ORNL-5180

DR. 2292

Exposure Calculation Code Module for Reactor Core Analysis: BURNER

D. R. Vondy
G. W. Cunningham

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

BLANK PAGE

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,α), (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.

BLANK PAGE

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).

BLANK PAGE

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 pr[illegible] involved. To hold down computation cost, a relatively long expc[illegible]iod is required between neutronics problems. Techniques are use[illegible] a reliable calculation over a long exposure period. The [illegible] may be readjusted to effect the desired average power level, an[illegible] 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 Δ,

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

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 Δ. 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

BLANK PAGE

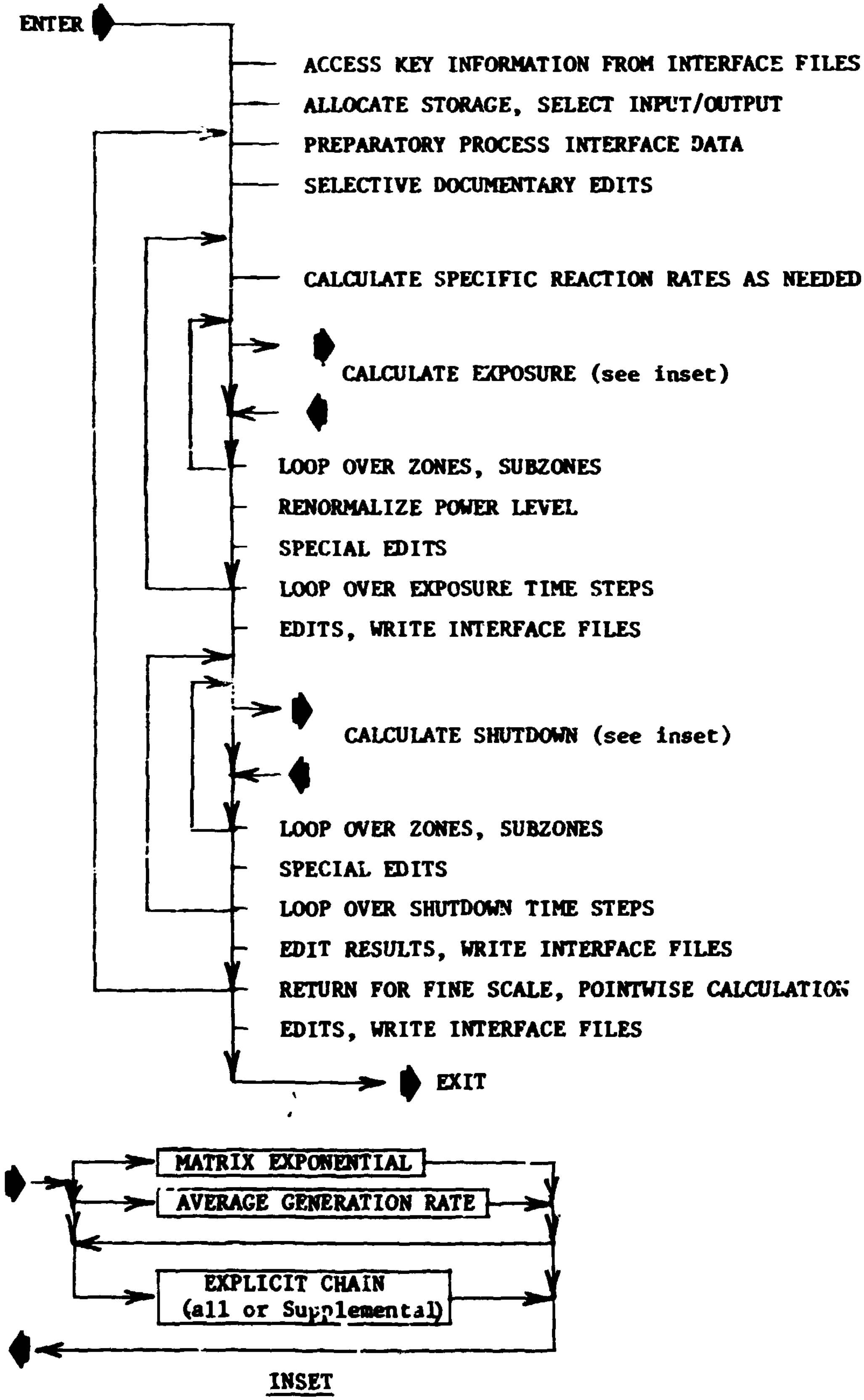


Figure 2.1. User Flow Diagram of BURNER Module.

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.

BLANK PAGE

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     BTTE    WRITE CONDENSED EDIT                                        -
C     BFIX    NORMAL EXPOSURE CALCULATION                                 -
C     BGXS    PROCESS NEXT-TO-LATEST GRUPXS                               -
C     BINP    INITIAL INTERFACE PROCESSING (EDYSRP, GEODST, GRUPXS,       -
C              AND EXPOSE) AND DATA PREPARATION                           -
C     BMCV    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     BPIN    CONTROL SETUP FOR POINT EXPOSURE AND SHUTDOWN               -
C     BPCI    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     BRNP    SETUP INTERNAL CROSS-REFERENCING INFORMATION FOR ABSOLUTE -
C              NUCLIDE, NUCLIDE CLASS, AND ZONE CLASS                     -
C     BPNC    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     BPNW    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     PRN1    OVERALL CALCULATION CONTROL                                 -
C     BRN3    PROCESS PZFLUX 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     CNOV    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     DEEP    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     ESZT    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 MONITORING 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     LEGP    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     NRCP    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      PRN7     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      PRPP     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 EXPORT                 -
C      REOR     CHANGE VOLUME AND LOCATION DATA ORDER FOR POINT              -
C                CALCULATION (METHOD 1)                                      -
C      RITE     DATA TRANSFER (MEMORY TO EXTERNAL DEVICE)                    -
C      ROXY     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      TIMEP    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      ZCPI    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 ZNPCWD        -
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      ANOP                                                                 -
C      ARRI                                                                 -
C      AUXE                                                                 -
C      BFIX     ARRI     BRNC     BRNY     DOEX     PARI     PDPT     POWL    -
C               REED     STOP     XEQC     XEXC     XEYC     ZCRI     ZNAW    -
C               ZZPD                                                        -
C      BGXS     BRN4     CHPI     PRTI     PRTT     REED     RITE     SEEK    -
C               SERR                                                        -
C      BINP     BGXS     BRNP     BRNW     BRNX     BRN4     BRN7     BZT1    -
C               EPFD     FERR     GNTC     PRTT     REED     SEEK     SKER    -
C               SKNU     STOR     ZIGY                                      -
C      BHOV     ARRI     BRNC     BRNY     DOEX     IX2D     PARI     PDPT    -
C               PONI     POWL     POWP     PROE     QFAT     QNAW     REED    -
C               RITE     STOR     XEQC     XEXC     XEYC     ZCRI     ZOND    -
C               ZONI     ZZPD     ZZPP                                      -
C      BPIA     CHEK     PGEO     PRN3     PRTI     PRTR     PTAT     PTNS    -
C               REOP     STOR                                               -
C      BPIB     PRTI     PRTP     PTNS     ZPNP     ZPNV     ZPN3            -
C      BPIC     BRPP     PRNA     PRND     PRNS     PRNT     PRNZ     PRPP    -
C               PZT2                                                        -
C      BPIN     BPIA     BPIB     BPIC                                      -
C      BRCI     FERR     REED     SEEK     SKER                             -
C      BRDS     BRN1     DOPC     ROXX     ROXY     FRRCOP   GETCOR          -
C      BRNA     REED     RITE                                               -
C      BRND     REED                                                        -
C      BRNP                                                                 -
C      BRNO                                                                 -
C      BRNS     DOPC     FERR                                               -
C      BRNT     RITE                                                        -
C      BRNW     ZUCY     ZUCZ                                               -
C      BRNX     HQUE                                                        -
C      BRNY                                                                 -
C      BRNZ     LEGP     REED     RITE     SEEK     SKER                    -
C      BRN1     BINP     BPIN     BURN     BZIN     FERR     FCUL     PURN    -
C      BRN3     ISTP     REED     RITE     SEEK     SKER     XEXC            -
C      BRN4     CHPH     CHPI     PRTH     PRTI                             -
C      BRN7     REED     RITE                                               -
C      BRPP     REED     RITE                                               -
C      BRRP     REED     RITE                                               -
C      BURN     AUXE     BRNY     EDEP     EXPH     OEXP     OCHN     TPNE    -
C               XEQC                                                        -
C      BZIN     BRNA     BRND     BRNS     BRNT     BRNZ     BRN3     BRRP    -
C               BZT2     CHOV     DEEP     FERR     PRRP                    -
C      BZT1     REED     SEEK     SERR                                      -
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      DEEP                                                            -
C      DOEX    JAGY    JPMY    JUCY                                    -
C      DOPC    FEEF    PREW    REED    RITE    SEEK    PESAM   PDISP   -
C              CLOSDA  DEFILE  RCHECK                                  -
C      DOSH    LAGY    LEMY    LUCY                                    -
C      DOWN    RPMY    DOSH    STOP    ZNAW                            -
C      ECHK                                                            -
C      EDED                                                            -
C      EDEP    EDED    ETAB    REED    SEEK    SKEP                    -
C      EPPD                                                            -
C      EPH2                                                            -
C      ESET                                                            -
C      ETAB    REPD    XEQC    XEYC                                    -
C      EXPH    CPH1    CPH2    ECHK    EPH2    ESET    PLUC    PLUE    -
C              LEGP    MXPP    REED    REHT    RITE    SEEK    SKER    -
C              STOP    XEYC    XPYC                                    -
C      FERR    SEEK                                                    -
C      FLUC                                                            -
C      FLUE    REED                                                    -
C      FOUL                                                            -
C      GCHK                                                            -
C      GMZC    FEPP    REED    SEEK    SKER    STOP                    -
C      HOUP                                                            -
C      ISTR                                                            -
C      IX2D                                                            -
C      IX3D                                                            -
C      JAGY    JAOD                                                    -
C      JAOD                                                            -
C      JEMY    JAOD    MEIT                                            -
C      JUCY                                                            -
C      LAGY    LAOD                                                    -
C      LAOD                                                            -
C      LEGP                                                            -
C      LEMY    LAOD    MEIT                                            -
C      LUCY                                                            -
C      MAIN    BPCI    BRDS    DOPC    TIMER                           -
C      MEIT    AMOR    MEMA    MEPA    MESA    MESP    METS    PRTD    -
C      MEMA                                                            -
C      MEPA                                                            -
C      MESA                                                            -
C      MESB                                                            -
C      METS                                                            -
C      MMRP                                                            -
C      MSEK    PRTD    PRTI                                            -
C      MSHO                                                            -
C      MSH1    PRTD                                                    -
C      MSH3                                                            -
```

(CONT)

```
C      MXPP                                                         -
C      NRCP    REED    RITE                                         -
C      OEXP    OPIX    OMOV    XEQC                                 -
C      OPIX    BPIX                                                 -
C      OMOV    BMOV                                                 -
C      OOWN    DOWN                                                 -
C      PARI                                                         -
C      PDPT                                                         -
C      PDST    MWRP    MXRP    PRTR                                 -
C      PFIX    DOPX    PDPT    PDST    PWAW    PRNY    REED    STOP -
C              XEQC    XEXC    XEYC                                 -
C      PGEO    GCHF    MSHK    MSHO    MSH1    MSH3    MPCF    PLOC -
C              PRTI    PRTR    REED    RITE    SEEK    SERM    STOP -
C              VOLP                                                 -
C      PLOC    REED                                                 -
C      PWAW    REED    RITE    SEEK    SERM    STOP                 -
C      POWI                                                         -
C      POWL                                                         -
C      POWN    DOSH    PWAW    PRNY    STOP                         -
C      POWP                                                         -
C      PPOP    PRTP                                                 -
C      PRWA    REED    RITE                                         -
C      PRWD    REED                                                 -
C      PRWS    DOPC                                                 -
C      PRWT    RITE                                                 -
C      PRWY                                                         -
C      PRWZ    CMPI    LEGP    PRTI    REED    RITE    SEEK    SERM -
C      PRW3    PRTR    REED    RITE    SEEK    SERM    XEXC         -
C      PRPP    REED                                                 -
C      PRRP    REED                                                 -
C      PRTD                                                         -
C      PRTH                                                         -
C      PRTI                                                         -
C      PRTR                                                         -
C      PRTT                                                         -
C      PTAT    PRTI    REED    SEEK    SERM                         -
C      PTWS                                                         -
C      PURN    PFIX    POWN    PRNY                                 -
C      PZT2    PRTR    REED                                         -
C      QWAT    REED    RITE    SEEK                                 -
C      QWAW    REED    RITE    SEEK    SKER                         -
C      REMT    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      SKWD                                                         -
C      STOR                                                         -
C      TIMER   IDAY    TIME    MODEL   ICLOCK  IOLEFT  ITTIME  JOBNUM -
C              JSTIME                                               -
```

(CONT)

```
C      TPWE                                                                     -
C      VOLP     PEED                                                            -
C      XEQC                                                                     -
C      XEXC                                                                     -
C      XEYC                                                                     -
C      XPYC                                                                     -
C      ZCPI                                                                     -
C      ZPMP     PRTI     PRTP     PEED                                          -
C      ZPMV                                                                     -
C      ZPM3     PRTP     PEED     PITE     XEXC                                 -
C      ZIGY                                                                     -
C      ZNAV     PEED     PITE     SEEK     SKEP                                 -
C      ZOND                                                                     -
C      ZONI                                                                     -
C      ZUCY                                                                     -
C      ZUCZ                                                                     -
C      ZZPD     PRTR     PITE     SEEK                                          -
C      ZZPP                                                                     -
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      FCHPCF   (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      IOLEPT                                                                   -
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     AVOE    BEXT                                                      -
C     ABRI    BPIX    BMOV                                              -
C     AUXE    BURN                                                      -
C     BPIX    OPIX                                                      -
C     BGXS    BINP                                                      -
C     BINP    BRN1                                                      -
C     BMOV    OMOV                                                      -
C     BPIA    BPIN                                                      -
C     BPIB    BPIN                                                      -
C     BPIC    BPIN                                                      -
C     BPIN    PRN1                                                      -
C     BPCI    MAIN                                                      -
C     BRDS    MAIN                                                      -
C     BRNA    BZIN                                                      -
C     BRND    BZIN                                                      -
C     BRNP    BINP                                                      -
C     BRNO    BPIX    BMOV                                              -
C     BRNS    BZIN                                                      -
C     BRNT    BZIN                                                      -
C     BRNW    BINP                                                      -
C     BRNX    BINP                                                      -
C     BRNY    BPIX    BMOV    BURN    DOWN                              -
C     BRNZ    BZIN                                                      -
C     BRN1    BRDS                                                      -
C     BRN3    BZIN                                                      -
C     BRN4    BGXS    BINP                                              -
C     BRN7    BINP                                                      -
C     BRPP    BPIC                                                      -
C     BRRP    BZIN                                                      -
C     BURN    BRN1                                                      -
C     BZIN    BRN1                                                      -
C     BZT1    BINP                                                      -
C     BZT2    BZIN                                                      -
C     CHEK    BPIA                                                      -
C     CMOV    BZIN                                                      -
C     CNPM    BRN4                                                      -
C     CNPI    BGXS    BRN4    PRNZ                                      -
C     CPN1    EXPN                                                      -
C     CPN2    EXPN                                                      -
C     DEEP    BZIN                                                      -
C     DOEX    BPIX    BMOV    PPIX                                      -
C     DOPC    BRDS    BRNS    MAIN    PRNS                              -
C     DOSN    DOWN    POWN                                              -
C     DOWN    OOWN                                                      -
C     ECHK    EXPN                                                      -
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    BRNS    BRN1    BZIN    DOPC    GNZC    -
C             WITE                                                -
C     FLUC    EXPH                                                -
C     FLUE    EXPH                                                -
C     FOUL    BRN1                                                -
C     FRECOM  BRDS                                                -
C     GCHK    PGEO                                                -
C     GETCOR  BRNS                                                -
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    DOPX                                                -
C     LAGY    DOSE                                                -
C     LAOD    LAGY    LEMY                                        -
C     LEGP    BRN7    EXPH    PRNZ                                -
C     LEMY    DOSE                                                -
C     LUCY    DOSE                                                -
C     MAIN                                                        -
C     MEIT    JEMY    LEMY                                        -
C     MEMA    MEIT                                                -
C     MEPA    MEIT                                                -
C     MESA    MEIT                                                -
C     MESB    MEIT                                                -
C     METS    MEIT                                                -
C     MNPP    PDST                                                -
C     MSHK    PGEO                                                -
C     MSH0    PGEO                                                -
C     MSH1    PGEO                                                -
C     MSH3    PGEO                                                -
C     MXRP    EXPH    PDST                                        -
C     NPCF    PGEO                                                -
C     OEXP    BURN                                                -
C     OPIX    OEXP                                                -
C     OMOV    OEXP                                                -
C     OOWN    BURN                                                -
C     PARI    BPIX    BMOV                                        -
C     PDPT    BPIX    BMOV    PPIX                                -
C     PDST    PPIX                                                -
C     PPIX    BURN                                                -
C     PGEO    BPIX                                                -
C     PLOC    PGEO                                                -
```

(CONT)

```
C     PNAW   PPIX   POWN                                           -
C     POSI   BMOV                                                  -
C     POWL   BPIX   BMOV                                           -
C     POWN   PURN                                                  -
C     POWP   BMOV                                                  -
C     PPOE   BMOV                                                  -
C     PRNA   BPIC                                                  -
C     PRND   BPIC                                                  -
C     PRNS   BPIC                                                  -
C     PRNT   BPIC                                                  -
C     PRNY   PPIX   POWN   PURN                                    -
C     PRNZ   BPIC                                                  -
C     PRN3   BPIA                                                  -
C     PRPP   BPIC                                                  -
C     PRRP   BZIN                                                  -
C     PRTD   MEIT   MSHK   MSH1                                    -
C     PRTH   BRN4                                                  -
C     PRTI   BGXS   BPIA   BPIB   BRN4   CHEK   MSHK   PGEO        -
C            PRNZ   PTAT   ZPMP                                    -
C     PRTR   BPIA   BPIB   BZT2   CHEK   CPH2   PDST   PGEO        -
C            PPOE   PRN3   PZT2   REHT   ZPMP   ZPM3   ZZPD        -
C     PRTT   BGXS   BINP                                           -
C     PTAT   BPIA                                                  -
C     PTNS   PPIA   BPIB                                           -
C     PURN   PRN1                                                  -
C     PZT2   BPIC                                                  -
C     QNAT   BMOV                                                  -
C     QNAW   BMOV                                                  -
C     REED   BPIX   BGXS   BINP   BMOV   BRCI   BRNA   BRPD        -
C            BRNZ   BRN3   BRN7   BRPP   BRRP   BZT1   BZT2        -
C            CHEK   CPH1   CPH2   DOPC   EDEP   ETAB   EXPH        -
C            FLUE   GNZC   MRCP   PPIX   PGEO   PLOC   PNAW        -
C            PRNA   PRND   PRNZ   PRN3   PRPP   PRRP   PTAT        -
C            PZT2   QNAT   QNAW   REHT   SPEK   VCLP   ZPMP        -
C            ZPM3   ZNAW                                           -
C     REHT   EXPH                                                  -
C     REOR   BPIA                                                  -
C     RITE   BGXS   BMOV   BRNA   BRNT   BRNZ   BRN3   BRN7        -
C            BRPP   BRRP   CPH1   DOPC   EXPH   MRCP   PGEO        -
C            PNAW   PRNA   PRNT   PRNZ   PRN3   QNAT   QNAW        -
C            SEEK   ZPM3   ZNAW   ZZPD                             -
C     ROXX   BRDS                                                  -
C     ROXY   BRDS                                                  -
C     RSTI   CPH2                                                  -
C     SEEK   BGXS   BINP   BRCI   BRNZ   BRN3   BZT1   DOPC        -
C            EDEP   EXPH   PERR   GNZC   PGEO   PNAW   PRNZ        -
C            PRN3   PTAT   QNAT   QNAW   SKER   ZNAW   ZZPD        -
C     SERM   BGXS   BZT1   PGEO   PNAW   PPNZ   PRN3   PTAT        -
C     SKER   BINP   BRCI   BRNZ   BRN3   EDEP   EXPH   GNZC        -
C            QNAW   ZNAW                                           -
C     SKND   BINP                                                  -
C     STOR   BPIX   BINP   BMOV   BPIA   DOWN   EXPH   GNZC        -
C            PPIX   PGEO   PNAW   POWN                             -
```

(CONT)

```
C     TIMER   MAIN                                                              -
C     TPNE    BURN                                                              -
C     VOLP    PGEO                                                              -
C     XEQC    BFIX    BMOV    BURN    ETAB    OEXP    PFIX                      -
C     XEXC    PFIX    BMOV    BRN3    PFIX    PRN3    ZPM3                      -
C     XEYC    BFIX    BMOV    ETAB    EXPH    PFIX    REHT                      -
C     YPYC    EXPH                                                              -
C     ZCRI    BFIX    BMOV                                                      -
C     ZPMP    BPIB                                                              -
C     ZPMV    BPIB                                                              -
C     ZPM3    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     ZZPP    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     IOLEPT  TIMER                                                             -
C     ITTIME  TIMER                                                             -
C     JOBNUM  TIMER                                                             -
C     JSTIME  TIMER                                                             -
C     MODEL   TIMER                                                             -
C     TIME    TIMER                                                             -
C                                                                               -
C***********************************************************************-
```

(CONT)

```
C*****************************************************************************-
C                                                                             -
C       PURNER COMMON                                                         -
C       -------------                                                         -
C                                                                             -
C       COMMON   ********* REFERENCED IN SUBROUTINE **********************-
C                                                                             -
C       ACES1    BZIN    EDEP    EXPH    OPIX    CMOV                         -
C       ACES2    BPIC    PURN                                                 -
C       CPEED    BMOV    BRNS    BZIN    CMOV    DEEP    QNAW                 -
C       FACES    BGXS    BINP    BPIA    BPIB    BPIC    BRNS    BURN         -
C                BZIN    EDEP    EXPH    OPIX    CMOV    OCWN    PRNS         -
C                PURN                                                         -
C       GEODS    BPIA    BPIB    BPIC    PGEO    PURN                         -
C       GLOBE    AUXE    BPIX    BGXS    BINP    BMOV    BPIA    BPIB         -
C                BPIC    BPIN    BRMO    BRNS    BRNW    BRNX    BRNZ         -
C                BRN1    BRN3    BURN    BZIN    BZT1    BZT2    DEEP         -
C                DOEX    DOSH    DOWN    EDEP    ETAB    EXPH    FOUL         -
C                JAGY    JENY    JUCY    LAGY    LENY    LUCY    MEIT         -
C                PAPI    PPIX    PGEO    PNAW    PONI    PCWN    PPOE         -
C                PRNS    PRNZ    PRN3    PURN    PZT2    QNAT    QNAW         -
C                REHT    ZPMP    ZPM3    ZNAW    ZONI    ZZPD    ZZPP         -
C       PARMS    BINP    BPIC    BRNS    BURN    BZIN    EDEP    EXPH         -
C                OEXP    OPIX    OMOV    OOWN    PPMS    PURN                 -
C       PARMY    BPIX    BINP    BMOV    BPIA    BPIB    BPIC    BZIN         -
C                DOWN    EDEP    ETAB    EXPH    MAIN    PPIX    PNAW         -
C                PCWN    PURN    QNAT    QNAW    REHT    ZNAW    ZZPD         -
C       PBURN    BPIA    BPIB    BPIC    PRNS    PURN                         -
C       POINT    BPIX    BINP    BMOV    BPIA    BPIB    BPIC    BRN1         -
C                BURN    BZIN    DOEX    DOSH    DOWN    EDEP    EXPH         -
C                OEXP    OPIX    OMOV    OOWN    PPIX    PCWN    PURN         -
C       PEACX    BPIX    BINP    BMOV    BPIC    BZIN    DOEX    PPIX         -
C                PURN                                                         -
C       RPTCL    AUXE    BPIX    BGXS    BINP    BMOV    BPIA    BPIB         -
C                BPIC    BPIN    BRCI    BRNS    BRNW    BRNX    BRNY         -
C                BRNZ    BRN1    BRN3    BURN    BZIN    BZT1    BZT2         -
C                DEEP    DOEX    DOSH    DOWN    EDEP    ETAB    EXPH         -
C                JAGY    JENY    JUCY    LAGY    LENY    LUCY    MEIT         -
C                OEXP    PDST    PPIX    PGEO    PNAW    POWN    PRNS         -
C                PRNZ    PRN3    PURN    PZT2    QNAT    QNAW    REHT         -
C                ZPMP    ZPM3    ZIGY    ZNAW    ZZPD                         -
C       UNITS    BPIX    BINP    BMOV    BPIA    BPIB    BPIC    BPIN         -
C                BRN1    BURN    BZIN    DOWN    EDEP    ETAB    EXPH         -
C                FOUL    MAIN    PPIX    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  PRECOR  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                              BRE1                                       -
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                              LEGP                LIBRARY                -
```

(CONT)

```
C                         CMPH              LIBRARY                 -
C                         CMPI              LIBRARY                 -
C                         ISTR              LIBRARY                 -
C                         RSTI              LIBRARY                 -
C                         PERR              LIBRARY                 -
C                         SERM              LIBRARY                 -
C                         SKEB              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                         IOLEPT            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                         CPEED             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    DEEP    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   BRNP    BRNT     *            PTAT    ZFMP   PRNS               -
```

(CONT)

```
C     BRNW    BZT2     *              PGEO    ZPH3     PBEZ              -
C     ZUCZ    BRNA     *              GCHK    ZPHV     PBET              -
C     ZUCY    BRND     *              NSHO             PZT2              -
C     ZIGY    BRRP     *              NSHK             PBWA              -
C     EPFD    PRRP     *              NSH1             PBND              -
C     BRWX             *              NSH3             BRPP              -
C     HQUE             *              NRCP             PBPP              -
C     SKNU             *              VOLP                               -
C                      *              PLOC                               -
C                      *              PRP3                               -
C                      *              REOR                               -
C                      *              CHEK                               -
C                      *                                                 -
C                      *                                                 -
C              **************************                                -
C               *       *       *       *                                -
C             OEXP    EXPH    EDEP    DOWN                               -
C             POWL    CPH1    EDED    DOWN                               -
C             ABRI    ECHK    ETAB                                       -
C             ZCRI    ESET                                               -
C             PARI    PLUC                                               -
C             BRNO    PLUE                                               -
C               *     REHT                                               -
C               *     CPH2                                               -
C               *     EPH2                                               -
C               *                                                        -
C               *                                                        -
C       ******************                                               -
C       *               *                                                -
C     OPIX            OHOV                                               -
C     BPIX            BHOV                                               -
C                       *                                                -
C                       *                                                -
C              ******************                                        -
C               *               *                                        -
C             ZOND            PONI                                       -
C             ZZPP            PPOE                                       -
C             ZONI            QHAW                                       -
C             POWP            QHAT                                       -
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 (ISP3)    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 (ISP4)    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 (ISP5)    INITIAL POINT DENSITIES                       -
C       NUMBER OF RECORDS     NPT                                             -
C       LENGTH OF RECORD      NNS              WORDS                          -
C       ALWAYS USED FOR POINT CALCULATION                                     -
C                                                                             -
C     LOGICAL UNIT 58 (ISP6)    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     NINTF                                           -
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 EXPOSURE 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 QUATDN INTERFACE                                       -
C       USED WHEN MULTIPLE PASSES ARE DONE FOR CONTINUOUS FUELING OPTION-
C                                                                          -
C     LOGICAL UNIT 50 (ISR10)  DENSITIES TO BE WRITTEN ON QUATDN           -
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 = IALP + 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     IALP    (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

BLANK PAGE

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 94-1 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 0.0)                                   -
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 OF 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                 LBPXCH('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 SATISFY 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                     'PTFLUX' 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 IX(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                 OF THE FILE ARE USED                                -
C                                                                      -
CD    IX(26)      FLUENCE DATA TO BE SAVED OF '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 IX(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                                                                             -
```

```
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 'DVPNTR' 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         IX(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 IX(6), IX(10), IX(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                                                                      -
CF    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    NYEP          NUMBER OF ENERGY RANGES FOR YIELD DATA             -
CD                   (GENERALLY NON-ZERO)                               -
CD    NGEP          NUMBER OF ENERGY RANGES FOR GAMMA RAYS             -
CD    NFSLR         NUMBER OF IDENTIFIED FISSILE NUCLIDES WHICH YIELD  -
CD                   FISSION PRODUCTS                                   -
CD    NFPP          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*NFPPR*NYER .GT. 0                         -
C                                                                       -
CL    (((YFPP(K,L,N),K=1,NFSLR),L=1,NFPPR),N=1,NYER)                    -
C                                                                       -
CW           NFSLR*NFPPR*NYER                                           -
C                                                                       -
CD    YFPP(K,L,N)     YIELD OF FISSION PRODUCT IFPR(L) FROM             -
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 NMATIX .GT. 0                                   -
C                                                                       -
CL    ((MATIX(J,I),J=1,3),I=1,NMATIX)                                   -
C                                                                       -
CW           3*NMATIX                                                   -
C                                                                       -
CD    MATIX(1,I)      SOURCE NUCLIDE                                    -
CD    MATIX(2,I)      PRODUCT NUCLIDE                                   -
CD    MATIX(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 IF 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 FROM 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 EXPORT

```
C***************************************************************************-
C                                                                           -
CF          EXPORT                                                          -
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 INIST)                                 -
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) 'EXPORT'                                -
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    EXPM1,EXPM2,EXPM3,EFL01,EFL02,INIST,IZONE,ISZ,                        -
CL    NFLUT,NFLU1,NFLU2,IXPM12,IXPM13,NRR1,NRR2,NRR3,                       -
CL    NRR4,IXPM18,IXPM19,IXPM20                                             -
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(N),N=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(N),N=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(N),N=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-----------------------------------------------------------------------
CN     11D    UNDEFINED                                                -
C                                                                      -
CC            PRESENT IF NRN4 = 1                                      -
C                                                                      -
CL     (RN4(NN),NN=1,ITZSZ)                                            -
C                                                                      -
CW            ITZSZ = IZONE + ISZ                                      -
C                                                                      -
CD     RN4            UNDEFINED                                        -
C                                                                      -
C-----------------------------------------------------------------------

C**********************************************************************-
C                                                                      -
CEOF          EXPORT                                                   -
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)                                      -
```

```
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     (NZPNT(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     NZPNT(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      -
CL                     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-----------------------------------------------------------------------
CR     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                                                                       -
CE          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    NFV          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                                                                       *-
CR            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     (XPV(I),I=1,10),NLP,NRZ,(IPV(J),J=1,8)                           *-
C                                                                       *-
CW            20                                                        *-
C                                                                       *-
CD     XPV(1)          REFERENCE VOLUME, CC                             *-
CD     XPV(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     ((FLP(K,N),K=1,NGROUP),N=1,NLP)                                  *-
C                                                                       *-
CW            NGROUP*NLP                                                *-
C                                                                       *-
CD     FLP             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***********************************************************************-
```

SPECIFICATIONS FOR INTERFACE FILE ZNTEMP

```
C***********************************************************************-
C                                                                      -
CR         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 ZNPCWD

```
C*************************************************************************-
C                                                                         -
CN          ORIGINAL SPECS REVISED TO INCLUDE SUBZONE DATA WHEN NEEDED    -
C                                                                         -
CF          ZNPCWD                                                        -
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) 'ZNPCWD'                               -
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) = VPPA(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(N),N=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(N),N=1,NZONE),(VFSZ(J),J=1,NSZ)                           -
C                                                                      -
CW            NZONE + NSZ                                              -
C                                                                      -
CD     VFPA           VOLUME FRACTIONS FOR PRIMARY ZONE ASSIGNMENTS    -
CD     VFSZ           VOLUME FRACTIONS FOR SUBZONE ASSIGNMENTS         -
C                                                                      -
C-----------------------------------------------------------------------
```

(CONT)

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

TABLE 04-1 END

Information About the Exposure Data

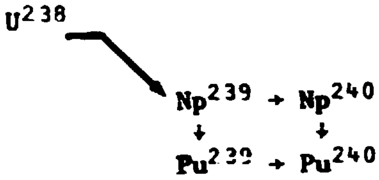
The data which must be supplied for the exposure calculation in file EXPOSE documented on page 04-17 is discussed here. The primary data required for reactor calculations are the decay constants, the yield of products from fission, and the chain coupling information. Data to produce auxiliary information 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^{235} 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



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 X 10^{14} and a thermal flux of 2.5 X 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,γ) 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,γ) capture]. The specifications for the explicit chain treatment include only the principle chain routes, excluding feedback mechanisms of α 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.

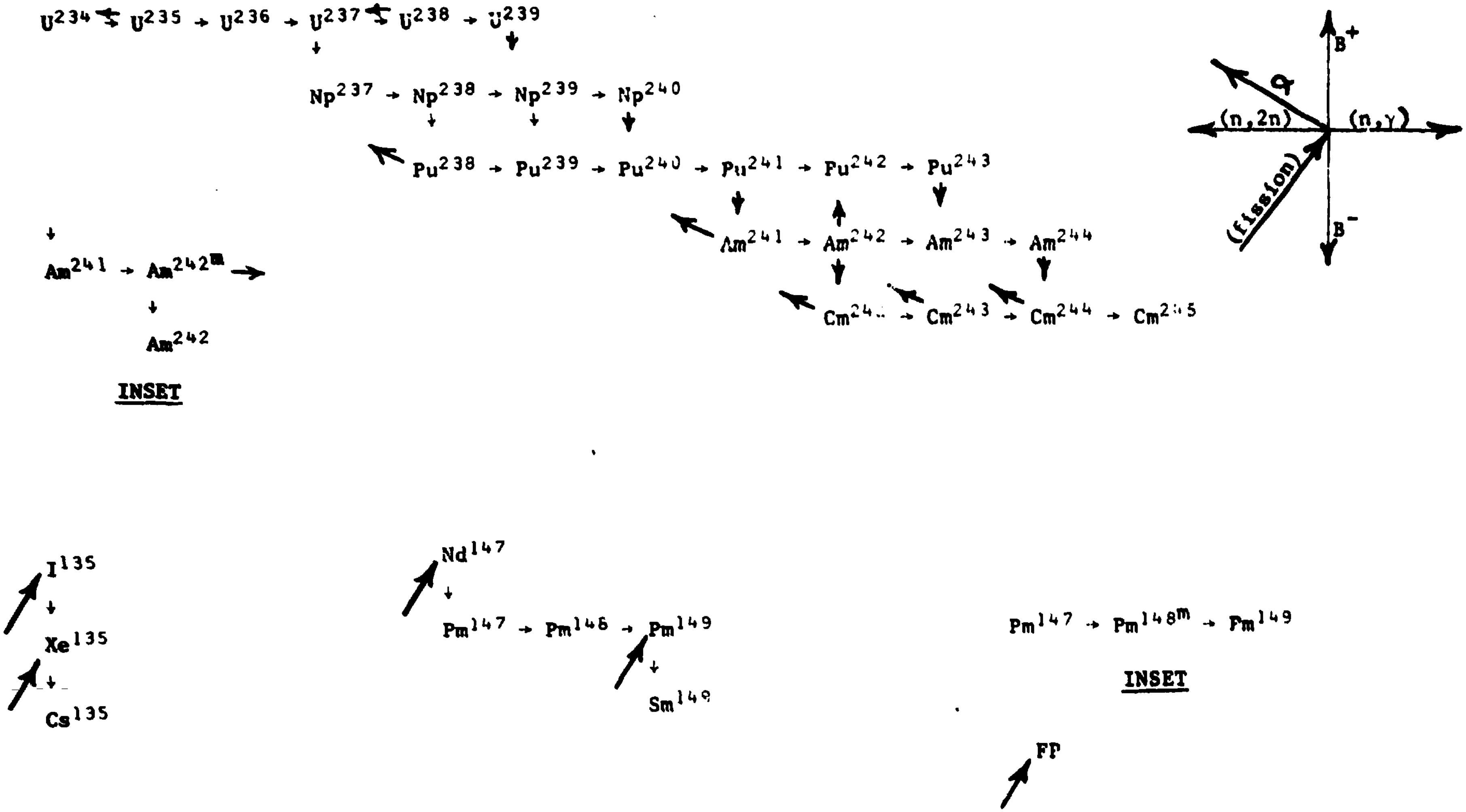


Figure 06-1. Nuclide chains for the First Sample Problem

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

```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - JULY 6,1970)

MODULE CONTROL1 WILL BE CALLED  TIME OF DAY  1.09.41  DATE 79.376

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

  LASLIB                                                                     DRIVERS
  CY GROUPS      THIS DATA CAN NOT BE USED FOR A FLUX CALCULATION
  1D  2 35 0 0 0 1 290 0 0 0 1 1 0 0
  2D /
  * TWO-GROUP DEPLETION PROBLEM (BENCHMARK FROM SSL)   (S,T) IS (N,G)*     *
  *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 PM149 PM148MPM149 *
  *SM149 FPLL  *
   1.0 0.0   0.0 0.0   1.092+7 0.652+8 0.0
  8D /
  *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 PM149 PM148MPM149 *
  *SM149 FPLL  *
   (*SEL   *) 35R  (*SIGMASO) 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
   243.0 244.0 245.0 135.0 135.0 135.0 147.0 147.0 149.0 148.0 149.0
   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 3
   8 8 8 8 8 8 8 8 8 8 8  / 99R
    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  5.9072  16.059  14.991  0.53250  0.00315  20.072  5.2600        SIGC1
    26.301  0.0  7.3125  9.0650  166.09  8.0305  51.023  11.030             SIGC1
   83.0000  2.3301  26.016  91.056  0.0  3.1202  9.9059  32.128           SIGC1
    8.0993  0.0  283.87  0.0  0.0  131.38  3369.0  2921.0                   SIGC1
    0.0  105.85  16.376                                                     SIGC1
    0.02700  12.379  0.16660  0.17139  0.081330  3.27291  0.01867          SIGF1
    87.812  0.0  0.0  1.5015  10.403  0.56033  29.906  0.03060             SIGF1
    29.392  1.1130  31.137  100.79  0.30700  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  0.0083972  0.0  0.00023100  0.0 28R            SIGN2N1
    0.0 16R  6.7096   0.0 12R  117.00   0.0 5R                              SIGCN1
  5D 0.0 35R     0.0 35R  / GROUP 2
    26.368  26.020  1.0399  132.12  0.73101  6.1613  71.060  55.812         SIGC2
    16.650  0.0  119.91  196.77  96.079  152.28  5.1903  21.609             SIGC2
   353.137  0.0  800.09  20.900  0.0  8.7195  69.309  3.6915  82.972        SIGC2
    0.0  1060790.0  0.0  0.0  30.727  823.09  7551.6  0.0  23397.0          SIGC2
    10.829                                                                  SIGC2
    0.0  108.18  0.0  0.55512  0.0  8.2009  0.0090250  555.12  0.0          SIGF2
    0.0  3.5896  308.89  0.016700  352.73  0.0  89.963  2.3817  693.90      SIGF2
    1776.0  0.0  803.29  0.93267  198.29  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   39.503   0.0 12R   31.007    0.0 5R                           SIGCN2
  7D  1 35R    1 35R   / GROUP 1
```

```
8D  0.0 35*
7D  1 35*   1 35*  / GROUP 2
8D  0.0 35*
3V GEODST
1D  1 100 0 17*
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 35*  / NPF
  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 2 3 3 3 3 3 1 2 1 3 3 3 3 1 3 3 3 3 3 3
  4 4 4 4 4 4 4 4 4 4  / PCLT
   35 0 0 4  /  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  / NOP
3D  1.0 1.0 1  / VOLZ,VFPA,NSPA
0V ZNATDN
1D  0.0 0  1 35 1
2D  0.0  0.48803-4  0.0  0.0  0.69369-2  0.0 30*
0V RZFLUX
1D  0.0 1.0+6  1.0  1.0  0.0  0.0  1.0  1.0  0.0 48
     1.0  1.0  0.0  0.0  0  1  2  0
2D  6.1274+14  2.5074+14
0V RI2O5E
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 (DEDUC[illegible] FROM SRL)  (N,T) IS (N,G)N    *
*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  /  TFD
     2 5 12 14  /  IFSLD
     26 27 33 29 35  /  IFPR
     26 27 29 30 31 32 33 4 6 8 9 10 14 16 18 21  /  IDCTP
     11 17 22 23 24  / IDCTP ADDED
4D   2.874-5  2.093-5  7.226-7  8.289-9  1.098-6  1.976-7
     3.626-6  1.190-6  4.915-4  3.029-6  3.410-6  1.583-1
     1.600-9  3.806-5  1.394-5  4.000-4  /  ALPHA
     2.550-10  5.390-11  4.910-8  6.060-10  1.250-9  /  ALPHA 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   0.0200   0.0205   0.0220   /  ND149  YIELD
     0.9010   0.8910   0.8905   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 2        18 20 2
```

```
    19 20 2   20 21 2   21 24 1   22 21 2   23 24 2   24 25 2
    2 1 5   5 4 5   / (5,25)
    19 22 9.33273   19 15 1.46733   /  BETA-,BETA+
    11 9 1   17 7 1   22 11 1   23 12 1   24 11 1   /  ALPHA
    25 27 1   27 28 1   29 30 1   30 31 2        30 32 2
    31 33 2   32 33 2   33 34 1
80 /  PRIMARY EXPLICIT CHAINS (15 CHAINS, 229 ENTRIES)
 5  2  4  1  8  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  8  1  12  2  13  2  14  1  17  2  19  0.33271  22  2  23
 2  -24  2  -25  0
 5  2  6  1  9  2  10  1 -13  2 -14  1 -17  2 -19  0.33271 -22  2 -23
 2  -24  2  -25  0
 2  2  3  2  8  1  7  2  9  2  -9  1  -12  2  -13  2  -14  0
 5  5  8  1  7  2  9  2  -9  1  -12  0
 2  2  3  2  8  1  7  2  9  1  11  2  -12  2  -13  2  -14  0
 2  2  3  2  8  1  7  2  8  1  11  1  1  0
 5  5  -8  1  -7  2  -9  1  -11  1  -1  0
 2  5  -1  2  -2  0
-5  2 -6  1 -9  1 -12  2 -13  2 -14  1 -17  2  19  2 -23  2 -21  1 -24
 2 -25  0
29   1   30   2   31   2   33   1   34   0
29   1   30   2   32   2  -33   1  -34   0
 26   1   27   1   28   0   35   0   0
0V CONTRL
1D *PROBIUS* /
* MATRIX EXPONENTIAL SOLUTION  (ASSUMING EQUILIBRIUM)                  *
* ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)                    *
*USER  * *IDENT *   0.0 7HR  0 100R
1D *DVPINS*  0.0 100P  10000  0 99R
1D *EXPINS*    50.0  0.0 99R
  $1S 0  $2S 0  $3 DEBUGS 1  $4S 0  $5 METHODS 0  $6 SUBSTEPS 1
  $7 SUBSTEPSS 0  $8S 0  $9S 0  $10S 0  $11 AGRIDS 0    $12 POWERS 0
  $13S 0  $14S  1  $15S 0  $16S 0  $17S 0  $18S 0  $19S 0  $20S 0
  $21S 1  $22-29S 0  8R  $30S 0  $31S 0  $32S 1  $33S 1  $34S 0  $35S 1
  $36S C  $37S 0  $38S 0  $39S 0  $40S 0  $41S 0  $42S 0  $43S 0
  $44S 0  $45S 0  $46-100S 0 55R
1D *       *  0.0 100R  0 100R
   STOP
END                                                                    DRIVERE

LASLIN                                                                 DRIVERS
0V ZBATRP
1D  0.0 0  1 35 1
2D  0.0  0.70003-8  0.0  0.0  0.59340-2  0.0 33R
0V CONTRL
1D *PROBIUS*  /
* EXPLICIT CHAIN SOLUTION                                             *
* ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)                    *
*USER  * *IDENT *   0.0 7HR  0 100R
1D *DVPINS*  0.0 100P  10000  0 99P
1D *EXPINS*    50.0  0.0 99R
  $1S 0  $2S 0  $3 DEBUGS 1  $4S 0  $5 METHODS 1  $6 SUBSTEPS 1
  $7 SUBSTEPSS 0  $8S 0  $9S 0  $10S 0  $11 AGRIDS 0    $12 POWERS 0
  $13S 0  $14S  1  $15S 0  $16S 0  $17S 0  $18S 0  $19S 0  $20S 0
  $21S 1  $22-29S 0  8R  $30S 0  $31S 0  $32S 1  $33S 1  $34S 0  $35S 1
  $36S 0  $37S 0  $38S 0  $39S 0  $40S 0  $41S 0  $42S 0  $43S 0
  $44S 0  $45S 0  $46-100S 0 55R
1D *       *  0.0 100R  0 100R
   STOP
END                                                                    DRIVERE

LASLIN                                                                 DRIVERS
0V ZBATRP
```

```
1D  0.0 0  1 35 1
2D  0.0  0.78003-4  0.0  0.0  0.69360-2  0.0 10R
0V CONTRL
1D *PROCESS*  /
* AVERAGE GENERATION RATE SOLUTION                                     *
* ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)                     *
*USER*  * *ORDER* *   0.0 7RR  0 100R
1D *DEVRISS*  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  $6 SUBSTEPS$ ,
  $7 SUBSTEPS$ 0  $8$ 0  $9$ 0  $10$ 0  $11 ASRINC$  0    $12 POWERS 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 ZNATOM
1D  0.0 0  1 35 1
2D  0.0  0.78003-4  0.0  0.0  0.69360-2  0.0 10R
0V CONTRL
1D *PROCESS*  /
* MATRIX EXPONENTIAL SOLUTION                                          *
* ANL-7416 SUP 2 BENCHMARK PROBLEM BOOK (ID.15-A2)                     *
*USER*  * *ORDER* *   0.0 7R*  0 100R
1D *DEVRISS*  0.0 100R  10000  0 99R
1D *EXPINS*     50.0  0.0 99R
  $1$ 0  $2$ 0  $3 DEBUG$ 1  $4$ 0  $5 METHOD$ 3  $6 SUBSTEPS$ 1
  $7 SUBSTEPS$ 0  $8$ 0  $9$ 0  $10$ 0  $11 ASRINC$  0    $12 POWERS 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    2030

MODULE CONTROL1 WILL BE CALLED  TIME OF DAY  1.52.20  DATE 78.336

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

 LASLIN                                                         DRIVERS
  0V GPNPXS
  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  XE135APM147APM148APM148ASM149A*
      *MSFPA SSFPA TA181ACR-BA FE-BA NI-BA U235B U236B U238B PU239B*
      *PU240BPU241BPU242BO16B  NA23B CR-B  MN55B FE-B  NI-B  XE135B*
      *PM147BPM148BMPM148BSM149BMSFPB SSFPB TA181B*
  6.17000E-01 3.73900E-01 1.00000E-02 2.03625E 09 6.09100E 04 1.50330E 08
  1.09200E 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 MSFP  SSFP  *
      *TA181 CR    FE    NI    U235  U236  U238  PU239 PU240 PU241 *
```

```
*U7202 016   9A23  C9    4855  FE    NI    TE135 PU167 PRIMER*
*PU100 SR109 RSPP  SSPP  TR101 CITRESCITRES.ITRESCITRESCITRES*
*CITRESCITRESCITRESCITRESCITRESCITRESCITRESCITRESCITRESCITRES*
*CITRESCITRESCITR  ITRESCITRESCITRESCITRESCITRESCITRESCITRES*
*CITRESCITRESCITRESCITRESCITRESCITRESCITRESCITRESCITRESCITRES*
*CITRESCITRESCITRESCITRESCITRESCITRESCITRESCITRESCITRESCITRES*
*10      11     12     14     15     16     17     23     25     31     *
*32      33     35     59     63     64     65     67     76     77     *
*81      131    133    135    10     11     12     14     15     16     *
*17      23     25     31     32     33     35     59     63     64     *
*65      67     76     77     81     *
2.35700E 02 2.36990E 02 2.38000E 02 2.39000E 02 2.40000E 02 2.41000E 02
2.42900E 02 1.50600E 01 2.27900E 01 5.15500E 01 5.44790E 01 5.53600E 01
5.82100E 01 1.35907E 02 1.47000E 02 1.48300E 02       2R   1.49C00E 02
0.0               2R   1.41700E 02 5.15500E 01 5.53690E 01 5.82100E 01
2.35900E 02 2.36700E 02 2.38007E 02 2.39901E 02 2.40000E 02 2.41300E 02
2.42900E 02 1.50600E 01 2.27900E 01 5.15500E 01 5.44700E 01 5.53600E 01
5.82110E 01 1.35907E 02 1.47000E 02 1.48700E 02       2R   1.49000E 02
0.0               2R   1.41000E 02 3.23300E-11 3.26790E-11 3.31000E-11
3.30900E-11 3.34009E-11 3.37000E-11 3.38099E-11 0.0               17R
3.23700E-11 3.28007E-11 3.31099E-11 3.30900E-11 3.36260E-11 3.37000E-11
1.39000E-11 0.0               239R
    1       3       2       1       2       1       1       3       6
    5       42      4       7R      7       46      1       3       2       1
    2       1       3       0       6       5       4R      1       7R      7
    1       1       8R      0       1       59      9       1       6       2R
    1       9       3R      1       109     9       1       5R      0       1
    9       2R      1       0       10R
5R   4.65099E 00 4.79700E 00 4.70009E 00 4.99900E 00 4.75700E 00
4.60990E 00 4.40990E 00 1.52300E 00 1.83000E 00 2.31400E 00 2.40009E 00
2.79903E 00 2.58007E 00 2.00900E-04 6.42999E 00 2.92000E 00 7.56090E-02
3.94090E 00 3.90900E-02 2.00700E-01 4.00000E 00 2.31400E 00 2.79300E 00
7.54700E 00 4.70700E 00 4.84000E 00 4.77907E 00 4.91500E 00 4.77900E 00
4.61099E 00 4.41307E 00 1.59090E 00 1.86000E 00 2.29900E 00 2.51300E 00
2.79207E 00 2.59007E 00 4.00000E-04 6.47000E 00 3.00700E 00 7.77000E-02
4.93300E 00 4.00300E-02 1.00900E-01 4.00700E 00 0.0               45R
4.69444E-02 1.07500E-01 5.47009E-02 9.00075E-03 4.99992E-02 8.39996E-02
7.19995E-02 5.37707E-02 2.40776E-03 4.37440E-03 4.70000E-03 8.96019E-03
1.02990E-01 2.03399E-04 1.50540E-01 2.92070E 00 7.56000E-02 7.96080E-02
3.99900E-02 2.07003E-01 3.00909E-02 4.37440E-03 8.95319E-03 1.02999E-01
4.89999E-02 1.10290E-01 5.80000E-02 9.60978E-03 5.23309E-02 8.69000E-02
3.19996E-02 7.54900E-03 2.40587E-03 4.39950E-03 4.67100E-03 8.38160E-03
9.33978E-02 4.00000E-04 1.56726E-01 3.00009E 00 7.77900E-02 4.20300E-02
4.00300E-02 3.00009E-01 3.00709E-02 1.23500E 00 8.12200E-01 4.30709E-01
1.86600E 00 1.53599E 00 1.67600E 00 1.51000E 00 0.0               2.24000E-06
2.26000E-05 1.52090E-04 5.94000E-05 1.83000E-04 0.0               1.46000E-07
0.0               2R   1.23009E-02 0.0               3R   2.26000E-05
5.99900E-05 1.87790E-06 1.23990E 00 8.00400E-01 4.14399E-01 1.06690E 00
1.52990E 00 1.69490E 00 1.50900E 00 0.0               3.16590E-06 3.05990E-05
1.09000E-01 7.80000E-05 2.52000E-06 0.0               1.67400E-03
0.0               2R   1.29003E-02 0.0               3R   2.71000E 00
2.73000E 00       2R   3.22900E 00 3.18990E 00 3.27000E 00 3.18000E 00
0.0         2.00900E 00       5R   0.0               2.00900E 00
0.0               2R   2.00000E 00 0.0               1R
2.00000E 00       3R   2.71090E 00       2R   2.74300E 00 3.21001E 00
3.13700E 00 1.26900E 00 3.16000E 00 0.0               2.33300E 00       3R
0.0         2.03999E 00 0.0               2R   2.00000E 00
0.0               3R   6.17000E-01       7R   0.0
6.17790E-01       5R   0.0               6.17900E-01 0.0               2R
6.17000E-01 0.0               3R   6.17060E-01    10R   0.0
6.17900E-01       5R   0.0               6.17009E-01 0.0               2R
6.17000E-01 0.0               3R
5R   7.74000E 00 6.76300E 00 8.11090E 00 7.78009E 00 7.54000E 00
8.17700E 00 7.29909E 00 3.61000E 00 7.46000E 00 3.81900E 00 4.83000E 00
2.90009E 00 4.60090E 00 1.00900E-03 6.20009E 00 8.58300E 00 2.22000E-01
8.26000E 00 5.00090E-02 4.00000E-01 6.00009E 00 3.01900E 00 7.99300E 00
```

```
4.60000E 00 4.11000E 00 4.12000E 00 8.47000E 00 8.37900E 00 7.83600E 00
8.59000E 00 7.59000E 00 3.77000E 00 7.83000E 00 4.74000E 00 5.00000E 00
3.02000E 00 4.78000E 00 3.03000E-03 6.25300E 00 9.13000E 00 2.36000E-01
8.51000E 00 7.00000E-02 5.03300E-01 6.00000E 00 0.0               85P
2.60000E-01 3.08600E-01 1.51300E-01 1.46000E-01 1.85300E-01 1.90300E-01
1.23000E-01 0.0               5.11000E-04 5.40000E-03 9.60300E-03 7.05000E-03
1.05500E-02 1.01000E-03 3.81000E-01 4.58000E 00 2.22000E-01 8.03000E-01
5.00000E-02 8.07000E-01 3.05000E-01 5.49000E-03 7.25000E-03 1.05500E-02
2.83000E-01 3.08950E-01 1.59650E-01 1.63000E-01 1.92700E-01 2.04300E-01
1.28400E-01 0.0               5.28200E-04 5.80000E-01 1.34000E-02 7.62000E-03
1.09000E-02 3.00000E-01 3.95100E-01 9.14000E 00 2.16700E-01 5.27000E-01
7.00000E-02 5.77000E-01 3.00000E-01 7.35100E 00 3.65300E-02 1.70000E-03
1.53700E 00 3.40000E-01 1.79000E 00 2.49000E-01 0.0               17P
1.37500E 00 1.85500E-02 8.50000E-04 1.52200E 00 2.52300E-01 1.02400E 00
1.69300E-01 0.0               18P 2.84000E 00 2.51000E 00 2.49000E 00
2.93000E 00 2.95000E 00 2.98000E 00 2.92000E 00 0.0               17P
2.45000E 00 2.50000E 00 2.89000E 00 2.92000E 00 2.95300E 00 2.90000E 00
2.90000E 00 0.0               18P 2.71000E-01       7P    0.0
3.71000E-01       5P    0.0               3.71000E-01 0.0               2P
3.73000E-01 0.0               3P 3.73000E-01       10P   0.0
3.73000E-01       5P    0.0               3.71000E-01 0.0               2P
3.71000E-    .0               3P
5P   1.840     01 1.44000E 01 1.42000E 01 1.43000E 01 1.41000E 01
1.56400E 01 1.61000E 01 3.55000E 00 6.76000E 00 6.01000E 00 2.64000E 01
8.07000E 00 1.60000E 01 6.19000E-02 1.51000E 01 1.37700E 02 3.40000E 02
1.67000E 01 3.00000E-01 2.50000E 00 1.50000E 01 6.31000E 00 8.37700E 00
1.60000E 01 1.51000E 01 1.47000E 01 1.41100E 01 1.47300E 01 1.44700E 01
1.61600E 01 1.60600E 01 3.57000E 00 5.92000E 00 5.28700E 00 2.56000E 01
8.40000E 00 1.50000E 01 2.70000E-01 1.53160E 01 3.31300E 02 5.40000E 02
1.90000E 01 5.00000E-01 5.00000E 00 1.50000E 01 0.0               85P
  13900E 00 9.93100E-01 5.55000E-01 1.01700E 00 7.46300E-01 8.79900E-01
7.10800E-01 1.06100E-07 1.73000E-08 3.62500E-02 1.02300E-01 3.03000E-02
5.31000E-02 6.70300E-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 3.03900E-02 5.33000E-02
1.27500E 00 1.19600E 00 5.29400E-01 1.18500E 00 1.23910E 00 9.66000E-01
9.71840E-01 2.33900E-07 1.70000E-03 3.22000E-02 2.39700E-01 2.95300E-02
8.96000E-02 2.70000E-01 8.61600E 00 3.31000E 02 5.44000E 02 4.30000E 00
5.00000E-01 5.00000E 00 2.00000E 00 3.09000E 00 0.0               2P
2.15900E 00 1.06300E-01 3.79000E 00 3.52000E-02 0.0               17P
3.39200E 00 0.0               2P 2.51100E 00 1.02900E-01 4.27000E 00
3.61000E-02 0.0               18P 2.83000E 00 0.0               2P
2.89000E 00 2.84300E 00 2.94000E 00 2.81000E 00 0.0               17P
2.83000E 00 0.0               2P 2.88000E 00 2.99000E 00 2.94000E 00
2.81000E 00 0.0               18P 1.00000E-02       7P    0.0
1.00000E-02       5P    0.0               1.00000E-02 0.0               2P
1.00000E-02 0.0               3P 1.00000E-02       10P   0.0
1.00000E-02       5P    0.0               1.00000E-02 0.0               2P
1.00000E-02 0.0               3P
7P         1     90P
8P   4.80000E 00 4.79000E 00 4.48000E 00 4.36000E 00 4.79000E 00
4.68000E 00 4.81000E 00 1.63500E 00 2.27000E 00 2 66000E 00 2.45000E 00
2.72000E 00 2.83000E 00 0.0               4.79000E 00 0.0               2P
5.09000E 00 0.0               2P 3.00000E 00 2.66000E 00 2.72000E 00
2.80000E 00 4.71000E 00 4.69500E 00 4.43000E 00 4.29000E 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               2P
5.11000E 00 0.0               2P 3.00000E 00
7P        2     13P      1        2        1      2P       2        1      2P
     2     17P       1        2        1      2P       2        1      2P       2
     1     45P
8P   7.60000E 00 9.90000E-01 9.80000E 00 1.03000E 00 9.53000E 00
2.20000E 00 8.02000E 00 1.18200E 00 9.04000E 00 1.04300E 00 8.62000E 00
1.02300E 00 8.79000E 00 7.53000E-01 7.69000E 00 3.22000E-01 3.76000E 00
4.18000E-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               2P 7.30000E 00 1.50000E 00 0.0               2P
```

```
5.03900E 00 1.90390E 00 4.79000E 00 6.05000E-01 3.18090E 00 5.32000E-01
4.45C00E 00 4.99990E-01 7.79000E 00 1.03890E 00 1.04700E 01 1.87050E 00
9.79900E 00 2.31000E 00 8.27000E 00 1.16400E 00 4.35490E 00 1.96203E 00
8.83900E 00 1.07400E 00 9.08000E 00 7.64500E-01 3.82390E 00 4.17900E-01
3.42000E 00 4.09200E-01 5.06000E 00 6.01500E-01 5.11000E 00 6.74000E-01
3.28000E 00 5.81500E-01 5.09000E 00 5.10090E-01 0.0         5.84000E 00
1.57000E 00 0.0            2P   7.40300E 00 1.55000E 00
0.0            2P   5.00000E 00 1.00000E 00
7P       3    139      1      3      1     2P      3      1     2P
     3    17P      1      3      1     2P      3      1     2P      3
     1    45P
9P  1.09000E 01 1.00000E-01 1.90000E-02 1.39000E 01 1.69000E-01
4.05000E-02 1.34000E 01 1.72000E-01 5.17000E-02 1.16500E 01 1.10000E-01
7.99000E-02 1.30700E 01 1.85000E-01 1.37900E-02 1.17400E 01 2.11000E-01
2.63000E-02 1.59000E 01 1.34200E-01 2.15700E-02 3.59700E 00 1.90000E-01
2.78000E-05 6.07990E 00 1.40000E-01 5.37900E-03 5.32290E 00 2.89203E-02
1.44600E-02 2.69000E 01 1.59600E-01 2.46050E-02 9.12300E 00 8.94000E-02
6.43000E-03 1.79070E 01 9.10000E-02 2.20000E-02 0.0         1.17000E 01
4.19900E-02 3.94000E-02 0.0            2P   1.36400E 01 2.55000E-01
1.53000E-02 0.0            2P   1.00000E 01 2.00000E-01 1.07000E-01
6.32290E 00 2.00700E-02 1.48600E-02 8.12300E 00 8.94300E-02 6.03003E-03
1.70900E 01 9.17000E-02 2.20000E-02 1.07500E 01 1.67600E-01 1.82700E-02
1.39300E 01 2.03000E-01 5.09000E-02 1.39100E 01 2.09900E-01 5.15000E-02
1.15990E 01 1.36500E-01 2.97000E-02 1.78300E 01 2.25300E-01 1.22000E-02
1.17500E 01 2.05000E-01 2.30000E-02 1.56900E   1.69500E-01 2.13500E-02
3.58500E 00 2.42200E-01 2.71000E-05 6.00300E 00 .78300E-01 4.77000E-03
5.69000E 00 3.67500E-02 1.04000E-02 2.57000E 01 1.71000E-0  2.70300E-02
4.57900E 00 1.37000E-01 6.07000E-03 1.52000E 01 1.16900E-01 2.32000E-02
0.0         1.07670E 01 5.06000E-02 4.00000E-02 0.0            2P
1.44000E 01 2.94000E-01 1.37000E-02 0.0            2P   1.09000E 01
2.00000E-01 1.00000E-01
7T EXPOSE
1D  0 14 0 2 2 7 5 5 0 0 0 10 0 33 0 1 1 1 0 0
2D /
* PREFDER REACTOR EXPOSURE DATA                                        *
*U235  * *U236  * *U238  * *PU239 * *PU240 * *PU241 * *PU242 * *XE135 *
*PM147 * *SM149 * *NSFP  * *SSFP  * *PM148M* *PM148 *
3D  1.0+5  0.0 / TEP
  1.0+6  0.5+6  / GEP
   1 2 3 4 5 6 7 /  IPSLP
   8 9 10 11 12 /   IFPP
   6 8 9 13 14 /    IDCYP
4D  1.689-9  2.093-5  8.209-9  1.976-7  1.880-6  / 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 1.5866 1.5866 1.5011 1.5866 1.5011 1.5866  / NSFP YIELD
    0.0138   7P )   2P  / 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 FICTITIONS $
9D     0.0  5P   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 C.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 14P   1.0+6  14P
      STOP
```

```
                                                                                DRIVERS
DRIVERS                                                                         DRIVERS
                                                                                    1-1
                                             2500.0                 0.97      0.5   1-2
                                                                                    1-3
                                                                                    1-4
  1                             50                                                  1-5
  1   1   1   1              0    0        1       1          0   1                 1-6
                                                                                    2-1
                                                                                    2-2
      1   1                                                                         2-3
                                                                                    2-4
                                                                                    2-5
                                                                                    2-6
                                                                                    3-1
  1   1   2   2   1   0   0   1   0   0   0   0   0                                 3-2
          0.0                                                                       3-3
                                                                                    4-1
  2   91.2213  2  37.7007  2  24.9900  2  13.4914  2  12.5256  2  30.0000           4-2
                                                                                    4-2
  2   30.2007  1  19.0002  1  18.[illegible]  2  [illegible].0399  2  22.0309      4-2
                                                                                    5-1
 22 22 22 22 22 22                                                                  5-2
  8 10 12 15 20 21                                                                  5-2
  7  9 11 15 10 21                                                                  5-2
  2  4  6 14 19 21                                                                  5-2
  1  3  5 11 17 21                                                                  5-2
 12                                                                                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 14  2107       1.0                                                             12-3
 17 20  2109       1.0                                                             12-3
 21 21  4109       1.0                                                             12-3
 22 22  4110       1.0                                                             12-3
  0                                                                                12-3
 13                                                                                13-1
 21                                                                                13-2
 21                                                                                13-3
U235A U236A U238A PU239APU240APU241APU242AO16A  NA23A CR-A  MN55A FE-A             13-4
NI-A  ZR135APM147APM148APM148ASM149ASM151A SSFPA TA181A                            13-4
 21                                                                                13-3
U235B U236B U238B PU239BPU240BPU241BPU242BO16B  NA23B CR-B  MN55B FE-B             13-4
NI-B  ZR135BPM147BPM148BPM148BSM149BSM151B 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
 20                                                                                20-1
  1  2                                                                             20-2
U235A      2.2870-5U238A      7.5003-3PU239A     9.6771-4PU240A     3.3536-4       20-3
PU241A     6.0215-5PU242A     2.5591-5O16A       1.7680-2NA23A      9.0595-3       20-3
FE-A       9.7856-3CR-A       2.6107-3NI-A       1.3793-3TA181A     1.000-10       20-3
                                                                                   20-3
  3  4                                                                             20-2
U235A      2.3915-5U238A      7.9475-3PU239A     9.9061-4PU240A     3.8260-4       20-3
PU241A     7.3271-5PU242A     2.9201-5O16A       1.8693-2NA23A      8.4932-3       20-3
FE-A      10.0066-3CR-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     4.4740-4       20-3
```

```
272818     8.5788-592828   3.8368-50168   1.9553-298238   8.2275-3    20-3
PE-1      10.1726-3C9-8    2.7223-3BI-8   1.8329-17R181R  1.000-10    20-3
                                                                      20-3
  7  8                                                                20-2
72359      2.9395-592398   9.3176-398238  9.3505-3PE-B    9.7956-3    20-3
C8-P       2.6787-3BI-B    1.3793-30168   1.0692-2                    20-3
  9 10                                                                20-2
72358      3.0092-592398   9.0787-39823   9.0932-3PE-B   10.0866-3    20-3
C8-P       2.6993-3BI-B    1.8296-30165   1.9079-2                    20-3
 11 12                                                                20-2
72358      3.9582-592388  10.0222-398238  9.2275-3PE-B   10.1726-3    20-3
C8-B       2.7225-3BI-B    1.8328-30168   2.0185-2                    20-3
 13 20                                                                20-2
72358      8.3183-592388   1.8170-298238  8.2208-3PE-B    9.9333-3    20-3
C8-P       2.6582-3BI-8    1.3881-30168   2.9826-2                    20-3
 21 22                                                                20-2
98238      1.0987-2PE-P    3.0715-2CP-B   8.2196-3BI-P    8.3261-3    20-3
                                                                      20-3
  0                                                                   20-2
END                                                                DRIVERS

DUTLIN                                                             DRIVERS
EXFISS          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
  C  0  1  0  1  2  0  0  C  6  0  0  0  1  0  0  0  8  0  C  0  0  C  0  1-24
 -1  1  1  1  1  1  0  1  0  0  1  0  0  0  0  0  0  0  0  C  0  0  0  C 25-48
                                                                        49-72
  1  1  0  0  0  1  0  0  0  C  0  1  1  0  0  0  0  0  0  0  0  0  C  0 73-96
BLANK
END                                                                DRIVERS

DUTLIN                                                             DRIVERS
EXFISS          0 12  0 96
         75.0          0.0          0.0          0.0          0.0          0.0
          0.0          0.0          0.0          C.0          0.0          0.0
  0  0  C  0  1  2  0  C  0  0  0  0  0  0  0  0  0  8  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  C  C  0  0  C 25-48
                                                                        49-72
  1  C  0  0  0  0  0  0  0  0  0  0  0  C  0  0  0  0  0  0  0  C  0  0 73-96
BLANK
END                                                                DRIVERS

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  1.57.82  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 17  7 -2  7  0

 END

 INPUT PROCESSOR
  CV ISOTXS
  10      8     20      0      3     20      1      8      1
   20 /
      * FOUR GROUP MICROSCOPIC GAS COOLED REACTOR CROSS SECTIONS   *
      *BURNER CODE    C    I-135XE-135PM-147PM148PM-148SM-149 U-236*
                   *  FP2   FP1 TH-232THX232PA-233 U-233 U-234 U-235*
             *PU-149ND-143  HE  RECYCL*
  9.672508-01 3.275168-02 5.466038-09 9.850208-13 1.183072 09 1.089838 08
  6.190998 06 5.099688 05 1.891038 07 1.831558 05 5.829872 02 1.855802 00
  5.000008-03
   0 6 12 18 20 22 25 30 36 38 40 46 52 58 64 70 76 82 88 94
   80 /
```

```
    000000 AMPX  0000  *
0.0              1R   9.00000E 02 0.0                2R
     0      3R      1      0      4*      1      2*      0      2R      1
     2      1       1      5R     2       1      4      1      2       3R
     1      2       3R     1      2       3R     1      16R
5R  2.46495E 00 4.35172E 00 4.49904E 00 5.20407E 00 2.40576E 00
4.51123E 00 4.75415E 00 4.76155E 00 7.71149E-07 9.40718E-06 1.02531E-04
1.72627E-03 1.57549E-04 0.0                 3R
7R  2.61137E 00 4.57929E 00 1.94211E-01 4.63977E 00 1.23849E-01
2.55491E-07 4.75962E 00 1.14203E-01 0.0              6.33724E-10
7R  1.02244E 00 9.47622E-01-1.61141E-01 8.98736E-01-1.59791E-01
0.0         -1.01162E-01
7R  4.55948E-01 5.68112E-02-3.07351E-02 4.59877E-02-1.36361E-02
0.0         -1.24560E-02
7R  6.22074E-02 9.43920E-04-2.04549E-03 1.49141E-04-4.12344E-04
0.0         -7.56096E-04
 4R /
    000000 AMPX  0000  *
0.0              3R   9.00000E 02 0.0                2R
     0      3R      1      2R      0      3R      1      2R      0      2R
     1      2       1      1      5*      2      1      4      1
     2      3R      1      2      3R      1      2      3R      1      16R
5R  3.13209E 00 3.49211E 00 3.56222E 00 4.26429E 00 3.57417E 00
3.59211E 00 3.71071E 00 3.85076E 00-1.31012E-11 1.85394E-07 9.47902E-06
7.81301E-05 2.36170E-03 0.0              3R    4.13940E-05
0.0              3R
7R  3.43969E 00 3.51929E 00 1.36979E-01 3.64207E 00 7.20136E-02
8.00963E-08 3.85044E 06 4.04274E-02 0.0              7.39404E-11
7R  1.33022E 00 3.94203E-01-1.47211E-01 5.27982E-01-6.65327E-02
0.0         -6.27515E-02
7R  2.00541E 00 8.81380E-03 1.06699E-02 2.29815E-02-5.96633E-03
0.0         -5.67032E-03
7R  3.04041E-01-3.30483E-03 6.04760E-04-3.32961E-03-3.90659E-04
0.0         -3.75275E-04
 4R /
    000000 AMPX  0000  *
0.0              3R   9.00000E 02 0.0                2R
     0      4R      1      2R      0      41R
5R  0.0          1.57024E-05 3.43907E 01 1.11992E 06 0.0
1.57025E-05 3.61949E 01 1.11993E 06 0.0            1.57025E-05 3.41949E 01
1.11993E 06
 4R /
    000003 AMPX  0000  *
4.28400E-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
5R  6.33956E 00 2.24317E 01 4.59573E 02 1.02065E 02 6.37194E 00
2.25075E 01 4.69094E 02 1.01944E 02 2.64410E-01 6.34250E 00 3.45114E 02
1.01844E 02 3.09010E-04 0.0                 3R
7R  6.00819E 00 1.61376E 01 9.95159E-02 1.14969E 02 2.73572E-02
1.05621E-06 0.0          1.11237E-02
7R  9.71400E-02 2.42431E-01-2.30279E-02 1.50929E 00-2.02012E-02
0.0         -1.12029E-02
7R  5.70030E-02 1.93196E-01 9.40644E-04 1.30464E 00 8.67579E-04
0.0          2.44644E-04
7R -2.07583E-03-1.93186E-02 3.50152E-04-5.97924E-02 1.10700E-02
0.0         -5.02103E-04
 4R /
    000003 AMPX  0000  *
1.97620E-07 0.0               2R   9.00000E 02 0.0                2R
     0      8R      1      2R      0      41R
5R  5.20293E 00 4.35190E 02 4.52295E 03 1.16523E 04 5.20293E 00
4.35195E 02 4.52296E 03 1.16523E 04 5.20293E 00 4.35190E 02 4.52276E 03
1.16523E 04
 4R /
```

```
    *00001 AMPX  0000  *
1.88890E-06 0.0                 2R   9.00000E 02 0.0                 2R
     0      9R      1      2R      0    81R
5R  1.38086E-01 9.03715E 02 7.81233E 03 6.87357E 02 1.38996E-01
9.03715E 02 7.81231E 03 6.87352E 02 1.38086E-01 9.03715E 02 7.81201E 03
6.87352E 02
 8R /
    *00003 AMPX  0000  *
0.0                3R   9.00000E 02 0.0                2R
     0      3R      1      3R      0      2R      1      2R      0      2R
     1       2      1       1     5R       2      1      2R      1
     2      3R      1       2     3R       1      2      3R      1     16R
5R  6.19878E 00 2.17381E 01 2.20198E 02 3.55991E 00 7.29491E 00
2.17218E 01 2.20500E 02 3.55977E 00 2.08199E-01 8.72390E 00 1.99186E 02
3.51308E 00 8.11282E-05 0.0                3R   8.11282E-05
0.0                3R   2.06179E-03 0.0                3R
7R  6.75315E 00 1.49162E 01 3.39961E-01 7.22137E 01 3.25339E-02
3.66807E-05 1.99308E 02 2.31890E-02 9.60931E-09
7R  3.29051E 00-1.29288E-02-3.75031E-02 1.27758E 00-9.16336E-02
0.0         -2.28129E-02
7R  7.91629E 00 2.20639E-01 1.87068E-02-7.73361E-02-9.65960E-03
0.0         -1.97188E-08
7R  8.38987E 00-2.91009E-02-7.15515E-03-2.11063E-01 9.99253E-06
0.0         -2.91597E-08
 8R /
    *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      1       1     5R       2      1      2
     1       2     3R       1      2      3R      1       2     3R
     1     16R
5R  6.85392E 00 1.61302E 01 7.31890E 01 1.22099E 01 9.59539E 00
1.68166E 01 7.38190E 01 1.20561E 01 2.13182E-01 1.58158E 00 8.92720E 01
2.69110E 00 3.35591E-01 0.0                3R   2.67199E 00
0.0                3R   9.67891E-01 3.25090E-02 0.0                2R
1.92903E-01 0.0                 3R
7R  7.89229E 00 1.89090E 01 2.25522E-01 2.51356E 01 8.63062E-02
5.63585E-09 9.37873E 00 3.13733E-02
7R  6.82839E 00 9.39522E-01-1.79799E-02 7.89599E-01-8.57083E-02
0.0         -1.13259E-02
7R  5.81333E 00 1.70217E-01-3.28581E-03-1.39539E-01-2.87698E-08
0.0          3.10992E-05
7R  5.86002E 00 6.92368E-02-7.52168E-08 1.35115E 00-1.32073E-05
0.0         -1.85699E-08
 8R /
    *00000 AMPX  0000  *
0.0                3R   9.00000E 02 0.0                2R
     0      9R      1      2R      0    81R
5R  1.96967E-02 2.83616E-01 1.01253E 00 8.79872E-01 1.96967E-02
2.83616E-01 1.01253E 00 8.79872E-01 1.96967E-02 2.83616E-01 1.01253E 00
8.79872E-01
 8R /
    *00000 AMPX  0000  *
0.0                3R   9.00000E 02 0.0                2R
     0      9R      1      2R      0    81R
5R  6.86115E-02 7.08818E-01 1.13373E 01 6.19355E 00 6.86116E-02
7.08818E-01 1.13373E 01 6.19355E 00 6.86116E-02 7.08818E-01 1.13373E 01
6.19355E 00
 8R /
    *20012 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      1       1     5R       2      3      2
     1       2     3R       1      2      3R      1       2     3R
     1     16R
5R  6.78675E 00 1.87389E 01 2.61218E 01 1.58002E 01 7.79197E 00
```

```
1.880706E 01 2.616509E 01 1.556497E 01 1.329162E-01 1.078002E 00 7.080362E 00
3.082952E 00 4.640952E-02 0.0                  3R   2.387708E 00
0.0                3R   9.667262E-01 3.327352E-02 0.0                   2R
8.922702E-03 0.0                3R
7R  7.397902E 00 1.377522E 01 2.181202E-01 1.906172E 01 3.780332E-02
3.868492E-06 1.252152E 01 1.587062E-02
7R  3.105612E 00 8.579922E-01-2.150812E-02 1.782092E-01-3.598802E-02
0.0          -1.597322E-02
7R  2.079122E 00 1.378202E-01-1.118002E-03 2.670112E-02 2.571152E-03
0.0           3.311322E-08
7R  2.088312E 00 3.990832E-02 1.199812E-08-8.662682E-03 2.861092E-03
0.0          -7.151792E-08
 8D /
    *00012 AMPX  0000  *
0.0                3R   9.000002E 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
5R  6.786772E 00 1.871872E 01 2.508862E 01 1.588022E 01 7.781992E 00
1.886672E 01 2.512922E 01 1.556882E 01 1.325162E-01 1.053782E 00 6.051862E 00
3.982982E 00 3.860962E-02 0.0                  3R   2.387702E 00
0.0                3R   9.667262E-01 3.327352E-02 0.0                   2R
8.922722E-03 0.0                3R
7R  7.397722E 00 1.377512E 01 2.191372E-01 1.906192E 01 3.780322E-02
3.868522E-06 1.252172E 01 1.587062E-02
7R  3.105632E 00 8.579372E-01-2.150822E-02 1.782092E-01-3.599792E-02
0.0          -1.597322E-02
7R  2.079182E 00 1.378202E-01-1.118002E-03 2.678092E-02 2.571152E-03
0.0           3.311322E-08
7R  2.088322E 00 3.990092E-02 1.199812E-08-8.662702E-03 2.861982E-03
0.0          -7.151792E-08
 8D /
    *00019 AMPX  0000  *
2.927902E-07 0.0                2R   9.000002E 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
5R  5.718582E 00 1.317652E 01 7.277382E 01 6.583232E 01 7.961162E 00
1.332812E 01 7.280922E 01 6.898192E 01 2.208782E-01 2.818852E 00 6.079362E 01
5.896162E 01 5.577552E-01 0.0                  3R   2.716572E 00
0.0                3R   9.667262E-01 3.327352E-02 0.0                   2R
2.128262E-03 0.0                3R
7R  6.829562E 00 1.009192E 01 3.587302E-01 1.269282E 01 1.760912E-02
6.869992E-06 1.002022E 01 2.276082E-02
7R  6.739872E 00 8.505532E-01-1.187682E-02 1.228372E-01-1.355602E-02
0.0          -2.281952E-02
7R  6.888562E 00 5.811562E-02-9.383752E-02 6.797322E-02 2.247362E-03
0.0           3.857952E-08
7R  8.862972E 00-7.883882E-02 5.773992E-08-9.718692E-03 7.578162E-03
0.0          -1.000262E-03
 8D /
    *00012 AMPX  0000  *
0.0                3R   9.000002E 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
5R  5.788812E 00 1.616652E 01 9.521812E 01 2.817812E 02 7.597092E 00
1.863902E 01 9.528782E 01 2.818632E 02 9.985782E-02 7.262332E-01 1.556032E 01
2.898782E 01 1.993262E 00 5.881132E 00 6.777712E 01 2.880982E 02 2.608082E 00
2.502952E 00 2.592902E 00 2.503002E 00 9.667262E-01 3.327352E-02
0.0                2R   2.216122E-03 0.0                3R
7R  5.383782E 00 1.001572E 01 1.519382E-01 1.189802E 01 1.608912E-02
3.889182E-06 1.252502E 01 1.608892E-02
```

```
7D  5.51055E 00 1.02199E 00-7.13662E-03 1.10675E-01-1.53250E-02
0.0          -1.61553E-02
7F  4.77171E 00 3.58706E-01-2.97403E-03 3.32679E-02 3.16567E-03
0.0           1.54131E-04
7D  4.32962E 00 5.60678E-02-1.73640E-03-2.0      -03 1.15353E-03
0.0          -7.17930E-08
 8P /
    00C009 AMPX  0000  0
0.0               3R   9.00000E 02 0.0               2R
     7      1      2P      0      2P      1      3     7                29
     0     2S      1       2      3       1      5P                      2
     1      2     3R       1      2      3R      1
     1    16P
5P  5.07055E 00 1.22906E 01 1.30406E 02 4.52315E 01 7.7996
1.26950E 01 1.30596E 02 4.09479E 01 1.05039E-01 1.04177E       0010    02
3.59523E 01 8.40402E-01 6.23185E-03 0.0               2R
2.51190E 00 0.0               2P   9.67091E-01 1.25300E-0
0.0               2P   7.16235E-04 0.0               3R
7P  5.69050E 00 1.12264E 01 1.70022E-01 3.64253E 01 1.
2.47011E-06 9.01530E 00 1.32770E-02
7D  6.96365E 00 1.21113E 00-1.22277E-02 3.23912E-01-1.7  49E-
0.0          -1.71090E-02
7D  7.09070E 00 3.16720E-02-8.60607E-03 7.30990E-02 4.40690E-04
0.0           2.70231E-04
7P  5.02383E 00 1.47091E-03 6.20570E-04-8.50055E-03 3.53050E-03
0.0          -5.96297E-06
 8P /
    00C009 AMPX  0000  0
0.0               3P   9.00000E 02 0.0               2R
     0      1      2P      0      2P      1      3     2P      1      29
     0     2P      1       2      3       1     5S      2      3       4
     1      2     3P       1      2      3R      1      2     3P
     1    169
5D  5.72376E 00 1.62070E 01 6.26451E 01 2.50376E 02 7.75411E 00
1.69015E 01 6.26760E 01 2.50031E 02 1.34206E-01 1.84067E 00 2.02084E 01
3.75663E 01 1.23611E 00 4.12570E 00 3.07048E 01 1.94406E 02 2.57170E 00
2.08356E 00 2.08199E 00 2.43018E 00 9.67491E-01 3.25390E-02
0.0               2P   2.72492E-03 0.0               3P
7P  6.22609E 00 1.00100E 01 1.61096E-01 1.17510E 01 1.67659E-02
3.03773E-05 1.25100E 01 1.62969E-02 1.10022E-04 1.98160E-07
7P  6.09709E 00 1.58700E 00-7.72057E-03 1.12312E-01-1.29040E-02
0.0          -1.61925E-02
7P  5.32309E 00 4.33790E-01-3.07040E-03 4.20564E-02 2.35191E-03
0.0           3.30247E-04
7D  4.05601E 00 7.03195E-02-7.05941E-04-9.03994E-03 7.16220E-03
0.0          -7.27019E-08
 8P /
    00001 AMPX  0000  0
0.0               3R   9.00000E 02 0.0               2R
     0     3P      1      2P      0      3P      1     2P      0      2R
     1      2      3       1     5R       2     3P      1      2      3P
     1      2     3R       1      2      3P      1    169
5P  2.93676E 00 3.39650E 00 1.55302E 00 4.06017E 00 1.71922E 00
3.57522E 00 3.70058E 00 3.66156E 00 5.02697E-09 0.0               2P
7.58101E-05 3.16126E-03 0.0               3P   4.06651E-06
0.0               3P
7D  3.55011E 00 3.50237E 03 1.17933E-01 1.53357E 00 1.20613E-02
3.66125E 00 6.73116E-02
7P  2.38739E 00 5.05135E-01-4.21079E-02 5.22502E-01-6.60307E-02
0.0          -6.14059E-02
7P  2.05082E 00 7.07079E-02-2.17790E-02 4.27035E-02-5.09829E-03
0.0          -5.35953E-03
7E  6.49208E-01 2.79619E-02 5.70990E-04-3.61752E-03-4.68773E-04
0.0          -1.55357E-03
 8P /
    00009 AMPX  0000  0
```

```
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      169
5R  6.48211E 00 6.62002E 00 2.20608E 01 1.35224E 02 6.83713E 00
6.66810E 00 2.21275E 01 1.33725E 02 4.54604E-02 9.83970E-01 1.07299E 01
1.33725E 02 1.02927E-03 0.0                 3R
7R  6.30390E 00 5.68837E 00 8.83871E-02 1.13227E 01 1.26315E-02
8.78881E-07 0.0             7.58908E-02
7R  1.05035E-01 8.82550E-02-2.50691E-02 2.11096E-01-9.29727E-03
0.0          -7.58100E-02
7R  6.10051E-02 6.73230E-02 1.03187E-03 1.36321E-01 1.60813E-04
0.0           1.38611E-03
7R -2.12290E-03-8.09920E-03 3.03150E-04-3.63088E-02 5.85296E-03
0.0          -3.36037E-03
 8D /
    900000 ANPE  3000  0
0.0                3R   9.00000E 02 0.0                2R
     0      4R      1      0      3R      1      2R      0      2R      1
     2      1       1      5R     2       1R     1       2      3R     1
     2      3R      1      2      3R      1      168
5R  2.57987E 00 6.67602E-01 6.96275E-01 9.38091E-01 3.18836E 00
7.25981E-01 7.28268E-01 7.91167E-01 0.0                 2R   2.83833E-05
2.99289E-03 1.19322E-06 1.33870E-05 2.16788E-04 0.0
7R  2.97878E 00 6.78810E-01 1.69568E-01 6.77024E-01 5.11521E-02
7.88157E-01 8.69973E-02
7R  1.70586E 00 3.13985E-01-2.15520E-01 3.98825E-01-1.26720E-02
0.0          -2.99905E-02
7R  2.89352E 00 2.37621E-02 8.87551E-02 6.10913E-02-1.65595E-02
0.0          -1.52587E-02
7D  1.85560E 00-8.19358E-03 7.82280E-04 1.73908E-03-1.90510E-03
0.0          -1.08735E-03
 8D /
    900000 ANPE  0000  0
0.0                3R   9.00000E 02 0.0                2R
     0      9R      1      2R      0      41R
5R  1.92809E-04 2.10190E-03 3.56295E-02 8.31568E-01 1.92801E-04
2.10190E-03 3.56295E-02 8.31568E-01 1.92801E-04 2.10190E-03 3.56295E-02
8.31568E-01
0V EXPOSE /     C EXPOSURE DATA FOR GAS COOLED REACTOR
1R   20105  16  0  1  0  1  7  7  0  0  0 1 0 49 0 0 0 0 0 0
2R  FOR TH-232, U-233 U-235 FUEL (NO U-238) CHAIN EXPOSURE DATA
  12R
         5 TH-232PA-233 U-233 U-234 U-235 U-236 I-135XE-135PM-147
   82PM-148PM148MRH-105RH-105PD-107  FP1   FP2
3R  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  2.39E-5  8.29E-9  1.89E-6  1.90E-7  3.63E-6  /
5D    .0539   .0562   .0617  /
      .0021   .0022    .0028  /
      .0392   .0193   .0236   /
      .00905  .0077   .0111  /
      .00     .0591   .0607  /
    .98  .99  1.11 /
   3.6   3.6   3.9  /
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 PRINT
1R  2  0  0  0
2D 6NZDATDN   0  1  0
2D 6NUDISRP   0  1  0
 0V ZDATDN
 1R  1.20000E 04
```

```
      7       57      17       1
2E  2.80906E-08 3.39906E-07 7.97607E-07 3.00039E-09 5.56561E-05
1.20478E-06 8.00292E-02 9.97908E-10 3.06370E-10 9.52996E-08 7.05213E-10
1.72148E-09 1.89962E-09 2.92720E-09 2.96995E-07 5.52321E-04 1.90906E-05
2.85358E-08 8.52590E-07 2.39859E-06 1.73925E-07 8.22371E-05 3.80687E-06
8.09700E-02 2.73960E-09 5.78169E-10 2.50380E-07 2.81390E-09 2.96217E-09
5.08630E-09 5.92619E-09 8.77827E-07 1.77607E-05 6.20750E-05 2.02026E-08
1.05227E-06 8.09390E-06 8.35993E-07 2.93572E-05 6.11190E-06 8.00000E-02
2.71585E-09 8.68872E-10 3.33999E-07 3.59213E-09 3.77080E-09 6.20080E-09
5.59502E-07 1.37590E-06 1.60980E-05 1.96019E-08 2.39368E-08 1.07392E-06
5.29179E-06 7.29985E-07 2.01131E-05 7.56294E-05 8.00000E-02 1.05399E-09
3.51869E-10 7.30085E-07 3.60333E-09 3.64562E-09 5.50735E-09 8.63037E-09
1.65817E-06 3.96128E-05 1.02915E-08 2.36296E-08 9.02091E-07 5.77955E-06
9.77943E-07 1.08160E-05 8.29991E-06 8.09003E-02 1.29552E-09 2.60325E-10
3.17883E-07 3.00180E-09 1.19892E-09 1.93507E-09 3.66800E-09 1.77130E-06
8.60717E-05 1.60830E-08 2.30287E-08 6.33597E-07 6.10351E-06 1.13068E-06
1.11871E-05 8.57920E-06 9.00900E-02 8.00999E-10 2.12963E-10 2.03735E-07
2.23809E-09 2.77200E-09 2.00995E-09 2.92716E-09 1.79907E-06 5.00109E-05
1.85221E-08 2.32897E-08 8.20650E-07 6.39217E-06 1.27087E-06 9.37550E-06
8.78158E-05 8.00000E-02 5.11200E-10 1.72420E-10 2.57530E-07 1.00086E-09
2.26000E-09 1.00175E-09 2.39309E-09 1.75673E-06 5.23593E-05 1.95059E-08
2.32907E-08 2.28162E-07 6.87323E-06 1.27059E-06 8.56496E-06 8.03650E-06
8.00000E-02 2.52980E-10 1.27992E-10 2.35367E-07 7.43990E-10 1.70096E-09
6.16920E-10 1.91781E-09 1.79307E-06 5.30993E-05 2.30530E-08 2.00516E-08
7.00556E-07 8.03622E-07 8.12719E-08 7.22396E-05 1.92756E-06 8.00000E-02
1.29342E-09 1.97279E-09 1.02267E-07 7.12351E-09 1.54366E-09 2.54209E-09
3.81568E-09 8.81669E-07 9.57095E-06 2.97019E-05 2.05162E-08 8.59035E-07
2.90072E-05 2.20173E-07 5.19959E-05 5.90270E-06 8.00000E-02 2.01702E-09
7.21232E-10 1.59960E-07 3.81190E-09 8.07391E-09 6.63109E-09 7.70530E-09
1.39667E-06 2.69951E-05 9.06025E-05 2.00902E-08 1.70978E-06 6.62279E-06
5.56566E-07 2.36151E-05 9.90202E-06 8.00000E-02 2.75221E-09 5.53057E-10
6.35166E-07 8.59790E-09 8.95879E-09 7.03735E-09 6.99577E-09 1.95330E-06
8.87073E-05 1.50591E-08 2.36934E-08 1.09709E-06 5.63051E-06 9.00781E-07
2.17772E-05 1.08709E-05 8.00009E-02 2.05811E-09 3.93651E-10 8.07235E-07
8.70983E-09 8.02593E-09 6.81765E-09 5.19577E-09 2.23719E-06 5.67627E-05
2.06085E-08 2.31650E-08 9.30550E-07 6.09992E-06 1.10509E-06 1.07390E-05
1.70200E-05 8.00000E-02 1.35696E-09 2.40330E-10 1.51800E-07 3.37707E-09
1.59617E-09 8.29613E-09 1.99735E-09 2.20500E-06 6.08761E-05 2.39223E-08
2.31220E-08 8.21506E-07 6.31960E-06 1.36003E-06 1.35067E-05 1.36711E-05
9.00000E-02 8.04255E-10 2.12759E-10 3.01530E-07 2.10096E-09 2.00053E-09
2.59157E-09 7.02996E-09 2.20270E-06 6.09365E-05 2.59510E-08 2.29522E-08
8.78525E-07 6.80377E-06 1.06395E-06 8.59517E-06 1.17295E-05 8.00000E-02
8.90313E-10 7.67979E-10 2.63550E-07 1.52962E-09 2.37695E-09 1.09265E-09
2.39057E-09 2.39952E-06 7.30505E-05 2.71725E-08 2.29798E-08 2.10085E-07
6.57017E-06 1.50929E-06 7.71326E-06 1.17319E-05 8.00000E-02 2.02907E-10
1.22792E-10 2.38716E-07 7.95203E-10 1.79607E-09 6.02971E-10 1.09015E-09
2.15606E-06 7.26029E-05 2.77664E-08 2.50995E-08 0.0                 30
6.19011E-05 0.0               8.00009E-02 0.0               130   2.50000E-08
0.0               30    8.19011E-05 0.0           9.00000E-02
0.0               100   2.50000E-02 0.0               500   5.00000E-04
0.0               50    6.99999E-02 0.0               100   1.00000E-02
0.0               160   8.99179E-08 2.05000E-07 5.39135E-07 9.70130E-09
1.00735E-10 8.00292E-11 6.99999E-02 5.01160E-12 2.93510E-12 5.07720E-10
2.19092E-12 8.29795E-12 7.15076E-12 2.12997E-11 1.09001E-09 3.17006E-08
1.15780E-07 8.96267E-08 8.69091E-07 2.01032E-06 9.92607E-08 8.60093E-09
7.96099E-11 6.99999E-02 6.02100E-11 1.96399E-11 5.75000E-09 8.27290E-11
6.00116E-11 9.15999E-11 1.06773E-10 2.05561E-08 3.50000E-07 1.31030E-06
8.91033E-06 1.55503E-06 5.33079E-06 1.95592E-07 3.51669E-09 1.21200E-09
6.99999E-02 2.30610E-10 5.50510E-11 2.26040E-09 2.21960E-10 2.55396E-10
8.33793E-10 8.57929E-10 8.90993E-08 1.60092E-06 6.06790E-06 8.80606E-08
1.91019E-06 8.95129E-06 8.99051E-07 1.17101E-07 6.80501E-09 6.99999E-02
8.97955E-10 9.77995E-11 5.10727E-08 5.07301E-10 5.69772E-10 1.00110E-09
9.60199E-10 2.23037E-07 8.20232E-06 1.59969E-05 8.70063E-08 1.00632E-06
9.03562E-06 1.00336E-06 2.39937E-07 1.07002E-09 6.99999E-02 6.73597E-10
1.29070E-10 8.70010E-08 8.51005E-10 8.66000E-10 1.07212E-09 1.19620E-09
3.05272E-07 7.07950E-06 2.90497E-05 8.73300E-08 1.54520E-06 1.98132E-05
```

```
[illegible]
2.27...E-05 8.81...E-05 0.0             2.1000E-08 5.00000E-05
0.0          150    2.10000E-08 5.00000E-05 0.0              150
2.10000E-08 5.00000E-05 0.0              150   2.10000E-08 5.00000E-05
0.0          150    2.10000E-08 5.00000E-05 0.0              150
2.10000E-08 5.00000E-05 0.0              150   2.10000E-08 5.00000E-05
0.0          150    2.10000E-08 5.00000E-05 0.0              150
2.10000E-08 5.00000E-05 0.0              150   2.10000E-08 5.00000E-05
0.0          150    2.10000E-08 5.00000E-05 0.0              150
2.10000E-08 5.00000E-05 0.0              150   2.10000E-08 5.00000E-05
0.0          100
STOP
END

XCPSPR        CROSS SECTION PROCESSING
        1  1          1  1                                        1
           29               1
TH-232TH-232            232.          1.10    -11              2
THT232TH-232            232.          1.10    -11              2
PA-233PA-233            233.          1.19    -11              1
U-233 U-233             233.          1.19    -11              1
U-238 U-238             238.          1.19    -11              2
U-235 U-235             235.          1.21    -11              1
U-236 U-236             236.          1.24    -11              3
 C     C                 12.                                   5
 OX    OX                 8.                                   5
SPCTSLSPCTSL              1.                                   5
 I-135 I-135            135.                                   8
XE-135XE-135            135.                                   8
```

[illegible]

```
11 11  2  9       .3005   1
12 12  2 10       .335    1
13 13  2 11       .3295   1
14 15  2 12       .320    1
16 18  2 14       .3995   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       .59     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
  9
 111
  17
  17
TH-232PA-231 U-233 U-234 U-235 U-236  C     I-135XE-135PM-147PM-148PM148M
PM-149SM-149SM-103  PP1   PP2
  17
TH232PA-233 U-233 U-234 U-235 U-236  C     I-135XE-135PM-147PM-148PM148P
PM-149SP-149SM-103  PP1   PP2
  3
  C      82  RECYCL
329     -1
028
  1

  4                    1  3
  1  3
 U-235    2.      -5
  9  11
 U-235    2.      -5
 17 18
 U-235    1.      -5

END

DATLIB       MODULE CONTROL INSTRUCTIONS
DTBIPS         0 13  0 72
                                           1500.   +6   .99       5.      -6
9
  3.       -5
0                          2                   1            0
                         1                   1

FTPTPS         0  6  0 48
      0.       0.0
         0  0  1  9  1
                    2

END

MODULE CONTROL IS FINISHED.  USER COMPLETION CODE  9000. CPU TIME USED    71.60 (SECONDS). I/O'S USED   12097
```

```
[illegible] VENTURE [illegible] AT [illegible] 360/ 91, CONTROL MOD=CONTROL1, DATE=12-03-70, TIME=01.49.03, [illegible] .
INITIALIZATION, DEPENDENCE - REMAINING I/O= 29.94, CPU MIN= 5.00
RUN TITLE AND CONTROL MODULE DATA
 DEPLETION BENCHMARK COMPARING VARIOUS SOLUTION METHODS
 [illegible]    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          CODE   USER-UNIT   USER-STACK        VERSION       WRITTEN    IDENTIFICATION
    10              CONTRL                                   1             1      [illegible]  12-03-70

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

READ DATA AND ACCESS MODULE  1      - REMAINING I/O=  29.06, CPU MIN=   0.99
READ INPUT DATA ONLY (LONG-[illegible]) - REMAINING I/O=  29.03, CPU MIN=   0.96
ACCESS MODULES 13  0  0  0  0       - REMAINING I/O=  28.90, CPU MIN=   0.93
     TIME AFTER SHUTDOWN   30.000 DAYS, ESTIMATED K  3.0     , FISSILE INVENTORY 2.7095[illegible]-05 KG, CONVERSION RATIO(HM)     0.76453
ACCESS INPUT MODULE  1              - REMAINING I/O=  28.77, CPU MIN=   0.91
READ INPUT DATA ONLY (LONG-[illegible]) - REMAINING I/O=  28.51, CPU MIN=   0.90
ACCESS MODULES 13  0  0  0  0       - REMAINING I/O=  28.46, CPU MIN=   0.90
     TIME AFTER SHUTDOWN   30.000 DAYS, ESTIMATED K  3.0     , FISSILE INVENTORY 2.7090[illegible]-05 KG, CONVERSION RATIO(HM)     0.76420
ACCESS INPUT MODULE  1              - REMAINING I/O=  28.25, CPU MIN=   0.87
READ INPUT DATA ONLY (LONG-[illegible]) - REMAINING I/O=  27.98, CPU MIN=   0.85
ACCESS MODULES 13  0  0  0  0       - REMAINING I/O=  27.94, CPU MIN=   0.85
     TIME AFTER SHUTDOWN   30.000 DAYS, ESTIMATED K  3.0     , FISSILE INVENTORY 2.7095[illegible]-05 KG, CONVERSION RATIO(HM)     0.76447
ACCESS INPUT MODULE  1              - REMAINING I/O=  27.72, CPU MIN=   0.83
ACCESS MODULES 13  0  0  0  0       - REMAINING I/O=  27.46, CPU MIN=   0.80
     TIME AFTER SHUTDOWN   30.000 DAYS, ESTIMATED K  0.0     , FISSILE INVENTORY 2.709[illegible]-05 KG, CONVERSION RATIO(HM)     0.76429
                              FINAL I/O FILE MANAGEMENT TABLES
                        FILE NAME SUPPLIED BY
                     -------------------------------                              USER
FILE NUMBER          CODE   USER-UNIT   USER-STACK        VERSION       WRITTEN    IDENTIFICATION
    10              CONTRL                                   1             1      LASL 1    [illegible]
    11              [illegible]                              1             1      LASL 1    [illegible]
    12              [illegible]                              1             1      LASL 1    [illegible]
    13              [illegible]                              1             1      LASL 1    [illegible]
    14              [illegible]                              1             1      USER      IDENT
    15              [illegible]                              1             1      LASL 1    [illegible]
    16              [illegible]                              1             1      LASL 1    [illegible]

[illegible] RUN COMPLETE. -- RETURN TO SEEK NEW CASE - REMAINING I/O=  27.19, CPU MIN=   0.57 - TIME=01.52.[illegible]
```

```
BOLD VENTURE VBRS-2 RUN AT E-10 ON 360/ 91. CONTROL MOD=CONTROL1, DATE=12-02-70, TIME=01.53.26, JOBNAME=GUESARP .

INITIALIZATION, REFERENCE - REMAINING I/O=  27.14, CPU RT=   0.57

RUN TITLE AND CONTROL MODULE DATA
 BURNUP REACTOR SAMPLE PROBLEM FOR THE BURNER CODE
 10007      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       USER   USER-EXIST   USER-STACK       VERSION       WRITTEN    IDENTIFICATION
    10            CONTRL                                  1              1     GUESARP   12-02-70

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 RT=   0.57

READ DATA FOR A SPECIAL PROCESSOR - REMAINING I/O=  26.52, CPU RT=   0.51

ACCESS PROCESSOR 'OUTPUT'         - REMAINING I/O=  26.47, CPU RT=   0.51

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  26.20, CPU RT=   0.50

ACCESS MODULES  7  0  0  0  0     - REMAINING I/O=  26.21, CPU RT=   0.49
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, E -   35  -0.862100-05   0.0           5.275308 02    1.0133471
     POSITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   1.02317   1.05097   3.13083E 10

ACCESS PROCESSOR 'OUTLIN'         - REMAINING I/O=  25.30, CPU RT=   0.39

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  25.99, CPU RT=   0.39

ACCESS MODULES 13  0  0  0  0     - REMAINING I/O=  25.04, CPU RT=   0.36
     TIME AFTER EXPOSURE   75.000 DAYS, ESTIMATED K  1.015330, FISSILE INVENTORY 3.200736E 03 KG, CONVERSION RATIO(RD)    1.40106

ACCESS MODULES  7  0  0  0  0     - REMAINING I/O=  24.56, CPU RT=   0.33
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, E -   21   0.901130-05   0.0           5.202018 02    1.0130110
     POSITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   1.00633   1.00595   3.13080E 10

ACCESS PROCESSOR 'OUTLIN'         - REMAINING I/O=  23.56, CPU RT=   0.29

ACCESS MODULES 13  0  0  0  0     - REMAINING I/O=  23.05, CPU RT=   0.25
     TIME AFTER EXPOSURE  150.000 DAYS, ESTIMATED K  1.016606, FISSILE INVENTORY 3.322005E 03 KG, CONVERSION RATIO(RD)    1.30509

ACCESS MODULES  7 13  0  0  0     - REMAINING I/O=  23.01, CPU RT=   0.21
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, E -   10   0.836050-05   0.0           5.120128 02    1.0152505
     POSITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   1.30030   1.03320   3.13063E 10
     TIME AFTER EXPOSURE  225.000 DAYS, ESTIMATED K  1.017035, FISSILE INVENTORY 3.397509E 03 KG, CONVERSION RATIO(RD)    1.37077

ACCESS MODULES  7  0  0  0  0     - REMAINING I/O=  21.90, CPU RT=   0.10
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, E -   10   0.006820-05   0.0           5.056638 02    1.0163003
     POSITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   1.37532   1.02136   3.10197E 10

                      FINAL I/O FILE MANAGEMENT TABLES
                  FILE NAME SUPPLIED BY
              --------------------------------                                      USER
FILE NUMBER       USER   USER-EXIST   USER-STACK       VERSION       WRITTEN    IDENTIFICATION
    10            CONTRL                                  1              1     GUESARP   12-02-70
    11            GEODST                                  1              1     LASL 1    TEST P
```

12	[illegible]	1	1	[illegible]	INPUT P
13	[illegible]	1	1	[illegible]	INPUT
14	[illegible]	1	1	[illegible]	INPUT
15	[illegible]	1	1	[illegible]	INPUT
16	[illegible]	1	1	GUCSAMP	12-02-70
17	[illegible]	1	1	GUCSAMP	12-02-70
18	[illegible]	2	1	GUCSAMP	12-02-70
19	[illegible]	1	1	GUCSAMP	12-02-70
2?	[illegible]	1	1	GUCSAMP	12-02-70
30	[illegible]	1	1	GUCSAMP	12-02-70
31	[illegible]	3	1	GUCSAMP	12-02-70
32	[illegible]	2	1	GUCSAMP	12-02-70
33	[illegible]	0	1	GUCSAMP	12-02-70
34	[illegible]	3	1	GUCSAMP	12-02-70

WRAP-UP NOW COMPLETE. -- DRIVER TO SEEK NEW CASE - REMAINING I/O= 20.07, CPU MIN= 0.31 - TIME=01.57.02

```
BOLD VENTURE VERS-2 RUN AT 8-10 ON 360/ 91. CONTROL MOD=CONTROL1, DATE=12-02-78, TIME=01.57.44, JOBNAME=GUCSANP .

INITIALIZATION, REFERENCE - REMAINING I/O=  20.43, CPU MIN=   0.31

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      3  3  3  1  0  0  0
  1  2  2  6  2  7 11 -2  3  3  2  7 11  7 -2  1
  0      0      0      0      0      0      0      0      0


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


MODULES TO 23 ACCESSED IN ORDER
    1    2    2    6    2    7   11    7   11    7   11    1    2    7   11    7   11    7   11    7

READ DATA AND ACCESS MODULE  1    - REMAINING I/O=  20.11, CPU MIN=   0.00

READ DATA FOR A SPECIAL PROCESSOR - REMAINING I/O=  19.61, CPU MIN=   1.91

ACCESS PROCESSOR 'DCRSPR'         - REMAINING I/O=  19.56, CPU MIN=   1.91

READ DATA FOR A SPECIAL PROCESSOR - REMAINING I/O=  19.42, CPU MIN=   1.92

ACCESS PROCESSOR 'ROTLIN'         - REMAINING I/O=  19.36, CPU MIN=   1.90

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  19.27, CPU MIN=   1.89

ACCESS MODULES  6  0  0  0  0     - REMAINING I/O=  19.22, CPU MIN=   1.88

ACCESS PROCESSOR 'OUTPUT'         - REMAINING I/O=  17.70, CPU MIN=   1.85

READ INPUT DATA ONLY (LOOK-AHEAD) - REMAINING I/O=  17.63, CPU MIN=   1.84

ACCESS MODULES  7 11  0  0  0     - REMAINING I/O=  17.53, CPU MIN=   1.83
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    41  -1.01019E-05   2.53131E-06   1.67327E 01   1.0300004
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59666   0.59666   1.89521E 10
     TIME AFTER EXPOSURE12999.996 DAYS, ESTIMATED K  0.999704, FISSILE INVENTORY 8.08690E 02 KG, CONVERSION RATIO(HD)    0.59794
     EXPOSURE TIME STEP 1000.000 DAYS,                      TOTAL POWER 1.49999E 09 W(TH)
     ZONE    - PEAK POWER DENSITY 4.57900E 01 W(TH)/CC, PATH POWER 1.08081E 09 W(TH), FISSILE FEED RATE 1.32027E 00 KG/DAY
     SUBZONE - PEAK POWER DENSITY 1.27106E 01 W(TH)/CC, PATH POWER 4.19169E 08 W(TH), FISSILE FEED RATE 0.0           KG/DAY

ACCESS MODULES  7 11  0  0  0     - REMAINING I/O=  15.65, CPU MIN=   3.62
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    27   6.91601E-07   4.93312E-06   1.60330E 01   3.0000394
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59666   0.59666   1.89519E 10
     TIME AFTER EXPOSURE13999.996 DAYS, ESTIMATED K  0.999730, FISSILE INVENTORY 8.00772E 02 KG, CONVERSION RATIO(HD)    0.59790
     EXPOSURE TIME STEP 1000.000 DAYS,                      TOTAL POWER 1.49999E 09 W(TH)
     ZONE    - PEAK POWER DENSITY 4.57933E 01 W(TH)/CC, PATH POWER 1.08085E 09 W(TH), FISSILE FEED RATE 1.32036E 00 KG/DAY
     SUBZONE - PEAK POWER DENSITY 1.27173E 01 W(TH)/CC, PATH POWER 4.19143E 08 W(TH), FISSILE FEED RATE 0.0           KG/DAY

ACCESS MODULES  7 11  0  0  0     - REMAINING I/O=  13.69, CPU MIN=   3.45
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -     2  -4.38486E-05  -1.80996E-06   1.60298E 01   1.0333014
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59665   0.59666   1.89519E 10
     TIME AFTER EXPOSURE14999.996 DAYS, ESTIMATED K  0.999730, FISSILE INVENTORY 8.00771E 02 KG, CONVERSION RATIO(HD)    0.59791
     EXPOSURE TIME STEP 1000.000 DAYS,                      TOTAL POWER 1.49999E 09 W(TH)
     ZONE    - PEAK POWER DENSITY 4.57935E 01 W(TH)/CC, PATH POWER 1.08085E 09 W(TH), FISSILE FEED RATE 1.32036E 00 KG/DAY
     SUBZONE - PEAK POWER DENSITY 1.27169E 01 W(TH)/CC, PATH POWER 4.19141E 08 W(TH), FISSILE FEED RATE 0.0           KG/DAY
```

```
ACCESS MODULES  3  0  0  0  0      - REMAINING I/O=  12.18, CPU MIN=    3.31

ACCESS PROCESSOR 'OUTLIN'          - REMAINING I/O=  12.06, 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 -     3  -1.11983D-05   0.0           1.602972E 01    1.0300022
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59665    0.59666    1.095198 13
     SHUTDOWN CALCULATION DONE FOR TIME     0.000 DAYS

ACCESS MODULES  7 13  0  0  0      - REMAINING I/O=  13.83, CPU MIN=    3.22
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    32   1.23060P-05   0.0           1.590718 01    3.9581648
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.61399    0.52325    1.102028 13
     SHUTDOWN CALCULATION DONE FOR TIME     0.000 DAYS

ACCESS MODULES  7 13  0  0  0      - REMAINING I/O=   9.73, CPU MIN=    3.90
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    34   1.15066P-05   0.0           1.603058 0.     0.9723047
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.60583    0.54071    1.899598 13
     SHUTDOWN CALCULATION DONE FOR TIME     0.000 DAYS

ACCESS MODULES  7  0  0  0  0      - REMAINING I/O=   8.62, CPU MIN=    2.90
     ITERATIONS, CONVERGENCE, SEARCH, PEAK POWER DENSITY, K -    31  -2.00423P-05   0.0           1.606418 01    0.9925759
     PRIMITIVE CONVERSION RATIO, ALSO FOR CRITICAL SYSTEM, FUEL CONSUMPTION(ATOMS/WATT-SEC) -   0.59881    0.56175    1.894168 13

                         FINAL I/O FILE MANAGEMENT TABLES
                    FILE NAME SUPPLIED BY
                -------------------------------                                           USER
FILE NUMBER     USER    USER-EXIST   USER-STACK       VERSION       WRITTEN     IDENTIFICATION
     10         CONTRL                                   1             1        GUCSAMP   12-02-78
     11         INDT2S                                   1             1        LASL I    NPUT P
     12         DEPOSE                                   1             1        LASL I    NPUT P
     14         ZNATDN                                   3             1        GUCSAMP   12-02-78
     15         CZPPDN                                   1             1        CONSTI    RATION
     16         INDTRS                                   2             1        LASL I    NPUT P
     17         GRUPES                                   1             1        OPNL N    ADE
     18         GPOOST                                   1             1        DVENTR    INPUT
     19         NDTSDP                                   1             1        DVENTR    INPUT
     20         SEARCH                                   1             1        DVENTR    INPUT
     30         ZNATDN                                   4             1        GUCSAMP   12-02-78
     31         DEPLTE                                   1             1        GUCSAMP   12-02-78
     32         RTPLTN                                   1             1        GUCSAMP   12-02-78
     33         ZNPOWD                                   1             1        GUCSAMP   12-02-78
     34         QNATDN                                   1             1        GUCSAMP   12-02-78

WRAP-UP NOW COMPLETE. -- DRIVER TO SEEK NEW CASE - REMAINING I/O=   7.57, CPU MIN=   2.82 - TIME=02.07.20
```

BURNER - EXPOSURE MODULE - PRE-RELEASE VERSION IF - NOVEMBER 14, 1978 - QUALITY ASSURANCE LEVEL 3

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

SELF CONTAINED ARRAYS, CONTROL + DATA

SUBSET TITLE
TWO-GROUP DEPLETION PROBLEM (BENCHMARK PROB 9B1) (N,?) IS (N,3)N

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

NO.	NORD	NISS	NABSOL	HABSOL	UCLAS	ICLAS
1	1	1	1	U234	1	1
2	2	2	2	U235	1	2
3	3	3	3	U236	1	3
4	4	4	4	U237	1	4
5	5	5	5	U238	2	0
6	6	6	6	U239	1	0
7	7	7	7	NP237	1	0
8	8	8	8	NP238	1	0
9	9	9	9	NP239	1	0
10	10	10	10	NP240	1	0
11	11	11	11	PU238	1	0
12	12	12	12	PU239	1	0
13	13	13	13	PU240	2	0
14	14	14	14	PU241	1	0
15	15	15	15	PU242	1	0
16	16	16	16	PU243	1	0
17	17	17	17	AM241	1	0
18	18	18	18	AM242	1	0
19	19	19	19	AM242M	1	0
20	20	20	20	AM243	1	0
21	21	21	21	AM244	1	0
22	22	22	22	CM242	1	0
23	23	23	23	CM243	1	0
24	24	24	24	CM244	1	0
25	25	25	25	CM245	1	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

NSCLAS - THE NUMBER OF DIFFERENT SORT CLASSES IS 1

NO. NSCLS ISCLS

METHOD OF SOLUTION - MATRIX EXPONENTIAL

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

ISOTOPE NUCLIDES
NUCLIDE NAMES ARE ABSOLUTE

1)	U234
2)	U235
3)	U236
4)	U237
5)	U238
6)	U239
7)	NP237
8)	NP238
9)	NP239
10)	[illegible]
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	8.390006E-09
5)	PM148	31	1.487999E-06
6)	PM148M	32	1.975999E-07
7)	PM149	33	3.625997E-06
8)	U237	4	1.189999E-06
9)	U239	6	4.916999E-04
10)	NP238	8	3.816997E-06
11)	NP239	9	3.409999E-06
12)	PU240	13	1.502999E-[illegible]
13)	PU241	14	1.679999E-09
14)	PU243	16	3.889999E-05
15)	AM242	18	1.195999E-05
16)	AM244	21	[illegible]
17)	PU238	11	2.503999E-10
18)	AM241	17	5.099001E-11
19)	CM242	22	4.909999E-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

FISSIONING NUCLIDE

FISSION PRODUCT			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	0.032700	0.002400
3)	PM149	33	0.011300	0.021000	0.013000	0.012000
4)	ND147	29	0.023600	0.020000	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
INNUC      1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20
INNUC     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

 NOPPT  =  0 NODEBP = -1

MINOWT ACTUALLY USED WILL BE     3239

INTERFACE FILE RFLUX VERSION    1 UNIT  15
 TIME   =  0.0             POWER =  1.000000E 06
 VOL    =  1.000000E 00 EFFK   =  1.000000E 00
 EIVS   =  0.0             DNDS   =  0.0
 TWL    =  1.000000E 00 TWA    =  1.000000E 00
 TWSL   =  0.0             TWOL   =  0.0
 TWBAL  =  0.0             TWCBA  =  0.0
 PC     =  1.000000E 00 CRTP   =  1.000000E 00
 E3     =  0.0             E4     =  0.0
 ITPS   =       0          NSONE  =       1
 NGROUP=       2          NCY    =       0

RFLUX REFERENCE TIME          0.0     DAYS INDICATOR        1

INTERFACE FILE ZNATDN VERSION    1 UNIT  16
 TIME   =  0.0
 NCY    =       0          NTZSZ =       1
 NNS    =      35          NBLKAD=       1
```

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

POS. DEN.	ZONE 1 POS. SIG.	IDENTIFIER UNIQUE	SET 1 ABSORPTION	FISSION	PRODUCTION	CAPTURE(NG)	(N,2N)	(N,T)
1	1	U234	2.748128E 16	2.62337E 14	0.0	2.72109E 16	0.0	0.0
2	2	U235	5.505403E 16	4.47525E 16	0.0	1.03002E 16	1.59756E 12	0.0
3	3	U236	1.381008E 16	1.02274E 14	0.0	1.37081E 16	0.0	0.0
4	4	U237	4.380559E 16	2.44402E 14	0.0	4.35611E 16	0.0	0.0
5	5	U238	5.629078E 14	4.99204E 13	0.0	5.10280E 14	2.69074E 12	0.0
6	6	U239	3.011678E 15	1.22095E 15	0.0	1.79072E 15	0.0	0.0
7	7	NP237	3.305548E 16	2.59310E 14	0.0	3.27960E 16	1.23632E 11	0.0
8	8	NP238	1.858648E 17	1.68311E 17	0.0	1.71525E 16	0.0	0.0
9	9	NP239	2.038308E 16	0.0	0.0	2.03830E 16	0.0	0.0
10	10	NP240	0.0	0.0	0.0	0.0	0.0	0.0
11	11	PU238	3.641988E 16	1.86080E 15	0.0	3.45590E 16	0.0	0.0
12	12	PU239	1.517358E 17	9.63342E 16	0.0	5.54010E 16	0.0	0.0
13	13	PU240	2.492158E 17	3.35821E 14	0.0	2.48879E 17	0.0	0.0
14	14	PU241	1.499699E 17	1.06961E 17	0.0	4.31074E 16	0.0	0.0
15	15	PU242	3.337238E 16	2.66731E 14	0.0	3.31056E 16	0.0	0.0
16	16	PU243	4.218698E 16	2.99681E 16	0.0	1.21947E 16	0.0	0.0
17	17	AM241	1.308328E 17	1.20037E 15	0.0	1.15493E 17	0.0	1.40585E 16
18	18	AM242	1.985418E 17	1.93125E 17	0.0	5.43998E 15	0.0	0.0
19	19	AM242M	6.359072E 17	5.12254E 17	0.0	1.23653E 17	0.0	0.0
20	20	AM243	6.233818E 16	1.88934E 14	0.0	6.21492E 16	0.0	0.0
21	21	AM244	1.172128E 17	1.17212E 17	0.0	0.0	0.0	0.0
22	22	CM242	3.307118E 15	2.08817E 14	0.0	3.09929E 15	0.0	0.0
23	23	CM243	1.298538E 17	1.05372E 17	0.0	2.44910E 16	0.0	0.0
24	24	CM244	2.168948E 16	1.79403E 15	0.0	2.06606E 16	0.0	0.0
25	25	CM245	1.813308E 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	2.671758E 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	1.691918E 17	0.0	0.0	8.93176E 16	0.0	7.98715E 16
31	31	PM148	2.172678E 19	0.0	0.0	2.17267E 19	0.0	0.0
32	32	PM148M	3.689038E 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	5.930058E 18	0.0	0.0	5.93005E 18	0.0	0.0
35	35	FPLL	1.128068E 14	0.0	0.0	1.12806E 14	0.0	0.0

START OF STEP ATOM DENSITIES AT TIME 0.0 DAYS

ZONE NUMBER 1

U235	7.800299E-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 5.9987319D 00 FROM DIAGONAL TERMS AND MULTIPLY DENSITIES BY 2.8819000D-03

POWER 1.1705818E 02 WATTS, MAXIMUM POWER DENSITY 1.1705818E 02 WATTS/CC IN ZONE 1 AT START OF SUBSTEP 1
POWER 1.2936678E 02 WATTS, MAXIMUM POWER DENSITY 1.2936678E 02 WATTS/CC IN ZONE 1 AT END OF SUBSTEP 1

AVERAGE POWER AT END OF SUBSTEP 1.2271248E 02 WATTS

END OF EXPOSURE STEP ATOM DENSITIES AT TIME 5.0000000E 01 DAYS

ZONE NUMBER 1

U234	8.2002107E-10
U235	5.0339027E-05
U236	2.8605608E-06
U237	3.5677993E-08
U238	6.0191098E-03
U239	7.1936017E-09
NP237	1.7073998E-07
NP238	7.9051008E-10
NP239	1.0298403E-06
NP240	1.3229258E-11
PU238	8.0196917E-09
PU239	1.0578729E-05
PU240	9.9592098E-07
PU241	3.3020373E-07
PU242	1.6378331E-08
PU243	1.3635579E-11
AM241	5.9600307E-10
AM242	4.2099028E-12
AM242M	5.9403117E-12
AM243	8.5706337E-10
AM244	6.3802917E-10
CM242	8.4960107E-11
CM243	9.5097018E-10
CM244	2.0678707E-11
CM245	2.[illegible]3373E-13
I135	9.0275297E-09
XE135	9.1075079E-10
CS135	7.7169268E-08
ND147	1.2119658E-07
PM147	2.0191308E-07
PM148	8.5708178E-09
PM148M	3.8672108E-09
PM149	1.9960168E-08
SM149	1.1977908E-08
FPLL	1.0522738E-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 53.000 DAYS: INVENTORY (KG)	ABSORPTION	FISSION	PRODUCTION	CAPTURE (N,G)
1	U234	0.0	0.0	0.0	0.0	0.0	1.66615E-10	1.22499E-06	1.17120E-08	0.0	1.21530E-06
2	U235	2.88761E-05	5.10645E-01	4.15093E-01	0.0	9.55372E-02	2.27640E-05	3.36410E-01	2.71035E-01	0.0	6.29652E-02
3	U236	0.0	0.0	0.0	0.0	0.0	1.12095E-06	3.21976E-03	3.04610E-05	0.0	3.18935E-03
4	U237	0.0	0.0	0.0	0.0	0.0	1.40401E-08	1.02726E-04	9.07091E-07	0.0	1.01819E-04
5	U238	2.76009E-03	4.89355E-01	4.33975E-02	0.0	4.43611E-01	2.73433E-03	4.35426E-01	3.59633E-02	0.0	3.97610E-01
6	U239	0.0	0.0	0.0	0.0	0.0	2.65077E-09	2.25251E-06	9.13305E-07	0.0	1.33910E-06
7	NP237	0.0	0.0	0.0	0.0	0.0	4.12172E-08	3.60479E-06	2.82780E-08	0.0	3.57650E-06
8	NP238	0.0	0.0	0.0	0.0	0.0	3.30406E-10	1.50720E-05	1.36705E-05	0.0	1.39142E-06
9	NP239	0.0	0.0	0.0	0.0	0.0	4.08527E-07	2.10044E-03	0.0	0.0	2.10044E-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	1.70619E-09	1.67556E-05	8.56090E-07	0.0	1.58995E-05
12	PU239	0.0	0.0	0.0	0.0	0.0	4.19651E-06	1.67064E-01	1.06006E-01	0.0	6.09807E-02
13	PU240	0.0	0.0	0.0	0.0	0.0	3.96603E-07	2.50022E-02	3.09227E-05	0.0	2.50074E-02
14	PU241	0.0	0.0	0.0	0.0	0.0	1.33776E-07	4.21003E-03	3.71003E-03	0.0	1.53303E-03
15	PU242	0.0	0.0	0.0	0.0	0.0	6.57962E-10	5.64455E-05	4.54703E-07	0.0	5.44409E-05
16	PU243	0.0	0.0	0.0	0.0	0.0	5.50179E-12	5.98366E-08	4.25179E-08	0.0	1.73187E-08
17	AM241	0.0	0.0	0.0	0.0	0.0	2.34650E-10	7.90003E-08	7.01701E-08	0.0	7.05151E-09
18	AM242	0.0	0.0	0.0	0.0	0.0	2.00350E-12	1.05541E-07	1.04763E-07	0.0	7.79417E-10
19	AM242M	0.0	0.0	0.0	0.0	0.0	2.02950E-12	3.30209E-07	2.69253E-07	0.0	6.09951E-08
20	[illegible]	0.0	0.0	0.0	0.0	0.0	1.44610E-13	2.95567E-08	8.99113E-09	0.0	2.05761E-08
21	[illegible]	0.0	0.0	0.0	0.0	0.0	2.54095E-14	7.79400E-10	7.79400E-10	0.0	0.0
22	CM242	0.0	0.0	0.0	0.0	0.0	1.80693E-11	1.54840E-08	9.77605E-13	0.0	1.45261E-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	8.37670E-12	4.55904E-08	3.20411E-09	0.0	4.44402E-08
25	CM245	0.0	0.0	0.0	0.0	0.0	4.69945E-14	4.19611E-09	3.89375E-09	0.0	6.03340E-10
26	I135	0.0	0.0	0.0	0.0	0.0	1.47876E-09	0.0	0.0	0.0	0.0
27	XE135	0.0	0.0	0.0	0.0	0.0	2.25051E-10	2.54467E-02	0.0	0.0	2.54467E-02
28	CS135	0.0	0.0	0.0	0.0	0.0	1.72902E-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	1.55510E-03	0.0	0.0	1.67670E-03
31	PM148	0.0	0.0	0.0	0.0	0.0	1.12115E-09	1.31390E-03	0.0	0.0	1.01390E-03
32	PM148M	0.0	0.0	0.0	0.0	0.0	9.50346E-10	1.40510E-03	0.0	0.0	1.40510E-03
33	PM149	0.0	0.0	0.0	0.0	0.0	4.40022E-09	0.0	0.0	0.0	0.0
34	SM149	0.0	0.0	0.0	0.0	0.0	2.96333E-09	7.30535E-03	0.0	0.0	7.30535E-03
35	FPLL	0.0	0.0	0.0	0.0	0.0	2.41103E-05	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	4.17660E-01	0.0	5.78640E-01
	OTHER LOSS RATE		2.38019E-07					1.19209E-07			
	TOTAL LOSS RATE		1.00000E 00					1.00000E 00			
	SYSTEM LOSS RATE(N/SEC)		7.87850E 12					8.82841E 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 9.731460E 12 N/SEC

ZONE CLASS ID.	FISSILE 1	FERTILE 2	O. ACTINIDE 3	FISSION PROD 4
1	0.5086059	0.4576902	0.0032922	0.0305417
	----------	----------	----------	----------
SUM	0.5086059	0.4576902	0.0032922	0.0305417

ZONE CLASS ID.	ABSORPTION LOSSES	FISSILE INVENTORY (KG) 0.0 DAYS	FISSILE INVENTORY (KG) 50.000 DAYS	EFFECTIVE CONVERSION RATIO FISSION RATE	EFFECTIVE CONVERSION RATIO MASS BALANCE	POWER (WATTS)
1	0.9999999	2.9076111E-05	2.7394242E-05	1.01050	0.76829	1.227124E 02
	----------	------------	------------	----------	----------	------------
OVERALL	0.9999999	2.9076111E-05	2.7394242E-05	1.01050	0.76829	1.227124E 02
OTHER LOSSES	0.0000001					

TOTAL LOSSES	1.0000000					

FISSILE CONSUMPTION PER UNIT ENERGY GENERATION IS 1.426226E-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

PNSTY 9.999995E-25
TNSTP 0.0 5.000000E 01
TNSTS 0.0

SUMMARY OF CALCULATION

MATRIX EXPONENTIAL - EXPOSURE
MAT. STEPS (INTERVALS) USED 572
NUM. STEPS (INTERVALS) USED 572

MAX ARRAY SIZE USED 1237 WORDS - FOR ZONE CALCULATION

MAX ARRAY SIZE USED 1237 WORDS

TOTAL CPU TIME USED 0.220 MINUTES TOTAL CLOCK TIME USED 1.410 MINUTES TOTAL I/O USED 152

NORMAL END OF EXPOSURE MODULE

BURNUP - EXPOSURE MODULE - PRE-RELEASE VERSION 15 - NOVEMBER 14, 1978 - QUALITY ASSURANCE LEVEL 3

CASE TITLE - BREEDER REACTOR SAMPLE PROBLEM FOR THE BURNUP CODE

SITE CONTAINED ARRAYS, CONTROL 6 DATA 1

GROUPS 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
NOCLAS - THE NUMBER OF DIFFERENT ISOTOPE CLASSES IN SYSTEM IS 8

NO.	NORP	NOSS	NASSOL	NASSO.	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	RSFP	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	6	0
43	40	0	19	6	0
44	41	0	20	6	0
45	42	0	21	7	0

NUCLAS - THE NUMBER OF DIFFERENT ZONE CLASSES IS 13

NO.	NUCLS	ISCLS
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	9	0
21	9	0
22	10	0

METHOD OF SOLUTION - EXPLICIT CHAIN

THE LONGEST EXPLICIT CHAIN IS 10

* DEFINED 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	1.6009997E-09
2)	XE135	8	2.0929999E-05
3)	PM147	9	8.3009996E-09
4)	PM148M	13	1.9750999E-07
5)	PM148	14	1.4079999E-06

FISSION PRODUCT YIELD DATA

```
                         ENERGY RANGE   1 CUTOFF AT    1.000000E 05 EV

                          FISSIONING NUCLIDE
                                1)          2)          3)          4)          5)          6)          7)
                          U235        U236        U238        PU239       PU240       PU241       PU242
FISSION PRODUCT                 1           2           3           4           5           6           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    1.506599    1.506599    1.501100    1.506599    1.501100    1.506599
 5)  SSFP           12    0.013000    0.013000    0.013000    0.013000    0.013000    0.013000    0.013000

                         ENERGY RANGE   2 CUTOFF AT    0.0          EV

                          FISSIONING NUCLIDE
                                1)          2)          3)          4)          5)          6)          7)
                          U235        U236        U238        PU239       PU240       PU241       PU242
FISSION PRODUCT                 1           2           3           4           5           6           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    1.506599    1.506599    1.501100    1.506599    1.501100    1.506599
 5)  SSFP           12    0.013000    0.013000    0.013000    0.013000    0.013000    0.013000    0.013000

      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    1.4920000E 07   1.3240990E 06   8.6519978E 04   5.0030062E-03
THR       1.0000000E 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
INNUC     1    2    3    4    5    6    7   14   15   18   19   20   16   17
SET       2  NUCLIDES INCLUDED   14
INNUC     1    2    3    4    5    6    7   14   15   18   19   20   16   17
SET       3  NUCLIDES INCLUDED    0
INNUC     0    0    0    0    0    0    0    0    0    0    0    0    0    0
SET       4  NUCLIDES INCLUDED    0
INNUC     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    1670

        STORAGE SUPPLIED IS     10000
MAXIMUM STORAGE REQUIRED IS      5011
MINIMUM STORAGE REQUIRED IS      3165

 NODMP  =  0 NODEMP =  0

MEMORY ACTUALLY USED WILL BE     5011

INTERFACE FILE RTFLUX VERSION    1 UNIT   16
 TIME   =  0.0              POWER  =  1.2500000E 09
 VOL    =  1.5025050E 07 EFFK   =  1.0127467E 00
 EIVE   =  0.0              NEDS   =  0.0
 TNL    =  1.1062102E 20 TNA    =  1.0922231E 20
 TNSL   =  1.3000612E 18 TNOL   =  0.0
 TNBAL  =  0.0              TNCRA  =  0.0
 PC     =  5.0000000E-01 CSTP   =  9.7000000E-01
 X3     =  1.0000000E 00 X4     =  0.0
 ITPS   =        1          NSOFF  =      22
 NGROUP=         3          NCY    =       2

RTFLUX REFERENCE TIME          0.0     DAYS INDICATOR        1

INTERFACE FILE ZNATDN VERSION    1 UNIT   15
 TIME   =  0.0
 NCY    =        0          NTUSE  =      22
 NZN    =       21          NBLKAD=        1


START OF STEP ATOM DENSITIES AT TIME    0.0            DAYS


ZONE NUMBER      1
U235A       2.2069990E-05  U238A       7.5002099E-03  PU239A      8.6771000E-04  PU240A      3.1535990E-04
PU241A      6.0215000E-05  PU242A      2.5591000E-05  O16A        1.7600000E-02  NA23A       8.0500000E-03
CR-A        2.6107000E-03  FE-A        9.7055960E-03  NI-A        1.3703000E-03  TA181A      9.9999990E-11

ZONE NUMBER      2
U235A       2.2069990E-05  U238A       7.5002099E-03  PU239A      8.6771000E-04  PU240A      3.1535990E-04
PU241A      6.0215000E-05  PU242A      2.5591000E-05  O16A        1.7600000E-02  NA23A       8.0500000E-03
CR-A        2.6107000E-03  FE-A        9.7055960E-03  NI-A        1.3703000E-03  TA181A      9.9999990E-11

ZONE NUMBER      3
U235A       2.3915000E-05  U238A       7.0074990E-03  PU239A      9.9060990E-04  PU240A      3.4260000E-04
```

PU241A	7.327099E-05	PU242A	2.920099E-05	O16A	1.860300E-02	NA23A	8.403197E-03				
CP-A	2.699300E-03	FE-A	1.000660E-02	NI-A	1.820600E-03	TA181A	0.000000E-11				
ZONE NUMBER	4										
U235A	2.381500E-05	U238A	7.007490E-03	PU239A	9.006000E-04	PU240A	3.824900E-04				
PU241A	7.327099E-05	PU242A	2.920099E-05	O16A	1.860300E-02	NA23A	8.403197E-03				
CP-A	2.699300E-03	FE-A	1.000660E-02	NI-A	1.820600E-03	TA181A	0.000000E-11				
ZONE NUMBER	5										
U235A	2.357300E-05	U238A	7.735490E-03	PU239A	1.150700E-03	PU240A	4.070700E-04				
PU241A	9.570799E-05	PU242A	3.016000E-05	O16A	1.855300E-02	NA23A	8.227497E-03				
CP-A	2.722300E-03	FE-A	1.017260E-02	NI-A	1.832000E-03	TA181A	0.000000E-11				
ZONE NUMBER	6										
U235A	2.357300E-05	U238A	7.735490E-03	PU239A	1.150700E-03	PU240A	4.070700E-04				
PU241A	9.570799E-05	PU242A	3.016000E-05	O16A	1.855300E-02	NA23A	8.227497E-03				
CP-A	2.722300E-03	FE-A	1.017260E-02	NI-A	1.832000E-03	TA181A	0.000000E-11				
ZONE NUMBER	7										
U235B	2.039499E-05	U238B	8.317590E-03	O16B	1.860200E-02	NA23B	8.558449E-03				
CP-B	2.618700E-03	FE-B	9.785596E-03	NI-B	1.170300E-03						
ZONE NUMBER	8										
U235B	2.039499E-05	U238B	8.317590E-03	O16B	1.860200E-02	NA23B	8.558449E-03				
CP-B	2.618700E-03	FE-B	9.785596E-03	NI-B	1.170300E-03						
ZONE NUMBER	9										
U235B	3.009199E-05	U238B	9.070690E-03	O16B	1.861300E-02	NA23B	8.403197E-03				
CP-B	2.699300E-03	FE-B	1.000660E-02	NI-B	1.820600E-03						
ZONE NUMBER	10										
U235B	3.009199E-05	U238B	9.070690E-03	O16B	1.861300E-02	NA23B	8.403197E-03				
CP-B	2.699300E-03	FE-B	1.000660E-02	NI-B	1.820600E-03						
ZONE NUMBER	11										
U235B	3.056200E-05	U238B	1.002220E-02	O16B	2.010500E-02	NA23B	8.227497E-03				
CP-B	2.722300E-03	FE-B	1.017260E-02	NI-B	1.832000E-03						
ZONE NUMBER	12										
U235B	3.056200E-05	U238B	1.002220E-02	O16B	2.510500E-02	NA23B	8.227497E-03				
CP-B	2.722300E-03	FE-B	1.017260E-02	NI-B	1.832000E-03						
ZONE NUMBER	13										
U235B	4.318300E-05	U238B	1.017000E-02	O16B	2.042600E-02	NA23B	8.226197E-03				
CP-B	2.650200E-03	FE-B	9.833297E-03	NI-B	1.300100E-03						
ZONE NUMBER	14										
U235B	4.318300E-05	U238B	1.017000E-02	O16B	2.042600E-02	NA23B	8.226197E-03				
CP-B	2.650200E-03	FE-B	9.833297E-03	NI-B	1.300100E-03						
ZONE NUMBER	15										
U235B	4.318300E-05	U238B	1.017000E-02	O16B	2.042600E-02	NA23B	8.226197E-03				
CP-B	2.650200E-03	FE-B	9.833297E-03	NI-B	1.300100E-03						
ZONE NUMBER	16										
U235B	4.318300E-05	U238B	1.017000E-02	O16B	2.042600E-02	NA23B	8.226197E-03				
CP-B	2.650200E-03	FE-B	9.833297E-03	NI-B	1.300100E-03						
ZONE NUMBER	17										
U235B	4.318300E-05	U238B	1.017000E-02	O16B	2.042600E-02	NA23B	8.226197E-03				
CP-B	2.650200E-03	FE-B	9.833297E-03	NI-B	1.300100E-03						
ZONE NUMBER	18										
U235B	4.318300E-05	U238B	1.017000E-02	O16B	2.042600E-02	NA23B	8.226197E-03				
CP-B	2.650200E-03	FE-B	9.833297E-03	NI-B	1.300100E-03						

ZONE NUMBER 19							
U235B	8.310300E-05	U238B	3.017000E-02	O16B	2.002600E-02	NA23B	8.220397E-03
CR-B	2.650200E-03	FE-B	9.033297E-03	NI-B	1.399100E-03		

ZONE NUMBER 20							
U235B	8.310300E- [illegible]	U238B	3.017300E-02	O16B	2.002600E-02	NA23B	8.220397E-03
CR-B	2.650200E- [illegible]	[illegible]	9.033297E-03	NI-B	1.399100E-03		

ZONE NUMBER 21							
NA23B	1.984700E-02	FE-B	3.071530E-02	CR-B	8.219400E-03	NI-B	4.126390E-03

ZONE NUMBER 22							
NA23B	1.984700E-02	FE-B	3.071530E-02	CR-B	8.219400E-03	NI-B	4.126390E-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 2.499990E 09 WATTS, MAXIMUM POWER DENSITY 4.801115E 02 WATTS/CC IN ZONE 1 AT START OF SUBSTEP 1
POWER 2.596527E 09 WATTS, MAXIMUM POWER DENSITY 4.795476E 02 WATTS/CC IN ZONE 1 AT END OF SUBSTEP 1

AVERAGE POWER AT END OF SUBSTEP 2.501263E 09 WATTS

INITIAL FRACTION RATES WILL BE MULTIPLIED BY 9.967464E-01 FOR NEXT SUBSTEP 9.967871E-01 9.971465E-01

POWER 2.493450E 09 WATTS, MAXIMUM POWER DENSITY 4.770674E 02 WATTS/CC IN ZONE 1 AT START OF SUBSTEP 2
POWER 2.499557E 09 WATTS, MAXIMUM POWER DENSITY 4.760366E 02 WATTS/CC IN ZONE 1 AT END OF SUBSTEP 2

AVERAGE POWER AT END OF SUBSTEP 2.499965E 09 WATTS

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

ZONE NUMBER 1							
U235A	2.050735E-05	U236A	5.110005E-07	U238A	7.029621E-03	PU239A	8.600900E-04
PU240A	3.021307E-04	PU241A	6.154201E-05	PU242A	2.669445E-05	O16A	1.760090E-02
NA23A	9.050490E-03	CR-A	2.610703E-03	FE-A	9.705590E-03	NI-A	1.190120E-03
XE135A	8.450910E-09	PM147A	2.371030E-06	PM148MA	2.230140E-06	PM148A	8.417050E-10
SM149A	1.250002E-06	NSFPA	1.115323E-04	SSFPA	1.102290E-06	TA181A	9.499905E-11

ZONE NUMBER 2							
U235A	2.120515E-05	U236A	3.704040E-07	U238A	7.020700E-03	PU239A	8.771041E-04
PU240A	3.004290E-04	PU241A	6.210940E-05	PU242A	2.596911E-05	O16A	1.760093E-02
NA23A	9.050490E-03	CR-A	2.610700E-03	FE-A	9.705590E-03	NI-A	1.191100E-03
XE135A	1.159902E-08	PM147A	1.621901E-06	PM148MA	1.350257E-06	PM148A	5.152610E-10
SM149A	9.009497E-07	NSFPA	9.322900E-05	SSFPA	8.104401E-07	TA181A	9.999940E-11

ZONE NUMBER 3							
U235A	2.170130E-05	U236A	4.935311E-07	U238A	7.200090E-03	PU239A	9.007107E-04
PU240A	3.092607E-04	PU241A	7.012510E-05	PU242A	2.070700E-05	O16A	1.460190E-02
NA23A	9.003107E-03	CR-A	2.699300E-03	FE-A	1.000600E-02	NI-A	1.023600E-03
XE135A	8.730207E-09	PM147A	2.421600E-06	PM148MA	2.201125E-06	PM149A	9.319109E-12
SM149A	1.320123E-06	NSFPA	1.310449E-06	SSFPA	1.216691E-06	TA181A	4.999900E-11

ZONE NUMBER 4							
U235A	2.231030E-05	U236A	1.590042E-07	U238A	7.775071E-01	PU239A	4.402311E-04
PU240A	3.075006E-04	PU241A	7.090321E-05	PU242A	2.657601E-05	O16A	1.000100E-02
NA23A	9.003197E-01	CR-A	2.699100E-03	FE-A	1.990060E-02	NI-A	1.023406E-01
XE135A	3.325605E-08	PM147A	1.711913E-06	PM148MA	1.352030E-06	PM148A	4.201378E-10

SM149A	4.2862151E-07	NSFPA	9.0241095E-05	SSFPA	8.6503091E-07	TA181A	9.4999998E-11
ZONE NUMBER 5							
U235A	2.2167590E-05	U236A	3.1366640E-07	U238A	7.6723039E-03	PU239A	1.1511119E-03
PU240A	4.5246709E-05	PU241A	8.1115581E-06	PU242A	1.4536730E-05	O16A	1.4551320E-02
NA23A	8.2274070E-03	CR-A	2.7223030E-03	FE-A	1.3172060E-02	NI-A	1.4120700E-03
XE135A	3.0790631E-10	PM147A	1.7001170E-06	PM148A	1.3175407E-08	PM149A	6.7564227E-10
SM149A	4.7024628E-07	NSFPA	1.5205590E-06	SSFPA	4.7257110E-07	TA181A	9.4999998E-11
ZONE NUMBER 6							
U235A	2.2566130E-05	U236A	2.2501678E-07	U238A	7.6035470E-03	PU239A	1.1510100E-03
PU240A	4.5129190E-05	PU241A	9.2632708E-06	PU242A	3.4416400E-05	O16A	1.4551320E-02
NA23A	8.2274070E-03	CR-A	2.7223000E-03	FE-A	1.3172060E-02	NI-A	1.4120600E-03
XE135A	2.0305057E-10	PM147A	1.2657770E-06	PM148A	7.1062702E-09	PM149A	2.7217010E-10
SM149A	6.7700690E-07	NSFPA	7.2116190E-05	SSFPA	6.1057120E-07	TA181A	9.4999998E-11
ZONE NUMBER 7							
U235B	2.7277230E-05	U236B	2.0635800E-07	U238B	4.2705190E-03	PU239B	4.1455110E-05
PU240B	1.0700160E-07	PU241B	5.9900260E-10	PU242B	1.1710290E-12	O16B	1.4692087E-02
NA23B	9.2500900E-03	CR-B	2.6107700E-03	FE-B	9.7055060E-03	NI-B	1.1161570E-03
XE135B	1.0997090E-09	PM147B	7.0905000E-20	PM148B	4.9562110E-15	PM149B	1.4454597E-11
SM149B	4.7264990E-20	NSFPB	4.1162240E-20	SSFPB	1.7476190E-14		
ZONE NUMBER 8							
U235B	2.7923060E-05	U236B	1.2501730E-07	U238B	1.2050407E-03	PU239B	1.7552608E-05
PU240B	3.5006020E-20	PU241B	4.0773050E-11	PU242B	4.2515160E-14	O16B	1.4602107E-02
NA23B	9.2504900E-03	CR-B	2.6107720E-03	FE-B	4.7055060E-03	NI-B	1.1701220E-03
XE135B	1.0709917E-10	PM147B	1.0210730E-06	PM148B	4.9511321E-11	PM149B	2.1155551E-12
SM149B	1.9077060E-20	NSFPB	1.0606600E-06	SSFPB	9.2027010E-08		
ZONE NUMBER 9							
U235B	2.0055750E-05	U236B	2.6037650E-07	U238B	6.0300130E-03	PU239B	1.7021670E-05
PU240B	1.5001050E-07	PU241B	4.1012110E-16	PU242B	7.1501000E-11	O16B	1.0050200E-02
NA23B	9.0031570E-03	CR-B	2.6001590E-03	FE-B	1.3200030E-02	NI-B	1.4220560E-03
XE135B	1.1062650E-09	PM147B	7.1605600E-07	PM148B	4.3320050E-13	PM149B	1.5570270E-11
SM149B	4.0932010E-08	NSFPB	4.3760120E-06	SSFPB	1.5205720E-08		
ZONE NUMBER 10							
U235B	2.4677220E-05	U236B	1.9952020E-19	U238B	4.0501010E-03	PU239B	1.5157201E-05
PU240B	2.5010630E-09	PU241B	2.0372000E-11	PU242B	2.9700720E-10	O16B	1.0015060E-02
NA23B	9.0031970E-03	CR-B	2.6991000E-03	FE-B	1.0900600E-02	NI-B	1.0250000E-03
XE135B	3.1705600E-10	PM147B	1.6601060E-20	PM148B	5.2250007E-11	PM149B	1.7202120E-12
SM149B	9.6036670E-20	NSFPB	6.2700500E-07	SSFPB	6.1350010E-09		
ZONE NUMBER 11							
U235B	2.9000210E-05	U236B	1.6002250E-07	U238B	9.0971760E-03	PU239B	2.1020007E-05
PU240B	5.0150070E-09	PU241B	1.0019510E-10	PU242B	1.0002010E-11	O16B	2.2155900E-02
NA23B	8.2274070E-03	CR-B	2.7221030E-03	FE-B	1.3172607E-02	NI-B	1.0120000E-03
XE135B	4.1290200E-12	PM147B	8.5100720E-06	PM148B	1.0160070E-10	PM149B	6.5220000E-12
SM149B	2.7012730E-20	NSFPB	2.0015090E-06	SSFPB	2.1562150E-20		
ZONE NUMBER 12							
U235B	3.0207090E-05	U236B	6.7100997E-20	U238B	1.9012620E-02	PU239B	4.4010427E-10
PU240B	9.3566150E-09	PU241B	6.5170110E-12	PU242B	2.7109120E-15	O16B	2.7109007E-02
NA23B	8.2274070E-03	CR-B	2.7223200E-03	FE-B	1.0172600E-02	NI-B	1.4120000E-03
XE135B	1.0362000E-10	PM147B	6.0302050E-06	PM148B	2.0161070E-11	PM149B	6.0901170E-11
SM149B	5.7565790E-09	NSFPB	5.5050010E-07	SSFPB	6.0350120E-08		
ZONE NUMBER 13							
U235B	4.1050120E-05	U236B	3.9075000E-07	U238B	1.0122007E-02	PU239B	4.0070040E-05
PU240B	1.0207030E-07	PU241B	3.1030000E-10	PU242B	4.3000770E-13	O16B	2.0025907E-02
NA23B	4.2263970E-03	CR-B	2.6502300E-03	FE-B	4.0132070E-03	NI-B	1.1001000E-01
XE135B	1.0209600E-09	PM147B	1.0110620E-07	PM148B	5.1700600E-15	PM149B	1.0110107E-11
SM149B	6.2003100E-08	NSFPB	5.5500170E-06	SSFPB	4.0907007E-08		
ZONE NUMBER 14							

U2350	0.2311190E-05	U2360	2.1906190E-07	U2380	1.0136500E-02	PU2390	1.1590759E-05
PU2400	7.1625700E-09	PU2410	1.1000000E-10	PU2420	1.1120000E-11	O160	2.0020000E-02
NA230	0.2203079E-03	CR-0	2.6502000E-03	FE-0	0.0332079E-01	NI-0	1.1001000E-03
XE1350	1.1926751E-09	PM1470	6.7673227E-10	PM1480	2.7097000E-13	PM1490	9.1300070E-12
SM1490	0.2100307E-08	NSFPD	3.7010500E-16	SSFPD	3.2103100E-06		

ZONE NUMBER 15

U2350	0.2790050E-05	U2360	1.0110920E-07	U2380	1.0156317E-02	PU2390	1.0339790E-05
PU2400	1.5103618E-00	PU2410	1.1170090E-11	PU2420	0.0050708E-15	O160	2.0020000E-02
NA230	0.2203978E-03	CR-0	2.0502200E-03	FE-0	0.0332979E-01	NI-0	1.1001900E-03
XE1350	7.2020260E-10	PM1470	1.7951600E-00	PM1480	1.0664200E-11	PM1490	1.2150645E-12
SM1490	1.0670700E-09	NSFPD	9.6935560E-07	SSFPD	6.6667531E-06		

ZONE NUMBER 16

U2350	0.3039202E-05	U2360	0.6670073E-06	U2380	1.0100250E-02	PU2390	9.6716107E-06
PU2400	2.0221200E-09	PU2410	7.2235200E-13	PU2420	1.2000051E-16	O160	2.0020400E-02
NA230	0.2203979E-03	CR-0	2.6502000E-03	FE-0	0.0332030E-01	NI-0	1.1001100E-03
XE1350	9.1553500E-11	PM1470	0.9000003E-00	PM1480	0.7355117E-12	PM1490	1.0511600E-11
SM1490	2.7909500E-09	NSFPD	2.7625100E-07	SSFPD	2.5270111E-10		

ZONE NUMBER 17

U2350	0.2655960E-05	U2360	1.3072000E-07	U2380	1.0150000E-02	PU2390	1.9037000E-05
PU2400	2.9060290E-09	PU2410	2.0156255E-11	PU2420	1.7300200E-10	O160	2.0020000E-02
NA230	0.2203070E-03	CR-0	2.6502700E-03	FE-0	0.0332050E-03	NI-0	1.1001500E-03
XE1350	0.2202000E-10	PM1470	2.2700011E-00	PM1480	4.3012700E-11	PM1490	2.7010000E-12
SM1490	1.3201700E-09	NSFPD	1.2507000E-04	SSFPD	1.1027710E-00		

ZONE NUMBER 18

U2350	0.3059900E-05	U2360	9.0000620E-06	U2380	1.0155700E-02	PU2390	1.1017557E-05
PU2400	1.0705640E-00	PU2410	1.0023930E-11	PU2420	0.5007300E-15	O160	2.0026000E-02
NA230	0.2203079E-03	CR-0	2.6502707E-01	FE-0	0.0332277E-01	NI-0	1.1001006E-01
XE1350	2.0500160E-10	PM1470	1.5503090E-10	PM1480	1.2015000E-11	PM1490	1.6410770E-12
SM1490	6.7702260E-09	NSFPD	6.5000700E-57	SSFPD	7.5011050E-00		

ZONE NUMBER 19

U2350	0.3023510E-05	U2360	0.7720720E-00	U2380	1.0101200E-02	PU2390	6.6015670E-06
PU2400	1.3250310E-09	PU2410	3.1003720E-12	PU2420	2.0070050E-16	O160	2.0020067E-02
NA230	0.2203070E-03	CR-0	2.6502700E-03	FE-0	0.0332707E-01	NI-0	1.1001000E-01
XE1350	1.0020120E-10	PM1470	5.0005610E-10	PM1480	4.5010000E-12	PM1490	2.6101500E-11
SM1490	1.3300010E-09	NSFPD	3.2765720E-07	SSFPD	2.0001250E-10		

ZONE NUMBER 20

U2350	0.1105900E-05	U2360	2.9721710E-00	U2380	1.0167100E-02	PU2390	2.0726560E-[illegible]
PU2400	4.2007053E-10	PU2410	0.0017630E-10	PU2420	6.7120077E-10	O160	2.0020090E-[illegible]
NA230	0.2203978E-03	CR-0	2.6502030E-03	FE-0	0.0332558E-01	NI-0	1.1001060E-03
XE1350	3.9002022E-11	PM1470	3.1100000E-00	PM1480	1.0650570E-12	PM1490	3.2552007E-10
SM1490	1.3623190E-09	NSFPD	1.1057100E-07	SSFPD	1.0002150E-00		

ZONE NUMBER 21

NA230	1.0007000E-02	FE-0	1.0715500E-02	CR-0	0.2106050E-01	NI-0	0.1207500E-01

ZONE NUMBER 22

NA230	1.0007000E-02	FE-0	1.0715900E-02	CR-0	0.2106000E-01	NI-0	0.1260940E-01

08-41

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 75.000 DAYS ************ 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	1.63186E 00	4.34672E-05	5.44731E-06	1.46319E-05	3.60199E-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	1.31901E-01	4.76665E-01
4	PU239	2.75438E 03	3.10585E-01	2.45019E-01	7.18752E-01	6.55757E-02	2.84906E 03	3.14404E-01	2.47837E-01	7.26965E-01	6.65669E-02
5	PU240	1.06409E 03	4.02407E-02	1.85017E-02	5.59522E-02	2.17390E-02	1.08387E 03	4.07334E-02	1.87262E-02	5.66308E-02	2.20072E-02
6	PU241	2.05506E 02	3.04464E-02	2.59440E-02	7.68530E-02	4.50161E-03	1.98713E 02	2.93199E-02	2.48806E-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	1.11134E-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	1.03783E-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	3.61999E-02	5.69502E 04	3.61119E-02	8.54180E-06	1.70835E-05	3.61334E-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	1.39816E-07	0.0	0.0	1.39816E-07
15	PM147	0.0	0.0	0.0	0.0	0.0	1.20527E 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	1.26703E-05	0.0	0.0	1.26703E-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	RSFP	0.0	0.0	0.0	0.0	0.0	0.0	2.34796E-03	0.0	0.0	2.34796E-03
20	SFFP	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	1.33283E-08	0.0	0.0	1.33283E-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	1.01511E 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					9.96786E-01			

06-42

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 3.209308E 20 N/SEC

ZONE CLASS NO.	FISSILE 1	FERTILE 2	O. ACTINIDE 3	FISSION PROD 4	STRUCTURAL 5	COOLANT 6	CONTROL ROD 7	OTHER 8
101	0.1233919	0.1573020	0.0009000	0.0006939	0.0143537	0.0002605	0.0000000	0.0006900
102	0.1297044	0.1534406	0.0009607	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	0.0000006	0.0034403	0.0001204	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	0.0000000	0.0000069	0.0023604	0.0000414	0.0	0.0000644
108	0.0005470	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	0.0053917	0.0000734	0.0	0.0
SUM	0.3547232	0.5603929	0.0026052	0.0016000	0.0567114	0.0011120	0.0000000	0.0021318

ZONE CLASS NO.	ABSORPTION LOSSES	FISSILE INVENTORY (KG) 0.0 DAYS	FISSILE INVENTORY (KG) 75.000 DAYS	EFFECTIVE CONVERSION RATIO REACTION RATE	EFFECTIVE CONVERSION RATIO MASS BALANCE	POWER (WATTS)
101	0.2976486	8.718159E 02	8.779272E 02	1.09513	1.00715	8.577050E 08
102	0.2993225	9.932793E 02	9.926743E 02	1.00149	0.99179	9.092793E 08
103	0.2045545	1.157943E 03	1.189101E 03	0.85315	0.83774	6.607063E 08
104	0.0453162	2.005400E 01	4.209500E 01	24.57222	24.84361	1.575746E 07
105	0.0410466	2.210088E 01	4.102136E 01	25.50649	25.80263	1.469022E 07
106	0.0254843	2.243201E 01	3.450909E 01	28.06142	29.24298	8.984285E 06
107	0.0457962	3.765649E 01	5.950716E 01	27.25711	27.59051	1.991576E 07
108	0.0196562	3.765674E 01	4.742706E 01	32.37958	32.85000	8.037670E 06
109	0.0030361	0.0	0.0	0.0	0.0	0.0
110	0.0054687	0.0	0.0	0.0	0.0	0.0
OVERALL	0.9873639	3.163738E 03	3.240736E 03	1.01260	1.00106	2.499005E 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 10 WITH DENSITIES AT TIME 7.500000E 01 DAYS

ZONE POWER DENSITY

1)	4.499385E 02	2)	3.186902E 02	3)	4.782056E 02	4)	1.359417E 02	5)	3.519414E 02
6)	2.464430E 02	7)	1.446036E 01	8)	3.532372E 00	9)	1.359318E 01	10)	3.087400E 00
11)	4.240502E 00	12)	1.820635E 00	13)	1.847270E 01	14)	1.229400E 01	15)	3.204303E 00
16)	9.134049E-01	17)	4.107669E 00	18)	2.055074E 00	19)	1.088102E 00	20)	3.934430E-01
21)	0.0	22)	0.0						

POWER COMPUTED FROM POWER DENSITY 2.499802E 09

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

CUMULATIVE EXPOSURE INFORMATION

TN1
1) 7.724766E 19

TN2
1) 0.0

TN3
1) 2.499775E 09

TN4
1) 7.196300E 04

INTERFACE FILE REPORT 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)	5.005644E 26	12)	2.665944E 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)	5.005644E 26	22)	2.665944E 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)	3.691474E 22	4)	2.598116E 22	5)	2.371340E 22
6)	1.659327E 22	7)	1.169075E 22	8)	8.465400E 21	9)	1.311246E 22	10)	3.726910E 21
11)	6.395175E 21	12)	2.235230E 21	13)	8.084226E 21	14)	5.222716E 21	15)	2.520402E 21
16)	9.229494E 20	17)	3.373613E 21	18)	2.393924E 21	19)	1.751315E 21	20)	4.482061E 20
21)	6.064923E 20	22)	7.443438E 20						

FLUENCE (RANGE 1 - TO CUTOFF ENERGY 1.000000E 03 EV) BY ZONE (NEUTRONS/CM**2)

1)	2.715056E 22	2)	1.944199E 22	3)	2.677470E 22	4)	1.808535E 22	5)	1.691976E 22
6)	1.171662E 22	7)	6.443453E 21	8)	2.092197E 21	9)	5.778547E 21	10)	1.767611E 21
11)	3.075675E 21	12)	1.365066E 21	13)	5.321556E 21	14)	1.677540E 21	15)	1.299075E 21
16)	4.172148E 20	17)	1.692763E 21	18)	1.445704E 21	19)	6.993147E 20	20)	1.466024E 20
21)	2.463372E 20	22)	2.944030E 20						

FLUENCE (RANGE 2 - TO CUTOFF ENERGY 1.000000E 05 EV) BY ZONE (NEUTRONS/CM**2)

1)	2.169450E 22	2)	1.503987E 22	3)	2.129673E 22	4)	1.452444E 22	5)	1.302641E 22
6)	9.481392E 21	7)	4.299566E 21	8)	1.161893E 21	9)	1.015940E 21	10)	9.944488E 20
11)	2.457621E 21	12)	6.355957E 20	13)	3.795313E 21	14)	2.602619E 21	15)	9.067144E 20
16)	2.202764E 20	17)	1.320337E 21	18)	7.358272E 20	19)	2.402202E 20	20)	4.631719E 19
21)	1.092764E 20	22)	1.279171E 20						

FISSIONS BY ZONE (SUBZONE) (FISSIONS/CM**3)

1)	8.736246E 19	2)	6.197372E 19	3)	8.294407E 19	4)	6.522618E 19	5)	6.012212E 19
6)	4.786082E 19	7)	2.844604E 18	8)	6.949236E 17	9)	2.673610E 18	10)	6.113090E 17
11)	1.626536E 19	12)	3.622481E 17	13)	3.613031E 18	14)	2.422247E 18	15)	6.494766E 17
16)	1.974620E 17	17)	9.203741E 17	18)	5.643045E 17	19)	2.141294E 17	20)	7.036960E 16
21)	9.165937E 12	22)	1.026213E 13						

EXPOSURE BY ZONE (SUBZONE) (MEGAWATT(THERMAL)-DAYS/KG)

1)	9.721240E 00	2)	6.875007E 00	3)	9.751050E 00	4)	6.838018E 00	5)	7.260200E 00
6)	4.938619E 00	7)	2.930773E-01	8)	7.169885E-02	9)	2.622351E-01	10)	5.413597E-02
11)	1.556627E-01	12)	3.451673E-02	13)	2.465370E-01	14)	1.661270E-01	15)	6.308655E-02
16)	1.219540E-02	17)	5.590121E-02	18)	3.812705E-02	19)	1.452022E-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)	2.169485E 22	1	2.169485E 22	1
MAXIMUM FISSIONS (FISSIONS/CM**3)	9.286407E 19	1	9.286407E 19	1
MAXIMUM EXPOSURE (MEGAWATT(THERMAL)-DAYS/KG)	9.751053E 00	3	9.751050E 00	1
TOTAL SYSTEM FISSIONS (FISSIONS)	5.035686E 26		5.035686E 26	
TOTAL SYSTEM EXPOSURE (MEGAWATT(THERMAL)-DAYS/KG)	2.695800E 00		2.695840E 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) 1.000000E 06	2) 5.000000E 05
1)	PU241	6	1.699999E-09	7.000000E 03	9.000000E 03	0.0	5.799999E 02
2)	XE135	8	2.092999E-05	3.999999E 05	1.000000E 06	0.0	5.000000E 05
3)	PM147	9	8.289996E-09	9.999999E 04	1.499999E 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	1.497999E-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) 1.000000E 06	2) 5.000000E 05
1)	U235	1	2.000000E 06	7.000000E 06	9.999998E 04
2)	U236	2	2.000000E 06	6.000000E 05	1.999999E 05
3)	U238	3	2.000000E 06	5.000000E 06	2.499999E 05
4)	PU239	4	2.000000E 06	8.000000E 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)	RSFP	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 9.947850E-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

	1)	2)	3)	4)	5)	6)
DECAY	9.405010E 17	3.816669E 17	8.550406E 17	4.733817E 17	0.0	4.733817E 17
FISSION	8.601881E 19	2.698912E 19	8.601881E 19	5.906969E 19	5.365560E 19	5.414095E 18
CAPTURE	1.102725E 20	1.807502E 19	1.102725E 20	9.219750E 19	9.219750E 19	0.0
TOTAL	1.972399E 20	4.503578E 19	1.971463E 20	1.517406E 20	1.458531E 20	5.887677E 18

ZONE NUMBER 2 SYSTEM ZONE VOLUME TIMES VOLUME FRACTION 1.150257E 06 CM**3

	1)	2)	3)	4)	5)	6)
DECAY	6.713741E 17	2.700786E 17	6.350263E 17	3.369875E 17	0.0	3.369875E 17
FISSION	6.088876E 19	1.930133E 19	6.088876E 19	4.180383E 19	3.796767E 19	3.835765E 18
CAPTURE	7.966395E 19	1.305736E 19	7.966395E 19	6.660660E 19	6.660663E 19	0.0
TOTAL	1.412201E 20	3.240875E 19	1.411537E 20	1.087650E 20	1.045743E 20	4.173713E 18

ZONE NUMBER 3 SYSTEM ZONE VOLUME TIMES VOLUME FRACTION 1.150243E 06 CM**3

	1)	2)	3)	4)	5)	6)
DECAY	1.005934E 18	4.087109E 17	9.066927E 17	5.019818E 17	0.0	5.019818E 17
FISSION	9.102245E 19	2.855001E 19	9.102245E 19	6.247244E 19	5.672440E 19	5.747517E 18
CAPTURE	1.078351E 20	1.762959E 19	1.078351E 20	9.020650E 19	9.020655E 19	0.0
TOTAL	1.998635E 20	4.658330E 19	1.997642E 20	1.531909E 20	1.469314E 20	6.249404E 18

ZONE NUMBER 4 SYSTEM ZONE VOLUME TIMES VOLUME FRACTION 1.150243E 06 CM**3

	1)	2)	3)	4)	5)	6)
DECAY	7.062793E 17	2.841014E 17	6.364353E 17	3.523339E 17	0.0	3.523339E 17
FISSION	6.398401E 19	2.006296E 19	6.398401E 19	4.397105E 19	3.997986E 19	4.041198E 18
CAPTURE	7.710527E 19	1.260324E 19	7.710527E 19	6.450203E 19	6.450203E 19	0.0
TOTAL	1.417555E 20	3.295024E 19	1.416957E 20	1.087356E 20	1.043849E 20	4.393531E 18

ZONE NUMBER 5 SYSTEM ZONE VOLUME TIMES VOLUME FRACTION 1.150274E 06 CM**3

	1)	2)	3)	4)	5)	6)
DECAY	7.359905E 17	2.970004E 17	6.658452E 17	3.684046E 17	0.0	3.684046E 17
FISSION	6.655483E 19	2.098390E 19	6.655483E 19	4.561093E 19	4.137040E 19	4.240527E 18
CAPTURE	7.319159E 19	1.160325E 19	7.319159E 19	5.878835E 19	5.878835E 19	0.0
TOTAL	1.374850E 20	3.264422E 19	1.374119E 20	1.047677E 20	1.001580E 20	4.609412E 18

ZONE NUMBER 6 SYSTEM ZONE VOLUME TIMES VOLUME FRACTION 1.150274E 06 CM**3

	1)	2)	3)	4)	5)	6)
DECAY	5.173993E 17	2.081199E 17	4.660176E 17	2.578986E 17	0.0	2.578986E 17
FISSION	4.668403E 19	1.468312E 19	4.668403E 19	3.196113E 19	2.898677E 19	2.974565E 18
CAPTURE	4.997458E 19	8.116528E 19	4.997458E 19	4.105406E 19	4.105036E 19	0.0
TOTAL	9.713636E 19	2.300776E 19	9.709503E 19	7.407726E 19	7.084402E 19	1.232463E 18

ZONE NUMBER 7 SYSTEM ZONE VOLUME TIMES VOLUME FRACTION 9.411190E 05 CM**3

	1)	2)	3)	4)	5)	6)
DECAY	3.175155E 16	1.274666E 16	2.861257E 16	1.586591E 16	0.0	1.586591E 16
FISSION	3.932693E 18	1.027102E 18	3.932693E 18	2.805592E 18	2.660836E 18	1.447560E 17
CAPTURE	3.779231E 19	6.406169E 18	3.779231E 19	3.130614E 19	3.130614E 19	0.0
TOTAL	4.165675E 19	7.526316E 18	4.165365E 19	3.412754E 19	3.396698E 19	1.606226E 17

ZONE NUMBER 8 SYSTEM ZONE VOLUME TIMES VOLUME FRACTION 9.411190E 05 CM**3

	1)	2)	3)	4)	5)	6)
DECAY	7.761027E 15	3.112268E 15	6.991610E 15	3.879345E 15	0.0	3.879345E 15
FISSION	9.520969E 17	2.413049E 17	9.520968E 17	7.107879E 17	6.825159E 17	2.827203E 16
CAPTURE	1.601123E 19	2.751722E 18	1.601123E 19	1.325951E 19	1.325951E 19	0.0
TOTAL	1.697109E 19	2.996163E 18	1.697332E 19	1.397818E 19	1.394203E 19	3.215117E 16

ZONE NUMBER 9 SYSTEM ZONE VOLUME TIMES VOLUME FRACTION 9.411080E 05 CM**3

	1)	2)	3)	4)	5)	6)
DECAY	2.933742E 16	1.177502E 16	2.643596E 16	1.466015E 16	0.0	1.466015E 16
FISSION	3.547353E 18	9.459011E 17	3.547359E 18	2.601857E 18	2.470107E 18	1.313502E 17
CAPTURE	3.485251E 19	5.983623E 18	3.485251E 19	2.886890E 19	2.886893E 19	0.0
TOTAL	3.842923E 19	6.941300E 18	3.842630E 19	3.148502E 19	3.133900E 19	1.463101E 17

ZONE NUMBER 10 SYSTEM ZONE VOLUME TIMES VOLUME FRACTION 9.411083E 05 CM**3

	1)	2)	3)	4)	5)	6)
DECAY	6.607376E 15	2.681126E 15	6.023782E 15	3.342657E 15	0.0	3.342657E 15
FISSION	8.210726E 17	2.070084E 17	8.210726E 17	6.148663E 17	5.911788E 17	2.369552E 16
CAPTURE	1.396497E 19	2.400511E 18	1.396497E 19	1.156888E 19	1.156888E 19	0.0

```
TOTAL       1)  1.479353E 19   2)  2.610220E 18   3)  1.479207E 19   4)  1.218265E 19   5)  1.215562E 19   6)  2.702810E 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)  8.580467E 15   5)  0.0            6)  8.580467E 15
FISSION     1)  2.088548E 18   2)  5.479607E 17   3)  2.088548E 18   4)  1.540507E 18   5)  1.468226E 18   6)  7.236133E 16
CAPTURE     1)  2.177250E 19   2)  3.741122E 18   3)  2.177250E 19   4)  1.803187E 19   5)  1.803187E 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)  1.550484E 15   3)  3.484487E 15   4)  1.933999E 15   5)  0.0            6)  1.933999E 15
FISSION     1)  4.775195E 17   2)  1.188860E 17   3)  4.775305E 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)  7.055020E 18   5)  7.055020E 18   6)  0.0
TOTAL       1)  9.001550E 18   2)  1.585150E 18   3)  9.001173E 18   4)  7.416315E 18   5)  7.401314E 18   6)  1.473009E 16

ZONE NUMBER    13     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   6.145690E 05 CM**3
DECAY       1)  3.850852E 16   2)  1.545456E 16   3)  3.469909E 16   4)  1.924452E 16   5)  0.0            6)  1.924452E 16
FISSION     1)  4.462637E 18   2)  1.239916E 18   3)  4.462637E 18   4)  3.422721E 18   5)  3.251951E 18   6)  1.707715E 17
CAPTURE     1)  4.003667E 19   2)  7.314100E 18   3)  4.003667E 19   4)  3.302250E 19   5)  3.302250E 19   6)  0.0
TOTAL       1)  4.553701E 19   2)  8.269470E 18   3)  4.553400E 19   4)  3.726454E 19   5)  3.707453E 19   6)  1.905165E 17

ZONE NUMBER    14     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   6.145690E 05 CM**3
DECAY       1)  2.519842E 16   2)  1.010824E 16   3)  2.270218E 16   4)  1.259305E 16   5)  0.0            6)  1.259305E 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)  2.880910E 19   2)  4.957640E 18   3)  2.880910E 19   4)  2.389151E 19   5)  2.389151E 19   6)  0.0
TOTAL       1)  3.193692E 19   2)  5.773480E 18   3)  3.193483E 19   4)  2.616595E 19   5)  2.604151E 19   6)  1.199390E 17

ZONE NUMBER    15     SYSTEM ZONE VOLUME TIMES VOLUME FRACTION   5.028291E 05 CM**3
DECAY       1)  6.838818E 15   2)  2.739251E 15   3)  6.155693E 15   4)  3.416846E 15   5)  0.0            6)  3.416846E 15
FISSION     1)  8.408423E 17   2)  2.116887E 17   3)  8.438420E 17   4)  6.291872E 17   5)  6.050837E 17   6)  2.415357E 16
CAPTURE     1)  1.296959E 19   2)  2.230284E 18   3)  1.296959E 19   4)  1.073939E 19   5)  1.073939E 19   6)  0.0
TOTAL       1)  1.381727E 19   2)  2.448594E 18   3)  1.381659E 19   4)  1.137200E 19   5)  1.134441E 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)  1.738903E 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)  1.820383E 17   5)  1.766501E 17   6)  5.388261E 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)  5.364056E 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)  8.918870E 15   2)  3.575311E 15   3)  8.033290E 15   4)  4.457978E 15   5)  0.0            6)  4.457978E 15
FISSION     1)  1.094868E 18   2)  2.764431E 17   3)  1.396368E 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)  3.315365E 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)  7.416890E 17   2)  1.949838E 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   5.028123E 05 CM**3
DECAY       1)  2.300148E 15   2)  9.218560E 14   3)  2.071802E 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)  2.169195E 17   5)  2.103461E 17   6)  6.552811E 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)  8.378851E 14   2)  3.355752E 14   3)  7.544905E 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)  8.326366E 16   5)  7.826303E 16   6)  2.050671E 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)  4.884796E 24   4)  2.705439E 24   5)  0.0            6)  2.705439E 24
FISSION     1)  4.950808E 26   2)  1.548733E 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)  6.419833E 26   6)  0.0
```

```
TOTAL      1)   1.269069E 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   9.102205E 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

PHSTE   9.999995E-25   9.987859E-25
THSTE   0.0            3.750000E 01   7.500000E 01
THSTS   0.0

        SUMMARY OF CALCULATION

    EXPLICIT CHAIN - EXPOSURE
      SIGNIFICANCE EVENTS ENCOUNTERED                  10


     MAX ARRAY SIZE USED     5010 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         NSCL  =     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         NBASS =       1
 NGOP1 =        0         NGOP2 =       0
 NGOP3 =        0         NGOP4 =       0
 NGOP5 =        0

MEMORY SETUP FOR GEODST PROCESSING     600 ALLOWING FOR      96 POINTS (     348      295      216      630)

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  =  1.0123477 00 POWER  =  2.5000008 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

 NGOSP  =  0 NOSBPP =  0

MEMORY ACTUALLY USED WILL BE     3213

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


START OF STEP ATOM DENSITIES AT TIME    0.0            DAYS


POINT NUMBER      1
U235A       2.206999E-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        9.058490E-03
CR-A        2.610700E-03  FE-A         9.705596E-03  NI-A         1.378300E-03  TA181A       9.999999E-11

POINT NUMBER      2
U235A       2.206999E-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        9.058490E-03
CR-A        2.610700E-03  FE-A         9.705596E-03  NI-A         1.378300E-03  TA181A       9.999999E-11

POINT NUMBER      3
U235A       2.206999E-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        9.058490E-03
```

06-49

CR-A	2.618700E-03	FE-A	9.785596E-03	NI-A	1.378300E-03	TA181A	9.999998E-11

POINT NUMBER 4

U235A	2.206999E-05	U238A	7.504299E-03	PU239A	8.677100E-04	PU240A	3.353599E-04
PU241A	6.021500E-05	PU242A	2.559100E-05	O16A	1.760000E-02	NA23A	9.058498E-03
CR-A	2.618700E-03	FE-A	9.785596E-03	NI-A	1.378300E-03	TA181A	9.999998E-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	9.999998E-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	9.999998E-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	9.999998E-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	9.999998E-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	6.948737E-07	U238A	7.484726E-03	PU239A	8.787159E-04
PU240A	3.410962E-04	PU241A	6.163090E-05	PU242A	2.607709E-05	O16A	1.760000E-02
NA23A	9.058490E-03	CR-A	2.618700E-03	FE-A	9.785596E-03	NI-A	1.378300E-03
XE135A	8.270309E-08	PM147A	2.179683E-06	PM148MA	2.104961E-08	PM148A	6.829359E-10
SM149A	1.197680E-06	NSFPA	1.260025E-04	SSFPA	1.095820E-06	TA181A	9.999998E-11

POINT NUMBER 2

U235A	2.066878E-05	U236A	6.953860E-07	U238A	7.484476E-03	PU239A	8.795100E-04
PU240A	3.410631E-04	PU241A	6.162714E-05	PU242A	2.607575E-05	O16A	1.760000E-02
NA23A	9.058490E-03	CR-A	2.618700E-03	FE-A	9.785596E-03	NI-A	1.378300E-03
XE135A	8.293673E-08	PM147A	2.190191E-06	PM148MA	2.116196E-08	PM148A	8.875307E-10
SM149A	1.203803E-06	NSFPA	1.266855E-04	SSFPA	1.101016E-06	TA181A	9.999998E-11

POINT NUMBER 3

U235A	2.050714E-05	U236A	5.315480E-07	U238A	7.396610E-03	PU239A	8.805413E-04
PU240A	3.423970E-04	PU241A	6.149079E-05	PU242A	2.611296E-05	O16A	1.760000E-02
NA23A	9.058490E-03	CR-A	2.618700E-03	FE-A	9.785596E-03	NI-A	1.378300E-03
XE135A	8.621806E-08	PM147A	2.351339E-06	PM148MA	2.351781E-08	PM148A	9.562777E-10
SM149A	1.296567E-06	NSFPA	1.363106E-04	SSFPA	1.182786E-06	TA181A	9.999998E-11

POINT NUMBER 4

U235A	2.050045E-05	U236A	5.320303E-07	U238A	7.396474E-03	PU239A	8.804409E-04
PU240A	3.423665E-04	PU241A	6.148459E-05	PU242A	2.611108E-05	O16A	1.760000E-02
NA23A	9.058490E-03	CR-A	2.618700E-03	FE-A	9.785596E-03	NI-A	1.378300E-03

XE135A	8.6461112E-08	PM147A	2.3601868E-06	PM148MA	2.3665537E-08	PM148A	9.6252812E-10
SM149A	1.3009791E-06	NSPPA	1.3705068E-04	SSPPA	1.1890988E-06	TA181A	9.999999E-11
POINT NUMBER 5							
U235A	2.1668111E-05	U236A	5.0239831E-07	U238A	7.7851588E-03	PU239A	9.9896472E-04
PU240A	3.8948652E-04	PU241A	7.0309778E-05	PU242A	2.9719788E-05	O16A	1.8693008E-02
NA23A	8.0031972E-03	CR-A	2.6993008E-03	FE-A	1.0086608E-02	NI-A	1.4206008E-03
XE135A	8.8002708E-08	PM147A	2.8552858E-06	PM148MA	2.3361908E-08	PM148A	9.2863278E-10
SM149A	1.3471618E-06	NSPPA	1.4197678E-04	SSPPA	1.2139108E-06	TA181A	9.999999E-11
POINT NUMBER 6							
U235A	2.1906228E-05	U236A	4.4707028E-07	U238A	7.7565318E-03	PU239A	9.9428938E-04
PU240A	3.9858628E-04	PU241A	7.0511238E-05	PU242A	2.9658868E-05	O16A	1.8693008E-02
NA23A	8.0031978E-03	CR-A	2.6993008E-03	FE-A	1.0086608E-02	NI-A	1.4206008E-03
XE135A	8.2828558E-08	PM147A	2.1993368E-06	PM148MA	1.9689018E-08	PM148A	7.6021808E-10
SM149A	1.2019678E-06	NSPPA	1.2667288E-04	SSPPA	1.1084938E-06	TA181A	9.999999E-11
POINT NUMBER 7							
U235A	2.1889068E-05	U236A	5.4064798E-07	U238A	7.7160248E-03	PU239A	9.9519558E-04
PU240A	3.8997348E-04	PU241A	7.0130808E-05	PU242A	2.9759098E-05	O16A	1.8693008E-02
NA23A	8.0031978E-03	CR-A	2.6993008E-03	FE-A	1.0086608E-02	NI-A	1.4206008E-03
XE135A	5.1977678E-08	PM147A	2.6525128E-06	PM148MA	2.6189398E-08	PM148A	1.0572378E-09
SM149A	1.4604378E-06	NSPPA	1.5360608E-04	SSPPA	1.3337198E-06	TA181A	9.999999E-11
POINT NUMBER 8							
U235A	2.1787988E-05	U236A	4.9250438E-07	U238A	7.7490628E-03	PU239A	9.9488958E-04
PU240A	3.8905058E-04	PU241A	7.0358048E-05	PU242A	2.9643598E-05	O16A	1.8693008E-02
NA23A	8.0031978E-03	CR-A	2.6993008E-03	FE-A	1.0086608E-02	NI-A	1.4206008E-03
XE135A	8.6800358E-08	PM147A	2.3779838E-06	PM148MA	2.2155568E-08	PM148A	8.7295508E-10
SM149A	1.3034298E-06	NSPPA	1.3722368E-04	SSPPA	1.1981978E-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)   4.331073E 02       3)   4.661381E 02       4)   4.688579E 02

   2) ZONE      1 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)   4.852709E 02       2)   4.331047E 02       3)   5.255000E 02       4)   4.692642E 02

INTERFACE FILE RTFLUX 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     165

NORMAL END OF EXPOSURE MODULE
```

```
CASE TITLE -  BREEDER REACTOR SAMPLE PROBLEM FOR THE BURNER CODE

RITE CONTAINED ARRAYS, CONTROL        6 DATA        1

          GROUPS 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     1700

STORAGE REQUIRED FOR BASIC DATA IS     1678

        STORAGE SUPPLIED IS     10000
MAXIMUM STORAGE REQUIRED IS      5911
MINIMUM STORAGE REQUIRED IS      3165

 MODRR  =  0 MODRPP =  0

MEMORY ACTUALLY USED WILL BE     5911

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    2.499996E 09 WATTS, MAXIMUM POWER DENSITY    4.716111E 02 WATTS/CC IN ZONE              3   AT START OF SUBSTEP     1
POWER    2.506058E 09 WATTS, MAXIMUM POWER DENSITY    4.707558E 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    9.951683E-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              1   AT START OF SUBSTEP     2
POWER    2.499570E 09 WATTS, MAXIMUM POWER DENSITY    4.677825E 02 WATTS/CC IN ZONE              1     AT END OF SUBSTEP     2

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

INVENTORY AND REACTION RATES BY ABSOLUTE NUCLIDE

		START OF STEP TIME	75.000 DAYS				END OF STEP TIME	150.000 DAYS			
NO.	NAME	INVENTORY (KG)	ABSORPTION	FISSION	PRODUCTION	CAPTURE (N,G)	INVENTORY (KG)	ABSORPTION	FISSION	PRODUCTION	CAPTURE (N,G)
1	U235	1.96964E 02	1.19611E-02	9.12009E-03	2.23466E-02	2.84099E-03	1.90497E 02	1.12115E-02	8.55935E-03	2.09709E-02	2.67219E-03
2	U236	1.63146E 00	4.35660E-05	5.48041E-06	1.47234E-05	3.80064E-05	3.13491E 00	8.28111E-05	1.03725E-05	2.78659E-05	7.24307E-05
3	U238	6.74490E 04	5.25610E-01	4.87300E-02	1.32047E-01	4.76904E-01	6.71563E 04	5.23089E-01	4.81659E-02	1.31256E-01	4.71943E-01
4	PU239	2.84906E 03	3.13500E-01	2.47155E-01	7.20982E-01	6.63528E-02	2.93935E 03	3.16991E-01	2.49725E-01	7.32482E-01	6.72660E-02
5	PU240	1.98367E 03	4.06193E-02	1.86057E-02	5.65096E-02	2.19340E-02	1.09826E 03	4.11146E-02	1.89091E-02	5.71853E-02	2.22955E-02
6	PU241	1.99713E 02	2.92249E-02	2.48088E-02	7.37734E-02	4.81613E-03	1.92763E 02	2.82475E-02	2.39791E-02	7.13064E-02	4.26819E-03
7	PU242	8.33457E 01	2.59108E-03	1.12250E-03	3.81953E-03	1.46930E-03	8.43423E 01	2.61947E-03	1.13438E-03	3.45573E-03	1.48508E-03
8	O16	9.57692E 03	2.14057E-03	0.0	0.0	2.14057E-03	9.57662E 03	2.13570E-03	0.0	0.0	2.13570E-03
9	NA23	1.07873E 04	1.11900E-03	2.73721E-07	3.47444E-07	1.11877E-03	1.07873E 04	1.11650E-03	2.73109E-07	5.46219E-07	1.11627E-03
10	CR	1.41975E 04	1.03466E-02	8.74113E-07	1.74923E-06	1.03457E-02	1.41915E 04	1.03235E-02	8.72157E-07	1.74411E-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	8.59618E-06	1.71883E-05	3.61522E-02
13	NI	8.43019E 03	1.02570E-02	3.73429E-08	7.46957E-08	1.02570E-02	8.43019E 03	1.02340E-02	3.72591E-08	7.45187E-08	1.02340E-02
14	XE135	5.72171E-02	1.30661E-07	0.0	0.0	1.30661E-07	5.72242E-02	1.39813E-07	0.0	0.0	1.39813E-07
15	PM147	3.20527E 00	4.36565E-04	3.63504E-09	7.27094E-09	4.36520E-04	6.10237E 00	8.27993E-04	6.87042E-08	1.37560E-07	8.27925E-04
16	PM148M	2.46570E-02	2.00321E-04	0.0	0.0	2.00321E-04	5.91921E-02	4.43569E-04	0.0	0.0	4.43569E-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	1.34026E-07	2.14401E-04	1.55941E 00	4.33275E-04	3.34120E-07	6.68257E-07	4.29941E-04
19	NSFP	0.0	2.30557E-01	0.0	0.0	2.30557E-01	0.0	4.67325E-01	0.0	0.0	4.67325E-01
20	SSFP	0.0	1.69199E-04	0.0	0.0	1.69199E-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	6.37400E-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 8
101	0.1262376	0.1586086	0.0009564	0.0021291	0.0149973	0.0002663	0.0000000	0.0007170
102	0.1277906	0.1501803	0.0009939	0.0019593	0.0133804	0.0002310	0.0000000	0.0007364
103	0.0927221	0.0953911	0.0007186	0.0008793	0.0088031	0.0001871	0.0000000	0.0004904
104	0.0027242	0.0410753	0.0000035	0.0000303	0.0035642	0.0001335	0.0	0.0000467
105	0.0022169	0.0166619	0.0000027	0.0000230	0.0010557	0.0001013	0.0	0.0000436
106	0.0010701	0.02.5311	0.0000010	0.0000091	0.0018616	0.0000612	0.0	0.0000272
107	0.0021462	0.0410372	0.0000022	0.0000214	0.0023141	0.0000804	0.0	0.0000452
108	0.0096784	0.0178463	0.0000094	0.0000027	0.0010316	0.0000174	0.0	0.0000111
109	0.0	0.0	0.0	0.0	0.0029010	0.0090407	0.0	0.0
110	0.0	0.0	0.0	0.0	0.0055467	0.0000756	0.0	0.0
	----------	----------	----------	----------	----------	----------	----------	----------
SUM	0.3555809	0.5637210	0.0026604	0.0053516	0.0567910	0.0011170	0.0000090	0.0031182

ZONE CLASS ID.	ABSORPTION LOSSES	FISSILE INVENTORY (KG) 75.000 DAYS	FISSILE INVENTORY (KG) 150.000 DAYS	EFFECTIVE CONVERSION RATIO REACTION RATE	EFFECTIVE CONVERSION RATIO MASS BALANCE	POWER (WATTS)
101	0.3035116	4.7732725 02	4.8290028 02	1.07770	1.06923	8.765327E 08
102	0.2952624	9.9267015 02	9.9151668 02	0.99350	0.98404	9.909236E 08
103	0.1987020	1.1091519 03	1.1026815 03	0.85557	0.84602	6.661610E 08
104	0.0479776	4.2299008 01	6.3109978 01	14.70775	14.04156	2.265726E 07
105	0.0421960	4.1021368 01	6.0205098 01	15.99673	14.19066	1.959589E 07
106	0.0255603	3.0509098 01	4.6261298 01	26.30496	20.51076	1.5735478 07
107	0.0456311	5.4507162 01	9.2610898 01	18.27503	18.02551	2.165422E 07
108	0.0195011	4.7027068 01	5.6994058 01	25.99019	26.29155	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	3.2447168 03	3.1226098 03	1.39627	1.38589	2.099999E 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 3.110215E-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 2.099887E 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)	3.901573E 22	1	7.901793E 22	1
MAXIMUM FLUENCE (RANGE 1)	(NEUTRONS/CM**2)	2.762232E 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	1.974991E 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)	5.501069E 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)	1.544606E 26	3)	4.950064E 26	4)	3.405370E 26	5)	3.097207E 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)	1.268302E 27	2)	2.037707E 26	3)	1.267846E 27	4)	9.844757E 26	5)	9.505293E 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 2.005950E 20 EV/(SEC-CM**3) AT ZONE 1

SUMMARY OF CALCULATION

EXPLICIT CHAIN - EXPOSURE
SIGNIFICANCE EVENTS ENCOUNTERED 10

MAX ARRAY SIZE USED 5810 WORDS - FOR ZONE CALCULATION

06-56

```
AUXILIARY POINT CALCULATION HAS BEEN REQUESTED

REFERENCE ZONE NUMBERS FROM PTATOW
     1)        1        2)        3

MEMORY AVAILABLE FOR GEOBST PROCESSING     8310

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

MEMORY USED FOR GEODST PROCESSING      348 ACTUAL POINTS       0 (      348      295      216      248)

MAXIMUM ARRAY SIZE USED FOR INITIAL PROCESSING IS    2038

STORAGE REQUIRED FOR BASIC DATA IS    1718

        STORAGE SUPPLIED IS     10300
MAXIMUM STORAGE REQUIRED IS      3213
MINIMUM STORAGE REQUIRED IS      2331

 NODUP  =  0 NODUPP =  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   4.231681E 02 AT POINT      2

POWER DENSITY
     1)   4.791135E 02       2)   4.231681E 02       3)   5.181877E 02       4)   4.579207E 02

INTERFACE FILE PWDINT VERSION  2 (NEW) HAS BEEN WRITTEN ON UNIT  32  WITH DENSITIES AT TIME   1.550000E 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 3

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

WITH CONTAINER ARRAYS, CONTROL 6 DATA 1

GRUPIS 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 4

NO.	NOBB	NOSS	NABSOL	NABSOL	NCLAS	ICLAS
1	1	1	1	C	5	1
2	2	2	2	I-135	4	2
3	3	3	3	XE-135	4	1
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	RECYCL	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	4	2.9299990E-07
2)	I-135	7	2.8699990E-05
3)	XE-135	8	2.0899990E-05
4)	PM-147	9	8.3699990E-09
5)	PM-148	10	1.4899990E-06
6)	PM148M	11	1.9799990E-07
7)	PM-149	12	3.6299997E-06

FISSION PRODUCT YIELD DATA

ENERGY RANGE 1 CUTOFF AT 0.0 EV

FISSIONING NUCLIDE

FISSION PRODUCT			1) TH-232 1	2) U-233 3	3) U-235 5
1)	I-135	7	0.053900	0.056200	0.061700
2)	XE-135	8	0.002100	0.002200	0.002300
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	0.998000	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                                                                   3
 6)              (N,G)        1.000000                                        2
 7)   U-234                                                                   4
 8)              (N,G)        1.000000                                        2
 9)   U-235                                                                   5
10)              (N,G)        1.000000                                        2
11)   U-236                                                                   6
12)     END CHAIN      1                                                      0
     START CHAIN      2     LENGTH IS    10            13   22
13)  TH-232                                                                   1
14)              (N,G)        1.000000                                        2
15)  PA-233                                                                   2
16)              (N,G)        1.000000                                        2
17)   U-234                                  ADDED CONTRIBUTION              -4
18)              (N,G)        1.000000                                        2
19)   U-235                                  ADDED CONTRIBUTION              -5
20)              (N,G)        1.000000                                        2
21)   U-236                                  ADDED CONTRIBUTION              -6
22)     END CHAIN      2                                                      0
     START CHAIN      3     LENGTH IS     4            23   26
23)   I-135                                                                   7
24)              DECAY        1.000000                                        1
25)  XE-135                                                                   8
26)     END CHAIN      3                                                      0
     START CHAIN      4     LENGTH IS     8            27   34
27)  PM-147                                                                   9
28)              (N,G)        0.530000                                   530302
29)  PM-148                                                                  10
30)              (N,G)        1.000000                                        2
31)  PM-149                                                                  12
32)              DECAY        1.000000                                        1
33)  SM-149                                                                  11
34)     END CHAIN      4                                                      0
     START CHAIN      5     LENGTH IS     8            35   42
35)  PM 147                                                                   9
36)              (N,G)        0.470000                                   470302
37)  PM148M                                                                  11
38)              (N,G)        1.000000                                        2
39)  PM-149                                  ADDED CONTRIBUTION             -12
40)              DECAY        1.000000                                        1
41)  SM-149                                  ADDED CONTRIBUTION             -13
42)     END CHAIN      5                                                      0
     START CHAIN      6     LENGTH IS     2            43   44
43)  ND-143                                                                  14
44)     END CHAIN      6                                                      0
     START CHAIN      7     LENGTH IS     4            45   48
45)     FP1                                                                  15
46)              (N,G)        1.000000                                        2
47)     FP2                                                                  16
48)     END CHAIN      7                                                      0
49)     END OF CHAIN SPECIFICATIONS                                           0


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

 NCSEP  =  0 NODUMP = -1

MEMORY ACTUALLY USED WILL BE     9594

INTERFACE FILE RBURN VERSION    1 UNIT  31
 TIME   =  1.200700E 04 POWER  =  7.499996E 03
 VOL    =  1.010896E 03 EPPR   =  1.000000E 00
 ETPS   = -8.013446E-06 DPDS   =  0.0
 THL    =  4.001155E 14 THA    =  5.307242E 14
 TEEL   =  3.657917E 13 TEPL   =  1.601155E 13
 TMRAT  =  0.0          TNCRA  =  0.0
 PC     =  5.000000E-04 CRIT   =  9.900000E-01
 V3     =  1.000000E 00 X0     =  0.0
 ITPS   =        1      NZONE  =     23
 NGROUP =        4      NCY    =      0

REFLUX REFERENCE TIME     11999.9961 DAYS INDICATOR        1

INTERFACE FILE ZNATRN VERSION    2 UNIT  30
 TIME   =  1.200000E 04
 NCY    =        0      NTZSZ  =     57
 NNS    =       17      NOLRAD =      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   1.499999E 09 WATTS

                             AVERAGE POWER   1.499930E 09 WATTS FOR PASS      1
               MAXIMUM AVERAGE POWER DENSITY   4.579769E 01 WATTS/CC IN ZONE           10
               MAXIMUM AVERAGE POWER DENSITY   1.271795E 01 WATTS/CC IN SUBZONE        18

        INITIAL REACTION RATES WILL BE MULTIPLIED BY   1.000039E 00 FOR NEXT PASS              1.000080E 00

        REFERENCE POWER LEVEL HAS BEEN ATTAINED

     FEED DENSITIES FOR ZONE PATH    1

TH-232     2.099999E-04   U-235     6.104359E-05    C        7.999999E-02


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

TH-232     2.320042E-04  PA-233     1.202737E-07   U-233     6.559322E-06   U-234     1.205601E-06
 U-235     6.356485E-06   U-236     8.848609E-06    C        7.999990E-02   I-135     1.360332E-10
```

XE-135	1.011962E-13	PM-147	2.251089E-07	PM-148	8.389602E-10	PM148M	1.379773E-09
PM-149	2.064805E-13	SM-149	1.716079E-09	ND-143	1.788326E-06	FP1	5.305361E-05
FP2	2.019046E-08						

FEED DENSITIES FOR ZONE PATH 2

TH-232	2.499999E-04	U-235	9.106359E 05	C	7.999990E-02

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

TH-232	2.305659E-04	PA-233	1.233819E-07	U-233	6.649600E-06	U-234	1.519055E-06
U-235	7.402157E-06	U-236	1.172935E-05	C	7.999990E-02	I-135	1.303289E-10
XE-135	9.667309E-11	PM-147	2.223380E-07	PM-148	8.329999E-10	PM148M	1.359222E-09
PM-149	2.756013E-10	SM-149	1.646361E-09	ND-143	2.106997E-06	FP1	7.295753E-05
FP2	2.792669E-08						

FEED DENSITIES FOR SUBZONE PATH 1

TH232	8.999999E-04	C	8.999907E-02

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

TH232	8.658839E-04	PA-233	2.384967E-07	U-233	1.216016E-05	U-234	2.451223E-06
U-235	4.721726E-07	U-236	8.167031E-08	C	6.999987E-02	I-135	1.251422E-10
XE-135	9.203212E-11	PM-147	1.213409E-07	PM-148	2.358872E-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	6.959790E-05						

FEED DENSITIES FOR SUBZONE PATH 2

TH232	8.999990E-04	C	6.999997E-02

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

TH232	8.590766E-04	PA-233	2.277776E-07	U-233	1.229953E-05	U-234	3.000601E-06
U-235	7.553666E-07	U-236	1.339761E-07	C	6.999987E-02	I-135	1.202339E-10
XE-135	9.512703E-11	PM-147	1.336994E-07	PM-148	2.539102E-10	PM148M	7.923070E-10
PM-149	2.359005E-10	SM-149	1.225545E-09	ND-143	9.101078E-07	FP1	2.310328E-05
FP2	8.966257E-05						

AVERAGE POWER 1.699983E 09 WATTS PER PASS 2
MAXIMUM AVERAGE POWER DENSITY 8.579808E 01 WATTS/CC IN ZONE 10
MAXIMUM AVERAGE POWER DENSITY 1.271062E 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	1.39670E-06	1.48250E-06	0.0	0.0	0.0	0.0
3	XE-135	0.0	0.0	1.03450E-06	1.09981E-05	0.0	0.0	0.0	0.0
4	PM-147	0.0	0.0	2.34003E-03	1.60906E-03	0.0	0.0	0.0	0.0
5	PM148M	0.0	0.0	1.57137E-05	9.93802E-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	1.09912E-01	2.20558E-03	0.0	0.0	0.0	0.0
9	FP2	0.0	0.0	2.10541E 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	8.49824E 00	1.00367E 01	8.18199E 00	9.26602E 00	0.0	0.0	0.0	0.0
12	PA-233	0.0	0.0	2.27901E-03	4.60290E-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	1.37806E-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	1.55549E-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	RECYC	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 00 2) 6.575926E 00

TOTAL POWER (WATTS) FOR ZONE PATHS 1.080818E 01

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) 2.071965E 02

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

POWER (WATTS) FOR EACH SUBZONE PATH
1) 1.501758E 00 2) 2.689930E 00

TOTAL POWER (WATTS) FOR SUBZONE PATHS 4.191695E 00

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 4.176307E 01

INVENTORY AND REACTION RATES BY ABSOLUTE NUCLIDE

NO.	NAME	INVENTORY (KG)	ABSORPTION	FISSION	PRODUCTION	CAPTURE (N,G)
1	C	1.75016E 05	1.15822E-02	0.0	0.0	1.08290E-02
2	I-135	2.20970E-02	1.70242E-10	0.0	0.0	7.07680E-12
3	XE-135	5.38170E-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	6.02516E-02	7.54910E-03	0.0	0.0	7.54910E-03
8	U-236	1.66000E 02	1.28942E-02	7.28164E-05	1.94564E-04	1.28210E-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	1.67025E 04	2.47505E-01	8.66875E-04	2.06983E-03	2.36601E-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	1.60602E-01	4.02265E-01	2.00836E-02
14	U-234	1.81727E 01	9.76300E-03	5.47075E-05	1.46996E-04	9.70828E-03
15	U-235	5.31791E 02	3.06095E-01	2.44550E-01	5.94910E-01	6.15341E-02
16	PR-145	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	HE	1.53145E 02	5.13360E-05	0.0	0.0	4.80740E-05
19	PPCVEL	8.55331E 00	1.84921E-03	0.0	0.0	1.84923E-03
		-----------	-----------	-----------	-----------	-----------
	TOTALS	1.96616E 05	9.09216E-01	4.06275E-01	9.99704E-01	5.02068E-01

OTHER LOSS RATE 4.07837E-02
TOTAL LOSS RATE 1.30100E 00
SYSTEM LOSS RATE(N/SEC) 1.17657E 20
RELATIVE FLUX LEVEL 1.00004E 00

06-65

SUMMARY TABLES FOR EXPOSURE ENDING AT TIME 1.3000000E 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 1.1765468E 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	0.0035480	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 FRACTION RATE	POWER (WATTS)
1	0.8990026	0.57082	1.4880237E 09
2	0.0038379	21.19359	5.1102068E 05
3	0.0063784	17.19588	1.0899568E 06
	----------	-----------	-------------
OVERALL	0.9092189	0.59670	1.4899937E 09
OTHER LOSSES	0.0907851		

TOTAL LOSSES	1.0000000		

EFFECTIVE CONVERSION RATIO FROM MASS BALANCE 0.59748

FISSILE INVENTORY IS 8.9069C48 02 KG

FISSILE CONSUMPTION PER UNIT ENERGY GENERATION IS 1.5108848E-14 KG/WATT-SEC
FISSILE CONSUMPTION RATE IS 2.2721978E-05 KG/SEC

INTERFACE FILE ZNATOM VERSION 2 (OLD) HAS BEEN WRITTEN ON UNIT 30 WITH DENSITIES AT TIME 1.3000000E 04 DAYS

ZONE POWER DENSITY

1)	2.9856092E 01	2)	3.7316648E 01	3)	3.2506598E 01	4)	2.3723758E 01	5)	1.5985617E 01
6)	1.0112668E 01	7)	5.7394858E 00	8)	2.1269638E 00	9)	3.8697028E 01	10)	4.5788848E 01
11)	3.7170918E 01	12)	2.5356698E 01	13)	1.6194878E 01	14)	9.9424928E 00	15)	5.5422228E 00
16)	2.0376128E 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)	1.0996358E-01	2)	1.7759638E 00	3)	6.3379298E 00	4)	1.0222648E 01	5)	1.1718118E 01
6)	1.0597638E 01	7)	8.1156928E 00	8)	5.1648128E 00	9)	2.0133018E 00	10)	2.1601048E-01
11)	2.1566098E 00	12)	7.0296468E 00	13)	1.1492988E 01	14)	1.2718628E 01	15)	1.1218988E 01
16)	8.8678828E 00	17)	5.3168858E 00	18)	2.0017378E 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 1.4899918E 09

INTERFACE FILE RZFLUX VERSION 1 (NEW) HAS BEEN WRITTEN ON UNIT 31

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

```
PNSTY    1.0000398-24
TNSTE    1.2000000E 04    1.3000000E 04
TNSTS    0.0
```

```
        SUMMARY OF CALCULATION

    EXPLICIT CHAIN - EXPOSURE
      SIGNIFICANCE EVENTS ENCOUNTERED                 48


     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 16, 1978 - QUALITY ASSURANCE LEVEL 3
--------------------------------------------------------------------------------------------------

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

SIZE CONTAINED ARRAYS, CONTROL       6 DATA       1

          GROUPS 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    1368

         STORAGE SUPPLIED IS    10300
MAXIMUM STORAGE REQUIRED IS     9363
MINIMUM STORAGE REQUIRED IS     2699

 MODPR  =  0 MODPFP = -1

MEMORY ACTUALLY USED WILL BE    9363

SHUTDOWN TIME STEP STARTS AT   1.500000E 03  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 ZNATOM VERSION  4 (OLD) HAS BEEN WRITTEN ON UNIT  30  WITH DENSITIES AT TIME   1.500400E 03  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    0.130 MINUTES     TOTAL I/O USED     156

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	0.719396-08	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)	PRIMARY CHAINS (15)		(8 NUCLIDES)	(6 NUCLIDES)
	(1 STEP)	(1 STEP)	(4 STEPS)	(2 STEPS)	(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 α 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.

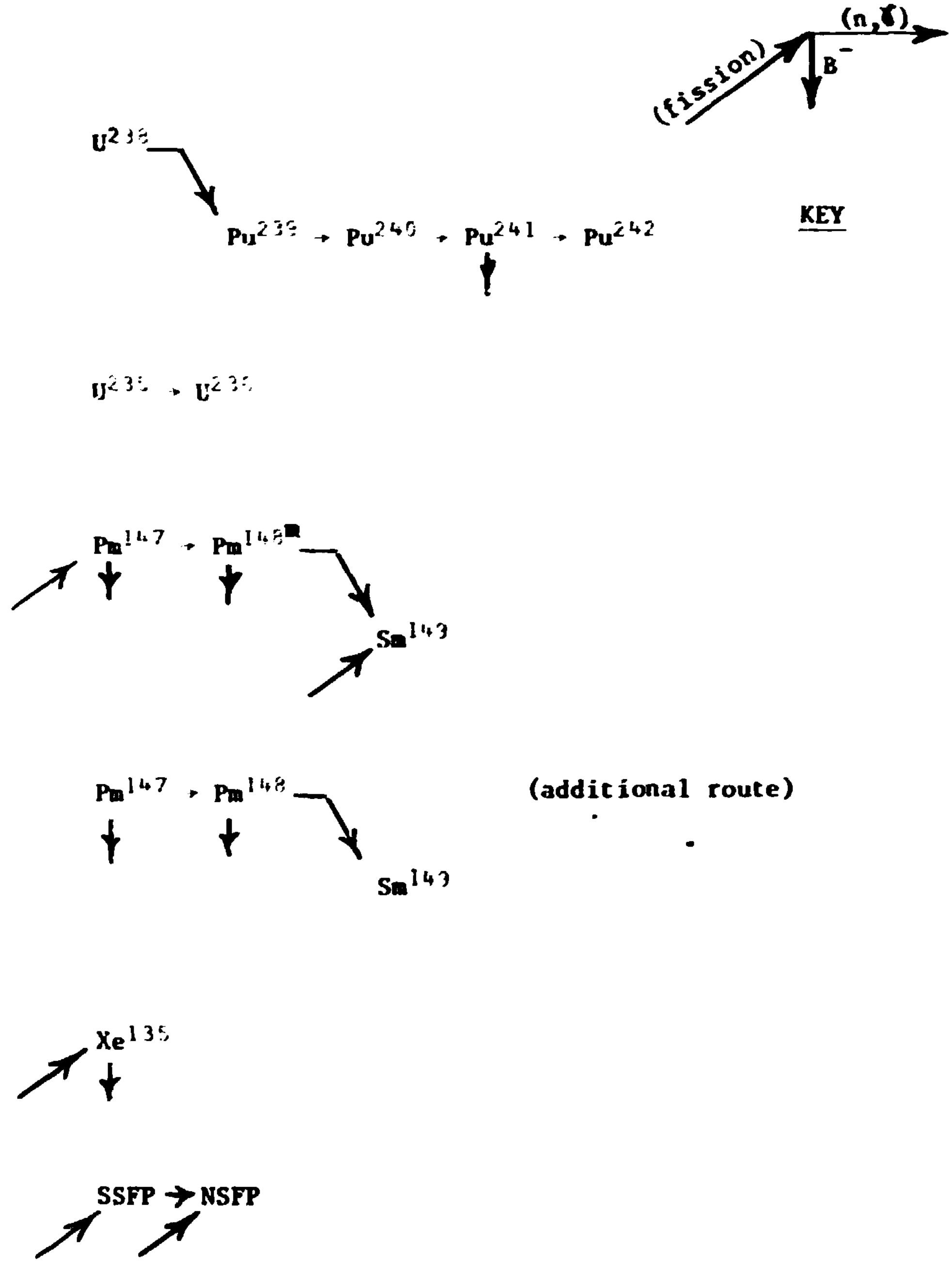


Figure 06-2. Nuclide Chains for the Second Sample Problem

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),

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

where ℓ refers to an identified fissile nuclide,

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

ϕ_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 σ_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 Δ each, $\Delta = T/L$.

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

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

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

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 α 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

$$N_n(T) = N_n(0)e^{-a_n T} + Y_n\left(\frac{1-e^{-a_n T}}{a_n}\right) \qquad (08\text{-}10)$$

$$+ \sum_j \sum_{i=1}^{n-1} [N_i(0)Q_{j,n,i} + Y_{j,i}U_{j,n,i}] \ ,$$

where

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

and

$$U_{j,n,i} = \left[\frac{1-e^{-a_n T}}{a_n}\right] \prod_{m=i}^{n-1} \frac{b_{j,m\to m+1}}{a_m}$$

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

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 Δ, 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;

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

$$= I - \Delta A[I - \frac{\Delta}{2} A[I - \frac{\Delta}{3} A[I - \ldots]]] \quad (08\text{-}14)$$

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

$$AN = - \dot{N} \quad (08\text{-}15)$$

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

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

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

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

for an exposure period Δ 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

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

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

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

$$H_j = -\left(\frac{1}{j}\right) E H_{j-1} \ ,$$

$$M_j = M_{j-1} + H_j \ . \qquad (08\text{-}18)$$

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 Δa_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

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

$$A e^{-\alpha \Lambda} Z = - \frac{d}{dt} [e^{-\alpha \Lambda} Z] \; ,$$

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

where $B = (A - \alpha)$;

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

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

$$\alpha = \frac{1}{2} \max a_n \qquad (08\text{-}20)$$

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

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

$$M_0 = N(0) \ ,$$

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

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

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

Then

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

$$H_i = F_i E_i \text{ , and} \quad (08\text{-}21)$$

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

The solution $N(\Delta) = M_I e^{-\alpha\Delta}$ is obtained upon truncation at required convergence, $I = J/2 + 1$. 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 $e^{\lambda L}$ 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→n) and all ℓ having coupling (n→ℓ), replace all (n→ℓ) 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

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

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

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 $(a_n \cdot)$ 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 $a_n\Delta \ll 1$.

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	0.417145	0.419777	0.419655
$N_3(T)$	0	0.073686	0.111757	0.110979	0.111158
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 α although this may be obvious for this simple case; increasing the value of α 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.

<u>Shutdown and Negative Exposure Step</u>

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

$$B(n+1) = \frac{1}{2} B(n) \cdot n+1 - \frac{1}{P_o} [n \bar{P}_n + \frac{1}{2} P_E(n)] , \tag{08-23}$$

where

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

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 Δ. The flux values are initially weighted by the formulation

$$\Phi(\Delta) = \Phi(t) + A[\Phi(t+\ell) - \Phi(t)] \ , \qquad (08\text{-}24)$$

where A is determined as[a]

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

where t+ℓ 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+ℓ 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

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

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

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, σ 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

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

where B is a solution matrix dependent on Δ, 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,

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

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.

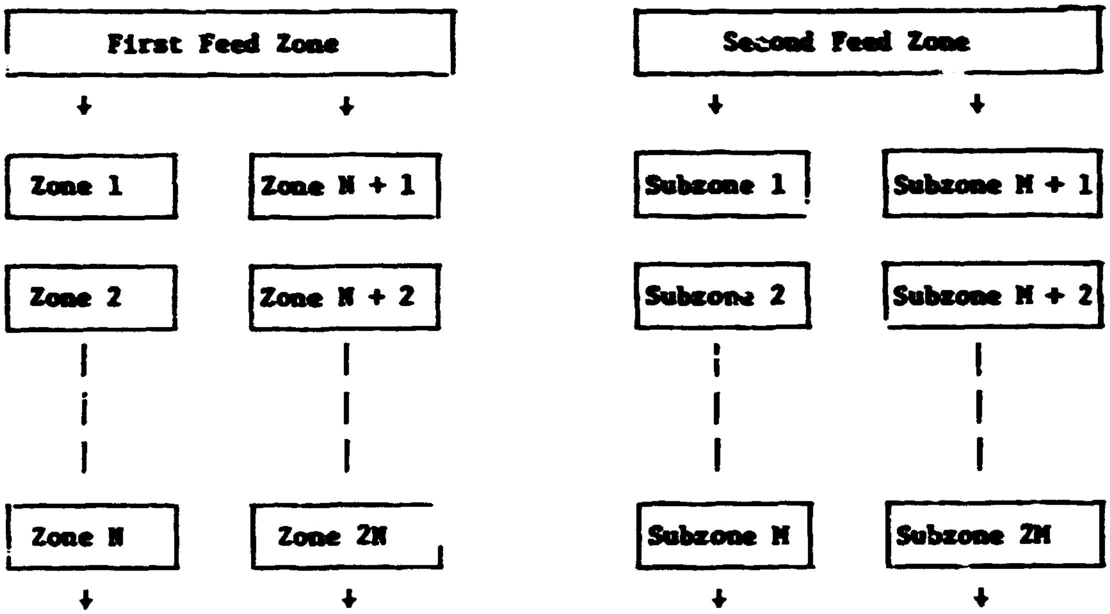
It is noted that the overall flux, eigenvalue, and nuclide concentration distribution problem which must usually be solved involves iteration; successive neutronics and exposure calculations are performed with parameter changes made to drive the problem to a steady-state solution. A simple criticality 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.

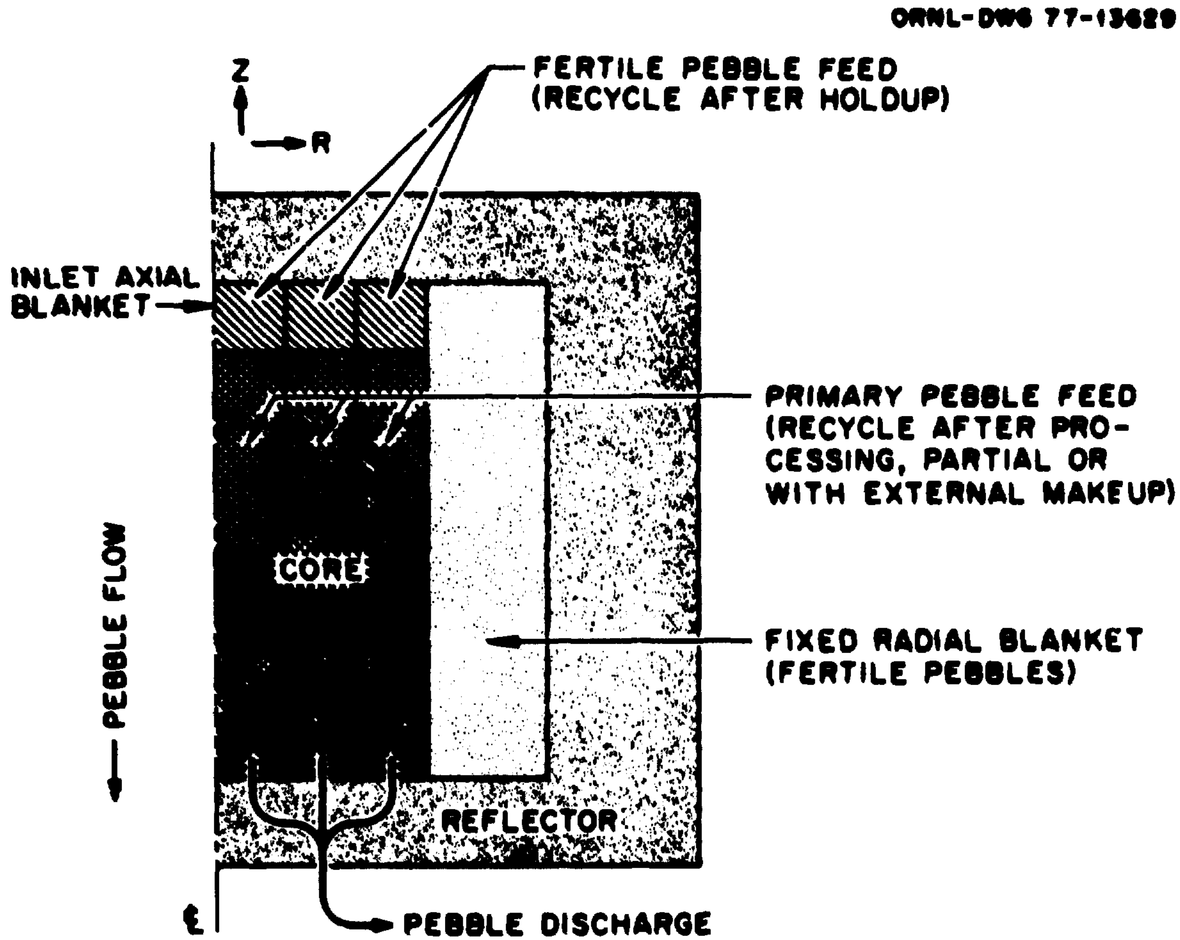
The multi-dimensional problem is a direct extension of the one-dimensional problem with provision for more than one path of material passing through the core. Residence time along each path may be specified.

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



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

$$N_n(\psi) = N_n(T) + F\,[N_n(0) - N_n(T)] \;, \tag{08-30}$$

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.

<u>Integrals</u>

Basic mass balance data and gross absorption and power generation integrals are always edited for the exposure period. Integrated reaction rates are quite straightforward sums of the local contributions times volumes using zone average flux values.

Mass balances are reported in kgms,

$$Q_n = \frac{A_n}{602.25} \sum_z V_z \left\{N_{n,z} + \sum_{sz} \frac{V_{sz}}{V_z} N_{n,sz}\right\} \tag{08-31}$$

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

$$R_{n,x} = \sum_z \{N_{n,z} + \sum_{sz} \frac{V_{sz}}{V_z} N_{n,sz}\} \sum_g \bar{\phi}_{g,z} \sigma_{x,n,g}$$

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

$\bar{\phi}_{g,z}$ 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,

$$F(z,i,T) = \sum_{\Delta\epsilon T} \Delta \sum_{g\epsilon i} \bar{\phi}_{z,g} , \qquad (08\text{-}34)$$

where Δ is an interval of time in period T, $\Sigma\Delta = T$, wi[illegible]r interpolation done within the cut-off group on the basis of le[illegible]dth.

Similarly, atomic destruction by fission is determined [illegible]

$$D(z,T) = \sum_{\Delta\epsilon T} \Delta \sum_{n} N_{n,z} \sum_{g} \sigma_{f,n,g} \bar{\phi}_{z,g} , \qquad (08\text{-}35)$$

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:

$$\sigma(T) = \sigma(T_1) + X [\sigma(T_2) - \sigma(T_1)] , \qquad (08\text{-}36)$$

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 α is supplied,

$$X = \frac{\tan^{-1}(\alpha\gamma)}{\tan^{-1}(\alpha)} , \qquad (08\text{-}37)$$

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)