UCRL 7477

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**RHOBURN: A NUCLEAR REACTOR CODE
FOR CALCULATING BURNUP AND
OPERATIONAL PARAMETERS FOR THE LPTR**

Livermore, California

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UCRL-7477

Reactor Technology, UC-80
TID-4500 (20th Ed.)

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Livermore, California

Contract No. W-7405-eng-48

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Gordon V. Pefley, Jr.

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Printed in USA. Price \$1.00. Available from the
Office of Technical Services
U. S. Department of Commerce
Washington 25, D.C.

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ABSTRACT

RHOBURN is a nuclear reactor code that determines various parameters for the Livermore Pool Type Reactor using a matrix of 840 cells, stored in two-dimensional form. The code calculates the burnup of U^{235} on the basis of the megawatt days run during a fuel cycle and as a function of the neutron flux and fuel inventory in each of the 840 homogeneous cells in the reactor core. The thermal utilization and various other parameters for each core, and values for calculating the reactivity change between different cores can also be obtained. RHOBURN is written in Fortran for the IBM 7094, to be run under monitor control.

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I. INTRODUCTION

RHOBURN is a nuclear reactor code that determines various parameters for the Livermore Pool Type Reactor (LPTR)¹ using a matrix of 840 cells, stored in two-dimensional form. The code calculates the burnup of U^{235} on the basis of the megawatt days run during a fuel cycle and as a function of the neutron flux and fuel inventory in each of the 840 homogeneous cells in the reactor core. The thermal utilization and various other parameters for each core, and values for calculating the reactivity change between different cores can also be obtained. RHOBURN is written in Fortran for the IBM 7094, to be run under monitor control.

Description of Livermore Pool Type Reactor (LPTR)

The LPTR is a tank type, thermal, heterogeneous, research reactor facility located at the Livermore Site of the Lawrence Radiation Laboratory. The core consists of a 5×7 array of 18-plate 93% enriched MTR type standard fuel elements, 9-plate special fuel elements, beryllium reflector elements, and a sample irradiation element. The active length of the fuel in both the standard and special fuel elements is 23-5/8 inches. Moderation and cooling is obtained by forced circulation of light water. Control is achieved with four boron-carbide shim safety rods and one stainless steel regulating rod.

The core loading for normal 2-MW, three-shift operation is maintained around 3.5 kg of U^{235} . Aluminum is the primary structural material in the core.

Reason for Developing RHOBURN

In the past few years of operation of the LPTR, it has become evident that a more efficient method of calculating burnup, investigating reactor parameters, and maintaining an inventory of fuel elements could be developed by using the computer facility available at the Lawrence Radiation Laboratory. The previous hand calculational method for determining the burnup of U^{235} in the reactor core gave increasingly inaccurate results as the operating time of the reactor increased. The inaccuracies were due to the simplifying assumptions made to facilitate the hand calculations, such as uniform fuel distribution and uniform flux distribution over the entire reactor core. These simplifying assumptions became less valid as the maximum fuel burn was increased from 15 to 25%, as a result of the change from two to three shift operation. The introduction in March 1962 of new elements of 189 grams in place of the 169-gram elements which had been used previously also added an additional problem for hand calculation.

By this time, the techniques of mapping the flux throughout the reactor core by use of copper wire activation had become greatly improved, and a large amount of flux data for the beginning and end of a number of cycles was available.

The grid plate of the reactor core has 35 positions in a 5×7 array. The typical core loading can be seen in Fig. 1. A large amount of the flux data had been taken in 24 increments along the active length of the fuel, and from this, the matrix was fixed at $5 \times 7 \times 24 = 840$ cells.

II. GENERAL DESCRIPTION OF RHOBURN

RHOBURN is written in Fortran to be run on the IBM 7094 under monitor control. Calculations are based on a matrix of 840 cells. The 840 cells are stored in the computer in two-dimensional form. One dimension consists of the position of the element in the grid plate, which has $5 \times 7 = 35$ positions. The second dimension corresponds to the height above the grid plate, which has 24 positions. A third dimension is reserved as a core configuration variable to allow cell-by-cell comparison between two different cores. The element position number is denoted by the variable J, the height by the variable K and the core configuration by the variable L. J varies from 1 to 35, as shown in Fig. 2. K varies from 1 to 24 with the top of the core corresponding to $K = 1$. L must be equal to 1 at present; however, this variable was

Fig. 1. Typical core loading for the LPTR.

GLL-639-2067

Fig. 2. Assignment of J values.

carried throughout the code in order to provide for future modifications. Each uranium fuel element is assigned a number I, in the range from 1 to 100. A beryllium reflector element is assigned an I of 250. The sample irradiation element is assigned an I of 820.

Burnup of U^{235}

The calculation of the distribution of the burnup of U^{235} in the reactor core was the primary reason for the inception of this code. The total burnup in the core in each fuel cycle^{2,3} is found by multiplying the number of megawatt days (obtained from the integrating megawatt-day recorder) by 1.287, the number of grams burned per megawatt day. The power is determined by monitoring the N^{16} activity in the primary coolant.⁴ The N^{16} activity is normalized, at equilibrium xenon concentration, to the power level determined from the primary coolant flow rate and the change in temperature between the inlet and outlet of the primary coolant stream.

The unnormalized flux values are found from measurements of the activation of copper wires of 0.064-in. diameter irradiated throughout the reactor core. The measurements that are presently used to provide the best

average for the fuel cycle are those taken at the equilibrium xenon condition.⁵

The flux values are normalized in the following manner: the average flux in the core, $\bar{\phi}_{\text{core}}$, is determined by:

$$\bar{\phi}_{\text{core}} = \frac{\text{CONST.} \times \text{POWER}}{M_{25_{\text{core}}}}, \quad (1)$$

where

CONST. is a constant with a value of $2.186 \times 10^{16} \text{ g/cm}^2 \cdot \text{sec} \cdot \text{MW}$,

POWER is the power in MW, and

$M_{25_{\text{core}}}$ is the total mass of U^{235} in the core in grams.

The normalized flux values $\phi(L, K, J)$ can then be found from the values of the copper wire activations, $D(L, K, J)$, from the following relationship:

$$\phi(L, K, J) = \frac{D(L, K, J) \times \bar{\phi}_{\text{core}} \times N}{\sum_{K, J} D(L, K, J)}, \quad (2)$$

where

N is the number of cells containing fuel.

The burnup of U^{235} in grams per cycle for each cell, $B(L, K, J)$, is then calculated from:

$$B(L, K, J) = \frac{\phi(L, K, J) \times M_{25}(L, K, J) \times B_{\text{TOT}}}{\sum_{K, J} M_{25}(L, K, J) \times \phi(L, K, J)}, \quad (3)$$

where

$M_{25}(L, K, J)$ is the mass in grams of U^{235} in cell L, K, J at the start of the cycle, and

B_{TOT} is the total number of grams of U^{235} burned in the cycle.

Thermal Utilization

The thermal utilization is calculated for the beginning and end of each fuel cycle in four different ways. At present there is some question regarding which of these values of thermal utilization accurately reflects the

physical condition of the core. The values of thermal utilization will be compared to the experimentally observed reactivity changes using the formula $\Delta\rho = \Delta f/f$.

The first calculated value of the thermal utilization is a gross approximation assuming a point-reactor core. This is calculated only as an interesting sidelight and is in the form

$$f_1 = \frac{M_{25_{\text{core}}}}{M_{25_{\text{core}}} + K_1 M_{\text{FP}} + K_2},$$

where

$M_{25_{\text{core}}}$ is the total mass of U^{235} in the core,

M_{FP} is the mass of the fission products,

K_1 is a constant equal to $\frac{\sigma_{\text{FP}}}{\sigma_{a_{25}}}$,

σ_{FP} is the cross section of the fission products,

$\sigma_{a_{25}}$ is the total absorption cross section of U^{235} , and

K_2 is a constant which is proportional to the absorption of the aluminum and water in the total core region, including the central sample irradiation element.

The flux in the central sample irradiation element is assumed to be the same as in D-3 ($J = 12$).

The second value of the thermal utilization is calculated in the same manner as f_1 , except that it is done for each fuel-containing cell in the reactor core plus the central sample irradiation element and weighted by the square of the flux:

$$f_2 = \frac{\sum_i f_i \phi_i^2}{\sum_i \phi_i^2}. \quad (5)$$

In this method, the proper value of K_2 to be used in the calculation of the f_i 's is one of two values, depending upon whether the cell under consideration is in a regular or a special element.

The third value of the thermal utilization is calculated in a different manner from the first two methods, as follows:

$$f_3 = \frac{\sum_i N_{25,i} \sigma_{25} \phi_i}{\sum_i \left[N_{25,i} \sigma_{25} + N_{25,i}^0 \sigma_0^{FP}(b) + N_{S,i} \sigma_S + N_{M,i} \sigma_M \right] \phi_i} \quad (6)$$

where

$N_{25,i}^0$ is the original U^{235} fuel number density in region i ,

$N_{25,i}$ is the present U^{235} fuel number density in region i ,

ϕ_i is the thermal neutron flux in region i ,

σ_{25} , σ_S , σ_M are the absorption cross sections for the U^{235} , the structural material, and the moderating material, respectively, and

$\sigma_0^{FP}(b)$ is the gross fission products absorption cross section per original fuel atom including U^{236} , as a function of the burnup b .

The Sm^{149} and Xe^{135} chains are not included in this calculation.

The value of the fission-product cross section is calculated for each cell from a sixth-degree polynomial which is a least-squares fit to the data of Hansen and Judge.⁶ The values obtained from this polynomial are valid in the range from 0 to 30% burnup.

The fourth method of calculating the thermal utilization is identical to the third with the exception that the weighting is by the second power of the flux instead of the first power.

$$f_4 = \frac{\sum_i N_{25,i} \sigma_{25} \phi_i^2}{\sum_i \left[N_{25,i} \sigma_{25} + N_{25,i}^0 \sigma_0^{FP}(b) + N_{S,i} \sigma_S + N_{M,i} \sigma_M \right] \phi_i^2} \quad (7)$$

All of these calculations assume that the flux in the fuel and in the moderator for each cell are the same (the disadvantage factor $\phi_M/\phi_F = 1$). Since the fuel is 93% enriched in U^{235} , the absorption of the U^{234} and U^{238} are considered to be negligible.

Fuel Inventory and Accounting

RHOBURN is also useful for calculating and displaying information concerning the fuel inventory at the LPTER. The inventory of the initial grams of U^{235} , the grams at the end of the cycle, and the percent burnup for each fuel element are listed in two ways. One is by increasing fuel element number which is useful for the Material Balance Accounting. The second lists the fuel elements in order of decreasing mass of U^{235} , which is convenient in the construction of future core configurations.

The total mass of U^{235} in the core, the core configuration, and several other useful items are displayed for easy reference. A sample output listing is shown in Appendix 2 for illustration.

III. RHOBURN OPERATION

The assembly of the RHOBURN program and data cards is shown in Fig. 3. A listing of the entire RHOBURN program written in Fortran, and a sample input problem is shown in Appendix 1. Below are the arrangement, format, and brief description of the control, program, and input data cards.

Control and Program Cards

1. Identification Card (Format in Monitor Manual).
2. Execution Card, Control Cards, and Comment Cards (Format in Monitor Manual).
3. RHOBURN.
4. Subroutine BURN.
5. Subroutine RHOMFP.
6. Subroutine ORDER.
7. Data Card (Format in Monitor Manual).

Input Data Cards

8. GI(I) Initial grams of U^{235} (cold and clean) for each fuel element, $I = 1, 100.$ (10F7.2)
9. CONST., POWER, GPMWD, SIGFP, (3E10.3, 3F7.2, 2F7.4)
SIGUT, HILLK2, FK2STD, FK2SPC
CONST. and POWER are the constants

GLL-639-2068

Fig. 3. Assembly of RHOBurn program and data cards.

used in Eq. (1). GPMWD is the number of grams of U^{235} burned per megawatt day. This value is used to calculate B_{TOT} as shown in Eq. (3).

SIGFP/SIGUT is the constant K_1 in Eq.

(4). HILLK2 is the constant K_2 in Eq.

(4). FK2STD and FK2SPC are the two values of K_2 as used in Eq. (5) that depend on whether the cell is in a standard or a special element.

10. C1, C2, C3, C4, C5, C6, ALH2OR,

(6E12.5)

ALH2OS, ALH2OC

C1, C2, C3, C4, C5, and C6 are the coefficients used for calculating the values of the fission-product cross sections as a function of burnup as found in Eqs. (6) and (7). The formula used is

$$\sigma_0^{FP}(b) = \sum_{i=1}^6 C_i b^i$$

ALH2OR, ALH2OS, and ALH2OC are the constants used for the aluminum plus water absorption terms in Eqs. (6) and (7) for a regular, special, and sample irradiation element, respectively. The calculations of f_3 and f_4 in RHOBURN are determined in a slightly different manner (though numerically equal) than that shown in Eqs. (6) and (7). In place of the fuel number density N_{25} , the weight in grams per cell, M_{25} , is used. The aluminum plus water absorption terms are then equal to

$$M_{Al} \frac{A^{235}}{A_{Al}} \sigma_{Al} + M_{H_2O} \frac{A^{235}}{A_{H_2O}} \sigma_{H_2O}$$

where M_{Al} , M_{H_2O} , A^{Al} , A^{H_2O} are the masses and mass numbers of aluminum and water, respectively. A^{235} is the mass number of U^{235} .

11. AA, BB

(2E12.6)

These are the constants used in the calculation

$$Y = \sum_i AA \times M_{25_i} \times \phi_i^2 + \sum_i BB \times M_{25_i} \times \phi_i^2.$$

This calculation was used in a primitive attempt to predict reactivity changes in the core.

12. L, LNUM, RMWD

(2I4, F10.5)

L must be equal to 1, and is presently only a dummy variable. It was carried throughout the code to provide for future modifications. LNUM is the cycle number, used for identification purposes only. RMWD is the number of megawatt days in cycle LNUM.

13. GS (L, K, I)

These values are the grams of U^{235} per cell at the start of the first cycle to be calculated by RHOBURN. If several cycles are to be calculated consecutively, the values of GS (L, K, I) for the start of each succeeding cycle are stored in the memory. At the end of the last cycle to be calculated, the final values of GS (L, K, I) can be punched out. This provides the input data to be used in succeeding calculations.

14. FUN (L, K, J) (12F6.3)

These are the unnormalized flux values in each cell that contains fuel.

15. ENPJ(L, J) (14F5.0)

The values of ENPJ(L, J) correspond to either a number of a fuel element with an I value in the range from (1-100), a number corresponding to the beryllium reflector elements (250), or a number corresponding to the sample irradiation element (820), for each of the J = 35 core locations. Any number > 100 is not used in the calculations, and is used for identification purposes only.

16. MOUT (M) (24F3)

This card determines which calculations are to be performed, and what the form of the optional output is to be. A positive integer in the field indicates the calculation is to be performed or the output is to be displayed. A zero or a blank field indicates no operation. There are 24 fields corresponding to MOUT (M) from 1 to 24, of which only 8 fields are presently in use.

MOUT (M)	Columns	
1	1-3	Call subroutine BURN
2	4-6	Write FUN (L, K, J)
3	7-9	---
4	10-12	Write PCTBJ (L, J)
5	13-15	---
6	16-18	Write Fuel Inventory
7	19-21	Punch GE (L, K, I)
8	22-24	Write GS (L, K, I)
9	25-27	Call subroutine ORDER
10	28-30	---
11	31-33	Call subroutine RHOMFP

Subroutine BURN is called when the burnup of each fuel element is to be determined for any core configuration.

The unnormalized flux values FUN (L, K, J) can be printed whenever desired.

PCTBJ (L, J) is the percent burnup of each fuel element in the reactor core at the end of the fuel cycle.

Fuel Inventory displays the element number, initial grams of U^{235} (cold and clean), grams of U^{235} at the end of the cycle, and percent burnup for the elements in numerical order from 1-100.

The values GE (L, K, I) can be punched out at the end of any cycle to provide the input data for succeeding problems.

The output obtained from subroutine ORDER differs from the Fuel Inventory output described above, only in the order of the fuel elements. This routine displays the fuel element inventory in descending order of the amount of fuel remaining in each element.

Subroutine RHOMFP calculates the four values for the thermal utilization at the beginning and at the end of each cycle. This subroutine also calculates various other data as shown in the sample output listing in Appendix 2.

17. NDPROB, NEWFUN

(214)

NDPROB states whether this is the last problem or not. A positive integer indicates that all problems have been completed, a negative integer that another problem follows. NEWFUN states whether the next problem requires new unnormalized flux values to be read as input data. A positive integer indicates new flux values are to be read. A negative integer indicates that no changes in the flux values are to be made.

A number of checks are made for internal consistency of the input data. If such an error is found, the values of the indices L, I, J, K and the fuel cycle number LNUM are printed on the output sheet, and the program is terminated. The output sheet will also print out an error number. The error numbers can be found in the right hand column of the program cards as shown in Appendix 1. This facilitates finding the location in the program where the error occurred, and from this knowledge, the error in the input data can more easily be found.

Sense switch 1 can be depressed to terminate the program before all the cycles have been calculated. The final GE (L, K, J) values are then printed and punched, in addition to the values of LNUM, L, I, J, and K, for the last cycle that has been calculated.

ACKNOWLEDGMENTS

I would like to express my appreciation to Ronald Fleming and Ernest Hill for their help and encouragement in the inception and development of this program. I would also like to thank Ray Jewell and the members of the Fortran Group for their assistance with coding and running RHOBURN. This work was done under the auspices of the U. S. Atomic Energy Commission.

REFERENCES

- ¹J. B. Radcliffe and E. E. Hill, The Livermore Pool Type Reactor, Lawrence Radiation Laboratory (Livermore) Rept. UCRL-4919 Rev. Nov., 1960 (unpublished).
- ²E. E. Hill and F. J. Shon, Fuel Programming in Pool-Type Research Reactors of Intermediate Power Level, Nucl. Sci. Eng. 11, 105 (1961).
- ³E. E. Hill, Fuel Management for an Intermediate Power Research Reactor, Lawrence Radiation Laboratory (Livermore) Rept. UCRL-7335 April, 1963 (unpublished).
- ⁴H. E. Kongsø, P. Z. Skanborg, and K. O. Nielsen, Power Measurements at the Danish Reactor DR 2 Based on N^{16} Activity of the Primary Coolant, Danish Atomic Energy Commission Research Establishment Risø, Rept. No. 29 July, 1961 (unpublished).
- ⁵S. A. Massey, Control Rod Calibration and Xenon Poisoning Studies at the LPTR, Lawrence Radiation Laboratory (Livermore) Rept. UCRL-7353 May, 1963 (unpublished).
- ⁶E. C. Hansen and F. D. Judge, Neutron-Flux-Spectrum Histories and Their Effect on Predicted Gross-Fission-Product Poisoning, Trans. ANS 5, 355 (1962).

APPENDIX 1 LISTING OF RHO BURN PROGRAM AND A SAMPLE INPUT PROBLEM

```

*IC 122PNK                                RHO BURN      FEFLEY      ECX 105
*E  RUN 15 MINUTES
*   XEC
*   PANIC                                DEC,*
*   LIST
*   CARES COLUMN
*   MAP
*   FORTRAN
C   LPTR RHO BURN PROBLEM
    CCMCN ERR,GI,FUN,GS,ENPJ,SUMGS,GSTCT,AFC,SUML,FCNUM,SUMUT,FNC,FXG
    ITCT,CBTCT,FNOXGS,GB,GBK,GBJKL,GE,GEK,GECYC,NCLT,GISTCT,FCTBCE,GECY
    2CT,GILJ,PCTBEL,PCTBJ,L,LNUM,RMWD,CONST,POWER,GPMWD,SUMRC1,SUMRC2,
    3SUMRC3,SUMRC4,SUMRC5,SUMRCT,AA,BB,GSDUP,SUMRC,SIGFP,SIGUT,HILLK2,FK
    4K2STC,FK2SPC,RFMF1,RFMF2,RFCMF3,RFFPF2,RFGBF2,SPHISC,FREFS,FREFE,
    5PCTBCS,C1,C2,C3,C4,ALH2CR,ALH2OS,C1,C2,C3,C4,C5,C6,FAVGS,FAVGE,
    6ALH2CC
    DIMENSION ERR(20),GI(100),FUN(2,24,35),GS(2,24,100),ENPJ(2,35)
    1,SUMGS(2,35),GSTOT(2),AFC(2),SUML(2,35),FCNUM(2),SUMUT(2),FNC(2,2
    24,35),FXCTCT(2),GBTCT(2),FNOXGS(2,35),GB(2,24,35),GEK(2,35),
    3GEJKL(2),GE(2,24,100),GEK(2,100),GECYC(2,35),NCLT(24),GISTCT(2),
    4PCTBCE(2),GECYCT(2),GILJ(2,35),PCTBEL(2,100),PCTBJ(2,35)
    5,SUMRC1(2,35),SUMRC2(2,35),SUMRC3(2,35),SUMRC4(2,35),SUMRC5(2,35),
    6SUMRCT(2),GSDUP(2,24,100),SUMRC(2),SPHISC(2),PCTBCS(2)
    1 FORMAT (2I4,F10.5)                                L,LNUM,R
    2 FORMAT (1CF7.2)                                    GI
    3 FORMAT (3E10.3,3F7.2,2F7.4)                      CCNSTPCW
    4 FORMAT (12F6.3)                                    FUN
    5 FORMAT (12F6.3)                                    GS,GEIK
    6 FORMAT (14F5.0)                                    ENPJ
    7 FORMAT (22H THIS IS FROM ERROR F3.C)              ERR(N)
    8 FORMAT (24I2)                                      NCLT
    9 FORMAT (42H1 GRAMS OF U235 IN CORE AT START OF CYCLE I4,4H IS F8.2
    1/43H THE CORE CONFIGURATION AT START OF CYCLE I4/45H E
    2 D C B A /(1X5F10.4))
    10 FORMAT (42H GRAMS OF U235 IN CORE AT START OF CYCLE I4/44H E
    1 D C B A /(1X5F10.4))
    11 FORMAT (2E12.6)                                    AA,EE
    12 FORMAT (6E12.5)
    13 FORMAT (3CH AT TIME OF ERROR, LNUM WAS I4,7H L WAS I4,7H I WAS I
    14,7H J WAS I4,7H K WAS I4)
    14 FORMAT (2I4)
    17 FORMAT (61H1 FOLLOWING ARE THE FLN(L,K,J) VALUES FOR THE START OF
    1 CYCLE I4/(2X12F8.3))
    CC 49C N = 1,20
    ERR(N) = N
49C CONTINUE
    READ INPUT TAPE 2, 2,(GI(I), I=1,100)
    READ INPUT TAPE 2,3,CONST,POWER,GPMWD,SIGFP,SIGUT,HILLK2,FK2STC,FK
    12SPC
    READ INPUT TAPE 2,12,C1,C2,C3,C4,C5,C6,ALH2CR,ALH2OS,ALH2CC
    READ INPUT TAPE 2,11,AA,BB
    READ INPUT TAPE 2, 1, L, LNUM, RMWD

```

```

      READ INPUT TAPE 2, 5, ((GS(L,K,I), K=1,24), I=1,100)
      READ INPUT TAPE 2, 4, ((FLN(L,K,J), K=1,24), J=1,35)
      READ INPUT TAPE 2, 6, (ENPJ(L,J), J=1,35)
535  DO 540 J = 1, 35
540  SUMGS(L,J) = C.
      DO 541 I=1,100
      GEK(L,I) = C.
      DO 541 K=1,24
541  GE(L,K,I) = C.
      DO 550 I=1,100
      K=1
      IF (GS(L,K,I)) 514, 547,543
543  DO 545 K=1,24
545  GEK(L,I) = GEK(L,I) + GS(L,K,I)
      GO TO 550
547  GEK(L,I) = G1(I)
550  CONTINUE
      GSTOT(L) = C.
      GISTOT(L) = C.
      DO 560 J=1,35
      IF (101. - ENPJ(L,J)) 560, 501, 552
552  K = 1
      I = ENPJ(L,J)
      IF (GS(L,K,I)) 502,556,554
554  DO 555 K=1,24
555  SUMGS(L,J)=SUMGS(L,J) + GS(L,K,I)
      GO TO 559
556  DO 558 K=1,24
      GS(L,K,I) = G1(I)/24.
558  SUMGS(L,J)=SUMGS(L,J) + GS(L,K,I)
559  GSTOT(L) = GSTOT(L) + SUMGS(L,J)
      GISTOT(L) = GISTOT(L) + G1(I)
560  CONTINUE
      AFC(L) = CONST * POWER / GS101(L)
      DO 580 J=1,35
      SUMU(L,J) = C.
580  GECYC(L,J)=C.
      FCNUM(L) = C.
      SUMUT(L) = C.
      DO 590 J=1,35
      K = 1
      IF (FUN(L,K,J)) 503,550,586
586  FCNUM(L) = FCNUM(L) + 1.0
      DO 588 K=1,24
588  SUML(L,J)=SUML(L,J) + FUN(L,K,J)
      SUMUT(L) = SUMUT(L) + SUML(L,J)
590  CONTINUE
      DO 600 J=1,35
      DO 600 K=1,24
      FNC(L,K,J)=FUN(L,K,J)*AFC(L)*FCNUM(L)*24./SUMUT(L)
600  CONTINUE
      DO 610 M=1,24

```

ERR (14)

ERR(1)

ERR(2)

ERR(3)

```

610 MCUT(M) = 0
    READ INPUT TAPE 2, 6, (MCUT(M), M=1,24)
    READ INPUT TAPE 2, 14, NUPROB, NEWFUN
640 IF (MCUT(1)) 911, 662, 661                                ERR (11)
661 CALL PURN
    GO TO 664
662 WRITE OUTPUT TAPE 3, 9, LNUM, GSTGT(L), LNUM, (ENPJ(L,J), J=1,35)
    WRITE OUTPUT TAPE 3, 10, LNUM, (SUMGS(L,J), J=1,35)
    IF (MCUT(2)) 911, 664, 663                                ERR (11)
663 WRITE OUTPUT TAPE 3, 17, LNUM, ((FUN(L,K,J), K=1,24), J=1,35)
664 IF (MCUT(3)) 911, 720, 665                                ERR (11)
665 GO TO 720
720 IF (MCUT(5)) 911, 730, 725                                ERR (11)
725 CALL ORDER
730 IF (MCUT(10)) 911, 740, 735                                ERR (11)
735 GO TO 740
740 IF (MCUT(11)) 911, 750, 745                                ERR (11)
745 CALL R-CONF
750 IF (MCUT(12)) 911, 800, 755                                ERR (11)
755 GO TO 800
800 LAST = L
    IF (SENSE SWITCH 1) 850, 805
805 IF (NDPRCB) 810, 999, 999
810 READ INPUT TAPE 2, 1, L, LNUM, RMV
    IF (NEWFUN) 820, 912, 815
815 READ INPUT TAPE 2, 4, ((FUN(L,K,J), K=1,24), J=1,35)
820 READ INPUT TAPE 2, 6, (ENPJ(L,J), J=1,35)
    IF (LAST - L) 913, 935, 913                                ERR (13)
850 PUNCH 5, ((GS(L,K,I), K=1,24), I=1,100)
    WRITE OUTPUT TAPE 3, 5, ((GS(L,K,I), K=1,24), I=1,100)
    WRITE OUTPUT TAPE 3, 13, LNUM, L, I, J, K
    GO TO 999
901 WRITE OUTPUT TAPE 3, 7, ERR(1)
    GO TO 999
902 WRITE OUTPUT TAPE 3, 7, ERR(2)
    GO TO 999
903 WRITE OUTPUT TAPE 3, 7, ERR(3)
911 WRITE OUTPUT TAPE 3, 7, ERR(11)
    GO TO 999
912 WRITE OUTPUT TAPE 3, 7, ERR(12)
    GO TO 999
913 WRITE OUTPUT TAPE 3, 7, ERR(13)
    GO TO 999
914 WRITE OUTPUT TAPE 3, 7, ERR(14)
    GO TO 999
995 WRITE OUTPUT TAPE 2, 13, LNUM, L, I, J, K
    CALL DUMP
999 CALL EXIT
    FNC
*   CARDS COLUMN
*   LIST
*   MAP

```

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* PANIC DEC,*
* FCRTAN
* PANIC DEC,*
* LIST
* CARES COLUMN
* MAP
* FCRTAN
SUBROUTINE BURN
COMMON ERR,C1,FUN,GS,ENPJ,SLMGS,GSTCT,AFC,SLML,FCNUM,SLMLT,FNC,FXC
1TCT,GBTCT,FNOXGS,GB,GBK,GBJKL,GE,GEK,GECYC,MCUT,GISTCT,PCTECE,GECY
2CT,GILJ,PCTBEL,PCTBJ,L,LNUM,RMWD,CONST,PWER,GPMWD,SUMRC1,SUMRC2,
3SUMRC3,SUMRC4,SUMRC5,SUMRCT,AA,BB,GSDLP,SUMRC,SIGFP,SIGUT,FILLK2,F
4K2STC,FK2SPC,RFMF1,RFMF2,RFCMF3,RFFFF2,RFCBF2,SPHISC,FREFS,FREFE,
5PCTBCS,C1,C2,C3,C4,ALH2OR,ALH2CS,C1,C2,C3,C4,C5,C6,FAVGS,FAVGE,
6ALH2CC
DIMENSION ERR(20),GI(100),FUN(2,24,35),GS(2,24,100),ENPJ(2,35)
1,SLMGS(2,35),GSTCT(2),AFC(2),SLML(2,35),FCNUM(2),SLMLT(2),FNC(2,2
24,35),FXCTCT(2),GBTCT(2),FNOXGS(2,35),GB(2,24,35),GEK(2,35),
3GBJKL(2),GE(2,24,100),GEK(2,100),GECYC(2,35),MCUT(24),GISTCT(2),
4PCTECE(2),GECYC(2),GILJ(2,35),PCTBEL(2,100),PCTBJ(2,35)
5,SUMRC1(2,35),SUMRC2(2,35),SUMRC3(2,35),SUMRC4(2,35),SUMRC5(2,35),
6SUMRCT(2),GSDLP(2,24,100),SUMRC(2),SPHISC(2),PCTBCS(2)
5 FORMAT (12F6.2)
7 FORMAT (22H THIS IS FROM ERROR F3.C) EFRIN)
9 FORMAT (/////////17H1 RHGBURN /42H GRAMS OF U235 IN CORE A
1T START OF CYCLE14,4H IS F8.3/28H THE GRAMS BURNED IN CYCLE14,4H
2 IS F9.3,11H , (CHECK =F9.3,11H)/52H THE PERCENT BURNUP OF THE CCR
3E AT START OF CYCLE 14,4H IS F7.3,36H PERCENT SINCE IT WAS COLD A
4ND CLEAN/52H THE PERCENT BURNUP OF THE CCR AT THE END OF CYCLE14
5,4H IS F7.3,36H PERCENT SINCE IT WAS COLD AND CLEAN//)
10 FORMAT (43H GRAMS OF U235 IN CORE AT START OF CYCLE 14/44H E
1 C C B A/(1X5F10.4))
11 FORMAT (41H GRAMS OF U235 IN CORE AT END OF CYCLE 14/ 44H E
1 C C B A/(1X5F10.4))
12 FORMAT (4CH GRAMS OF U235 BURNED IN EACH POSITION / 44H E
1 D C B A/(1X5F10.4))
13 FORMAT (3CH AT TIME OF ERROR, LNUM WAS 14,7H L WAS 14,7H I WAS I
14,7H J WAS 14,7H K WAS 14)
16 FORMAT (69H1 FOLLOWING IS THE STATUS OF THE FUEL ELEMENTS AT THE
1END OF CYCLE 14//58H ELEMENT INITIAL GRAMS GRAMS END CYCLE
2PERCENT BURN /(1X,14,8X,F7.2,10X,F8.3,8X,F7.3))
17 FORMAT (68H PERCENT BURN OF U235 IN EACH FUEL ELEMENT IN CORE AT
1END OF CYCLE 14/44H E D C B A/(1
2X5F10.4))
18 FORMAT (57H1 FOLLOWING ARE THE GS(L,K,I) VALUES FOR END OF CYCLE
1 14/(12F6.3))
19 FORMAT (35H CORE CONFIGURATION AT START OF CYCLE14/45H E
1 C C B A/(1X5F10.4))
FXCTCT(L) = C.
GEJKL(L) = C.
GBTCT(L) = RMWD * GPMWD
DO 500 I=1,100

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```

      CC 500 K=1,24
      GSCLP(L,K,I) = GS(L,K,I)
      GE(L,K,I) = GS(L,K,I)
500  CC CONTINUE
      CC 601 J=1,35
601  FNOXGS(L,J) = C.
      CC 619 J=1,35
      I = ENPJ(L,J)
      IF (101 - I) 619,619,602
602  CC 608 K = 1,24
      IF (GS(L,K,I)) 504, 605, 607
605  IF (FNO(L,K,J)) 505,619, 506
607  IF (FNO(L,K,J)) 507,508, 608
608  FNOXGS(L,J)=FNOXGS(L,J) + FNO(L,K,J)*GS(L,K,I)
      FXGTCT(L) = FXGTCT(L) + FNOXGS(L,J)
619  CONTINUE
      CC 621 J=1,35
      GBK(L,J)=C.
      CC 621 K=1,24
      GB(L,K,J) = C.
621  CC CONTINUE
      CC 630 J=1,35
      K = 1
      IF (FNO(L,K,J)) 509,628,624
624  I = ENPJ(L,J)
      IF (101 - I) 515,515,625
625  CC 627 K = 1,24
      GE(L,K,J) = FNO(L,K,J)*GS(L,K,I)*GB(L,K,J)/FXGTCT(L)
627  GBK(L,J) = GBK(L,J) + GB(L,K,J)
      CC TC 629
628  GBK(L,J)=C.
      CC TC 630
629  GBJKL(L) = GBJKL(L) + GBK(L,J)
630  CC CONTINUE
      GECYCT = C.
      CC 650 J=1,35
      IF (GBK(L,J)) 510, 650, 640
640  I = ENPJ(L,J)
      IF (101 - I) 516,516,642
642  CC 649 K = 1,24
      GE(L,K,I)=GS(L,K,I) - GB(L,K,J)
      GS(L,K,I)=GE(L,K,I)
649  GEK(L,I) = GEK(L,I) - GB(L,K,J)
      GILJ(L,J) = GI(I)
      GECYC(L,J) = GEK(L,I)
      GECYCT(L) = GECYCT(L) + GECYC(L,J)
650  CC CONTINUE
      PCTBCE(L) = C.
      PCTBCE(L) = (1. - GECYCT(L)/GISTCT(L))*100.
      PCIECS(L) = C.
      PCTBCE(L) = (1. - GSTOT(L)/GISTCT(L))*100.
      WRITE OUTPUT TAPE 3,9,LNUM,GSTOT(L),LNUM,GBTCT(L),GBJKL(L),LNUM,PC

```

ERR(4)
ERR(5,6)
ERR(7,f)

ERR(9)
ERR(15)

ERR(10)
ERR(16)


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1TECS(L),LNUM,PCTBCE(L)
WRITE OUTPUT TAPE 3,19,LNUM,(ENPJ(L,J),J=1,35)
WRITE OUTPUT TAPE 3, 10,LNUM,(SUMCS(L,J), J=1,35)
WRITE OUTPUT TAPE 3, 11,LNUM,(GECYC(L,J), J=1,35)
WRITE OUTPUT TAPE 3, 12,(GBK(L,J), J=1,35)
IF (MCUT(4)) 911,68C,675
675 CC 675 J=1,35
PCTEJ(L,J) = C.
PCTEJ(L,J) = (1. - GECYC(L,J)/GILJ(L,J))*100.
679 CC CONTINUE
WRITE OUTPUT TAPE 3, 17,LNUM,(PCTEJ(L,J), J = 1,35)
680 IF (MCUT(5)) 911,69C,685
685 CC TC 69C
690 IF (MCUT(6)) 911,70C,695
695 CC 697 I=1,100
697 PCTBEL(L,I) = (1. - GEK(L,I)/GI(I))*100.
WRITE OUTPUT TAPE 3,16,LNUM,(I,GI(I),GEK(L,I),PCTBEL(L,I),I=1,100)
700 IF (MCUT(7)) 911,71C,705
705 PUNCH 5, ((GS(L,K,I), K=1,24), I=1,100)
710 IF (MCUT(8)) 911,100C,715
715 WRITE OUTPUT TAPE 3,18,LNUM,((GS(L,K,I),K=1,24),I=1,100)
CC TC 100C
904 WRITE OUTPUT TAPE 3, 7, ERR(4)
CC TC 995
905 WRITE OUTPUT TAPE 3, 7, ERR(5)
CC TC 995
906 WRITE OUTPUT TAPE 3, 7, ERR(6)
CC TC 995
907 WRITE OUTPUT TAPE 3, 7, ERR(7)
CC TC 995
908 WRITE OUTPUT TAPE 3, 7, ERR(8)
CC TC 995
909 WRITE OUTPUT TAPE 3, 7, ERR(9)
CC TC 995
910 WRITE OUTPUT TAPE 3, 7, ERR(10)
CC TC 995
911 WRITE OUTPUT TAPE 3, 7, ERR(11)
CC TC 995
915 WRITE OUTPUT TAPE 3, 7, ERR(15)
CC TC 995
916 WRITE OUTPUT TAPE 3, 7, ERR(16)
CC TC 995
995 WRITE OUTPUT TAPE 3,13,LNUM,L,I,J,K
CALL COMP
999 CALL EXIT
100C RETURN
ENC
* PANIC DEC,*
* LIST
* CARDS COLUMN
* MAP
* FCRTAN

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SUBROUTINE ORDER
COMMON ERR,GI,FUN,GS,ENPJ,SUMGS,GSTCT,AFC,SUML,FCNUM,SUMUT,FNC,FXG
ITCT,GBTCT,FNOXGS,GB,GBK,GBJKL,GE,GEK,GECYC,PCUT,GISTCT,PCTBCE,GECY
ZCT,GILJ,PCTBEL,PCIBJ,L,LNUM,RMWD,CONST,POWER,GPMWD,SUMRC1,SUMRC2,
3SUMRC3,SUMRC4,SUMRC5,SUMRCT
DIMENSION NN(100)
DIMENSION ERR(20),GI(100),FUN(2,24,35),GS(2,24,100),ENPJ(2,35)
1,SUMGS(2,35),GSTCT(2),AFC(2),SUML(2,35),FCNUM(2),SUMUT(2),FNC(2,2
24,35),FXGTCT(2),GBTCT(2),FNOXGS(2,35),GB(2,24,35),GEK(2,35),
3GBJKL(2),GE(2,24,100),GEK(2,100),GECYC(2,35),PCUT(24),GISTCT(2),
4PCTBCE(2),GECYCT(2),GILJ(2,35),PCIBEL(2,100),PCTBJ(2,35)
5,SUMRC1(2,35),SUMRC2(2,35),SUMRC3(2,35),SUMRC4(2,35),SUMRC5(2,35),
6SUMRCT(2)
4 FORMAT (68H FOLLOWING IS THE STATUS OF THE FUEL ELEMENTS AT THE
1END OF CYCLE 14 /16H ELEMENT NUMBER 17H INITIAL
2GRAMS19H END CYCLE GRAMS19H PER CENT BURNUP/)
5 FORMAT (16H YOU MADE A BOOBGC)
6 FORMAT (311C)
7 FORMAT (1X,19,12X,F10.2,7X,F10.3,10X,F10.3)
DO 2 I=1,100
NN(I) = 1
2 CONTINUE
10 NUM = 0
DO 50 I=1,99
MEM1=NN(I)
MEM2=NN(I + 1)
IF (GEK(L,MEM1) - GEK(L,MEM2)) 3C,50,50
30 NN(I)=MEM2
NN(I + 1) = MEM1
NUM = NUM + 1
50 CONTINUE
IF (NUM) 901,51,10
51 WRITE OUTPUT TAPE 3,4,LNUM
DO 55 I = 1,100
MEM=NN(I)
WRITE OUTPUT TAPE 3, 7, MEM, GI(MEM),GEK(L,MEM),PCTBEL(L,MEM)
55 CONTINUE
CC TC 999
901 WRITE OUTPUT TAPE 3, 5
CC TC 995
995 WRITE OUTPUT TAPE 3, 6, LNUM, L, I
999 RETURN
END
* PANIC DEC,*
* LIST
* CARDS COLUMN
* MAP
* FLIRAN
SUBROUTINE RFORMP
COMMON ERR,GI,FLN,GS,ENPJ,SUMGS,GSTCT,AFC,SUML,FCNUM,SUMUT,FNC,FXG
ITCT,GBTCT,FNOXGS,GB,GBK,GBJKL,GE,GEK,GECYC,PCUT,GISTCT,PCTBCE,GECY
ZCT,GILJ,PCTBEL,PCTBJ,L,LNUM,RMWD,CONST,POWER,GPMWD,SUMRC1,SUMRC2,

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3SUMRC3,SUMRC4,SLMRC5,SUMRCT,AA,BB,GSOLP,SLMRC,SIGFP,SIGUT,HILLK2,F
4KZSTD,FK2SPC,RFMF1,RFMF2,RFCMF3,RFFPF2,RFGBF2,SPHISC,FREFS,FREFE,
5PCTECS,C1,C2,C3,C4,ALH2GR,ALH2CS,C1,C2,C3,C4,C5,C6,FAVCS,FAVCE,
6ALF2CC
  DIMENSION ERR(20), GI(100), FUN(2,24,35), GS(2,24,100), ENPJ(2,35)
1,SUMGS(2,35),GSTOT(2),AFC(2),SLML(2,35),FCALM(2), SLMUT(2),FNC(2,2
24,35), FXGTCT(2),GBTCT(2), FNCXGS(2,35),GE(2,24,35),GEK(2,35),
3GBJKL(2),GE(2,24,100),GEK(2,100),GECYC(2,35),MCLT(24),GISTCT(2),
4PCTBCE(2),GECYCT(2),GILJ(2,35),PCTBEL(2,100),PCTBJ(2,35)
5,SUMRC1(2,35),SUMRC2(2,35),SLMRC3(2,35),SLMRC4(2,35),SUMRC5(2,35),
6SLMRC(2),GSOLP(2,24,100),SLMRC(2),SPHISC(2),PCTECS(2)
1 FORMAT (119H THE PSEUDO K EFFECTIVE FOUND BY SUMMING M X PHI SQUA
1REC FOR M(U235) AND M(FISSION PRODUCTS), MULTIPLIED BY CONSTANTS/
26H AA = E12.6,1CH AND BB = E12.6,18H RESPECTIVELY, IS E12.6,23H AT
3 THE START OF CYCLE 14)
5 FORMAT (119H THE PSEUDO K EFFECTIVE FOUND BY SUMMING M X PHI SQUA
1REC FOR M(U235) AND M(FISSION PRODUCTS), MULTIPLIED BY CONSTANTS/
26H AA = E12.6,1CH AND BB = E12.6,18H RESPECTIVELY, IS E12.6,16H AT
3 END OF CYCLE 14/15H WHICH HAS RUN FIC.5,14H MEGAWATT DAYS)
6 FORMAT (63H THE TOTAL GRAMS BURNED HAS NOT BEEN CALCULATED FOR TH
1IS CYCLE)
7 FORMAT (5CH AT LEAST ONE OF THE CONSTANTS (AA OR BB) IS ZERO)
99 FORMAT (152H TRIFLES AND COMMENTS AS COLLECTED AT START OF CYCLE 14RF
1/2X22H TOTAL M(235) X PHI = E14.8/2X3CH TOTAL M(235) X PHI SQUARED RF
2 = E14.8/2X36H TOTAL M(235) X PHI CUBED X 1.0E-10 = E14.8/2X31H TCRF
3TAL M(F.P.) X PHI SQUARED = E14.8/61H GROSS THERMAL UTIL. = M(23RF
45)/M(235) + K1 X M(F.P.) + K2 = FIC.6/17H WHERE K1 = F10.6,1GRF
5H AND K2 = F10.3/67H AVERAGE THERMAL UTIL. = SUM(F X PHI SQUARED RF
6)/SUM(PHI SQUARED) = FIC.6/106H WHERE F IS CALCULATED FOR EACH
7CELL USING THE FORMULA FOR GROSS THERMAL UTILIZATION WITH THE CNS
8TANTS/12H K2(STD.)=F7.4,14H, K2(SPEC.) = F7.4,24H, AND K1 = SIGFP
9/SIGUT = F7.4)
100 FORMAT (37H TRIFLES AND COMMENTS AT END OF CYCLE 14,15H AFTER RUNN
1NG FIC.5,25H MEGAWATT DAYS THIS CYCLE/43H GRAMS BURNED THIS CYCL
2E X PHI SQUARED = E14.8/25H GROSS THERMAL UTIL. = F10.6/34H AV
3ERAGE THERMAL UTILIZATION = FIC.6)
101 FORMAT (7CH ALL OF THE VALUES CALCULATED FOR THE THERMAL UTILIZA
1TION FOR CYCLE 14,13H, ARE INVALID, /46H BECAUSE POSITION C-4 IS NO
2T OCCUPIED BY WATER )
102 FORMAT (113H REFINED THERMAL UTILIZATION = SUM(M(U235) X SIGMA X
1 PHI)/SUM(M(U235) X SIGMA X PHI + M(U235) X SIGMA(F.P.) / 33X,
237H + N X SIGMA (ALUMINUM + H2O)) PHI / 3CX,3H = E12.5 /
3 97H THE REFINED THERMAL UTILIZATION WEIGHTED BY THE FLUX SQUARE
4C INSTEAD OF THE FLUX AS ABOVE IS = E12.5)
103 FORMAT (33H REFINED THERMAL UTILIZATION = E12.5 /55H FLUX SQUA
1REC WEIGHTED REFINED THERMAL UTILIZATION = E12.5)
  IF (AA) 8,25,8
  IF (BB) 8,25,8
9 CONTINUE
RFMF1=0.
RFMF2=C.
RFCMF3=C.

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RF
RF

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RFFFF2 = C.
RFGCF2 = C.
SPFISQ = C.
SFF2S = C.
SFF2E = C.
SF2TCT = C.
SF212 = C.
FREFS = C.
FREFE = 0.
SMTCPS = C.
SMICPE = C.
SMECTS = C.
SMECTE = C.
SALF1C = C.
SALF2C = C.
SF12 = C.
SMTF2S = C.
SMTF2E = C.
SMFF2S = C.
SMFF2E = C.
FREF2S = C.
FREF2E = C.
HILLK1 = SIGFP/SIGUT
THMLUS = GSTOT(L)/(GSTOT(L) + (GISICT(L)-GSTOT(L))*(SIGFP/SIGUT) +
1HILLK2)
THMLUE = (GISICT(L) - GRICT(L))/(GSTOT(L) - GETCT(L) + (GISICT(L) -
1GSTOT(L) + GRCT(L))*(SIGFP/SIGUT) + HILLK2)
DO 10 J=1,35
SUMRC1(L,J)=C.
SUMRC2(L,J) = C.
SUMRC3(L,J)= C.
SUMRC4(L,J)=C.
10 CONTINUE
SUMRC(L)=C.
SUMRCT(L)=C.
DO 20 J=1,35
IF (101. - ENPJ(L,J)) 20,20,12
12 NN=ENPJ(L,J)
DO 19 K=1,24
PHISQR = FNC(L,K,J)**2
RCKA1 = (GSDLP(L,K,NN)*PHISQR)*AA
SUMRC1(L,J) = SUMRC1(L,J) + RCKA1
RCKE1 = ((GI(NN)/24. - GSDLP(L,K,NN))*PHISQR)*BB
SUMRC2(L,J) = SUMRC2(L,J) + RCKE1
RCKA2 = (GE(L,K,NN)*PHISQR)*AA
SUMRC3(L,J) = SUMRC3(L,J) + RCKA2
RCKE2 = ((GI(NN)/24. - GE(L,K,NN))*PHISQR)*BB
SUMRC4(L,J) = SUMRC4(L,J) + RCKE2
RFMF1 = RFMF1 + GSDLP(L,K,NN)*FNC(L,K,J)
RFMF2 = RFMF2 + GSDLP(L,K,NN)*PHISQR
STORE = 1.0E-10*GSDLP(L,K,NN)*PHISQR
RFCMF2 = RFCMF2 + STORE*FNC(L,K,J)

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RF
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      RFFFF2= RFFFF2+ (RCKB1/BB)
      RFGBF2 = RFGBF2 + GB(L,K,J)*PHISQR
      SPFISQ = SPFISQ + PHISQR
      GICELL=G1(NN)/24.
      BURNS=(1.-GSDUP(L,K,NN)/GICELL)
      BURNE=(1.-GS(L,K,NN)/GICELL)
      SFPS = C1*BURNS + C2*BURNS**2 + C3*BURNS**3 + C4*BURNS**4 +C5*BURN
1S**5 + C6*BURNS**6
      SFPE = C1*BURNE + C2*BURNE**2 + C3*BURNE**3 + C4*BURNE**4 +C5*BURN
1E**5 + C6*BURNE**6
      TCPS=(1.-BURNS)*GICELL*SIGUT*FNC(L,K,J)
      TCPE=(1.-BURNE)*GICELL*SIGUT*FNC(L,K,J)
      TCPF2S = TOPS*FNC(L,K,J)
      TCPF2E = TOPE*FNC(L,K,J)
      IF (BC - NN) 15,17,17
15 SFF2S = SFF2S +(GSDUP(L,K,NN)/(GSCLP(L,K,NN) + HILLK1*(G1(NN)/24.
1 - GSDUP(L,K,NN)) + FK2SPC))*PHISQR
      UMASS = GSDUP(L,K,NN) - GB(L,K,J)
      SFF2E = SFF2E + (LMASS/(LMASS + HILLK1*(G1(NN)/24.-LMASS)+FK2SPC))
1*PHISQR
      BCTS=TCPS+(GICELL*SFPS+ALH2GS)*FNC(L,K,J)
      BCTE=TCPE+(GICELL*SFPE+ALH2GS)*FNC(L,K,J)
      BCTF2S = BOTS*FNC(L,K,J)
      BCTF2E = BOTE*FNC(L,K,J)
      GO TO 18
17 SFF2S = SFF2S +(GSCLP(L,K,NN)/(GSCLP(L,K,NN) + HILLK1*(G1(NN)/24.
1 - GSDUP(L,K,NN)) + FK2STD))*PHISQR
      UMASS = GSDUP(L,K,NN) - GB(L,K,J)
      SFF2E = SFF2E + (LMASS/(LMASS + HILLK1*(G1(NN)/24.-LMASS)+FK2STD))
1*PHISQR
      BCTS=TOPS + (GICELL*SFPS + ALH2CR)*FNC(L,K,J)
      BCTE=TOPE+(GICELL*SFPE+ALH2CR)*FNC(L,K,J)
      BCTF2S = BOTS*FNC(L,K,J)
      BCTF2E = BOTE*FNC(L,K,J)
18 CONTINUE
      SMTOPS=SMTOPS+TCPS
      SMTCPPE=SMTCPPE+TCPE
      SMCOTS=SMCOTS+BCTS
      SMCOTE=SMCOTE+BCTE
      SMTF2S = SMTF2S + TCPF2S
      SMTF2E = SMTF2E + TCPF2E
      SMCF2S = SMCF2S + BCTF2S
      SMCF2E = SMCF2E + BCTF2E
19 CONTINUE
      SUMRCT(L) = SUMRCT(L) + SUMRC1(L,J) + SUMRC2(L,J)
      SUMRC(L) = SUMRC(L) + SUMRC3(L,J) + SUMRC4(L,J)
20 CONTINUE
      J = 18
      NN = ENPJ(L,J)
      IF (NN - E2C) 23,21,23
23 WRITE OUTPUT IAPF 3,1C1,LNCP
21 J = 12

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RF

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      CC 22 K=1,24
      SF212= SF212+ FNO(L,K,J)**2
      SF12 = SF12 + FNO(L,K,J)
22  CONTINUE
      SALH1C = 24.*ALH2CC*SF12
      SALH2C = 24.*ALH2CC*SF212
      SF2TGT= SPHISQ + SF212
      FAVGS = SFF2S/SF2TGT
      FAVGE = SFF2E/SF2TGT
      GO TO 25
25  WRITE OUTPUT TAPE 3,1, AA,BB,SUMRCT(L),LNUM
      WRITE OUTPUT TAPE 3,99,LNUM,RFMF1,RFMF2,RFCMF3 ,RFFFF2,THMLUS,FILLRF
      IK1,FILLK2,FAVGS,FK2STD,FK2SPC,HILLK1 RF
      FREFS = SMTQPS/(SMBQTS + SALH1C)
      FREF2S = SMTF2S/(SMBF2S + SALH2C)
      WRITE OUTPUT TAPE 3, 102,FREFS,FREF2S
      WRITE OUTPUT TAPE 3,100,LNUM,RMWD,RFGBF2,THMLUE,FAVGE RF
      FREFE = SMTQPE/(SMBQTE + SALH1C)
      FREF2E = SMTF2E/(SMBF2E + SALH2C)
      WRITE OUTPUT TAPE 3, 103,FREFE,FREF2E
      IF (GBTGT) 28,28,24
24  WRITE OUTPUT TAPE 3,5,AA,BB,SUMRC(L),LNUM,RMWD
      GO TO 30
28  WRITE OUTPUT TAPE 3,6
      GO TO 30
29  WRITE OUTPUT TAPE 3,7
30  RETURN
      END
      DATA
      +169.92+169.92 +169.92+169.74+169.74+169.74+169.74 G1 1-10
      +169.46+168.70 +168.84 +168.84+168.84 G1 11-20
      +169.92+169.50+169.88 +169.92+168.73 +168.24+168.24 G1 21-30
      +168.48+168.48+167.91 +169.40+168.48 G1 31-40
      +188.51+188.51+188.51+188.39+188.39+188.51+188.64+188.64+188.64+188.64 G1 41-50
      +188.64+188.64+188.64+188.64+188.92+188.92+188.92+188.92+188.92+188.92 G1 51-60
      +189.27+189.27+189.27+189.27+189.27+189.81+189.81+189.81+189.81+189.81 G1 61-70
      +190.11+190.11+190.11+190.11+190.11+189.28+189.30+189.01+188.77+189.01 G1 71-80
      +94.54 +94.54 +94.54 +94.35 +94.35 G1 81-90
      +94.35 +94.35 +94.35 +94.35 +94.35 +94.35 +94.35 G191-100
      +2.186+16 +2.000+00 +1.287+00 52. 682. 1040. 1.666 1.750 CCNSTPCW
      +0.88331E+C2-C.37601E+C3+C.14118E+C4-C.14599E+C4-C.77168E+C4+C.1852CE+C5C1,C2,C3
      +C.1140CE+04+C.12038E+04+C.13554E+04 ALH2CR,A
      +C.1000GE-30+C.1000CE-30 AA,EE
      +1 +27 23.236 CYCLE 27

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6.804 6.856 6.829 6.783 6.732 6.682 6.632 6.572 6.523 6.452 6.391 6.344GS 2-1
6.286 6.264 6.244 6.249 6.274 6.297 6.343 6.406 6.467 6.535 6.595 6.576GS 2-2
6.852 6.896 6.871 6.837 6.796 6.750 6.709 6.668 6.621 6.565 6.508 6.474GS 2-1

```


6.420 6.403 6.388 6.391 6.414 6.436 6.465 6.520 6.575 6.625 6.682 6.663GS 3-2

6.897 6.919 6.892 6.866 6.830 6.752 6.757 6.724 6.683 6.641 6.597 6.576GS 6-1
 6.537 6.523 6.518 6.521 6.542 6.567 6.597 6.637 6.684 6.728 6.764 6.721GS 6-2
 6.810 6.862 6.832 6.793 6.747 6.692 6.645 6.602 6.544 6.482 6.412 6.376GS 7-1
 6.310 6.252 6.276 6.277 6.305 6.332 6.368 6.426 6.451 6.553 6.616 6.592GS 7-2
 6.874 6.912 6.892 6.859 6.822 6.788 6.752 6.706 6.673 6.621 6.580 6.544GS 8-1
 6.505 6.488 6.474 6.478 6.495 6.510 6.546 6.591 6.633 6.682 6.724 6.711GS 8-2
 6.714 6.775 6.732 6.678 6.612 6.538 6.473 6.409 6.332 6.246 6.158 6.108GS 9-1
 6.026 6.000 5.980 5.984 6.023 6.062 6.116 6.196 6.284 6.370 6.449 6.401GS 9-2
 6.600 6.670 6.605 6.537 6.448 6.350 6.263 6.178 6.073 5.964 5.848 5.788GS 10-1
 5.682 5.647 5.627 5.632 5.686 5.744 5.817 5.921 6.040 6.154 6.253 6.168GS 10-2

6.895 6.930 6.912 6.888 6.858 6.827 6.797 6.766 6.734 6.694 6.655 6.630GS 14-1
 6.592 6.581 6.570 6.572 6.588 6.602 6.627 6.664 6.702 6.740 6.778 6.765GS 14-2
 6.922 6.932 6.915 6.895 6.877 6.855 6.834 6.814 6.790 6.766 6.742 6.731GS 15-1
 6.711 6.703 6.701 6.704 6.717 6.733 6.752 6.775 6.802 6.829 6.846 6.813GS 15-2

6.650 6.712 6.666 6.606 6.534 6.458 6.386 6.314 6.233 6.141 6.050 5.996GS 17-1
 5.912 5.882 5.862 5.868 5.909 5.952 6.013 6.098 6.192 6.284 6.366 6.309GS 17-2

6.734 6.791 6.761 6.712 6.656 6.602 6.547 6.483 6.429 6.351 6.284 6.234GS 19-1
 6.170 6.146 6.125 6.129 6.157 6.182 6.233 6.300 6.368 6.441 6.507 6.486GS 19-2
 6.920 6.942 6.931 6.911 6.889 6.871 6.850 6.821 6.804 6.772 6.751 6.729GS 20-1
 6.708 6.698 6.689 6.692 6.701 6.709 6.731 6.757 6.781 6.809 6.832 6.826GS 20-2

6.995 7.014 7.007 6.992 6.977 6.964 6.949 6.925 6.917 6.895 6.880 6.864GS 22-1
 6.845 6.842 6.836 6.838 6.845 6.850 6.866 6.884 6.901 6.921 6.937 6.932GS 22-2
 7.035 7.032 7.028 7.022 7.016 7.011 7.005 6.998 6.992 6.986 6.981 6.979GS 23-1
 6.976 6.973 6.974 6.975 6.979 6.985 6.991 6.997 7.005 7.012 7.015 6.999GS 23-2
 6.815 6.844 6.805 6.765 6.712 6.659 6.605 6.560 6.501 6.442 6.383 6.354GS 24-1
 6.302 6.282 6.277 6.282 6.314 6.351 6.396 6.453 6.519 6.584 6.630 6.557GS 24-2

7.066 7.065 7.068 7.065 7.062 7.060 7.058 7.054 7.052 7.048 7.046 7.042GS 26-1
 7.041 7.040 7.038 7.035 7.040 7.041 7.044 7.047 7.050 7.053 7.056 7.055GS 26-2

6.725 6.760 6.718 6.675 6.619 6.565 6.511 6.457 6.397 6.334 6.276 6.246GS 29-1

6.196 6.174 6.171 6.177 6.210 6.250 6.300 6.360 6.428 6.497 6.541 6.457GS 29-2

6.618 6.636 6.572 6.506 6.418 6.342 6.259 6.172 6.085 5.992 5.914 5.865GS 32-1
 5.805 5.770 5.770 5.782 5.832 5.895 5.976 6.064 6.164 6.268 6.326 6.179GS 32-2
 6.731 6.755 6.712 6.666 6.606 6.550 6.492 6.434 6.370 6.303 6.242 6.208GS 33-1
 6.155 6.121 6.126 6.133 6.168 6.209 6.262 6.326 6.398 6.471 6.520 6.434GS 33-2

3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936GS 85-1
3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936 3.936GS 85-2
4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022GS 86-1
4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022GS 86-2
4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022GS 87-1
4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022 4.022GS 87-2

3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931GS 89-1
3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931GS 89-2
3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931GS 90-1
3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931 3.931GS 90-2

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2.49392.60832.62322.58352.56012.42582.30682.15501.92701.77311.60041.618120201043
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2.47772.60962.67002.66752.60702.48892.36862.23742.03671.81301.63211.730121201043
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4.00514.24514.32964.37314.32034.21703.99973.77043.43413.05692.70762.496022201043
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2.39162.46262.42852.35622.28962.13591.95441.79031.58951.38211.31711.742930201043

250.	250.	250.	250.	250.	250.	14.	8.	15.	10.	15.	85.	22.	86.	CYCLE271
33.	24.	20.	820.	2.	23.	7.	89.	26.	90.	9.	32.	6.	87.	CYCLE272
3.	17.	250.	250.	250.	250.	250.								CYCLE273
1	1				1	1								MCUT
-1	-1													NCPRGENE
+1	+28		25.022											CYCLE 28
250.	250.	250.	250.	250.	33.	6.	15.	20.	32.	24.	85.	30.	86.	CYCLE281
2.	8.	26.	820.	23.	29.	19.	89.	22.	90.	3.	9.	14.	87.	CYCLE282
7.	17.	250.	250.	250.	250.	250.								CYCLE283
1		1		1	1	1								MCUT
-1	-1													NCPRGENE
+1	+29		24.030											CYCLE 29
250.	250.	250.	250.	250.	2.	6.	15.	20.	17.	24.	85.	30.	86.	CYCLE291
3.	8.	26.	820.	23.	29.	19.	89.	22.	90.	14.	33.	39.	87.	CYCLE292
7.	9.	250.	250.	250.	250.	250.								CYCLE293
1		1		1	1	1								MCUT
-1	-1													NCPRGENE
+1	+20		28.950											CYCLE 30
250.	250.	250.	250.	250.	3.	6.	15.	20.	9.	24.	85.	30.	86.	CYCLE301
14.	8.	26.	820.	23.	29.	19.	89.	22.	90.	39.	2.	40.	87.	CYCLE302
7.	32.	250.	250.	250.	250.	250.								CYCLE303
1		1		1	1	1								MCUT
-1	-1													NCPRGENE
+1	+21		15.759											CYCLE 31
250.	250.	250.	250.	250.	3.	15.	23.	20.	9.	24.	85.	30.	86.	CYCLE311
14.	8.	41.	820.	26.	7.	19.	89.	22.	90.	39.	2.	40.	87.	CYCLE312
6.	33.	250.	250.	250.	250.	250.								CYCLE313
1		1		1	1	1								MCUT
-1	-1													NCPRGENE
+1	+32		24.367											CYCLE 32
250.	250.	250.	250.	250.	3.	15.	23.	22.	33.	8.	85.	42.	86.	CYCLE321
14.	20.	41.	820.	26.	7.	24.	89.	30.	90.	39.	2.	40.	87.	CYCLE322
6.	19.	250.	250.	250.	250.	250.								CYCLE323
1		1		1	1	1								MCUT
-1	-1													NCPRGENE
+1	+23		24.344											CYCLE 33
250.	250.	250.	250.	250.	3.	15.	23.	22.	33.	8.	91.	42.	86.	CYCLE331
14.	20.	41.	820.	26.	7.	24.	89.	30.	90.	39.	2.	40.	87.	CYCLE332
6.	19.	250.	250.	250.	250.	250.								CYCLE333
1		1		1	1	1								MCUT
-1	-1													NCPRGENE
+1	+24		15.98											CYCLE 34
250.	250.	250.	250.	250.	14.	15.</								

APPENDIX 2

SAMPLE OUTPUT LISTING FROM RHOBURN PROGRAM

RHOBURN

GRAMS OF U235 IN CORE AT START OF CYCLE 27 IS 3470.311
 THE GRAMS BURNED IN CYCLE 27 IS 29.905 , (CHECK = 29.905)
 THE PERCENT BURNUP OF THE CORE AT START OF CYCLE 27 IS 6.110 PERCENT SINCE IT WAS COLD AND CLEAN
 THE PERCENT BURNUP OF THE CORE AT THE END OF CYCLE 27 IS 6.910 PERCENT SINCE IT WAS COLD AND CLEAN

CORE CONFIGURATION AT START OF CYCLE 27

E	D	C	B	A
250.0000	250.0000	250.0000	250.0000	250.0000
29.0000	14.0000	8.0000	19.0000	10.0000
15.0000	85.0000	22.0000	86.0000	33.0000
24.0000	20.0000	820.0000	2.0000	23.0000
7.0000	89.0000	26.0000	90.0000	9.0000
32.0000	6.0000	87.0000	3.0000	17.0000
250.0000	250.0000	250.0000	250.0000	250.0000

GRAMS OF U235 IN CORE AT START OF CYCLE 27

E	D	C	B	A
0.	0.	0.	0.	0.
154.0580	161.3730	159.8610	153.8280	145.7000
163.1640	94.4640	165.8890	96.5280	153.4030
156.4000	163.1260	0.	156.1360	167.9680
156.6360	94.3440	169.2350	94.3440	151.6660
147.2150	160.5140	96.5280	158.5370	149.3940
0.	0.	0.	0.	0.

GRAMS OF U235 IN CORE AT END OF CYCLE 27

E	D	C	B	A
0.	0.	0.	0.	0.
152.9341	160.0194	158.4040	152.4763	144.7055
161.8579	93.4767	164.2208	95.5659	152.2182
155.1122	161.5235	0.	154.6124	166.6704
155.4479	93.3711	167.5671	93.3900	150.4491
146.1679	159.1564	95.4529	157.2675	148.3383
0.	0.	0.	0.	0.

GRAMS OF U235 BURNED IN EACH POSITION

E	D	C	B	A
0.	0.	0.	0.	0.
1.1239	1.3536	1.4570	1.3517	0.9944
1.3061	0.9873	1.6681	0.9621	1.1848
1.2878	1.6024	0.	1.5235	1.2975
1.1881	0.9729	1.6678	0.9540	1.2169
1.0471	1.3576	1.0751	1.2694	1.0557
0.	0.	0.	0.	0.

PERCENT BURN OF U235 IN EACH FUEL ELEMENT IN CORE AT END OF CYCLE 27

E	D	C	B	A
100.0000	100.0000	100.0000	100.0000	100.0000
9.0977	5.5710	6.6784	9.6919	14.7487
4.0558	3.1731	3.3540	1.0090	9.6521
8.6931	4.3334	100.0000	9.0087	1.6694
8.4200	1.0376	1.3847	1.0175	11.3650
13.2432	6.3345	1.1261	7.4461	12.1427
100.0000	100.0000	100.0000	100.0000	100.0000

FOLLOWING IS THE STATUS OF THE FUEL ELEMENTS AT THE END OF CYCLE 27

ELEMENT	INITIAL GRAMS	GRAMS END CYCLE	PERCENT BURN
1	-0.	-0.	100.000
2	169.92	154.612	9.009
3	169.92	157.268	7.446
4	-0.	-0.	100.000
5	-0.	-0.	100.000
6	169.92	159.156	6.335
7	169.74	155.448	8.420
8	169.74	158.404	6.678
9	169.74	150.449	11.365
10	169.74	144.706	14.749
11	-0.	-0.	100.000
12	-0.	-0.	100.000
13	-0.	-0.	100.000
14	169.46	160.019	5.571
15	168.70	161.858	4.056
16	-0.	-0.	100.000
17	168.84	148.338	12.143
18	-0.	-0.	100.000
19	168.84	152.476	9.692
20	168.84	161.524	4.333
21	-0.	-0.	100.000
22	169.92	164.221	3.354
23	169.50	166.670	1.669
24	169.88	155.112	8.693
25	-0.	-0.	100.000
26	169.92	167.567	1.385
27	168.73	160.730	0.
28	-0.	-0.	100.000
29	168.24	152.934	9.098
30	168.24	168.240	0.
31	-0.	-0.	100.000
32	168.48	146.168	13.243
33	168.48	152.218	9.652
34	167.91	167.910	0.
35	-0.	-0.	100.000
36	-0.	-0.	100.000
37	-0.	-0.	100.000
38	-0.	-0.	100.000
39	169.40	169.400	0.
40	168.48	168.480	0.
41	188.51	188.510	0.
42	188.51	188.510	0.
43	188.51	188.510	0.
44	188.39	188.390	0.
45	188.39	188.390	0.
46	188.51	188.510	0.
47	188.64	188.640	0.
48	188.64	188.640	0.
49	188.64	188.640	0.
50	188.64	188.640	0.
51	188.64	188.640	0.
52	188.64	188.640	0.
53	188.64	188.640	0.
54	188.64	188.640	0.
55	188.92	188.920	0.
56	188.92	188.920	0.
57	188.92	188.920	0.

58	188.92	188.920	0.
59	188.92	188.920	0.
60	188.92	188.920	0.
61	189.27	189.270	0.
62	189.27	189.270	0.
63	189.27	189.270	0.
64	189.27	189.270	0.
65	189.27	189.270	0.
66	189.81	189.810	0.
67	189.81	189.810	0.
68	189.81	189.810	0.
69	189.81	189.810	0.
70	189.81	189.810	0.
71	190.11	190.110	0.
72	190.11	190.110	0.
73	190.11	190.110	0.
74	190.11	190.110	0.
75	190.11	190.110	0.
76	189.28	189.280	0.
77	189.30	189.300	0.
78	189.01	189.010	0.
79	188.77	188.770	0.
80	189.01	189.010	0.
81	-0.	-0.	100.000
82	-0.	-0.	100.000
83	-0.	-0.	100.000
84	-0.	-0.	100.000
85	96.54	93.477	3.173
86	96.54	95.566	1.009
87	96.54	95.453	1.126
88	-0.	-0.	100.000
89	94.35	93.371	1.038
90	94.35	93.390	1.017
91	94.35	94.350	0.
92	94.35	94.350	0.
93	94.35	94.350	0.
94	94.35	94.350	0.
95	94.35	94.350	0.
96	94.35	94.350	0.
97	94.35	94.350	0.
98	-0.	-0.	100.000
99	-0.	-0.	100.000
100	-0.	-0.	100.000

-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
6.772	6.829	6.800	6.748	6.691	6.637	6.581	6.514	6.461	6.382	6.316	6.264	
6.201	6.177	6.155	6.160	6.187	6.212	6.263	6.332	6.399	6.474	6.540	6.519	
6.825	6.875	6.847	6.809	6.763	6.712	6.667	6.622	6.569	6.508	6.444	6.407	
6.348	6.329	6.313	6.316	6.341	6.366	6.401	6.458	6.518	6.578	6.637	6.616	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
6.870	6.895	6.866	6.834	6.793	6.750	6.710	6.671	6.626	6.576	6.527	6.501	
6.458	6.444	6.439	6.443	6.464	6.494	6.528	6.572	6.626	6.676	6.719	6.674	
6.783	6.839	6.807	6.765	6.715	6.656	6.605	6.557	6.495	6.429	6.354	6.314	
6.246	6.225	6.208	6.209	6.238	6.269	6.307	6.367	6.437	6.505	6.572	6.546	
6.842	6.885	6.862	6.824	6.781	6.741	6.699	6.648	6.610	6.553	6.506	6.466	
6.424	6.406	6.392	6.395	6.414	6.433	6.472	6.522	6.571	6.626	6.674	6.661	
6.688	6.753	6.707	6.650	6.580	6.502	6.432	6.364	6.282	6.191	6.097	6.041	
5.957	5.930	5.911	5.915	5.955	5.998	6.054	6.138	6.229	6.320	6.403	6.353	
6.575	6.649	6.586	6.510	6.417	6.316	6.225	6.137	6.029	5.917	5.799	5.737	
5.630	5.594	5.573	5.579	5.633	5.693	5.769	5.876	5.997	6.115	6.219	6.132	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
6.868	6.904	6.884	6.855	6.820	6.783	6.748	6.713	6.676	6.631	6.587	6.558	
6.518	6.505	6.493	6.495	6.512	6.528	6.559	6.600	6.643	6.688	6.731	6.720	
6.893	6.907	6.887	6.868	6.841	6.814	6.789	6.764	6.736	6.707	6.677	6.661	
6.639	6.629	6.627	6.630	6.644	6.663	6.684	6.712	6.744	6.778	6.800	6.765	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
6.629	6.690	6.640	6.577	6.500	6.421	6.345	6.269	6.184	6.088	5.995	5.940	
5.854	5.823	5.805	5.811	5.854	5.900	5.965	6.054	6.152	6.249	6.332	6.264	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	
6.709	6.765	6.731	6.677	6.617	6.558	6.497	6.428	6.370	6.286	6.215	6.161	
6.095	6.070	6.049	6.053	6.082	6.112	6.168	6.240	6.314	6.392	6.460	6.427	

[illegible]

[illegible]

FOLLOWING IS THE STATUS OF THE FUEL ELEMENTS AT THE END OF CYCLE 27			
ELEMENT NUMBER	INITIAL GRAMS	END CYCLE GRAMS	PER CENT BURNUP
1	10.00	9.95	0.5
2	10.00	9.90	1.0
3	10.00	9.85	1.5
4	10.00	9.80	2.0
5	10.00	9.75	2.5
6	10.00	9.70	3.0
7	10.00	9.65	3.5
8	10.00	9.60	4.0
9	10.00	9.55	4.5
10	10.00	9.50	5.0
11	10.00	9.45	5.5
12	10.00	9.40	6.0
13	10.00	9.35	6.5
14	10.00	9.30	7.0
15	10.00	9.25	7.5
16	10.00	9.20	8.0
17	10.00	9.15	8.5
18	10.00	9.10	9.0
19	10.00	9.05	9.5
20	10.00	9.00	10.0
21	10.00	8.95	10.5
22	10.00	8.90	11.0
23	10.00	8.85	11.5
24	10.00	8.80	12.0
25	10.00	8.75	12.5
26	10.00	8.70	13.0
27	10.00	8.65	13.5
28	10.00	8.60	14.0
29	10.00	8.55	14.5
30	10.00	8.50	15.0
31	10.00	8.45	15.5
32	10.00	8.40	16.0
33	10.00	8.35	16.5
34	10.00	8.30	17.0
35	10.00	8.25	17.5
36	10.00	8.20	18.0
37	10.00	8.15	18.5
38	10.00	8.10	19.0
39	10.00	8.05	19.5
40	10.00	8.00	20.0
41	10.00	7.95	20.5
42	10.00	7.90	21.0
43	10.00	7.85	21.5
44	10.00	7.80	22.0
45	10.00	7.75	22.5
46	10.00	7.70	23.0
47	10.00	7.65	23.5
48	10.00	7.60	24.0
49	10.00	7.55	24.5
50	10.00	7.50	25.0
51	10.00	7.45	25.5
52	10.00	7.40	26.0
53	10.00	7.35	26.5
54	10.00	7.30	27.0
55	10.00	7.25	27.5
56	10.00	7.20	28.0
57	10.00	7.15	28.5
58	10.00	7.10	29.0
59	10.00	7.05	29.5
60	10.00	7.00	30.0
61	10.00	6.95	30.5
62	10.00	6.90	31.0
63	10.00	6.85	31.5
64	10.00	6.80	32.0
65	10.00	6.75	32.5
66	10.00	6.70	33.0
67	10.00	6.65	33.5
68	10.00	6.60	34.0
69	10.00	6.55	34.5
70	10.00	6.50	35.0
71	10.00	6.45	35.5
72	10.00	6.40	36.0
73	10.00	6.35	36.5
74	10.00	6.30	37.0
75	10.00	6.25	37.5
76	10.00	6.20	38.0
77	10.00	6.15	38.5
78	10.00	6.10	39.0
79	10.00	6.05	39.5
80	10.00	6.00	40.0
81	10.00	5.95	40.5
82	10.00	5.90	41.0
83	10.00	5.85	41.5
84	10.00	5.80	42.0
85	10.00	5.75	42.5
86	10.00	5.70	43.0
87	10.00	5.65	43.5
88	10.00		

71	190.11	190.110	0.
72	190.11	190.110	0.
73	190.11	190.110	0.
74	190.11	190.110	0.
75	190.11	190.110	0.
66	189.81	189.810	0.
67	189.81	189.810	0.
68	189.81	189.810	0.
69	189.81	189.810	0.
70	189.81	189.810	0.
77	189.30	189.300	0.
76	189.28	189.280	0.
61	189.27	189.270	0.
62	189.27	189.270	0.
63	189.27	189.270	0.
64	189.27	189.270	0.
65	189.27	189.270	0.
78	189.01	189.010	0.
80	189.01	189.010	0.
55	188.92	188.920	0.
56	188.92	188.920	0.
57	188.92	188.920	0.
58	188.92	188.920	0.
59	188.92	188.920	0.
60	188.92	188.920	0.
79	188.77	188.770	0.
47	188.64	188.640	0.
48	188.64	188.640	0.
49	188.64	188.640	0.
50	188.64	188.640	0.
51	188.64	188.640	0.
52	188.64	188.640	0.
53	188.64	188.640	0.
54	188.64	188.640	0.
41	188.51	188.510	0.
42	188.51	188.510	0.
43	188.51	188.510	0.

46	188.51	188.510	0.
44	188.39	188.390	0.
45	188.39	188.390	0.
39	169.40	169.400	0.
27	168.73	168.730	0.
40	168.48	168.480	0.
30	168.24	168.240	0.
34	167.91	167.910	0.
26	169.92	167.567	1.385
23	169.50	166.670	1.669
22	169.92	164.221	3.354
15	168.70	161.858	4.056
20	168.84	161.524	4.333
14	169.46	160.019	5.571
6	169.92	159.156	6.735
8	169.74	158.404	6.678
3	169.92	157.268	7.446
7	169.74	155.448	8.420
24	169.88	155.112	8.693
2	169.92	154.612	9.009
29	168.24	152.934	9.098
19	168.84	152.476	9.692
33	168.48	152.218	9.652
9	169.74	150.449	11.365
17	168.84	148.338	12.143
32	168.48	146.168	13.243
10	169.74	144.706	14.749
86	96.54	95.566	1.009
87	96.54	95.453	1.126
91	94.35	94.350	0.
92	94.35	94.350	0.
93	94.35	94.350	0.
94	94.35	94.350	0.
95	94.35	94.350	0.
96	94.35	94.350	0.
97	94.35	94.350	0.
85	96.54	93.477	3.173
90	94.35	93.390	1.017
89	94.35	93.371	1.038
1	-0.	-0.	100.000
4	-0.	-0.	100.000
5	-0.	-0.	100.000
11	-0.	-0.	100.000
12	-0.	-0.	100.000
13	-0.	-0.	100.000
16	-0.	-0.	100.000
18	-0.	-0.	100.000
21	-0.	-0.	100.000
25	-0.	-0.	100.000
28	-0.	-0.	100.000
31	-0.	-0.	100.000
35	-0.	-0.	100.000
36	-0.	-0.	100.000
37	-0.	-0.	100.000
38	-0.	-0.	100.000
81	-0.	-0.	100.000
82	-0.	-0.	100.000
83	-0.	-0.	100.000
84	-0.	-0.	100.000
88	-0.	-0.	100.000
98	-0.	-0.	100.000
99	-0.	-0.	100.000
100	-0.	-0.	100.000

0

THE PSEUDO K EFFECTIVE FOUND BY SUMMING $M \times \text{PHI SQUARED}$ FOR $M(U235)$ AND $M(\text{FISSION PRODUCTS})$, MULTIPLIED BY CONSTANTS $AA = 1.000000E-31$ AND $BB = 1.000000E-31$ RESPECTIVELY, IS $0.657120E-01$ AT THE START OF CYCLE 27

TRIFLES AND ODDMENTS AS COLLECTED AT START OF CYCLE 27

TOTAL $M(U235) \times \text{PHI} = 0.42846604E 17$

TOTAL $M(U235) \times \text{PHI SQUARED} = 0.61732520E 30$

TOTAL $M(U235) \times \text{PHI CUBED} \times 1.0E-10 = 0.99763877E 33$

TOTAL $M(F.P.) \times \text{PHI SQUARED} = 0.39793905E 29$

GROSS THERMAL UTIL. = $M(U235)/M(U235) + K1 \times M(F.P.) + K2 = 0.766491$

WHERE $K1 = 0.076246$ AND $K2 = 1040.000$

AVERAGE THERMAL UTIL. = $\text{SUM}(F \times \text{PHI SQUARED})/\text{SUM}(\text{PHI SQUARED}) = 0.712804$

WHERE F IS CALCULATED FOR EACHCELL USING THE FORMULA FOR GROSS THERMAL UTILIZATION WITH THE CONSTANTS

$K2(\text{STD.}) = 1.6660$, $K2(\text{SPEC.}) = 1.7500$, AND $K1 = \text{SIGFP}/\text{SIGUT} = 0.0762$

REFINED THERMAL UTILIZATION = $\text{SUM}(M(U235) \times \text{SIGMA} \times \text{PHI})/\text{SUM}(M(U235) \times \text{SIGMA} \times \text{PHI} + M(U235) \times \text{SIGMA}(F.P.) + N \times \text{SIGMA}(\text{ALUMINUM} + \text{H2O})) \times \text{PHI}$

= $0.59055E 00$

THE REFINED THERMAL UTILIZATION WEIGHTED BY THE FLUX SQUARED INSTEAD OF THE FLUX AS ABOVE IS = $0.53594E 00$

TRIFLES AND ODDMENTS AT END OF CYCLE 27 AFTER RUNNING 23.23600 MEGAWATT DAYS THIS CYCLE

GRAMS BURNED THIS CYCLE $\times \text{PHI SQUARED} = 0.69629961E 28$

GROSS THERMAL UTIL. = 0.764551

AVERAGE THERMAL UTILIZATION = 0.710277

REFINED THERMAL UTILIZATION = $0.58779E 00$

FLUX SQUARED WEIGHTED REFINED THERMAL UTILIZATION = $0.53281E 00$

THE PSEUDO K EFFECTIVE FOUND BY SUMMING $M \times \text{PHI SQUARED}$ FOR $M(U235)$ AND $M(\text{FISSION PRODUCTS})$, MULTIPLIED BY CONSTANTS

$AA = 1.000000E-31$ AND $BB = 1.000000E-31$ RESPECTIVELY, IS $0.657120E-01$ AT END OF CYCLE 27

WHICH HAS RUN 23.23600 MEGAWATT DAYS

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