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**TURBO-40 -- A TWO-DIMENSIONAL NUCLEAR REACTOR
DEPLETION PROGRAM FOR THE IBM 7040-44 COMPUTER**

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TURBO-40 -- A TWO-DIMENSIONAL NUCLEAR REACTOR DEPLETION PROGRAM FOR THE IBM 7040-44 COMPUTER

BY

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U. S. Atomic Energy Commission Research and Development Report
Issued Under Contract AT(10-1)-1230
Idaho Operations Office

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ABSTRACT

TURBO-40 is an IBM 7040-44 computer program which obtains a numeric solution to the few-group, time-independent, two-dimensional neutron-diffusion equations with coupling to the linear, first order, ordinary differential equations which describe the build-up and depletion of isotopic number densities over a time interval. The group-averaged macroscopic cross sections for the few-group neutron diffusion equations are computed from fitted few-group microscopic cross sections and isotopic atom densities. The build-up or depletion of isotopic number densities describing the materials present is calculated from the fitted cross sections and the neutron flux. The flux is assumed to be constant over the time interval of each step and is recomputed for each succeeding step. The solution is obtained either over a rectangular surface in X-Y coordinates or over a right cylinder in R-Z coordinates. The number of lethargy groups is two, three, or four, and the total number of mesh points of solution is limited to 20,000.

TURBO-40 is a conversion to the IBM 7040-44 of the TURBO program as reported in "Nuclear Reactor Depletion Programs for the Philco-2000 Computer", WAPD-TM-221. The purpose of this report is to serve as a user's guide for the TURBO-40 program.

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TURBO-40 -- A TWO-DIMENSIONAL NUCLEAR REACTOR DEPLETION PROGRAM FOR THE IBM 7040-44 COMPUTER

BY

G. R. Poetschat and R. J. Wagner

I. INTRODUCTION

TURBO-40 is an IBM 7040-44 computer program which obtains a numeric solution to the few-group, time-independent, two-dimensional neutron-diffusion equations with coupling to the linear, first order, ordinary differential equations which describe the build-up and depletion of isotopic number densities over a time interval. Isotopic number densities are used to describe various material regions, each of which is initially homogeneous. Few-group macroscopic cross sections for the neutron-diffusion equations are computed from few-group microscopic cross sections and the isotopic number densities. The solution to the few-group neutron-diffusion equations provides the spatial distribution of the neutron flux. The spatial power shape is determined from the neutron flux and the fission cross sections, and the flux is normalized to a given power level for use in the depletion equations. Nonuniformity in the number-density distribution results from the depletion or build-up of these isotopic densities as a function of the cross sections and neutron flux. The flux is assumed to be constant over each time interval of depletion and is recalculated for each succeeding step.

The solution to the few-group, two-dimensional neutron-diffusion equations is obtained either over a rectangular surface in X-Y coordinates or over a right cylinder in R-Z coordinates. The methods of solving the neutron-diffusion equations have been taken from the PDQ-40^[1] program. Either a zero flux or a zero derivative of the flux (mirror symmetry) condition can be applied along each exterior boundary of the problem. In addition, a 180° rotational symmetry condition can be applied along the top boundary, or 90° rotational symmetry conditions can be applied along the top and left sides of a problem. The conditions of continuity of flux and current are used at diffusion-region interfaces, and logarithmic derivative conditions can be applied at interval boundaries for control rod descriptions. The number of lethargy groups is two, three, or four. The total number of solution mesh points is limited to 20,000. Up to 150 materials and/or subregions of interest can be placed in a problem. The output of the code consists of the code's interpretation of the input data, the macroscopic cross sections as calculated from the isotopic number densities and the microscopic cross sections, the eigenvalue and iteration data, pointwise flux and power edits, various integrated and average quantities, and numerous atom densities and cross section edits.

TURBO-40 is a conversion to the IBM 7040-44 of the Philco-2000 code TURBO^[2], programmed by the Bettis Atomic Power Laboratory of Westinghouse. The design of the input format and output options is nearly identical to the TURBO program. With minor modifications and limitations, the input to TURBO can be run with TURBO-40, giving similar results. The purpose of this report is to serve as a user's guide for the TURBO-40 program. The user should be familiar with the TURBO report, WAPD-TM-221^[2], and the PDQ-40^[1] report before proceeding to use the TURBO-40 program.

II. PROGRAM DESCRIPTION

The TURBO-40 program can be divided into four sections plus input and output. The first section provides the macroscopic cross sections which are calculated from isotopic number densities and are required in the few-group diffusion equations; the second section solves the diffusion equations in the selected geometry for the neutron flux and eigenvalue (multiplication constant); the third section generates the power shape by using the spatial flux values and fission cross sections and normalizes the flux to a specified power level; and the fourth section solves the linear, first-order, ordinary differential equations which describe the build-up and depletion of the isotopic number densities. This final calculation assumes a constant flux over the time-step. A total of thirteen time-dependent isotopes is allowed including U-235, U-236, U-238, Pu-239, Pu-240, Pu-241, Pm-149, Sm-149, I-135, Xe-135, B-10, and two fictitious isotopes which are usually chosen to represent the gross fission products. When U-238 is not present, four isotopes of hafnium or four isotopes of iridium can be studied. See Appendix A for the system identification of the isotopes.

1. MACROSCOPIC CROSS SECTIONS

Macroscopic cross sections are determined for each mesh rectangle in the problem. Macroscopic cross sections are inserted directly into the problem or are calculated as sums of products of isotopic number densities and few-group fitted microscopic cross sections in four lethargy groups. This section of TURBO-40 has been taken directly from the TURBO program and uses the equations as given in WAPD-TM-221[2].

For regions designated type 1, normal diffusion-theory macroscopic cross sections are inserted directly into the problem. These cross sections can be changed at any time-step but no depletion is calculated. A special use of the macroscopic constants is in rod regions where logarithmic derivative conditions can be applied. A rod region is a region in which the neutron flux in one or more lethargy groups is not defined inside the region but satisfies the following logarithmic derivative along its boundary,

$$\frac{D_i(x)}{\phi_i(x)} \frac{\partial \phi_i(x)}{\partial n} = - C_i(x). \quad (1-1)$$

Here $C_i(x)$ is a positive quantity and the derivative is taken normal to the boundary in the direction of the rod region. In any lethargy group in which this condition is not applied, the rod region is treated as a diffusion region. A rod region may be placed anywhere in a problem including along an external boundary or, adjacent to another rod region; however, the logarithmic derivative boundary condition is applied only at an interface between a rod region and a diffusion region. The value of $C_i(x)$ is placed in the input location of Σ_a^1 and the value of D_i , Σ_R^1 , $v\Sigma_f^1$, and $\kappa\Sigma_f^1$ are input as zeroes.

For all other regions, a library of four-group microscopic cross sections is input by the user along with the number densities and self-shielding factors. A library of fast cross sections is available from the conversion of the original

TURBO code. A description of these cross sections is quoted from the TURBO manual[3]: "A library of fast cross sections is available which has been determined by averaging results of MUFT calculations taken over a wide range of material compositions". However, the authors have not checked these cross sections. The user should check these cross sections thoroughly before using. It is possible to correct any or all of these cross sections to obtain a more accurate fit for the particular problem of interest. Thermal-microscopic cross sections are required as input.

The four-group macroscopic cross sections are calculated as follows.

For isotopic element M and group i let

- $\sigma_{tr}^{M,i}$ = the transport cross section
- $\sigma_a^{M,i}$ = the absorption cross section where $\sigma_a = \sigma_c + \sigma_f$
- σ_c = the capture cross section
- σ_f = the fission cross section
- $\sigma_R^{M,i}$ = the removal cross section
- $(\nu\sigma_f)^{M,i}$ = Nu (average number of neutrons produced per fission) times the fission cross section
- $\kappa^{M,i}$ = watts per fission divided by Nu
- g^M = the self-shielding factor
- N^M = the number density of element M.

The diffusion cross sections are calculated from the following equation

$$D_i = \left(3 \sum_M N^M \sigma_{tr}^{M,i} \right)^{-1} ; i = 1, \dots, 4. \quad (1-2)$$

The absorption cross sections are calculated as follows,

$$\Sigma_a^i = \sum_M N^M \sigma_a^{M,i} ; i = 1, 2 \quad (1-3)$$

$$\Sigma_{a,0}^3 = \sum_{M \neq 29} N^M \sigma_a^{M,3} + N^{29} g^{29,3} \sigma_a^{29,3} \quad (1-4)$$

where

$\sigma_a^{20,3}$ = smooth absorption cross section for U-238

M = 29 refers to boron-10 for which a variable self-shielding factor is permitted in the epithermal group

$g^{29,3}$ = variable self-shielding factor for boron-10 in group 3

$$g^{29,3} = \left[a_{34} + a_{35} F^{29}(t) \right]^{-1} \text{ if } a_{35} \neq 0$$

$$= a_{34} \text{ if } a_{35} = 0$$

$$F^{29}(t) = N^{29}(t)/N^{29}(0)$$

$$\Sigma_a^4 = \sum_M \sigma_a^{M,4} g^M N^M \quad (1-5)$$

g^M = thermal self-shielding factor

$g^M = a_M$ for each material composition, $M \neq 18, 29$

$$g^{18} = \left[a_{18} + a_{31} F^{18}(t) \right]^{-1} \text{ if } a_{31} \neq 0, \text{ or } a_{18} \text{ if } a_{31} = 0$$

$$g^{29} = \left[a_{29} + a_{32} F^{29}(t) \right]^{-1} \text{ if } a_{32} \neq 0, \text{ or } a_{29} \text{ if } a_{32} = 0$$

$$F^M(t) = N^M(t)/N^M(0).$$

The removal cross sections are calculated from the following equations

$$\Sigma_R^i = \sum_M N^M \sigma_R^{M,i} ; i = 1, 2, \quad (1-6)$$

$$\Sigma_{R,0}^3 = \sum_M N^M \sigma_R^{M,3}. \quad (1-7)$$

The Nu fission cross sections are calculated from the following equations

$$\nu \Sigma_F^i = \sum_A (\nu \sigma_F)^{A,i} N^A, \quad i = 1, 2, 3 \quad (1-8)$$

A = materials M = 18(U-235), 20(U-238), 21(Pu-239), 23(Pu-241)

$$\nu \Sigma_F^4 = \sum_A (\nu \sigma_F)^{A,4} g^A N^A \quad (1-9)$$

$g^A = g^M$ as described in Equation (1-5).

The power generation cross sections are calculated by the following equations

$$\kappa \Sigma_F^i = \sum_A \kappa^{A,i} (\nu \sigma_F)^{A,i} N^A, \quad i = 1, 2, 3 \quad (1-10)$$

$$\kappa \Sigma_F^4 = \sum_A \kappa^{A,4} (\nu \sigma_F)^{A,4} g^A N^A. \quad (1-11)$$

$g^A = g^M$ as defined in Equation (1-5).

A correction is made to the epithermal absorption and removal cross sections to account for the U-238 resonance (Material 20). Note that in Equations

(1-4) and (1-7) the absorption and removal terms have been defined as $\Sigma_{a,0}^3$ and $\Sigma_{R,0}^3$. These terms are used in the following equation for the epithermal absorption and removal corrections.

$$\Sigma_R^3 = \frac{p_r^{(a+1)}}{a + p_r} \Sigma_{R,0}^3 - \frac{a}{a + p_r} \left[(\Sigma_{a,0}^3 - \Sigma_{a,s}^{20,3}) p_r + \Sigma_{a,s}^{20,3} \right] \quad (1-12)$$

where $\Sigma_{a,s}^{20,3} = N_{a,s}^{20} \sigma_{a,s}^{20,3}$ is the smooth absorption of U-238

a = fitting parameter

p_r = resonance escape probability, constant or polynomial

$p_r = \sum_{j=0}^5 a_j [N^{20}(t)]^j$ polynomial resonance escape probability

$$\Sigma_a^3 = \Sigma_{a,0}^3 + \frac{1 - p_r}{p_r} (\Sigma_R^3 + \Sigma_{a,s}^{20,3}). \quad (1-13)$$

Two- and three-group cross sections are obtained from these four-group numbers as weighted average of the first three groups or the first two groups in a manner similar to that used in MUFT[4].

$$r^i = \frac{\chi_F^i + \Sigma_R^{i-1} r^{i-1}}{B_M^2 D_i^1 + \Sigma_a^i + \Sigma_R^i}, \quad \Sigma_R^0 = 0, \quad i = 1, \dots, \ell \quad (1-14)$$

Here $\ell = 5-k$ where k is the number of groups, D_i^1 , Σ_a^i and Σ_R^i refer to four-group cross sections, B_M^2 is the material buckling, and χ_F^i is the fitting spectrum. If $r^i = 0/0$ results, then $r^i = 1$ is used.

$$\bar{r}^i = r^i / \sum_{i=1}^{\ell} r^i; \quad \Sigma^1 = \sum_{i=1}^{\ell} \bar{r}^i \Sigma^i \text{ for } \Sigma = D, \Sigma_a, \nu \Sigma_f \text{ and } \kappa \Sigma_f \quad (1-15)$$

$$\Sigma_R^1 = \bar{r}^{\ell} \Sigma_R^{\ell}. \quad (1-16)$$

The thermal cross sections are used without change in both schemes, and, in the three group scheme, the epithermal cross sections are used directly.

An explicit representation of boron makes use of fictitious diffusion and absorption constants which are fitted by polynomials in a time-dependent number density. In type 2 compositions, an average boron depletion is calculated while in type 3 regions a pointwise depletion is calculated. Element 30 is used as the special composition of types 2 and 3. The special equations for types 2 and 3 compositions are as follows:

$$[D_j^i]^{-1} = \sum_{\ell=0}^4 d_{\ell,k}^i [f_j(t)]^{\ell}, \quad f_j(t) = N_j^{30}(t)/N_k^{30}(0) \quad (1-17)$$

$$\Sigma_{a,j}^i = \sum_{\ell=0}^4 a_{\ell,k}^i [f_j(t)]^{\ell} \quad (1-18)$$

$$\Sigma_{R,j}^1 = \nu \Sigma_{f,j}^1 = \kappa \Sigma_{f,j}^1 = 0 \quad (1-19)$$

for mesh element j in composition k of type 3 regions. In type 2 regions N_j^{30} is constant for every j in composition k . The d_k^1 and a_k^1 quantities are input values of the polynomial.

2. SPATIAL CALCULATION

The spatial calculation solves the few-group, time-independent, two-dimensional neutron-diffusion equations using the same procedure as given in PDQ-40.

The group neutron equations solved by TURBO-40 are

$$\left\{ \begin{aligned} & -\nabla \cdot D_i(x) \nabla \phi_i(x) + \left[\Sigma_i^a(x) + \Sigma_i^r(x) + D_i(x) B_i^2(x) + \lambda_i \Sigma_p \right] \phi_i(x) \\ & = \chi_i(x) \frac{\psi(x)}{\lambda} + \Sigma_{i-1}^r(x) \phi_{i-1}(x) \end{aligned} \right\}_{i=1}^k \quad (2-1)$$

Here x represents the spatial variables, either X-Y or R-Z; i is the lethargy group index; and k , the index of the thermal group, may be two, three, or four. In addition,

$$\Sigma_0^r(x) \equiv 0$$

$$\Sigma_k^r(x) \equiv 0$$

and

$$\psi(x) = \sum_{i=1}^k \nu \Sigma_i^f(x) \phi_i(x). \quad (2-2)$$

The physical interpretations of these symbols are:

D = the diffusion coefficient

ϕ = the neutron flux

Σ^a = the macroscopic absorption cross section

Σ^r = the macroscopic removal cross section

Σ_p = the poison cross section

B^2 = the geometric buckling (zero for R-Z geometry)

χ = the fission source fraction

ψ = the fission source

λ = the eigenvalue

ν = the average number of neutrons produced per fission

Σ^f = the macroscopic fission cross section

t = the poison fraction for each group.

Power iterations are performed to determine ρ , the spectral radius of the iteration matrix for each group. Iterations are performed until $\bar{\rho} - \underline{\rho}$ is less than 0.01 or 30 iterations have been done.

The desired number of flux iterations n (inner iterations) to be performed for each group is determined using the following formulas.

$$\omega = \frac{2}{1 + \sqrt{1 - \rho}} \quad (2-3)$$

$\delta = 0.150$ if the calculations is for a non-cell problem, or

$\delta = 0.075$ if the calculation is for a cell problem

and n is determined from

$$2 \sqrt{1 + \frac{1}{\omega-1}} \left[\omega-1 \right]^n = \delta. \quad (2-4)$$

The number of iterations scheduled will be the first multiple of the ripple depth r greater than n . The ripple depth is the number of iterations per tape read of the coefficients and the source. If a negative flux is detected after these iterations, the negative values are set to zero, and a set of r iterations is made. This continues until no negative fluxes are detected. The ripple depth is problem dependent and will vary between 2 and 5.

During the inner iterations for each group the following terms are calculated.

$$\begin{aligned} R_1 &= \sum_{s,t} \left(\phi_{s,t}^1 - \phi_{s,t}^0 \right)^2 \\ R_2 &= \sum_{s,t} \left(\phi_{s,t}^n - \phi_{s,t}^{n-1} \right)^2 \end{aligned} \quad (2-5)$$

where $\phi_{s,t}^i$ is the flux calculated at point s,t , during inner iteration i and n is the last inner iteration for the group. The ratio of these terms is also calculated

$$\text{DELTA} = \frac{R_2}{R_1}. \quad (2-6)$$

The terms R_1 , DELTA, and the number of inner iterations (a negative inner iteration number means a negative flux was detected requiring additional inner iterations) are printed at the end of the inner iterations for each group.

The source iterations (outer iterations) are terminated when

$$\epsilon^m = \frac{\lambda^m - \underline{\lambda}^m}{2\lambda^m} \leq \epsilon^2 \quad (2-7)$$

where λ^m is the eigenvalue calculated at the end of the outer iteration m , λ^m and $\underline{\lambda}^m$ are the calculated upper and lower bounds, and ϵ is an input parameter.

3. POWER AND FLUX NORMALIZATION

The third section of the TURBO-40 program generates the power shape and normalizes the flux to a specified power level. The power shape is calculated using the flux values given in the spatial calculation and the fission cross sections.

$$p = \sum_i v \Sigma_F^i \phi^i \quad (3-1)$$

where p is the power, i is the group index, and ϕ is the flux. The power shape is integrated to obtain the total power which is then normalized to a specified input power level using the following equation.

$$P = \beta \int_R p dV \quad (3-2)$$

where P = the input power, β = the normalization factor, R = the entire region of solution, and dV = the differential element suitable to the geometry chosen. The numerical approximations to Equations (3-1) and (3-2) are given in the section on output data.

The normalization factor β is used to normalize the flux for use in the depletion equations. The average flux for each mesh rectangle is required for use in the depletion equations. The following equation is used to calculate the normalized average flux for each mesh rectangle and each lethargy group.

$$\bar{\phi}_{\Delta}^i = \beta \frac{\int_{\Delta} \phi^i dV}{\int_{\Delta} dV} \quad (3-3)$$

where Δ = a mesh rectangle.

4. DEPLETION CALCULATIONS

The fourth section in the TURBO-40 program solves the linear, first-order, ordinary differential equations which describe the buildup and depletion of isotopic number densities. Because of the difference equation approximation to the diffusion equations, it is necessary to calculate an average depletion for the rectangles enclosed by adjacent mesh points. The average flux for each

mesh rectangle is defined and normalized to specified power in Equation (3-3). The average flux is assumed to be constant for the time increment. In the case of rapidly changing densities, an analytical solution of the differential equation is evaluated, while for the slowly changing densities a quadratic approximation is used. When self-shielded boron is used, account is taken of the change of the thermal self-shielding factor over the time-step. When explicit boron is represented by fictitious diffusion constants, an effective absorption rate for each mesh rectangle or an average rate for each region is used to recalculate the density. This section has been taken directly from the TURBO program and uses the equations as given in WAPD-TM-221[2].

The isotopic densities are calculated as follows. For isotopic element M as given in Appendix A, let

$$A_M = \sigma_{a,1}^M \phi_1 + \sigma_{a,2}^M \phi_2 + \sigma_{a,3}^M g_3^M \phi_3 + \sigma_{a,4}^M g_4^M \phi_4 \text{ for four groups,} \quad (4-1)$$

$$A_M = \left[\sigma_{a,1}^M \bar{r}_1 + \sigma_{a,2}^M \bar{r}_2 \right] \phi_1 + \sigma_{a,3}^M g_3^M \phi_2 + \sigma_{a,4}^M g_4^M \phi_3 \text{ for three groups, or} \quad (4-2)$$

$$A_M = \left[\sigma_{a,1}^M \bar{r}_1 + \sigma_{a,2}^M \bar{r}_2 + \sigma_{a,3}^M g_3^M \bar{r}_3 \right] \phi_1 + \sigma_{a,4}^M g_4^M \phi_2 \text{ for two groups} \quad (4-3)$$

C_M = similar expression in which $\sigma_{c,i}^M$ is used, $\sigma_c = \sigma_a - \sigma_f$

F_M = similar expression using $\sigma_{f,i}^M$

where

ϕ_i = average flux in group i for each mesh element as defined in Equations (3-3)

$g_3^M = 1$ for $M \neq 29$

g_3^{29} is defined in Equation (1-4)

g_4^M is defined in Equation (1-5)

and

$\bar{r}_i$ = average weighting factors used in the reduction [Equation (1-15)].

The depletion equations for the U-235 chain are

$$\frac{dN_{18}}{dt} = -A_{18}N_{18}, \quad \frac{dN_{19}}{dt} = -A_{19}N_{19} + C_{18}N_{18}. \quad (4-4)$$

The depletion equations for the U-238 (Hf-177 or Ir-191) chains are

$$\frac{dN_{20}}{dt} = -A_{20}N_{20} - \frac{1 - P_r}{P_r} (\Sigma_R + \Sigma_{a,s}^{20})_{k-1} \phi_{k-1} \quad \text{for three or four groups,} \quad (4-5)$$

$$\frac{dN_{20}}{dt} = -A_{20}N_{20} - \bar{F}_3 \frac{1 - P_r}{P_r} (\Sigma_R + \Sigma_{a,s}^{20})_3 \phi_1 \quad \text{for two groups;} \quad (4-6)$$

$$\frac{dN_{21}}{dt} = -(\lambda_{21} + A_{21})N_{21} + N_{20}C_{20} + \frac{1 - P_r}{P_r} (\Sigma_R + \Sigma_{a,s}^{20})_3 \phi_3 \quad (4-7)$$

with similar correction for two groups as in Equation (4-6);

$$\frac{dN_{22}}{dt} = -A_{22}N_{22} + C_{21}N_{21} \quad (4-8)$$

$$\frac{dN_{23}}{dt} = -(\lambda_{23} + A_{23})N_{23} + A_{22}N_{22}. \quad (4-9)$$

For fission product equations let

$$Y_M = \sum_A \bar{N}_A \gamma_{M,A} F_A, \quad A = 18, 20, 21, 23, \quad \text{where } \bar{N}_A = 1/2(N(t_0) + N(t_1))$$

and $\gamma_{M,A}$ is the fractional yield of fission product M for the fissionable isotope A.

Then

$$\frac{dN_{24}}{dt} = -\lambda_{24}N_{24} + Y_{24} \quad (4-10)$$

$$\frac{dN_{25}}{dt} = -\lambda_{25}N_{25} + Y_{25} \quad (4-11)$$

$$\frac{dN_{26}}{dt} = -A_{26}N_{26} + \lambda_{24}N_{24} \quad (4-12)$$

$$\frac{dN_{27}}{dt} = -(\lambda_{27} + A_{27})N_{27} + Y_{27} + \lambda_{25}N_{25} \quad (4-13)$$

$$\frac{dN_{28}}{dt} = Y_{28} - \theta_{28}A_{28}N_{28} \quad (4-14)$$

$$\frac{dN_{30}}{dt} = Y_{30} - \theta_{30}A_{30}N_{30} \quad (4-15)$$

The burnable poison equation is

$$\frac{dN_{29}}{dt} = -A_{29}N_{29} \quad (4-16)$$

For special compositions of types 2 and 3 (explicit boron), element 30 represents the boron isotope. The depletion is calculated from the equation

$$\frac{dN_{30}}{dt} = - \sum_{i=1}^k (\sigma_i \phi_i)_r N_{30} \quad (4-17)$$

When the regionwise depletion scheme is used, the quantity $(\sigma_i \phi_i)$ is the same for all mesh elements r in composition j and is given by

$$(\sigma_i \phi_i) = \left(\frac{\sum_{a,j}^i - a_{O,j}^i}{N_{30}^{30}(t)} \right) \beta \frac{\int_j \phi_i dV}{\int_j dV} \quad (4-18)$$

where β is the normalization factor and ϕ_i is the source-normalized flux given by the spatial calculation.

When the pointwise depletion is used, the quantity $(\sigma_i \phi_i)_r$ is given for each mesh element r by

$$(\sigma_i \phi_i)_r = \frac{\sum_{a,j}^i - a_{O,j}^i}{N_{30}^{30}(t)} \bar{\phi}_r^i \quad (4-19)$$

where $\bar{\phi}_r^i$ is the average power-normalized flux as defined in Equation (3-3). Note that the numerator is a polynomial in the isotopic density of element 30.

When elements 20-23 represent the U-238 chain, $\lambda_{21} = 0$, $\lambda_{23} = 0.17 \times 10^{-8}$, while for hafnium $\lambda_{21} = \lambda_{23} = 0$, for iridium $\lambda_{21} = 1.077 \times 10^{-7}$, $\lambda_{23} = 0$. The value of p_r is a constant term or fitted by a fifth degree polynomial in N_{20} as

$$p_r = \sum_{j=0}^5 b_j N_{20}^j$$

The solutions to these equations are given as follows:

Let $N_M(t_0) = N_0^M$, $N_M(t_1) = N_1^M$, $\bar{N}^M = \frac{1}{2}(N_0^M + N_1^M)$, and $\Delta t = t_1 - t_0$. Elements 18 and 19 as well as elements 20 to 23 when they represent the U-238 chain have equations of the general form

$$\frac{dN_M}{dt} = -A_M N_M + C_L N_L - R_M \quad (4-20)$$

These are approximated by

$$N_1^M = \frac{(2 - A_M \Delta t) N_0^M + 2 C_L \bar{N}_L^L \Delta t - 2 R_M \Delta t}{2 + A_M \Delta t} \quad (4-21)$$

When elements 20-23 represent hafnium or iridium the solutions are

$$N_1^{20} = \left\{ (2 - A_{20}\Delta t)N_0^{20} - \Delta t(\Sigma_R + \Sigma_{a,s}^{20})_{k-1}\phi_{k-1} \frac{2 - p_{r,0} - p'_{r,1}}{p_{r,0}} \right\} / (2 + A_{20}\Delta t) \quad (4-22)$$

where N_1^{20} is calculated with $p_{r,0} = p'_{r,1} = p_r(N_0)$ and then $p'_{r,1} = p_r(N_1^{20})$ is used to give N_1^{20} ;

$$N_1^{21} = N_0^{21} \exp \left\{ -\lambda_{21}^* \Delta t \right\} + \bar{S}_{21} \left[(1 - \exp \left\{ -\lambda_{21}^* \Delta t \right\}) / \lambda_{21}^* \right] \quad (4-23)$$

where $\lambda_{21}^* = \lambda_{21} + A_{21}$,

$$\bar{S}_{21} = A_{20}N_0^{20} + (\Sigma_R + \Sigma_{a,s}^{20})_{k-1}\phi_{k-1} \frac{2 - p_{r,0} - p'_{r,1}}{2p_{r,0}} \quad (4-24)$$

and

$$N_1^{22} = \left\{ N_0^{22}(2 - A_{22}\Delta t) + 2\bar{S}_{22}\Delta t \right\} / (2 + A_{22}\Delta t) \quad (4-25)$$

with

$$\bar{S}_{22} = A_{21} \left[\bar{S}_{21} / \lambda_{21}^* + (\bar{S}_{21} / \lambda_{21}^* - N_0^{21}) \left(\frac{\exp \left\{ -\lambda_{21}^* \Delta t \right\} - 1}{\lambda_{21}^* \Delta t} \right) \right] \quad (4-26)$$

The solution for N_1^{23} is as indicated for the U-238 chain. The resonance correction term in the equations for elements 20 and 21 is multiplied by $\bar{\Gamma}_3$ for two-group problems.

The equation for element 29 is solved as follows. If the thermal self-shielding factor is constant ($a_{32} = 0$), then

$$N_1^{29} = N_0^{29} \exp \left\{ -A_{29}\Delta t \right\} = y_1^{29} N_0^{29} \quad (4-27)$$

When the self-shielding factor is not constant, the above equations represents a first estimate of the depletion where $A_{29} = A_{29,0}$ is calculated using N_0^{29} . If the epithermal factor is assumed constant over the interval, the analytic solution can be obtained in an implicit form and can be used to give the time $t_0 + \tau$ at which the fractional y_1 calculated above actually occurs. Then an

additional step of length $t - \tau$ with revised thermal factor can be made to give a better approximation. Let

$$F = A_{29,0} - \sigma_4 \phi_4 g_{4,0}, \quad g_{4,0} = g_4(f_0^{29}), \quad f_0^{29} = N_0^{29}(t_0)/N_0^{29}(0)$$

and

$$A = \sigma_4 \phi_4 + a_{29} F.$$

Then

$$\tau = \frac{1}{A} \left[a_{29} A_{29,0} \Delta t + \frac{\sigma_4 \phi_4}{F} \ln \left(\frac{A_{29,0} g_{4,1}'}{A_{29,1} g_{4,0}'} \right) \right]$$

where $A_{29,1}'$ and $g_{4,1}'$ are calculated using $N_0^{29} = N_0^{29} y_1$. The additional fractional depletion is given by

$$y_2 = \exp \left\{ - A_{29,1}' (\Delta t - \tau) \right\} \quad (4-29)$$

and

$$N_1^{29} = y_1 y_2 N_0^{29} \quad (4-30)$$

is taken as the final density value.

The solutions to the fission product equations are:

$$N_1^{24} = \frac{1 - \exp \left[- \lambda_{24} \Delta t \right]}{\lambda_{24}} Y_{24} + N_0^{24} \exp \left[- \lambda_{24} \Delta t \right] \quad (4-31)$$

with a similar solution for element 25 with 24 replaced by 25;

$$\begin{aligned} N_1^{26} = & \frac{1 - \exp \left[- A_{26} t \right]}{A_{26}} Y_{24} + N_0^{26} \exp \left[- A_{26} \Delta t \right] \\ & + \frac{\lambda_{24} N_0^{24} - Y_{24}}{A_{26} - \lambda_{24}} \left(\exp \left[- \lambda_{24} \Delta t \right] - \exp \left[- A_{26} \Delta t \right] \right) \end{aligned} \quad (4-32)$$

$$\begin{aligned} N_1^{27} = & \frac{1 - \exp \left[- (\lambda_{27} + A_{27}) \Delta t \right]}{\lambda_{27} + A_{27}} (Y_{25} + Y_{27}) + N_0^{27} \exp \left[- (\lambda_{27} + A_{27}) \Delta t \right] \\ & + \frac{\lambda_{25} N_0^{25} - Y_{25}}{\lambda_{27} + A_{27} - \lambda_{25}} \left(\exp \left[- \lambda_{25} \Delta t \right] - \exp \left[- (\lambda_{27} + A_{27}) \Delta t \right] \right) \end{aligned} \quad (4-33)$$

$$N_1^{28} = \frac{1 - \exp \left[- \theta_{28} A_{28} \Delta t \right]}{\theta_{28} A_{28}} Y_{28} + N_0^{28} \exp \left[- \theta_{28} A_{28} \Delta t \right], \text{ if } \theta_{28} \neq 0 \quad (4-34)$$

or

$$N_1^{28} = N_0^{28} + Y_{28}\Delta t, \quad \text{if } \theta_{28} = 0 \quad (4-35)$$

and a similar equation for element 30 with 28 replaced by 30.

The special boron equation is solved as follows. The time-step Δt is subdivided into ten equal parts and the solution is stepped ahead over each subinterval by assuming the quantity $(\sigma_i \phi_i)_r$ to be constant and by using the approximation

$$N_j = \frac{2 - A_{j-1}\Delta t'}{2 + A_{j-1}\Delta t'} N_{j-1} \quad \text{where } \Delta t' = 0.1\Delta t \quad (4-36)$$

and

$$A_j = \sum_i (\sigma_i \phi_i)_r \quad \text{with } N_j \text{ used to give } (\sigma_i \phi_i)_r.$$

5. GEOMETRY AND BRANCH CALCULATIONS

The geometry in TURBO-40 is the same as described in the PDQ-40 report. The region of solution is a rectangular surface in X-Y geometry and a right cylinder with no angular dependence in R-Z geometry. Either a zero flux or a zero derivative of the flux can be used at the boundaries with an independent choice at each boundary. In addition, a 180° rotational symmetry condition can be applied along the top boundary or a 90° rotation symmetry condition can be applied along the top and left sides of the problem. The maximum column boundary is 151, the maximum row boundary is 201, and the maximum number of interior mesh points is 20,000. These mesh line and mesh point limitations are identical to those in PDQ-40. However, the number of compositions in TURBO-40 is limited to 150. The user should read the geometry description in the PDQ-40 report for a more complete explanation.

A branch calculation is defined as a particular problem in which the nonuniform isotopic densities of the time-dependent elements at some time-step of a problem are used as input to a second problem. Branch calculations are generally auxiliary studies at some point in the original problem such as temperature changes, coolant voiding, stuck rod problems, fuel replacement, etc. A new history tape is created in the branch calculation. Two types of branch calculations are available in TURBO-40.

A branch-only calculation is made when the user desires a new history tape but does not wish to alter the densities of the 30 elements. This option is identical to a normal time-step calculation. The storage of the time steps of a problem on one history tape may not be possible when there are a large number of mesh points and many time-steps. Hence, when a history tape is nearly full of data, the user can make a branch only calculation and create a new history tape for continuation of a normal problem.

The second type of branch calculation is replacement. Replacement refers to the substitution of a set of homogeneous densities for the generally nonuniform densities in selected compositions. Such a composition is selected by specifying as negative quantities the new atom densities which are to replace the old atom densities in the specified compositions.

III. INPUT PREPARATION

This section on input preparation describes the input data required for TURBO-40 and the various options available. Input forms are supplied for input items. The forms originated from the Westinghouse TURBO report, WAPD-TM-221, and have been revised to agree with the present TURBO-40 input preparation. Some options shown on the input forms have not been implemented in TURBO-40 and are so designated in this section and on the input forms. Appendix B contains a complete set of these forms filled out for a sample problem. Appendix C contains a listing of the input cards punched from the input forms and the output produced by the program for the sample problem.

The information on the input forms for TURBO-40 is key punched on cards in a self-forming form which is identical to the procedure used in PDQ-40. Section III of the PDQ-40 report gives the description of the card format.

The numeric information on each card is identified by a six-digit number punched in the first six columns. Each card in the case should have a separate ID number. If two cards are read with the same ID number, the first card read will be ignored and the second card will be used. A TURBO-40 problem usually consists of more than one case or time-step each of which is considered a separate calculation. Input is carried over from case to case within a particular computer run. Hence, the first case must contain a complete set of numeric input data necessary to run the problem, and each succeeding case need only contain those cards for which the data are to be changed from the previous case. Each TURBO-40 deck must contain at least one series card, one case card, one complete set of numeric data cards, and a \$TURBO card at the end of the data. Additional cases or time-steps may be run by including a case card, data cards specifying changes or additional information, and a \$TURBO card for each case. A run may have several problems; each must start with a series card. If the user has performed a TURBO-40 problem and wishes to continue the problem from a previous time-step saved on a history tape, the user must include the series card, a filetype card listing the problem identification label and the reel number of the history tape, a case card, a complete set of data including the specific time-step at which the user is continuing the problem, and a \$TURBO card.

The remainder of this section will describe the input data as given on the input forms in Appendix B.

1. CONTROL INFORMATION AND MISCELLANEOUS DATA, SERIES 01

1.1 Series Card

A series card must be the first card of any problem series deck. The series card is also required when using the continuation option since this defines a new problem series. Any comments can be placed through columns 80. Column 1 is always an asterisk, and columns 1-6 will comprise the problem label or identification on a history tape if the "save flux" option is requested. When performing the continuation option a new history tape will be created, and hence the problem label in columns 1-6 should be different from the problem label on the history tape from which the continuation is made.

1.2 Filetape Card

The filetype card is required when restarting a problem from a previous time-step on a history tape. The word FILTAP should be placed in columns 1-6. Columns 7-12 are the problem identification label on the history tape. Columns 13-18 are the reel number of the history tape. Any comment can be placed in columns 19-80.

1.3 Case Card

The case card is required for every time-step. Any comment can be made in columns 1-80. An asterisk may not be placed in column 1.

1.4 Edit Options

Normal, Input, Output A, or Output B. The normal edit option is used for making the usual time-step calculations. When the normal edit option is checked, the TURBO-40 program processes the input, calculates the macroscopic cross sections, solves the few-group diffusion equations for the eigenvalue and flux, normalizes the fluxes to a specified power, performs the depletion calculations, and edits the output data. The input edit option is used to obtain a check of the input data. The input edit also provides the macroscopic cross sections which are calculated from the isotopic number densities and are required for the few-group diffusion equations.

The output A and output B edit options are nearly identical except for the method of handling the depletion calculations. Both output edits provide the input checks and calculate the macroscopic cross sections. At this point in the output edits, the TURBO-40 program uses the fluxes on the history tape at the specified time-step to perform the composition edits and power and flux normalizations. Nothing has been written on the history tape up to this point in the output edit. The TURBO-40 program is ready to perform the depletion calculation, and the output A and output B edits now differ.

Output A edit option recalculates the depletion and writes the new atom densities on the history tape. Hence, the output A edit option allows the user to respecify the time interval of depletion and/or the power level to obtain new atom densities for the next time-step calculation. The new atom densities are rewritten on the history tape. If this time-step is not the last time-step on the history tape, all the information for the following time-steps on the history tape will be destroyed. Therefore the user must be very careful when using the output A edit option.

Output B edit option does not destroy any of the information on the history tape. If a zero time increment of depletion is used, the output B edit option does not perform the depletion. This case is then finished and the following case will be performed. If a nonzero time increment of depletion is used, the TURBO-40 program uses the time increment and power level specified for this output edit and calculates new atom densities. These atom densities are not saved on the history tape. Any succeeding case will use the atom densities which are on the history tape for performing any other calculations.

1.5 Branch Options

No, Yes, Replacement. The branch option allows for a branch from the main calculation to study special problems. When this option is selected (either

Yes or Replacement), a new history tape is created and the original tape is saved. Check No on the input form if the option is not desired; ie, if the user wishes to continue the problem with the time-step to be placed on the present history tape, the option No should be checked. Although the branch option is effective only for the first case of a multiple-case job, the second and succeeding cases must indicate No continuation. The time-step number associated with the number density distribution desired is supplied as the current time-step number of the problem. Thus, all branch problems will begin with a nonzero time-step number since a branch at time-step zero is not necessary.

In TURBO-40 there are three options. The following table lists the number to be supplied for the option requested. The user should note that the options for expansion or contraction of the mesh as explained in the original TURBO manual (WAPD-TM-221) have not been included in the TURBO-40 program.

<u>ENTRY</u>	<u>TYPE</u>
0	No continuation (normal calculation or rerun)
1	Branch only, no replacement
-1	Branch with replacement

The no continuation option is used for running a normal time-step calculation or for rerunning a previous time-step. When rerunning a previous time-step, the user should take care as the information recorded on tape beyond that which is used for the time-step being rerun will be lost except in the input and output B options.

The branch only with no replacement is used to create a new history tape starting with the specified time-step. This option is identical to the normal (No continuation) option except for the creation of a new history tape. When the user is running a large problem near 15,000 meshpoints and six or more time-steps, sufficient storage may not be available to save all the time-steps on a single history tape. Hence, the branch only with No replacement option allows the user to continue with normal calculations by creating a new history tape. This option is also used for studying special problems such as stuck rod calculations or maximum xenon problems. (At present the maximum xenon option has not been implemented for use in the TURBO-40 program.)

The replacement option refers to the substitution of a set of homogeneous densities for the generally nonuniform densities in selected compositions. Such a composition is selected by specifying as a negative quantity the density of each of the elements 1 through 30 which one desires to change from the history tape values. Densities not specified as negative quantities remain the same as saved on the history tape for the specified time-step. A new history tape is created when using the replacement option.

1.6 Geometry

X-Y or R-Z. The geometry must be X-Y if there is diagonal symmetry or if there is 90° or 180° rotational symmetry.

1.7 Diagonal Symmetry

Yes or No. If the problem has symmetry about X-Y, card series 06 can be omitted and only one half of the compositions overlay need be specified. Problem running time is not affected.

1.8 Number of Groups

Give the number of lethargy groups, $2 \leq k \leq 4$.

1.9 Number of Compositions

Insert the number of compositions, $c \leq 150$. This is the largest composition number for which input parameters are provided. The number of compositions c is used as a check of final termination points.

1.10 Number of Columns

Give the number of the last column, $ss \leq 151$, in the mesh. Number from the left to the right beginning with zero.

1.11 Number of Rows

Give the number of the last row, $tt \leq 201$, in the mesh. Number from the top to the bottom beginning with zero.

The number of interior mesh points is given by the product $(ss-1)(tt-1)$ and may not exceed 20,000.

The row and columns boundaries and mesh point spacing must be equal if there is diagonal symmetry or 90° rotational symmetry. For 180° rotation, the right most mesh point (column boundary ss) must be even.

1.12 Boundary Conditions

Zero flux, symmetry, 90° rotational, or 180° rotational. The left-hand boundary condition must be symmetry if the geometry is R-Z. The left-hand and upper boundary conditions must be the same if there is diagonal symmetry or 90° rotational symmetry. The left-hand and right-hand boundary conditions must be the same if there is 180° rotational symmetry.

1.13 Save Tape Option

Yes or No. If the save flux option is checked Yes on the first time-step of a new history tape, the history tape will be automatically saved for every succeeding time-step placed on the history tape.

1.14 Initial Eigenvalue Estimate

Give the initial eigenvalue estimate for the first case in the job. $\lambda_0 \neq 0+0$ for the first case of a series. The λ_0 estimate from the first case of a job will be used for the λ_0 estimate for each succeeding case except when the succeeding case includes the data card containing a new λ_0 estimate. A new λ_0 estimate can be entered for each case. If the λ_0 estimate is zero, the converged lambda from the previous case will be used. When performing an output edit, the converged eigenvalue for the problem which created the fluxes should be entered for the λ_0 estimate.

1.15 Convergence Parameter

$\epsilon > 0$. The use of ϵ is described in Section II-2.

1.16 Microscopic Data

If this number is set to zero, all cross sections are specified on card series 16, while one, two, and three refer to fast group cross sections appropriate to U-238, hafnium, or iridium. The fast group constants in the TURBO-40 program originally came from the TURBO (WAPD-TM-221) program, and the authors do not know how valid these cross sections are.

1.17 Chain Number

The chain number is to be zero, one, or two to indicate that elements 20 to 23 represent U-238, hafnium, or iridium. The use of chain number one and two for hafnium and iridium has not been checked out for use in TURBO-40. If the user encounters problems using these chains, contact one of the authors.

1.18 Special Compositions

Type 1, Type 2, Type 3. Subregions of compositions type 1 are those in which macroscopic data are to be given. If present, they are identified with compositions one to C_1 ; $C_1=0$, if this option is not used. Subregions of compositions type 2 are regions of average depletion for explicit boron as described in Section II-1. Compositions C , $C_1 < C \leq C_2$, are type 2 unless the option is not used when $C_2=0$. Subregion of type 3 composition are regions of pointwise depletion for explicit boron as described in Section II-1. Compositions C , $C_2 < C \leq C_3$ if $C_2 \neq 0$, or $C_1 < C \leq C_3$ if $C_2=0$, are type 3 unless the option is not used when $C_3=0$. All other compositions up to and including the total number of compositions are general materials using microscopic data and atom densities.

1.19 Isotopic Density Reset Option (NZERO)

The number NZERO is used to reset the isotopic density of certain fission products to zero prior to the spatial calculation. It is formed by adding the control numbers associated with the fission products to be set to zero where 1-24, 2-25, 4-26, 8-27, and 16-28 are the correspondences. For example, NZERO=21 would set the densities of elements 24, 26, and 28 to zero. This option has not been implemented in TURBO-40.

1.20 Time Step

The time-step number for the current case is entered. Begin numbering the time-steps with zero. Each succeeding case must be one greater than the previous case. The time-step number is used to determine the positioning for the history tape. The user should be careful in specifying the time-step number since TURBO-40 does not protect the information on the history tape. For example, if the user has a history tape with time-steps 0, 1, and 2 and wishes to run time-step 3, an incorrect specification of the time-step number such as 1 will cause the time-step 1 to be rerun using the data input for time-step 3. This incorrect rerun destroys original time-steps 1 and 2 and places the incorrect information on the history tape for the new run.

1.21 Time Increment

The time increment is the time interval in seconds for the depletion during the specified time-step.

1.22 Power Level

The power level is the power in watts which is used to normalize the calculated fluxes for use in the depletion equations.

1.23 Problem Type

Equilibrium xenon or maximum xenon. Equilibrium xenon is used when making a normal calculation. Maximum xenon calculations have not been implemented in the TURBO-40 at the present time.

1.24 Chi for Diffusion Equations

Supply k values of the fission spectrum to be used in the diffusion equations.

1.25 Chi and "a" for Fitting Scheme

For four-group problems, give the value of the fitting parameter, a , if it differs from $a=0.67$, or omit the card. The fitting parameter, a , is used in the correction of the epithermal absorption and removal cross sections as shown in Equations (1-12) and (1-13). If the user desires composition dependent values of the fitting parameter, use the epithermal absorption and parameter " a " cards in TURBO-40 Form 9. For two- and three-group problems, give 5- k values of the fitting spectrum [see Equation (1-14)] and the value of a .

1.26 Poison Fraction for Each Group

Give a value for a poison fraction, t_i , for each group unless identically zero; then omit the card. The use of the poison fractions and poison cross section has not been checked out for use in TURBO-40.

1.27 Fractional Fission Yields and θ^M

For elements 25(I-135), 28(FP-1), and 30(FP-2), supply the fractional fission yield γ for each fissionable isotope. For elements 28 and 30, give the parameter θ which is used as shown in Equations (4-14) and (4-15) of Section II as an absorption fraction loss.

1.28 Power Fraction for Maximum Xe-135

Supply the fraction by which the power will be reduced for use in the maximum Xe-135 calculation. The maximum Xe-135 calculation has not been implemented in TURBO-40.

1.29 Miscellaneous Physical Parameters (no form used)

The TURBO-40 program includes values for the miscellaneous physical parameters listed below. The user has the option of changing any or all of these values for the physical parameters by using the card numbers given and supplying the number of floating-point quantities indicated.

010020 (4) $\gamma_{24,A}$, yields for Pm-149, $A = 18, 20, 21, 23$

010021 (4) $\gamma_{27,A}$, yields for Xe-135, $A = 18, 20, 21, 23$

010022 (1) λ_{21} , decay for Ir-192

010023 (1) λ_{23} , decay for Pu-241

- 010024 (1) λ_{24} , decay for Pm-149
- 010025 (1) λ_{25} , decay for I-135
- 010026 (1) λ_{27} , decay for Xe-135
- 010027 (4) $\kappa_{18,i}$, energy per fission neutron for U-235, $i = 1, 2, 3, 4$
- 010028 (4) $\kappa_{20,i}$, energy per fission neutron for U-238, $i = 1, 2, 3, 4$
- 010029 (4) $\kappa_{21,i}$, energy per fission neutron for Pu-239, $i = 1, 2, 3, 4$
- 010030 (4) $\kappa_{23,i}$, energy per fission neutron for Pu-241, $i = 1, 2, 3, 4$

The yields for I-135 and fission products 1 and 2 are given on cards 010008 to 010010 of Form 1.

2. EDIT CONTROL, SERIES 01

2.1 Flux-Weight Edits, Form 8

The flux-weight edit for each composition and for the set of all fuel compositions is automatically output by the TURBO-40 code. Up to nine additional sets of compositions for the flux-weight edits can be specified by the user. The flux-weight edits are indicated on Form 8. For each set, s , begin with sequence number $n=1$ and supply the numbers of the compositions to be flux-weighted. The sets must be in sequential order starting with $s=1$.

2.2 Pointwise Edits, Form 3

2.21 Pointwise Flux. For $t=2$, s = the group number, and n = the sequence number, give the subregions for pointwise flux edits desired in each group. Each subregion is given by the left and right column numbers and the upper and lower row numbers.

2.22 Power Edit. For $t=4$, $s=1$, and n = the sequence number, give the subregions over which point-to-core average power is to be printed. Each subregion is given by the left and right column numbers and the upper and lower row numbers.

2.23 Regions Over Which Cross Section and Atom Density Edits are Desired. For $t=5$, $s=1$, and n = the sequence number, give the subregions over which the cross sections and atom density edits are desired. Each subregion is given by the left and right column numbers and the upper and lower row numbers.

2.24 Cross Section and Atom Density Edits. For $t=6$, $s=1$, and n = the sequence number, give the library number of desired materials for which old atom densities (atom densities before the depletion calculation of this step) are desired. For $s=2$ and n = the sequence number, give the library number of desired materials for which new atom densities (atom densities after depletion calculation of this step) are desired. For $s=3$ and n = the group number, give the cross section numbers according to the following: $1=D$, $2=\Sigma_a$; $3=\nu\Sigma_f$; $4=\Sigma_T$; $5=\kappa\Sigma_f$; $6=\Sigma_{tot}$; for which macroscopic cross sections are desired. The cross sections

and atom densities are edited for each mesh rectangle in the subregions specified with t=5 above.

3. MACROSCOPIC DATA, SERIES 02, FORM 4

For special compositions of type 1, $c \leq c_1$ give values for D , Σ_a , Σ_r , $\nu\Sigma_f$, $\kappa\Sigma_f$ in sequential expansion form with the upper termination point being the number c_1 . If $c_1=0$, this series is not used. A full set must be given for each group. See the PDQ-40 manual for a more complete explanation of the use of sequential expansion. To specify rod regions by using the logarithmic derivative condition, set $D = \Sigma_r = \nu\Sigma_f = \kappa\Sigma_f = 0$ and $\Sigma_a = C$, the parameter used in the logarithmic derivative condition, for the required group(s).

4. MESH INTERVALS, SERIES 05 AND 06, FORM 6

Mesh intervals are specified for both the X(R) and Y(Z) coordinate directions. The series number for the X or R coordinate direction is 05 and the final termination point must be the column boundary. The series number for the Y or Z coordinate direction is 06 and the final termination point must be the row boundary.

The mesh intervals are expanded in the manner H,cc. The mesh interval H is followed by the column or row number cc at which the interval changes from this value to the next specified. There may be as many sets H,cc per card and as many cards in this series as needed. The successive values of cc must be increasing and the last value specified must be equal to the right column (or bottom row) boundary. The mesh specification must always begin at column 0 or row 0, even if there is a symmetry axis at column 1 or row 1.

The mesh intervals must be nonzero and positive, and must be in units of centimeters. No change in intervals is permitted at a symmetry axis. If the X and Y mesh intervals are identical, the Y(series 06) intervals may be omitted. If there is diagonal symmetry or 90° rotational symmetry, the Y intervals are ignored. If there is 180° rotational symmetry, the total number of X intervals must be even and the intervals must be symmetric about the midpoint of ss/2.

5. BUCKLING, SERIES 08, FORM 5

Group and composition-dependent buckling values may be specified. The series number is 08, the subseries number is the group number if the bucklings are group dependent, and the subseries number is 5 if the bucklings are group independent. The sequence begins with 001, and the final termination point must be the composition limit. The bucklings are input using the composition expansion method, and the number of pairs may be more or less than indicated on the input form. If subseries 5 is present, subseries 1 through 4 cannot be present

and vice-versa. If the series is omitted, the buckling will be identically zero. The series 08 cards may not be present in R-Z geometry.

6. POISON CROSS SECTIONS, SERIES 09, FORM 5

If $\Sigma_p=0$, the series can be omitted. Specify values of Σ_p for each composition in sequential expansion form.

7. RESONANCE ESCAPE PROBABILITY P_r , SERIES 10 and 11

Either a constant or a polynomial term can be entered for the resonance escape probability for U-238 in each composition. The constant p_r terms are entered using series 10 on Form 5. Unless identically one, give values of constant p_r for each composition in sequential expansion form. The polynomial p_r terms are entered using series 11 on Form 9. For all compositions in which p_r is represented by a polynomial give the six polynomial coefficients. Upper and lower termination points are composition numbers. Data supplied in polynomial form are overlaid on the data given in card series 10. Omit series 10 and 11 if $p_r=1$ everywhere. Omit series 11 if polynomial p_r terms are not used.

8. ISOTOPIC NUMBER DENSITIES, SERIES 12, FORM 5

For each element present give the value of its number density for each composition in a sequential expansion form. Termination point is a composition number and a full set must be given. Use the element number $1 \leq M \leq 30$, as the subseries number. Omit the subseries for elements which are not present. Isotopic number densities are saved on tape, and therefore the isotopic number density cards are ignored in all cases except the initial time-step 0 and the branch calculation with replacement.

Note that when a branch calculation involving the replacement option is selected, all number densities from the previous time-step are used except for the element number densities specified as negative quantities. The nonuniform number density of an element in a specified composition is replaced by a uniform number density when replacement occurs.

Further note the dual use of element 30. In special compositions of types 2 and 3, it is the burnable poison, while in normal regions it is a lumped fission product.

9. SELF-SHIELDING FACTORS, SERIES 13, FORM 5

Give constant thermal self-shielding factors differing from unity for elements 1 to 30 by using the element number as the subseries number. Termination point is the composition limit and a full set must be given. Variable factor parameters are given for element 18 by using subseries numbers 18 and 31, variable thermal factor parameters for element 29 by using subseries numbers 29 and 32, and variable epithermal factor parameters for element 29 by using numbers 34 and 35. [See Equations (1-4) and (1-5).]

10. POLYNOMIAL CROSS SECTIONS FOR TYPE 2 AND 3 SPECIAL COMPOSITIONS, SERIES 14 AND 15, FORM 9

Series 14 is used to input the d_g polynomial values for the diffusion coefficients. Series 15 is used to input the a_g polynomial values for the absorption cross section. For each composition of types 2 and 3, $c_1 \leq c \leq c_3$ and for each group give the five polynomial coefficients for D and Σ_a in the overlay expansion Form 9. [See Equations (1-17) and (1-18).] No check is made to ensure that all compositions are specified.

11. MICROSCOPIC CROSS SECTIONS, SERIES 16

The series 16 is used to specify microscopic cross sections for the elements. As previously mentioned, a fast cross section library is available in the code for the isotopes specified in Appendix A. Corrections can be made to this fast cross section library or the user can enter a completely independent set of cross sections. Thermal cross section must be entered by the user. Give epithermal absorption cross sections for element 20 and element 23 and fitting parameter a for each composition, if desired, by using Form 9. The fitting parameter given in Form 9 will replace the previously specified fitting parameter given on card 010006. Give the microscopic cross sections for the elements by using Form 2. In group four omit σ_T . Give σ_f and $\nu\sigma_f$ for elements 18, 20, 21, and 23 only. The subseries in Form 2 is the group number using two digits and the sequence number is the element number in two digits.

12. COMPOSITION DESCRIPTION, SERIES 17, FORM 7

The series number for the composition description is 17 and the sequencing begins with the sequence number 0001. Each composition overlay set consists of five integer numbers specifying the following data: (a) the first number is the composition which is to be placed in all mesh rectangles included in the rectangular region specified by the remaining four numbers; (b) the second number is the column mesh line specifying the left edge of the rectangular region; (c) the third number is the column mesh line specifying the right edge; (d) the fourth number is the row mesh line specifying the top edge of the rectangular region; and (e) the fifth line is the row mesh line specifying the bottom edge. Any

mesh rectangle may be included in as many overlay sets as desired; however, the last composition specified for any mesh rectangle will be used in the calculation. A composition must be placed in every mesh rectangle in the problem. The total number of composition overlay sets is limited by the overall restriction of 9,700 input quantities including card numbers. Refer to the PDQ-40 report for a more complete description.

13. COMPOSITION AREAS, SERIES 18, FORM 5

Use the series 18 cards to supply estimates for the volume or area integrals for each composition. The final termination point must be the composition limit.

The inclusion of the composition areas is optional. When this option is exercised, the calculated composition areas are compared with the input values. If all input values are within one percent of the calculated areas, the problem is run as usual. If one or more input values do not agree, the calculated areas are printed, the picture edit is performed even if not requested, and the problem is rejected. If the areas are not entered, the calculated areas are printed. This description of the composition areas holds for X-Y geometry. For R-Z geometry, substitute the word volume for the word area.

14. FLUX GUESS, SERIES 21, FORM 5

The flux guess is specified by group and composition using the series number 21. The subseries number is the group number and a subseries for every group is required. Within each subseries the final termination point must be the composition limit. The flux guess values are input using the composition expansion method. The series may be omitted for every problem except the initial time step zero which requires input flux guess values.

IV. OUTPUT

1. INPUT EDIT

The input edit consists of the code's interpretation of the control information; the sequence of mesh intervals in each coordinate direction; the picture edit of the composition overlay (optional); the calculated areas or volumes of the compositions in the overlay; the microscopic cross sections; the macroscopic cross sections D , Σ_a , Σ_r , $v\Sigma_f$, Σ_{total} , and B^2 by group and composition; and the resonance escape probability and fitting parameter by composition.

2. ITERATION EDIT

At the beginning of the iteration procedure, the calculation of the spectral radius ρ is performed for each group. The editing of the rho calculation includes the spectral radius ρ , upper and lower bounds $\bar{\rho}$ and $\underline{\rho}$, and the number of rho iterations performed.

For every outer iteration, the initial residual, DELTA, and the number of inner iterations are given for each group. The editing at the end of each outer iteration includes the eigenvalue, upper and lower bounds $\bar{\lambda}$ and $\underline{\lambda}$, the ϵ convergence, and the source renormalization factor. An estimate of $\bar{\sigma}$, the ratio of λ to the next largest eigenvalue, is made at the beginning of each source extrapolation cycle, and the extrapolation factors α and β are given for each succeeding iteration.

3. COMPOSITION INTEGRATION EDITS

The composition integration and power fraction edit consists of the composition area (volume) and the integrals and averages of the group fluxes and power for each compositions in the mesh. The fluxes are not normalized but the powers are normalized to the input power. The power fraction is the fraction of the total core power that each compositions contributes. These values are obtained by calculating the flux and power integrals and the area (volume) for each interior mesh rectangle and taking appropriate sums of these quantities.

The integrated flux in group i for mesh rectangle r , bounded by columns $s-1$ and s , rows $t-1$ and t , for X-Y geometry is

$$\tilde{\phi}_{i,r} = \frac{h_t s}{4} (\phi_{i,s-1,t-1} + \phi_{i,s-1,t} + \phi_{i,s,t-1} + \phi_{i,s,t}) \quad (3-1)$$

and for R-Z geometry is

$$\begin{aligned} \tilde{\phi}_{i,r} = \pi \frac{h_s h_t}{2} \left[\left(r_s + \frac{h_s}{4} \right) (\phi_{i,s-1,t-1} + \phi_{i,s-1,t}) \right. \\ \left. + \left(r_s + \frac{3h_s}{4} \right) (\phi_{i,s,t-1} + \phi_{i,s,t}) \right] \end{aligned} \quad (3-2)$$

Here h_s is the interval between columns $s-1$ and s , h_t the interval between row $t-1$ and t , and r_s the distance from the symmetry axis to the mesh columns $s-1$ in R-Z geometry. The area of mesh rectangle r in X-Y geometry is

$$A_r = h_s h_t \quad (3-3)$$

and the volume in R-Z geometry is

$$V_r = \pi h_s h_t (2r_s + h_s) \quad (3-4)$$

The integrated power for mesh rectangle r is

$$\tilde{P}_r = \sum_{i=1}^k \kappa_i \Sigma_i^f \tilde{\phi}_{i,r} \quad (3-5)$$

The unnormalized integrated power for each composition c is

$$\tilde{P}_c = \sum_{r(c)} \tilde{P}_r \quad (3-6)$$

where the $\sum_{r(c)}$ is the sum of all mesh rectangles r in composition c . The unnormalized integrated powers for all compositions are summed and normalized to the input power using the following equation,

$$P = \beta \sum_c \tilde{P}_c \quad (3-7)$$

where P is the input power and β is the normalization factor. The normalized power for each composition is obtained by the following equation,

$$P_c = \beta \tilde{P}_c \quad (3-8)$$

The power fraction for each composition is

$$\text{Fraction} = \frac{P_c}{P} \quad (3-9)$$

The composition-average distribution analysis edit gives the full core average group flux and power. The edit also gives the composition-averages with the minimum and maximum group flux and power. The composition integration and power fraction edit and the composition-average distribution analysis edit are automatically output by TURBO-40.

4. FLUX-WEIGHTED MACROSCOPIC PARAMETERS

Flux-weighted macroscopic parameters are automatically output by group for each composition and for the set of all fuel compositions. Additional sets of compositions for which flux-weighted macroscopic parameters are requested are computed by TURBO-40. The flux-weighted cross sections are computed from the following equations. Let

$$W_c(\sigma_i) = \int_c \sigma_i \phi_i dV \quad (4-1)$$

where c refers to the subregions comprising a composition, the subregions containing fuel, or the subregions of a specified set of compositions.

Then

$$\bar{\sigma}_c^i = W_c(\sigma_i) / \int_c \phi_i \, dV \quad (4-2)$$

for $\sigma = D, \Sigma_a, \nu\Sigma_f, \kappa\Sigma_f$, and Σ_r . Also

$$\begin{aligned} \bar{B}_c^{2i} = & \left\{ \frac{\chi_i}{\lambda} \sum_{j=1}^k W_c(\nu\Sigma_f^j) + W_c(\Sigma_r^{i-1}) - B_{c,i}^2 W_c(D_i) \right. \\ & \left. - W_c(\Sigma_a^i + \Sigma_r^i + t_1 \Sigma_{p,c}^i) \right\} / W_c(D_i). \end{aligned} \quad (4-3)$$

The quantity $B_{c,i}^2$ is the input buckling.

5. POINTWISE FLUX AND POWER EDITS

Pointwise values of flux and power are edited over the regions specified in the input. The pointwise values are displayed in a row and column array.

The power at a point is not well defined in that $\kappa\Sigma^f$ may be multiple-valued. Figure 1 illustrates the most severe case in which three different fuel materials and one nonfuel material surround a mesh point n . The values of $\kappa\Sigma^f$ are different for each material. For output purposes quadrant values, $P_{n,q}$, are computed at each point, and an average over the fuel quadrants is called the point power at the point n . The equations are

$$P_{n,q} = \sum_{i=1}^k \kappa\Sigma_{i,n,q}^f \phi_{i,n,q}, \quad P_n = \sum_{q=1}^{q=4} S_{n,q} / \sum_{q=4}^{q=4} \eta_q \quad (5-1)$$

$$\text{where } \eta_q = \begin{cases} 0, & \text{if quadrant is nonfuel} \\ 1, & \text{if quadrant is fuel} \end{cases}$$

and q is the quadrant NE, SE, SW, or NW. The distinct nonzero values at each point in the mesh are divided by the average fuel region power and these normalized values are printed.

FIG. 1 MATERIAL SURROUNDING MESH POINT N.

6. FLUX CONTOUR PLOTS

The calcomp plotter and a separate program, Phillips Petroleum Program Number 40*0302, can be used to obtain flux contour plots using the fluxes saved on a history tape. Power contour plots are not available.

7. COMPOSITION POWER FRACTION PER ISOTOPE

The total power per composition and the fraction of the total power produced by each fissionable isotope in the composition is automatically output by TURBO-40.

8. NUMBER DENSITY EDITS

The average end-of-time-step number densities for the thirteen time-dependent isotopes are edited for each composition. Average number densities are given by

$$\frac{\int_c N_m(t_i) dV}{\int_c dV} \quad (8-1)$$

The average number densities are followed by the integral of the number density times the flux for each group.

The isotopic number densities in the mesh rectangles of specified regions are printed if desired. Both old atom densities (number densities of specified isotopes before the depletion calculation of this step) and new atom densities (number densities of specified isotopes after the depletion calculation of this step) can be obtained.

9. POINTWISE MACROSCOPIC EDITS

Macroscopic cross sections in the mesh rectangles of specified regions are printed if desired. The macroscopic cross sections D , Σ_a , Σ_r , $v\Sigma_f$, $\kappa\Sigma_f$, and Σ_{tot} can be obtained.

10. PROBLEM IDENTIFICATION AND PROBLEM TIME

The problem identification consists of the time-step number, the Computer Center reel number on which this problem has been placed, and the problem label on the history tape if the "save flux" option is requested. This problem identification is listed at the end of each case. The computer time required for making the time-step calculation is also recorded at the end of the printout for each time-step.

V. COMPUTER REQUIREMENTS

A 32,768-word IBM 7040 or 7044 with floating point instructions, extended instruction set, and a minimum of 12 tape drives, is required for TURBO-40. If there are only 12 tape drives, the system library tapes will have to be removed at start of execution and those tape drives will have to be dialed to scratch units. Tape drives required are printed on the typewriter at the start of every TURBO-40 run. Tape organization for TURBO-40 is given in Table 1. A TURBO-40 logical tape unit is related to a system symbolic tape unit.

TABLE 1

TURBO-40 TAPE ORGANIZATION

<u>Logical Tape No.</u>	<u>System Designation</u>	<u>Information On Tape</u>
2	S.SIN1	Input
3	S.SOU1	Output
4	S.SU09	Scratch
5	S.SU03	Scratch
6	S.SU05	Scratch
7	S.SU00	Scratch
8	S.SU02	TURBO-40 Program Tape
9	S.SU04	Scratch
10	S.SU11	History Tape (Regular Problem) or Scratch
11	S.SU08	Scratch or History Tape (Con- tinuation or Replacement)
12	S.SU07	Scratch
13	S.SU10	Scratch

Logical tape unit 10 is the TURBO-40 history tape for regular problems while unit 11 is used as a scratch tape. When making a continuation or replacement calculation, the old history tape is mounted on unit 10 and a new history tape is created on unit 11. After the continuation or replacement calculation has been initiated, the program instructs the operator to remove the old history tape from unit 10 and mount a scratch tape for completion of the problem. Logical tape unit 8 is the TURBO-40 program tape.

VI. TURBO-40 HISTORY TAPE

The organization of the data saved on the TURBO-40 history tape is given in this section. The user may need to know this information if problems are encountered when using the history tape for additional calculation.

The TURBO-40 history tape is written using the TAPE40 subroutine. (The TAPE40 routine provides tape positioning capability not provided by the standard operating system. It does this by trailer records for each file. These trailer records are processed by TAPE40 and are not considered as data.) The description here will describe only the pertinent data in the files of the TURBO-40 history tape. The tape is composed of an initial file labeling the tape, a set of files for each problem saved on the history tape, and a final file specifying the end of the data on the history tape.

FILE 1 consists of one record containing four computer words:

BCI 4,TURBO HISTORY TAPEXXXXXX

where X's represent the tape number of the history tape. This number is the Computer Center reel number for this tape input by the computer operator when the user creates a new TURBO-40 history tape. This number is given in the output of each problem placing results on a history tape that will be saved. This file is written at time-step zero or as a new history tape is created in a continuation problem, and then only if the save tape option is indicated. A tape without this file cannot be called by the FILTAP card. The save tape option need be indicated only at the time the tape is created. Subsequent runs using the history tape need not indicate the save tape option since the code will always save a tape that has been requested by a FILTAP card.

FILE 2 consists of one record containing five words:

LAB,TSNO,NGRP,CBDY,RBDY.

The symbol LAB indicates the label in columns 1 through 6 of the series card, TSNO is the time-step number entered on card 010004 at the time the tape is created, NGRP is the number of groups, CBDY is the number of columns, and RBDY is the number of rows. This file and the next NGRP+1 files constitute the information stored for a time-step. If the tape is created during time step zero, TSNO of this file will be zero, and the next NGRP+1 files will be obtained from the expansion of the series 12 and 21 cards. If a history tape is created during a continuation problem, this file and the next NGRP+1 files are copied from files of a previously created history tape associated with the time-step number on card 010004. The LAB will be different for the two tapes, and the number density file can be modified by the series 12 cards during a replacement branch problem.

FILE 3 through File 2+NGRP.

For time-step zero, each file contains RBDY records, each record containing CBDY words. Each file contains the quadrant fluxes for an energy group, starting with group 1. Each record contains the fluxes for one row of quadrants; the first record contains the fluxes for the quadrants between mesh rows 0 and 1. The first word in a record is the flux for the quadrant between columns 0 and 1 of that row. These files are obtained from the series 21 flux guess cards and the series 17 overlay cards. For time-steps other than zero, each file contains RBDY-1 records, each record containing CBDY-1 words.

Each file contains the mesh point fluxes for an energy group, starting with group 1. Each record contains the fluxes for one row of mesh points; the first record contains the fluxes for the mesh points in row 1. The first word in a record is the flux for mesh point 1 of that row. These files are calculated by the PDQ portion of TURBO.

File NGRP+3

This file contains the number densities of each quadrant. It consists of RBDY records, each containing 30*CBDRY words. Each record contains the number densities for one row of quadrants. The first 30 words of a record contain the number densities for the first quadrant of a row. The first word of a group of 30 is the number density for element 1, the second word is the number density for element 2, etc. The ordering of quadrants is the same as the flux files. This file is obtained from the series 12 number density cards and the series 17 overlay cards for time-step zero. It is obtained from a previous history tape plus optional modification from series 12 and 17 cards in continuation problems.

For each time-step stored on a history tape, there are additional NGRP+2 files in the format described above. Thus a history tape contains information for at least two time-step numbers. The TSNO of a time-step is 1 greater than that of the time-step preceding it. In the running of a TURBO-40 problem, the fluxes associated with the time-step number on the 010004 card are used as the flux guess to the PDQ portion of the code, and the number densities associated with that time-step number are the initial number densities for the current time advancement being computed. The results of the PDQ portion of TURBO-40 written on the history tape are associated with the time-step number 1 greater than that on card 010004.

Final number densities, associated with the time-step number 1 greater than that on card 010004, are computed from the initial number densities using the fluxes obtained from the PDQ portion of the code.

The last file consists of one record containing five words:

LAB,77777777777777777777,NGRP,CBDRY,RBDRY

This signifies the end of a history tape. If another time-step is placed on the tape, this file will be written over and rewritten at the end of the new time-step data.

VII. REFERENCES

1. R. J. Wagner and G. R. Poetschat, PDQ-40 -- An IBM 7040-44 Program for the Solution of the Steady State Neutron Diffusion Equations in Two Dimensions, IDO-17257 (November 1967).
2. O. J. Marlow et al, Nuclear Reactor Depletion Programs for the Philco 2000 Computer, WAPD-TM-221 (January 1961).
3. Ibid p 3.
4. H. Bohl Jr., MUFT-5 -- A Fast Neutron Spectrum Program for the Philco 2000, WAPD-TM-218 (November 1960).

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APPENDIX A
NUMBERING SYSTEM FOR THE ISOTOPES

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APPENDIX A

NUMBERING SYSTEM FOR THE ISOTOPES

<u>Number</u>	<u>Isotope</u>	<u>Isotope</u>	<u>Number</u>
1	H-1	B-10	29,30b
2	O-16	C	4
3	Zr	Cr	11
4	C	Fe	6
6	Fe	Fns Pr 1,2	28,30a
7	Ni	H-1	1
8	Nb	Hf-177	20b
11	Cr	Hf-178	21b
18	U-235	Hf-179	22b
19	U-236	Hf-180	23b
20	U-238 Hf-177 Ir-191	I-135	25
21	Pu-239 Hf-178 Ir-192	Ir-191	20c
22	Pu-240 Hf-179 Ir-193	Ir-192	21c
23	Pu-241 Hf-180 Ir-194	Ir-193	22c
24	Pm-149	Ir-194	23c
25	I-135	Nb	8
26	Sm-149	Ni	7
27	Xe-135	O-16	2
28	Fsn Pr 1	Pm-149	24
29	B-10	Pu-239	21a
30	Fsn Pr 2 or burnable poison	Pu-240	22a
		Pu-241	23a
		Sm-149	26
		U-235	18
		U-236	19
		U-238	20a
		Xe-135	27
		Zr	3

A library of fast cross sections is available for the isotopes listed above. However, if the user wishes to input his own microscopic cross sections for isotopes 1 through 17, any number 1 through 17 can be used for any non-depletable isotope.

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APPENDIX B
TURBO-40 INPUT FORMS

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APPENDIX B

TURBO-40 INPUT FORMS

The following nine pages contain a complete set of the input forms filled out for a TURBO-40 sample problem. The form numbers 4, 5, 6, and 7 can also be used for the PDQ-40¹¹ program and hence may contain additional information not described in Section III on the input preparation. The input forms are brief. When questions arise, the user should refer to the main text.

TURBO-40

CONTROL INFORMATION

FORM 1

PROGRAM NUMBER 40-0021

SERIES CARD (REQUIRED FOR TIME STEP 0 OF ALL PROBLEMS, WHEN A PROBLEM IS RESTARTED, OR WHEN USING THE BRANCH OPTION)

* SAMPLE PR0B. F0R TURB0-40, CELL WITH TYPE 1+3 REGIONS

ANY COMMENTS THRU COLUMNS 80

COLUMNS 2-8 WILL COMPRISE THE PROBLEM LABEL OR IDENTIFICATION ON A HISTORY TAPE IF THE "SAVE FLUX" OPTION IS REQUESTED.

FILETAPE CARD (REQUIRED ONLY WHEN RESTARTING PROBLEM FROM PREVIOUS TIME STEP OR IN BRANCH PROBLEMS).

FILTAPE*

COLUMNS 7-12 ARE PROBLEM IDENTIFICATION ON HISTORY TAPE

COLUMNS 13-18 ARE REEL NUMBER OF HISTORY TAPE

COLUMNS 1-80 ANY DATA

CASE CARD (REQUIRED FOR EVERY TIME STEP)

* SAMPLE PROBLEM IN WAPD-TM-221 TIME STEP 0

EDIT OPTION	BRANCH	GEOMETRY	SYMMETRY	GROUPS	NO. OF COMPS	NO. OF COLS.	NO. OF ROWS	BOUNDARY CONDITIONS	SAVE TAPE
0 NORMAL	0 NO	1 XY	1 YES	2	9	13	15	0 ZERO	0 NO
1 INPUT	1 YES	2 RZ	0 NO	3				1 SYM	1 YES
2 OUTPUT A	-1 REPLACEMENT			4				2 90 ROT	
3 OUTPUT B								3 180 ROT	

EDIT OPTION	BRANCH	GEOMETRY	SYMMETRY	GROUPS	NO. OF COMPS	NO. OF COLS.	NO. OF ROWS	BOUNDARY CONDITIONS	SAVE TAPE
0 NORMAL	0 NO	1 XY	1 YES	2	9	13	15	0 ZERO	0 NO
1 INPUT	1 YES	2 RZ	0 NO	3				1 SYM	1 YES
2 OUTPUT A	-1 REPLACEMENT			4				2 90 ROT	
3 OUTPUT B								3 180 ROT	

EDIT OPTION	BRANCH	GEOMETRY	SYMMETRY	GROUPS	NO. OF COMPS	NO. OF COLS.	NO. OF ROWS	BOUNDARY CONDITIONS	SAVE TAPE
0 NORMAL	0 NO	1 XY	1 YES	2	9	13	15	0 ZERO	0 NO
1 INPUT	1 YES	2 RZ	0 NO	3				1 SYM	1 YES
2 OUTPUT A	-1 REPLACEMENT			4				2 90 ROT	
3 OUTPUT B								3 180 ROT	

EDIT OPTION	BRANCH	GEOMETRY	SYMMETRY	GROUPS	NO. OF COMPS	NO. OF COLS.	NO. OF ROWS	BOUNDARY CONDITIONS	SAVE TAPE
0 NORMAL	0 NO	1 XY	1 YES	2	9	13	15	0 ZERO	0 NO
1 INPUT	1 YES	2 RZ	0 NO	3				1 SYM	1 YES
2 OUTPUT A	-1 REPLACEMENT			4				2 90 ROT	
3 OUTPUT B								3 180 ROT	

EDIT OPTION	BRANCH	GEOMETRY	SYMMETRY	GROUPS	NO. OF COMPS	NO. OF COLS.	NO. OF ROWS	BOUNDARY CONDITIONS	SAVE TAPE
0 NORMAL	0 NO	1 XY	1 YES	2	9	13	15	0 ZERO	0 NO
1 INPUT	1 YES	2 RZ	0 NO	3				1 SYM	1 YES
2 OUTPUT A	-1 REPLACEMENT			4				2 90 ROT	
3 OUTPUT B								3 180 ROT	

EDIT OPTION	BRANCH	GEOMETRY	SYMMETRY	GROUPS	NO. OF COMPS	NO. OF COLS.	NO. OF ROWS	BOUNDARY CONDITIONS	SAVE TAPE
0 NORMAL	0 NO	1 XY	1 YES	2	9	13	15	0 ZERO	0 NO
1 INPUT	1 YES	2 RZ	0 NO	3				1 SYM	1 YES
2 OUTPUT A	-1 REPLACEMENT			4				2 90 ROT	
3 OUTPUT B								3 180 ROT	

EDIT OPTION	BRANCH	GEOMETRY	SYMMETRY	GROUPS	NO. OF COMPS	NO. OF COLS.	NO. OF ROWS	BOUNDARY CONDITIONS	SAVE TAPE
0 NORMAL	0 NO	1 XY	1 YES	2	9	13	15	0 ZERO	0 NO
1 INPUT	1 YES	2 RZ	0 NO	3				1 SYM	1 YES
2 OUTPUT A	-1 REPLACEMENT			4				2 90 ROT	
3 OUTPUT B								3 180 ROT	

FORM INC-1115 (4-68)

MICROSCOPIC CROSS SECTIONS

Problem _____ Page _____ of _____

1. For group 4 leave Blank.

Group No. is 2 Digits.

2. Supply σ_i and $\gamma\sigma_i$ only for Elements 18, 20, 21, and 23.

Element No. Is 2 Digits.

For all others leave Blank.

TURBO - 40

POINTWISE EDIT CONTROL

FORM 3

Problem _____

Page _____ of _____

		T S N																	
01	0	2	4	1	0	10	0	15											
01	0	4	1	1	0	10	0	15											
01	0	5	1	1	0	10	0	15											
01	0	6	1	1	18	28	30												
01	0	6	2	1	18	28	30												
01	0	6	3	1	4														
01	0																		
01	0																		
01	0																		
01	0																		
01	0																		
01	0																		
01	0																		
8TURBO																			

T=2 Pointwise Flux

T=4 Power Edit

S= Group No.

S=1 Point Edit

N= Sequence No.

N= Sequence No.

T=5 Regions over which
quantities of T=6 will
be edited.

T=6 Cross-Section and
Atom Density Edit

S=1

S=1 Old Densities

S=2 New Densities

S=3 Macroscopic

Cross Section

N= Sequence No.

N= Sequence No.

N= Sequence No.

N= Group No.

Regions are specified for T=2, 4 and 5, by giving the left, right, upper and lower boundaries of the rectangle in that order.

For T=6 and S=1 or 2, give library numbers of desired materials.

For T=6, and S=3 cross-sections are requested according to the following: 1=D;

2= Σ_a ; 3= $\nu \Sigma_f$; 4= Σ_R ; 5= $K \Sigma_f$; 6= Σ_{Tot}

MACROSCOPIC DATA

Problem _____

Page ____ of ____

8PDQ

Subseries number is the group number (one digit)

TURBO-40

OR PDQ-40

MISC. PARAMETER

FORM 5

Problem _____

Page _____ of _____

Sub. Ser. Ser. Seq.	Value	Comp. (Region)	Value	Comp. (Region)	Value	Comp. (Region)	Value	Comp. (Region)
08 5 001	2,-2	5	0	7	2,-2	9		
12 06 01	0,+0	7	1,+1	8	0,+0	9		
12 07 01	0,+0	8	1,+1	9				
12 18 01	0	7	27991	-3	8	62441	-3	9
12 20 01	0	7	19778	-4	8	44121	-4	9
12 30 01	0	5	26253	-2	7	0	9	
13 18 01	1,+1	7	116506	+1	8	1,+1	9	
13 20 01	1,+1	7	11430	+1	8	1,+1	9	
13 26 01	1,+1	7	124082	+1	8	1,+1	9	
13 27 01	1,+1	7	127765	+1	8	1,+1	9	
13 28 01	1,+1	7	114553	+1	8	1,+1	9	
13 31 01	0	9						
21 1 001	5,+2	9						
21 2 001	5,+2	9						
21 3 001	5,+2	9						
21 4 001	5,+2	9						

8TURBO
8PDQ

PARAMETER	SERIES NUMBER	SUBSERIES NUMBER	PARAMETER	SERIES NUMBER	SUBSERIES NUMBER
X	03	Group No. (1 digit)	Pr	10	0
Source	04	0	Number Density	12	Element No. (2 digits)
Buckling	08	PDQ 0 or Group No. (1 digit)	Self-Shielding	13	Element No. (2 digits)
Poison Cross	09	TURBO 5 or Group No. (1 digit)	Factor		
Section		0	Composition Area	18	0
			Flux Guess	21	Group No. (1 digit)

Begin each subseries with sequence number 1
 Sequence number has two or three digits to bring card number to 6 digits
 Series 09, 10, 12, 13 are used in TURBO-40 only.

FORM INC-686 (9-67)

OR **PDQ - 40**

FORM 7

COMPOSITION DESCRIPTION

Problem _____

Page ____ of ____

[illegible][illegible]

✓	8TURBO
	8PDQ

Begin with sequence number 0001.

FORM INC-688 (9-67)

TURBO - 40
FLUX WEIGHT EDIT CONTROL

Problem _____ Page _____ of _____

Composition Numbers In Ascending Order

[illegible]This image shows a full page of blank graph paper. The grid consists of small squares formed by thin black lines. There are 20 columns and 20 rows of squares. A thicker vertical line runs down the left side, creating a margin. A thicker horizontal line runs across the top, creating a header space. The rest of the page is filled with the standard grid pattern.

8 TURBO

S = Set number (1 to 9) total number composition sets requested may not exceed 9.

N = Sequence number (1 to 9) within each set.

FORM INC-1118 (4-68)

FORM 9

DEPLETION CALCULATIONS - OVERLAY EXPANSION

POLYNOMIALS FOR RESONANCE PROBABILITY

POLYNOMIALS FOR DIFFUSION AND ABSORPTION

EPITHERMAL ABSORPTION FOR ELEMENTS 20-23 AND PARAMETER α

Problem _____

Page ____ Of ____

[illegible]

Use 3 digit sequence beginning with 001 for each new series and/or subseries.

Quantity	Series	Subseries
----------	--------	-----------

pr	11	0	Supply	A ₀ Thru A ₅	} P _N (X) = $\sum_{j=0}^N A_j X^j$
D _i	14	Group	} Leave	A ₅ <u>Blank</u>	
Σ _a	15	Group			
σ _a ^{M,3} _a	16	1	For A ₀ To A ₃ give σ _a ^{M,3} M=20 To 23, for A ₄ give value of a, leave A ₅ Blank		

FORM INC-1119
(4-68)

APPENDIX C
SAMPLE PROBLEMS FOR TURBO-40

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WAS INTENTIONALLY
LEFT BLANK

1. LISTING OF DATA CARDS FOR SAMPLE PROBLEMS

* SAMPLE PROB. FOR TURBO=40, CELL WITH TYPE 1-3 REGIONS

SAMPLE PROBLEM IN WAPD=TM=221 TIME STEP 0

010001,0,0,1,0,4,9,13,15,1,1,1,1,=1
 010002,11+1,1+0
 010003,1,0,5,0,7,0
 010004,0,72+6,15994+5,0
 010005,75165+0,248175+0,0,0
 010006,0+0
 010008,6+1,0,0,0
 010009,1+1,0,0,0,0
 010010,0,0,0,0,0
 010241,0,10,0,15
 010411,0,10,0,15
 010511,0,10,0,15
 010611,18,28,30
 010621,18,28,30
 010631,4
 021001,2557173+1,1161+2,86973-1,0,0,1
 022001,1313644+1,1000+4,120506+0,0,0,1
 023001,7383812+0,7690+3,122977+0,0,0,1
 024001,2534006+0,1178+1,0,0,0,1
 021002,2244810+1,1723+2,56966+1,0,0,2
 022002,1131894+1,4880+3,57258+1,0,0,2
 023002,9121025+0,1592+2,57858-1,0,0,2
 024002,4272005+0,8247+2,0,0,0,2
 021003,2171213+1,1804+2,47127-1,0,0,3
 022003,1093854+1,6170+3,40083-1,0,0,3
 023003,9845129+1,1600+2,40139-1,0,0,3
 024003,5287002+1,1124+1,0,0,0,3
 021004,2122374+1,1817+2,40193-1,0,0,4
 022004,1072099+1,7020+3,28965-1,0,0,4
 023004,1040113+1,1546+2,28618-1,0,0,4
 024004,6265005+0,6582+2,0,0,0,4
 021005,2107081+1,1812+2,37979-1,0,0,5
 022005,1065996+1,7270+3,25608-1,0,0,5
 023005,1058473+1,1518+2,25132-1,0,0,5
 024005,1871292+0,6371+2,0,0,0,5
 050001,79500+0,2,18055+1,3,36101+1,4,10833+1,7
 050002,10160+1,8,31750+0,9,52917+0,13
 060001,9944+0,2,18631+1,3,3175+0,4,7455+0,5
 060002,1905+0,6,1204+1,7,1905+0,8,11303+1,9
 060003,22606+1,11,56515+0,13,9525+1,15
 085001,2+2,5,0,7,2-2,9
 120601,0+0,7,1+1,8,0+0,9

120701,0+0,8,1+1,9
 121801,0,7,27991-3,8,62441-3,9
 122001,0,7,19778-4,8,44121-4,9
 123001,0,5,26253+2,7,0,9
 131801,1+1,7,116506+1,8,1+1,9
 132001,1+1,7,11430+1,8,1+1,9
 132601,1+1,7,124082+1,8,1+1,9
 132701,1+1,7,127765+1,8,1+1,9
 132801,1+1,7,114553+1,8,1+1,9
 133101,0,9
 141001,6,4-1,0,0,0,0,7
 142001,6,4-1,0,0,0,0,7
 143001,6,518443-1,=309392+1,618186+0,=541253+0,171157+0,6
 143002,7,514137-1,=412264+1,604497+0,=52565+0,165147+0,7
 144001,6,215720+0,952202+1,1327861+2,=16414+2,897288+1,6
 144002,7,136226+0,977556+1,4203921+1,=272207+1,156909+1,7
 151001,6,0,11213-2,0,0,0,7
 152001,6,0,57213-2,0,0,0,7
 153001,6,544919-3,382052+0,=512636+1,989042+2,232957+3,6
 153002,7,242585-3,360808+0,=696622+1,442028+1,=163179+1,7
 154001,6,109369-1,48311+1,=260411+1,105213+1,=235351+0,6
 154002,7,=412601-2,435667+1,=244317+1,125822+1,=363659+0,7
 160406,646+2,595768+0
 160407,5571-2,517964+0
 160418,2896+3,31152+3,2437+3,601939+3
 160420,1258+1,11275+2,0+0,0+0
 160426,4522+5,4522+5
 160427,1275+7,1275+7
 160428,4652+2,4652+2
 170001,4,0,7,0,2,5,7,13,0,3,3,0,2,2,15
 170002,9,2,5,2,13,8,5,7,2,13,7,2,5,5,6
 170003,6,5,7,5,6,7,2,5,13,15,6,5,7,13,15
 170004,2,7,8,3,15,1,8,13,3,15
 211001,5+2,9
 212001,5+2,9
 213001,5+2,9
 214001,5+2,9
 \$TURBO
 SAMPLE PROBLEM IN WAPD=TM=221 TIME STEP 1
 010004,1,144+7,15994+5,0
 010611
 \$TURBO

2. COMPUTER OUTPUT FROM SAMPLE PROBLEMS

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

CS. 1 03/13/68 PG. 1

SAMPLE PROBLEM IN WAPD-TM-221 TIME STEP 0

TIME STEP 0 159940-05 WATTS 720000+06 SECS. OR 200000+03 HOURS

XY GEOMETRY NO DIAGONAL SYMMETRY 13 COLUMNS 15 ROWS BDRY COND= 1,1,1,1 EPSILON= 100-00
4 GROUPS 9 COMPOSITIONS WITH 5 TYPE 1 0 TYPE 2 2 TYPE 3

FISSION SPECTRUM	751650+00	248175-00	000000+00	000000+00
POISON FRACTIONS	000000+00	000000+00	000000+00	000000+00

FISSION PRODUCTS ISOTOPE	Y-235	Y-238	Y-239	Y-241	THETA	DECAY
IR-192						107700-06
PU-241						170000-08
PM-149	140000-01	140000-01	140000-01	140000-01		385000-05
I -135	600000-01	000000+00	000000+00	000000+00		288000-04
XE-135	300000-02	300000-02	300000-02	300000-02		211000-04
F.P. 1	100000+01	000000+00	000000+00	000000+00	000000+00	
F.P. 2	000000+00	000000+00	000000+00	000000+00	000000+00	

S MESH INTERVALS

INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL
795000+00	2	180550+01	3	351010+01	4	108330+01	7	101600+01	8	317500-00	9
529170+00	13										

T MESH INTERVALS

INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW
994400+00	2	186310+01	3	317500-00	4	745500+00	5	190500-00	6	120400+01	7
190500-00	8	113030+01	9	226060+01	11	565150+00	13	952500-01	15		

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 2

PICTURE EDIT

```

000 001 002 003 004 005 006 007 008 009 010 011 012 013
000 *****
*004 004 004 004 004 004 004*005 005 005 005 005*
001 *
*004 004 004 004 004 004 004*005 005 005 005 005*
002 * * * * *
*003 003*009 009 009*008 008*005 005 005 005 005*
003 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
004 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
005 *
*003 003*007 007 007*006 006*002*001 001 001 001 001*
006 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
007 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
008 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
009 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
010 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
011 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
012 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
013 *
*003 003*007 007 007*006 006*002*001 001 001 001 001*
014 *
*003 003*007 007 007*006 006*002*001 001 001 001 001*
015 *****

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* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 3

COMPOSITION AREAS

1	181453+02
2	967745+01
3	905358+01
4	940752+01
5	834679+01
6	619106+00
7	185706+01
8	240545+02
9	721534+02

THERMAL POISON VALUES SET TO ZERO

MICROSCOPIC CROSS SECTIONS

ELEMENT NUMBER	REMOVAL				TRANSPORT				ABSORPTION			
	GROUP1	GROUP2	GROUP3	GROUP4	GROUP1	GROUP2	GROUP3	GROUP4	GROUP1	GROUP2	GROUP3	GROUP4
1	14505+01	22128+01	22543+01	15659+01	25837+01	63389+01	00000+00	00000+00	20000-03	14200-01	00000+00	00000+00
2	23710-00	88900-01	45000-00	12777+01	39450+01	42553+01	00000+00	42500-01	00000+00	00000+00	00000+00	00000+00
3	82300-01	31900-01	18300-01	18906+01	74082+01	10003+02	00000+00	00000+00	00000+00	77000-02	00000+00	00000+00
4	22480-00	11410-00	80900-01	97970+00	36306+01	48184+01	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00
6	53928-01	51973-01	52438-01	14906-00	29605-00	35600-00	59577+00	17465-02	51557-03	15360-02	64600-02	64600-02
7	53809-01	51988-01	52376-01	14789-00	29399-00	35430-00	51796+00	17362-02	50188-03	16139-02	55710-02	55710-02
8	82300-01	31800-01	18300-01	18906+01	74082+01	10003+02	00000+00	00000+00	00000+00	77000-02	00000+00	00000+00
11	25400-00	83400-01	00000+00	29200+01	56600+01	55400+01	00000+00	00000+00	00000+00	98400-01	00000+00	00000+00
18	13060+01	-77000+00	-16500+02	56700+01	94760+01	99000+01	31152+03	12450+01	20730+01	34000+02	28960+03	28960+03
20	15600+01	-55000-01	-11000+02	50460+01	90400+01	20000+01	11275+02	41000-00	23000-00	23000+02	12580+01	12580+01
26	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	45220+05	00000+00	00000+00	00000+00	45220+05	45220+05
27	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	12750+07	00000+00	00000+00	00000+00	12750+07	12750+07
28	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	46520+02	00000+00	00000+00	00000+00	46520+02	46520+02
29	00000+00	00000+00	00000+00	44920-00	22919+01	17209+03	00000+00	44920-00	22919+01	17209+03	00000+00	00000+00

ELEMENT NUMBER	FISSION				NU FISSION			
	GROUP1	GROUP2	GROUP3	GROUP4	GROUP1	GROUP2	GROUP3	GROUP4
18	11170+01	16250+01	22358+02	24370+03	30940+01	40300+01	55000+02	60194+03
20	34400-00	00000+00	00000+00	00000+00	93000+00	00000+00	00000+00	00000+00
21	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00
23	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00

ELEMENT NUMBER	KAPPA			
	GROUP1	GROUP2	GROUP3	GROUP4
18	11435-10	12772-10	12876-10	12905-10
20	11732-10	00000+00	00000+00	12801-10
21	96601-11	10824-10	10885-10	10947-10
23	92167-11	10327-10	10385-10	10582-10

END OF INPUT

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 5

COMP	GROUP	BUCKLING	DIFFUSION	ABSORPTION	NU FISSION	REMOVAL	TOTAL	P SUB R.	A
1	1	200000-02	255717+01	116100-02	000000+00	869730-01	932483-01		
1	2	200000-02	131364+01	100000-04	000000+00	120506-00	123143-00		
1	3	200000-02	738381+00	769000-03	000000+00	122577-00	124823-00		
1	4	200000-02	253401-00	117800-01	000000+00	000000+00	122868-01		
								100000+01	000000+00
2	1	200000-02	224481+01	172300-02	000000+00	569660-01	631786-01		
2	2	200000-02	113189+01	486000-03	000000+00	572580-01	600078-01		
2	3	200000-02	912102+00	159200-02	000000+00	578580-01	612742-01		
2	4	200000-02	427201-00	824700-02	000000+00	000000+00	910140-02		
								100000+01	000000+00
3	1	200000-02	217121+01	180400-02	000000+00	471270-01	532734-01		
3	2	200000-02	109385+01	617000-03	000000+00	400830-01	428877-01		
3	3	200000-02	984513+00	160000-02	000000+00	401390-01	437080-01		
3	4	200000-02	528700+00	112400-01	000000+00	000000+00	122974-01		
								100000+01	000000+00
4	1	200000-02	212237+01	181700-02	000000+00	401930-01	462547-01		
4	2	200000-02	107210+01	702000-03	000000+00	289650-01	318112-01		
4	3	200000-02	104011+01	154600-02	000000+00	286180-01	322442-01		
4	4	200000-02	626500+00	658200-02	000000+00	000000+00	783500-02		
								100000+01	000000+00
5	1	200000-02	210708+01	181200-02	000000+00	379790-01	440052-01		
5	2	200000-02	106600+01	727000-03	000000+00	256080-01	284670-01		
5	3	200000-02	105847+01	151800-02	000000+00	251320-01	287669-01		
5	4	200000-02	187129-00	637100-02	000000+00	000000+00	674526-02		
								100000+01	000000+00
6	1	000000+00	250000+02	112130-02	000000+00	000000+00	112130-02		
6	2	000000+00	250000+02	572130-02	000000+00	000000+00	572130-02		
6	3	000000+00	371754+01	341457-00	000000+00	000000+00	341457-00		
6	4	000000+00	659316-01	305471+01	000000+00	000000+00	305471+01		
								100000+01	000000+00
7	1	000000+00	250000+02	112130-02	000000+00	000000+00	112130-02		
7	2	000000+00	250000+02	572130-02	000000+00	000000+00	572130-02		
7	3	000000+00	393420+01	319273-00	000000+00	000000+00	319273-00		
7	4	000000+00	771443-01	280393+01	000000+00	000000+00	280393+01		
								100000+01	000000+00
8	1	200000-02	221121+01	210310-02	884435-03	543244-01	608499-01		
8	2	200000-02	111527+01	110037-02	112804-02	517564-01	550873-01		
8	3	200000-02	928995+00	115078-01	153950-01	476019-01	609678-01		
8	4	200000-02	487908-00	100930-00	196299-00	000000+00	101906-00		
								100000+01	000000+00
9	1	200000-02	219800+01	253168-02	197296-02	546933-01	616210-01		
9	2	200000-02	110998+01	180643-02	251637-02	515048-01	555312-01		
9	3	200000-02	924462+00	238586-01	343425-01	415879-01	672954-01		
9	4	200000-02	467523-00	186456-00	375857-00	000000+00	187391-00		
								100000+01	000000+00

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 05/16/68 PG. 6

SPECTRAL RADIUS CALC.

GROUP 1 MAX= 999187+00 RHO= 997727+00 MIN= 990237+00 NO.IT.= 15
GROUP 2 MAX= 999272+00 RHO= 998174+00 MIN= 989195+00 NO.IT.= 30
GROUP 3 MAX= 994393+00 RHO= 989997+00 MIN= 977895+00 NO.IT.= 30
GROUP 4 MAX= 963727+00 RHO= 951506+00 MIN= 866159+00 NO.IT.= 30

OUTER ITERATION 1

GROUP 1 R(1) = 252616+03 NO. IT. = 39 DELR = 381137-00
GROUP 2 R(1) = 368701+03 NO. IT. = 42 DELR = 325984-00
GROUP 3 R(1) = 352971+03 NO. IT. = 18 DELR = 179350-00
GROUP 4 R(1) = 677744+03 NO. IT. = 9 DELR = 820993-01

MAX= 26455954+01 LAMDA= 93004471+00 MIN= 47919173-00 EPS= 11646771+01
ALPHA = 000000+00 BETA = 000000+00 RENORM = 966061+00 SIGMA = 000000+00

OUTER ITERATION 2

GROUP 1 R(1) = 103177+03 NO. IT. = 39 DELR = 141128-00
GROUP 2 R(1) = 106430+03 NO. IT. = 42 DELR = 275842-00
GROUP 3 R(1) = 916704+02 NO. IT. = 18 DELR = 221860-00
GROUP 4 R(1) = 113450+03 NO. IT. = 9 DELR = 121069-00

MAX= 11901428+01 LAMDA= 10600213+01 MIN= 97105319+00 EPS= 10334207-00
ALPHA = 000000+00 BETA = 000000+00 RENORM = 100226+01 SIGMA = 000000+00

OUTER ITERATION 3

GROUP 1 R(1) = 119339+02 NO. IT. = 39 DELR = 358145-00
GROUP 2 R(1) = 164904+02 NO. IT. = 42 DELR = 547701+00
GROUP 3 R(1) = 179964+02 NO. IT. = 18 DELR = 352789-00
GROUP 4 R(1) = 240079+02 NO. IT. = 9 DELR = 138308-00

MAX= 11101948+01 LAMDA= 10846474+01 MIN= 10652916+01 EPS= 20699468-01
ALPHA = 000000+00 BETA = 000000+00 RENORM = 100192+01 SIGMA = 000000+00

OUTER ITERATION 4

GROUP 1 R(1) = 345297+01 NO. IT. = 39 DELR = 380763-00
GROUP 2 R(1) = 487573+01 NO. IT. = 42 DELR = 582786+00
GROUP 3 R(1) = 587718+01 NO. IT. = 18 DELR = 351453-00
GROUP 4 R(1) = 793809+01 NO. IT. = 9 DELR = 126491-00

MAX= 10994281+01 LAMDA= 10920709+01 MIN= 10868880+01 EPS= 57414239-02

COMPOSITION INTEGRATION AND POWER FRACTION EDIT

COMP	AREA	GROUP 1	GROUP 2	GROUP 3	GROUP 4	POWER	FRACTION
1	181453+02	190420+04 104941+03	243771+04 134344+03	230087+04 126802+03	438844+04 241850+03	000000+00 000000+00	000000+00
2	967745+01	110585+04 114271+03	141642+04 146363+03	122062+04 126130+03	151771+04 156830+03	000000+00 000000+00	000000+00
3	905358+01	122164+04 134934+03	161885+04 178808+03	115884+04 127998+03	321060+03 354623+02	000000+00 000000+00	000000+00
4	940752+01	118342+04 125795+03	161547+04 171721+03	120147+04 127714+03	518231+03 550869+02	000000+00 000000+00	000000+00
5	834679+01	890747+03 106717+03	125310+04 150130+03	106314+04 127371+03	131361+04 157380+03	000000+00 000000+00	000000+00
6	619106+00	771775+02 124660+03	100048+03 161601+03	752709+02 121580+03	367577+02 593723+02	000000+00 000000+00	000000+00
7	185706+01	249107+03 134140+03	322469+03 173645+03	225278+03 121309+03	408331+02 219880+02	000000+00 000000+00	000000+00
8	240545+02	302417+04 125722+03	387791+04 161214+03	301133+04 125188+03	203129+04 844455+02	415731+04 172829+03	259929-00
9	721534+02	983262+04 136274+03	127038+05 176067+03	906232+04 125598+03	246558+04 341714+02	118367+05 164049+03	740071+00

POWER NORMALIZATION FACTOR IS 713197+12

COMPOSITION-AVERAGE DISTRIBUTION ANALYSIS EDIT

QUANTITY	MINIMUM COMP.	AVG.	MAXIMUM COMP.	AVG.	FULL CORE AVERAGE
GROUP1	1	104941+03	9	136274+03	127117+03
GROUP2	1	134344+03	3	178808+03	165319+03
GROUP3	7	121309+03	3	127998+03	126010+03
GROUP4	7	219880+02	1	241850+03	824026+02
POWER	9	164049+03	8	172829+03	104321+03

FLUX-WEIGHTED MACROSCOPIC PARAMETERS BY COMPOSITION

GROUP	COMP	D	SIGMA-A	SIGMA-R	NU SIGMA-F	K SIGMA-F	BZ**2
1	1	255717+01	116100-02	869730-01	000000+00	000000+00	-364654-01
	2	224481+01	172300-02	569660-01	000000+00	000000+00	-281443-01
	3	217121+01	180400-02	471270-01	000000+00	000000+00	-245362-01
	4	212237+01	181700-02	401930-01	000000+00	000000+00	-217939-01
	5	210708+01	181200-02	379790-01	000000+00	000000+00	-208844-01
	6	250000+02	112130-02	000000+00	000000+00	000000+00	-448520-04
	7	250000+02	112130-02	000000+00	000000+00	000000+00	-448520-04
	8	221121+01	210310-02	543244-01	884435-03	101191-13	189830-01
	9	219800+01	253168-02	546933-01	197296-02	225733-13	129929-01
2	1	131364+01	100000-04	120506-00	000000+00	000000+00	-420243-01
	2	113189+01	486000-03	572580-01	000000+00	000000+00	-137225-01
	3	109385+01	617000-03	400830-01	000000+00	000000+00	-669579-02
	4	107210+01	702000-03	289650-01	000000+00	000000+00	-220831-02
	5	106600+01	727000-03	256080-01	000000+00	000000+00	-137923-02
	6	250000+02	572130-02	000000+00	000000+00	000000+00	-228852-03
	7	250000+02	572130-02	000000+00	000000+00	000000+00	-228852-03
	8	111527+01	110037-02	517564-01	112804-02	144077-13	123319-01
	9	110998+01	180643-02	515048-01	251637-02	321401-13	887066-02
3	1	738381+00	769000-03	122577-00	000000+00	000000+00	386006-02
	2	912103+00	159200-02	578580-01	000000+00	000000+00	566678-02
	3	984513+00	160000-02	401390-01	000000+00	000000+00	124796-01
	4	104011+01	154600-02	286180-01	000000+00	000000+00	644292-02
	5	105847+01	151800-02	251320-01	000000+00	000000+00	133849-02
	6	371754+01	341457-00	000000+00	000000+00	000000+00	-918502-01
	7	393420+01	319273-00	000000+00	000000+00	000000+00	-811533-01
	8	928995+00	115078-01	476019-01	153950-01	198230-12	611713-02
	9	924462+00	238586-01	415879-01	343425-01	442202-12	530636-02
4	1	253401-00	117800-01	000000+00	000000+00	000000+00	205132-00
	2	427201-00	824700-02	000000+00	000000+00	000000+00	876187-01
	3	528700+00	112400-01	000000+00	000000+00	000000+00	250768-00
	4	626500+00	658200-02	000000+00	000000+00	000000+00	933970-01
	5	187129-00	637100-02	000000+00	000000+00	000000+00	726485-01
	6	659316-01	305471+01	000000+00	000000+00	000000+00	-463314+02
	7	771443-01	280393+01	000000+00	000000+00	000000+00	-363466+02
	8	487908-00	100930-00	000000+00	196299-00	253322-11	-642290-01
	9	467523-00	186456-00	000000+00	375857-00	485039-11	-738644-01

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS TS. 0 CS. 1 03/13/68 PG. 10

FLUX-WEIGHTED MACROSCOPIC PARAMETERS BY SET OF COMPOSITIONS

GROUP	D	SIGMA-A	SIGMA-R	NU SIGMA-F	K SIGMA-F	BZ**2
COMPOSITIONS	8 9					
1	220111+01	243087-02	546065-01	171691-02	196439-13	144084-01
2	111122+01	164131-02	515636-01	219169-02	279931-13	968308-02
3	925593+00	207782-01	430879-01	296168-01	381352-12	550932-02
4	476731-00	147823-00	000000+00	294749-00	380370-11	-694100-01

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS TS. 0 CS. 1 03/13/68 PG. 11

GROUP 4 FLUX POINTWISE EDIT

	1	2	3	4	5	6	7	8	9	10
1	475974+C2	468344+02	438403+02	534202+02	657528+02	814802+02	984504+02	141498+03	151701+03	165001+03
2	461614+02	444684+02	404223+02	490420+02	618584+02	785856+02	973555+02	143136+03	154109+03	168494+03
3	371469+02	345762+02	284810+02	342423+02	474175+02	677843+02	977546+02	156276+03	174204+03	197948+03
4	353870+02	324047+02	259165+02	311173+02	435953+02	638030+02	987424+02	156977+03	179066+03	205732+03
5	315138+02	264269+02	189034+02	227076+02	324603+02	499736+02	930316+02	161234+03	187508+03	219004+03
6	311744+02	261110+02	182512+02	224686+02	334520+02	532585+02	962417+02	163222+03	189897+03	222065+03
7	350869+02	323934+02	260702+02	336286+02	511624+02	791545+02	123122+03	181583+03	207251+03	239223+03
8	356597+02	331105+02	269395+02	349268+02	531917+02	820247+02	126176+03	184024+03	209578+03	241483+03
9	384453+02	359957+02	302464+02	401775+02	612163+02	929797+02	138330+03	195420+03	220663+03	252223+03
10	394482+02	369687+02	313093+02	421733+02	644079+02	975950+02	144252+03	202274+03	227767+03	259638+03
11	346425+02	321992+02	263362+02	347140+02	538525+02	843732+02	131440+03	192723+03	219566+03	253261+03
12	325050+02	293374+02	229578+02	299647+02	465432+02	741998+02	122261+03	188697+03	216760+03	251623+03
13	307342+02	254146+02	183488+02	237674+02	368181+02	595887+02	109207+03	185463+03	214858+03	250653+03
14	306847+02	245003+02	157607+02	204183+02	310684+02	493660+02	106633+03	185391+03	214831+03	250649+03

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 12

TOTAL POWER POINTWISE EDIT

	1	2	3	4	5	6	7	8	9	10
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	120694+01	112103+01	129658+01	117920+01	977270+00	118089+01	000000+00	000000+00	000000+00
3	000000+00	996811+00	866845-00	982600+00	946604+00	857949+00	118395+01	000000+00	000000+00	000000+00
4	000000+00	950472+00	811853-00	915871+00	884867+00	814027+00	119429+01	000000+00	000000+00	000000+00
5	000000+00	822819+00	661278-00	736061+00	705027+00	661755+00	113107+01	000000+00	000000+00	000000+00
6	000000+00	816277+00	647723-00	731099+00	720739+00	697457+00	116596+01	000000+00	000000+00	000000+00
7	000000+00	953002+00	818222-00	971210+00	100669+01	981754+00	145955+01	000000+00	000000+00	000000+00
8	000000+00	968703+00	837293+00	999214+00	103949+01	101328+01	149293+01	000000+00	000000+00	000000+00
9	000000+00	103235+01	910470+00	111287+01	116944+01	113371+01	162575+01	000000+00	000000+00	000000+00
10	000000+00	105456+01	934709+00	115629+01	122110+01	118431+01	169026+01	000000+00	000000+00	000000+00
11	000000+00	949956+00	824673+00	994045+00	104924+01	103822+01	154937+01	000000+00	000000+00	000000+00
12	000000+00	888026+00	751137+00	891852+00	931114+00	926410+00	144892+01	000000+00	000000+00	000000+00
13	000000+00	803480+00	651269+00	758849+00	774175+00	765994+00	130624+01	000000+00	000000+00	000000+00
14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 13

COMP	U 235	COMP. POWER FRACTION PER ISOTOPE U 238	PU239	PU241	TOTAL POWER PER COMP
8	999888+00	111952-03	000000+00	000000+00	185381+12
9	999715+00	285192-03	000000+00	000000+00	527816+12

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 14

AVERAGED END-OF-TIME-STEP NUMBER DENSITIES BY COMP.
 FOLLOWED BY INTEGRAL OF N TIMES FLUX FOR EACH GROUP I

COMP I	U 235	U 236	P 149	I 135	SM149	XE135	F.P.1	R 10	F.P.2
6	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	251250-02
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	247161+11
2	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	322343+11
3	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	242511+11
4	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	117030+11
7	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	257353-02
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	198280+12
2	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	257605+12
3	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	179717+12
4	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	314636+11
8	275175-03	863586-06	183333-07	112029-07	160568-07	283345-08	387171-05	000000+00	000000+00
1	104903+13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	134063+13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
3	104523+13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
4	731592+12	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
9	619714-03	998803-06	175081-07	106968-07	253919-07	619129-08	369680-05	000000+00	000000+00
1	189359+14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	244114+14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
3	174173+14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
4	476215+13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 15

AVERAGED END-OF-TIME-STEP NUMBER DENSITIES BY COMP.
 FOLLOWED BY INTEGRAL OF N TIMES FLUX FOR EACH GROUP I

COMP I	U 238	PU239	PU240	PU241
8	197466-04	309120-07	000000+00	000000+00
1	741230+11	000000+00	000000+00	000000+00
2	947269+11	000000+00	000000+00	000000+00
3	738541+11	000000+00	000000+00	000000+00
4	516931+11	000000+00	000000+00	000000+00
9	440524-04	674909-07	000000+00	000000+00
1	133802+13	000000+00	000000+00	000000+00
2	172492+13	000000+00	000000+00	000000+00
3	123071+13	000000+00	000000+00	000000+00
4	336495+12	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 16

TURBO INITIAL NUMBER DENSITIES ELEMENT 18 TSNO. 0

	0	1	2	3	4	5	6	7	8	9	10
0	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
3	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
4	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
5	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
6	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
7	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
8	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
9	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
10	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
11	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
12	000000+00	000000+00	624410-03	624410-03	624410-03	279910-03	279910-03	000000+00	000000+00	000000+00	000000+00
13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
15	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 17

TURBO INITIAL NUMBER DENSITIES ELEMENT 28 TSNO. 0

	0	1	2	3	4	5	6	7	8	9	10
0	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
3	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
4	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
5	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
6	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
7	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
8	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
9	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
10	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
11	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
12	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
15	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 18

TURBO INITIAL NUMBER DENSITIES ELEMENT 30 TSNO. 0

	0	1	2	3	4	5	6	7	8	9	10
0	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
3	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
4	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
5	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
6	000000+00	000000+00	262530-02	262530-02	262530-02	262530-02	262530-02	000000+00	000000+00	000000+00	000000+00
7	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
8	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
9	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
10	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
11	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
12	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
14	000000+00	000000+00	262530-02	262530-02	262530-02	262530-02	262530-02	000000+00	000000+00	000000+00	000000+00
15	000000+00	000000+00	262530-02	262530-02	262530-02	262530-02	262530-02	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 19

TURBO FINAL NUMBER DENSITIES ELEMENT 18 TSNO. 0

	0	1	2	3	4	5	6	7	8	9	10
0	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	000000+00	619440-03	619360-03	618442-03	276151-03	275126-03	000000+00	000000+00	000000+00	000000+00
3	000000+00	000000+00	620070-03	620129-03	619296-03	276555-03	275292-03	000000+00	000000+00	000000+00	000000+00
4	000000+00	000000+00	620494-03	620634-03	619924-03	276956-03	275567-03	000000+00	000000+00	000000+00	000000+00
5	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
6	000000+00	000000+00	620505-03	620584-03	619667-03	276627-03	275014-03	000000+00	000000+00	000000+00	000000+00
7	000000+00	000000+00	620121-03	620072-03	618901-03	276037-03	274308-03	000000+00	000000+00	000000+00	000000+00
8	000000+00	000000+00	619929-03	619810-03	618505-03	275746-03	273960-03	000000+00	000000+00	000000+00	000000+00
9	000000+00	000000+00	619722-03	619525-03	618065-03	275420-03	273557-03	000000+00	000000+00	000000+00	000000+00
10	000000+00	000000+00	619911-03	619754-03	618374-03	275617-03	273746-03	000000+00	000000+00	000000+00	000000+00
11	000000+00	000000+00	620304-03	620256-03	619094-03	276121-03	274293-03	000000+00	000000+00	000000+00	000000+00
12	000000+00	000000+00	620663-03	620714-03	619759-03	276630-03	274859-03	000000+00	000000+00	000000+00	000000+00
13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
15	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TJR80-40.

CELL WITH TYPE 1+3 REGIONS

TS. 0 CS. 1 03/13/68 PG. 20

TURBO FINAL NUMBER DENSITIES ELEMENT 28 TSNO. 0

0	1	2	3	4	5	6	7	8	9	10
0	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	000000+00	392494-05	399514-05	476912-05	304923-05	391174-05	000000+00	000000+00	000000+00
3	000000+00	000000+00	339767-05	335208-05	405449-05	271093-05	377338-05	000000+00	000000+00	000000+00
4	000000+00	000000+00	304355-05	293021-05	352866-05	237513-05	354320-05	000000+00	000000+00	000000+00
5	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
6	000000+00	000000+00	303312-05	297054-05	374417-05	265154-05	400829-05	000000+00	000000+00	000000+00
7	000000+00	000000+00	335227-05	339758-05	438435-05	314673-05	460063-05	000000+00	000000+00	000000+00
8	000000+00	000000+00	351227-05	361570-05	471537-05	339054-05	489326-05	000000+00	000000+00	000000+00
9	000000+00	000000+00	368315-05	385290-05	508356-05	366364-05	523160-05	000000+00	000000+00	000000+00
10	000000+00	000000+00	352633-05	366218-05	482598-05	349935-05	507379-05	000000+00	000000+00	000000+00
11	000000+00	000000+00	319575-05	324436-05	422490-05	307691-05	461479-05	000000+00	000000+00	000000+00
12	000000+00	000000+00	290121-05	286302-05	366877-05	264980-05	414002-05	000000+00	000000+00	000000+00
13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
15	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS TS. 0 CS. 1 03/13/68 PG. 21

TURBO FINAL NUMBER DENSITIES ELEMENT 30 TSNO. 0

0	1	2	3	4	5	6	7	8	9	10
0	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
3	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
4	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
5	000000+00	000000+00	257265-02	257562-02	256553-02	253853-02	249144-02	000000+00	000000+00	000000+00
6	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
7	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
8	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
9	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
10	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
11	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
12	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
13	000000+00	000000+00	257458-02	257702-02	256519-02	253565-02	247939-02	000000+00	000000+00	000000+00
14	000000+00	000000+00	257458-02	257702-02	256519-02	253565-02	247939-02	000000+00	000000+00	000000+00
15	000000+00	000000+00	257458-02	257702-02	256519-02	253565-02	247939-02	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS TS. 0 CS. 1 05/16/68 PG. 22

	TURBO	REMOVAL	CROSS SECTION	GROUP 1	TSNO. 0						
0	1	2	3	4	5	6	7	8	9	10	
0	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	379790-01	379790-01	379790-01	
1	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	379790-01	379790-01	379790-01	
2	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	379790-01	379790-01	379790-01	
3	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	569660-01	869730-01	869730-01	
4	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	569660-01	869730-01	869730-01	
5	471270-01	471270-01	000000+00	000000+00	000000+00	000000+00	000000+00	569660-01	869730-01	869730-01	
6	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	569660-01	869730-01	869730-01	
7	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	569660-01	869730-01	869730-01	
8	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	569660-01	869730-01	869730-01	
9	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	569660-01	869730-01	869730-01	
10	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	569660-01	869730-01	869730-01	
11	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	569660-01	869730-01	869730-01	
12	471270-01	471270-01	546933-01	546933-01	546933-01	543244-01	543244-01	569660-01	869730-01	869730-01	
13	471270-01	471270-01	000C00+00	000000+00	000000+00	000000+00	000000+00	569660-01	869730-01	869730-01	
14	471270-01	471270-01	000C00+00	000000+00	000000+00	000000+00	000000+00	569660-01	869730-01	869730-01	
15	471270-01	471270-01	000C00+00	000000+00	000000+00	000000+00	000000+00	569660-01	869730-01	869730-01	

PROBLEM TOOK 6575+01 MIN

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

CS. 2 03/13/68 PG. 23

SAMPLE PROBLEM IN WAPD-TM-221 TIME STEP 1

TIME STEP 1 159940+05 WATTS 144000+07 SECS. OR 400000+03 HOURS

XY GEOMETRY NO DIAGONAL SYMMETRY 13 COLUMNS 15 ROWS BDRY COND= 1,1,1,1 EPSILON= 100-00
4 GROUPS 9 COMPOSITIONS WITH 5 TYPE 1 0 TYPE 2 2 TYPE 3

FISSION SPECTRUM 751650+00 248175-00 000000+00 000000+00

POISON FRACTIONS 000000+00 000000+00 000000+00 000000+00

FISSION PRODUCTS

ISOTOPE	Y-235	Y-238	Y-239	Y-241	THETA	DECAY
IR-192						107700-06
PU-241						170000-08
PM-149	140000-01	140000-01	140000-01	140000-01		385000-05
I -135	600000-01	000000+00	000000+00	000000+00		288000-04
XE-135	300000-02	300000-02	300000-02	300000-02		211000-04
F.P. 1	100000+01	000000+00	000000+00	000000+00	000000+00	
F.P. 2	000000+00	000000+00	000000+00	000000+00	000000+00	

S MESH INTERVALS

INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL	INTERVAL	COL
795000+00	2	180550+01	3	361010+01	4	108330+01	7	101600+01	8	317500-00	9
529170+00	13										

T MESH INTERVALS

INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW	INTERVAL	ROW
994400+00	2	186310+01	3	317500-00	4	745500+00	5	190500-00	6	120400+01	7
190500-00	8	113030+01	9	226060+01	11	565150+00	13	952500-01	15		

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 24

PICTURE EDIT

```

000 001 002 003 004 005 006 007 008 009 010 011 012 013
000 *****
*004 004 004 004 004 004 004*005 005 005 005 005*
001 *
*004 004 004 004 004 004 004*005 005 005 005 005*
002 * * * * *
*003 003*009 009 009*008 008*005 005 005 005 005*
003 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
004 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
005 *
*003 003*007 007 007*006 006*002*001 001 001 001 001*
006 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
007 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
008 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
009 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
010 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
011 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
012 *
*003 003*009 009 009*008 008*002*001 001 001 001 001*
013 *
*003 003*007 007 007*006 006*002*001 001 001 001 001*
014 *
*003 003*007 007 007*006 006*002*001 001 001 001 001*
015 *****

```

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 25

COMPOSITION AREAS

1	181453+02
2	967745+01
3	905358+01
4	940752+01
5	834679+01
6	619106+00
7	185706+01
8	240545+02
9	721534+02

THERMAL POISON VALUES SET TO ZERO

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 26

MICROSCOPIC CROSS SECTIONS

ELEMENT NUMBER	REMOVAL				TRANSPORT				ABSORPTION			
	GROUP1	GROUP2	GROUP3	GROUP4	GROUP1	GROUP2	GROUP3	GROUP4	GROUP1	GROUP2	GROUP3	GROUP4
1	14505+01	22128+01	22543+01	15659+01	25837+01	63389+01	00000+00	00000+00	20000-03	14200-01	00000+00	00000+00
2	23710-00	88900-01	45000-00	12777+01	39450+01	42553+01	00000+00	42500-01	00000+00	00000+00	00000+00	00000+00
3	82300-01	31900-01	18300-01	18906+01	74082+01	10003+02	00000+00	00000+00	00000+00	77000-02	00000+00	00000+00
4	22480-00	11410-00	80900-01	97970+00	36306+01	48184+01	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00
6	53928-01	51973-01	52438-01	14906-00	29605-00	35600-00	59577+00	17465-02	51557-03	15360-02	64600-02	64600-02
7	53809-01	51988-01	52376-01	14789-00	29399-00	35430-00	51796+00	17362-02	50188-03	16139-02	55710-02	55710-02
8	82300-01	31800-01	18300-01	18906+01	74082+01	10003+02	00000+00	00000+00	00000+00	77000-02	00000+00	00000+00
11	25400-00	83400-01	00000+00	29200+01	56600+01	55400+01	00000+00	00000+00	00000+00	98400-01	00000+00	00000+00
18	13060+01	-77000+00	-16500+02	56700+01	94760+01	99000+01	31152+03	12450+01	20730+01	34000+02	28960+03	28960+03
20	15600+01	-55000-01	-11000+02	50460+01	90400+01	20000+01	11275+02	41000-00	23000-00	23000+02	12580+01	12580+01
26	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	45220+05	00000+00	00000+00	00000+00	45220+05	45220+05
27	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	12750+07	00000+00	00000+00	00000+00	12750+07	12750+07
28	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	46520+02	00000+00	00000+00	00000+00	46520+02	46520+02
29	00000+00	00000+00	00000+00	44920-00	22919+01	17209+03	00000+00	44920-00	22919+01	17209+03	00000+00	00000+00

ELEMENT NUMBER	FISSION				NU FISSION			
	GROUP1	GROUP2	GROUP3	GROUP4	GROUP1	GROUP2	GROUP3	GROUP4
18	11170+01	16250+01	22358+02	24370+03	30940+01	40300+01	55000+02	60194+03
20	34400-00	00000+00	00000+00	00000+00	93000+00	00000+00	00000+00	00000+00
21	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00
23	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00	00000+00

ELEMENT NUMBER	KAPPA			
	GROUP1	GROUP2	GROUP3	GROUP4
18	11435-10	12772-10	12876-10	12905-10
20	11732-10	00000+00	00000+00	12801-10
21	96601-11	10824-10	10885-10	10947-10
23	92167-11	10327-10	10385-10	10582-10

END OF INPUT

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 27

COMP	GROUP	BUCKLING	DIFFUSION	ABSORPTION	NU FISSION	REMOVAL	TOTAL	P SUB R	A
1	1	200000-02	255717+01	116100-02	000000+00	869730-01	932483-01		
1	2	200000-02	131364+01	100000-04	000000+00	120506-00	123143-00		
1	3	200000-02	738381+00	769000-03	000000+00	122577-00	124823-00		
1	4	200000-02	253401-00	117800-01	000000+00	000000+00	122868-01		
								100000+01	000000+00
2	1	200000-02	224481+01	172300-02	000000+00	569660-01	631786-01		
2	2	200000-02	113189+01	486000-03	000000+00	572580-01	600078-01		
2	3	200000-02	912102+00	159200-02	000000+00	578580-01	612742-01		
2	4	200000-02	427201-00	824700-02	000000+00	000000+00	910140-02		
								100000+01	000000+00
3	1	200000-02	217121+01	180400-02	000000+00	471270-01	532734-01		
3	2	200000-02	109385+01	617000-03	000000+00	400830-01	428877-01		
3	3	200000-02	984513+00	160000-02	000000+00	401390-01	437080-01		
3	4	200000-02	528700+00	112400-01	000000+00	000000+00	122974-01		
								100000+01	000000+00
4	1	200000-02	212237+01	181700-02	000000+00	401930-01	462547-01		
4	2	200000-02	107210+01	702000-03	000000+00	289650-01	318112-01		
4	3	200000-02	104011+01	154600-02	000000+00	286180-01	322442-01		
4	4	200000-02	626500+00	658200-02	000000+00	000000+00	783500-02		
								100000+01	000000+00
5	1	200000-02	210708+01	181200-02	000000+00	379790-01	440052-01		
5	2	200000-02	106600+01	727000-03	000000+00	256080-01	284670-01		
5	3	200000-02	105847+01	151800-02	000000+00	251320-01	287669-01		
5	4	200000-02	187129-00	637100-02	000000+00	000000+00	674526-02		
								100000+01	000000+00
6	1	000000+00	250000+02	108301-02	000000+00	000000+00	108301-02		
6	2	000000+00	250000+02	552593-02	000000+00	000000+00	552593-02		
6	3	000000+00	384733+01	330842-00	000000+00	000000+00	330842-00		
6	4	000000+00	691391-01	299094+01	000000+00	000000+00	299094+01		
								100000+01	000000+00
7	1	000000+00	250000+02	109964-02	000000+00	000000+00	109964-02		
7	2	000000+00	250000+02	561077-02	000000+00	000000+00	561077-02		
7	3	000000+00	401074+01	313681-00	000000+00	000000+00	313681-00		
7	4	000000+00	790516-01	276903+01	000000+00	000000+00	276903+01		
								100000+01	000000+00
8	1	200000-02	221149+01	209900-02	874260-03	543201-01	608421-01		
8	2	200000-02	111539+01	109357-02	111482-02	517589-01	550832-01		
8	3	200000-02	929079+00	113956-01	152147-01	476564-01	609102-01		
8	4	200000-02	485593-00	105252-00	193999-00	000000+00	106223-00		
								100000+01	000000+00
9	1	200000-02	219831+01	252699-02	196130-02	546883-01	616119-01		
9	2	200000-02	111011+01	179865-02	250127-02	515077-01	555265-01		
9	3	200000-02	924558+00	237297-01	341365-01	416505-01	672293-01		
9	4	200000-02	462662-00	194029-00	373601-00	000000+00	194954-00		
								100000+01	000000+00

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 05/16/68 PG. 28

SPECTRAL RADIUS CALC.

GROUP 1 MAX= 999187+00 RHO= 997727+00 MIN= 990238+00 NO.IT.= 15
GROUP 2 MAX= 999272+00 RHO= 998174+00 MIN= 989194+00 NO.IT.= 30
GROUP 3 MAX= 994503+00 RHO= 990204+00 MIN= 978234+00 NO.IT.= 30
GROUP 4 MAX= 963702+00 RHO= 951594+00 MIN= 863734+00 NO.IT.= 30

OUTER ITERATION 1

GROUP 1 R(1) = 757932+01 NO. IT. = 39 DELR = 302353-00
GROUP 2 R(1) = 105993+02 NO. IT. = 42 DELR = 204110-00
GROUP 3 R(1) = 945505+01 NO. IT. = 18 DELR = 114475-00
GROUP 4 R(1) = 210525+02 NO. IT. = 9 DELR = 739955-01

MAX= 10902327+01 LAMDA= 10651810+01 MIN= 10594815+01 EPS= 14434725-01
ALPHA = 000000+00 BETA = 000000+00 RENORN = 997417+00 SIGMA = 000000+00

OUTER ITERATION 2

GROUP 1 R(1) = 144765+01 NO. IT. = 39 DELR = 257959-00
GROUP 2 R(1) = 136788+01 NO. IT. = 42 DELR = 411706-00
GROUP 3 R(1) = 107396+01 NO. IT. = 18 DELR = 304472-00
GROUP 4 R(1) = 119442+01 NO. IT. = 9 DELR = 153094-00

MAX= 10674624+01 LAMDA= 10660418+01 MIN= 10649881+01 EPS= 11604959-02

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 29

COMPOSITION INTEGRATION AND POWER FRACTION EDIT

COMP	AREA	GROUP 1	GROUP 2	GROUP 3	GROUP 4	POWER	FRACTION
1	181453+02	187501+04 103333+03	240374+04 132472+03	227385+04 125313+03	432063+04 238112+03	000000+00 000000+00	000000+00
2	967745+01	108883+04 112513+03	139655+04 144341+03	120714+04 124739+03	149018+04 153985+03	000000+00 000000+00	000000+00
3	905358+01	120394+04 132980+03	159777+04 176479+03	114739+04 126734+03	309947+03 342347+02	000000+00 000000+00	000000+00
4	940752+01	116514+04 123852+03	159173+04 169198+03	118772+04 126252+03	501282+03 532853+02	000000+00 000000+00	000000+00
5	834679+01	877025+03 105073+03	123473+04 147929+03	105035+04 125839+03	129049+04 154610+03	000000+00 000000+00	000000+00
6	619106+00	760282+02 122803+03	987235+02 159459+03	745696+02 120447+03	361606+02 584078+02	000000+00 000000+00	000000+00
7	185706+01	245491+03 132193+03	318356+03 171430+03	223256+03 120220+03	393817+02 212065+02	000000+00 000000+00	000000+00
8	240545+02	297734+04 123775+03	382411+04 158977+03	297992+04 123882+03	197917+04 822788+02	415215+04 172615+03	259607-00
9	721534+02	968486+04 134226+03	125336+05 173708+03	897303+04 124360+03	236533+04 327820+02	118418+05 164120+03	740393+00

POWER NORMALIZATION FACTOR IS 742952+12

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 30

COMPOSITION-AVERAGE DISTRIBUTION ANALYSIS EDIT

QUANTITY	MINIMUM		MAXIMUM		FULL CORE AVERAGE
	COMP.	AVG.	COMP.	AVG.	
GROUP1	1	103333+03	9	134226+03	126021+03
GROUP2	1	132472+03	3	176479+03	164139+03
GROUP3	7	120220+03	3	126734+03	125515+03
GROUP4	7	212065+02	1	238112+03	809771+02
POWER	9	164120+03	8	172615+03	104321+03

FLUX-WEIGHTED MACROSCOPIC PARAMETERS BY COMPOSITION

GROUP	COMP	D	SIGMA-A	SIGMA-R	NU SIGMA-F	K SIGMA-F	BZ**2
1	1	255717+01	116100-02	869730-01	000000+00	000000+00	-364654-01
	2	224481+01	172300-02	569660-01	000000+00	000000+00	-281443-01
	3	217121+01	180400-02	471270-01	000000+00	000000+00	-245363-01
	4	212237+01	181700-02	401930-01	000000+00	000000+00	-217939-01
	5	210708+01	181200-02	379790-01	000000+00	000000+00	-208844-01
	6	250000+02	107331-02	000000+00	000000+00	000000+00	-429323-04
	7	250000+02	109921-02	000000+00	000000+00	000000+00	-439683-04
	8	221161+01	209720-02	543182-01	869789-03	995165-14	188760-01
	9	219839+01	252581-02	546871-01	195837-02	224065-13	129510-01
2	1	131364+01	100000-04	120506-00	000000+00	000000+00	-420975-01
	2	113189+01	486000-03	572580-01	000000+00	000000+00	-137851-01
	3	109385+01	617000-03	400830-01	000000+00	000000+00	-674378-02
	4	107210+01	702000-03	289650-01	000000+00	000000+00	-222943-02
	5	106600+01	727000-03	256080-01	000000+00	000000+00	-139832-02
	6	250000+02	547628-02	000000+00	000000+00	000000+00	-219051-03
	7	250000+02	560858-02	000000+00	000000+00	000000+00	-224343-03
	8	111544+01	109059-02	517600-01	110904-02	141651-13	121745-01
	9	111015+01	179669-02	515084-01	249747-02	318986-13	875022-02
3	1	738381+00	769000-03	122577-00	000000+00	000000+00	347690-02
	2	912103+00	159200-02	578580-01	000000+00	000000+00	546232-02
	3	984513+00	160000-02	401390-01	000000+00	000000+00	122988-01
	4	104011+01	154600-02	286180-01	000000+00	000000+00	632002-02
	5	105847+01	151800-02	251320-01	000000+00	000000+00	126242-02
	6	388287+01	328073-00	000000+00	000000+00	000000+00	-844924-01
	7	401235+01	313566-00	000000+00	000000+00	000000+00	-781501-01
	8	929117+00	113459-01	476805-01	151342-01	194871-12	596119-02
	9	924582+00	236973-01	416662-01	340841-01	438873-12	512124-02
4	1	253401-00	117800-01	000000+00	000000+00	000000+00	206088-00
	2	427200-00	824700-02	000000+00	000000+00	000000+00	884067-01
	3	528700+00	112400-01	000000+00	000000+00	000000+00	257789-00
	4	626500+00	658200-02	000000+00	000000+00	000000+00	957242-01
	5	187129-00	637100-02	000000+00	000000+00	000000+00	732653-01
	6	702670-01	296880+01	000000+00	000000+00	000000+00	-422503+02
	7	791112-01	276795+01	000000+00	000000+00	000000+00	-349882+02
	8	485777-00	105011-00	000000+00	192797-00	248802-11	-703878-01
	9	462488-00	194325-00	000000+00	372951-00	481289-11	-804057-01

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS TS. 1 CS. 2 03/13/68 PG. 32

FLUX-WEIGHTED MACROSCOPIC PARAMETERS BY SET OF COMPOSITIONS

GROUP	D	SIGMA-A	SIGMA-R	NU SIGMA-F	K SIGMA-F	BZ**2
COMPOSITIONS	8 9					
1	220150+01	242503-02	546003-01	170241-02	194779-13	143506-01
2	111138+01	163162-02	515672-01	217288-02	277529-13	955367-02
3	925713+00	206180-01	431656-01	293598-01	378043-12	533141-02
4	473097-00	153637-00	000000+00	290880-00	375378-11	-757197-01

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS TS. 1 CS. 2 03/13/68 PG. 33

GROUP 4 FLUX POINTWISE EDIT

	1	2	3	4	5	6	7	8	9	10
1	460478+02	452809+02	422619+02	515491+02	637193+02	792688+02	960917+02	138807+03	148929+03	162120+03
2	446415+02	429418+02	388795+02	472069+02	598525+02	763816+02	949980+02	140447+03	151331+03	165592+03
3	359353+02	333735+02	273246+02	328667+02	459018+02	660604+02	957904+02	153699+03	171410+03	194861+03
4	342453+02	312928+02	248726+02	298767+02	422448+02	622855+02	969156+02	154434+03	176242+03	202563+03
5	305283+02	255680+02	181701+02	218367+02	315862+02	491260+02	917361+02	158745+03	184635+03	215687+03
6	302001+02	252653+02	175550+02	215965+02	325171+02	522470+02	948472+02	160697+03	186983+03	218699+03
7	339065+02	312332+02	249666+02	321683+02	494287+02	770546+02	120637+03	178481+03	203860+03	235467+03
8	344474+02	319106+02	257850+02	333903+02	513583+02	797977+02	123563+03	180837+03	206114+03	237666+03
9	370721+02	346225+02	288757+02	383048+02	589588+02	902460+02	135217+03	191847+03	216856+03	248116+03
10	380327+02	355506+02	298748+02	401755+02	619963+02	946875+02	140978+03	198577+03	223855+03	255450+03
11	335363+02	310995+02	252643+02	332504+02	521066+02	822610+02	128988+03	189733+03	216316+03	249675+03
12	315045+02	283778+02	220550+02	287422+02	451204+02	725267+02	120267+03	185938+03	213690+03	248169+03
13	298104+02	246208+02	176444+02	228225+02	357777+02	584943+02	107869+03	182933+03	211965+03	247349+03
14	297644+02	237522+02	152313+02	197081+02	304504+02	491967+02	105442+03	182845+03	211917+03	247318+03

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 34

TOTAL POWER POINTWISE EDIT

	1	2	3	4	5	6	7	8	9	10
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	121103+01	112185+01	129594+01	117986+01	976409+00	118136+01	000000+00	000000+00	000000+00
3	000000+00	100152+01	868197+00	982495+00	945030+00	859900+00	118930+01	000000+00	000000+00	000000+00
4	000000+00	956415+00	814575+00	917526+00	885259+00	818076+00	120240+01	000000+00	000000+00	000000+00
5	000000+00	830172+00	665852+00	740022+00	711942+00	669610+00	114415+01	000000+00	000000+00	000000+00
6	000000+00	823589+00	652591+00	734669+00	726685+00	703359+00	117645+01	000000+00	000000+00	000000+00
7	000000+00	958076+00	819878+00	969713+00	100786+01	981770+00	146286+01	000000+00	000000+00	000000+00
8	000000+00	972998+00	838038+00	996225+00	103885+01	101089+01	149268+01	000000+00	000000+00	000000+00
9	000000+00	103477+01	908692+00	110575+01	116480+01	112707+01	162041+01	000000+00	000000+00	000000+00
10	000000+00	105699+01	932586+00	114799+01	121541+01	117657+01	168375+01	000000+00	000000+00	000000+00
11	000000+00	956649+00	827649+00	993271+00	105082+01	103771+01	155164+01	000000+00	000000+00	000000+00
12	000000+00	896261+00	755917+00	893839+00	935794+00	930058+00	145729+01	000000+00	000000+00	000000+00
13	000000+00	812735+00	657278+00	762837+00	780335+00	772921+00	132023+01	000000+00	000000+00	000000+00
14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 35

COMP	U 235	COMP. POWER FRACTION PER ISOTOPE U 238	PU239	PU241	TOTAL POWER PER COMP
8	999885+00	114777-03	000000+00	000000+00	192875+12
9	999708+00	292044-03	000000+00	000000+00	550076+12

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 36

AVERAGED END-OF-TIME-STEP NUMBER DENSITIES BY COMP.
FOLLOWED BY INTEGRAL OF N TIMES FLUX FOR EACH GROUP I

COMP I	U 235	U 236	P 149	I 135	SM149	XE135	F.P.1	B 10	F.P.2
6	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	229205-02
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	242839+11
2	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	317146+11
3	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	239512+11
4	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	114438+11
7	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	247080-02
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	199589+12
2	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	259678+12
3	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	181871+12
4	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	309543+11
8	265798-03	257698-05	193511-07	110875-07	217988-07	277380-08	115354-04	000000+00	000000+00
1	105697+13	341719+10	728827+08	445363+08	623834+08	109205+08	153917+11	000000+00	000000+00
2	135310+13	436533+10	930708+08	568726+08	798057+08	139773+08	196552+11	000000+00	000000+00
3	105848+13	343255+10	732489+08	447601+08	625338+08	109389+08	154691+11	000000+00	000000+00
4	728316+12	246458+10	529694+08	323681+08	436384+08	755601+07	111864+11	000000+00	000000+00
9	610341-03	300359-05	186079-07	106601-07	564376-07	616458-08	110651-04	000000+00	000000+00
1	192810+14	312855+11	548922+09	335369+09	796095+09	193026+09	115904+12	000000+00	000000+00
2	248985+14	403973+11	708779+09	433035+09	102798+10	249257+09	149657+12	000000+00	000000+00
3	178282+14	289479+11	508057+09	310402+09	736549+09	178511+09	107275+12	000000+00	000000+00
4	471498+13	774785+10	136640+09	834818+08	196788+09	473522+08	288513+11	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 37

AVERAGED END-OF-TIME-STEP NUMBER DENSITIES BY COMP.
FOLLOWED BY INTEGRAL OF N TIMES FLUX FOR EACH GROUP I

COMP I	U 238	PU239	PU240	PU241
8	196822-04	944465-07	000000+00	000000+00
1	758917+11	119427+09	000000+00	000000+00
2	971501+11	152852+09	000000+00	000000+00
3	760045+11	119631+09	000000+00	000000+00
4	523424+11	826666+08	000000+00	000000+00
9	439114-04	206316-06	000000+00	000000+00
1	137066+13	210971+10	000000+00	000000+00
2	177000+13	272426+10	000000+00	000000+00
3	126739+13	195079+10	000000+00	000000+00
4	335224+12	516466+09	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40. CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 38

TURBO FINAL NUMBER DENSITIES ELEMENT 18 TSNO. 1

	0	1	2	3	4	5	6	7	8	9	10
0	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	000000+00	609503-03	609233-03	606542-03	268678-03	265633-03	000000+00	000000+00	000000+00	000000+00
3	000000+00	000000+00	611374-03	611555-03	609067-03	269858-03	266097-03	000000+00	000000+00	000000+00	000000+00
4	000000+00	000000+00	612627-03	613057-03	610920-03	271028-03	266879-03	000000+00	000000+00	000000+00	000000+00
5	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
6	000000+00	000000+00	612662-03	612918-03	610169-03	270065-03	265268-03	000000+00	000000+00	000000+00	000000+00
7	000000+00	000000+00	611534-03	611413-03	607923-03	268344-03	263234-03	000000+00	000000+00	000000+00	000000+00
8	000000+00	000000+00	610971-03	610649-03	606769-03	267501-03	262234-03	000000+00	000000+00	000000+00	000000+00
9	000000+00	000000+00	610366-03	609817-03	605485-03	266559-03	261078-03	000000+00	000000+00	000000+00	000000+00
10	000000+00	000000+00	610908-03	610476-03	606372-03	267116-03	261602-03	000000+00	000000+00	000000+00	000000+00
11	000000+00	000000+00	612053-03	611937-03	608464-03	268571-03	263157-03	000000+00	000000+00	000000+00	000000+00
12	000000+00	000000+00	613111-03	613285-03	610421-03	270058-03	264781-03	000000+00	000000+00	000000+00	000000+00
13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
15	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 39

TURBO FINAL NUMBER DENSITIES ELEMENT 28 TSNO. 1

0	1	2	3	4	5	6	7	8	9	10
0	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	000000+00	117620-04	119563-04	142692-04	910871-05	116715-04	000000+00	000000+00	000000+00
3	000000+00	000000+00	101971-04	100469-04	121546-04	811971-05	112841-04	000000+00	000000+00	000000+00
4	000000+00	000000+00	915063-05	880031-05	106042-04	713907-05	106287-04	000000+00	000000+00	000000+00
5	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
6	000000+00	000000+00	911659-05	891338-05	112325-04	794804-05	119852-04	000000+00	000000+00	000000+00
7	000000+00	000000+00	100550-04	101678-04	131117-04	939263-05	136943-04	000000+00	000000+00	000000+00
8	000000+00	000000+00	105224-04	108036-04	140767-04	100993-04	145344-04	000000+00	000000+00	000000+00
9	000000+00	000000+00	110227-04	114953-04	151495-04	108904-04	155057-04	000000+00	000000+00	000000+00
10	000000+00	000000+00	105719-04	109472-04	144100-04	104236-04	150671-04	000000+00	000000+00	000000+00
11	000000+00	000000+00	962056-05	973162-05	126625-04	920476-05	137623-04	000000+00	000000+00	000000+00
12	000000+00	000000+00	873959-05	860718-05	110248-04	795680-05	123974-04	000000+00	000000+00	000000+00
13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
14	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
15	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 03/13/68 PG. 40

	TURBO FINAL NUMBER DENSITIES									
	ELEMENT 30 TSNO. 1									
	0	1	2	3	4	5	6	7	8	9
0	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
1	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
2	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
3	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
4	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
5	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
6	000000+00	000000+00	246820-02	247713-02	244720-02	236744-02	223140-02	000000+00	000000+00	000000+00
7	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
8	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
9	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
10	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
11	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
12	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
13	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00	000000+00
14	000000+00	000000+00	247360-02	248097-02	244590-02	235829-02	219636-02	000000+00	000000+00	000000+00
15	000000+00	000000+00	247360-02	248097-02	244590-02	235829-02	219636-02	000000+00	000000+00	000000+00

* SAMPLE PROB. FOR TURBO-40.

CELL WITH TYPE 1+3 REGIONS

TS. 1 CS. 2 05/16/68 PG. 41

	TURBO		REMOVAL		CROSS SECTION		GROUP 1		TSNO. 1		
	0	1	2	3	4	5	6	7	8	9	10
0	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	379790-01	379790-01	379790-01
1	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	401930-01	379790-01	379790-01	379790-01
2	471270-01	471270-01	546867-01	546866-01	546854-01	543195-01	543181-01	379790-01	379790-01	379790-01	
3	471270-01	471270-01	546875-01	546876-01	546865-01	543200-01	543183-01	569660-01	869730-01	869730-01	
4	471270-01	471270-01	546881-01	546883-01	546873-01	543205-01	543187-01	569660-01	869730-01	869730-01	
5	471270-01	471270-01	000000+00	000000+00	000000+00	000000+00	000000+00	569660-01	869730-01	869730-01	
6	471270-01	471270-01	546881-01	546882-01	546870-01	543201-01	543180-01	569660-01	869730-01	869730-01	
7	471270-01	471270-01	546876-01	546875-01	546860-01	543193-01	543170-01	569660-01	869730-01	869730-01	
8	471270-01	471270-01	546873-01	546872-01	546855-01	543189-01	543166-01	569660-01	869730-01	869730-01	
9	471270-01	471270-01	546871-01	546868-01	546849-01	543185-01	543161-01	569660-01	869730-01	869730-01	
10	471270-01	471270-01	546873-01	546871-01	546853-01	543188-01	543163-01	569660-01	869730-01	869730-01	
11	471270-01	471270-01	546878-01	546878-01	546863-01	543194-01	543170-01	569660-01	869730-01	869730-01	
12	471270-01	471270-01	546883-01	546884-01	546871-01	543201-01	543178-01	569660-01	869730-01	869730-01	
13	471270-01	471270-01	000000+00	000000+00	000000+00	000000+00	000000+00	569660-01	869730-01	869730-01	
14	471270-01	471270-01	000000+00	000000+00	000000+00	000000+00	000000+00	569660-01	869730-01	869730-01	
15	471270-01	471270-01	000000+00	000000+00	000000+00	000000+00	000000+00	569660-01	869730-01	869730-01	

PROBLEM TOOK 3890+01 MIN