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VULCAN - A DEPLETION PROGRAM FOR USE WITH INDEPENDENT ONE-DIMENSIONAL SPATIAL CALCULATIONS

by John L. Anderson, Jr.

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SUMMARY

A digital computer depletion program, VULCAN, which treats the time behavior of nuclide concentrations in a nuclear reactor, is described. This depletion program is suitable for use with any multigroup one-dimensional spatial solution; that is, it is independent of the actual generating source of cross sections or fluxes. This flexibility allows any space-energy calculational sequence to be extended, without alteration, to include a depletion stage.

The depletion calculation is performed for each mesh interval, and an averaging process is used to reduce the number of regions for which new atom densities are required. The depletion equations for several classes of nuclides are shown and cast into forms solvable by a computer. Data input instructions, a sample problem, and a FORTRAN IV listing of the program are included. VULCAN, written for an IBM 7094, relies entirely on fast memory computer storage (32K).

INTRODUCTION

In the face of various economic and operational restrictions the life expectancy of a nuclear reactor must be considered as a part of its design. This life expectancy or lifetime is essentially the length of time a reactor core or fuel element may operate before reactivity or structural considerations force a shutdown. For example, the structural consideration may be the governing one because of gaseous fission products and consequent pressure buildup.

In the interest of economics the degree of fuel utilization within a spent element or core should be as large as possible. Budgetary requirements and, for commercial power reactors, subsequent consumer costs make necessary the availability of a cost per unit time figure which depends on the fuel utilization. In another vein, space applications of nuclear reactors, for which maintenance is rather inconvenient, demand

lifetime and performance foreknowledge.

The lifetime determination based on reactivity considerations may be made by considering the time behavior of fissionable and parasitic nuclide concentrations. The behavior of individual nuclides is governed by depletion (productive and parasitic absorption, decay and physical losses) and by buildup (decay and fission sources). The differential equations describing the various isotopic populations are typically solved by programs for digital computers; generically, these programs are called depletion programs.

Depletion programs may emphasize any of several facets: speed, intervention convenience, tape handling convenience, and calculational detail. Usually, the programs include the spatial (generally diffusion theory) calculations and cross section libraries in one all-encompassing computer program. These programs may treat reactors whose symmetry allows their calculation to be performed in one (refs. 1 and 2), two (refs. 3 and 4), or three dimensions. They allow several depletion cycles to be performed without any other input or intervention. However, such codes typically have energy group and diffusion theory limitations because of insufficient computer memory capacity. These limitations may be overcome by auxiliary storage on peripheral devices but at the expense of computer execution time. A somewhat more comprehensive review of the literature and programs may be found in reference 5.

This depletion program, VULCAN, may be used with any one-dimensional space-energy solution. The cross sections and fluxes (mesh interval averages) that VULCAN requires may be from any source (constant, analytical, or even experimental) in any format. Consequently VULCAN is independent of the actual generating source of cross sections or fluxes. This flexibility allows any space-energy calculational sequence to be extended without alteration to include a depletion stage. A particular advantage resulting from the independent status of VULCAN is the availability of considerably more fast memory computer storage since the multigroup energy and spatial solutions to Boltzmann's equation have been obtained from other programs. This additional storage enables pointwise (at each discrete mesh interval of the spatial calculation) rather than zonal (average over several mesh intervals) nuclide concentrations to be followed. A representative 7 energy group-14 mesh interval-13 isotope-1 time step problem required 0.15 minute of IBM 7094-II computer execution time.

The VULCAN program is comprised of about 1200 source statements and relies entirely on fast memory computer storage. However, because no peripheral storage is used, the following restrictions are imposed on this version of VULCAN:

Nuclides	≤40
Energy groups	≤40
Mesh intervals	≤20
Zones	≤190
Materials	≤190

Some of the restrictions may be relaxed but at the expense of tightening others (see the section VULCAN DESCRIPTION). VULCAN is written in FORTRAN IV language for use on an IBM 7094 with 32K memory.

PREPARATION OF DEPLETION EQUATIONS

General Solutions and Approximations

The general equation governing the concentration of a particular isotope N as a function of space $\vec{r}$, time t, and energy E is

$$\frac{dN(\vec{r},t)}{dt} = \sum_{i}^{NF} \Gamma_i^N N_i(\vec{r},t) \int_0^\infty \Phi(\vec{r},E,t)\sigma_f^i(E)\,dE + \lambda_p N_p(\vec{r},t) + N_r(\vec{r},t) \int_0^\infty \Phi(\vec{r},E,t)\sigma_{n,\gamma}^r(E)\,dE$$

$$- \lambda_N N(\vec{r},t) - N(\vec{r},t) \int_0^\infty \Phi(\vec{r},E,t)\sigma_a^N(E)\,dE - \xi_N N(\vec{r},t) \qquad (1)$$

where

$\Phi(\vec{r},E,t)$	neutron flux as function of space, energy, and time, neutrons/(b) (sec); neutrons/$(10^{-28}\ m^2)$ (sec)
$\sigma_f^k, \sigma_{n,\gamma}^k, \sigma_a^k$	microscopic fission, (n,γ), and absorption cross sections for isotope k, b; $10^{-28}\ m^2$
λ_k	decay constant for isotope k, sec^{-1}
N_k	atom concentration of isotope k, atoms/(b)(cm); atoms/$(10^{-30}\ m^3)$
NF	number of fissionable isotopes considered

The first term on the right side of the equation is the source of isotope N from the fission yield Γ_i^N of each fissionable isotope i considered. The second term is the

source from beta decay of the precursor nuclide N_p. The third term is the source from radiative capture (n, γ reaction) by N_r. The fourth term is the loss resulting from beta decay of the isotope N itself. The fifth term is the loss from depletion or burnup of N. The sixth term represents losses of isotope N such as expulsion of material fragments or diffusion of gaseous constituents or products (ξ_N is the loss rate).

There are two simplifications to be considered before this generalized equation may be used in a depletion scheme. The first is the reduction from the continuous variables $\vec{r}$, E, and t to their discrete counterparts. In particular, the GAM-GATHER (refs. 6 and 7) multigroup energy structure and the TDSN (ref. 8) spatial interval structure may establish the discrete E and $\vec{r}$. There remains only the discrete t to assign, and this is done as part of the VULCAN input.

The second simplification begins with the realization that the form of equation (1) and its consequent solution will depend on the nuclear behavior of the isotope. Contrast, for example, the form of the equation for uranium 235 (U^{235}) which is fissionable and may be formed by radiative capture in U^{234} and the form for xenon 135 (Xe^{135}) which is a fission product and is both created and depleted by beta decay.

Now, before enumerating the forms of the depletion equation to be considered, it is convenient to discuss some methods for their solution. There are two assumptions in general use which facilitate the solutions: (1) constant flux or (2) constant power over a time interval, each of which will be expressed mathematically hereinafter. As the time interval decreases, the two approximations approach each other. However, the constant power approximation (CPA) seems to be appropriate since the usually understood objective of the reactors considered is that of providing a constant power output. Since most of the power in a reactor is produced by any of six isotopes (thorium 232 (Th^{232}), U^{233}, U^{235}, U^{238}, plutonium 239 (Pu^{239}), and Pu^{241}), the CPA need only be applied to equations which dictate their behavior. The equations for all other isotopes may be treated by the constant flux approximation and then solved analytically.

At this stage it is appropriate to cast equation (1) in its discrete form, that is,

$$\int_0^\infty \Phi(\vec{r}, E, t)\sigma_x^N(E)\,dE$$

becomes

$$\sum_j^{NG} \Phi_{jm}(t)\sigma_{x_j}^N$$

for any isotope N, mesh interval (spatial location) m, cross section σ_x, and time t and where NG is the total number of energy groups. Thus,

$$\left.\frac{dN_m(t)}{dt}\right]_m = \sum_i^{NF} \Gamma_i^N N_{im}(t) \sum_j^{NG} \Phi_{jm}(t)\sigma_{f_j}^i + \lambda_p N_{pm}(t) + N_{rm}(t) \sum_j^{NG} \Phi_{jm}(t)\sigma_{n,\gamma_j}^r$$

$$- \lambda_N N_m(t) - N_m(t) \sum_j^{NG} \Phi_{jm}(t)\sigma_{a_j}^N - \xi_N N_m(t) \qquad (2)$$

In the CPA, $N_{im}(t) \sum_j^{NG} \Phi_{jm}\sigma_{f_j}^i$ is a constant for any mesh interval m where i corresponds to the six isotopes mentioned previously. In the constant flux assumption, Φ_{jm} is considered constant over the time interval, and $N_m(t)$ is thus free to be combined with $dN_m(t)$ leading to an analytic solution. Of course, in either case, Φ_{jm} and $\sigma_{x_j}^i$ are implicitly constant over the energy j and space m intervals as is required by the respective codes. For the finite difference solution to the CPA, the following two substitutions must be made:

$$\frac{dN(t)}{dt} \rightarrow \frac{N_{t+\Delta t} - N_t}{\Delta t}$$

and

$$N(t) \rightarrow \frac{N_{t+\Delta t} + N_t}{2}$$

Formulation of Specific Equations

It now becomes necessary to determine the isotopes which will be explicitly considered. A fixed base of twelve fissionable isotopes and five assorted fission products was established, and the basic depletion equations determined. These equations and two other general forms are considered adequate for any foreseeable reactor application.

The twelve fissionable isotopes used as a base are the constituent nuclides in two chains $Th^{232} \rightarrow U^{236}$ and $U^{238} \rightarrow Pu^{242}$. The other five base isotopes are Xe^{135}, samarium 149 (Sm^{149}), iodine 135 (I^{135}), promethium 149 (Pm^{149}), and a fission product aggregate; I^{135} and Pm^{149} are considered merely because they are precursors of Xe^{135} and Sm^{149}, which are major parasitic absorbers. Four additional categories of isotopes may also be treated. The first of these categories is labeled "Special

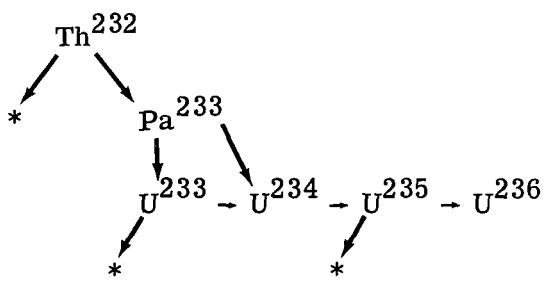
Materials" and may include additional fission products and aggregates and neutron capture products. These isotopes are formed from fission and/or capture and decay (see the section INPUT INSTRUCTIONS). The analytic solution is used and so is applicable to rapidly saturating nuclides. The second is headed "Burnable Poisons" and treats isotopes depleted by absorption and those which are not continuously formed (e.g., boron 10). The third category, called "Repeated Fissionable Nuclides" allows any fissionable isotope to be included more than once. If, for example, U^{235} occurs in two locations in a reactor where the flux spectra differ, the microscopic cross sections may be sufficiently different to make separate depletion desirable. The fourth category is headed "Nondepletable Nuclides" and it allows nondepletable isotopes such as hydrogen, oxygen, or aluminum to be carried through the VULCAN calculation unaltered.

The following two sections contain the specific depletion equations considered. Their solutions, in a form suitable for computer analysis, are shown along with some exemplary, but condensed, derivations. In the equations that follow, any $\sigma_x^i \Phi$ implies a type of summation convention, that is,

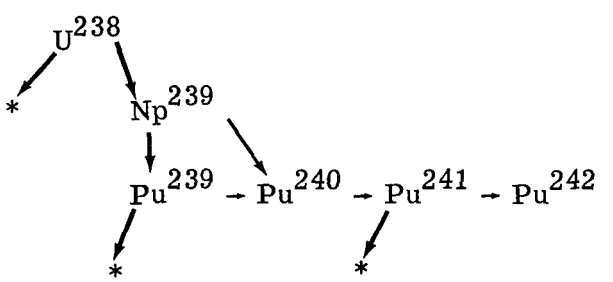
$$\sum_j^{NG} \sigma_{x_j}^i \Phi_j \rightarrow \sigma_{x_j}^i \Phi_j \rightarrow \sigma_x^i \Phi$$

Fissionable nuclides. - The following two simplified heavy element chains provided the twelve basic fissionable nuclides:

$Th^{232} \rightarrow U^{236}$ chain:



$U^{238} \rightarrow Pu^{242}$ chain:



where

↘ (n, γ) process followed by β decay

↓ β decay

→ (n, γ) reaction

*↙ fission (all isotopes fission but virtually all power is produced by the six indicated)

The two chains appear to obey identical reaction mechanisms. To the extent of the considerations in this depletion analysis, this is the case, with but one exception; Pu^{241} undergoes β decay with a nonnegligible decay whereas U^{235}, for these depletion purposes, is stable. Consequently, seven equations suffice to treat the twelve fissionable nuclides.

In the following equations the superscripts represent the VULCAN internal identification (VID) number (see the section Nuclide List) for the first chain considered ($Th^{232} \rightarrow U^{236}$). The isotope in the second chain ($U^{238} \rightarrow Pu^{242}$) to which each equation applies is also indicated. The equation designation (a) will denote the differential equation and (b) will denote the finite difference form used in the program.

Th^{232} (VID = 1) or U^{238} (VID = 7)

$$\frac{dN^1}{dt} = - N^1 \sigma_a^1 \Phi \tag{3a}$$

$$\frac{N^1_{t+\Delta t} - N^1_t}{\Delta t} = -\left(\frac{N^1_{t+\Delta t} + N^1_t}{2}\right)\sigma_a^1 \Phi$$

$$N^1_{t+\Delta t} = N^1_t \left(\frac{2 - \sigma_a^1 \Phi \, \Delta t}{2 + \sigma_a^1 \Phi \, \Delta t}\right) \tag{3b}$$

Pa^{233} (VID = 2) or Np^{239} (VID = 8)

$$\frac{dN^2}{dt} = N^1\left(\sigma_a^1 - \sigma_f^1\right)\Phi - N^2\left(\lambda^2 + \sigma_a^2 \Phi\right) \tag{4a}$$

$$\left\{\ln\left[N^2\left(\lambda^2 + \sigma_a^2\Phi\right) - N^1\left(\sigma_a^1 - \sigma_f^1\right)\Phi\right]\right\}_{N_t^2}^{N_{t+\Delta t}^2} = -\left(\lambda^2 + \sigma_a^2\Phi\right)\Delta t$$

$$N_{t+\Delta t}^2 = \frac{N_{t+\Delta t}^1 + N_t^1}{2}\,\frac{\left(\sigma_a^1 - \sigma_f^1\right)\Phi}{\lambda^2 + \sigma_a^2\Phi}\left\{1 - \exp\left[-\left(\lambda^2 + \sigma_a^2\Phi\right)\Delta t\right]\right\} + N_t^2 \exp\left[-\left(\lambda^2 + \sigma_a^2\Phi\right)\Delta t\right] \tag{4b}$$

U^{233} (VID = 3) or Pu^{239} (VID = 9)

$$\frac{dN^3}{dt} = -N^3\sigma_a^3\Phi + N^2\lambda^2 \rightarrow \frac{N_{t+\Delta t}^3 - N_t^3}{\Delta t} = -\left(\frac{N_{t+\Delta t}^3 + N_t^3}{2}\right)\sigma_a^3\Phi + N^2\lambda^2 \tag{5a}$$

$$N_{t+\Delta t}^3 = \frac{N_t^3\left(2 - \sigma_a^3\Phi\,\Delta t\right) + \left(N_{t+\Delta t}^2 + N_t^2\right)\lambda^2\,\Delta t}{2 + \sigma_a^3\Phi\,\Delta t} \tag{5b}$$

If VID = 2 (VID = 8) is not included, then the following equation is used:

$$N_{t+\Delta t}^3 = \frac{N_t^3\left(2 - \sigma_a^3\Phi\,\Delta t\right) + \left(N_{t+\Delta t}^1 + N_t^1\right)\left(\sigma_a^1 - \sigma_f^1\right)\Phi\,\Delta t}{2 + \sigma_a^3\Phi\,\Delta t} \tag{5c}$$

U^{234} (VID = 4) or Pu^{240} (VID = 10)

$$\frac{dN^4}{dt} = -N^4\sigma_a^4\Phi + N_t^2\left(\sigma_a^2 - \sigma_f^2\right)\Phi + N^3\left(\sigma_a^3 - \sigma_f^3\right)\Phi \tag{6a}$$

$$N_{t+\Delta t}^4 = N_t^4 e^{-\sigma_a^4\Phi\,\Delta t} + \left[\left(N_{t+\Delta t}^2 + N_t^2\right)\left(\sigma_a^2 - \sigma_f^2\right) + \left(N_{t+\Delta t}^3 + N_t^3\right)\left(\sigma_a^3 - \sigma_f^3\right)\right]\left(\frac{1 - e^{-\sigma_a^4\Phi\,\Delta t}}{2\sigma_a^4}\right) \tag{6b}$$

U^{235} (VID = 5)

$$\frac{dN^5}{dt} = - N^5\sigma_a^5\Phi + N^4\left(\sigma_a^4 - \sigma_f^4\right)\Phi \tag{7a}$$

$$N_{t+\Delta t}^5 = \frac{N_t^5\left(2 - \sigma_a^5\Phi\,\Delta t\right) + \left(N_{t+\Delta t}^4 + N_t^4\right)\left(\sigma_a^4 - \sigma_f^4\right)\Phi\,\Delta t}{2 + \sigma_a^5\Phi\,\Delta t} \tag{7b}$$

Pu^{241} (VID = 11)

$$\frac{dN^{11}}{dt} = - N^{11}\left(\sigma_a^{11}\Phi + \lambda^{11}\right) + N^{10}\left(\sigma_a^{10} - \sigma_f^{10}\right)\Phi \tag{8a}$$

$$N_{t+\Delta t}^{11} = \frac{N_t^{11}\left[2 - \left(\lambda^{11} + \sigma_a^{11}\Phi\right)\Delta t\right] + \left(N_{t+\Delta t}^{10} + N_t^{10}\right)\left(\sigma_a^{10} - \sigma_f^{10}\right)\Phi\,\Delta t}{2 + \left(\lambda^{11} + \sigma_a^{11}\Phi\right)\Delta t} \tag{8b}$$

U^{236} (VID = 6) or Pu^{242} (VID = 12)

$$\frac{dN^6}{dt} = - N^6\sigma_a^6\Phi + N^5\left(\sigma_a^5 - \sigma_f^5\right)\Phi \tag{9a}$$

$$N_{t+\Delta t}^6 = \frac{N_t^6\left(2 - \sigma_a^6\Phi\,\Delta t\right) + \left(N_{t+\Delta t}^5 + N_t^5\right)\left(\sigma_a^5 - \sigma_f^5\right)\Phi\,\Delta t}{2 + \sigma_a^6\Phi\,\Delta t} \tag{9b}$$

Poisons: Explicit fission products (Xe^{135}, I^{135}, Sm^{149}, and Pm^{149}). - Each of these explicit fission products is treated under a separate heading. The analytic solutions enable the rapidly saturating fission products to be followed within a single time step. For each of the four products an equilibrium concentration equation is given, and in the case of Xe^{135} the buildup after shutdown is treated.

Xe^{135}: The equation governing the time behavior of the Xe^{135} nuclide concentration X(t) is

$$\frac{dX(t)}{dt} = \lambda_i I(t) + \sum_{i=1}^{NF} \Gamma_i^x \sum_j^{NG} \Phi_j \Sigma_{f_j}^i - \lambda_x X(t) - \sigma_a^x \Phi X(t) - \xi_x X(t) \qquad (10a)$$

where

$$\Sigma_{f_j}^i = \bar{N}^i \sigma_{f_j}^i = \frac{\left(N_{t+\Delta t}^i + N_t^i\right)\sigma_{f_j}^i}{2}$$

is the average macroscopic fission cross section for isotope i, energy group j; ξ_x represents the removal rate for xenon other than by σ_a^x and λ_x; and ξ_I is the corresponding quantity for iodine.

In the following derivations, in the interest of brevity, the time dependence will not always be shown and the summation over all energy groups will be implied. The Xe^{135} concentration at time $t + \Delta t$ is then

$$X_{t+\Delta t} = \frac{\lambda_I'\left[I_t\left(\lambda_I' + \sigma_a^I\Phi\right) - \Gamma^I\right]}{\left(\lambda_I' + \sigma_a^I\Phi\right)\left(\lambda_x^* + \sigma_a^x\Phi - \lambda_I' - \sigma_a^I\Phi\right)}\left\{\exp\left[-\left(\lambda_I' + \sigma_a^I\Phi\right)\Delta t\right] - \exp\left[-\left(\lambda_x^* + \sigma_a^x\Phi\right)\Delta t\right]\right\}$$

$$+ \frac{\Gamma^x\left(\lambda_I' + \sigma_a^I\Phi\right) + \Gamma^I\lambda_I'}{\left(\lambda_I' + \sigma_a^I\Phi\right)\left(\lambda_x^* + \sigma_a^x\Phi\right)}\left\{1 - \exp\left[-\left(\lambda_x^* + \sigma_a^x\Phi\right)\Delta t\right]\right\} + X_t \exp\left[-\left(\lambda_x^* + \sigma_a^x\Phi\right)\Delta t\right] \qquad (10b)$$

in which $\lambda_x^* = \lambda_x + \xi_x$, $\lambda_I' = \lambda_I - \xi_I$, $\Gamma^K = \sum_i^{NF} \Gamma_i^K \sum_j^{NG} \Sigma_{f_j}^i$, and I_t and X_t represent concentrations of I^{135} and Xe^{135} at the start of the time interval. In the event I^{135} is not considered, equation (10b) is altered internally by letting $\lambda_I' = 0$ and $\Gamma^x = \Gamma^x + \Gamma^I$. The equilibrium or steady-state Xe^{135} concentration is given by

$$X_{ss} = \frac{\lambda_I' I_{ss} + \Gamma^x}{\lambda_x^* + \sigma_a^x\Phi} \qquad (10c)$$

with Γ^x defined as in the preceding sentence and I_{ss} representing the I^{135} equilibrium concentration.

The equation for Xe^{135} concentration at a time Δt after shutdown may be obtained from equation (10b) by letting Φ, Γ^I, and Γ^x equal zero. Then, I_t and X_t become I_{sd} and X_{sd}, the respective concentrations at shutdown. The time after shutdown of maximum Xe^{135} concentration is

$$t_{max} = \frac{1}{\lambda_x^* - \lambda_I'} \ln\left\{\frac{\lambda_x^*}{\lambda_I'}\left[1 - \frac{\left(\lambda_x^* - \lambda_I'\right)}{\lambda_I'}\frac{X_{sd}}{I_{sd}}\right]\right\} \tag{10d}$$

I^{135}: The isotope I^{135} does not have a decay precursor, thus its equation differs slightly from that of Xe^{135} (eq. (10a)). Another loss mechanism ξ_I (e.g., diffusion or expulsion) may be incorporated into λ_I, that is, $\lambda_I^* = \lambda_I + \xi_I$. The I^{135} nuclide concentration obeys the equation

$$\frac{dI(t)}{dt} = -\lambda_I^* I(t) - I(t)\sigma_a^I \Phi + \sum_{i=1}^{NF} \Gamma_i^I \sum_{j=1}^{NG} \Sigma_{f_j}^i \Phi \tag{11a}$$

In finite difference form, equation (11a) becomes

$$I_{t+\Delta t} = I_t \exp\left[-\left(\lambda_I^* + \sigma_a^I \Phi\right)\Delta t\right] + \frac{\Gamma^I}{\lambda_I^* + \sigma_a^I \Phi}\left\{1 - \exp\left[-\left(\lambda_I^* + \sigma_a^I \Phi\right)\Delta t\right]\right\} \tag{11b}$$

The steady-state concentration is given by

$$I_{ss} = \frac{\Gamma^I}{\lambda_I^* + \sigma_a^I \Phi} \tag{11c}$$

Pm^{149}: The isotope Pm^{149} has the same creation and destruction mechanisms as I^{135} except that its effect on reactivity is small enough so that no additional loss mechanisms are considered. Thus the finite difference equation is

$$P_{t+\Delta t} = P_t \exp\left[-\left(\lambda_p + \sigma_a^P \Phi\right)\Delta t\right] + \left(\frac{\Gamma^P}{\lambda_p + \sigma_a^P \Phi}\right)\left\{1 - \exp\left[-\left(\lambda_p + \sigma_a^P \Phi\right)\Delta t\right]\right\} \tag{12a}$$

and the steady state concentration is given by

$$P_{ss} = \frac{\Gamma^P}{\lambda_p + \sigma_a^P \Phi} \tag{12b}$$

Sm^{149}: This isotope is similar to Xe^{135} except that it is stable and no extra loss mechanisms are considered necessary. The equations for Sm^{149} are

$$\frac{dS(t)}{dt} = \lambda_p P(t) + \sum_i^{NF} \Gamma_i^S \sum_{j=1}^{NG} \Sigma_{f_j}^i \Phi - S(t)\sigma_a^S \Phi \tag{13a}$$

and

$$S_{t+\Delta t} = \frac{\lambda_p \left[P_t \left(\lambda_p + \sigma_a^P \Phi \right) - \Gamma^P \right]}{\left(\lambda_p + \sigma_a^P \Phi \right) \left(\sigma_a^S \Phi - \lambda_p - \sigma_a^P \Phi \right)} \left\{ \exp \left[-\left(\lambda_p + \sigma_a^P \Phi \right) \Delta t \right] - \exp \left(- \sigma_a^S \Phi \, \Delta t \right) \right\}$$

$$+ \frac{\Gamma^S \left(\lambda_p + \sigma_a^P \Phi \right) + \Gamma^P \lambda_p}{\left(\lambda_p + \sigma_a^P \Phi \right) \left(\sigma_a^S \Phi \right)} \left[1 - \exp \left(- \sigma_a^S \Phi \, \Delta t \right) \right] + S_t \exp \left(- \sigma_a^S \Phi \, \Delta t \right) \tag{13b}$$

In the event Pm^{149} is not considered, equation (13b) is altered internally by letting $\lambda_p = 0$ and $\Gamma^S = \Gamma^S + \Gamma^P$. The steady state concentration is

$$S_{ss} = \frac{\lambda_p P_{ss} + \Gamma^S}{\sigma_a^S \Phi} \tag{13c}$$

Special materials: These materials, which include fission products and aggregates, obey the following depletion equation:

$$N_{t+\Delta t}^{SP} = \frac{\Gamma^{SP} + \frac{1}{2} \left(N_{t+\Delta t}^{SP-1} + N_t^{SP-1} \right) \sigma_a^{SP-1} \Phi \, \delta^{SP}}{\sigma_a^{SP} \Phi} \left[1 - \exp \left(- \sigma_a^{SP} \Phi \, \Delta t \right) \right] + N_t^{SP} \exp \left(- \sigma^{SP} \Phi \, \Delta t \right) \tag{14}$$

where $\delta^{SP} = 1$ if material SP is a capture product (e.g., (n,γ)) of the preceding material (SP - 1) and $\delta^{SP} = 0$ if it is not (see the section INPUT INSTRUCTIONS). For the fission product aggregates (VID = 13), $\delta^{SP} = 0$.

Burnable poisons: The concentrations of the nuclides considered as burnable poisons obey the simple analytic form

$$N^K_{t+\Delta t} = N^K_t \exp\left(- \sigma^K_a \Phi \Delta t\right) \tag{15}$$

Depletion cycle: These depletion equations may now be incorporated into a complete depletion program. Such a depletion program, coupled with the energy and space codes (e.g., GAM-GATHER and TDSN, refs. 6 to 8) enables a depletion cycle to be performed. A typical depletion cycle proceeds according to the flow diagram in figure 1.

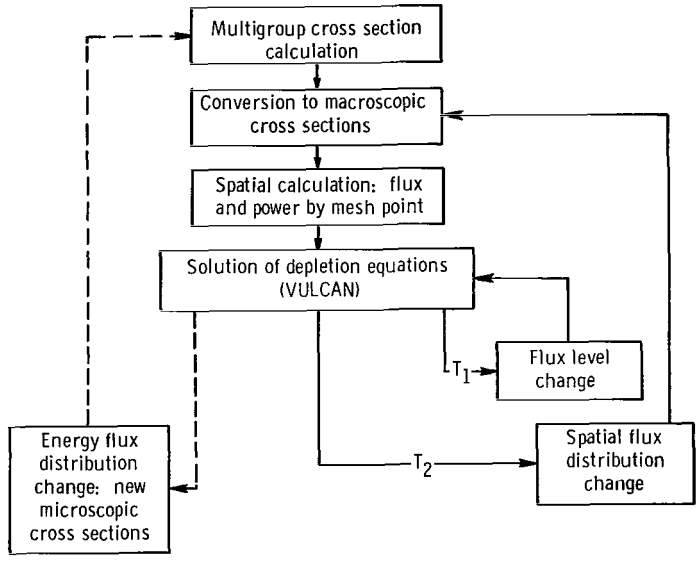


Figure 1. - VULCAN flow diagram.

Before entering the depletion program, two time intervals must be chosen. The shortest time interval T_1 will be that between renormalizations of the flux level (within VULCAN) to a given power. The other time interval T_2 will be that between recalculations to the spatial flux distribution. VULCAN will treat the T_2/T_1 normalizations sequentially as a single problem.

SAMPLE PROBLEM

This sample problem serves as a check on the solution of the depletion equations insofar as the original solution is concerned and as a device for displaying certain options of the program. To illustrate the flexibility of VULCAN, a problem previously solved by the depletion program CANDLE (ref. 2) but found in reference 9, was chosen as the sample problem. The problem has 2 energy groups and 14 mesh intervals comprising three regions in a slab geometry, and the depletion is over a single time step. Although the input to VULCAN illustrates the use of several options, only the output pertinent to

the sample problem in reference 9 is given. The input information (e.g., cross sections and fluxes) listed in reference 9 was supplied to VULCAN. The first flux normalization factor in the VULCAN output (0.999738 E-09) indicates the degree to which this input was duplicated. For exact duplication of the variables controlling the power, this factor should be 1.0 E-09, with the exponent indicating the transition of flux level as used in the VULCAN input to neutrons per barn per second. The optional cross section input format used illustrates that particular option. Subroutine TABLE, as listed, contains current data; however, the following parameters assumed these values in the sample problem: THERNU(5) = 2.46, THERNU(9) = 2.88, THERNU(11) = 3.00, FIWATT = 3.15×10^{10}, DECAY(14) = 2.11×10^{-5}, DECAY(16) = 2.88×10^{-5}, and DECAY(17) = 3.85×10^{-6}.

A comparative list of atom densities at the end of the depletion interval is given in table I. In reference 9, however, only region-averaged atom densities were printed out. Although VULCAN does not normally yield atom densities averaged over the original regions, an appropriate value of the averaging criterion ϵ (see the section Subroutine OUTPUT) will yield these.

TABLE I. - COMPARATIVE ATOM DENSITIES

Nuclide	Material 1		Material 2	
	CANDLE (ref. 9)	VULCAN	CANDLE (ref. 9)	VULCAN
U^{235}	0.138761-3	0.138763-3	0.485625-4	0.485632-4
U^{236}	.500194-6	.500687-6	.937653-7	----------
Pm^{149}	.261273-7	.261213-7	.563627-8	.561020-8
I^{135}	.297741-7	.297672-7	.642296-8	.639333-8
Sm^{149}	.505137-8	.505096-8	.136152-8	.135575-8
Xe^{135}	.122126-8	.122129-8	.451111-9	.449453-9
FP2	.258698-5	.258238-5	.558072-6	.554921-6
U^{238}	----------	---------	.677028-2	.677051-2
Pu^{239}	----------	---------	.655909-6	.428466-6
Pu^{240}	----------	---------	.349750-8	.225741-8
Pu^{241}	----------	---------	.227263-10	.145501-10

The discrepancy in Pu^{239}, Pu^{240}, and Pu^{241} may be attributed primarily to the absence of a resonance correction to the smooth cross sections of U^{238} and Pu^{239}; VULCAN assumes the cross sections directly reflect any resonance structure.

Input

```
1      VULCAN TEST PROBLEM    FROM WAPD-TM-95 (WAPD-TM-221) (CANDLE) REF 9
         2          1          18          3          2          3          22
         6         14           2          0
         1          2           4          5          2          2
         1          2           1          0          0          1
6495.33    1.0         1.0         50.0
.01          .1          .5
    1    23             HYD
    2    24             OXY
    3     5            1U-235
    4     7            1U-238
    5     6             U-236
    6    17             PM149
    7    16             I-135
    8    15             SM149
    9    14             XE135
   10    13             FP2
   11    21    15       2ND25
   12    19             B10 1
   13    20             B10 2
   14     9            1PU239
   15    10             PU240
   16    11            1PU241
   17    18             SPMAT
   18    22    15       XFIS2
    1 2.54             1
    1 7.62             1
    1 12.7             2
    4 35.9             2
    1 38.1             2
    6 68.1             3
       13 1.0          1.0         1.0         1.0
       14 .003         .003        .003        .003
       15 .0           .0          .0          .0
       16 .06          .06         .06         .06
       17 .014         .014        .014        .014
1.0
1.0
1.0
1.0
1.0
1.0
(36X,2F12.8/)
HYDROGEN
                                    .00444
                                    .2151
OXYGEN
                                    .014


U235
                                    11.9416     8.8224
                                    418.2       872.32
U-238
                                    .36457      .12498
                                    1.79        0.
U-236
                                    .0          .0
                                    3.9         .0
PM-149
                                    0.
                                    0.
I-135
                                    0.
                                    0.
```

```
SM-149
                                0.
                                50000.
XE-135
                                0.
                                2700000.
FP2
                                0.
                                65.
2ND25
                                12.1801         9.03777
                                418.2           872.32
B10 1
                                60.
                                2470.
B10 2
                                60.
                                2470.
PU239
                                0.              0.
                                987.            1874.9
PU240
                                0.              0.
                                373.            0.
PU241
                                0.              0.
                                1080.           2415.
SPMAT
                                60.
                                2470.
XFIS2
                                11.9416
                                418.2
        7           1           2           3          12          13          17
       18
.02738     .01369     .00014185 .001        .001        .001        .00014185
        4           1           2           4          11
.023643    .025464    .006771    .00004915
        2           1           2
.051714    .025857
1.00431    .922701    .735115    .528068    .369309    .252466    .16132
.103651    .0646481   .0314333   .0152257   .00725616  .0032126   .00090724
.268374    .263683    .246155    .202483    .147527    .104308    .0801488
.0830485   .096636    .085596    .0556303   .0315068   .0154594   .00458762
        2
1.25       1.25
        3
        5          19          20
1.0        1.0
.99        .80
.99        .80
        5           1           2           3          12          13
.02738     .01369     .00014185 .001        .001
        4           1           2           4          11
.023643    .025464    .006771    .00004915
        2           1           2
.051714    .025857
        3
        5          19          20
1.0        1.0
.99        .80
.99        .80
```

Output

```
                    * MEMORY MAP *

SYSTEM                                  00000 THRU  02717
FILE BLOCK ORIGIN                       02720
FILES       1.      UNIT06              (NO BUFF POOL ATTACHED)
            2.      UNIT05              (NO BUFF POOL ATTACHED)
PRE-EXECUTION INITIALIZATION            02750
CALL ON OBJECT PROGRAM                  02757
OBJECT PROGRAM                          02764 THRU  76056

      DECK  ORIGIN      CONTROL SECTIONS  (/NAME/=NON D LENGTH, (LOC)=DELETED, *=NOT REFERENCED)

  1. VULCAN  02764      /SET1  / 02765    /SET2  / 23615    /SET3  / 37445    /SET4  / 42235    /SET5  / 42603
                        /SET6  / 43461    /SET7  / 43471    /SET8  / 43477    /SET9  / 43507    /SET10 / 43513
                        /SET11 / 43521     ......  51430 *
  2. TTABLE  51454      /SET1  /(02765)   /SET2  /(23615)   /SET3  /(37445)   /SET4  /(42235)   /SET5  /(42603)
                         TABLE   51736
  3. TXENON  51764      /SET1  /(02765)   /SET2  /(23615)   /SET3  /(37445)   /SET4  /(42235)   /SET5  /(42603)
                        /SET6  /(43461)   /SET7  /(43471)   /SET8  /(43477)   /SET10 /(43513)    XENON   52470
  4. POUT    52525      /SET1  /(02765)   /SET2  /(23615)   /SET3  /(37445)   /SET14 /(42235)   /SET5  /(42603)
                        /SET6  /(43461)   /SET8  /(43477)    OUTPUT  54603
  5. FADE    54623      /SET1  /(02765)   /SET2  /(23615)   /SET3  /(37445)   /SET4  /(42235)   /SET5  /(42603)
                        /SET6  /(43461)   /SET7  /(43471)   /SET8  /(43477)   /SET9  /(43507)   /SET10 /(43513)
                         FISEQ1  56026     FISEQ2  56031
  6. ABFLUX  56034      /SET1  /(02765)   /SET2  /(23615)   /SET3  /(37445)   /SET4  /(42235)   /SET5  /(42603)
                        /SET6  /(43461)   /SET9  /(43507)    ABSPHI  56464
  7. SELSH   56502      /SET1  /(02765)   /SET2  /(23615)   /SET3  /(37445)   /SET4  /(42235)   /SET5  /(42603)
                        /SET11 /(43521)    SSF     56736
  8. BURNT   56764      /SET1  /(02765)   /SET2  /(23615)   /SET3  /(37445)   /SET14 /(42235)   /SET5  /(42603)
                        /SET6  /(43461)   /SET7  /(43471)   /SET8  /(43477)   /SET9  /(43507)   /SET10 /(43513)
                        /SET11 /(43521)    BURNUP  65766
  9. .LXCON  66006       .LXSTR  66006     .LXSTP  66011     .LXOUT  66033 *   .LXERR  66042 *   .LXCAL  66045
                         .LXRTN  66045 *   IBEXIT  66045     .DBCLS  66225 *   .LXARG  66314 *   .LO     66323 *
                         .CLSE   66331 *   .LFBL   66332 *   .LUNB   66333 *   .DFOUT  66334
 10. .LXSL   66340       .LXSEL  66340     .LXSL1  66341     .LXTST  66344     .LXOVL  66404     .LXMOD  66446
                         .LXIND  66472     .LXDIS  66475 *   .LXFLG  66476 *   .LTCH   66477
 11. .FPTRP  66505       .FPPT.  66505 *   .FXEM.  66507     .FXEM   66507 *   .ETAG   66736 *   .FMCRT  67052 *
                         .GOTO   67065 *   .FXOUT  67071 *   .FXARG  67103 *   .EXIT.  67105 *   EXIT    67105 *
                         .OVCHK  67112 *   OVFLOW  67113 *   SYSONE  67140     .NOP    67141     .BLANK  67154
 12. .ERAS.  67171       E.1     67171     E.2     67172     E.3     67173     E.4     67174
 13. .XCC.   67175       CC.1    67175     CC.2    67176     CC.3    67177     CC.4    67200
 14. FCNV    67201       .FCON.  67201     .DDPRE  67211 *   .FCNV.  67217     .ENDFS  67230     .CNVSW  67232
                         .FDX1   67236     .FDX2   67237     .DBC    67241     .DBC14  67304 *   .STOP4  67307 *
                         .DBC20  67323     .DBC10  67337     .DBC99  67352 *   .DDSW   67375 *   .FIXSW  67404
                         .DXPSE  67420 *   .DDZET  67525 *   .IC10   67566 *   .STOPJ  67603 *   .FCOUT  67613 *
                         .FCARG  67621 *   .ALCOD  67623 *   .ANPT   67634     .ONPT   67651     .LNTP   67725
                         .ADUT   67764     .DOUT   67776     .LOUT   70025     .GOUT   70035     .TGOUT  70044 *
                         .FLT    70144     .FXFL1  70301     .FXD    70305     .FXFL2  70311     .FXFL3  70315
                         .INTG   70321     .TOPAC  70337     .WIDTH  70343     .FPACK  70350     .TEST   70351
                         .DDSF   70402 *   .KOUNT  70403     .LIST   70406     .DONE   70415     .OUTBF  70551
                         .CHAR   71003     .DEXP   71012 *   .TEN    71016 *   .FBD8F  71020     .DATUM  71026 *
                         .WORD   71041     .MQD    71042     .PEX    71043     .FEXP   71044     .DIG    71045
 15. FIOH    71060       .FIOH.  71060     .DDIO   71105 *   .DDLET  71243 *   .DCPT1  71446 *   .FXPT   71644 *
                         .FFIL.  71675     .DDFIN  71713 *   .FRTN.  71722     .DDRTN  71726 *
 16. FIOS.   72030       ..FIOS  72030     .FCLS   72052 *   ..FIOC  72077     ..FSEL  72120     ..FBCK  72137 *
                         ..FTCK  72141     .IOFF   72225 *   ..XEM   72233 *   ..FCHK  72250 *
 17. FRDD.   72353       ..FRDD  72353
 18. FWRD.   72400       ..FWRD  72400
 19. FBCD.   72426       ..FBCD  72426     ..FBCW  72430     ..FBCB  72441
 20. UNIT06  72471       ..UN06  72471
 21. UN05    72472       .UN05.  72472
 22. UN06    72473       .UN06.  72473
 23. FPUN    72474       .FPUN.  72474
 24. FLOG    72531       ALOG10  72531 *   ALOG    72532
 25. FXPF    72706       EXP     72706
 26. .IOE.   73011
 27. .IOE56  73023
 28. .RWDOE  73031
 29. .BCREA  73051       BCREAD  73051     BCREAD (73051)
 30. .BCRWD  73131       ..BCRD  73131     ..BCWD  73133 *   ..BRDB  73145
 31. FXP2    73203       .XP2.   73203
 32. PISTUG  73276      /JOLO  / 73277     PISTUG (73276)
 33. PLOTXY  74102      /JOLO  /(73277)    PLOTXY (74102)
 34. KHAR    75761       KHAR    (75761)
 35. .LOGE.  76033       .LOGER  76033
 36. .TLEX.  76041       .TLEXP  76041
 37. .XEXP.  76045       .NGDEF  76045     .XEXP   76051 *   .ZUDEF  76054

UNUSED CORE                             76057 THRU  77777

  BEGIN EXECUTION.
```

VULCAN TEST PROBLEM FROM WAPD-TM-95 (WAPD-TM-221) (CANDLE) REF 9

NG	NFG	NISOT	NMAT	NTINC	NFRACT	KCELL
2	1	18	3	2	3	22

NZONR	NRM	MOROUT	NUF
6	14	2	0

NSPMAT	NBPOI	NFIS	NYDNUC	NONDPL	NFIRPT
1	2	4	5	2	2

KGEO	KFLUX	KSSF	KHAIN	KFAST	KFORM
1	2	1	0	0	1

POWER IN WATTS	FIRST DISTANCE (CM)	SECOND DISTANCE (CM)	TIME INCREMENT (HOURS)	XENON REMOVAL PROBABILITY	IODINE REMOVAL PROBABILITY	DIFFER
.64953E 04	1.00000	1.00000	50.00	-0.	-0.	-0.

SEQUENTIAL ID	VULCAN ID		NRPT	ISOTOPE LABEL
1	23		-0	HYD
2	24		-0	OXY
3	5	Y	-0	U-235
4	7	Y	-0	U-238
5	6		-0	U-236
6	17		-0	PM149
7	16		-0	I-135
8	15		-0	SM149
9	14		-0	XE135
10	13		-0	FP2
11	21		15	2ND25
12	19		-0	B10 1
13	20		-0	B10 2
14	9	Y	-0	PU239
15	10		-0	PU240
16	11	Y	-0	PU241
17	18		-0	SPMAT
18	22		15	XFIS2

NMIR(I)	RAR(I)	MIDRZ(I)-MAP
1	2.5400	1
1	7.6200	1
1	12.7000	2
4	35.9000	2 2 2 2
1	38.1000	2
6	68.1000	3 3 3 3 3 3

MESH VOLUMES

0.254000E 01 0.508000E 01 0.508000E 01 0.580000E 01 0.580000E 01 0.580000E 01 0.580000E 01 0.220000E 01
0.500000E 01 0.500000E 01 0.500000E 01 0.500000E 01 0.500000E 01 0.500000E 01 0.681000E 02

ZONE VOLUMES

0.254000E 01 0.508000E 01 0.508000E 01 0.232000E 02 0.220000E 01 0.300000E 02

FISSION PRODUCT	YIELD FROM 5 (U-235)	YIELD FROM 7 (U-238)	YIELD FROM 9 (PU239)	YIELD FROM 11 (PU241)	YIELD FROM (	YIELD	YIELD	YIELD	YIELD	YIELD
17 (PM149)	0.01400	0.01400	0.01400	0.01400						
16 (I-135)	0.06000	0.06000	0.06000	0.06000						
15 (SM149)	0.	0.	0.	0.						
14 (XE135)	0.00300	0.00300	0.00300	0.00300						
13 (FP2)	1.00000	1.00000	1.00000	1.00000						
18 (SPMAT)	0.	0.	0.	0.						

GROUP	NU FOR VID 1	NU FOR VID 2	NU FOR VID 3	NU FOR VID 4	NU FOR VID 5	NU FOR VID 6	NU FOR VID 7	NU FOR VID 8	NU FOR VID 9	NU FOR VID 10	NU FOR VID 11	NU FOR VID 12
1	0.	0.	0.	0.	1.000	1.000	1.000	0.	1.000	1.000	1.000	0.
T	2.600	0.	2.503	0.	2.460	0.	2.600	0.	2.880	0.	3.000	0.

```
SEQUENTIAL ID =  1   VULCAN ID = 23

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.444000E-02  0.215100E 00


SEQUENTIAL ID =  2   VULCAN ID = 24

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.140000E-01 -0.


SEQUENTIAL ID =  3   VULCAN ID =  5

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.119416E 02  0.418200E 03
NU*FISSION BY GROUP (HIGH TO LOW)
 0.882240E 01  0.872320E 03
  FISSION BY GROUP (HIGH TO LOW)
 0.882240E 01  0.354602E 03


SEQUENTIAL ID =  4   VULCAN ID =  7

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.364570E 00  0.179000E 01
NU*FISSION BY GROUP (HIGH TO LOW)
 0.124980E 00  0.
  FISSION BY GROUP (HIGH TO LOW)
 0.124980E 00  0.


SEQUENTIAL ID =  5   VULCAN ID =  6

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.            0.390000E 01
NU*FISSION BY GROUP (HIGH TO LOW)
 0.            0.
  FISSION BY GROUP (HIGH TO LOW)
 0.            0.


SEQUENTIAL ID =  6   VULCAN ID = 17

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.            0.


SEQUENTIAL ID =  7   VULCAN ID = 16

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.            0.


SEQUENTIAL ID =  8   VULCAN ID = 15

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.            0.500000E 05


SEQUENTIAL ID =  9   VULCAN ID = 14

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.            0.270000E 07


SEQUENTIAL ID = 10   VULCAN ID = 13

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.            0.650000E 02


SEQUENTIAL ID = 11   VULCAN ID = 21

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.121801E 02  0.418200E 03
NU*FISSION BY GROUP (HIGH TO LOW)
 0.903777E 01  0.872320E 03
  FISSION BY GROUP (HIGH TO LOW)
 0.903777E 01  0.354602E 03


SEQUENTIAL ID = 12   VULCAN ID = 19

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.600000E 02  0.247000E 04


SEQUENTIAL ID = 13   VULCAN ID = 20

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.600000E 02  0.247000E 04


SEQUENTIAL ID = 14   VULCAN ID =  9

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.            0.987000E 03
NU*FISSION BY GROUP (HIGH TO LOW)
 0.            0.187490E 04
  FISSION BY GROUP (HIGH TO LOW)
 0.            0.651007E 03
```

```
SEQUENTIAL ID = 15   VULCAN ID = 10

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.              0.373000E 03
NU*FISSION BY GROUP (HIGH TO LOW)
 0.              0.
  FISSION BY GROUP (HIGH TO LOW)
 0.              0.


SEQUENTIAL ID = 16   VULCAN ID = 11

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.              0.108000E 04
NU*FISSION BY GROUP (HIGH TO LOW)
 0.              0.241500E 04
  FISSION BY GROUP (HIGH TO LOW)
 0.              0.805000E 03


SEQUENTIAL ID = 17   VULCAN ID = 18

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.600000E 02  0.247000E 04


SEQUENTIAL ID = 18   VULCAN ID = 22

 ABSORPTION BY GROUP (HIGH TO LOW)
 0.119416E 02  0.418200E 03
NU*FISSION BY GROUP (HIGH TO LOW)
-0.             -0.
  FISSION BY GROUP (HIGH TO LOW)
-0.             -0.
```

VULCAN ID	ISOTOPE LABEL	MATERIAL 1	MATERIAL 2	MATERIAL 3	MATERIAL 0	MATERIAL 0	MATERIAL 0	MATERIAL 0
23	HYD	0.27380E-01	0.23643E-01	0.51714E-01				
24	OXY	0.13690E-01	0.25464E-01	0.25857E-01				
5	U-235	0.14185E-03	0.	0.				
7	U-238	0.	0.67710E-02	0.				
6	U-236	0.	0.	0.				
17	PM149	0.	0.	0.				
16	I-135	0.	0.	0.				
15	SM149	0.	0.	0.				
14	XE135	0.	0.	0.				
13	FP2	0.	0.	0.				
21	2N025	0.	0.49150E-04	0.				
19	B1C 1	0.10000E-02	0.	0.				
20	B10 2	0.10000E-02	0.	0.				
9	PU239	0.	0.	0.				
10	PU240	0.	0.	0.				
11	PU241	0.	0.	0.				
18	SPMAT	0.10000E-02	0.	0.				
22	XFIS2	0.14185E-03	0.	0.				

```
FLUXES BY GROUP AND MESH POINT
     FOR THE BASIC CELL
  GROUP   1
 0.100431E 01  0.9227C1E 00  0.735115E 00  0.528068E 00  0.369309E 00  0.252466E 00  0.161320E 00  0.103651E 00
 0.646481E-01  0.314333E-01  0.152257E-01  0.725615E-02  0.321260E-02  0.907240E-03
  GROUP   2
 0.268374E 00  0.2636E3E 00  0.246155E 00  0.202483E 00  0.147527E 00  0.1043C8E 00  0.801488E-01  0.830485E-01
 0.966360E-01  0.855960E-01  0.556303E-01  0.315063E-01  0.154594E-01  0.458762E-02
```

****

FOR THE START OF TIME INTERVAL NUMBER 1 OF 2

FLUX NORMALIZATION FACTOR 0.999738E-09 CONVERTS TO ABSOLUTE FLUX IN NEUTRONS/BARN*SEC
FOR A POWER LEVEL OF 0.649533E 04 WATTS

CELL NUMBER 1 OF 2

****

```
 THE POWER FOR EACH CORE REGION
 0.125000E 01  0.125000E 01

 THESE ARE THE RADIAL POWER FACTORS
 0.100000E 01  0.100000E 01

    THE POWER FACTOR FOR THIS CELL IS  1.0000000
FLUXES BY GROUP AND MESH POINT
     FOR CELL NUMBER   1
  GROUP   1
 0.100405E-08  0.922459E-09  0.734922E-09  0.527930E-09  0.369212E-09  0.252400E-09  0.161278E-09  0.103624E-09
 0.646311E-10  0.314251E-10  0.152217E-10  0.725425E-11  0.321176E-11  0.907002E-12
  GROUP   2
 0.268304E-09  0.263614E-09  0.246090E-09  0.202430E-09  0.147488E-09  0.104281E-09  0.801278E-10  0.830267E-10
 0.966107E-10  0.855736E-10  0.556157E-10  0.314985E-10  0.154553E-10  0.458642E-11

    SELF-SHIELDING FACTORS USED ARE (HIGH TO LOW ENERGY)

  VULCAN ID =  5     1.000000  1.000000

  VULCAN ID = 19     0.990000  0.800000

  VULCAN ID = 20     0.990000  0.800000
```

** ** ** ** ** ** ** ** ** ** ** MESH INTERVAL NUMBER 1 ** ** ** ** ** ** ** ** ** ** **

FISSION PRODUCT CONCENTRATIONS AT VARIOUS FRACTIONS OF THE TIME STEP

FRACTION	XE135	SM149	I 135	PM149
0.01	0.702148E-10	0.126074E-11	0.153549E-08	0.366376E-09
0.10	0.505588E-09	0.115001E-09	0.122953E-07	0.355198E-08
0.50	0.114142E-08	0.195720E-08	0.281185E-07	0.155357E-07
EQUILIBRIUM	0.123286E-08	0.152252E-07	0.303941E-07	0.530516E-07

TIME AFTER SHUTDOWN UNTIL MAXIMUM XENON CONCENTRATION IS REACHED = 10.83 HOURS
THE XENON-135 CONCENTRATION (PEAK) AT THIS TIME IS 0.134919E-07

ISOTOPE DESCR.	N(T)	N(T+1)	N(T+1)/N(T)	POWER FRACTION	POISON FACTOR
HYD - 1	0.273800E-01	0.273800E-01	0.100000E 01	0.	0.494032E-01
OXY - 2	0.136900E-01	0.136900E-01	0.100000E 01	0.	0.558504E-02
U-235- 3	0.141850E-03	0.138714E-03	0.977892E 00	0.100000E 01	0.499992E 00
U-238- 4	0.	0.	0.	0.	0.
U-236- 5	0.	0.509904E-06	0.	0.	0.154853E-04
PM149- 6	0.	0.265219E-07	0.	0.	0.
I-135- 7	0.	0.302238E-07	0.	0.	0.
SM149- 8	0.	0.509474E-08	0.	0.	0.198363E-02
XE135- 9	0.	0.122601E-08	0.	0.	0.257766E-01
FP2 -10	0.	0.262193E-05	0.	0.	0.132710E-02
2ND25-11	0.	0.	0.	0.	0.
B10 1-12	0.100000E-02	0.899276E-03	0.899276E 00	0.	0.153938E 02
B10 2-13	0.100000E-02	0.899276E-03	0.899276E 00	0.	0.153938E 02
PU239-14	0.	0.	0.	0.	0.
PU240-15	0.	0.	0.	0.	0.
PU241-16	0.	0.	0.	0.	0.
SPMAT-17	0.100000E-02	0.877980E-03	0.877980E 00	0.	0.184219E 02
XFIS2-18	0.141850E-03	0.138714E-03	0.977892E 00	-0.	0.499992E 00

** ** ** ** ** ** ** ** ** ** ** MESH INTERVAL NUMBER 2 ** ** ** ** ** ** ** ** ** ** **

FISSION PRODUCT CONCENTRATIONS AT VARIOUS FRACTIONS OF THE TIME STEP

FRACTION	XE135	SM149	I 135	PM149
0.01	0.691652E-10	0.123237E-11	0.150070E-08	0.358076E-09
0.10	0.502168E-09	0.112548E-09	0.120167E-07	0.347150E-08
0.50	0.113477E-08	0.192420E-08	0.274815E-07	0.151837E-07
EQUILIBRIUM	0.122574E-08	0.151450E-07	0.297055E-07	0.518496E-07

TIME AFTER SHUTDOWN UNTIL MAXIMUM XENON CONCENTRATION IS REACHED = 10.83 HOURS
THE XENON-135 CONCENTRATION (PEAK) AT THIS TIME IS 0.131954E-07

ISOTOPE DESCR.	N(T)	N(T+1)	N(T+1)/N(T)	POWER FRACTION	POISON FACTOR
HYD - 1	0.273800E-01	0.273800E-01	0.100000E 01	0.	0.494573E-01
OXY - 2	0.136900E-01	0.136900E-01	0.100000E 01	0.	0.525265E-02
U-235- 3	0.141850E-03	0.138787E-03	0.978409E 00	0.100000E 01	0.499992E 00
U-238- 4	0.	0.	0.	0.	0.
U-236- 5	0.	0.496078E-06	0.	0.	0.151524E-04
PM149- 6	0.	0.259210E-07	0.	0.	0.
I-135- 7	0.	0.295390E-07	0.	0.	0.
SM149- 8	0.	0.502907E-08	0.	0.	0.196936E-02
XE135- 9	0.	0.121893E-08	0.	0.	0.257757E-01
FP2 -10	0.	0.256260E-05	0.	0.	0.130455E-02
2ND25-11	0.	0.	0.	0.	0.
B10 1-12	0.100000E-02	0.901563E-03	0.901563E 00	0.	0.154201E 02
B10 2-13	0.100000E-02	0.901563E-03	0.901563E 00	0.	0.154201E 02
PU239-14	0.	0.	0.	0.	0.
PU240-15	0.	0.	0.	0.	0.
PU241-16	0.	0.	0.	0.	0.
SPMAT-17	0.100000E-02	0.880588E-03	0.880588E 00	0.	0.184828E 02
XFIS2-18	0.141850E-03	0.138787E-03	0.978409E 00	-0.	0.499992E 00

** ** ** ** ** ** ** ** ** ** ** MESH INTERVAL NUMBER 3 ** ** ** ** ** ** ** ** ** ** **

FISSION PRODUCT CONCENTRATIONS AT VARIOUS FRACTIONS OF THE TIME STEP

FRACTION	XE135	SM149	I 135	PM149
0.01	0.262346E-10	0.454001E-12	0.552582E-09	0.131849E-09
0.10	0.196862E-09	0.416535E-10	0.442475E-08	0.127826E-08
0.50	0.446576E-09	0.724495E-09	0.101191E-07	0.559089E-08
EQUILIBRIUM	0.482488E-09	0.597372E-08	0.109381E-07	0.190919E-07

TIME AFTER SHUTDOWN UNTIL MAXIMUM XENON CONCENTRATION IS REACHED = 10.80 HOURS
THE XENON-135 CONCENTRATION (PEAK) AT THIS TIME IS 0.487247E-08

ISOTOPE DESCR.	N(T)	N(T+1)	N(T+1)/N(T)	POWER FRACTION	POISON FACTOR
HYD - 1	0.236430E-01	0.236430E-01	0.100000E 01	0.	0.128201E 00
OXY - 2	0.254640E-01	0.254640E-01	0.100000E 01	0.	0.252797E-01
U-235- 3	0.	0.	0.	0.	0.
U-238- 4	0.677100E-02	0.677014E-02	0.999872E 00	0.118150E 00	0.462777E 00
U-236- 5	0.	0.	0.	0.	0.
PM149- 6	0.	0.954454E-08	0.	0.	0.
I-135- 7	0.	0.108767E-07	0.	0.	0.
SM149- 8	0.	0.192306E-08	0.	0.	0.228314E-02
XE135- 9	0.	0.479799E-09	0.	0.	0.307605E-01
FP2 -10	0.	0.943688E-06	0.	0.	0.145650E-02
2ND25-11	0.491500E-04	0.481702E-04	0.980065E 00	0.859464E 00	0.519940E 00
B10 1-12	0.	0.	0.	0.	0.
B10 2-13	0.	0.	0.	0.	0.
PU239-14	0.	0.735355E-06	0.	0.223838E-01	0.172339E-01
PU240-15	0.	0.542739E-08	0.	0.	0.480696E-04
PU241-16	0.	0.437833E-10	0.	0.164799E-05	0.112280E-05
SPMAT-17	0.	0.	0.	0.	0.
XFIS2-18	0.	0.	0.	-0.	0.

** ** ** ** ** ** ** ** ** ** ** MESH INTERVAL NUMBER 4 ** ** ** ** ** ** ** ** ** ** **

FISSION PRODUCT CONCENTRATIONS AT VARIOUS FRACTIONS OF THE TIME STEP

FRACTION	XE135	SM149	I 135	PM149
0.01	0.227396E-10	0.365149E-12	0.443954E-09	0.105908E-09
0.10	0.188422E-09	0.338872E-10	0.355419E-08	0.102677E-08
0.50	0.432886E-09	0.615993E-09	0.812822E-08	0.449090E-08
EQUILIBRIUM	0.468043E-09	0.583334E-08	0.878603E-08	0.153356E-07

TIME AFTER SHUTDOWN UNTIL MAXIMUM XENON CONCENTRATION IS REACHED = 10.71 HOURS
THE XENON-135 CONCENTRATION (PEAK) AT THIS TIME IS 0.394938E-08

ISOTOPE DESCR.	N(T)	N(T+1)	N(T+1)/N(T)	POWER FRACTION	POISON FACTOR
HYD - 1	0.236430E-01	0.236430E-01	0.100000E 01	0.	0.131065E 00
OXY - 2	0.254640E-01	0.254640E-01	0.100000E 01	0.	0.227367E-01
U-235- 3	0.	0.	0.	0.	0.
U-238- 4	0.677100E-02	0.677032E-02	0.999900E 00	0.105724E 00	0.453791E 00
U-236- 5	0.	0.	0.	0.	0.
PM149- 6	0.	0.766668E-08	0.	0.	0.
I-135- 7	0.	0.873678E-08	0.	0.	0.
SM149- 8	0.	0.170460E-08	0.	0.	0.208432E-02
XE135- 9	0.	0.465411E-09	0.	0.	0.307306E-01
FP2 -10	0.	0.758215E-06	0.	0.	0.120525E-02
2ND25-11	0.491500E-04	0.483507E-04	0.983738E 00	0.876022E 00	0.532051E 00
B10 1-12	0.	0.	0.	0.	0.
B10 2-13	0.	0.	0.	0.	0.
PU239-14	0.	0.585230E-06	0.	0.182531E-01	0.141259E-01
PU240-15	0.	0.355822E-08	0.	0.	0.324573E-04
PU241-16	0.	0.237101E-10	0.	0.914434E-06	0.626222E-06
SPMAT-17	0.	0.	0.	0.	0.
XFIS2-18	0.	0.	0.	-0.	0.

** ** ** ** ** ** ** ** ** ** ** MESH INTERVAL NUMBER 5 ** ** ** ** ** ** ** ** ** ** **

FISSION PRODUCT CONCENTRATIONS AT VARIOUS FRACTIONS OF THE TIME STEP

FRACTION	XE135	SM149	I 135	PM149
0.01	0.181886E-10	0.264636E-12	0.321126E-09	0.766226E-10
0.10	0.179272E-09	0.249158E-10	0.257139E-08	0.742847E-09
0.50	0.423315E-09	0.480016E-09	0.588060E-08	0.324908E-08
EQUILIBRIUM	0.458413E-09	0.579243E-08	0.635652E-08	0.110950E-07

TIME AFTER SHUTDOWN UNTIL MAXIMUM XENON CONCENTRATION IS REACHED = 10.53 HOURS
THE XENON-135 CONCENTRATION (PEAK) AT THIS TIME IS 0.291075E-08

ISOTOPE DESCR.	N(T)	N(T+1)	N(T+1)/N(T)	POWER FRACTION	POISON FACTOR
HYD - 1	0.236430E-01	0.236430E-01	0.100000E 01	0.	0.132028E 00
OXY - 2	0.254640E-01	0.254640E-01	0.100000E 01	0.	0.220301E-01
U-235- 3	0.	0.	0.	0.	0.
U-238- 4	0.677100E-02	0.677051E-02	0.999928E 00	0.102256E 00	0.4517C3E 00
U-236- 5	0.	0.	0.	0.	0.
PM149- 6	0.	0.554669E-08	0.	0.	0.
I-135- 7	0.	0.632088E-08	0.	0.	0.
SM149- 8	0.	0.140941E-08	0.	0.	0.173961E-02
XE135- 9	0.	0.455785E-09	0.	0.	0.303786E-01
FP2 -10	0.	0.548729E-06	0.	0.	0.880470E-03
2ND25-11	0.491500E-04	0.485680E-04	0.988159E 00	0.884419E 00	0.537949E 00
B10 1-12	0.	0.	0.	0.	0.
B10 2-13	0.	0.	0.	0.	0.
PU239-14	0.	0.424005E-06	0.	0.133249E-01	0.103307E-01
PU240-15	0.	0.188173E-08	0.	0.	0.173264E-04
PU241-16	0.	0.918375E-11	0.	0.356880E-06	0.244843E-06
SPMAT-17	0.	0.	0.	0.	0.
XFIS2-18	0.	0.	0.	-0.	0.

** ** ** ** ** ** ** ** ** ** ** MESH INTERVAL NUMBER 6 ** ** ** ** ** ** ** ** ** ** **

FISSION PRODUCT CONCENTRATIONS AT VARIOUS FRACTIONS OF THE TIME STEP

FRACTION	XE135	SM149	I 135	PM149
0.01	0.138902E-10	0.186272E-12	0.225782E-09	0.538729E-10
0.10	0.166770E-09	0.177436E-10	0.180793E-08	0.522292E-09
0.50	0.411354E-09	0.358588E-09	0.413462E-08	0.228441E-08
EQUILIBRIUM	0.446543E-09	0.576008E-08	0.446923E-08	0.780084E-08

TIME AFTER SHUTDOWN UNTIL MAXIMUM XENON CONCENTRATION IS REACHED = 10.27 HOURS
THE XENON-135 CONCENTRATION (PEAK) AT THIS TIME IS 0.210290E-08

ISOTOPE DESCR.	N(T)	N(T+1)	N(T+1)/N(T)	POWER FRACTION	POISON FACTOR
HYD - 1	0.236430E-01	0.236430E-01	0.100000E 01	0.	0.132801E 00
OXY - 2	0.254640E-01	0.254640E-01	0.100000E 01	0.	0.214598E-01
U-235- 3	0.	0.	0.	0.	0.
U-238- 4	0.677100E-02	0.677066E-02	0.999950E 00	0.994652E-01	0.4500C6E 00
U-236- 5	0.	0.	0.	0.	0.
PM149- 6	0.	0.389985E-08	0.	0.	0.
I-135- 7	0.	0.444418E-08	0.	0.	0.
SM149- 8	0.	0.110963E-08	0.	0.	0.137985E-02
XE135- 9	0.	0.443908E-09	0.	0.	0.298086E-01
FP2 -10	0.	0.385904E-06	0.	0.	0.623847E-03
2ND25-11	0.491500E-04	0.487387E-04	0.991632E 00	0.891100E 00	0.542660E 00
B10 1-12	0.	0.	0.	0.	0.
B10 2-13	0.	0.	0.	0.	0.
PU239-14	0.	0.298431E-06	0.	0.943504E-02	0.732565E-02
PU240-15	0.	0.937784E-09	0.	0.	0.869955E-05
PU241-16	0.	0.324948E-11	0.	0.127035E-06	0.872817E-07
SPMAT-17	0.	0.	0.	0.	0.
XFIS2-18	0.	0.	0.	-0.	0.

** ** ** ** ** ** ** ** ** ** ** MESH INTERVAL NUMBER 7 ** ** ** ** ** ** ** ** ** ** **

FISSION PRODUCT CONCENTRATIONS AT VARIOUS FRACTIONS OF THE TIME STEP

FRACTION	XE135	SM149	I 135	PM149
0.01	0.109043E-10	0.139640E-12	0.158999E-09	0.403241E-10
0.10	0.151570E-09	0.133770E-10	0.135324E-08	0.390937E-09
0.50	0.391463E-09	0.277898E-09	0.329478E-08	0.170989E-08
EQUILIBRIUM	0.426035E-09	0.561103E-08	0.334523E-08	0.583895E-08

TIME AFTER SHUTDOWN UNTIL MAXIMUM XENON CONCENTRATION IS REACHED = 10.02 HOURS
THE XENON-135 CONCENTRATION (PEAK) AT THIS TIME IS 0.161651E-08

ISOTOPE DESCR.	N(T)	N(T+1)	N(T+1)/N(T)	POWER FRACTION	POISON FACTOR
HYD - 1	0.236430E-01	0.236430E-01	0.100000E 01	0.	0.136074E 00
OXY - 2	0.254640E-01	0.254640E-01	0.100000E 01	0.	0.184331E-01
U-235- 3	0.	0.	0.	0.	0.
U-238- 4	0.677100E-02	0.677075E-02	0.999964E 00	0.849365E-01	0.438979E 00
U-236- 5	0.	0.	0.	0.	0.
PM149- 6	0.	0.291905E-08	0.	0.	0.
I-135- 7	0.	0.332648E-08	0.	0.	0.
SM149- 8	0.	0.887707E-09	0.	0.	0.114023E-02
XE135- 9	0.	0.423447E-09	0.	0.	0.293708E-01
FP2 -10	0.	0.288892E-06	0.	0.	0.482354E-03
2ND25-11	0.491500E-04	0.488372E-04	0.993635E 00	0.907911E 00	0.555429E 00
B10 1-12	0.	0.	0.	0.	0.
B10 2-13	0.	0.	0.	0.	0.
PU239-14	0.	0.220330E-06	0.	0.715295E-02	0.558656E-02
PU240-15	0.	0.532431E-09	0.	0.	0.510182E-05
PU241-16	0.	0.142090E-11	0.	0.570408E-07	0.394222E-07
SPMAT-17	0.	0.	0.	0.	0.
XFIS2-18	0.	0.	0.	-0.	0.

** ** ** ** ** ** ** ** ** ** ** MESH INTERVAL NUMBER 8 ** ** ** ** ** ** ** ** ** ** **

FISSION PRODUCT CONCENTRATIONS AT VARIOUS FRACTIONS OF THE TIME STEP

FRACTION	XE135	SM149	I 135	PM149
0.01	0.106788E-10	0.137407E-12	0.165463E-09	0.397189E-10
0.10	0.145596E-09	0.131649E-10	0.133293E-08	0.385070E-09
0.50	0.373428E-09	0.272579E-09	0.304833E-08	0.168423E-08
EQUILIBRIUM	0.406250E-09	0.533385E-08	0.329503E-08	0.575133E-08

TIME AFTER SHUTDOWN UNTIL MAXIMUM XENON CONCENTRATION IS REACHED = 10.05 HOURS
THE XENON-135 CONCENTRATION (PEAK) AT THIS TIME IS 0.158600E-08

ISOTOPE DESCR.	N(T)	N(T+1)	N(T+1)/N(T)	POWER FRACTION	POISON FACTOR
HYD - 1	0.236430E-01	0.236430E-01	0.100000E 01	0.	0.142640E 00
OXY - 2	0.254640E-01	0.254640E-01	0.100000E 01	0.	0.121660E-01
U-235- 3	0.	0.	0.	0.	0.
U-238- 4	0.677100E-02	0.677077E-02	0.999966E 00	0.554120E-01	0.415632E 00
U-236- 5	0.	0.	0.	0.	0.
PM149- 6	0.	0.287524E-08	0.	0.	0.
I-135- 7	0.	0.327656E-08	0.	0.	0.
SM149- 8	0.	0.867318E-09	0.	0.	0.118577E-02
XE135- 9	0.	0.403793E-09	0.	0.	0.298108E-01
FP2 -10	0.	0.284552E-06	0.	0.	0.505739E-03
2ND25-11	0.491500E-04	0.488327E-04	0.993544E 00	0.937421E 00	0.578700E 00
B10 1-12	0.	0.	0.	0.	0.
B10 2-13	0.	0.	0.	0.	0.
PU239-14	0.	0.209840E-06	0.	0.716734E-02	0.566315E-02
PU240-15	0.	0.525376E-09	0.	0.	0.535835E-05
PU241-16	0.	0.145240E-11	0.	0.613429E-07	0.428905E-07
SPMAT-17	0.	0.	0.	0.	0.
XFIS2-18	0.	0.	0.	-0.	0.

** ** ** ** ** ** ** ** ** ** MESH INTERVALS NUMBER 9 THRU 14 ** ** ** ** ** ** ** ** ** ** **

NO FISSIONABLE ISOTOPES OR CONSEQUENT FISSION PRODUCTS OCCUR IN MESH INTERVALS 9 THRU 14

ISOTOPE DESCR.	N(T)	N(T+1)	N(T+1)/N(T)	POWER FRACTION	POISON FACTOR
HYD - 1	0.517140E-01	0.517140E-01	0.100000F 01	0.	0.
OXY - 2	0.258570E-01	0.258570E-01	0.100000F 01	0.	0.
U-235- 3	0.	0.	0.	0.	0.
U-238- 4	0.	0.	0.	0.	0.
U-236- 5	0.	0.	0.	0.	0.
PM149- 6	0.	0.	0.	0.	0.
I-135- 7	0.	0.	0.	0.	0.
SM149- 8	0.	0.	0.	0.	0.
XE135- 9	0.	0.	0.	0.	0.
FP2 -10	0.	0.	0.	0.	0.
2ND25-11	0.	0.	0.	0.	0.
B10 1-12	0.	0.	0.	0.	0.
B10 2-13	0.	0.	0.	0.	0.
PU239-14	0.	0.	0.	0.	0.
PU240-15	0.	0.	0.	0.	0.
PU241-16	0.	0.	0.	0.	0.
SPMAT-17	0.	0.	0.	0.	0.
XFIS2-18	0.	0.	0.	0.	0.

ALL MESH INTERVALS HAVE BEEN TRAVERSED FOR TIME INTERVAL 1
THE FLUX WILL NOW BE RENORMALIZED FOR THE NEXT TIME INTERVAL

****

FOR THE START OF TIME INTERVAL NUMBER 2 OF 2

FLUX NORMALIZATION FACTOR 0.101036E 01 CONVERTS TO ABSOLUTE FLUX IN NEUTRONS/BARN*SEC
FOR A POWER LEVEL OF 0.649533E 04 WATTS

CELL NUMBER 1 OF 2

****

NEW ATOM DENSITIES BY MESH INTERVAL FOR EACH ISOTOPE AT THE END OF TIME INTERVAL 1

****

LAST ENTRY FOR EACH ISOTOPE IS ONE BARN-TH OF ITS TOTAL NUMBER OF ATOMS IN THE CONFIGURATION

****

VULCAN ID = 23
0.273800E-01 0.273800E-01 0.236430E-01 0.236430E-01 0.236430E-01 0.236430E-01 0.236430E-01 0.236430E-01
0.517140E-01 0.517140E-01 0.517140E-01 0.517140E-01 0.517140E-01 0.517140E-01 0.248069E 01

VULCAN ID = 24
0.136900E-01 0.136900E-01 0.254640E-01 0.254640E-01 0.254640E-01 0.254640E-01 0.254640E-01 0.254640E-01
0.258570E-01 0.258570E-01 0.258570E-01 0.258570E-01 0.258570E-01 0.258570E-01 0.165617E 01

VULCAN ID = 5
0.138714E-03 0.138787E-03 0. 0. 0. 0. 0. 0.
0. 0. 0. 0. 0. 0. 0.105737E-02

VULCAN ID = 7
0. 0. 0.677014E-02 0.677032E-02 0.677051E-02 0.677066E-02 0.677075E-02 0.677077E-02
0. 0. 0. 0. 0. 0. 0.206365E 00

VULCAN ID = 6
0.5C9904E-06 0.4C6078E-06 0. 0. 0. 0. 0. 0.
0. 0. 0. 0. 0. 0. 0.381523E-05

VULCAN ID = 17
0.265219E-07 0.259210E-07 0.954454E-08 0.765668E-08 0.554669E-08 0.389985E-08 0.291905E-08 0.287524E-08
0. 0. 0. 0. 0. 0. 0.370043E-06

VULCAN ID = 16
0.302238E-07 0.295390E-07 0.108767E-07 0.873678E-08 0.632088E-08 0.444418E-08 0.332648E-08 0.327656E-08
0. 0. 0. 0. 0. 0. 0.421693E-06

VULCAN ID = 15
0.509474E-08 0.502907E-08 0.192306E-08 0.170460E-08 0.140941E-08 0.110963E-08 0.887707E-09 0.867318E-09
0. 0. 0. 0. 0. 0. 0.798113E-07

```
  VULCAN ID = 14
0.122601E-08  0.121893E-08  0.479799E-09  0.465411E-09  0.455785E-09  0.443908E-09  0.423447E-09  0.403793E-09
0.            0.            0.            0.            0.            0.            0.230056E-07

  VULCAN ID = 13
0.262193E-05  0.256260E-05  0.943688E-06  0.758215E-06  0.548729E-06  0.385904E-06  0.288892E-06  0.284552E-06
0.            0.            0.            0.            0.            0.            0.365918E-04

  VULCAN ID = 21
0.            0.            0.481702E-04  0.483507E-04  0.485680E-04  0.487387E-04  0.488372E-04  0.488327E-04
0.            0.            0.            0.            0.            0.            0.148020E-02

  VULCAN ID = 19
0.899276E-03  0.901563E-03  0.            0.            0.            0.            0.            0.
0.            0.            0.            0.            0.            0.            0.686410E-02

  VULCAN ID = 20
0.899276E-03  0.901563E-03  0.            0.            0.            0.            0.            0.
0.            0.            0.            0.            0.            0.            0.686410E-02

  VULCAN ID =  9
0.            0.            0.735355E-06  0.585230E-06  0.424005E-06  0.298431E-06  0.220330E-06  0.209840E-06
0.            0.            0.            0.            0.            0.            0.130596E-04

  VULCAN ID = 10
0.            0.            0.542739E-08  0.355822E-08  0.188173E-08  0.937784E-09  0.532431E-09  0.525376E-09
0.            0.            0.            0.            0.            0.            0.688059E-07

  VULCAN ID = 11
0.            0.            0.437833E-10  0.237101E-10  0.918375E-11  0.324948E-11  0.142090E-11  0.145240E-11
0.            0.            0.            0.            0.            0.            0.443487E-09

  VULCAN ID = 18
0.877980E-03  0.880588E-03  0.            0.            0.            0.            0.            0.
0.            0.            0.            0.            0.            0.            0.670346E-02

  VULCAN ID = 22
0.138714E-03  0.138787E-03  0.            0.            0.            0.            0.            0.
0.            0.            0.            0.            0.            0.            0.105737E-02
```

CONVERSION RATIO BY MESH INTERVAL AT START OF TIME INTERVAL 1

```
-0.           -0.           0.759312E 00  0.739331E 00  0.733734E 00  0.729275E 00  0.707063E 00  0.664022E 00
 0.            0.           0.            0.            0.            0.
```

CONVERSION RATIO BY MESH INTERVAL AT END OF TIME INTERVAL 1

```
-0.           -0.           0.749893E 00  0.732101E 00  0.728515E 00  0.725613E 00  0.704489E 00  0.661847E 00
 0.            0.           0.            0.            0.            0.
```

BY MESH INTERVAL THE POWER IS

```
0.462717E 03  0.452355E 03  0.168815E 03  0.135525E 03  0.979981E 02  0.688741E 02  0.515376E 02  0.507576E 02
0.            0.            0.            0.            0.            0.            0.649533E 04
```

BY MESH INTERVAL THE POWER (NORMALIZED TO VOLUME-AVERAGED POWER) IS

```
0.271419E 01  0.265340E 01  0.990226E 00  0.794954E 00  0.574833E 00  0.403998E 00  0.302307E 00  0.297731E 00
0.            0.            0.            0.            0.            0.            0.170481E 03
```

VOLUME AVERAGED EQUILIBRIUM CONCENTRATIONS OF MAJOR FISSION PRODUCTS
IN NUCLEI/BARN*CM IF THE POWER LEVEL OF .649533E 04 WATTS IS MAINTAINED

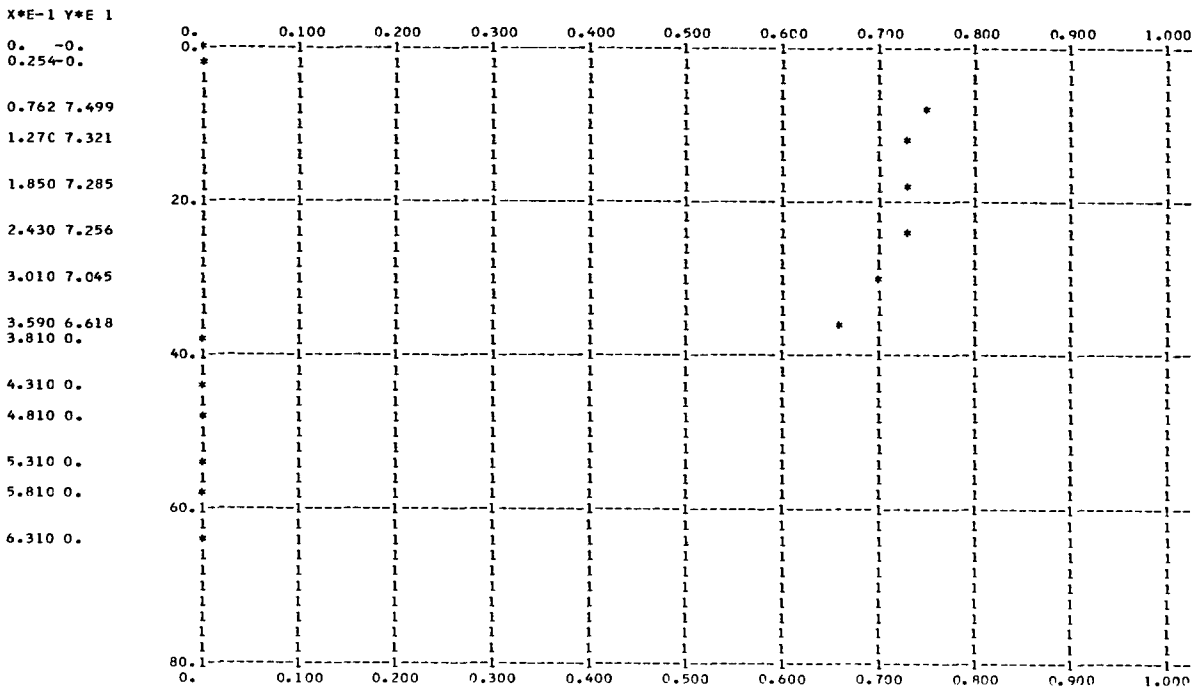
XENON-135	0.607281E-09
SAMARIUM-149	0.763967E-08
IODINE-135	0.111305E-07
PROMETHIUM-149	0.194277E-07

FISSIONABLE ISOTOPE	INITIAL MASS IN KILOGRAMS	FINAL MASS IN KILOGRAMS	FRACTIONAL POWER
U-235	0.142829E-02	0.140295E-02	0.944316E 00
U-238	0.815713E-01	0.815653E-01	0.483206E-01
U-236	0.	0.149527E-05	0.
PU239	0.	0.518351E-05	0.736294E-02
PU240	0.	0.274243E-07	0.
PU241	0.	0.177500E-09	0.370968E-06

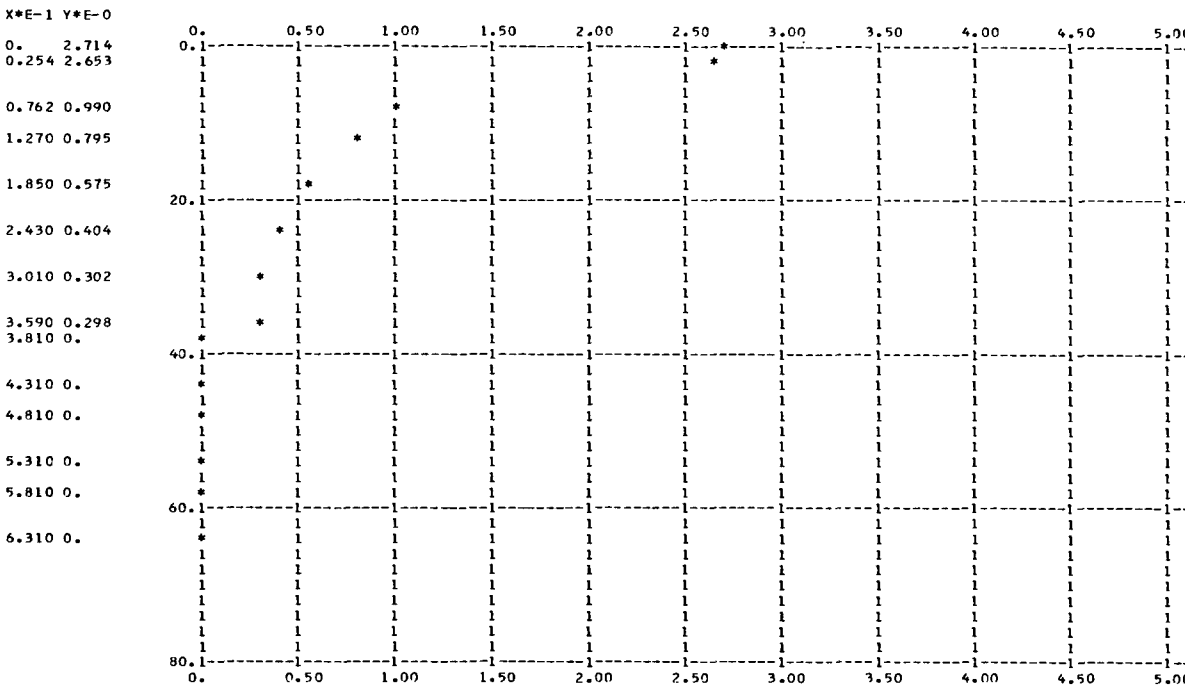
THE FOLLOWING EDIT IS AVERAGED OVER ALL MESH INTERVALS IN WHICH EACH ISOTOPE OCCURS

ISOTOPE DESCR.	N(I)	N(I+1)	N(I+1)/N(I)	POISON FACTOR
HYD -23	0.364272E-01	0.364272E-01	0.100000E 01	0.563034E-01
OXY -24	0.243197E-01	0.243197E-01	0.100000E 01	0.837446E-02
U-235- 5	0.141850E-03	0.138763E-03	0.978237E 00	0.196461E 00
U-238- 7	0.677100E-02	0.677051E-02	0.999927E 00	0.126868E 00
U-236- 6	0.	0.500686E-06	0.	0.599811E-05
PM149-17	0.	0.971242E-08	0.	0.
I-135-16	0.	0.110681E-07	0.	0.
SM149-15	0.	0.209479E-08	0.	0.129656E-02
XE135-14	0.	0.603820E-09	0.	0.186447E-01
FP2 -13	0.	0.960413E-06	0.	0.807945E-03
2ND25-21	0.491500E-04	0.485632E-04	0.988050E 00	0.149980E 00
B10 1-19	0.100000E-02	0.900801E-03	0.900801E 00	0.605550E 01
B10 2-20	0.100000E-02	0.900801E-03	0.900801E 00	0.605550E 01
PU239- 9	0.	0.428466E-06	0.	0.343608E-02
PU240-10	0.	0.225741E-08	0.	0.764434E-05
PU241-11	0.	0.145501E-10	0.	0.153195E-06
SPMAT-18	0.100000E-02	0.879719E-03	0.879719E 00	0.725433E 01
XFIS2-22	0.141850E-03	0.138763E-03	0.978237E 00	0.196461E 00

	INITIAL	FINAL
TOTAL FUEL INVENTORY IN KILOGRAMS	0.829996E-01	0.829789E-01
TOTAL FUEL INVENTORY IN POUNDS	0.182981E 00	0.182935E 00
CONVERSION RATIO	0.202256E 00	0.205006E 00
TOTAL POWER IN WATTS	0.649533E 04	0.642872E 04
MEGAWATT-DAYS/METRIC TON	0.654201E 06	



CONVERSION RATIO VS. MESH INTERVAL RADIUS



NORMALIZED POWER IN INTERVAL VS. MESH INTERVAL RADIUS

********** THIS COMPLETES TIME INTERVAL 1 OF 2

VULCAN DESCRIPTION

VULCAN is a one-dimensional point (mesh interval) depletion or burnup code primarily designed to use the GAM-GATHER-TDSN calculational system and its associated input and output. The input for VULCAN requires geometry and material specifications, macroscopic (atom density in atoms/(b)(cm)) specifications, microscopic cross sections in barns, and the space-energy flux, which is normalized, within VULCAN, to units of neutrons per barn per second. Variable input format options are available for the cross sections and the flux making VULCAN readily adaptable to any space-energy calculation sequence. Thus any reactor configuration, for which geometry and materials can be specified, microscopic cross sections obtained, and fluxes provided, may be treated. Input shortcuts are provided if several configurations, differing only in isotopic densities and flux shape, are considered. In particular, power factors may be used in order to adjust the flux levels. If, in a transverse dimension, a similar material configuration exists, then several transverse dimension regions may be treated sequentially within one VULCAN problem. Thus some measure of two-dimensional depletion is available. The program can treat up to 40 nuclides and 20 energy groups and can accommodate 190 mesh intervals. The mesh intervals may be grouped into 190 zones comprised of 190 distinct materials. These restrictions result because VULCAN is limited to storage in the fast memory of an IBM 7094 computer. However, minor reprogramming can greatly increase the range of problems that may be treated. The restrictions on the number of mesh intervals, zones, and materials NRM and energy groups NG may be varied subject to the following condition:

$$52 * NRM + NRM * NG + 112 * NG \leq 16\ 040$$

The COMMON blocks /SET 1/, /SET 2/, and /SET 3/ must be suitably altered in each subroutine and the source decks recompiled. The storage limitation (16 040) is dependent on the storage allocation for internal systems routines.

Description by Subroutine

Main program: VULCAN. - This is the main program and it performs virtually all input-output operations. It controls the flow of the program and performs special edits of power and conversion ratios in the form of plots at the end of each time interval T_1. The conversion ratio CR_m in any mesh interval m is the ratio of the creation rate C_m to destruction rate D_m of fissionable material in that mesh interval. The equation for CR_m is

$$CR_m = \frac{C_m}{D_m} = \frac{N^1\left(\sigma_a^1 - \sigma_f^1\right)\Phi + N^7\left(\sigma_a^7 - \sigma_f^7\right)\Phi + N^4\left(\sigma_a^4 - \sigma_f^4\right)\Phi + N^{10}\left(\sigma_a^{10} - \sigma_f^{10}\right)\Phi}{N^3\sigma_a^3\Phi + N^5\sigma_a^5\Phi + N^9\sigma_a^9\Phi + N^{11}\sigma_a^{11}\Phi + N^2\sigma_a^2\Phi\left(\frac{\lambda^2}{\lambda^2 + \sigma_a^2\Phi}\right) + N^8\sigma_a^8\Phi\left(\frac{\lambda^8}{\lambda^8 + \sigma_a^8\Phi}\right)} \quad (16)$$

The total conversion ratio CR over all mesh intervals NRM is

$$CR = \frac{\sum_{m=1}^{NRM} C_m \cdot (\text{Volume})_m}{\sum_{m=1}^{NRM} D_m \cdot (\text{Volume})_m}$$

New geometry and material specifications are punched by this routine (discussed in the section Subroutine OUTPUT).

Subroutine TABLE. - This subroutine contains tabular information such as, fission product yields, decay constants, atomic weights, thermal ν values (thermal ν = average number of neutrons per thermal fission), and the VULCAN internal identification assignments. It contains a constant, 3.1×10^{10} fissions per thermal watt-second, to be used for absolute flux normalization. The tabular information is taken, for the most part from references 10 to 12. Fission product yields of Xe^{135}, I^{135}, Sm^{149}, and Pm^{149} from fast and thermal fission of U^{233}, U^{235}, Pu^{239}, and Pu^{241} are included to the extent they are available. These tabulated yields will be used unless different values are specified in the input. The FORTRAN deck of this subroutine is short; thus any of the tabulated values may be changed and the deck recompiled with little effort.

Subroutine ABSPHI. -Within ABSPHI, prior to the solution of any depletion equations, the arbitrary level input flux is normalized to a specified power. At the end of the depletion time interval the flux is renormalized to the same power before calculating the final conversion ratios and before traversing another depletion time interval.

Subroutine XENON. - The equilibrium concentrations of the four specific fission products (XE^{135}, Sm^{149}, I^{135}, and Pm^{149}) are calculated here as well as the time after shutdown (at the end of the current time interval T_1) of peak Xe^{135} concentration and its value at that time.

Subroutine SSF. - If isotopic self-shielding factors by energy group are desired, they are read in by this subroutine. The absorption and fission cross sections are multiplied by their respective self-shielding factors.

Subroutines BURNUP and FISEQ. - These two subroutines perform the actual depletion calculation. For each isotope in each mesh interval, the new atom density, fractional change in atom density, fractional power supplied, and a poison factor are calculated. The poison factor for an isotope is the ratio of its macroscopic absorption cross section to the total macroscopic absorption cross section of the fuel. For each mesh interval, the power is calculated; after normalization to the volume-averaged power, a power distribution plot is produced in the main program VULCAN. A fuel inventory is carried out, volume-averaged atom densities obtained, and the conversion ratio determined before and after the depletion time step.

The subroutine allows the concentrations of the four specific fission products, within any mesh interval, to be determined at an arbitrary number of fractional times within any time interval T_1. For these specific fission products, equilibrium concentrations are determined for each mesh interval and volume averaged over all mesh intervals. For nondepletable regions, the atom densities for the first mesh interval within such a region are carried through as representative of the full region.

Detailed depletion information may be obtained for each mesh interval separately in addition to the information averaged over all mesh intervals. Upon completing the depletion calculation for all mesh intervals, the flux is renormalized (using new atom densities) to the specified power and a new time step T_1 within VULCAN is initiated.

Subroutine OUTPUT. - In a point (mesh interval) depletion program each point within a zone (constant material) will usually be depleted individually. Consequently, each point becomes a distinct material and zone in the next spatial calculation. It is desirable, then, to have some means of minimizing the number of materials or zones. Once all the desired time steps T_1 are completed within VULCAN, the macroscopic absorption cross sections are subjected to two comparative tests. One test determines whether the macroscopic absorption cross section (macs) of each isotope in a mesh interval is, within a predetermined limit, the same as the corresponding isotopic macs in a preceding mesh interval. The other test determines whether the macs of each isotope in a mesh interval constitutes a certain fraction of the total fuel macs in that mesh interval. Each test is performed for each energy group. The mathematical representation of these tests is

Test 1:

$$\left(1 - \left|\frac{\Sigma^k_{a_{jm}}}{\Sigma^k_{a_{j(m-n)}}}\right|\right) \leq n\epsilon \tag{17}$$

Test 2:

$$\Sigma^{k}_{a_{jm}} < 10\,\epsilon \sum_{i=1}^{NF} \Sigma^{i}_{a_{jm}} \qquad (18)$$

where

$\Sigma^{k}_{a_{jm}}$ macroscopic absorption cross section for isotope k, energy group j, and mesh interval m

ϵ predetermined limit (see DIFFER in the section INPUT INSTRUCTIONS)

n designates which preceding mesh interval is being compared with mesh interval m

i designates fissionable isotope

If all energy groups for all isotopes satisfy both tests for two or more mesh intervals, the atom densities for these intervals are volume averaged and thus constitute a single new material and zone. After performing these two tests through all mesh intervals, new atom densities for each distinct material are punched. These atom densities are used to obtain new material macroscopic cross sections which will then be used in the spatial calculation (see the section Depletion cycle).

This subroutine, on option, will print out macroscopic absorption cross sections by group, mesh interval, and isotope. Upon return to the main program the geometry and material specifications for input to TDSN are punched corresponding to the new region and material structure. The corresponding output for nondepletable regions maintains the atom densities and mesh structure unaltered and alters, not the material, but its external identification number.

Nuclide List

VID numbers 1 to 17 may be used only for the indicated isotope. If any of these isotopes is not to be considered, its VID number may not be used by another isotope. Nuclides other than the 17 specifically mentioned are assigned VID numbers in unbroken numeric order, beginning with VID = 18. Table II lists the VID number assignments which VULCAN uses.

TABLE II. - NUCLIDE LIST AND VID ASSIGNMENT

Nuclide	VID number
Th^{232}	1
Pa^{233}	2
U^{233}	3
U^{234}	4
U^{235}	5
U^{236}	6
U^{238}	7
Np^{239}	8
Pu^{239}	9
Pu^{240}	10
Pu^{241}	11
Pu^{242}	12
Fission product aggregate	13
Xe^{135}	14
Sm^{149}	15
I^{135}	16
Pm^{149}	17
Special Materials including additional fission product aggregates	[a] 17 + 1 → 17 + J
Burnable Poisons	[a] 17 + J + 1 → 17 + J + K
Repeated Fissionable Nuclides	[a] 17 + J + K + 1 → 17 + J + K + L
Nondepletable Nuclides	[a] 17 + J + K + L + 1 → 17 + J + K + L + M

[a] For a configuration containing J Special Materials, K Burnable Poisons, L Repeated Fissionable Nuclides, and M Nondepletable Nuclides where $J + K + L + M \leq (40 - 17)$.

INPUT INSTRUCTIONS

This section contains the input instructions and explanations of the input parameters. The symbol * after a card number means to use as much of the card or as many cards as necessary.

Card	Format	Variable	Description
1*	I1, 1X, 14A5	TITLE	Title, label, or problem description containing any alphameric information. The number 1 in card column 1 will signify the last title card.
2	7I10	NG	Number of energy groups ≤ 20
		NFG	Number of fast energy groups ≤ 20
		NISOT	Number of isotopes whose depletion and/or buildup is to be considered plus those classified as non-depletable ≤ 40.
		NMAT	Number of separate materials ≤ 190 (A material is any distinct macroscopic cross section set.)
		NTINC	Number of equal time intervals (DELHR) for which flux normalization and subsequent depletion will be performed.
		NFRACT	Number of fractional steps to be taken within a major time interval (DELHR) for intermediate poison calculations ≤ 10. NFRACT = 0 if MOREOUT = 0 or 1.
		KCELL	= 0 or 1 Normal single depletion $2 \leq$ KCELL ≤ 20 A series of KCELL successive problems with distinct atom densities and fluxes will be depleted. >21 A series of KCELL - 20 successive problems differing only in flux level will be depleted (treated by power factors to be supplied).
3	7I10	NZONR	Number of zones ≤ 190 - within each zone the material is constant.
		NRM	Number of mesh intervals ≤ 190

Card	Format	Variable	Description
		MOROUT	= 0 Only averaged information (always obtained) at the end of depletion sweep will be printed. = 1 Macroscopic absorption cross sections (with self-shielding factors included) will be printed. = 2 Individual mesh interval information will be printed. = 3 Both macroscopic absorption cross sections (with self-shielding factors included) and individual mesh interval information will be printed.
		NUF	= 0 Both $\nu\sigma_f$ and ν will be read in (ν is average number of neutrons per fission - by group and by isotope). = 1 Only σ_f will be read in.
4	7I10	NSPMAT	Number of special materials (see eq. (14)). If more than one fission product aggregate is to be considered, the number must be included in NSPMAT.
		NBPOI	Number of burnable poisons considered
		NFIS	Number of fissionable isotopes for which fission product yields are to be used (indicated by Y in the output) $\leq$ 10 (NFIS does not include any Repeated Fissionable Nuclides.)
		NYDNUC	Number of fission product nuclides for which yields are to be read in $\leq$ 20 (Total number whose yields are to be considered is equal to NYDNUC plus the number whose yields are to be taken from subroutine TABLE.)
		NONDPL	Number of nondepletable isotopes (carried through to maintain continuity of the calculational sequence)
		NFIRPT	Number of times that one or more of the twelve fissionable isotopes is repeated. For example, if three distinct cross section sets for U^{235} and two distinct sets for U^{238} are to be used in a single problem, then NFIRPT = (3 - 1) + (2 - 1) = 3.

Card	Format	Variable	Description
5	7I10	KGEO	Geometry indicator (one-dimensional): = 1 Slab = 2 Cylinder = 3 Sphere
		KFLUX	Format for flux input: = 1 Binary-TDSN output = 2 Decimal-NRM values for group 1, NRM values for group 2, and so forth (NG sets of NRM values)
		KSSF	Self-shielding factors: = 0 If none = 1 If factors are to be used
		KHAIN	Fission isotope chain applicable: = 0 Both chains = 1 $Th^{232} \rightarrow U^{236}$ chain = 2 $U^{238} \rightarrow Pu^{242}$ chain
		KFAST	= 0 For thermal reactor = 1 For fast reactor (This option chooses fission product yields for two general reactor classes.)
		KFORM	= 0 KFLUX option is used. = 1 Permits optional FORMAT statement to be read in for cross section input = 2 Permits optional FORMAT statement to be read in for flux input = 3 Permits optional FORMAT statement to be read in for both cross section input and flux input
6	7E10.5	POWER	Total power in watts (thermal power of 1 W = 3.1×10^{10} fissions/sec)
		DISTI	First transverse dimension equals height for cylinder or slab in centimeters (used to calculate power density)
		DIST2	Second transverse dimension equals thickness for slab in centimeters (used to calculate power density)

Card	Format	Variable	Description
		DELHR	Time increment in hours T_1 (Total depletion time is NTINC*DELHR.)
		XREMP	Xenon removal rate ξ_x (other than by decay and depletion, e.g., diffusion).
		REMIOD	Iodine removal rate ξ_I
		DIFFER	Averaging criterion for output materials. If DIFFER = 0, DIFFER will be set equal to 0.001 (0.1 percent). See ϵ in inequalities (17) and (18).

Card 7 is included only if NFRACT $\neq$ 0.

7*	7F10.8	FRACT(I)	Fractional values of DELHR to be used - no restriction on values except that NFRACT ($\leq$ 10) values are necessary.

Isotope Identification

One card 8 must be included for each of NISOT isotopes. Any isotope may have any sequential ID number (I), but cards 8 must be in numerical order by (I).

8*	4I5, A5	I	Sequential ID number
		VID(I)	VID number (see the section Nuclide List)
		NRPT(I)	= 0 If not a repeated fissionable nuclide = 10 + VID If a repeated fissionable nuclide If U^{235} were used twice in addition to the initial occurrence, each repeated time NRPT would be 10 + 5 = 15. Nuclides for which NRPT $\neq$ 0 must be in ascending NRPT number.
		KFIS(I)	= 0 If no fission product yield is to be used or if NRPT (I) $\neq$ 0 (Note that, upon completion of the input, the KFIS(I) array will contain NFIS nonzero values.) = 1 If a fission product yield is to be used
		DESCR	Arbitrary alphameric description of VID(I)

Card	Format	Variable	Description

Geometry and Material Specifications (NZONR Cards 9 Required)

NZONR cards 9 are required. The first card is for zone K = 1; the second card is for zone K = 2, and so forth; the last card is for zone K = NZONR.

9*	I5, F10.6, I5	NMIR(K)	Number of mesh intervals in zone K
		RAR(K)	External dimension of zone K (cm)
		MIDRZ(K)	Material number corresponding to zone K

If NYDNUC = 0, skip card 10. If NYDNUC $\neq$ 0, NYDNUC cards 10 are required.

10*	2I5, 6F10.8	KRON	= 0 If this isotope is not produced by decay of preceding isotope in NYDNUC series (always 0 for first card in series) = 1 If isotope is capture product of preceding nuclide
		IDFP	VID number of the particular isotope (e.g., if only Xe^{135} yields are to be read in IDFP = 14)
		YELD(J)	Fractional fission yield of isotope with VID = IDFP. YELD(1) from first nonzero KFIS isotope, YELD(2) from the second nonzero KFIS isotope, and so forth - supplied in the same sequence as (I) on cards 8*. If NFIS $\geq$ 7, continue the yields on the next card (format - 7F10.8).

If NUF = 1, skip cards 11. If NUF = 0, NFIS cards 11 are required.

For each fissionable isotope considered and if NUF = 0, the values of ν are read in for all fast groups. These groups are ordered from high to low. Note that σ_f rather than $\nu\sigma_f$ is used in VULCAN. The card sequence is ordered according to VID number.

11*	7F10.8	XNU(IG)	NFG values of ν in neutrons per fission. Do not include for the NFIRPT isotopes.

If KFORM = 0 or 2, skip card 12.

12	12A6	FMT(I)	Optional FORMAT statement for cross section input. For the specific format of cards 14, card 12 would read (36X, 2F12.8). Note omission of word FORMAT but the inclusion of parentheses.

Card	Format	Variable	Description

Microscopic Cross Sections

Include NISOT sets of cards 13 and 14 in the same sequential order as (I) on cards 8.

13	12A6	DUMMY	Not retained in VULCAN (may be title card for cross sections)

If KFORM = 1 or 3, read in absorption and fission cross sections for NG groups in specified format (card 12) on cards 14. For each card 13, there must follow NG cards 14.

14*	36X, 2F12.8 (or format indicated on card 12)	ABSIG(IG)	Absorption cross section for group IG in barns
		FUNSIG(IG)	σ_f or $\nu\sigma_f$ cross section in barns (depending on availability) with appropriate values of XNU(IG) on cards 11 and NUF on card 3.

Material Specifications (Atom Densities)

There must be NMAT sets of cards 15 and 16. The NMAT sets must be in numerical order by material number.

15	7I10	NCON	Number of constituent nuclides in this material ≤ 40 (Only those nuclides present at the start of the depletion interval need be included.)
		IDCON(I)	Sequential ID numbers in ascending order (as established by (I) on cards 8) - NCON values. If NCON > 6, continue with 7I10 format on as many cards as are needed.
16*	7F10.8	DENS(I)	Corresponding atom densities for this material (NCON values) in atoms per barn-centimeter

If KFORM = 0 or 1, skip card 17.

17	12A6	FMT(I)	Optional FORMAT statement for flux input

Card	Format	Variable	Description

Fluxes

The fluxes are supplied on cards 18.

18*	7E10.5	FLUX(I)	Average fluxes by mesh interval for each group; NG sets of NRM values (normalized to units of neutrons/(b)(sec) within VULCAN)

Power Factors

If KCELL $\leq$ 20, skip cards 19 and 20. If KCELL $>$ 21, the power factors are supplied on cards 19 and 20.

19	I10	NKOREG	Number of successive problems to be depleted using the same fluxes but adjusted by power factors $\leq$ 19
20*	7E10.5	CORPOW(I)	Actual, fractional, or relative power for successive problems; NKOREG values; the normalization is to the input, that is, $\frac{\text{POWER}}{\text{CORPOW(1)}}$ * CORPOW(I) = actual power in problem (I)

Self-Shielding Factors

If KSSF $>$ 0, read in the self-shielding factors on cards 21, 22, and 23.

21	I10	NSSF	Total number of nuclides for which self-shielding factors are to be considered $\leq$ 20
22*	7I10	JSMAT(I)	VID numbers for self-shielded nuclides - NSSF values
23*	7F10.6	SSF(I, J)	Self-shielding factors for NSSF isotopes (I) and NG groups (J); NSSF sets of NG values in the order established by JSMAT(I) (card 22)

If KCELL $>$ 21, read in KCELL - 21 sets of atom densities and self-shielding factors. Each set of atom densities is composed of the NMAT pairs of cards 15 and 16 and must

be similar to the first set to the extent that only density magnitude changes (i.e., no changes in material constituents) are allowed. Different self-shielding factors may be used for succeeding sets. If $2 \leq KCELL \leq 20$, read in KCELL - 1 additional sets of similar atom densities, fluxes, and self-shielding factors (cards 15, 16, 17 (if used before), 18, 21, 22, and 23).

LISTING OF PROGRAM DECKS

The FORTRAN listing of the VULCAN program which follows contains several particular features of the Lewis Monitor System. The subroutine BCREAD (called from main subroutine VULCAN) may be used to read fluxes from binary cards. The subroutine PLOTXY forms plots of two related variables. The following printer carriage control characters have been used as the first character in a format statement:

J Single space before printing rest of line

K Double space before printing rest of line

L Triple space before printing rest of line

$ Punch the line instead of print

* Print and punch this line

For the first three control characters, the character must be counted as one of those being printed, but for the last two, the format is given as if the control characters were not a part of the format statement. The last control character * is actually followed by a blank to make up the complete control symbol. If these characters are not available in the monitor system used, then other output control statements must be used.

```
$IBFTC VULCAN  DECK
C
C      VULCAN IS A POINT (MESH INTERVAL) DEPLETION CODE
C      IT HAS OPTIONAL INPUT FORMATS THAT MAKE IT ADAPTABLE TO
C      AN ARBITRARY ONE-DIMENSIONAL SPATIAL CALCULATION
C
C      VULCAN USES NO PERIPHERAL STORAGE
C
C      WRITTEN IN FORTRAN IV LANGUAGE
C
C      JL ANDERSON          NUCLEAR SYSTEMS DIVISION
C      LEWIS RESEARCH CENTER
C      AUGUST 9, 1966
C
       COMMON/SET1/ ATDEN(190,40),CONRAT(200),TOPOW(200),VOL(200),RR(200)
      1,RATBEF(200)
       COMMON/SET2/ FLUX(3800),SANSNU(40,20),ABSIG(40,20),SST(20,20),
      1 XNU(12,20)
       COMMON/SET3/ NMIR(200),RAUM(200),RAR(200),DELR(200),MIDRZ(400),
      1NEMO(200)
       COMMON/SET4/ATWGT(20),DECAY(40),THERNU(40),TNAME(40),FRACT(10),
      1NRPT(40),IDVULC(40)
       COMMON/SET5/ VULABS(40),VULFIS(40),VULAMF(40),ADPREV(40),IDYLD(10)
      1 ,Y(20,12),KKON(20)
       COMMON/SET6/ NG,NM,NISOT,TOTVOL,FIWATT,POWER,AVPOW,FNORM
       COMMON/SET7/NFIS,NSPMAT,NBPOI,NFRACT,NYDNUC,NFIRPT
       COMMON/SET8/ DELHR,KHAIN,AVOGAD,NZONR,MOROUT,MOOD,DIFFER,NONDPL
       COMMON/SET9/ KTIM,NTINC,KRELL,KCELL
       COMMON/SET10/ KOMP,KONG,KOG,LAND,DELSEC,MESH
       COMMON/SET11/ NSSF,JSMAT(20)
C
C
       DIMENSION CORPOW(20),RAPOF(20),TITLE(14),YELD(10),IDCON(40),
      1NUM(14),KFIS(40),DENS(40),IDFP(20),P(15),ONAME(10)
       DIMENSION FUNSIG(40,20)
       DIMENSION FMT(12)
C
       EQUIVALENCE (FUNSIG,SANSNU)
C
C
C      READ IN INPUT DATA
C
   14  WRITE(6,107)
    2  READ(5,100) IJK,(TITLE(I),I=1,14)
       WRITE(6,159) (TITLE(I),I=1,14)
       IF(IJK.NE.1) GO TO 2
       WRITE(6,110)
       READ(5,101) NG,NFG,NISOT,NMAT,NTINC,NFRACT,KCELL
       WRITE(6,101) NG,NFG,NISOT,NMAT,NTINC,NFRACT,KCELL
       WRITE(6,111)
       READ(5,101)  NZONR,NRM,MOROUT,NUF
       WRITE(6,101) NZONR,NRM,MOROUT,NUF
       WRITE(6,112)
       READ(5,101)  NSPMAT,NBPOI,NFIS,NYDNUC,NONDPL,NFIRPT
       WRITE(6,101) NSPMAT,NBPOI,NFIS,NYDNUC,NONDPL,NFIRPT
       WRITE(6,113)
       READ(5,101)  KGEO,KFLUX,KSSF,KHAIN,KFAST,KFORM
       WRITE(6,101) KGEO,KFLUX,KSSF,KHAIN,KFAST,KFORM
       WRITE(6,114)
       READ(5,102)  POWER,DIST1,DIST2,DELHR,XREMP,REMIOD,DIFFER
       WRITE(6,141) POWER,DIST1,DIST2,DELHR,XREMP,REMIOD,DIFFER
       IF(NFRACT.EQ.0) GO TO 3
       READ(5,104) (FRACT(JK),JK=1,NFRACT)
    3  WRITE(6,115)
       CALL TABLE (NISOT,FIWATT,AVOGAD,KFAST)
       DECAY(14)=DECAY(14)+XREMP
       DECAY(40)=DECAY(16)+REMIOD
C      DECAY(40) IS ACTUALLY DECAY(16) FOR THE I-135 EQUATION
       DECAY(16)=DECAY(16)-REMIOD
C      DECAY(16) IS FOR THE XE-135 EQUATION
       DO 1 KISS=1,NISOT
C      I REFERS TO MACGG SEQUENCE BUT CARDS (NISOT) MAY BE IN ANY ORDER
       READ(5,143) I,IDVULC(I),NRPT(I),KFIS(I),DESCR
       ISM=IDVULC(I)
       TNAME(ISM)=DESCR
       IF(KFIS(I).EQ.0) GO TO 4
       WRITE(6,145) I,IDVULC(I),NRPT(I),TNAME(ISM)
       GO TO 1
    4  WRITE(6,144) I,IDVULC(I),NRPT(I),TNAME(ISM)
    1  CONTINUE
       READ(5,103)  (NMIR(I),RAR(I),MIDRZ(I),I=1,NZONR)
       WRITE(6,116)
       WRITE(6,119)
       IGO=NRM+1
       DO 21 I=1,NZONR
       IEND=IGO+NMIR(I)-1
       DO 22 J=IGO,IEND
   22  MIDRZ(J)=MIDRZ(I)
   21  WRITE(6,138) NMIR(I),RAR(I),(MIDRZ(K),K=IGO,IEND)
C
C      MESH INTERVAL MANIPULATION
C
   11  PI=3.1415927
       DELR(1)=0.0
       DELR(1)=RAR(1)
       DO 12 I=2,NZONR
       DELR(I)=0.0
   12  DELR(I)=RAR(I)-RAR(I-1)
       DO 13 I=1,NZONR
       VMI=0.0
       VMI=NMIR(I)
```

```
   13 DELR(I)=DELR(I)/VMI
      RUN=0.0
      RR(1)=0.0
      K=1
      DO 17 J=1,NZONR
      NMES=NMIR(J)
      DO 17 I=1,NMES
      K=K+1
      RR(K)=0.0
   17 RR(K)=RR(K-1)+DELR(J)
      RUN=RR(NRM+1)
    9 CONTINUE
C
C     VOLUME CALCULATION
C
      NM=NRM
      DO 20 JK=1,NM
   20 VOL(JK)=0.0
      NRMP1=NRM+1
      GO TO (30,40,50),KGEO
   30 VOLT=DIST1*DIST2*RUN
      RAUM(1)=RAR(1)*DIST2*DIST1
      DO 23 NIL=2,NZONR
      RAUM(NIL)=0.0
   23 RAUM(NIL)=(RAR(NIL)-RAR(NIL-1))*DIST2*DIST1
      DO 31 K=2,NRMP1
   31 VOL(K-1)=(RR(K)-RR(K-1))*DIST2*DIST1
      GO TO 60
   40 VOLT=PI*RUN*RUN*DIST1
      RAUM(1)=PI*RAR(1)*RAR(1)*DIST1
      DO 35 MIL=2,NZONR
      RAUM(MIL)=0.0
   35 RAUM(MIL)=PI*(RAR(MIL)*RAR(MIL)-RAR(MIL-1)*RAR(MIL-1))*DIST1
      DO 41 K=2,NRMP1
   41 VOL(K-1)=PI*(RR(K)*RR(K)-RR(K-1)*RR(K-1))*DIST1
      GO TO 60
   50 VOLT=(4.*PI/3.)*(RUN**3)
      RAUM(1)=(4.*PI/3.)*(RAR(1)**3)
      DO 57 JIL=2,NZONR
      RAUM(JIL)=0.0
   57 RAUM(JIL)=(4.*PI/3.)*(RAR(JIL)**3-RAR(JIL-1)**3)
      DO 51 K=2,NRMP1
   51 VOL(K-1)=(4./3.)*PI*(RR(K)**3-RR(K-1)**3)
   60 TOTVOL=0.0
      DO 52 LBJ=1,NM
   52 TOTVOL=TOTVOL+VOL(LBJ)
      WRITE(6,117)
      WRITE(6,139) (VOL(K),K=1,NM),TOTVOL
      WRITE(6,150) (RAUM(KOK),KOK=1,NZONR)
      QUOT=VOLT/TOTVOL
      IF(ABS(1.-QUOT).LT..001) GO TO 215
      WRITE(6,133) TOTVOL,VOLT
C
C     READ IN MORE INPUT DATA
C
C     FISSION INFORMATION
C
  215 WRITE(6,107)
      DO 74 I=1,NYDNUC
      IF(NYDNUC.EQ.0) GO TO 230
      IF(NFIS.GT.6) GO TO 5
      READ(5,131) KRON(I),IDFP(I),(YELD(J),J=1,NFIS)
      GO TO 6
    5 READ(5,131) KRON(I),IDFP(I),(YELD(J),J=1,6)
      READ(5,104) (YELD(K),K=7,NFIS)
    6 IJK=IDFP(I)-12
C     IDFP IS IN VULCAN SEQUENCE
  230 DO 70 J=1,NFIS
      IFIS=0
      DO 73 ISEQ=1,NISOT
      IFIS=IFIS+KFIS(ISEQ)
      IF(IFIS.NE.J) GO TO 73
      IDYLD(J)=IDVULC(ISEQ)
      IDT=IDYLD(J)
      IF(NYDNUC.NE.0) Y(IJK,IDT)=YELD(J)
      QNAME(J)=TNAME(IDT)
      GO TO 70
   73 CONTINUE
   70 CONTINUE
   74 CONTINUE
   75 WRITE(6,124) (IDYLD(JA),JA=1,NFIS)
      WRITE(6,147) (QNAME(JA),JA=1,NFIS)
      NUG=NSPMAT+17
      DO 55 NASA=1,NISOT
      NAV=IDVULC(NASA)
      IF(NAV.LE.12.OR.NAV.GT.NUG) GO TO 55
      NUT=NAV-12
      DO 56 JET=1,NFIS
      ID=IDYLD(JET)
   56 YELD(JET)=Y(NUT,ID)
      WRITE(6,119)
      WRITE(6,146) NAV,TNAME(NAV),(YELD(JJ),JJ=1,NFIS)
   55 CONTINUE
      IF(NUF.EQ.1) GO TO 42
      WRITE(6,109)
C
C     NU IN VULCAN ID ORDER
C
      DO 79 J=1,12
      DO 221 MIG=1,NFG
```

```
  221 XNU(J,MIG)=0.0
      NUM(J)=J
      DO 220 NAX=1,NISOT
      IF(J.EQ.IDVULC(NAX)) READ(5,104) (XNU(J,IG),IG=1,NFG)
  220 CONTINUE
   79 CONTINUE
      WRITE(6,125) (NUM(J),J=1,12)
      WRITE(6,119)
      DO 76 IG=1,NFG
   76 WRITE(6,140) IG,(XNU(J,IG),J=1,12)
      IF(KFAST.EQ.0) WRITE(6,142) (THERNU(J),J=1,12)
   42 WRITE(6,107)
C
C     CROSS SECTIONS
C
      IF(KFORM.EQ.1.OR.KFORM.EQ.3) READ(5,135) (FMT(I),I=1,12)
      DO 67 ISOT=1,NISOT
C     MACGG SEQUENCE
      ID=IDVULC(ISOT)
      KID=ID
      READ(5,135) DUMMY
      IF(KFORM.EQ.0.OR.KFORM.EQ.2) GO TO 200
      DO 201 IG=1,NG
  201 READ(5,FMT) ABSIG(ID,IG),FUNSIG(ID,IG)
      GO TO 202
  200 DO 65 IG=1,NG
      READ(5,105) ABSIG(ID,IG),FUNSIG(ID,IG)
      READ(5,135) DUMMY
   65 CONTINUE
  202 WRITE(6,108)
      WRITE(6,121) ISOT,ID
      WRITE(6,122)
      WRITE(6,139) (ABSIG(ID,IG),IG=1,NG)
      IF(ID.GT.12.AND.NRPT(ISOT).EQ.0) GO TO 67
      IF(NUF.EQ.1) GO TO 300
      WRITE(6,123)
      WRITE(6,139) (FUNSIG(ID,IG),IG=1,NG)
  300 GNU=1.
      DO 68 IG=1,NG
      IF(NUF.EQ.1) GO TO 68
      IF(FUNSIG(ID,IG).EQ.0.) GO TO 68
      IF(NRPT(ISOT).EQ.0) GO TO 69
      KID=NRPT(ISOT)-10
   69 CONTINUE
      IF(IG.GT.NFG) GO TO 72
      GNU=XNU(KID,IG)
      IF(GNU.NE.0.) GO TO 68
      GNU=2.5
      WRITE(6,153) ID,IG
      GO TO 68
   72 GNU=THERNU(KID)
      IF(GNU.EQ.0.) GNU=1.
   68 SANSNU(ID,IG)=FUNSIG(ID,IG)/GNU
      WRITE(6,134)
      WRITE(6,139) (SANSNU(ID,IG),IG=1,NG)
   67 CONTINUE
C
C     ATOM DENSITIES
C
      LUNE=0
      LUX=0
      KANT=0
      IF(KCELL.LE.20) GO TO 207
      KANT=1
      KCELL=KCELL-20
  207 DO 208 NSEL=1,KCELL
      KTIM=1
      LUX=LUX+1
      KRELL=NSEL
      IF(NSEL.GT.1) WRITE(6,157) NSEL,KCELL
   61 DO 62 J=1,NMAT
      DO 64 K=1,40
   64 DENS(K)=0.0
      READ(5,101) NCON,(IDCON(I),I=1,NCON)
C     MACGG SEQUENCE IDCON
      READ(5,158) (DENS(I),I=1,NCON)
      LADD=0
      DO 53 K=1,NZONR
      MESH=0
      MAT=MIDRZ(K)
      LADD=LADD+NMIR(K)
      IF(MAT.NE.J) GO TO 53
      MESH=LADD-NMIR(K)
      NMES=NMIR(K)
      DO 53 L=1,NMES
      MESH=MESH+1
      DO 235 NEQ=1,40
  235 ATDEN(MESH,NEQ)=0.0
      DO 54 KKK=1,NCON
      IAGO=IDCON(KKK)
      ID=IDVULC(IAGO)
   54 ATDEN(MESH,ID)=DENS(KKK)
   53 CONTINUE
   62 CONTINUE
      NGOTO=0
      NST=0
      WRITE(6,107)
      MUSS=0
```

```
   36 NST=NGOTO+1
      IF(NMAT.GT.(NGOTO+7)) GO TO 37
      NGOTO=NMAT
      GO TO 45
   37 NGOTO=NGOTO+7
      WRITE(6,119)
   45 DO 38 KIX=1,7
      NUM(KIX)=0
      NUM(KIX)=NST+KIX-1
      IF(NUM(KIX).GT.NMAT) GO TO 330
      KRAD=0
      DO 310 JKT=1,NZONR
      KRAD=KRAD+NMIR(JKT)
      IF(MIDRZ(JKT).EQ.NUM(KIX)) GO TO 320
  310 CONTINUE
  320 NUM(KIX+7)=KRAD-NMIR(JKT)+1
      GO TO 38
  330 NUM(KIX)=0
   38 CONTINUE
      LARAY=NGOTO-NST+1
      IF(NGOTO.GT.7) WRITE(6,119)
      WRITE(6,118) (NUM(K),K=1,7)
      DO 66 MV=1,NISOT
      JV=IDVULC(MV)
      WRITE(6,119)
      DO 340 NVT=1,LARAY
      LOCUS=NUM(NVT+7)
  340 CONRAT(NVT)=ATDEN(LOCUS,JV)
      WRITE(6,120) JV,TNAME(JV),(CONRAT(J),J=1,LARAY)
   66 CONTINUE
      IF(NMAT.GT.NGOTO) GO TO 36
      WRITE(6,107)
C
C     FLUX
C
      LST=0
      LSP=0
      IF(NSEL.GT.1.AND.KANT.EQ.1) GO TO 88
      IST=0
      ISP=0
      KST=0
      KSP=0
  204 IF(KFORM.LT.2) GO TO (81,82), KFLUX
      READ(5,100) (FMT(I),I=1,12)
      DO 203 IG=1,NG
      IST=ISP+1
      ISP=IST+NM-1
  203 READ(5,FMT) (FLUX(ICON),ICON=IST,ISP)
      GO TO 87
   81 DO 77 IG=1,NG
      IGO=NM*(IG-1)+1
      ISTOP=IGO+NM-1
      CALL BCREAD(FLUX(IGO),FLUX(ISTOP))
   77 CONTINUE
      GO TO 87
   82 DO 86 IG=1,NG
      IST=ISP+1
      ISP=IST+NM-1
   86 READ(5,102)(FLUX(ICON),ICON=IST,ISP)
   87 CONTINUE
      IF(LUNE.EQ.0) WRITE(6,126)
      IF(KANT.EQ.1) WRITE(6,129)
      IF(KANT.EQ.0.AND.KCELL.GT.0) WRITE(6,130) NSEL
      DO 80 IG=1,NG
      WRITE(6,127) IG
      KST=KSP+1
      KSP=KST+NM-1
   80 WRITE(6,139) (FLUX(KCON),KCON=KST,KSP)
   88 CALL ABSPHI
      KOOL=0
      IF(KANT.EQ.0) GO TO 206
      IF(NSEL.GT.1) GO TO 212
      LUNE=LUNE+1
      READ(5,106) NKOREG
C     ACTUAL,FRACTIONAL OR RELATIVE POWER MAY BE READ IN
      READ(5,102) (CORPOW(KIP),KIP=1,NKOREG)
      WRITE(6,154) (CORPOW(KIP),KIP=1,NKOREG)
      DO 214 KRAT=1,NKOREG
  214 RAPOF(KRAT)=CORPOW(KRAT)/CORPOW(1)
      WRITE(6,128)(RAPOF(JOE),JOE=1,NKOREG)
  212 MG=NM*NG
      VIET=1.0
      IF(NSEL.GT.1) VIET=RAPOF(LOX-1)
      DO 205 KK=1,MG
  205 FLUX(KK)=FLUX(KK)*RAPOF(LOX)/VIET
      WRITE(6,160) RAPOF(LOX)
      WRITE(6,126)
      WRITE(6,130) NSEL
      DO 43 IGY=1,NG
      WRITE(6,127) IGY
      LST=LSP+1
      LSP=LST+NM-1
   43 WRITE(6,139) (FLUX(NAM),NAM=LST,LSP)
  206 DO 209 NTM=1,NTINC
      IF(KSSF.GT.0) CALL SSF(NG,NTM)
      KTIM=NTM+1
```

```
   89 CALL BURNUP
      IF(NTM.NE.NTINC) GO TO 90
   99 CALL OUTPUT
C
C     CALCULATION OF DIMENSION SPECIFICATIONS
C
      NET=1
      WRITE(6,148)
      DO 92 K=1,MOOD
      NET=NEMO(K)+NET
      RAR(K)=RR(NET)
      PUNCH 103, NEMO(K),RAR(K),K
   92 WRITE(6,149) NEMO(K),RAR(K),K
   90 P(1)=NM
      CALL PLOTXY(RR,CONRAT,64,P)
      WRITE(6,136)
      CALL PLOTXY(RR,TDPOW,64,P)
      WRITE(6,137)
      WRITE(6,107)
      WRITE(6,156) NTM,NTINC
  209 CONTINUE
  208 CONTINUE
   91 GO TO 14
  100 FORMAT(I1,1X,14A5)
  101 FORMAT(7I10)
  102 FORMAT(7E10.5)
  103 FORMAT(I5,F10.6,I5)
  104 FORMAT(7F10.8)
  105 FORMAT(36X,2E12.6)
  106 FORMAT(I10,6F10.7)
  107 FORMAT(1H1)
  108 FORMAT(1HK)
  109 FORMAT(1HL)
  110 FORMAT(1HL,7X,2HNG,8X,3HNFG,6X,5HNISOT,5X,4HNMAT,6X,5HNTINC,4X,
     16HNFRACT,4X,5HKCELL)
  111 FORMAT(1HL,6X,5HNZONR,5X,3HNRM,6X,6HMOROUT,6X,3HNUF)
  112 FORMAT(1HL,5X,6HNSPMAT,5X,5HNBPOI,5X,4HNFIS,5X,6HNYDNUC,4X,6HNONDP
     1L,4X,6HNFIRPT)
  113 FORMAT(1HL,6X,4HKGEO,6X,5HKFLUX,5X,4HKSSF,6X,5HKHAIN,5X,5HKFAST,
     15X,5HKFORM)
  114 FORMAT(1HL,9X,5HPOWER,6X,5HFIRST,8X,6HSECOND,8X,4HTIME,11X,5HXENON
     1,10X,6HIODINE/11X,2HIN,7X,9HDISTANCE ,4X,8HDISTANCE,4X,10H INCREME
     2NT,7X,7HREMOVAL,9X,7HREMOVAL,5X,6HDIFFER/10X,5HWATTS,6X,4H(CM),
     310X,6H(CM)  ,5X,
     4 8H (HOURS),4X,13H  PROBABILITY,5X,11HPROBABILITY)
  115 FORMAT(1HL,4X,10HSEQUENTIAL,7H VULCAN,8H  NRPT  ,7HISOTOPE/
     18X,2HID,8X,2HID,11X,5HLABEL)
  116 FORMAT(1HL,12H      NMIR(I),12H      RAR(I),23H            MIDRZ(I)-
     1MAP)
  117 FORMAT(1HL,15H   MESH VOLUMES//)
  118 FORMAT(8H  VULCAN,11H  ISOTOPE  ,7(13H   MATERIAL  )/4X,2HID,5X,
     15HLABEL,8X,7(I2,11X))
  119 FORMAT(1HJ)
  120 FORMAT(I5,6X,A5,3X,7E13.5)
  121 FORMAT(17H SEQUENTIAL ID = , I2 ,15H   VULCAN ID = ,I2)
  122 FORMAT(1HK,34H ABSORPTION BY GROUP (HIGH TO LOW))
  123 FORMAT(34H NU*FISSION BY GROUP (HIGH TO LOW))
  124 FORMAT(10H   FISSION,6X,10(10HYIELD     )/15H      PRODUCT  ,10(
     14HFROM,I3,3X))
  125 FORMAT(7H  GROUP,12(8H  NU FOR)/7X,12(5H  VID,I3))
  126 FORMAT(31H FLUXES BY GROUP AND MESH POINT)
  127 FORMAT(1HJ,8H  GROUP ,I2)
  128 FORMAT(1HK,35H THESE ARE THE RADIAL POWER FACTORS/(8E14.6))
  129 FORMAT(24H       FOR THE BASIC CELL)
  130 FORMAT(22H       FOR CELL NUMBER ,I2)
  131 FORMAT(2I5,6F10.8)
  133 FORMAT(1HL,13H   VOLUME SUM,F13.4,25H NOT EQUAL F(DIST1,DIST2),F13
     1.4)
  134 FORMAT(33H   FISSION BY GROUP (HIGH TO LOW))
  135 FORMAT(12A6)
  136 FORMAT(2HPL,55X,41HCONVERSION RATIO VS. MESH INTERVAL RADIUS)
  137 FORMAT(2HPL,55X,53HNORMALIZED POWER IN INTERVAL VS. MESH INTERVAL
     1RADIUS)
  138 FORMAT(I10,7X,F8.4, 9X,25(I3)/34X,25(I3))
  139 FORMAT(8E14.6)
  140 FORMAT(I5,2X,12F8.3)
  141 FORMAT(7X,E10.5,F11.5,F12.5,F14.2,F16.7,F16.7,F11.5)
  142 FORMAT(7H    T  ,12F8.3)
  143 FORMAT(4I5,A5)
  144 FORMAT(2I10,I7,4X,A5)
  145 FORMAT(2I10,2H Y,I5,4X,A5)
  146 FORMAT(I5,2H (,A5,1H),F9.5,9(F10.5))
  147 FORMAT(15X,10(1H(,A5,1H),3X))
  148 FORMAT(1HL,41H    DIMENSION SPECIFICATION INPUT TO TDSN//)
  149 FORMAT(I15,F10.6,I5)
  150 FORMAT(1HL,15H   ZONE VOLUMES//(8E14.6))
  152 FORMAT(F15.4)
  153 FORMAT(1HL,10(1H+),61H  A NON-ZERO FISSION CROSS SECTION HAS BEEN
     1SUPPLIED FOR VID ,I2/1X,10(1H+),8H  GROUP ,I2,54H BUT NO NON-ZERO
     2NU VALUE IS AVAILABLE. THEREFORE THIS/1X,10(1H+),41H  PARTICULAR N
     3U HAS BEEN SET EQUAL TO 2.5)
  154 FORMAT(1HK,31H THE POWER FOR EACH CORE REGION/(8E14.6))
  156 FORMAT(1H2,10(1H*),31H  THIS COMPLETES TIME INTERVAL ,I2,4H OF ,I2
     1)
  157 FORMAT(1HL,10(1H*),62H  THE FOLLOWING ATOM DENSITIES AND FLUXES AR
     1E FOR CELL NUMBER ,I2,4H OF ,I2)
  158 FORMAT(7E10.6)
  159 FORMAT(2X,14A5)
  160 FORMAT(1HK,38H    THE POWER FACTOR FOR THIS CELL IS ,F10.7)
      END
```

```
$IBFTC TTABLE  DECK
      SUBROUTINE TABLE (NISOT,FIWATT,AVOGAD,KFAST)
      COMMON/SET1/ ATDEN(190,40),CONRAT(200),TOPOW(200),VOL(200),RR(200)
     1,RATREF(200)
      COMMON/SET2/ FLUX(3800),SANSNU(40,20),ABSIG(40,20),SST(20,20),
     1 XNU(12,20)
      COMMON/SET3/ NMIR(200),RAUM(200),RAR(200),DELR(200),MIDRZ(400),
     1NEMO(200)
      COMMON/SET4/ATWGT(20),DECAY(40),THERNU(40),TNAME(40),FRACT(10),
     1NRPT(40),IDVULC(40)
      COMMON/SET5/ VULABS(40),VULFIS(40),VULAMF(40),ADPREV(40),IDYLD(10)
     1 ,Y(20,12),KRON(20)
C
C
C     SUPPLIES MOST COMMONLY USED TABULAR INFORMATION
C
C
C  VULCAN ID    NUCLIDE
C       1        TH232
C       2        PA233
C       3        U233
C       4        U234
C       5        U235
C       6        U236
C       7        U238
C       8        NP239
C       9        PU239
C      10        PU240
C      11        PU241
C      12        PU242
C      13        FISSION PRODUCT AGGREGATE (OR INDIVIDUAL PRODUCT)
C      14        XE135
C      15        SM149
C      16        I135
C      17        PM149
C      18        SPECIAL MATERIALS INCLUDING ADDITIONAL F.P. AGGREGATES
C       .                .
C       .                .
C       .                .
C       .        BURNABLE POISONS
C       .                .
C       .                .
C       .                .
C       .        REPEATED FISSIONABLE NUCLIDES
C       .                .
C       .                .
C       .                .
C       .        NON-DEPLETABLE NUCLIDES
C       .                .
C       .                .
C      40                .
C
C
      DO 10 JFK=1,20
      DO 10 LBJ=1,12
   10 Y(JFK,LBJ)=0.0
C     Y(PRODUCT,SOURCE)=FRACTIONAL YIELD
C     EACH Y(1,X) IS (1.-SUM OF INDIVIDUAL YIELDS)
C     PRODUCT NUMBER 2 = XE-135
C     PRODUCT NUMBER 3 = SM-149
C     PRODUCT NUMBER 4 = I-135
C     PRODUCT NUMBER 5 = PM-149
C     Y(1,3)=.9481
C     Y(1,5)=.9246
C     Y(1,9)=.9113
C     Y(1,11)=.9220
      Y(2,3)=.0020                                                  GUESS
      Y(2,5)=.0031                                                  GAFKAT C
      Y(2,9)=.0017                                                  GAFKAT C
      Y(2,11)=.0020                                                 GUESS
      Y(3,3)=.0012                                                  GAROOS C
      Y(3,5)=.0013                                                  GAROOS C
      Y(3,9)=.0070                                                  GAROOS C
      Y(3,11)=.006                                                  GUESS
      Y(4,3)=.0426                                                  NSE25 TN
      Y(4,5)=.0610                                                  GENERAL
      Y(4,9)=.0700                                                  GAFKAT
      Y(4,11)=.0600                                                 GUESS
      Y(5,3)=.0050                                                  GAROOS
      Y(5,5)=.0100                                                  GAROOS
      Y(5,9)=.0100                                                  GAROOS
      Y(5,11)=.0100                                                 GUESS
      IF(KFAST.EQ.0) GO TO 30
   20 Y(2,5)=.0025                                                  GAFKAT C
      Y(2,9)=.0090                                                  GAFKAT C
      Y(3,5)=.0015                                                  GAFKAT C
      Y(3,9)=.0035                                                  GAFKAT C
      Y(4,5)=.0600                                                  GAFKAT
      Y(4,9)=.0600                                                  GAFKAT
      Y(5,5)=.0100                                                  GAFKAT
      Y(5,9)=.0100                                                  GAFKAT
```

```
C      Y(1,5)=.9260
C      Y(1,9)=.9175
   30  ATWGT(1)=232.111
       ATWGT(2)=233.114
       ATWGT(3)=233.112
       ATWGT(4)=234.114
       ATWGT(5)=235.117
       ATWGT(6)=236.120
       ATWGT(7)=238.125
       ATWGT(8)=239.123
       ATWGT(9)=239.127
       ATWGT(10)=240.129
       ATWGT(11)=241.131
       ATWGT(12)=242.134
       DO 90 LBJ=1,NISOT
       DECAY(LBJ)=0.0
   90  THERNU(LBJ)=0.0                                                    ANL5800
       THERNU(1)=2.6                                                      GATHER
       THERNU(3)=2.503
C      THERNU(3)=2.494    ATOMIC ENERGY REVIEW VOL 3 =2 (1960)
       THERNU(5)=2.43
       THERNU(7)=2.60                                                     ANL5800
       THERNU(9)=2.882
C      THERNU(9)=2.871    ATOMIC ENERGY REVIEW VOL 3 =2 (1960)
       THERNU(11)=2.98
C      THERNU(11)=2.969   ATOMIC ENERGY REVIEW VOL 3 =2 (1960)
       FIWATT=3.10 E10
       AVOGAD=6.0247 E23
       DECAY(2)=2.928 E-7
       DECAY(8)=3.410 E-6                                                 NUD V1N5
       DECAY(11)=1.650 E-9                                                NUD V1N5
       DECAY(14)=2.10 E-5
       DECAY(16)=2.87 E-5
       DECAY(17)=3.63 E-6
       RETURN
       END
```

```
$IBFTC ABFLUX  DECK
       SUBROUTINE ABSPHI
       COMMON/SET1/ ATDEN(190,40),CONRAT(200),TOPOW(200),VOL(200),RR(200)
      1,RATBEF(200)
       COMMON/SET2/ FLUX(3800),SANSNU(40,20),ABSIG(40,20),SST(20,20),
      1 XNU(12,20)
       COMMON/SET3/ NMIR(200),RAUM(200),RAR(200),DELR(200),MIDRZ(400),
      1NEMO(200)
       COMMON/SET4/ATWGT(20),DECAY(40),THERNU(40),TNAME(40),FRACT(10),
      1NRPT(40),IDVULC(40)
       COMMON/SET5/ VULABS(40),VULFIS(40),VULAMF(40),ADPREV(40),IDYLD(10)
      1 ,Y(20,12),KRON(20)
       COMMON/SET6/ NG,NM,NISOT,TOTVOL,FIWATT,POWER,AVPOW,FNORM
       COMMON/SET9/ KTIM,NTINC,KRELL,KCELL
C
C      CALCULATES ABSOLUTE FLUX NORMALIZATION FACTOR
C
  107 FORMAT(1H1)
  132 FORMAT(1HL,45H        FOR THE START OF TIME INTERVAL NUMBER ,I2,
     14H OF ,I2)
  134 FORMAT(1HK,17H      CELL NUMBER ,I2,4H OF ,I2)
  135 FORMAT(1HL,29H   FLUX NORMALIZATION FACTOR ,E12.6, 48H  CONVERTS T
     1O ABSOLUTE FLUX IN NEUTRONS/BARN*SEC/20X,22H FOR A POWER LEVEL OF
     2,E12.6,7H  WATTS)
  136 FORMAT(1HL,30(3H***))
       IF(KTIM.EQ.1) WRITE(6,107)
       VOLPGR=0.0
       FISPHI=0.0
       DO 10 IG=1,NG
       FISPGR=0.0
       DO 9 IM=1,NM
       FISMAC=0.0
       LOC=NM*(IG-1)+IM
       DO 8 IMAT=1,NISOT
       ID=IDVULC(IMAT)
       IF(SANSNU(ID,IG).EQ.0..OR.ATDEN(IM,ID).EQ.0.) GO TO 8
       FISMAC=FISMAC+ATDEN(IM,ID)*SANSNU(ID,IG)*FLUX(LOC)
       IF(VOL(IM).LT.0.) GO TO 8
       VOL(IM)=-VOL(IM)
       VOLPGR=VOLPGR-VOL(IM)
    8 CONTINUE
       IF(VOL(IM).GT.0.) GO TO 9
       FISPGR=FISPGR-FISMAC*VOL(IM)
    9 CONTINUE
       FISPHI=FISPHI+FISPGR
   10 CONTINUE
       FISPHI=FISPHI/VOLPGR
       DO 6 K=1,NM
       IF(VOL(K).GE.0.) GO TO 6
       VOL(K)=-VOL(K)
    6 CONTINUE
       FNORM=(FIWATT*POWER/(VOLPGR*FISPHI))*10.**(-24)
       WRITE(6,136)
       WRITE(6,132) KTIM,NTINC
       WRITE(6,135) FNORM,POWER
       IF(KCELL.GT.0) WRITE(6,134) KRELL,KCELL
       WRITE(6,136)
       NGM=NG*NM
       DO 11 LOC=1,NGM
   11 FLUX(LOC)=FLUX(LOC)*FNORM
       AVPOW=POWER/VOLPGR
       RETURN
       END
```

```
$IBFTC TXENON  DECK
      SUBROUTINE XENON (GAINXE,GAINSM,GAINIO,GAINPM,AVGXE,AVGSM,AVGIO,
     1AVGPM)
      COMMON/SET1/ ATDEN(190,40),CONRAT(200),TOPOW(200),VOL(200),RR(200)
     1,RATBEF(200)
      COMMON/SET2/ FLUX(3800),SANSNU(40,20),ABSIG(40,20),SST(20,20),
     1 XNU(12,20)
      COMMON/SET3/ NMIR(200),RAUM(200),RAR(200),DELR(200),MIDRZ(400),
     1NEMO(200)
      COMMON/SET4/ATWGT(20),DECAY(40),THERNU(40),TNAME(40),FRACT(10),
     1NRPT(40),IDVULC(40)
      COMMON/SET5/ VULABS(40),VULFIS(40),VULAMF(40),ADPREV(40),IDYLD(10)
     1 ,Y(20,12),KRON(20)
      COMMON/SET6/ NG,NM,NISOT,TOTVOL,FIWATT,POWER,AVPOW,FNORM
      COMMON/SET7/NFIS,NSPMAT,NBPOI,NFRACT,NYDNUC,NFIRPT
      COMMON/SET8/ DELHR,KHAIN,AVOGAD,NZONR,MOROUT,MOOD,DIFFER,NONDPL
      COMMON/SET10/ KOMP,KONG,KOG,LAND,DELSEC,MESH
C
C     CALCULATES EQUILIBRIUM POISON CONCENTRATION AND TIME AFTER
C     SHUTDOWN OF MAXIMUM XENON CONCENTRATION
C
  101 FORMAT(73H   EQUILIBRIUM CONCENTRATIONS OF MAJOR FISSION PRODUCTS
     1IN NUCLEI/BARN*CM/33H   IF THE CURRENT POWER LEVEL OF ,E10.5,21H
     2WATTS IS MAINTAINED)
  102 FORMAT(1HK,71H    TIME AFTER SHUTDOWN UNTIL MAXIMUM XENON CONCENTR
     1ATION IS REACHED = ,F6.2,7H  HOURS)
  103 FORMAT(1HK,14X,14HXENON-135     ,E20.6/ 15X,14HSAMARIUM-149  ,E20.
     16/ 15X,14HIODINE-135    ,E20.6/ 15X,14HPROMETHIUM-149,E20.6)
  104 FORMAT(14H  EQUILIBRIUM ,4E15.6)
  105 FORMAT(1HL,51H ++ IT SEEMS THE FLUX LEVEL ISN,T HIGH ENOUGH FOR
     144H  ++ A VALID TIME AFTER SHUTDOWN CALCULATION)
  106 FORMAT(    55H    THE XENON-135 CONCENTRATION (PEAK) AT THIS TIME
     1IS ,E12.6)
C
C
      EQIOD=GAINIO/(DECAY(16)+VULABS(16))
      EQXEN=(GAINXE+DECAY(16)*EQIOD)/(DECAY(14)+VULABS(14))
      EQPRO=GAINPM/(DECAY(17)+VULABS(17))
      EQSAM=(GAINSM+DECAY(17)*EQPRO)/VULABS(15)
      IF(MOROUT.LT.2) GO TO 60
      IF(NFRACT.EQ.0) GO TO 30
      WRITE(6,104) EQXEN,EQSAM,EQIOD,EQPRO
      GO TO 40
   30 WRITE(6,101) POWER
      WRITE(6,103) EQXEN,EQSAM,EQIOD,EQPRO
   40 TEMP=1.-(DECAY(14)-DECAY(16))*EQXEN/(DECAY(16)*EQIOD)
      IF(TEMP.LT.0.) GO TO 10
      TMAX=ALOG(TEMP*DECAY(14)/DECAY(16))/(DECAY(14)-DECAY(16))/3600.
      GO TO 20
   10 TMAX=-1.
   20 WRITE(6,102) TMAX
      IF(TMAX.LT.0..AND.TMAX.NE.-1.) WRITE(6,105)
      TAFSEC=3600.*TMAX
      CONMAX=(DECAY(16)*EQIOD/(DECAY(14)-DECAY(16)))*(EXP(-TAFSEC*DECAY(
     116))-EXP(-TAFSEC*DECAY(14)))+EQXEN*EXP(-TAFSEC*DECAY(14))
      WRITE(6,106) CONMAX
   60 AVGXE=AVGXE+EQXEN*VOL(MESH)
      AVGSM=AVGSM+EQSAM*VOL(MESH)
      AVGIO=AVGIO+EQIOD*VOL(MESH)
      AVGPM=AVGPM+EQPRO*VOL(MESH)
   50 RETURN
      END
```

```
$IBFTC SELSH   DECK
      SUBROUTINE SSF(NG,NTM)
C
C     CALCULATES SSF AND ADJUSTS CROSS SECTIONS
C
      COMMON/SET1/ ATDEN(190,40),CONRAT(200),TOPOW(200),VOL(200),KR(200)
     1,RATBEF(200)
      COMMON/SET2/ FLUX(3800),SANSNU(40,20),ABSIG(40,20),SST(20,20),
     1 XNU(12,20)
      COMMON/SET3/ NMIR(200),KAUM(200),KAR(200),DELR(200),MIDRZ(400),
     1NEMU(200)
      COMMON/SET4/ATWGT(20),DECAY(40),THERNU(40),TNAME(40),FRACT(10),
     1NRPT(40),IDVULC(40)
      COMMON/SET5/ VULABS(40),VULFIS(40),VULAMF(40),ADPREV(40),IDYLD(10)
     1 ,Y(20,12),KRON(20)
      COMMON/SET11/ NSSF,JSMAT(20)
  100 FORMAT(7I10)
  101 FORMAT(7F10.6)
  103 FORMAT(1HL,56H    SELF-SHIELDING FACTORS USED ARE (HIGH TO LOW ENE
     1RGY)//)
  104 FORMAT(1HK,14H  VULCAN ID = ,I2,2X,9F10.6/(15X,9F10.6))
      IF(NTM.GT.1) RETURN
      WRITE(6,103)
      READ(5,100) NSSF
      READ(5,100) (JSMAT(I),I=1,NSSF)
  200 DO 201 ISF=1,NSSF
  201 READ(5,101) (SST(ISF,J),J=1,NG)
  500 DO 502 NSF=1,NSSF
      ISM=JSMAT(NSF)
      DO 503 MIG=1,NG
      ABSIG(ISM,MIG)=ABSIG(ISM,MIG)*SST(NSF,MIG)
  503 SANSNU(ISM,MIG)=SANSNU(ISM,MIG)*SST(NSF,MIG)
      WRITE(6,104) JSMAT(NSF),(SST(NSF,J),J=1,NG)
  502 CONTINUE
      RETURN
      END
```

```
$IBFTC BURNT   DECK
      SUBROUTINE BURNUP
C
C
C     PERFORMS ACTUAL DEPLETION, POWER, CONVERSION RATIO, AND
C     FUEL INVENTORY CALCULATIONS
C
C
C
      COMMON/SET1/ ATDEN(190,40),CONRAT(200),TOPOW(200),VOL(200),RR(200)
     1,RATBEF(200)
      COMMON/SET2/ FLUX(3800),SANSNU(40,20),ABSIG(40,20),SST(20,20),
     1 XNU(12,20)
      COMMON/SET3/ NMIR(200),RAUM(200),RAR(200),DELR(200),MIDRZ(400),
     1NEMO(200)
      COMMON/SET4/ATWGT(20),DECAY(40),THERNU(40),TNAME(40),FRACT(10),
     1NRPT(40),IDVULC(40)
      COMMON/SET5/ VULABS(40),VULFIS(40),VULAMF(40),ADPREV(40),IDYLD(10)
     1 ,Y(20,12),KRON(20)
      COMMON/SET6/ NG,NM,NISOT,TOTVOL,FIWATT,POWER,AVPOW,FNORM
      COMMON/SET7/NFIS,NSPMAT,NBPOI,NFRACT,NYDNUC,NFIRPT
      COMMON/SET8/ DELHR,KHAIN,AVOGAD,NZONR,MOROUT,MOOD,DIFFER,NONDPL
      COMMON/SET9/ KTIM,NTINC,KRELL,KCELL
      COMMON/SET10/ KOMP,KONG,KOG,LAND,DELSEC,MESH
      COMMON/SET11/ NSSF,JSMAT(20)
      DIMENSION FPIM(40),FADIN(40),BEGMAS(12),FINMAS(12),POISON(40)
      DIMENSION XNUMER(10),GAMSP(20),          TFRAP(40),TAX(40)
      DIMENSION PREDEN(40),PIZEN(40),VOLL(40)
C
C     INITIALIZATION
C
      AVGXE=0.0
      AVGSM=0.0
      AVGIO=0.0
      AVGPM=0.0
      DO 315 JAQ=1,NISOT
      TFRAP(JAQ)=0.0
      PREDEN(JAQ)=0.0
      PIZEN(JAQ)=0.0
  315 VOLL(JAQ)=0.0
      DO 50 MESH=1,NM
      RATBEF(MESH)=0.0
      CONRAT(MESH)=0.0
      TOPOW(MESH)=0.0
   50 CONTINUE
      MESH=1
      PETROL=0.0
      IGLOO=0
      POUR=0.0
      DO 2 L=1,12
      BEGMAS(L)=0.0
    2 FINMAS(L)=0.0
      BMASS=0.0
      FMASS=0.0
      TCONSB=0.0
      TDESTB=0.0
      TRBEF=0.0
      MUF=0
      KOOL=KOOL+1
      DELSEC=3600.*DELHR
      SECOND=DELSEC
C
C     BEGINNING OF MESH ITERATION
C
    1 CONTINUE
      KONG=0
      KOG=1
      KOMP=1
      LAND=0
      KLON=0
      JALP=0
      JUME=0
   11 DO 13 IDD=1,NISOT
      ID=IDVULC(IDD)
      VULABS(ID)=0.0
      VULFIS(ID)=0.0
      VULAMF(ID)=0.0
      DO 14 IG=1,NG
      LOC=NM*(IG-1)+MESH
      VULABS(ID)=VULABS(ID)+ABSIG(ID,IG)*FLUX(LOC)
   14 VULFIS(ID)=VULFIS(ID)+FLUX(LOC)*SANSNU(ID,IG)
   13 VULAMF(ID)=VULABS(ID)-VULFIS(ID)
      DENOM=0.0
      DO 3 ID=1,12
      IF(ATDEN(MESH,ID).NE.0.) GO TO 4
    3 CONTINUE
      DO 365 KORAN=1,NISOT
      ID=IDVULC(KORAN)
      IF(ATDEN(MESH,ID).NE.0..AND.NRPT(KORAN).NE.0) GO TO 4
  365 CONTINUE
      IF(NBPOI.EQ.0) GO TO 380
      JALP=NSPMAT+18
      JUME=JALP+NBPOI-1
      DO 381 KOCH=JALP,JUME
      IF(ATDEN(MESH,KOCH).EQ.0.) GO TO 381
C     KLON=1 INDICATES THAT A BURNABLE POISON WILL BE CONSIDERED
C     IN THE CURRENT MESH
      KLON=1
      GO TO 35
  381 CONTINUE
  380 MSUM=0
      DO 10 KAT=1,NZONR
```

```
      MSUM=MSUM+NMIR(KAT)
      IF(MSUM.EQ.(MESH-1)) GO TO 35
   10 CONTINUE
      WRITE(6,151) MSUM,MESH
      GO TO 35
    4 CONTINUE
      IF(NBPOI.EQ.0) GO TO 19
      JAA=NSPMAT+18
      JZZ=JAA+NBPOI-1
      DO 413 LOOK=JAA,JZZ
      IF(ATDEN(MESH,LOOK).EQ.0.) GO TO 413
      KLON=1
      GO TO 19
  413 CONTINUE
   19 IF(KHAIN.GT.1) CALL FISEQ2(59)
      CALL FISEQ1(59)
C
C     FISSION YIELDS (GAMMA)
C
    9 DO 21 JQ=1,NFIS
      ID=IDYLD(JQ)
      IF(NFIRPT.EQ.0.OR.ADPREV(ID).NE.0.) GO TO 361
      DO 360 KAD=1,NISOT
      IF((NKPT(KAD)-10).NE.ID) GO TO 360
      KONE=IDVULC(KAD)
      XNUMER(JQ)=(ADPREV(KONE)+ATDEN(MESH,KONE))*VULFIS(KONE)/2.
      GO TO 21
  360 CONTINUE
  361 XNUMER(JQ)=(ADPREV(ID)+ATDEN(MESH,ID))*VULFIS(ID)/2.
   21 DENOM=DENOM+XNUMER(JQ)
C
C     DENOM=TOTAL FISSION RATE PER BARN-CM FOR ISOTOPES WITH
C     CONSIDERED YIELDS
C
      IF(DENOM.EQ.0.) GO TO 35
      GAMFP=0.0
      GAMXE=0.0
      GAMSM=0.0
      GAMIOD=0.0
      GAMPM=0.0
      DO 26 JIG=1,NSPMAT
   26 GAMSP(JIG)=0.0
      DO 20 IQ=1,NFIS
      KQ=IDYLD(IQ)
      GAMXE=GAMXE+XNUMER(IQ)*Y(2,KQ)/DENOM
      GAMSM=GAMSM+XNUMER(IQ)*Y(3,KQ)/DENOM
      GAMIOD=GAMIOD+XNUMER(IQ)*Y(4,KQ)/DENOM
      GAMPM=GAMPM+XNUMER(IQ)*Y(5,KQ)/DENOM
      IF(NSPMAT.EQ.0) GO TO 20
      DO 27 JIG=1,NSPMAT
      JOG=JIG+5
   27 GAMSP(JIG)=GAMSP(JIG)+XNUMER(IQ)*Y(JOG,KQ)/DENOM
   20 GAMFP=GAMFP+XNUMER(IQ)*Y(1,KQ)/DENOM
      GAINXE=GAMXE*DENOM
      GAINIO=GAMIOD*DENOM
      GAINSM=GAMSM*DENOM
      GAINPM=GAMPM*DENOM
C
C     FISSION PRODUCT AGGREGATE (OR INDIVIDUAL PRODUCT)
C
      ADPREV(13)=ATDEN(MESH,13)
      ATDEN(MESH,13)=(GAMFP*DENOM/VULABS(13))*(1.-EXP(-DELSEC*VULABS(13)
     1))+ADPREV(13)*EXP(-DELSEC*VULABS(13))
      ITEM=0
      IF(MOROUT.LT.2) GO TO 44
      WRITE(6,107)
      WRITE(6,112) MESH
      WRITE(6,110)
   44 IF(NFRACT.EQ.0) GO TO 34
   37 ITEM=ITEM+1
      IF(ITEM.GT.1) GO TO 40
      DELSEC=3600.*DELHR*FRACT(ITEM)
      GO TO 41
   40 DELSEC=3600.*DELHR*(FRACT(ITEM)-FRACT(ITEM-1))
   41 IF(ITEM.GT.1) GO TO 34
      SAVXE=ATDEN(MESH,14)
      SAVIO=ATDEN(MESH,16)
      SAVSM=ATDEN(MESH,15)
      SAVPM=ATDEN(MESH,17)
      IF(MOROUT.LT.2) GO TO 34
      WRITE(6,102)
C
C     EXPLICIT YIELD AND DECAY POISONS
C
C
C     PM149
C
   34 ADPREV(17)=ATDEN(MESH,17)
      GAMTOS=0.0
      GAMTOX=0.0
      ATDEN(MESH,17)=ADPREV(17)*EXP(-DELSEC*(DECAY(17)+VULABS(17)))
     1+(GAINPM/(DECAY(17)+VULABS(17)))*(1.-EXP(-DELSEC*(DECAY(17)+
     2VULABS(17))))
C
C     SM149
C
      ADPREV(15)=ATDEN(MESH,15)
      IF(ATDEN(MESH,17).NE.0.) GO TO 500
      GAMTOS=GAINPM+GAINSM
      ATDEN(MESH,15)=(ADPREV(15)*EXP(-DELSEC*VULABS(15))+GAMTOS*
     1(1.-EXP(-DELSEC*VULABS(15))))/VULABS(15)
      GO TO 520
```

```
  500 ATDEN(MESH,15)= DECAY(17)* (ADPREV(17)*(DECAY(17)+VULABS(17))-
     1GAINPM)/((DECAY(17)+VULABS(17))*(VULABS(15)-DECAY(17)-VULABS(17)))
     2  *(EXP(-DELSEC*(DECAY(17)+VULABS(17)))-EXP(-DELSEC*VULABS(15)))
     3 +(GAINSM*(DECAY(17)+VULABS(17))+GAINPM*DECAY(17))/
     4((DECAY(17)+VULABS(17))
     5 *VULABS(15))*(1.-EXP(-DELSEC*VULABS(15)))+ ADPREV(15)*
     6 EXP(-DELSEC*VULABS(15))
C
C      I135
C
  520 ADPREV(16)=ATDEN(MESH,16)
      ATDEN(MESH,16)=ADPREV(16)*EXP(-DELSEC*(DECAY(40)+VULABS(16)))
     1 +(GAINIO/(DECAY(40)+VULABS(16)))*(1.-EXP(-DELSEC*(DECAY(40)
     2 +VULABS(16))))
C
C      XE135
C
   30 ADPREV(14)=ATDEN(MESH,14)
      IF(ATDEN(MESH,16).NE.0.) GO TO 510
      GAMTOX=GAINIO+GAINXE
      ATDEN(MESH,14)=(ADPREV(14)*EXP(-DELSEC*(DECAY(14)+VULABS(14)))+
     1GAMTOX*(1.-EXP(-DELSEC*(DECAY(14)+VULABS(14)))))/(DECAY(14)+VULABS
     2(14))
      GO TO 530
  510 ATDEN(MESH,14)=DECAY(16)*(ADPREV(16)*(DECAY(16)+VULABS(16))-GAINIO
     1) /((DECAY(16)+VULABS(16))*(DECAY(14)+VULABS(14)       -DECAY(16)
     2-VULABS(16)))*(EXP(-DELSEC*(DECAY(16)+VULABS(16)))-EXP(-DELSEC
     3*(DECAY(14)+VULABS(14))))+(GAINXE*(DECAY(16)+VULABS(16))+GAINIO*
     4 DECAY(16))/((DECAY(16)+VULABS(16))*
     5(DECAY(14)+VULABS(14)))      *(1.-EXP(-DELSEC*(DECAY(14)+VULABS(14
     6))))+ADPREV(14)*EXP(-DELSEC*(DECAY(14)+VULABS(14)))
  530 IF(DELSEC.EQ.SECOND) GO TO 38
      IF(NFRACT.EQ.0) GO TO 38
      IF(MOROUT.LT.2) GO TO 300
      WRITE(6,101) FRACT(ITEM),ATDEN(MESH,14),ATDEN(MESH,15),ATDEN(MESH,
     116),ATDEN(MESH,17)
  300 IF(ITEM.LT.NFRACT) GO TO 37
      DELSEC=SECOND
      ATDEN(MESH,14)=SAVXE
      ATDEN(MESH,15)=SAVSM
      ATDEN(MESH,16)=SAVIO
      ATDEN(MESH,17)=SAVPM
      GO TO 34
   38 CALL XENON (GAINXE,GAINSM,GAINIO,GAINPM,AVGXE,AVGSM,AVGIO,AVGPM)
      GO TO 39
C
C      SPECIAL MATERIALS INCLUDING FISSION PRODUCT AGGREGATES
C
   35 DO 42 NOD=1,17
   42 ADPREV(NOD)=0.0
      IF(KLON.EQ.0) GO TO 382
      WRITE(6,107)
      WRITE(6,112) MESH
      WRITE(6,164)
      GO TO 39
  382 LUSH=MESH+NMIR(KAT+1)-1
      IF(MOROUT.LT.2) GO TO 39
      WRITE(6,107)
      IF(NMIR(KAT+1).EQ.1) GO TO 43
      WRITE(6,152) MESH,LUSH
      WRITE(6,153) MESH,LUSH
      GO TO 39
   43 WRITE(6,112) MESH
      WRITE(6,100) MESH
   39 DO 362 KOT=1,NISOT
      JOT=IDVULC(KOT)
      IF(JOT.LE.17) GO TO 362
      IF(NRPT(KOT).NE.0.AND.ATDEN(MESH,JOT).NE.0.) GO TO 362
      ADPREV(JOT)=ATDEN(MESH,JOT)
  362 CONTINUE
      IF(DENOM.EQ.0.) GO TO 33
      IF(NSPMAT.EQ.0) GO TO 33
      DO 31 IV=1,NSPMAT
      DACRON=0.0
      DACRON=KRON(IV)
      NON=IV+17
      ADPREV(NON)=ATDEN(MESH,NON)
      ATDEN(MESH,NON)=((GAMSP(IV)*DENOM+((ATDEN(MESH,NON-1)+
     1 ADPREV(NON-1))*VULABS(NON-1)/2.)* DACRON)  /VULABS(NON))*
     2(1.-EXP(-DELSEC*VULABS(NON)))+ADPREV(NON)*EXP(-DELSEC*VULABS(NON))
   31 CONTINUE
C
C      KRON(I) IS THE KRONECKER DELTA--EQUAL TO 1 IF SPECIAL MATERIAL(I)
C      IS A DECAY PRODUCT OF THE SPECIAL MATERIAL(I-1) AND EQUAL TO
C      ZERO OTHERWISE
C
   33 DO 96 ISEQ=1,NISOT
      POISON(ISEQ)=0.0
   96 FPIM(ISEQ)=0.0
      IF(NBPOI.EQ.0) GO TO 48
      IF(KLON.EQ.0) GO TO 48
  403 DO 32 LUP=1,NBPOI
      LOOP=LUP+NSPMAT+17
      ADPREV(LOOP)=ATDEN(MESH,LOOP)
      ATDEN(MESH,LOOP)=ADPREV(LOOP)*EXP(-DELSEC*VULABS(LOOP))
   32 CONTINUE
   48 IF(DENOM.EQ.0.) GO TO 90
```

```
C
C     CONVERSION RATE AT THE START OF THE TIME INTERVAL
C
      CONSBE=0.0
      DESTBE=0.0
      CONSBE= ADPREV(1)*VULAMF(1)+ADPREV(7)*VULAMF(7)+ADPREV(4)*VULAMF(4
     1)+ADPREV(10)*VULAMF(10)
      DESTBE=  ADPREV(3)*VULABS(3)+ADPREV(5)*VULABS(5)+ADPREV(9)*VULABS(
     19)+  ADPREV(11)*VULABS(11) + ADPREV(2)*VULABS(2)*DECAY(2)/(DECAY(2
     2)+VULABS(2))+ADPREV(8)*VULABS(8)*DECAY(8)/(DECAY(8)+VULABS(8))
      IF(NFIRPT.EQ.0) GO TO 340
      DO 341 NWT=1,NISOT
      IF(NRPT(NWT).EQ.0) GO TO 341
      IGT=IDVULC(NWT)
      KROG=NRPT(NWT)-10
      GO TO (342,344,343,342,343,343,342,344,343,342,343,343),KROG
  342 CONSBE=CONSBE+ADPREV(IGT)*VULAMF(IGT)
      GO TO 341
  343 DESTBE=DESTBE+ADPREV(IGT)*VULABS(IGT)
      GO TO 341
  344 DESTBE=DESTBE+ADPREV(IGT)*VULABS(IGT)*DECAY(KROG)/(DECAY(KROG)+VUL
     1ABS(IGT))
  341 CONTINUE
  340 TCONSB=TCONSB+CONSBE*VOL(MESH)
      TDESTB=TDESTB+DESTBE*VOL(MESH)
      TRBEF=TCONSB/TDESTB
   81 IF(DESTBE.EQ.0.) GO TO 93
      RATBEF(MESH)=CONSBE/DESTBE
   93 CONTINUE
C
C     FUEL INVENTORY CALCULATION
C
      DO 15 JINX=1,12
      BEGMAS(JINX)=BEGMAS(JINX)+VOL(MESH)*ADPREV(JINX)*ATWGT(JINX)/
     1 (AVOGAD*10.**(-21))
   15 FINMAS(JINX)=FINMAS(JINX)+VOL(MESH)*ATDEN(MESH,JINX)*ATWGT(JINX)
     1 (AVOGAD*10.**(-21))
      FUEL=0.0
      DO 71 ID=1,12
   71 FUEL=FUEL+ATDEN(MESH,ID)*VULABS(ID)*VOL(MESH)
      PETROL=PETROL+FUEL
      IF(NFIRPT.EQ.0) GO TO 51
      DO 49 MIT=1,NISOT
      IF(NRPT(MIT).LE.0) GO TO 49
      META=IDVULC(MIT)
      MUTT=NRPT(MIT)-10
      FUEL=FUEL+ATDEN(MESH,META)*VULABS(META)*VOL(MESH)
      BEGMAS(MUTT)=BEGMAS(MUTT)+VOL(MESH)*ADPREV(META)*ATWGT(MUTT)/
     1 (AVOGAD*10.**(-21))
      FINMAS(MUTT)=FINMAS(MUTT)+VOL(MESH)*ATDEN(MESH,META)*ATWGT(MUTT)/
     1 (AVOGAD*10.**(-21))
   49 CONTINUE
      PETROL=PETROL+FUEL
C
C     POISON CALCULATION
C
   51 PHITOT=0.0
      DO 72 ID=1,NISOT
      IT=IDVULC(ID)
      PIZEN(ID)=PIZEN(ID)+ATDEN(MESH,IT)*VULABS(IT)*VOL(MESH)
   72 POISON(ID)=ATDEN(MESH,IT)*VULABS(IT)*VOL(MESH)/FUEL
C
C     POWER CALCULATION
C
   75 CONTINUE
      DO 92 ID=1,NISOT
      IDO=IDVULC(ID)
      IF(IDO.GT.12.AND.NRPT(ID).LE.0) GO TO 92
   78 SUM=0.0
      DO 91 IG=1,NG
      LOC=NM*(IG-1)+MESH
   91 SUM=SUM+SANSNU(IDO,IG)*FLUX(LOC)
      FPIM(ID)=ATDEN(MESH,IDO)*10.**(24)*SUM*VOL(MESH)/FIWATT
      TOPOW(MESH)=TOPOW(MESH)+FPIM(ID)
   92 CONTINUE
   77 IF(TOPOW(MESH).EQ.0.) GO TO 90
      IGLOO=IGLOO+1
      DO 89 IOTA=1,NISOT
      TFRAP(IOTA)=TFRAP(IOTA)+FPIM(IOTA)
   89 FPIM(IOTA)=FPIM(IOTA)/TOPOW(MESH)
   90 CONTINUE
      NBEG=17+NSPMAT+NBPOI+NFIRPT+1
   82 CONTINUE
      DO 94 ISEQ=1,NISOT
      FADIN(ISEQ)=0.0
      IDT=IDVULC(ISEQ)
      IF(ADPREV(IDT).EQ.0.) GO TO 94
      FADIN(ISEQ)=ATDEN(MESH,IDT)/ADPREV(IDT)
      PREDEN(ISEQ)=ADPREV(IDT)*VOL(MESH)+PREDEN(ISEQ)
   94 CONTINUE
      IF(MORDUT.LT.2) GO TO 47
   45 WRITE(6,129)
   79 CONTINUE
      DO 95 JSEQ=1,NISOT
      ID=IDVULC(JSEQ)
   95 WRITE(6,120) TNAME(ID),JSEQ,ADPREV(ID),ATDEN(MESH,ID),FADIN(JSEQ),
     1FPIM(JSEQ),POISON(JSEQ)
   47 POWR=POWR+TOPOW(MESH)
      IF(DENOM.GT.0..OR.KLON.EQ.1) GO TO 320
      MOST=MESH+1
      DO 321 LITE=MOST,LUSH
```

```
      DO 322 NITE=1,NISOT
      MITE=IDVULC(NITE)
  322 PREDEN(NITE)=ADPREV(MITE)*VOL(LITE)+PREDEN(NITE)
  321 CONTINUE
      MESH=LUSH
  320 MESH=MESH+1
      IF(MESH.LE.NM) GO TO 1
      POWIN=POWER
      NONE=KTIM-1
      IF(NONE.GT.1) WRITE(6,107)
      WRITE(6,156) NONE
      CALL ABSPHI
C
C     PRODUCTION RATE OF FISSIONABLE MATERIAL
C     USING NEW FLUX LEVEL AT END OF INTERVAL
C
      SPACE=0.0
      DO 87 MESH=1,NM
      TOPOW(MESH)=TOPOW(MESH)*FNORM
      IF(TOPOW(MESH).NE.0.) SPACE=SPACE+VOL(MESH)
      DO 85 IOTA=1,NISOT
      ID=IDVULC(IOTA)
      VULABS(ID)=0.0
      VULFIS(ID)=0.0
      VULAMF(ID)=0.0
      DO 86 IG=1,NG
      LOC=NM*(IG-1)+MESH
      VULABS(ID)=VULABS(ID)+ABSIG(ID,IG)*FLUX(LOC)
   86 VULFIS(ID)=VULFIS(ID)+FLUX(LOC)*SANSNU(ID,IG)
   85 VULAMF(ID)=VULABS(ID)-VULFIS(ID)
      PROD=0.0
      PROD       = ATDEN(MESH,1)*VULAMF(1)+ATDEN(MESH,7)*VULAMF(7)+
     1 ATDEN(MESH,4)*VULAMF(4)+ATDEN(MESH,10)*VULAMF(10)
C
C     DESTRUCTION RATE OF FISSIONABLE MATERIAL
C
      DEST=0.0
      DEST       = ATDEN(MESH,3)*VULABS(3)+ATDEN(MESH,5)*VULABS(5)
     1 + ATDEN(MESH,9)*VULABS(9)+ATDEN(MESH,11)*VULABS(11)+ATDEN(MESH,2)
     2 *VULABS(2)*DECAY(2)/(DECAY(2)+VULABS(2))+ATDEN(MESH,8)*
     3VULABS(8)*DECAY(8)/(DECAY(8)+VULABS(8))
      IF(NFIRPT.EQ.0) GO TO 350
      DO 351 NWT=1,NISOT
      IF(NRPT(NWT).EQ.0) GO TO 351
      IGT=IDVULC(NWT)
      KROG=NRPT(NWT)-10
      GO TO (352,354,353,352,353,353,352,354,353,352,353,353),KROG
  352 PROD=PROD+ATDEN(MESH,IGT)*VULAMF(IGT)
      GO TO 351
  353 DEST=DEST+ATDEN(MESH,IGT)*VULABS(IGT)
      GO TO 351
  354 DEST=DEST+ATDEN(MESH,IGT)*VULABS(IGT)*DECAY(KROG)/(DECAY(KROG)+
     1 VULABS(IGT))
  351 CONTINUE
  350 TPROD=TPROD+PROD*VOL(MESH)
      TDEST=TDEST+DEST*VOL(MESH)
      IF(DEST.EQ.0.) GO TO 97
C
C     CONVERSION RATE OF FISSIONABLE MATERIAL
C
      CONRAT(MESH)=PROD/DEST
      GO TO 98
   97 CONRAT(MESH)=0.0
   98 TCONV=0.0
      IF(TDEST.EQ.0.) GO TO 87
      TCONV=TPROD/TDEST
   87 CONTINUE
      AVGXE=AVGXE/SPACE
      AVGSM=AVGSM/SPACE
      AVGIO=AVGIO/SPACE
      AVGPM=AVGPM/SPACE
      FIGLOO=IGLOO
      IF(NFIRPT.LE.0) GO TO 370
      DO 371 JAR=1,NISOT
      IF(NRPT(JAR).LE.0) GO TO 371
      MATTE=NRPT(JAR)-10
      DO 410 LOCH=1,NISOT
      IF(MATTE.EQ.IDVULC(LOCH)) GO TO 411
  410 CONTINUE
  411 TFRAP(LOCH)=TFRAP(LOCH)+TFRAP(JAR)
  371 CONTINUE
  370 DO 83 JAM=1,NISOT
   83 TFRAP(JAM)=TFRAP(JAM)/POUR
      DO 73 ID=1,NISOT
   73 TAX(ID)=0.0
      DO 74 MESH=1,NM
      DO 74 KEN=1,NISOT
      ID=IDVULC(KEN)
      IF(ATDEN(MESH,ID).NE.0.) VOLL(KEN)=VOLL(KEN)+VOL(MESH)
   74 TAX(KEN)=TAX(KEN)+ATDEN(MESH,ID)*VOL(MESH)
      KTL=KTIM-1
      WRITE(6,105) KTL
      WRITE(6,121)
      DO 80 NOID=1,NISOT
      ID=IDVULC(NOID)
      WRITE(6,104) ID
      WRITE(6,106) (ATDEN(IMESH,ID),IMESH=1,NM),TAX(NOID)
   80 CONTINUE
      WRITE(6,113)  KTL,(RATBEF(ION),ION=1,NM)
      WRITE(6,114)  KTL,(CONRAT(ION),ION=1,NM)
      WRITE(6,109)
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      WRITE(6,117)
      DO 550 JMESH=1,NM
  550 TOPOW(JMESH)=TOPOW(JMESH)/VOL(JMESH)
      WRITE(6,106) (TOPOW(JMESH),JMESH=1,NM),POWER
      DO 88 JERK=1,NM
   88 TOPOW(JERK)=TOPOW(JERK)/ AVPOW
      WRITE(6,117)
      WRITE(6,115)
      WRITE(6,117)
      WRITE(6,106) (TOPOW(JMESH),JMESH=1,NM),AVPOW
      WRITE(6,110)
      WRITE(6,119) POWER
      WRITE(6,118) AVGXE,AVGSM,AVGIO,AVGPM
      WRITE(6,111)
      DO 330 ID=1,NISOT
      NOW=IDVULC(ID)
      IF(NOW.GT.12) GO TO 330
      WRITE(6,158)  TNAME(NOW),BEGMAS(NOW),FINMAS(NOW),TFRAP(ID)
  330 CONTINUE
      DO 301 ID=1,NISOT
      PIZEN(ID)=PIZEN(ID)/PETROL
      PREDEN(ID)=PREDEN(ID)/VOLL(ID)
  301 TAX(ID)=TAX(ID)/VOLL(ID)
      WRITE(6,107)
      WRITE(6,157)
      WRITE(6,155)
  311 CONTINUE
      DO 310 ID=1,NISOT
      JSEQ=IDVULC(ID)
  312 IF(PREDEN(ID).EQ.0.) GO TO 313
      XSU=TAX(ID)/PREDEN(ID)
      GO TO 310
  313 XSU=0.0
  310 WRITE(6,120) TNAME(JSEQ),JSEQ,PREDEN(ID),TAX(ID),XSU,PIZEN(ID)
      DO 84 LAWN=1,12
      BMASS=BMASS+BEGMAS(LAWN)
   84 FMASS=FMASS+FINMAS(LAWN)
      BEGLB=2.2046*BMASS
      FINLB=2.2046*FMASS
      DEGBUR=2200.*POWER*DELHR/(24.*(BEGLB-FINLB))*10.**(-6)
      WRITE(6,116)
      WRITE(6,140) BMASS,FMASS
      WRITE(6,141) BEGLB,FINLB
      WRITE(6,108) TRBEF,TCONV
      WRITE(6,103) POWIN,POUR
      WRITE(6,154) DEGBUR
C
  100 FORMAT(1HL,80H  NO FISSIONABLE ISOTOPES OR CONSEQUENT FISSION PROD
     1UCTS OCCUR IN MESH INTERVAL ,I4)
  101 FORMAT(F9.2,5X,4E15.6)
  102 FORMAT(71H   FISSION PRODUCT CONCENTRATIONS AT VARIOUS FRACTIONS O
     1F THE TIME STEP//12H    FRACTION,9X,5HXE135,10X,5HSM149,10X,5HI 13
     25,10X,5HPM149)
  103 FORMAT(1HK,24H    TOTAL POWER IN WATTS,10X,E12.6,10X,E12.6)
  104 FORMAT(1HL,15H   VULCAN ID = ,I2)
  105 FORMAT(1H1,84H   NEW ATOM DENSITIES BY MESH INTERVAL FOR EACH ISOT
     1OPE AT THE END OF TIME INTERVAL ,I2)
  106 FORMAT(8E14.6)
  107 FORMAT(1H1)
  108 FORMAT(1HK,24H    CONVERSION RATIO    ,10X,E12.6,10X,E12.6)
  109 FORMAT(1HK,34H    BY MESH INTERVAL THE POWER IS )
  110 FORMAT(1HK)
  111 FORMAT(1H1,64H   FISSIONABLE    INITIAL MASS IN    FINAL MASS IN
     1  FRACTIONAL/6X,7HISOTOPE,9X,9HKILOGRAMS,9X,9HKILOGRAMS,9X,5HPOWER
     2/)
  112 FORMAT(10(3H **),22H MESH INTERVAL NUMBER ,I4,1X,10(3H **))
  113 FORMAT(1H1,63H    CONVERSION RATIO BY MESH INTERVAL AT START OF TI
     1ME INTERVAL,I2//(8E14.6))
  114 FORMAT(1HK,63H    CONVERSION RATIO BY MESH INTERVAL AT END   OF TI
     1ME INTERVAL,I2//(8E14.6))
  115 FORMAT(73H     BY MESH INTERVAL THE POWER (NORMALIZED TO VOLUME-AV
     1ERAGED POWER) IS )
  116 FORMAT(1HL,37X,7HINITIAL,16X,5HFINAL)
  117 FORMAT(1HJ)
  118 FORMAT(1HL,14X,14HXENON-135     ,E20.6//15X,14HSAMARIUM-149  ,E20.
     16//15X,14HIODINE-135    ,E20.6//15X,14HPROMETHIUM-149,E20.6)
  119 FORMAT(75H     VOLUME AVERAGED EQUILIBRIUM CONCENTRATIONS OF MAJOR
     1 FISSION PRODUCTS  /45H     IN NUCLEI/BARN*CM IF THE POWER LEVEL O
     2F ,E11.6,20H WATTS IS MAINTAINED)
  120 FORMAT(3X,A5,1H-,I2,1X,6E15.6)
  121 FORMAT(1HK,20(4H****)//103H           LAST ENTRY FOR EACH ISOTOPE
     1IS ONE BARN-TH OF ITS TOTAL NUMBER OF ATOMS IN THE CONFIGURATION//
     21X,20(4H****))
  129 FORMAT(1HK,9H  ISOTOPE,10X,4HN(T),9X,6HN(T+1),7X,11HN(T+1)/N(T),7X
     1,5HPOWER,9X,6HPOISON/10H    DESCR.,53X,8HFRACTION,7X,6HFACTOR)
  131 FORMAT(1HK,26H  IN MESH INTERVAL NUMBER ,I4//15X,58HTHE CONVERSION
     1 RATIO AT THE START OF THE TIME INTERVAL IS ,F10.6//15X,56HTHE CON
     2VERSION RATIO AT THE END OF THE TIME INTERVAL IS ,F10.6)
  140 FORMAT(1HL,24H    TOTAL FUEL INVENTORY,10X,E12.6,10X,E12.6/9X,
     112HIN KILOGRAMS)
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141 FORMAT(1HK,24H     TOTAL FUEL INVENTORY,10X,E12.6,10X,E12.6/10X,
   19HIN POUNDS)
150 FORMAT(7E15.6)
151 FORMAT(1HL,10(1H+),95H  ALL ZONES HAVE BEEN SEARCHED FOR A NON-DEP
   1LETABLE ZONE STARTING POINT AND NONE HAS BEEN FOUND/1X,10(1H+),
   29H  MSUM = ,I3,12H AND MESH = ,I3)
152 FORMAT(10(3H **),23H MESH INTERVALS NUMBER ,I4,6H THRU ,I4,
   11X,10(3H **))
153 FORMAT(1HL,81H  NO FISSIONABLE ISOTOPES OR CONSEQUENT FISSION PROD
   1UCTS OCCUR IN MESH INTERVALS ,I4,6H THRU ,I4)
154 FORMAT(1HK,28H     MEGAWATT-DAYS/METRIC TON,17X,E12.6)
155 FORMAT(1HK,9H  ISOTOPE,10X,4HN(T),9X,6HN(T+1),7X,11HN(T+1)/N(T),7X
   1,6HPOISON/10H     DESCR.,54X,6HFACTOR)
156 FORMAT(1HL,60H   ALL MESH INTERVALS HAVE BEEN TRAVERSED FOR TIME I
   1NTERVAL ,I2/64H     THE FLUX WILL NOW BE RENORMALIZED FOR THE NEXT
   2TIME INTERVAL)
157 FORMAT(1HK,84H THE FOLLOWING EDIT IS AVERAGED OVER ALL MESH INTERV
   1ALS IN WHICH EACH ISOTOPE OCCURS)
158 FORMAT(1HK,6X,A5,E20.6,E18.6,E16.6)
164 FORMAT(1HL,56H   CONTAINS BURNABLE POISONS BUT NO FISSIONABLE ISOT
   1OPES)
    RETURN
    END
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$IBFTC FADE    DECK
      SUBROUTINE FISEQ1(*)
C
C
C     SOLVES DEPLETION EQUATIONS FOR FISSIONABLE ISOTOPES
C
C
      COMMON/SET1/ ATDEN(190,40),CONRAT(200),TOPOW(200),VOL(200),RR(200)
     1,RATBEF(200)
      COMMON/SET2/ FLUX(3800),SANSNU(40,20),ABSIG(40,20),SST(20,20),
     1 XNU(12,20)
      COMMON/SET3/ NMIR(200),RAUM(200),RAR(200),DELR(200),MIDRZ(400),
     1NEMO(200)
      COMMON/SET4/ATWGT(20),DECAY(40),THERNU(40),TNAME(40),FRACT(10),
     1NRPT(40),IDVULC(40)
      COMMON/SET5/ VULABS(40),VULFIS(40),VULAMF(40),ADPREV(40),IDYLD(10)
     1 ,Y(20,12),KRON(20)
      COMMON/SET6/ NG,NM,NISOT,TOTVOL,FIWATT,POWER,AVPOW,FNORM
      COMMON/SET7/NFIS,NSPMAT,NBPOI,NFRACT,NYDNUC,NFIRPT
      COMMON/SET8/ DELHR,KHAIN,AVOGAD,NZONR,MOROUT,MODD,DIFFER,NONDPL
      COMMON/SET9/ KTIM,NTINC,KRELL,KCELL
      COMMON/SET10/ KOMP,KONG,KOG,LAND,DELSEC,MESH
      J1=1
      J2=2
      J3=3
      J4=4
      J5=5
      J6=6
      GO TO 201
      ENTRY FISEQ2(*)
   22 J1=7
      J2=8
      J3=9
      J4=10
      J5=11
      J6=12
    8 GO TO (201,202,203,204,205,206),KOMP
C
C     ENTER THE ATOM DENSITY CALCULATIONS FOR FISSIONABLE ISOTOPES
C
C
C     TH232 OR U238
C
  201 ADPREV(J1)=ATDEN(MESH,J1)
      ATDEN(MESH,J1)=ADPREV(J1)*(2.-VULABS(J1)*DELSEC)/(2.+VULABS(J1)*
     1 DELSEC)
      IF(LAND.EQ.1) GO TO 7
C
C     PA233 OR NP239
C
  202 ADPREV(J2)=ATDEN(MESH,J2)
      ATDEN(MESH,J2)=(ATDEN(MESH,J1)+ADPREV(J1))*VULAMF(J1)/(2.*(
     1DECAY(J2)+VULABS(J2)))+(ADPREV(J2)-(ATDEN(MESH,J1)+ADPREV(J1))
     2*VULAMF(J1)/(2.*(DECAY(J2)+VULABS(J2))))*EXP(-(DECAY(J2)+
     3VULABS(J2))*DELSEC)
      IF(ATDEN(MESH,J2).EQ.0.) ATDEN(MESH,J2)=-ATDEN(MESH,J2)
      IF(LAND.EQ.1) GO TO 7
C
C     U233 OR PU239
C
  203 ADPREV(J3)=ATDEN(MESH,J3)
      DO 30 IKE=1,NISOT
      NIKE=IDVULC(IKE)
      IF(NIKE.NE.J2) GO TO 30
      GO TO 32
   30 CONTINUE
      ATDEN(MESH,J3)=(ADPREV(J3)*(2.-VULABS(J3)*DELSEC)+(ATDEN(MESH,J1)
     1 +ADPREV(J1))*VULAMF(J1)*DELSEC)/(2.+VULABS(J3)*DELSEC)
      GO TO 31
   32 ATDEN(MESH,J3)=(ADPREV(J3)*(2.-VULABS(J3)*DELSEC)+(ATDEN(MESH,J2)+
     1ADPREV(J2))*DECAY(J2)*DELSEC)/(2.+VULABS(J3)*DELSEC)
   31 IF(LAND.EQ.1) GO TO 7
C
C     U234 OR PU240
C
  204 ADPREV(J4)=ATDEN(MESH,J4)
      ATDEN(MESH,J4)=(ADPREV(J4)*(2.-VULABS(J4)*DELSEC)+(ATDEN(MESH,J3)+
     1ADPREV(J3))*VULAMF(J3)*DELSEC+(ATDEN(MESH,J2)+ADPREV(J2))*
     2VULAMF(J2)*DELSEC)/(2.+VULABS(J4)*DELSEC)
      IF(LAND.EQ.1) GO TO 7
C
C     U235 OR PU241
C
  205 ADPREV(J5)=ATDEN(MESH,J5)
      IF(J5.EQ.11) GO TO 29
      IF(KONG.EQ.11) GO TO 29
C     U235
      ATDEN(MESH,J5)=(ADPREV(J5)*(2.-VULABS(J5)*DELSEC)+(ATDEN(MESH,J4)
     1+ADPREV(J4))*VULAMF(J4)*DELSEC)/(2.+VULABS(J5)*DELSEC)
      IF(LAND.EQ.1) GO TO 7
      GO TO 206
C     PU241
   29 ATDEN(MESH,J5)=(ADPREV(J5)*(2.-(VULABS(J5)+DECAY(11))*DELSEC)+
     1(ATDEN(MESH,J4)+ADPREV(J4))*VULAMF(J4)*DELSEC)/(2.+(VULABS(J5)+
     2 DECAY(11))*DELSEC)
      IF(LAND.EQ.1) GO TO 7
```

```
C
C     U236 OR PU242
C
  206 ADPREV(J6)=ATDEN(MESH,J6)
      ATDEN(MESH,J6)=(ADPREV(J6)*(2.-VULABS(J6)*DELSEC)+(ATDEN(MESH,J5)
     1+ADPREV(J5))*VULAMF(J5)*DELSEC)/(2.+VULABS(J6)*DELSEC)
      IF(LAND.EQ.1) GO TO 7
      IF(J6.EQ.12) GO TO 25
      IF(KHAIN.EQ.0) GO TO 22
C
C     FOR DUPLICATE FISSIONABLE ISOTOPES
C
   25 IF(NFIRPT.EQ.0) RETURN 1
      LAND=1
    7 IF(KOG.GT.NISOT) RETURN 1
      DO 5 KIM=KOG,NISOT
      IF(NRPT(KIM).EQ.0) GO TO 5
      JADE=IDVULC(KIM)
      IF(ATDEN(MESH,JADE).EQ.0.) GO TO 5
      KOG=KIM+1
      KOMP=NRPT(KIM)-10
      IF(KOMP.GT.6) GO TO 320
      J1=1
      J2=2
      J3=3
      J4=4
      J5=5
      J6=6
      GO TO 330
  320 J1=7
      J2=8
      J3=9
      J4=10
      J5=11
      J6=12
  330 GO TO (301,302,303,304,305,306,301,302,303,304,305,306),KOMP
  301 J1=IDVULC(KIM)
      GO TO 315
  302 J2=IDVULC(KIM)
      IF(NRPT(KIM-1).EQ.11)  J1=IDVULC(KIM-1)
      IF(NRPT(KIM-1).EQ.17)  J1=IDVULC(KIM-1)
      GO TO 315
  303 J3=IDVULC(KIM)
      IF(NRPT(KIM-1).EQ.12)  J2=IDVULC(KIM-1)
      IF(NRPT(KIM-1).EQ.18)  J2=IDVULC(KIM-1)
      GO TO 315
  304 J4=IDVULC(KIM)
      IF(NRPT(KIM-1).EQ.13)  J3=IDVULC(KIM-1)
      IF(NRPT(KIM-1).EQ.19)  J3=IDVULC(KIM-1)
      IF(NRPT(KIM-2).EQ.12)  J2=IDVULC(KIM-2)
      IF(NRPT(KIM-2).EQ.18)  J2=IDVULC(KIM-2)
      GO TO 315
  305 J5=IDVULC(KIM)
      IF(NRPT(KIM-1).EQ.14)  J4=IDVULC(KIM-1)
      IF(NRPT(KIM-1).EQ.20)  J4=IDVULC(KIM-1)
      GO TO 315
  306 J6=IDVULC(KIM)
      IF(NRPT(KIM-1).EQ.15)  J5=IDVULC(KIM-1)
      IF(NRPT(KIM-1).EQ.21)  J5=IDVULC(KIM-1)
  315 CONTINUE
      KONG=KOMP
      IF(KOMP.LE.6) GO TO 8
      KOMP=KOMP-6
      GO TO 8
    5 CONTINUE
      RETURN
      END
```

```
$IBFTC POUT    DECK
      SUBROUTINE OUTPUT
      COMMON/SET1/ ATDEN(190,40),CONRAT(200),TOPOW(200),VOL(200),RR(200)
     1,RATBEF(200)
      COMMON/SET2/ FLUX(3800),SANSNU(40,20),ABSIG(40,20),SST(20,20),
     1 XNU(12,20)
      COMMON/SET3/ NMIR(200),RAUM(200),RAR(200),DELR(200),MIDRZ(400),
     1NEMO(200)
      COMMON/SET4/ATWGT(20),DECAY(40),THERNU(40),TNAME(40),FRACT(10),
     1NRPT(40),IDVULC(40)
      COMMON/SET5/ VULABS(40),VULFIS(40),VULAMF(40),ADPREV(40),IDYLD(10)
     1 ,Y(20,12),KRON(20)
      COMMON/SET6/ NG,NM,NISOT,TOTVOL,FIWATT,POWER,AVPOW,FNORM
      COMMON/SET8/ DELHR,KHAIN,AVOGAD,NZONR,MOROUT,MOOD,DIFFER,NONDPL
      DIMENSION LABEL(40),CARRY(40)
C
C     OUTPUT EDIT - DETERMINATION OF THE NUMBER OF MATERIALS TO BE
C     NEEDED FOR THE NEXT TDSN CALC - CALCULATES AVERAGE ATOM DENSITIES
C     AFTER CHOOSING ON THE BASIS OF MACROSCOPIC COMPARISONS
C
  100 FORMAT(1H1)
  102 FORMAT(1HL,46H   THE ATOM DENSITIES TO BE USED FOR THE NEXT ,I2,
     117H MESH INTERVALS ( ,I3,5H THRU ,I3, 5H) ARE//)
  103 FORMAT(8E14.6)
  104 FORMAT(2H* ,7I10)
  105 FORMAT(7E10.5)
  106 FORMAT(1HL,10X,23HMACGG INPUT CARD IMAGES//)
  107 FORMAT(5X,7E14.6)
  108 FORMAT(1H1,88H   MACROSCOPIC ABSORPTION CROSS SECTIONS BY MESH INT
     1ERVAL,BY GROUP,AND BY VULCAN ISOTOPE)
  109 FORMAT(1HL,24H   MESH INTERVAL NUMBER ,I3)
  110 FORMAT(1HK,23H   ENERGY GROUP NUMBER ,I3//)
  111 FORMAT(1HL,25H   MESH INTERVALS NUMBER ,I3,6H THRU ,I3)
  112 FORMAT(56H    AVERAGED ATOM DENSITIES FOR NEXT SPATIAL CALCULATION
     1)
  151 FORMAT(1HL,10(1H+),95H  ALL ZONES HAVE BEEN SEARCHED FOR A NON-DEP
     1LETABLE ZONE STARTING POINT AND NONE HAS BEEN FOUND/1X,10(1H+),
     29H  MSUM = ,I3,12H AND MESH = ,I3)
      LGO=0
      LSTOP=0
      IF(MOROUT.EQ.0.OR.MOROUT.EQ.2) GO TO 57
C
C     THROUGH STATEMENT 42 IS THE MACROSCOPIC PRINTOUT
C
      WRITE(6,108)
      KOKO=NISOT-NONDPL
      LIM=0
   55 LIM=LIM+1
      MSUM=0
      DO 50 MID=1,KOKO
      IF(ATDEN(LIM,MID).NE.0.) GO TO 52
   50 CONTINUE
      DO 51 KAT=1,NZONR
      MSUM=MSUM+NMIR(KAT)
      IF(MSUM.EQ.(LIM-1)) GO TO 53
   51 CONTINUE
      WRITE(6,151) MSUM,LIM
   53 IF(NMIR(KAT+1).EQ.1) GO TO 52
      LUSH=LIM+NMIR(KAT+1)-1
      WRITE(6,111) LIM,LUSH
      GO TO 54
   52 WRITE(6,109) LIM
   54 DO 43 LIG=1,NG
      DO 44 NIB=1,NISOT
      LID=IDVULC(NIB)
      IF(ABSIG(LID,LIG).EQ.0.) ADPREV(LID)=ATDEN(LIM,LID)
   44 ATDEN(LIM,LID)=ATDEN(LIM,LID)*ABSIG(LID,LIG)
      WRITE(6,110) LIG
      WRITE(6,103) (ATDEN(LIM,LID),LID=1,NISOT)
      DO 45 NIB=1,NISOT
      LID=IDVULC(NIB)
      IF(ABSIG(LID,LIG).EQ.0.) GO TO 47
      ATDEN(LIM,LID)=ATDEN(LIM,LID)/ABSIG(LID,LIG)
      GO TO 45
   47 ATDEN(LIM,LID)=ADPREV(LID)
   45 CONTINUE
   43 CONTINUE
      IF(MSUM.NE.0) LIM=LUSH
   42 IF(LIM.LT.NM) GO TO 55
C
C
   57 MESH=0
      IF(DIFFER.EQ.0.) DIFFER=.001
C     THE FOLLOWING LOOP IS FOR THE ZONE SWEEP
    5 DO 10 IX=1,NZONR
      LGO=LSTOP+1
      LSTOP=LGO+NMIR(IX)-1
      MARS=0
      METRO=0
      MESH=MESH+1
      JAVE=0
      METRO=NMIR(IX)-1
      IF(METRO.EQ.0) GO TO 17
C     FOLLOWING IS THE MESH SWEEP WITHIN ZONE IX
      DO 11 JX=1,METRO
      KAVG=1
      MESH=MESH+1
   14 RAVG=KAVG
      COVA=DIFFER*RAVG
      MM=MESH-KAVG
      LGRUP=0
```

```
      JIG=0
C     SWEEP BY GROUP
    1 JIG=JIG+1
C     THE 40 LOOP IS TO CHANGE TO MACROSCOPIC CROSS SECTIONS FOR
C     COMPARISON TEST BY MESH INTERVAL WITHIN REGION, THEN BY ISOTOPE
      DO 40 JIM=MM,MESH
      FAHR=0.0
      DO 40 NIB=1,NISOT
      JID=IDVULC(NIB)
      IF(ABSIG(JID,JIG).GT.0.) GO TO 56
      ATDEN(JIM,JID)=-ATDEN(JIM,JID)
      GO TO 40
   56 ATDEN(JIM,JID)=ATDEN(JIM,JID)*ABSIG(JID,JIG)
      IF(JIM.NE.MESH) GO TO 40
      IF(JID.LE.12.OR.NRPT(NIB).NE.0) FAHR=FAHR+ATDEN(MESH,JID)
   40 CONTINUE
      FAHR=10.*FAHR*DIFFER
C     THE 12 LOOP IS THE COMPARISON TEST BY ISOTOPE FOR GROUP JIG
    3 DO 12 KDZ=1,NISOT
      IDZ=IDVULC(KDZ)
      IF(ATDEN(MM,IDZ).GT.0.) GO TO 15
      QUOI=1.0
      GO TO 16
   15 QUOI=ATDEN(MESH,IDZ)/ATDEN(MM,IDZ)
   16 IF(ABS(QUOI-1.).GT.COVA.AND.ATDEN(MESH,IDZ).GT.FAHR) GO TO 19
   12 CONTINUE
      LGRUP=LGRUP+1
      GO TO 19
    4 IF(KAVG.GT.1) GO TO 13
C
C     JAVE AT ANY TIME IS EQUAL TO THE NUMBER OF ADJACENT COMPARISONS OR
C     MATCHES THAT HAVE ALREADY BEEN FOUND FOR ANY ONE AVERAGED SET.
C
      JAVE=JAVE+1
      IF(JAVE.GT.1) GO TO 13
C
C     KARY IS THE MESH INTERVAL THAT CONTAINS THE AVERAGED ATOM DENSITY
C     (NEGATIVE) FOR THE NEXT MESHM1-KARY MESH INTERVALS.
C
      KARY=MESH-1
   13 IF(MM.EQ.KARY) GO TO 18
C
C     KAVG IS THE ORDER OF THE COMPARISON AT HAND, E.G., =1 IF COMPAR-
C     ISON IS WITH AN ADJACENT MESH INTERVAL,=2 IF THE COMPARISON IS
C     WITH THE MESH INTERVAL SECOND PRECEDING THE CURRENT ONE,ETC.
C
      KAVG=KAVG+1
      GO TO 14
   18 IF(JX.EQ.METRO) GO TO 22
      GO TO 11
C     THE 46 LOOP CHANGES BACK TO ATOM DENSITIES FROM MACROSCOPICS
   19 DO 46 JIM=MM,MESH
      DO 46 NOK=1,NISOT
      JID=IDVULC(NOK)
      IF(ABSIG(JID,JIG).GT.0.) GO TO 90
      ATDEN(JIM,JID)=-ATDEN(JIM,JID)
      GO TO 46
   90 ATDEN(JIM,JID)=ATDEN(JIM,JID)/ABSIG(JID,JIG)
   46 CONTINUE
      IF(JIG.LT.NG) GO TO 1
      IF(LGRUP.EQ.NG) GO TO 4
      IF(KAVG.EQ.JAVE) GO TO 26
      IF(JAVE.NE.0) GO TO 26
      KARY=MESH-1
      MESHM1=KARY
      IF(JX.EQ.METRO) MARS=1
      GO TO 21
   26 MESHM1=MESH-1
      IF(JX.EQ.METRO) MARS=1
      GO TO 21
   22 MESHM1=MESH
   21 VOLUME=0.0
      DO 25 MED=KARY,MESHM1
   25 VOLUME=VOLUME+VOL(MED)
      DO 23 KDA=1,NISOT
      IDA=IDVULC(KDA)
      AXE=0.0
      DO 24 MED=KARY,MESHM1
   24 AXE=AXE+ATDEN(MED,IDA)*VOL(MED)
   23 ATDEN(KARY,IDA)=-AXE/VOLUME
   11 CONTINUE
      IF(MARS.EQ.1) GO TO 17
      GO TO 10
   17 DO 27 JMP=1,NISOT
      IMP=IDVULC(JMP)
   27 ATDEN(MESH,IMP)=-ATDEN(MESH,IMP)
   10 CONTINUE
```

```
C
C     CALCULATION OF MACGG INPUT
C
      WRITE(6,100)
      WRITE(6,112)
      NUDE=0
      MOOD=0
      DO 32 MOUT=1,NM
      DO 31 KOUT=1,NISOT
      IOUT=IDVULC(KOUT)
      IF(ATDEN(MOUT,IOUT).GT.0.) GO TO 30
      ATDEN(MOUT,IOUT)=-ATDEN(MOUT,IOUT)
   31 CONTINUE
      IF(NUDE.EQ.0) GO TO 30
   33 NEND=MOUT-1
      NART=MOUT-NUDE
      WRITE(6,102) NUDE,NART,NEND
      MOOD=MOOD+1
      NEMO(MOOD)=NUDE
      LUG=0
C
C     REARRANGE ATOM DENSITIES IN MACGG ORDER AND COMPRESS
C
      DO 36 MX=1,NISOT
      ID=IDVULC(MX)
      CARRY(MX)=0.0
   36 CARRY(MX)=ATDEN(NART,ID)
      DO 35 LX=1,NISOT
      IF(CARRY(LX).LE.0.) GO TO 35
      LUG=LUG+1
      CARRY(LUG)=CARRY(LX)
      LABEL(LUG)=LX
   35 CONTINUE
      WRITE(6,106)
      WRITE(6,104) LUG,(LABEL(KJ),KJ=1,LUG)
      PUNCH 105, (CARRY(KM),KM=1,LUG)
      WRITE(6,107) (CARRY(KM),KM=1,LUG)
      NUDE=1
      GO TO 34
   30 NUDE=NUDE+1
   34 IF(MOUT.NE.NM) GO TO 32
      MOUT=MOUT+1
      GO TO 33
   32 CONTINUE
      RETURN
      END
```

```
$IBMAP  BCREAD
        ENTRY   BCREAD                                          11/1/65   JMLR      1
BCREAD  SAVE    1,4                                             11/1/65   JMLR      2
        CLA     3,4             GET FIRST ARG.                  11/1/65   JMLR      3
        LDQ     4,4             GET SECOND ARG.                 11/1/65   JMLR      4
        TLQ     *+2             COMPARE                         11/1/65   JMLR      5
        XCA                     IF 2ND LESS  EXCHANGE           11/1/65   JMLR      6
        STQ     TEMP            STORE SMALLEST ARG              11/1/65   JMLR      7
        ADD     SYSONE          ADD 1                           11/1/65   JMLR      8
        STA     STD             STORE FOR MOVE                  11/1/65   JMLR      9
        SUB     TEMP            COMPUTE COUNT                   11/1/65   JMLR     10
        STA     IX1             STORE FOR MOVE                  11/1/65   JMLR     11
        AXC     UNC-3,4         LOCATE UNO5 LIKE FIV CALL       11/1/65   JMLR     12
        SXA     SYSLOC,4        AND SAVE IN SYSLOC              11/1/65   JMLR     13
        CALL    ..BCRD          SET UP READ                     11/1/65   JMLR     14
READ    TSX     ..FIOC,4        READ RECORD                     11/1/65   JMLR     15
        TSX     ..FTCK,4        CHECK READ                      11/1/65   JMLR     16
IX1     AXT     **,1            PICK UP COUNT LEFT              11/1/65   JMLR     17
        TXL     LASTC,1,22      IS ONLY 1 REC LEFT              11/1/65   JMLR     18
IX4     AXT     0,4             REC CNT                         11/1/65   JMLR     19
        CLA     ..BRDB+2,4      MOVE WORDS                      11/1/65   JMLR     20
STO     STO     **,1            TO STORE                        11/1/65   JMLR     21
        TIX     *+1,1,1         DECR. COUNT                     11/1/65   JMLR     22
        TXI     *+1,4,-1        DECR. REC COUNT                 11/1/65   JMLR     23
CKIR4   TXH     STO-1,4,-22       CR. REC COUNT                 11/1/65   JMLR     24
        SXA     IX1,1           NO SAVE REMAINING COUNT         11/1/65   JMLR     25
        TRA     READ            GO READ NEXT RECORD             11/1/65   JMLR     26
LASTC   TXL     DONE,1,0        ANY MORE WORDS                  04/26/66   TS      27
        AXT     DONE,4          YES STORE TO EXIT NEXT          11/1/65   JMLR     28
        SXA     LASTC-1,4       TIME                            11/1/65   JMLR     29
        SCD     CKIR4,1         SET REC CNT = NO WORDS LEFT     11/1/65   JMLR     30
        TRA     IX4             GO PROCESS RECORD               11/1/65   JMLR     31
DONE    AXT     READ,4          RESTORE EXIT                    11/1/65   JMLR     32
        SXA     LASTC-1,4                                       11/1/65   JMLR     33
        AXT     -22,4           RESTORE REC CNT                 11/1/65   JMLR     34
        SXD     CKIR4,4                                         11/1/65   JMLR     35
        RETURN  BCREAD                                          11/1/65   JMLR     36
UNC     PZE     .UNO5.          ADD OF UNIT 5                   11/1/65   JMLR     37
TEMP    PZE                                                     11/1/65   JMLR     38
        END                                                                       39
```

```
$IBFTC PLOTXY
      SUBROUTINE PLOTXY(X,Y,K,P)                                          1
C     REFERENCE NASA TN D-2174 , APRIL,1964, BY LOIS T. DELLNER
C     AND BETTY JO MOORE
C                                                                         2
      COMMON/JOLO/N,F,DX,XYX,FORY,STUG,LABOUT,TONLY,KSW64,KPWR,KFD,TLINX  3
       LOGICAL XYX,FORY, STUG,TONLY,XGL,LS                                4
      DIMENSION X(1),Y(1),P(1)                                            5
      DIMENSION FLS(3),FLAB(4),FYLAB(4),YLABEL(11),A(104),ELS(3)          6
      EQUIVALENCE (FLAB(3),IFLAB3),(FYLAB(3),IYLAB)                       7
      DATA MASK1, MASK2,MASK4,MASK8,MASK16,MASK32,MASK64   /              8
     1        01,   02,   04,   010,   020,   040,  0100   /              9
      DATA FYLAB(1),FYLAB(2),FYLAB3,FYLAB(4)   /                         10
     1    6H(2HP ,,6H20X,11  ,6H F10.0,1H)  /                            11
      DATA BLANK,XGRID,YGRID /1H ,1H-,1H1 /                              12
       DATA RMARK,PCSTD/0726060606060,1H*/                               13
      DATA  FLS(1),FLS28,FLS264,FLS2B,FLS38,FLS3B /                      14
     1    6H(2HP+,,4H11X,, 3H5X,,3HA5,,3HA6),6H2F6.3) /                  15
      DATA FLAB(1),FLAB(2),FLAB3,FLAB(4) /                               16
     1   6H(2HP+,,4H17X,,6H  F9.0,1H)    /                               17
C                                                                        18
  100 WRITE (6,500)                                                      19
  500 FORMAT(2HPT)                                                       20
  102 KODE=K                                                             21
       N=P(1)                                                            22
       LABOUT=1                                                          23
       FLAB(3) = FLAB3                                                   24
       LS = .FALSE.                                                      25
      FYLAB(3)=FYLAB3                                                    26
      KSW8=0                                                             27
      KSW64=0                                                            28
  110 PC=PCSTD                                                           29
  112 IF((AND(KODE,MASK1)).GT.0.)PC = P(2)                               30
  114 M=10                                                               31
  116 IF((AND(KODE,MASK2)).GT.0.)M=P(3)                                  32
  117 IF (M.EQ.0)M=1000                                                  33
  118 NY=10                                                              34
  120 IF((AND(KODE,MASK4)).GT.0.)NY = P(4)                               35
  121 IF(NY.EQ.0) NY=1000                                                36
  122 IF((AND(KODE,MASK64)).GT.0.)KSW64=2                                37
  124 IF((AND(KODE,MASK8)).GT.0.)KSW8=1                                  38
C                                                                        39
  125 K864=KSW8+KSW64                                                    40
  126 IF(K864-2) 132,128,138                                             41
  128 FLS(2)=FLS264                                                      42
  130 GO TO 139                                                          43
  132 FLS(2)=FLS28                                                       44
  134 FLS(3)=FLS38                                                       45
  136 GO TO 140                                                          46
  138 FLS(2)=FLS2B                                                       47
  139 FLS(3)=FLS3B                                                       48
C                                                                        49
  140 XYX=.FALSE.                                                        50
  142 FORY=.TRUE.                                                        51
  144  STUG=.FALSE.                                                      52
  146 TONLY=.FALSE.                                                      53
C                                                                        54
  148 IF((AND(KODE,MASK32).LE.0.))  GO TO 172                            55
  151 STUG=.TRUE.                                                        56
  152 KSY=P(9)                                                           57
  154 PWR10Y=10.**(KSY-6)                                                58
  156 FY =P(10)*PWR10Y                                                   59
  158 F = FY                                                             60
C                                                                        61
  160 IF(P(5).GE.2.) GO TO 172                                           62
  162 TONLY=.TRUE.                                                       63
  164 DY= P(11)*PWR10Y                                                   64
  166 DX= DY                                                             65
  172 CALL PISTUG(Y)                                                     66
  173 IF(DX.EQ.0.) GO TO 700                                             67
  174 FY=F                                                               68
  176 DY=DX                                                              69
  180 IF(KSW64.EQ.2) KPWRY=KPWR                                          70
  190 IYLAB=IYLAB-KFD                                                    71
C                                                                        72
  200 XYX =.TRUE.                                                        73
  202 FORY=.FALSE.                                                       74
  204 STUG=.FALSE.                                                       75
  206 TONLY=.FALSE.                                                      76
  208 TLINX=55*(1+N/35)                                                  77
C                                                                        78
  210 IF((AND(KODE,MASK16).LE.0.)) GO TO 232                             79
  213 STUG=.TRUE.                                                        80
  214 KSX = P(6)                                                         81
  216 PWR10X=010.**(KSX-6)                                               82
  218 FX= P(7)*PWR10X                                                    83
  220 F=FX                                                               84
```

```
C                                                                       85
  222 IF(MOD(IFIX(P(5)),2).EQ.1) GO TO 232                              86
  224 TONLY=.TRUE.                                                      87
  226 DX =P(8)*PWR10X                                                   88
  232 CALL PISTUG(X)                                                    89
      IF(DX.EQ.0.) GO TO 700                                            90
  234 FX=F                                                              91
  240 IF(KSW64.EQ.2) KPWRX=KPWR                                         92
  248 IFLAB3=IFLAB3-KFD                                                 93
C                                                                       94
  250 IF(KSW64.EQ.0)GO TO 264                                           95
  252 KOUTX=-KPWRX                                                      96
  254 KOUTY=-KPWRY                                                      97
  256 F10X=10.**KPWRX                                                   98
  258 F10Y=10.**KPWRY                                                   99
  260 WRITE (6,502) KOUTX,KOUTY                                        100
  502 FORMAT(2HPT,6X, 3HX*E,I2,4H Y*E,I2)                              101
C                                                                      102
  264 DO 278 I=1,11                                                    103
  266 TEMP = FY+FLOAT(I-1)*DY*10.                                      104
  268 ATEMP= ABS(TEMP)                                                 105
  270 IF (ATEMP.LT.1.E-7) TEMP = 0.                                    106
  272 IF (ATEMP.GE.1.E+7)LABOUT=2                                      107
  278 YLABEL(I)=TEMP                                                   108
  300 KSYLAB =1                                                        109
  302 WRITE (6,FYLAB) (YLABEL(I),I=1,11)                               110
  304 GO TO (306,700),KSYLAB                                           111
C                                                                      112
  306 KSYLAB =2                                                        113
  310 LCTR=0                                                           114
      NCTR=1                                                           115
      KOUT=1                                                           116
      KQUIT= 1                                                         117
C                                                                      118
  320 IF(MOD(LCTR,M))328,322,328                                       119
  322 AFILL= XGRID                                                     120
  324 XGL =.TRUE.                                                      121
      GO TO 330                                                        122
  328 XGL =.FALSE.                                                     123
      AFILL=BLANK                                                      124
  330 DO 332 I=2,104                                                   125
  332 A(I) = AFILL                                                     126
  334 DO 336  I=2,104,NY                                               127
  336 A(I)= YGRID                                                      128
      A(1) =BLANK                                                      129
  338 GO TO (340,400),KOUT                                             130
C                                                                      131
  340 KX =(X(NCTR)-FX)/DX +.5                                          132
  342 IF(KX-LCTR)630,350,600                                           133
  350 KY= (Y(NCTR)-FY)/DY+.5                                           134
  351 LS= .TRUE.                                                       135
  352 TPC = PC                                                         136
  353 KYL = KY+2                                                       137
  354 IF(KY.LT.0) GO TO 360                                            138
  356 IF(KY.GT.101)GO TO 364                                           139
  358 GO TO 370                                                        140
  360 KYL=1                                                            141
  362 GO TO 366                                                        142
  364 KYL=104                                                          143
  366 TPC=RMARK                                                        144
C                                                                      145
  370 A(KYL) =TPC                                                      146
  372 J=1                                                              147
  374 IF(KSW8.EQ.0) GO TO 380                                          148
  376 ELS(J)=P(NCTR+11)                                                149
  378 J= J+1                                                           150
  380 IF(KSW64.EQ.0) GO TO 386                                         151
  382 ELS(J)=X(NCTR)/F10X                                              152
  384 ELS(J+1) = Y(NCTR)/F10Y                                          153
C                                                                      154
  386 IF(NCTR.GE.N)GO TO 392                                           155
  388 NCTR=NCTR+1                                                      156
  390 GO TO 340                                                        157
C                                                                      158
  392 KOUT = 2                                                         159
  394 M= 10                                                            160
```

```
C                                                                       161
  400 IF(XGL.AND.(MOD(LCTR,10).EQ.0))KQUIT=2                            162
C                                                                       163
  600 WRITE (6,504)(A(I),I=1,104)                                       164
  504 FORMAT(2HP ,26X,104A1)                                            165
  602 IF(K864.NE.0) GO TO 620                                           166
C                                                                       167
  604 IF(MOD(LCTR,10))614,606,614                                       168
  606 XLABEL =FX+FLOAT(LCTR)*DX                                         169
  608 TEMP =ABS(XLABEL)                                                 170
  610 IF(TEMP.GE.1.E+7)LABOUT=2                                         171
  612 IF(TEMP.LT.1.E-7)XLABEL=0.                                        172
  613 WRITE(6,FLAB) XLABEL                                              173
C                                                                       174
  614 LCTR = LCTR+1                                                     175
  616 GO TO (320,302),KQUIT                                             176
C                                                                       177
  620 IF(.NOT.LS) GO TO 604                                             178
  622 LS = .FALSE.                                                      179
  624 WRITE (6,FLS)(ELS(I),I=1,K864)                                    180
  626 GO TO 604                                                         181
  630 LABOUT= 4                                                         182
  700 GO TO (710,702,706,704),LABOUT                                    183
  702 WRITE (6,506)                                                     184
  506 FORMAT(2HPL,3X,10HBAD LABELS  )                                   185
      GO TO 720                                                         186
C                                                                       187
  704 WRITE(6,520) NCTR                                                 188
  520 FORMAT(2HPL,18HX OUT OF ORDER. I=,I5)                             189
  706 WRITE(6,508)(X(I),Y(I),I=1,2),K,P(1)                              190
  508 FORMAT(2HPL,5H N.G.,4G20.8,I6,F8.2)                               191
  708 GO TO 720                                                         192
  710 WRITE(6,510)                                                      193
  510 FORMAT(2HPL)                                                      194
  720 RETURN                                                            195
      END                                                               196
```

```
$IBFTC PISTUG  ALTIO
       SUBROUTINE PISTUG(ARRAY)                                                  1
       DIMENSION ARRAY(1)                                                        2
      COMMON/JOLO/N,F,DX,XYX,FORY,STUG,LABOUT,TONLY,KSW64,KPWR,KFD,TLINX         3
       LOGICAL XYX,FORY, STUG,TONLY                                             4
  126 X1 = ARRAY(1)                                                             5
  128 IF(XYX) GO TO 133                                                         6
  130 DO 132 J = 2,N                                                            7
  132 X1 = AMIN1(X1,ARRAY(J))                                                   8
  133 IF(STUG) X1=F                                                             9
  134 XN = 0.0                                                                 10
  136 DO 146 J = 1,N                                                           11
  138 DIF = ABS(X1-ARRAY(J))                                                   12
  140 IF(DIF.LE.XN)GO TO 146                                                   13
  142 XN=DIF                                                                   14
  144 IHOLD=J                                                                  15
  146 CONTINUE                                                                 16
  147 XN = ARRAY(IHOLD)                                                        17
  148 IF(KSW64.EQ.2) KPWR = KHAR(AMAX1(ABS(X1),ABS(XN)))                       18
  149 IF(TONLY) GO TO 240                                                      19
  150 TLIN=101.                                                                20
  152 IF(.NOT.FORY) TLIN = TLINX                                               21
  154 C5 = (XN-X1)/TLIN                                                        22
  156 C6 = ABS(C5)                                                             23
  158 IF(C6.EQ.0.) GO TO 300                                                   24
  159 K7 = KHAR(C6)                                                            25
  160 C8 = 10.**K7                                                             26
  162 C9 = C6/C8                                                               27
  164 IF((2.5-C9).LE.0.0) GO TO 172                                            28
  166 D=2.                                                                     29
  168 IF((2.0-C9).LE.0.) D=2.5                                                 30
  170 GO TO 176                                                                31
  172 D=5.                                                                     32
  174 IF((5.-C9).LE.0.0) D=10.                                                 33
  176 C11 = D*C8                                                               34
  178 DX = SIGN(C11,C5)                                                        35
  179 HUND = 100.*DX                                                           36
  240 K7 = KHAR(ABS(DX))                                                       37
  250 KFD = 0                                                                  38
  252 IF(K7) 260,270,254                                                       39
  254 IF(K7.GE.5) LABOUT=2                                                     40
  256 GO TO 270                                                                41
  260 KFD = 6                                                                  42
  262 IF(K7.LT.(-7)) LABOUT = 2                                                43
  264 IF(K7.GT.(-6)) KFD = -K7                                                 44
  270 IF(STUG) GO TO 230                                                       45
  182 KC12 = INT(ABS(X1)/C11)                                                  46
  184 JJ = 1                                                                   47
  186 IF(X1) 188,192,190                                                       48
  188 JJ = 3                                                                   49
  190 IF(DX.LT.0.) JJ = JJ+1                                                   50
  192 GO TO (193,194,195,196),JJ                                               51
  193 KC14 = KC12                                                              52
       GO TO 198                                                               53
  194 KC14 = KC12+1                                                            54
       GO TO 198                                                               55
  195 KC14 = -KC12-1                                                           56
       GO TO 198                                                               57
  196 KC14 = -KC12                                                             58
  198 KC13 = MOD(KC12,10)                                                      59
       KC15 = KC12-KC13                                                        60
  199 KC18 = KC15                                                              61
  200 GO TO (212,202,202,210),JJ                                               62
  202 KC18 = KC18+10                                                           63
  204 IF(KC13.NE.9) GO TO 210                                                  64
  206 KC18 = KC14                                                              65
  208 GO TO 212                                                                66
  210 IF(X1.LT.0.)KC18 = -KC18                                                 67
  212 F=C11*FLOAT(KC18)                                                        68
  214 IF(.NOT.FORY) GO TO 230                                                  69
  220 TEMP = F+HUND                                                            70
  222 GO TO (224,228,224,228),JJ                                               71
  224 IF(TEMP.GE.XN) GO TO 230                                                 72
  226 GO TO 229                                                                73
  228 IF(TEMP.LE.XN) GO TO 230                                                 74
  229 F=C11*FLOAT(KC14)                                                        75
  230 CONTINUE                                                                 76
       RETURN                                                                  77
  300 DX=0.                                                                    78
       LABOUT=3                                                                79
       GO TO 230                                                               80
       END                                                                     81
$IBFTC KHAR    ALTIO
       FUNCTION KHAR(XMAX)                                                      1
       KHAR = INT(ALOG(XMAX)/2.302585+40.0)-40                                  2
       RETURN                                                                   3
       END                                                                      4
```

Lewis Research Center,
National Aeronautics and Space Administration,
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