi}_{z,g} , \tag{08-34}$$

where $\Delta$ is an interval of time in period T, $\Sigma\Delta = T$, with a linear interpolation done within the cut-off group on the basis of lethargy width.

Similarly, atomic destruction by fission is determined as

$$D(z,T) = \sum_{\Delta \varepsilon T} \Delta \sum_{n} N_{n,z} \sum_{g} \sigma_{f,n,g} \overline{\phi}_{z,g} , \tag{08-35}$$

but with account taken of flux level changes made to effect the desired power level. A simple approximation of start and end fission rates for the time step T may be used.

Account may be taken of the dependence of cross sections on the local temperature. For this calculation, two group-ordered microscopic cross section files GRUPXS are supplied, each of which is for a reference temperature. The correlation applied to all cross sections is:

$$\sigma(T) = \sigma(T_1) + X\,[\sigma(T_2) - \sigma(T_1)] , \tag{08-36}$$

where $T_1$ and $T_2$ are the reference temperatures for the cross section data, and T is the local zone temperature. Let

$$\gamma = \left[\frac{T - T_1}{T_2 - T_1}\right] ,$$

and if the correlating parameter $\alpha$ is supplied,

$$X = \frac{\tan^{-1}(\alpha\gamma)}{\tan^{-1}(\alpha)} , \tag{08-37}$$

defaulted to $X = \gamma$ if $\alpha = 0$.

Significance

Or a short-word computer (IBM), the exposure calculation chain equation solution is done fully in double precision so that normally results have adequate significance within the numerical approximations. However, the flux values used, the nuclide concentrations and the basic data such as cross sections are in single precision. Significance tests are made where deemed important, such as to avoid reporting a result (a change in a nuclide concentration) when the intermediate calculations lose significance. Regarding accuracy of results, a significant distortion to the solution of some global problem can come from several sources in addition to the numerical approximations used. Some of these sources are:

1) the modeling in general,
2) the approximation of the neutron flux for the steady state,
3) the microscopic cross sections,
4) treating exposure on a discrete zone basis,
5) separation of the problem into neutronics problems with discrete exposure steps in between,
6) selection of nuclides treated from the full set (consider that there are many fission products) to make the problem tractable, and
7) feedback effects which can move the approximate solution away from the facts when recycle of material is treated.

We are left with a serious challenge to access the reliability of a solution considering these many interrelated effects.

One arbitrary action is taken in this code which may affect the results. We do not consider it an acceptable practice to set results to zero when underflow occurs. To avoid underflow of numbers, action is taken which is illustrated for the simple situation by the equation

$$\frac{dN}{dt} = - rN ,$$

$$N(\Delta) = N(0)\ e^{-r\Delta} .$$

We set any calculated value of $N(\Delta) < 10^{-50} = 0$, and if $r\Delta > 60$ we set $e^{-r\Delta} = 0$. Thus nuclide concentrations calculated to be $< 10^{-50}$ are reported to be zero. This action can impact the use of trace concentrations to produce auxiliary information and may limit the use of a shutdown time step to something less than hundreds of years. Although it is true that generally underflow during exposure calculations could be allowed, extremely small nuclide concentrations can cause underflow in other calculational modules where such is not permitted. Also as the limit of machine capability to represent the exponent is approached, values obtained by series approximations become inaccurate and unreliable for use.

END OF SECTION

ORNL-5180
Distribution Category UC-79d

## INTERNAL DISTRIBUTION

1. L. S. Abbott
2. E. J. Allen
3. R. G. Alsmiller
4. D. E. Bartine
5. T. J. Burns
6. R. L. Childs
7. S. N. Cramer
8-12. G. W. Cunningham
13. J. D. Drischler
14. M. B. Emmett
15. W. W. Engle
16. G. F. Flanagan
17. V. M. Forsberg
18. T. B. Fowler
19. S. K. Fraley
20. W. E. Ford
21. E. H. Gift
22. H. Goldstein (consultant)
23. N. M. Greene
24. W. O. Harms
25. R. F. Hibbs
26. T. J. Hoffman
27. J. R. Knight
28. R. A. Lillie
29. J. L. Lucius
30. R. E. Maerker
31. F. C. Maienschein
32. J. H. Marable
33. R. G. Mashburn
34. B. F. Maskewitz
35. J. M. McAdoo
36. S. R. McNeany
37. F. R. Mynatt
38. B. Nakhai
39. H. Postma
40. E. M. Oblow
41. M. Y. Ozal
42. J. V. Pace
43. R. W. Peelle
44. F. G. Perey
45. L. M. Petrie
46. W. A. Rhoades
47. J. C. Robinson
48. D. L. Selby
49. D. B. Simpson
50. T. M. Sims
51. C. O. Slater
52. J. H. Swanks
53. J. S. Tang
54. E. T. Tomlinson
55-69. D. R. Vondy
70. C. C. Webster
71. C. R. Weisbin
72. J. E. White
73. G. E. Whitesides
74. L. R. Williams
75. M. L. Williams
76. B. A. Worley
77. A. Zucker
78. Paul Greebler (consultant)
79. W. Loewenstein (consultant)
80. R. E. Uhrig (consultant)
81. R. Wilson (consultant)
82-83. Central Research Library
84. Y-12 Document Reference Section
85-86. Laboratory Records Department
87. Laboratory Records, ORNL-RC
88. ORNL Patent Office

## EXTERNAL DISTRIBUTION

89-90. Director, Reactor Research and Technology Division, DOE Washington, D.C. 20545
91. Office of Assistant Manager, Energy Research and Development, DOE-ORO, Oak Ridge, Tennessee 37830
92. Director, Reactor Division, DOE-ORO
93-185. NPD Reactor Computer Code Distribution
186-445. UC-79d - Breeder Reactor Physics (Base)

☆U.S. GOVERNMENT PRINTING OFFICE: 1979-748-189/415