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"LOLA SYSTEM : A CODE BLOK FOR NODAL PWR SIMULATION"

PART. I - SIMULA-3 CODE.

por

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COMPUTER CODE ABSTRACT

LOLA SYSTEM

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This code has been included in the coordinated Research Programme (CRP) on "Codes Adaptable to Small and Medium Size Computers Available in developing countries for In-Core Fuel Management" of the International Atomic Energy Agency.

1. Program, Name and Title:

LOLA System, a code block for Nodal PWR simulation.

2. Problem solved:

The LOLA System is a part of the JEN-UPM code package for PWR fuel management, scope or design calculations. It is a code package for core burnup calculations using nodal theory based on a FLARE type code. The LOLA System includes four modules; the first one (MELON-3) generates the constants of the K_∞ and M^2 correlations to be input into SIMULA-3. It needs the K_∞ and M^2 fuel assembly values at different conditions of moderator temperature, Boron concentration, burnup, etc., which are provided by MARIA fuel assembly calculations.

The main module (SIMULA-3) is the core burnup calculations code in three dimensions and one group of energy, it normally uses a geometrical representation of one node per fuel assembly or per quarter of fuel assembly. It has included a thermal hydraulic feed-back on flow and voids and criticality searches on Boron concentration and control rods insertion.

The CONCON code makes the calculation of the albedoes, transport factors, K_∞ and M^2 correction factors to be input into SIMULA-3. The calculation is made in the XY transversal plane. The CONAXI code is similar to CONCON, but in the axial direction.

3. Method of solution:

MELON-3 makes a mean squares fit of K_∞ and M^2 values at different conditions in order to determine the constants of the feedback correlations.

SIMULA-3 uses a modified 1-group nodal theory, with a new transport kernel that provides the same node interface leakages than a fine mesh diffusion calculation.

CONCON and CONAXI determine the transport and correction factors, as well as the albedoes, to be input into SIMULA-3; by a method of leakages equivalence to the detailed diffusion

calculation of CARMEN or VENTURE, these factors include also the heterogeneity effects inside the node.

4. Restrictions:

No. of X,Y,Z nodes ≤ 15x15x17
No. of material types ≤ 15
No. of fuel assembly types ≤ 15

5. Unusual features of the system:

SIMULA-3 uses as input data the interface units generated by the other modules, with the correlation constants, the transport factors, the albedoes and the K_∞ and M^2 correction factors.

6. Relationship to other programs:

MARIA System generates the K_∞ and M^2 values at different conditions to be input into MELON-3.

CARMEN System provides the detailed fine-mesh fluxes and the cross sections by zone to be input into CONCON and CONAXI codes.

7. Other programming, restrictions or operating information:

None.

8. Computer and language.

UNIVAC-1100 and CYBER-835.
FORTRAN - V.

9. Typical Running Time.

The module with a more relevant running time is the SIMULA-3, with about 90 cpu seconds per burnup step in the UNIVAC-1100/80 or in the CYBER-835.

10. Operating System.

UNIVAC-1100, EXEC 8; CYBER-835, NOS 2.1

11. Machine requirements

18K works for the code source and about 38Kwords for the data.

12. Availability.

Available through the OECD-NEA Data Bank, Saclay, France.

13. Status.

Production.

14. References:

1.- J.M. Aragonés, C. Ahnert, J. Gómez Santamaría and I. Rodríguez Olabarría, "LOLA System, a code block for nodal PWR simulation". 1ª parte JEN-568, 2ª parte JEN-571 (1984).

2.- J.M. Aragonés, C. Ahnert, "MARIA System, a code block for PWR fuel assembly calculations". JEN-543 (1983).

3.- C. Ahnert, J.M. Aragonés. "CARMEN System, a code block for neutronic PWR calculation by diffusion theory with space dependent feedback effects". JEN-515 (1982).

I N D E X

1. INTRODUCTION.

The LOLA System is a part of the JEN-UPM code package, for PWR fuel management, scope or design calculations. It is also a code package for core burnup calculations using the nodal theory. The CARMEN [1] and MARIA [2] Systems complete the whole JEN-UPM package.

The MARIA System is the fuel assembly calculations block, and the CARMEN System is the core burnup calculations block by diffusion theory. The LOLA System is based on a FLARE type [3] nodal code, three dimensional and one energy group, this is the SIMULA-3 code. The SIMULA-3 code may use the geometrical representation of one node per fuel assembly or one node per quarter of fuel assembly.

The LOLA System also includes the MELON-3, CONCON and CONAXI codes (Figure 1). MELON-3 makes the generation of the constants of the k_∞ and M^2 correlations to be input into SIMULA-3. It needs as input data the k_∞ and M^2 fuel assembly values at different conditions of moderator temperature, Boron concentration, burnup, etc.

The fuel assembly calculations for PWR are made by the MARIA System.

The CONCON code makes the calculation of the albedoes, transport factors, k_∞ and M^2 correction factors to be input into SIMULA-3. These parameters are obtained in an explicit way, by a method that preserves the same leakage values in the nodal calculation by SIMULA-3, than in the reference calculation by diffusion theory with CARMEN. The calculation is made in the XY transversal plane.

CONAXI is quite similar to CONCON, but in the axial direction. The four codes are connected by interface units, those connections jointly with the connections to MARIA and CARMEN Systems can be seen in figure 1.

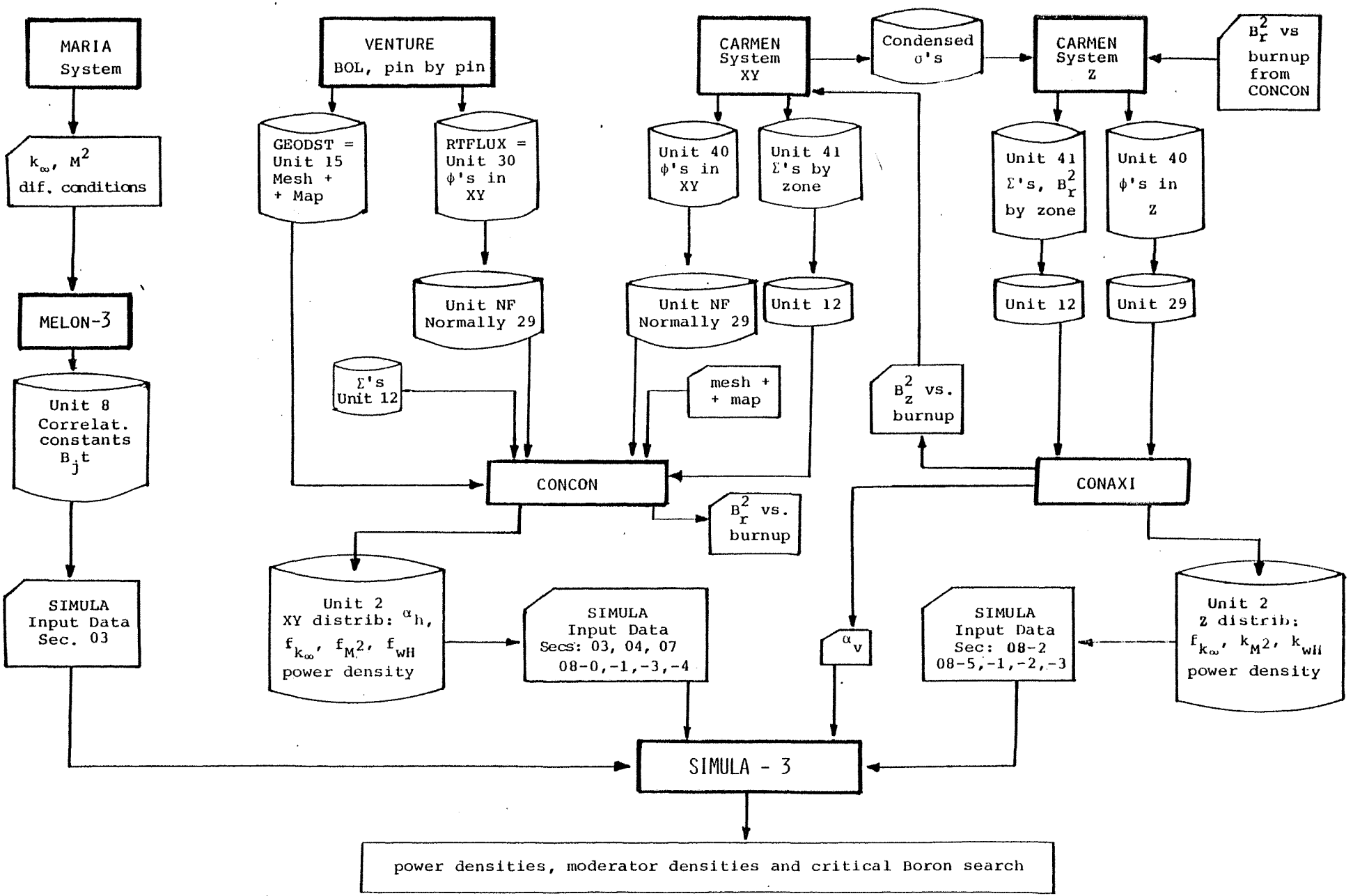


FIGURE 1 - LOLA SYSTEM

1. SIMULA-3 Code.

SIMULA-3 principally determines the region-dependent power (nodal power) distribution for a reactor core with three dimensional (XYZ) geometry. The model is based on a modification to a one-group diffusion theory in which only the average parameters, infinite multiplication factor (k_∞) and migration area (M^2), of each region are involved, The leakages from one region are treated by the "transport kernel", which is a function of the migration area and the node size. The lateral and axial reflectors are replaced by the albedo factor at the core surface, so that only the regions within the active fueled region are considered.

This code allows three dimensional core calculations under reasonable computer times, and provides the spatial distributions of moderator density, neutron source and exposure including the equilibrium Xenon influence, and by option, it is able to determine the temporal evolution of I-135 and Xe-135, the critical soluble poison concentration or control rod position, and permits the refueling and shuffling of the fuel elements at any time in core life.

The original code [4] has beem extended with many new options and procedures, which have been developed specially for PWR applications; accordingly the criterium adopted was to eliminate the options of the old version which were not of use in the PWR procedures and applications. It is possible to use one node per fuel assembly, or one node per quarter of fuel assembly; but is recommended to use the second one for PWR calculations.

The complete calculation, which is iterative in nature, consists of essentially four levels of iteration. The four levels are as follows:

a) Source or power iteration.
b) Void or moderator density iteration.
c) Critical searches.
d) Fuel burnup.

In the following paragraph the procedures used at each level of iteration will be described.

1.1. Methods and procedures.

1.1.1. Physical Model.

1.1.1.1. Source or Power iteration.

S_ℓ the rate of production of fission energy neutrons at node ℓ, is given by

$$\lambda S_\ell = k_{\infty\ell} A_\ell \qquad (1)$$

where

A_ℓ is the absorption rate at node ℓ.
λ is the eigenvalue.

As defined by Equation (1) k_∞ is identical to the usually defined k_∞ only when the spectrum at node ℓ is identical to that which would be present in an infinite array of nodes identical to ℓ. With nodal spacing large compared to the thermal diffusion lenght, L, and large compared to the neutron age from significant resonance capture energies to thermal energies, equation (1) is reasonably well satisfied with k_∞ equal to the usually defined k_∞ calculated for an individual cell identical to the volume associated with the node ℓ. This approximation is assumed in the Nodal calculation and is not unlike similar assumptions made whenever discrete geometries are replaced by homogenized cells in diffusion theory calculations.

The absorption rate at node ℓ is written in terms of

absorption probabilities as

$$A_\ell = \sum_m S_m W_{m\ell} + S_\ell W_{\ell\ell} \qquad (2)$$

where

$W_{m\ell}$ is the probability that a neutron born at node m is ultimately absorbed at node ℓ.

Combining the above two equations one obtains

$$\lambda S_\ell = k_{\infty\ell} \sum_m S_m W_{m\ell} + k_{\infty\ell} S_\ell W_{\ell\ell}$$

$$S_\ell = \frac{\frac{k_{\infty\ell}}{\lambda} \sum_m S_m W_{m\ell}}{1 - \frac{k_{\infty\ell}}{\lambda} W_{\ell\ell}} \qquad (3)$$

the assumption is made that $W_{m\ell}$ is finite only for nearest neighbor nodes so that the summation in (2) and (3) is taken only over the six adjacent nodes. To account for leakage from nodes at the core boundary, the quantity n_ℓ is introduced. n_ℓ is the number of missing neighbor nodes and is equal to zero for interior nodes. In each direction in which the neighbor node is missing, there will be leakage at a rate determined by the boundary condition. The boundary condition at each node is expressed by an albedo, α, for each direction in which there is a missing neighbor. In each direction, α may vary from 0 for no reflection of neutrons to 1 for complete reflection. The nodal albedo α_ℓ is taken as the sum of the albedoes in all directions in which there is a missing neighbor. Thus for a given node α_ℓ may vary from 0 up to n_ℓ. If there were no reflection of neutrons, α_ℓ would be 0 and the nodal leakage would be given by

$$L_\ell = S_\ell W_{\ell m} n_\ell$$

A positive value for α_ℓ can be considered equivalent to a reduction in n_ℓ so that the leakage in general is given by

$$L_\ell = S_\ell W_{\ell m} (n_\ell - \alpha_\ell) \qquad (4)$$

The leakage probability is then

$$\frac{L_\ell}{S_\ell} = W_{\ell m}(n_\ell - \alpha_\ell) \tag{5}$$

All neutrons which do not escape from their node of birth are eventually absorbed there so that the nodal self-absorption probability $W_{\ell\ell}$ is the nodal non leakage probability which can be written as one minus the probability for absorption at neighboring nodes minus the probability of leakage:

$$W_{\ell\ell} = 1 - (6 - n_\ell)W_{\ell m} - (n_\ell - \alpha_\ell)W_{\ell m} =$$

$$= 1 - (6 - \alpha_\ell)W_{\ell m} \tag{6}$$

Substituting equation (6) into equation (3) results in

$$S_\ell = \frac{\frac{k_{\infty\ell}}{\lambda}\Sigma' S_m W_{m\ell}}{1 - \frac{k_{\infty\ell}}{\lambda}\left[1 - (6-\alpha_\ell)W_{\ell m}\right]} \tag{7}$$

where the prime indicates summation over six adjacent nodes. A more general form of equation (7) has been coded for the possibility of $W_{\ell m}$ having different values in the horizontal and vertical directions in the form

$$S_\ell = \frac{\frac{k_{\infty\ell}}{\lambda}\left[\sum_m^v S_m W_{m\ell}^v + \sum_m^h S_m W_{m\ell}^h\right]}{1 - \frac{k_{\infty\ell}}{\lambda}\left[1 - (2-\alpha_\ell^v)W_{\ell m}^v - (4-\alpha_\ell^h)W_{\ell m}^h\right]} \tag{8}$$

where the superscripts refer to vertical and horizontal values.

In the steady state the summation over the entire reactor of the absorption at each node (from eq. 1) and the leakage at each node (from eq. 4) must equal the summation of the source at each node (eq. 7 or 8):

$$\sum_{\ell} S_{\ell} = \sum \frac{S_{\ell}\lambda}{k_{\infty\ell}} + \sum S_{\ell} W_{\ell m} \ (n_{\ell} - \alpha_{\ell}) \qquad (9)$$

where n_{ℓ} and α_{ℓ} are zero at all internal nodes so that the second term on the right gives a contribution only at boundary nodes.

Solving (9) for λ gives

$$\lambda = \frac{\sum_{\ell} S_{\ell} - \sum_{\ell} S_{\ell} W_{\ell m} \ (n_{\ell} - \alpha_{\ell})}{\sum_{\ell} \frac{S_{\ell}}{k_{\infty\ell}}} \qquad (10)$$

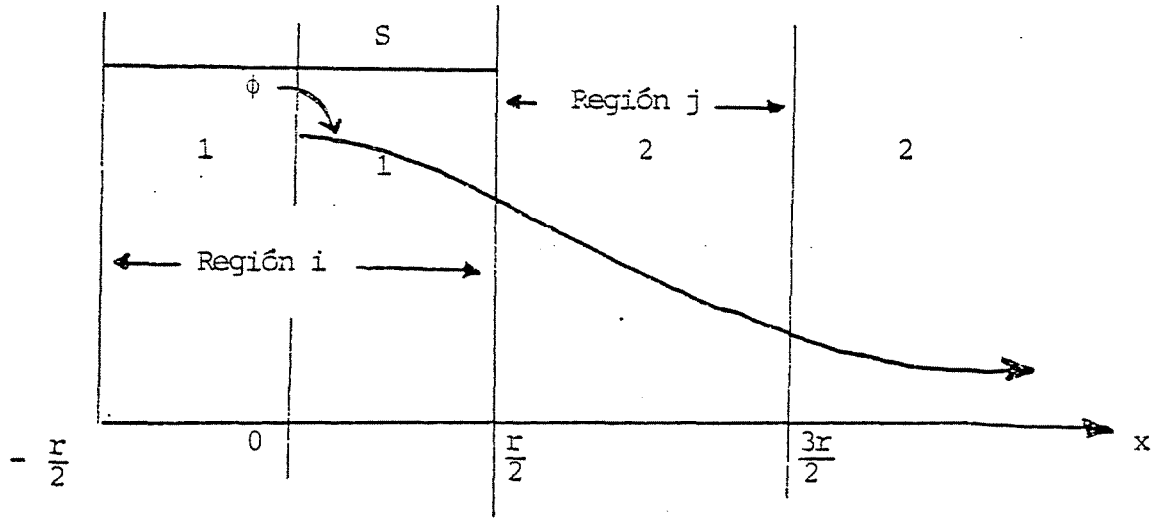
Equation (8) and (10) are solved iteratively starting from an initial guess for the source at each node and λ.

The source interation loop is described in Figure 2.

In the following parragraph the transport kernel expressions and the source iteration equations will be described.

a) Transport kernels.

The transport kernel $W_{\ell m}$ represents the probability that a neutron born at node ℓ is absorbed at node m. Using one dimensional diffusion theory in a uniform infinite medium one can calculate the probability of a neutron born uniformly in a slab of thickness r to be absorbed in an adjacent slab of thickness r.



Designating the region with a source with subscript 1, and without a source with subscript 2, the general solution for the flux in the two regions is given by

$$\Phi_1 = A_1 e^{\frac{x}{L}} + B_1 e^{-\frac{x}{L}} + \frac{S}{\Sigma_a}$$

$$\Phi_2 = A_2 e^{\frac{x}{L}} + B_2 e^{-\frac{x}{L}}$$

The boundary condition that the flux is symmetric about x=0 (current = 0) requires that $A_1=B_1$. The boundary condition that $\Phi_2 \to 0$ as $x \to \infty$, requires that $A_2=0$. Equating the net currents in the two regions at x=r/2 results in

$$B_2 = -A_1\left|e^{\frac{x}{L}} - 1\right|$$

Equating the fluxes in the two regions at x=r/2 allows one to evaluate A_1 and B_2. The solution for Φ_2 is

$$\Phi_2 = \frac{S}{2\Sigma_a}\left(\frac{e^{\frac{r}{L}} - 1}{e^{\frac{r}{2L}}}\right) e^{-\frac{x}{L}}$$

$$W_{ij} = \frac{\text{absorptions in region j}}{\text{source in region i}} = \frac{\int_{r/2}^{3r/2} \Sigma_a \Phi_2(x)\,dx}{\int_{-r/2}^{r/2} S(x)\,dx} =$$

$$= \frac{\frac{S}{2}\left(\frac{e^{\frac{r}{L}} - 1}{e^{\frac{r}{2L}}}\right)(-L)\left[e^{-\frac{x}{L}}\right]_{r/2}^{3r/2}}{Sr}$$

$$W_{ij} = \frac{L}{2r}\left[1 - 2e^{-\frac{r}{L}} + e^{\frac{-2r}{L}}\right] \qquad (11)$$

The W_{ij} value versus $\beta=L/r$ exhibits a broad maximum near $\beta=0.8$. For small values of β, large r, W_{ij} is small because the probability that a neutron escapes from its region of birth is small. For large values of β, small r, W_{ij} is small because the probability of an escaping neutron being captured in an adjacent slab of the same thickness decreases as the thickness decreases. In this case more neutrons are absorbed further away from their point of origin and interactions beyond the nearest neighbors would be important. For small values of β (i.e., values of r>>L) the first term in equation (11) provides a good approximation to W_{ij}.

For the case in which the mesh spacing is small compared with the migration length M, ordinary diffusion theory would be expected to apply. For k_∞ and M^2 constant, the difference form of the one group, one dimensional diffusion equation is

$$\Phi_{i+1} - 2\Phi_i + \Phi_{i-1} + \left(\frac{k_\infty - 1}{M^2}\right) h^2 \Phi_i = 0 \qquad (12)$$

Solving for Φ_i yields

$$\Phi_i = \frac{1}{2-\left(\frac{k_\infty - 1}{M^2}\right)h^2}\left|\Phi_{i+1} + \Phi_{i-1}\right| \qquad (13)$$

Assuming S_i is proportional to Φ_i, equation (13) with $\lambda=1$ leads to the following form for Φ_i:

$$\Phi_i = \frac{k_{\infty i}}{1-k_{\infty i}W_{ii}}\left[\Phi_{i+1} \cdot W_{i+1,i} + \Phi_{i-1}W_{i-1,i}\right] \qquad (14)$$

For the case in which k_∞ and M^2 are constant

$$W_{i+1,i} = W_{i-1,i} = W_{i,i+1} = W_{i,i-1} = W_{ij}$$

and equation (14) can be written

$$\Phi_i = \frac{k_{\infty i} W_{ij}}{1-k_{\infty i} W_{ii}} \left[\Phi_{i+1} + \Phi_{i-1}\right] \tag{15}$$

For the one dimensional situation $W_{ii} = 1-2W_{ij}$ and comparison of equations (13) and (15) results in the following form for W_{ij}.

$$W_{ij} = \frac{M^2}{h^2 k_{\infty i}} \tag{16}$$

This W_{ij} is no longer simply interpretable as an absorption probability but should be looked upon as the form required for W_{ij} in order that the nodal equations (14, 3 or 10) reduce to be equivalent to a one group diffusion theory model. For mesh spacing small compared with M, the one group diffusion theory solution would be expected to be more accurate than a solution based on equation (11) neglecting interactions beyond the nearest neighbors. In the code a general form for W_{ij} has been provided to allow the user to chose the model which best fits his situation. Thus equation (16) has been combined with the first term of equation (11) using a "mixing" factor g and defining

$$W_{ij} = (1-g) \frac{\sqrt{M_i^2}}{2r_{ij}} + g \frac{M_i^2}{r_{ij}^2} \tag{17}$$

In this equation the dependence of W_{ij} on $k_{\infty i}$ (equation 16) has been suppressed for the sake of arriving at a simpler kernel. For g=0, equation (17) reduces to the first term of equation (11) whereas for g=1 equation (17) reduces to equation (16) with $k_{\infty i}$=1.

It can be seen that with W_{ij} defined by equation (17) there is no assurance that

$$W_{ii} \equiv 1 - \sum_j W_{ij} \geq 0$$

For equal W_{ij} at six adjacent nodes this would require

$$W_{ij} < 0{,}1667$$

which can not be obtained for any value of g when $\beta > 0.4$.

From a physical standpoint there is no necessity for W_{ii} to be positive when using the second interpretation of the kernel (eq. 16) i.e., with g=1 in eq. (17). In any case a negative value for W_{ii} will not lead to unphysical results (i.e., negative values of S_ℓ) as can be seen from equation (3). However with g=0 and interpreting W_{ij} as an absorption probability, negative values are unrealistic and therefore an alternate form for the kernel (Second type) has been derived which forces W_{ii} to be ≥ 0. In this alternate kernel it is assumed that W_{ii} has the form

$$W_{ii} = 1 - e^{-\gamma^2 (a^2/M^2)} \tag{18}$$

where γ is an arbitrary constant, and a is the radius of a sphere with equivalent mean chord length.

This leads to the result

$$a = \frac{3(\Delta x)\ (\Delta z)}{2(\Delta x) + 4(\Delta z)}$$

If it is further assumed that

$$\frac{(W_{ij})_{\text{horiz}}}{(W_{ij})_{\text{vert}}} = \left(\frac{\Delta z}{\Delta x}\right)^n$$

then one obtains,

$$(W_{ij})_n = \frac{e^{-\gamma^2 (a^2/M^2)}}{4 + 2\left(\frac{\Delta x}{\Delta z}\right)^n}\ , \quad \gamma \equiv g_h \tag{19}$$

$$(W_{ij})_v = \left(\frac{\Delta x}{\Delta z}\right)^n (W_{ij})_h \cdot C_w, \quad n \equiv g_v \qquad (20)$$

C_w, g_h and g_v input quantities provided by the user

Equations 17, 19 and 20 provide the expressions of the first and second type of transport kernel available in the SIMULA-3 code.

The third type of transport kernel is the following:

$$(W_{ij})_h = \frac{g_h\, p_\ell}{4+2\left(\frac{\Delta x}{\Delta z}\right) g_v} \qquad (W_{ij})_v = g_v (W_{ij})_h \cdot \frac{\Delta x}{\Delta z} \qquad (21)$$

where p_ℓ is the escape probability.

The fourth type is recommended, and it has been developed for this version, following an equivalence principle to the leakages in diffusion theory calculations for particular values of the transport factors.

The expressions are the following

$$(W_{ij})_h = \frac{2}{1+\frac{f_i}{f_j}\frac{M_i^2}{M_j^2}} \cdot \frac{g^h \cdot M_i^2}{k_{\infty i} \cdot x^2} \qquad (22)$$

$$(W_{ij})_v = \frac{2}{1+f_{ij}\frac{M_i^2}{M_j^2}} \cdot \frac{g^v \cdot M_i^2}{k_{\infty i} \cdot z^2}$$

f_i and f_j are the "transport factors" and are input data to the code.

Note, that on the vertical direction the ratio $f_{ij} = f_i/f_j$

is directly used, because the experience shown that it is practically constant for all the nodes interfaces in this direction.

For the peripherical nodes the transport kernel is

$$W_i = \frac{M_i^2}{k_{\infty i}\, x^2}$$

and the neutron balance in the node ℓ is

$$\sum_m (W_{\ell m} \cdot S_\ell - W_{m\ell}\, S_m) + n_\ell (1-\alpha_\ell) W_\ell \cdot S_\ell + \frac{S_\ell}{k_{\infty \ell}} = \frac{1}{k_{eff}} \cdot S_\ell$$

Note, that for this transport kernel type, the eigenvalue (LAMBDA in the code) is the effective multiplication factor (source/absorption + leakage), while for the previous transport kernel types 1 to 3 the eigenvalue λ is: (source-leakage)/absorptions, which is equal to the effective multiplication factor if, and only if $\lambda = k_{eff} = 1$.

b) Source iteration equations.

The equations (8) and (10) are solved iteratively to get the source and eigenvalue convergence, using the following expressions.

For a given void loop where the moderator relative density is kept constant, the source iteration continues until the source or eigenvalue converges within a criteria or the number of iterations exceeds the limit.

b.1. Equations.

Node-by-node calculation for transport kernels types 1, 2 or 3 (old versions).

$$Z_{ijk} = \frac{\beta^h_{i-1,j,k} + \beta^h_{i+1,j,k} + \beta^h_{i,j-1,k} + \beta^h_{i,j+1,k} + \beta^v_{i,j,k-1} + \beta^v_{i,j,k+1}}{\lambda/k_{\infty ijk} - (1 - 2W^v_{ijk} - 4W^h_{ijk}) - \alpha^v_{ijk} W^v_{ijk} - \alpha^h_{ijk} W^h_{ijk}} \qquad (24)$$

$$\beta_{ijk} = S_{ijk} W_{ijk}$$

$$Z_{ijk} = \frac{k_{\infty ijk} \sum \beta_{i,j,k}}{\lambda + D_{ijk}}$$

$\sum \beta_{i,j,k}$ = numerator in Equation (24)

$S_T = \sum v_{ij} Z_{ijk}$ TOTAL SOURCE

$S_L = \sum v_{ij} G_{ijk} Z_{ijk}$

$S_K = \sum \left(v_{ij} Z_{ijk} / k_{\infty ijk} \right)$

v_{ij} = relative nodal area = 1: normal node; 1/2 nodes on symmetry axis; 1/4 central node on two symmetry axes

$$\lambda = \frac{S_T - S_L}{S_K}$$

Line by line axial calculation for transport kernel type 4 (SIMULA-3).

The succesive line elimination-substitution method is used ower the axial lines, with source overrelation (SLOR), for a factor $\beta = 1,7$, and about 8 source iterations per void iteration.

For a source convergence of 10^{-5}, this method requires only about

1/10 of the number of iterations needed with the point- Jacobi method, and less than 1/2 of those needed with the Gauss-Seidel or Chebyshev source acceleration.

b.2) Source acceleration

There are different types of source acceleration.

Γ_{NS} = Source acceleration factor at Nth iteration.

(1) Point Jacobi (IACCEL=0)

$$S^{*}_{ijk} = Z_{ijk}$$

$$\bar{S}_{ijk} = S_{ijk}$$

$$S_{ijk} = \bar{S}_{ijk} + (1 + \Gamma_{NS}) \left[\frac{N}{S_T} S^{*}_{ijk} - \bar{S}_{ijk} \right] \qquad (25)$$

$$S_N = v_{ij} S_{ijk}$$

$$\text{new } S_{ijk} = \frac{N}{S_L} S_{ijk}$$

where $N = K \sum v_{ij}$

$$S^{n}_{ijk} = \frac{N}{S_T} Z^{n}_{ijk} + \Gamma_{NS} \left| \frac{N}{S_T} Z^{n}_{ijk} - \frac{N}{S_N} S^{n-1}_{ijk} \right|$$

$$S^{N} = \bar{Z} - \Gamma_S (\bar{Z} - S^{\circ})$$

(2) Source over relaxation (IACCEL= -1)

$$\bar{S}_{ijk} = S_{ijk}$$

$$S_{ijk} = Z_{ijk} + \Gamma_{NS} (Z_{ijk} - \bar{S}_{ijk}) \qquad (26)$$

$$S_N = \sum v_{ij} S_{ijk}$$

$$\text{new } S_{ijk} = \frac{N}{S_N} S_{ijk}$$

$$S^n_{ijk} = Z^n_{ijk} + \Gamma_{NS}\left(Z^n_{ijk} - \frac{N}{S_N} S^{n-1}_{ijk}\right)$$

$$S^N = Z + \Gamma_S (Z - S^\circ)$$

(3) Gauss-Seidel (IACCEL = +1)

$$\overline{S}^*_{ijk} = S_{ijk}$$

$$S_{ijk} = Z_{ijk}$$

$$\overline{S}_{ijk} = \frac{N}{S_T} S_{ijk}$$

$$S_{ijk} = \overline{S}_{ijk} + \Gamma_{N_S}\left(\overline{S}_{ijk} - \overline{S}^*_{ijk}\right) \qquad (27)$$

$$S_N = \sum v_{ij} S_{ijk}$$

$$\text{new } S_{ijk} = \frac{N}{S_N} S_{ijk}$$

$$S^n_{ijk} = \frac{N}{S_T} Z^n_{ijk} + \Gamma_{NS}\left(\frac{N}{S_T} Z^n_{ijk} - S^{n-1}_{ijk}\right)$$

$$S^N = \overline{Z} + \Gamma_S (\overline{Z} - S^\circ)$$

1.1.1.2. Void or moderator density iteration.

The average steam volume fraction in the moderator is calculated on the basis of a fit of steam volume fraction versus quality. The quality at each node is calculated in the following way,

$$Q_{ijk} = \left(\frac{1}{KF'_{ij}}\right) \left| \sum_{\ell=1}^{k} P_{ij\ell} - \frac{P_{ijk}}{2} \right| (Q_{ex} - Q_0) + Q_0$$

where K = total number of axial nodes in the problem

F'_{ij} = ratio of flow in channel ij to average channel flow

Q_0 = inlet quality, $-\Delta h_s/h_{fg}$ (Δh_s = subcooling of inlet coolant)

Q_{ex} = exit quality, ($Q_{ex} - Q_0 = 3.413 \times 10^6 P_{th}/W.h_{fg}$)

P_{th} = thermal power, MWt

W = coolant flow, lb/hr

h_{fg} = enthalpy of evaporation, Btu/lb = C_7

P_{ijk} = relative power at node ijk=(S_{ijk}).(multiplier)

Void fraction calculation

Once the quality of the steam is obtained from Equation (28), void fraction (χ_{ijk}) is estimated from the following equation which represents the experimentally observed correlation between voids and quality (Q_{ijk}):

$$\chi_{ijk} = C_1 + C_2 Q_{ijk} + C_3 Q_{ijk}^2 - C_4 \exp\left(\frac{C_5 - Q_{ijk}}{C_6}\right) : Q_{ijk} > C_5 \qquad (29)$$

$$\chi_{ijk} = 0 : Q_{ijk} < C_5 \text{ or } C_6 \leq 0$$

This expression permits sub-cooled voids by proper choice of the parameter C_5 and gives reasonably good agreement with experimental data throughout the range of interest.

The relative moderator density has been approximated by

$$U_{ijk} = 1 - \chi_{ijk}\left(1 - \frac{\rho_g}{\rho_f}\right) \qquad (30)$$

where U_{ijk} = moderator density relative to saturated condition at node $\ell(i,j,k)$

ρ_g = density of steam = C_{15} (input data)

ρ_f = density of saturated moderator = C_{14} (input data)

Several assumptions have been made in the void iteration and they are:

(1) The flow rates and qualities are based on within-channel values, and therefore the nuclear parameters should be fit to in-channel moderator density.

(2) The total heat output is assumed to go into the in-channel coolant.

(3) The average void fraction at a node has been assumed to be equal to the void fraction of the average quality at that node.

The nuclear and thermal-hydraulic parameters are closely related, and the final solution of SIMULA represents the dynamic coupling of these parameters. Equations showing the interdependence of nuclear and thermal-hydraulic parameters and methods

used to calculate various parameters are shown in the next section.

Nodal Power calculation.

The relationship between nodal power and source is

$$P_{ijk} = S_{ijk}(B_{24} + B_{25}E + B_{26}E^2) \qquad (31)$$

Equation (31) is used to account for the difference between relative nodal source (number of neutrons produced) and relative nodal power (heat generated) due to change in the relative ratios of fissile nuclides as a function of fuel burnup. S_{ijk} is normalized to core average of unity prior to calculation of P_{ijk}, and P_{ijk} is also normalized to core average of unity after the calculation by Equation (31).

Budle Relative Flow Rate versus Relative Power.

$$F'_{ij} = F_{ij} \left| 1 + FP_{ij} \left(\overline{P}_{ij} - 1\right) \right| Z_8 \qquad (32)$$

where F'_{ij} = bundle relative flow

F_{ij} = relative channel flow (input data card type 6A)

FP_{ij} = power dependent flow factor (input data card type 6B)

$$\overline{P}_{ij} = \frac{1}{K} \sum_{k=1}^{K} P_{ijk}$$

Z_8 = normalization factor

The normalization factor, Z_8, is calculated internally by the code to maintain the average relative flow at unity.

1.1.1.3. Critical Searches.

Other loop of external iteration to the source-moderator density iteration, is a critical search, the possibilities available are for the moment:the control rod position or soluble poison concentration searches.

The corresponding iteration loop is in the Figure 2

a) Critical Control Rod Position Search

Individual control rod position which are initially given as input data are moved uniformly by a fixed distance, first by the initial guess (RINC) and then by the amount obtained by linear interpolation or extrapolation of the last two results, until the eigenvalue (λ) converges to the desired value (λ_0) within a criterion specified by DXLC. The interation will be terminated if the problem does not converge within the maximum allowable number of iterations given by NCMAX.

The control rods, which are initially "fully in" or "fully out", are not moved during the search iteration, and when any or some of the rods which were partly in the core initially become fully inserted or fully withdrawn during the search iteration, the case cannot be completed and will be terminated. At present, the rod position search option is designed for the full lenght control rods, and therefore, the usefulness for the partlength control rods can not be guaranteed.

b) Critical Soluble Poison Search

The option searches for a uniform soluble poison in the moderator, which provides a desired core reactivity (λ_0). It works ordinarily for the pressurized water reactor (PWR) types, but since the effect of soluble poison on k_∞ is a

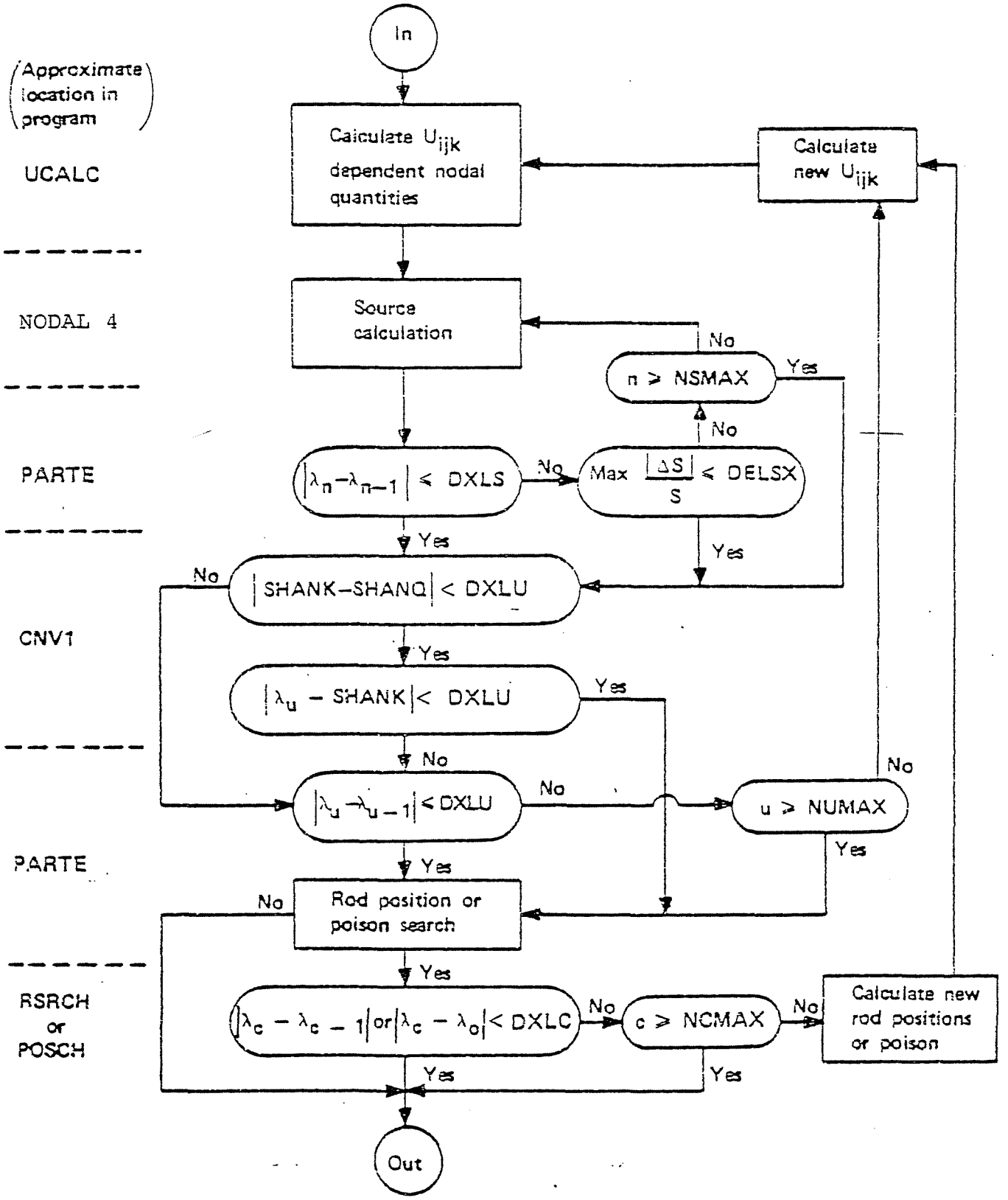


FIGURE 2

Source iteration Loop

function of the moderator relative density also, it can be used for any reactors with axially varying moderator density.

It must be noted, that the final value of critical poison is expressed in ppm (parts per million of moderator) in the moderator with relative density of unity.

In the search, SIMULA first computes the core λ with the initial guess of poison and then computes the core λ with the initial value plus 20 ppm which is an input. From these two values of λ, the code obtains the third guess of soluble poison by either linear interpolation or extrapolation of two λ's. And the new guess of poison is used to calculate a new core λ. For each successive iteration, a new value of poison is obtained by linear interpolation or extrapolation of the last two results. This process continues until the convergence criterion (DXLC) is satisfied between λ_0 and the last λ, or the maximum number of iteration (NCMAX) is exceeded.

1.1.1.4. Fuel Burnup

The code proceeds automatically in the cycle burnup calculation, going from one burnup step to the next one, determining at the begiming of each step the burnup by node. It provides complete lifetime analysis of the reactor, and permits refueling and shuffling of the fuel elements at any time in core life.

1.1.2. k_∞ and M^2 calculations.

In the neutron balance equation are involved the infinite multiplication factor k_∞, and through the transport kernel the migration area M^2, the nodal values of these parameters should be determined by the code, depending of the local values of the physical and neutronic variables that had any influence on them.

The migration area is determined versus the moderator density value, by an internal correlation in the code, whose constants are input data and should be determined previously by fuel assembly calculations at different moderator densities.

The same procedure is used for the k_∞ determination, best in this case, after the calculation versus the moderator density, some corrections or reactivity worthes are applied to take account the local value of the variables with relevant influence in the final value; those are, the exposure, the power density, the Xenon and Boron concentrations. The changes in reactivity associated to the mentioned variables are also determined by the code through special correlations, whose constants are also input data.

The local k_∞ value is determined by the following expression:

$$k_\infty = H \left[1 + \left(\frac{\Delta k_\infty}{k_\infty}\right)_{Xe} + \left(\frac{\Delta k_\infty}{k_\infty}\right)_{Dop}\right] \cdot \left[1 + \left(\frac{\Delta k_\infty}{k_\infty}\right)_{E} + \left(\frac{\Delta k_\infty}{k_\infty}\right)_{P}\right] \cdot \left[1 + \left(\frac{\Delta k_\infty}{k_\infty}\right)_{B}\right] \qquad (33)$$

where $H = \left[k^+ + \{(0.5)(c_t) - 0.5\}\ (k^+ - k^-)\right] XK'_{ij}$

k^+, k^- = k_∞ versus moderator density, with control and without control. See equations (35).

c_t = the fraction of control. See input card type 1.

XK'_{ij} = partial fuel factor (See input cards 8) the CONCON and CONAXI codes may be used to calculated these factors.

To determine the constants of the correlations used by the code, a set of fuel assembly calculations at different conditions should be executed. As the change in reactivity is determined for each isolated variable, the procedure is to run a set of

cases for each variable, changing only one of them, keeping the others at the reference condition. Of course, the variables should take values close to the reference conditions and in the range of the expected local values for the whole core calculation. The recommended way is to adopt the average conditions in the core as the reference conditions.

The correlations used by SIMULA-3 are the following:

a) M^2 as function of relative moderator density.

b) k_∞ as function of relative moderator density

c) Doppler worth as function of relative power density and moderator density.

d) Equilibrium Xenon worth as function of relative power density and moderator density.

e) Boron worth as function of Boron concentration and exposure.

f) Exposure worth as function of exposure.

g) Burnable poison.

The moderator density and power density are relative values in respect to the core average moderator density and power density at nominal operating conditions.

On these correlations is possible to see the influence of some "crossing effects", for instance the power density not only has an influence in the Doppler worth, besides it has also an influence in the Xenon worth. This is the way that has been found as more suitable to represent the actual behaviour.

The correlations used presently by the code are analized in the next parragraphs.

a) Migration area

$$M^2 \text{ (control)} = B_1(1+B_2U+B_3U^2)\ XM_{ij} \qquad (34)$$

$$M^2 \text{ (no control)} = B_4(1+B_5U+B_6U^2)\ XM_{ij}$$

U = relative moderator density.

B_1 to B_6 are input data.

XM_{ij} = M^2 correction factor (See input cards 8), they may be determined by CONCON and CONAXI codes.

M^2 for intermediate control rod positions are linearly interpolated between two values.

b) k_∞ versus moderator density.

$$k_\infty \text{ (control)} = B_7(1+B_8U + B_9U^2) = K^+$$
$$k_\infty \text{ (no control)} = B_{10}(1+B_{11}U + B_{12}U^2) = K^- \qquad (35)$$

B_7 to B_{12} are input data.

For other rod positions, k_∞ is determined by linear interpolation of two values.

c) Doppler worth.

$$-\left(\frac{\Delta k_\infty}{k_\infty}\right)_{Dop} = f_D(P) \cdot g_D(U)$$

$$f_D(P) = B_{16}P\ (1 + B_{42}P)$$
$$g_D(U) = 1 + B_{17}(1-U)\ .\ (1+B_{43}U) \qquad (36)$$

P = relative power density.
U = relative moderator density.

B_{16}, B_{17}, B_{42} and B_{43} are input data.

d) Equilibrium Xenon worth.

$$-\left(\frac{\Delta k_\infty}{k_\infty}\right)_{Xe} = f_X(P) \cdot g_X(E)$$

$$f_X(P) = \frac{B_{14}P\ (1+B_{13})}{P+B_{13}} \qquad (37)$$

$$g_X(E) = 1+B_{15}E+B_{44}E^2+B_{45}E^3+B_{46}E^4 \qquad (38)$$

P = relative power density.

E = exposure, in 10^3 Mwd/T units

B_{13}, B_{14}, B_{15}, B_{44}, B_{45} and B_{46} are input data.

e) Boron worth.

$$-\left(\frac{\Delta k_\infty}{k_\infty}\right)_B = U * f_B(B) * g_B(E)$$

$$f_B(B) = B.(B_{29}+B_{30}B+B_{31}B^2)$$

$$g_B(E) = 1+B_{32}E+B_{33}E^2+B_{40}E^3+B_{41}E^4 \qquad (39)$$

B = boron concentration in ppm.

E = exposure, in 10^3 Mwd/T units.

B_{29} to B_{33}, B_{40} and B_{41} are input data.

f) Exposure worth.

$$-\left(\frac{\Delta k_\infty}{k_\infty}\right)_E = B_{18}+B_{20}E+B_{21}E^2+B_{22}E^3+B_{23}E^4 \qquad (40)$$

E = exposure, in 10^3 Mwd/T units.

B_{18} and B_{20} to B_{23} are input data.

The exposure E, is computed as follows:

$$E_t = E_{t-1} + B_{28} \cdot \Delta E \cdot P \cdot Z_E \qquad (41)$$

where t = time step number

ΔE = exposure increment, 10^3 Mwd/T.

Z_E = normalization factor

B_{28} = is to account for non-uniform fuel loading.

The normalization factor, Z_E, is computed internally by the code to maintain the core average value at ΔE. B_{28} is used to account for non-uniform fuel loading.

g) Burnable poison.

$$-\left(\frac{\Delta k_\infty}{k_\infty}\right)_P = B_{18} \exp(-B_{19}E) \qquad (42)$$

this can be used to include other burnup dependent effects.

1.1.3. Geometry.

The rectangular parallelepiped reactor represented by the XYZ coordinates is subdivided into small regions which are called "nodes" or "nodal regions". A node, whose volume is given by $(\Delta X)^2(\Delta Z)$, is the fundamental region in all SIMULA calculations, and input and output data are given by nodes. The node numbering used is shown in Figure 3, where Node (1,1,1) is in the far left corner at the bottom. Where it is necessary to specify a particular edge or corner of a node, the following convention is used: the far left-hand corner at the top of each node is given the same index as the node itself.

Six different types of core boundaries due to symmetry conditions in the radial (XY) direction are available in SIMULA. These are shown in Figures 4 through 13 and are as follows:

1) 1/4 core, reflected at node centerline
2) 1/2 core, mirror symmetry, reflected at node centerline
3) 1/2 core, mirror symmetry, reflected at node boundary
4) 1/2 core, 180° rotational symmetry, reflected at node centerline.

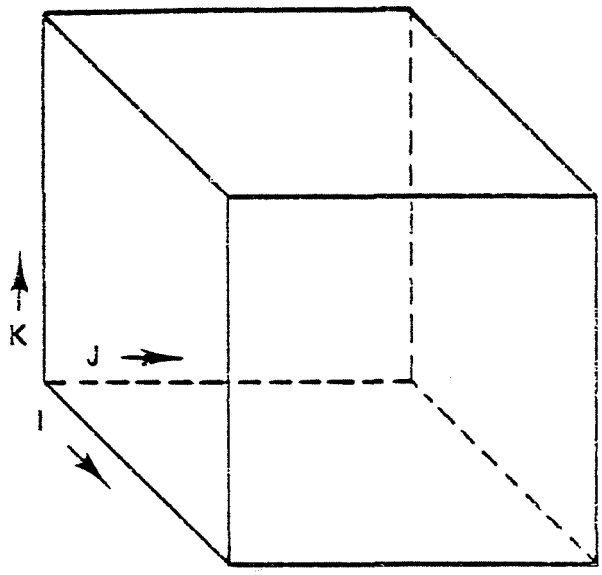


Figure 3

Schematic of Nodal Directions

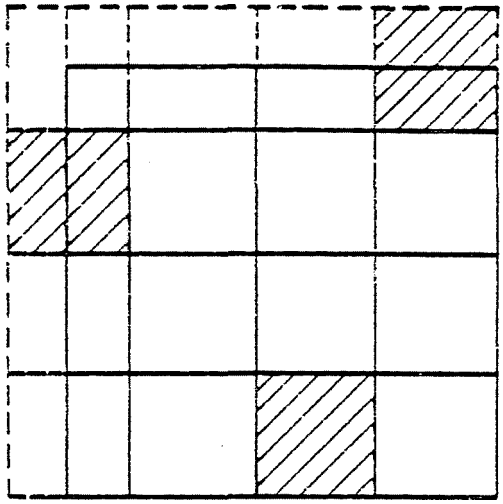


Figure 4

¼Core Symmetry,
Node Centerline (ISYM=4)

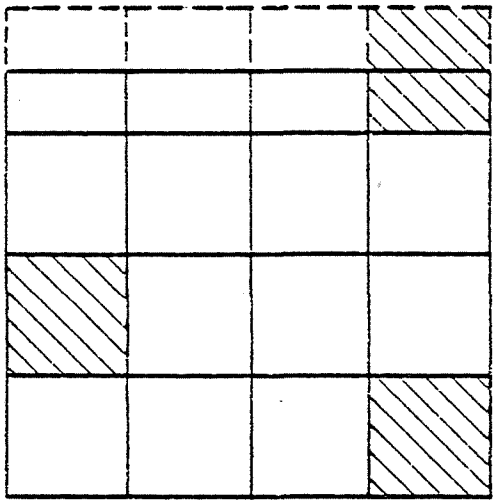


Figure 5

½Core, Mirror Symmetry,
Node Centerline (ISYM=3)

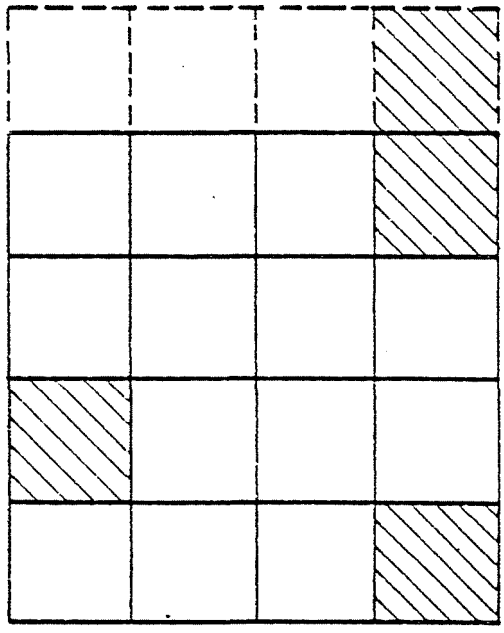


Figure 6

½Core, Mirror Symmetry,
Node Boundary (ISYM=1)

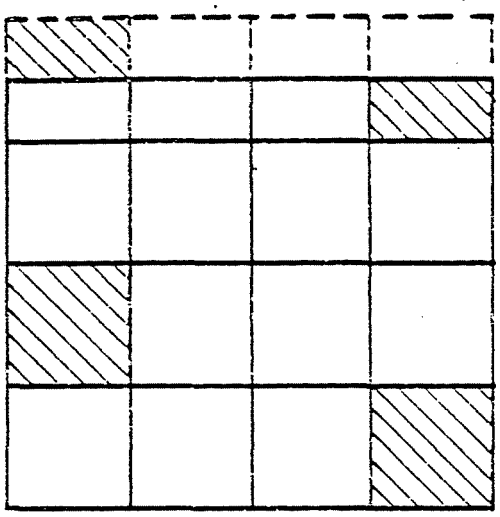


Figure 7

½Core, 180° Rotational Symmetry,
Node Centerline (ISYM=2)

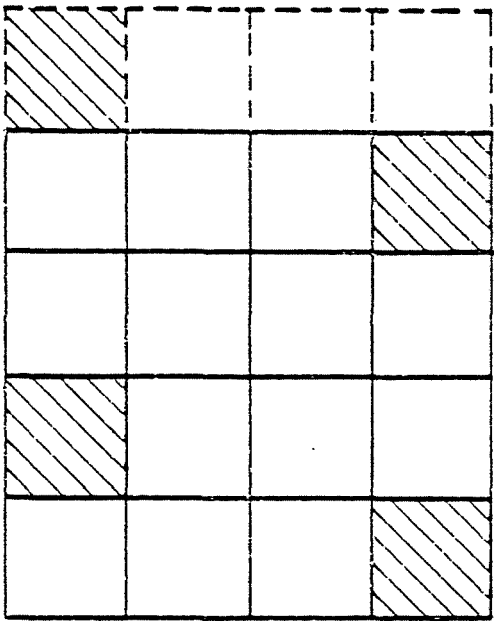


Figure 8

½Core, 180° Rotational Symmetry,
Node Boundary (ISYM=0)

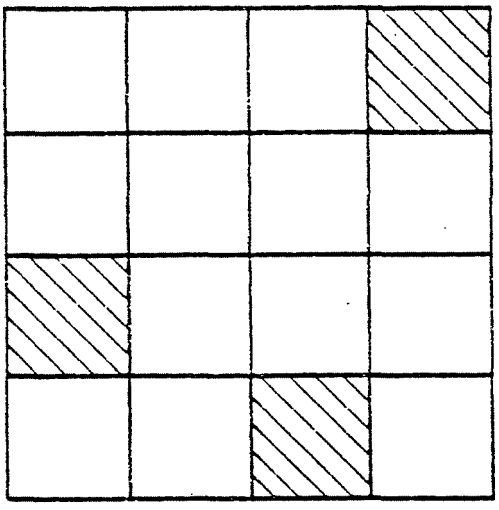


Figure 9

Full Core (ISYM=-1)

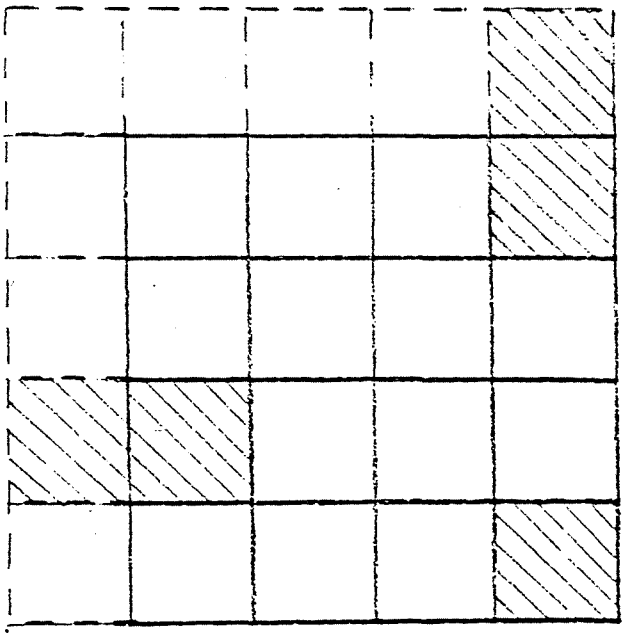


Figure 10

1/4 Core, Mirror Symmetry
Node Boundary (ISYM=5)

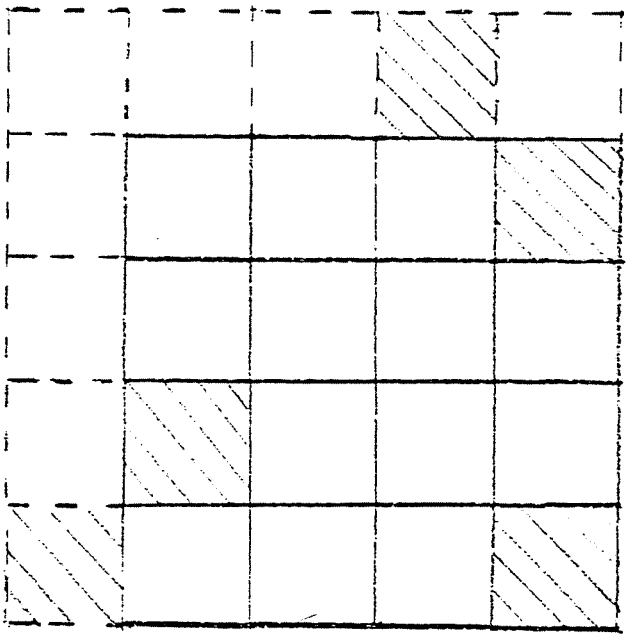


Figure 11

1/4 Core, 90°Rotational Symmetry

Node Boundary (ISYM=6)

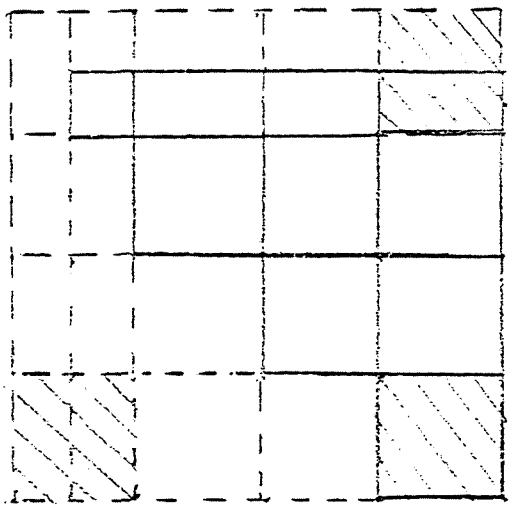


Figure 12

1/8 Core, Mirror Symmetry

Node Centerline (ISYM=-4)

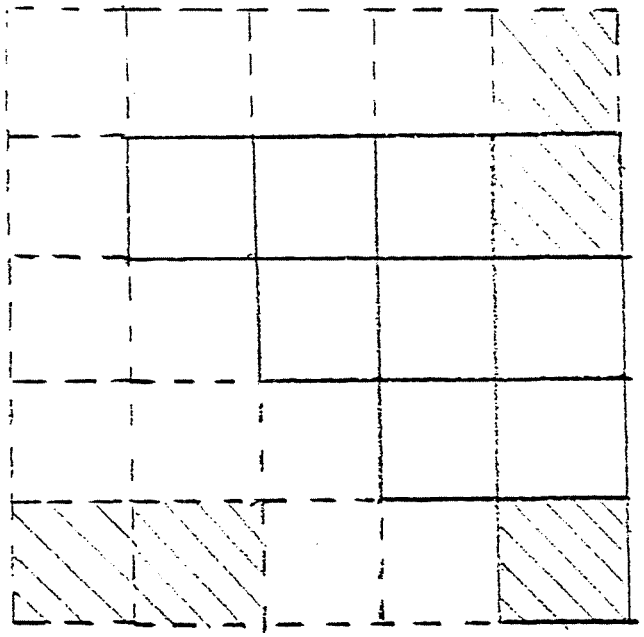


Figure 13

1/8 Core, Mirror Symmetry

Node Boundary (ISYM=-5)

5) 1/2 core, 180° rotational symmetry, reflected at node boundary.
6) Full core.
7) 1/4 core, mirror symmetry, reflected at node boundary.
8) 1/4 core, 90° rotational symmetry about node boundaries.
9) 1/8 core, mirror symmetry, reflected at node centerlines.
10) 1/8 core, mirror symmetry, reflected at node boundaries.

Calculation of Fuel Border Types.

NBT_{ij} is a border type indicator as shown below:

NBT_{ij} = 0, if inner elements (has 4 neighbors)

= +, if border elements (neighbor(s) missing)

= -, if no fuel element

and is calculated from:

$$NBT_{ij} = \delta_{ij-1} + 2\delta_{i,j+1} + 4\delta_{i+1,j} + 8\delta_{i-1,j}(1 + 6\delta_m) \qquad (43)$$

where δ_{ij} = 0, if fuel element in i, j

= 1, otherwise

δ_m = 1, if mirror symmetry

= 0, if 180° symetry

1.1.4. Transient Xenon Calculation.

The following are some of the types of transient Xe calculations which can be performed using SIMULA

1) I-135 and Xe-135 buildup and decay starting from the beginning of life at any power level (fuel burnup cannot be performed parallel to the Xe calculation but the existing spatially non-uniform fuel exposure can be maintained throughout the Xe calculation).

2) I-135 and Xe-135 buildup and decay from a given set of I-135 and Xe-135 concentrations and a nodal power distribution

at any power level.

3) Change power level (including zero power) from an equilibrium core condition at any power level and exposure distribution, and follow the buildup and decay of I-135 and Xe-135 and the change in power distribution with time. The power level and control rods can be changed at any time step, and the core transients can be followed without terminating the current job.

4) Follow the complete operating history of an operating reactor with fuel burnup and then do the I-135 and Xe-135 transient calculations at any power level.

The I-135 and Xe-135 decay and buildup equations are rigurously solved under the assumption of constant neutron flux for a given time step.

$$Xe_{t+\Delta t} = Xe_t \exp(-A_{Xe}\cdot\Delta t) + \frac{(y_I + y_{Xe})(S\cdot P\cdot\Phi\Sigma_f)}{A_{Xe}}\left[1-\exp(-A_{Xe}\cdot\Delta t)\right] + \frac{\lambda_I I_t - y_I\cdot S\cdot P\cdot\Phi\Sigma_f}{A_{Xe}-\lambda_I}\left[\exp(-\lambda_I\cdot\Delta t) - \exp(-A_{Xe}\cdot\Delta t)\right] \quad (44)$$

$$I_{t+\Delta t} = I_t\exp(-\lambda_I\cdot\Delta t) + \frac{y_I\cdot S\cdot P\cdot\Phi\Sigma_f}{\lambda_I}\left[1 - \exp(-\lambda_I\cdot\Delta t)\right] \quad (45)$$

$$Xe_{equil.} = \frac{(y_I + y_{Xe})(S\cdot P\cdot\Phi\Sigma_f)}{A_{Xe}} \quad (46)$$

where

$$\Phi\Sigma_f = \frac{(P_r)\quad(6.2422\times 10^{18})}{(k_f)(TN)(\Delta X)^2(\Delta Z)} \quad (47)$$

P_r = rated core power in MW

TN = total number of nodes with fuel

ΔX = radial dimension of node, cm.

ΔZ = axial dimension of node, cm.

SP = relative power density

$$(\sigma_a \phi)_{Xe} = B_{34} + B_{35}E \qquad (48)$$

K_f = Mev/fision = B_{36}
(default is 200.)

Y_I = yield of I-135/fission(fraction) =
(default is 0.062)

= B_{37}

Y_{Xe} = yield of Xe-135/fission(fraction) =
(default is 0.002)
= B_{38}

λ_I = decay constant for I-135, 2.88×10^{-5} sec^{-1}
(T 1/2 = 6.7 hr)

λ_{Xe} = decay constant for Xe-135, 2.11×10^{-5} sec^{-1}
(T 1/2 = 9.13 hr)

$$A_{Xe} = S.P.(\sigma_a \phi)_{Xe} + \lambda_{Xe} \qquad (49)$$

Δt = time increment in sec

$(\sigma_a \phi)_{Xe}$ = effective value of σ_a times ϕ for Xe-135, which includes both fast and thermal group effects.

The effect of time - dependent Xenon on k_∞ is

$$\left(\frac{\Delta k_\infty}{k_\infty}\right)_{Xe_t} = \left(\frac{\Delta k_\infty}{k_\infty}\right)_{equil.Xe} \left(\frac{Xe_t}{Xe_{equil.}}\right) \qquad (50)$$

1.2. Input Data.

All data input cards have the same format except the DIMENSION and TITLE cards, and when ID cards are used as in card 10A. Any characters may be punched in columns 1-10 for user identification. Three 2-column descriptors are punched in columns 11-16. The first descriptor is the card type punched in columns 11-12. The other two descriptors are used for further identification and for running options.

The general data supplied on each data card is punched in free form in columns 17 through 80. The general format is: (2A5,3I2, Free format). Free form requires that each number be separated by one or more spaces or a comma from its neighbors. Thus, no spaces may occur between the characters of a single value. Decimal points are not required unless the value is non-integer. Exponential scaling is optional with or without an E and followed by a signed integer scaling factor. In order to simplify the input, there are two options to avoid the input of unnecessary data

Sn : space or skip n input values.

Rn : repeat the last given input value n more times.

Maximum number of values per card: 70 (including the skipped and repeated values).

If the required data do not fit on a single card, the continuation card should have columns 11 to 16 as the previous card.

In a change case, only the input data that are changed from the previous case should be suplied.

1.2.1. Input data format and description.

The summary of SIMULA-3 input data which are described in this section is given in Table 1 at the end of this section. Arrangement of SIMULA-3 input data cards is shown in Table 2, also at the end of this section.

DIMENSION CARD (3I4) (always required)

Column	Content	Description
3-4	ID	Numbers of nodes used in the I(X), J(Y), and K(Z) directions by all the cases in this job. Any case in the job must have this set of ID, JD, and KD; otherwise, it must be run in another job with different ID, JD, and KD. Maximum KD is 34.
7-8	JD	
11-12	KD	
		This card must be placed before the case data which are described below. The purpose of this card is to specify the number of nodes used by all cases in this job and to check whether the current version is big enough to handle the number of nodes. See Section 1.5.4. for the relation between the size of code and the number of codes.

TITLE CARD (A1, A4, 15A5) (always required)

1		Case initialization parameter:
	"I"	= reference (independent) case, input data initialized before input read
	"D"	= change (dependent) case, input, data not initialized
		Restart case with a restart file (TAPE 1) must be a dependent case and the first case of a job. The restart tape must contain a case which has the same nodal meshes as the current case. See Section 1.5.1.
2-5		If this space is left blank, no action is taken
	"SAVE"	The code creates a restart file (TAPE 2) at the end of the case containing the case data. See Section 1.5.1. for tape contents.
6-80	ITITLE	Alphanumeric description of the case'

CARD TYPE 1 - Case Control Parameters (1)

11-12	01
13-14	

Column	Content	Description
15-16	IBURN (integer)	In this value is 0, the program will calculate a source for the exposure distribution up to (but not exceeding) $E=E_{max}$ and go the next case. If IBURN=1 an extra exposure distribution is calculated (but no additional source) before going to the next case.
17-80		FREE FROM DATA:
	(1) E_0	For fuel exposure calculation: initial average core exposure in 10^3 MWD/T. For transient Xe calculation: initial time in hr.
	(2) E_{max}	For fuel exposure calculation: final average core exposure in 10^3 MWD/T for which a source is to be calculated. For transient Xe calculation: final time in hr.
	(3) ΔE	For fuel exposure calculation: average core exposure increment per step in 10^3 MWD/T. For transient Xe calculation: time increment per step in hr. For a change case, if not given, the last value of exposure array from the preceding case is used. However, the cycle "0" exposure printed in the heading is E_0. Hence the average value of the three dimensional exposure array used in the calculation may not be the same as E_0. The case is terminated when $E_0 + n \cdot \Delta E > E_{max} \cdot E_0$, E_{max}, and ΔE are independent of P_r or P_{th} below.
	(4) ΔX	Radial ($\Delta X=\Delta Y$) dimension of node in cm; one value represents ΔX and ΔY for all nodes.
	(5) ΔZ	Axial dimension of node in cm; one value represents ΔZ for all nodes.
	(6) P_{th}	Actual thermal power of that part of the reactor included in the problem, Mw.
	(7) P_r	Rated thermal power of that part of the reactor included in the problem, Mw. P_{th} and P_r must be the values corresponding to the actual geometry given by ISYM in card type 2.
	(8) W_1 (9) W_2	These two values determine the total reactor coolant flow in lb/hr. Flow = $W_1+W_2(P_{th}/P_r)$. One might define W_1+W_2 as the total live

Column	Content	Description
17-80 (Cont'd)		water flow (throught the channels) at rated power and W_2 as the change in flow per fractional change in reactor power.
	(10) h_{s1} (11) h_{s2}	These two values are similar to the two above in that they are used to determine the subcooling of the inlet coolant in Btu/lb. Note that Δh_s is positive, and corresponds to $(h_f - h_{inlet})$, where h_f = enthalpy of saturation h_{inlet} = subcooling of inlet coolant $\Delta h_s = h_{s1} + h_{s2} (P_{th}/P_r)$ Normaly use for PWR applications: $h_{s1} = -h_{inlet}$, $h_{s2} = 0.0$.
	(12) CRNR	CRNR is defined as the number of corner rods which must be inserted around a node to give full control. Suppose that four corner rods are inserted about a node at the sixth level (k=6) to 5.4, 5.1, 3.8, and 6.8, respectively, and that the number of corner rods required is 3 (CRNR = 3.0). Then the fractional control exerted on that node is (0.4 + 0.1 + 0.0 + 1.0)/CRNR = 0.5 and that node is half controlled. See card type 5 for description of control rod positions. A control rod inserted past a node has unity (1.0) effect. If the node is at level k, a control rod inserted to positions between (k-1) and k has fractional effect. A control rod inserted to less than k has no effect. CRNR = 0 defines a control rod in the center of each fuel bundle which directly affects only that bundle and provides full control when inserted, that is the case of PWR applications. γ_{ijk} = fraction of a given node controlled at ijk. if $\gamma \leq 0$ $\quad e = 0$ $0 < \gamma < 1$ $\quad e = \gamma$ $1 \leq \gamma$ $\quad e = 1$ $c_t = \frac{2}{\text{rods/node}} (e_{ijk} + e_{i,j+1,k} + e_{i+1,j,k} + e_{i+1,j+1,k}) - 1 \qquad -1 \leq c_t \leq 1$

Column	Content	
17-80 (Cont'd)		where rods/node = CRNR and, if CRNR is zero, $c_t = 2e_{ijk} - 1$ The case for c_t=-1 and c_t=+1 represent "no and full control", respectively for the standard convention adopted for SIMULA-3. That is, it is assumed that the control rods are inserted from the bottom of a reactor as in BWR.
	(13) ITAPE	= 0: No effect = 1: Use a flat source guess instead of input values from cards or preceding case, or the restart tape (TAPE 2)
	(14) IMABWR	Option for thermohydraulic correlations: = 1.0, for PWR applications.
	(15) IBUG1	Debugging output option (Don't use for a normal run) = 0: No effect = 1: Additional output at the beginning of each case in the amount specified by IBUG2 = 2: Additional output for each void iteration in the amount specified by IBUG2 except NBT.
	(16) IBUG2	Debugging output control. = 0: Prints NBT and YY arrays = 1: Prints NBT, YY and CT arrays = 2: Prints above plus WV, WH, D, G, H, S, SRC, and U arrays = -1: Overrides IBUG1 and prints the content of the restart tape including E, F, FP, R, RH, XK, EID, and XEN.
	(17) RMAX	Critical control rod position search parameter: = 0: no rod position search. ≠ 0: upper limit of control rod position. This is the axial position of control rod at "fully-in" condition (for rods entering from the bottom).
	(18) RMIN	Valid only when RMAX≠0. The lower limit of control rod position. It is the axial position of control rod at "fully out" condition (for rods entering from the bottom as in BWR applications).

Column	Content	Description
17-80 (Cont'd)	(19) RINC	Relevant only when RMAX>0. First increment guess for control rod position search. A positive number means "upward" and a negative number means "downward". If not given, the code assumes +0.5. RMAX and RMIN must be given in nodes and fractions of node as in card type 5. For control rod position search (RMAX≠0), additional data (XLMBDA, DXLC, and NCMAX) or card type 2 must be provided.
	(20) NOPT	Special option parameters: = 0: no special option = 1: transient Xe calculation starting from zero concentrations of I-135 and Xe-135, or from the existing concentrations carried over from the preceding case. = 2: transient Xe calculation starting from equilibrium concentrations of I-135 and Xe-135. The transient Xe calculation is performed by each node with Equations (44) through (50) and material constants B_{34} through B_{38} on card type 3 are required for this calculation. = 3: critical soluble poison search. This option is primarily intended for the PWR types. This option requires PPM as the initial guess and it also requires material constants B_{29} through B_{33}, B_{40}, and B_{41} Equation (39) gives the effect of soluble poison on nodal k_∞. Additional data (XLMBDA, DXLC, NCMAX) on card type 2 are required for this option.
	(21) PPM	If NOPT=3, this value becomes the initial guess for the soluble poison search in ppm of uniform soluble poison. For this purpose PPM must be non-zero. The second guess of the soluble poison is the above value plus 20 ppm. If NOPT=0, this value becomes the uniform soluble poison and its effect on k_∞ is given also by Equation (42) or (51).

Column	Content	Description
17-80 (Cont'd)		For change cases, if not given, the code sets it to the value of PPM finally used in the preceding case.

CARD TYPE 2 - Case Control Parameter (2)

11-12	02	
13-14	KP (integer)	0: If KP=0, then the S, E, EID, and XEN arrays are punched in BCD form (identical to input formats) at the end of final exposure step if IPCH=1. (See 1.4.2.). N≠0: If KP=N, the above nodal parameters are punched after every N exposure (or time) steps if IPCH=1. (See 1.4.2.). If no burnup or xenon calculation is performed only S arrays will be punched as above; however, both S and E arrays are punched at the end of the Haling (reload option) calculations if KP=0 and IPCH=1 regardless of IHAL.
15-16	IPCH (integer)	1: Punching of nodal data performed as above. 2: Punching of nodal power only as above. 0: No punching of data.
17-80	(1) ISYM	FREE FORM DATA: This is a boundary condition indicator. Figures 4 through 13 illustrate the following table. = 4: 1/4 core, node centerline (Figure 4) = 3: 1/2 core, node centerline, mirror symmetry (Figure 5) = 1: 1/2 core, node boundary, mirror symmetry (Figure 6). = 2: 1/2 core, node centerline, 180° rotational symmetry (Figure 7). = 0: 1/2 core, node boundary, 180° rotational symmetry (Figure 8). = -1: Full core (Figure 9). = 5: 1/4 core, node boundary, mirror symmetry (Figure 10). = 6: 1/4 core, node boundary, 90° rotational symmetry (Figure 11). = -4:1/8 core,mode centerline, mirror symmetry (Figure 12). = -5: 1/8 core boundary, mirror symmetry (Fig. 13). Each figure is an X-Y plane, the type of boundary condition is the same for all Z.

Column	Content	Description
(2)	KMAX	Number of axial nodes for this case. Maximum allowable KMAX is KD. Minimum KMAX = 2.
		The following 7 parameters are used for termination of various iteration loops. See Figure 2 for the flow of iteration and the location of each convergence test.
(3)	DELSX	Convergence criterion for nodal source convergence.
(4)	NSMAX	Maximum number of source iterations per moderator density calculations (U_{ijk}). Two iterations will be run even if NSMAX<2. Use about 8, fewer if void dependence is severe, and more if void dependence slight.
(5)	BXLS	Eigenvalue convergence criterion within a void loop.
(6)	NUMAX	Maximum number of void loops (U_{ijk} calculation) per exposure or time step. If NUMAX=0, only U_{ijk} and $k_{\infty ijk}$ are recalculated, but S_{ijk} is not so, that input source (or from previous case) will be used in burnup calculation.
(7)	DXLU	If λ from the last source iteration of the previous void loop is less than DXLU from the λ of the last source iteration of this void loop, then the void loop is terminated (converged). $\lvert\lambda_u - \lambda_{u-1}\rvert \leq$ DXLU
(8)	NCMAX	Maximum number of search (control rod or poison) iterations. It must be greater than 2 if not zero.
(9)	DXLC	Eigenvalue convergence criterion for search calculations. The search is terminated when $\lvert\lambda_c - \lambda_0\rvert <$ DXLC. Where c is the search loop count, and λ_0 is the critical λ (XLMBDA). The magnitude of this value depends upon the accuracy of λ_c desired by the user.

Column	Content	Description
17-80 (cont'd)	(10) XLMBDA	Initial guess on core eigenvalue (λ_0)>0. This is also the value of critical eigenvalue (λ_0) to converge on, for a) power search, b) fuel reload option, c) control rod position search, and d) uniform poison search.
	(11) DLP	Power search option = 0: Normal eigenvalue calculation. > 0: Searches for the reactor core power level for an eigenvalue λ_0 and return to the void loop; it will do this until. $\lvert\lambda - \lambda_0\rvert \leq$ DLP or a maximum of five times. The estimate of core power is a straight line approximation using an assumed slope for estimating the second value of power and the input value for the first.
	(12) AV_1	Vertical albedo for bottom (k=1)
	(13) AV_{KMAX}	Vertical albedo for top (k=KMAX)
	(14) not used	
	(15) XKRNL	= 4: Use the fourth type transport kernel given by Equations (22). This is recommended.
	(16) g_v (17) g_h	Transport kernel maxing parameter for vertical (v) and horizontal (h) directions, respectively. See Equations (17), (19), (20), (21) and (22). Set both to 1.0 for XKRNL=4.
	(18) C_w	Constant for the second type transport kernel. See Equation (20). The code sets this to 1.0, if not provided or entered zero. For XKRNL=4, the horizontal albedoes are multiplied by C_w, it can be used as density factor.
	(19) not used	

Column	Content	Description
17-80 (cont'd)	(20) IPRT	= 1: prints the input B's. = 0: deletes the printing.
	(21) IPRT3	= 1: deletes the 3D printout of E, Xe and I arrays. $\leqslant$ 0: prints all 3D arrays. = 2: deletes also the 3D printout of U and H arrays. $\geqslant$ 3: deletes also the 3D printout of SRC (power). $\geqslant$ 5: deletes the printing of iteration monitor.
	(22) ICOMP	$\leqslant$ -2: prints the assembly average relative powers (2x2 nodes). Useful for 1/4 assembly/node calculations. $\geqslant$ 2: makes the comparison with powers of reference. = 1: calculates the peak power by node, multiplyng by a power distribution of reference, suplied as input. = -1: the same, and then makes the colapsing by assembly (2x2 nodes). = 0: not used.

CARD TYPE 3 - Fuel Material Constants:

11-12	03	
13-14		
15-16	T	The fuel material type (integer).
17-80		FREE FORM DATA:
	B_{jT}	Material constants of material type T. T cannot exceed 30. There are 58 constants for each material type and the definitions are given in Section 1.1.2. and below. Subscrip T is omitted for convenience. These data may be obtained by MELON code executions (See § 2 of [7])
	B_1-B_6	Used for calculation of neutron migration area See Equations (34).
	B_7-B_{12}	Used for calculation of nodal k_∞ as a function of relative moderator density (U) and control position. See Equations (35).

Column	Content	Description
17-80 (Cont'd)	B_{13}-B_{15}	Used for calculation of equilibrium Xe effect on nodal k_∞. See Equations (37).
	B_{16}-B_{17}	Used for calculation of Doppler effect on nodal k_∞. See Equations (36).
	B_{18} and B_{20}-B_{23}	Used for calculation of fuel exposure effect on nodal k_∞. See Equation (40).
	B_{24}-B_{26}	Used for conversion from relative nodal source to relative nodal power. See Equation (31).
	B_{27}	Set to 0.0 always.
	B_{28}	Used for calculation of fuel depletion. See Equation (41).
	B_{29} -B_{33}	Used for calculation of soluble poison effect on nodal k_∞. See Equations (39)..
	B_{34} -B_{35}	Used to calculate effective $(\sigma_a\phi)_{Xe}$ by equation (48).
	B_{36}	Mev released per fission, kf; if o, the code assumes a value of 200.0.
	B_{37}	I-135 yield per fission, Y_I; if 0, the code assumes a value of 0.062.
	B_{38}	Xe-135 direct yield per fission, Y_{Xe}; if 0, the code assumes a value of 0.002.
	B_{39}	$f_{ij} = f_i/f_j$ in $(V_{ij})_h$ expression for XKRNL=4. (See Equations (22)). It is the horizontal transport factor, average value by fuel type.
	B_{40}-B_{41}	Used for calculation of soluble poison effect on nodal k_∞. See Equation (39).
	B_{42}-B_{43}	Used for calculation of Doppler effect on nodal k_∞. See Equations (36).
	B_{44}-B_{46}	Used for calculation of equilibrium Xe effect on nodal k_∞. See Equation (38).
	B_{51}	f_{k_∞}; k_∞ correction factor, $(\overline{XK})$ average value by fuel type in the XY plane. See Equations (33).
	B_{52}-B_{53}	Coefficients for linear variation of f_{k_∞} with density and Boron.
	B_{54}	f_{M^2}; M^2 correction factor, average value by fuel type in the XY plane.
	B_{55}-B_{56}	Coefficients for linear variations of f_{M^2} with density and Boron.
	B_{57}-B_{58}	Coefficients for linear variations of f_{ij} with density and Boron.

Column	Content	Description
CARD TYPE 4A - Radial Fuel Assembly Type Array		
11-12	04	
13-14		
15-16	I	Row designation (integer)
17-80		FREE FORM DATA:
	NFT_{ij}	Fuel assembly type in j^{th} position of i^{th} row (Absence of fuel should be indicated by 0). NFT_{ij} cannot exceed LF, but it need not be in a consecutive order.
		If ISYM= -4, -5 the 1/4 core should be described.

CARD TYPE 4B - Axial Fuel Material Type Array

Column	Content	Description
11-12	04	
13-14	1	
15-16	NFT	Fuel Assembly type (integer)
17-80		FREE FROM DATA:
	T_k	Axially varying fuel material type (non-zero) from K=1 tp KMAX for a given NFT. Start with a new card for each NFT, and enter data for all the NFT's which are specified on card type 4A
		If no Type 4B cards appear in a case, the axial fuel material type for a given I, J location will be set to NFT_{ij} on card type 4A.
		Type 4A cards are needed if type 4B cards are given.

CARD TYPE 5A - Control Position.

11-12	05	
13-14		
15-16	I	Row designation (integer).

Column	Content	Description
17-80		FREE FORM DATA:
	R_{ij}	Axial position of control rod tip in nodes and fractions of node; measured from the bottom of core. In this manual it has been assumed that the control rods entered from the bottom as in BWR; because of that in PWR, the B_1, B_2, B_3, B_7, B_8 and B_9 should be associated with control and B_4, B_5, B_6, B_{10}, B_{11} and B_{12} with no control. If CRNR on card type 01 is non-zero and positive, care should be taken that the proper values of i, j are used. R_{ij} is also used as the initial guess for the critical control rod position search, that is, RMAX ≠ 0 on card type 1. RMAX and RMIN on card type 1 must be consistent with the definition of R_{ij} here'

CARD TYPE 5B - Control Length.

Column	Content	Description
11-12	05	
13-14	01	
15-16	I	Row designation (integer).
17-80		FREE FORM DATA:
	RH_{ij}	Length of control rod when the control rods are part-length types. Length of control rod in jth position of the ith row is given. It is not in cm , but in nodes and fractions of node. If RH_{ij}=0, the code assumes a full-lenght control rod. Type 5A cards are needed if Type 5B cards are given.

CARD TYPE 6A - Fractional Flow.

11-12	06	
13-14		
15-16	I	Row designation (integer)
17-80		FREE FORM DATA:
	F_{ij}	Relative flow up each channel (i,j), normalized to 1.0. For a Reference Case, this is set to 1.0 by the code before input read.

CARD TYPE 6B - Power Dependent Flow Factor.

11-12	06	
13-14	01	
15-16	I	Row Designation (integer).
17-80		FREE FORM DATA:
	FP_{ij}	Power dependent flow correction factor for each channel (i,j). See Equation (32). For a Reference Case, this is set to 0.0 by the code before input read. Type 6A cards are needed if type 6B cards are given.

CARD TYPE 7 - Horizontal Albedo.

Column	Content	Description
11-12	07	
13-14		
15-16	I	Row designation (integer)
18-75		FREE FORM DATA:
	AH_{ij}	Horizontal albedo of the node at the ij location. The albedo of i, j locations surrounded by fuel is 0.0, of those with one edge on a boundary of symmetry is 1.0, and of those i, j locations with two edges om symmetry boundaries would be 2.0; all four horizontal sides of a node are summed so that there is no distinction between sides. Albedos for sides other than the above should be chosen so that the results agree with experiment or more sophisticated calculations; this may take some iteration. Do not set AH_{ij}=1.0 at symmetry boundaries specified by Figures 5 through 9 and 11. Instead it should be set to 0.0. The code automatically accounts for the horizontal albedo at the above specified symmetry boundaries.

CARD TYPE 8 - Partial Fuel Factor.

11-12	08

Column	Content	Description
13-14	M	Input Data Type. = 0, XY distribution of the k_∞ correction factors, to be applied to the B_{51} value. = 1, radial power distribution of reference (XY distribution). = 2, axial power distribution of reference (Z distribution). = 3, XY distribucion of the M^2 correction factors, to be applied to the B_{54} value. = 4, XY distribution of the horizontal transport factor, to be applied to be B_{39} value. = 5, Z distribution of the vertical transport correction factors. All of these distributions may be determined by the CONCON and CONAXI codes. (See § 3 and § 4) of [7].
15-16	I	- For M=0, 1, 3 and 4: Row designation. - For M=2: always I=0. - For M=5: I=1: option for Z distribution of the k_∞ correction factor. I=2: option for Z distribution of the M^2 correction factor. I=3: option for Z distribution of the transport correction factors.
17-80	XK_{ij} or XK_k	Distribution of the previously selected parameter. Increasing the j index or the k index, for XY or Z distributions, respectively. Default values are 1.0.

CARD TYPE 9 - Source Guess.

11-12	09	
13-14	I	Row designation (integer)
15-16	J	Column designation (integer)

Column	Content	Description
17-80		FREE FORM DATA:
	S_{ijk}	Source guess: k=1 to KMAX for this i, j. Increment J by 1 for the next set of sources and so on until J=JMAX, then increment I by 1 and do the next set of J's (and their associated k's) until I=IMAX. The values of the source guess are normalized to an average value of 1.0 by the program. For a Reference Case, it is set to the value 1.0 prior to input read.

CARD TYPE 10A - Fuel Labels.

11-12	10	
13-14	I	Row designation (integer)
15-16		A4 FORMAT DATA:
17-20	$ID_{i,1}$	Four alpha-numeric characters. NOTE: This is not free form data. $ID_{i,j}$ is the identification of each bundle (i, j location) in the problem; use blanks where there is no fuel. If the S_{ijk}, E_{ijk}, V_{ijk}, EID_{ijk}, and XEN_{ijk} are punched (see card type 02). this ID will appear in columns 3-6 of each card.
21-24	$ID_{i,2}$	
etc.		
77-80	$ID_{i,16}$	The purpose of the fuel ID is to facilitate fuel switching and to maintain records of the rearrangement. Normally, Exposure cards (type 10B) will be read in originally for each i,j position with non-zero exposure, followed by the ID cards (type 10A) to label each fuel bundle. In Change Cases thereafter, ID cards for each row in which there is to be a bundle replaced will be ordered to precede the Exposure cards for the new bundles. An ID card for each such row, only, is required, but the label for all bundles in the row must be given.
		After one or more ID cards have been read in, all following exposure cards in each case will be assigned to the i, j position whose label in the ID array is equal to that punched in columns 3-6 of each Exposure card. Thus, an ID card not only changes the labels in the ID array but also forces all succeeding Exposure cards read in this or any following Change Case to be stored by the label in columns 3-6 rather than by the i, j carried in columns 13-14, 15-16 of Exposure cards. If Card 10A's are supplied. Card types 18 and 19 must have labels (ID_{ij}) on columns 3 through 6.

CARD TYPE 10B - Exposure.

Column	Content	Description
1-2	Run Number	(Punched output contains IPCH from the preceding case).
3-6	$ID_{I,J}$	
7-8	T	Fuel Type (overlays type 04 when arranged by $ID_{I,J}$, and type 10A cards are read in
11-12	10	before type 10B; not needed if there are no label cards). (integer).
13-14	I	Row designation (integer).
15-16	J	Column Designation (integer).
17-80		FREE FORM DATA:
	E_{ijk}	Exposure in 1000 MWD/T in the same manner as the source guess.

Exposure cards read in before any Label card (type 10A) since the last Reference Case Title Card will be stored according to the i,j location punched in columns 13-14, 15-16 of each Exposure card. However, once a Label card has been read in a series of Change cases, all succeeding Exposure cards (in whatever Change case) will be stored in the first i,j position whose label in the ID array equals the label punched in columns 3-6 of that card. Under these circumstances, Exposure cards with a blank label in columns 3-6 will be stored in the first i,j without fuel (probably 1,1 for a full-core problem). Exposure cards with a label which is not found in the ID array will be ignored. This permits Exposure cards which correspond to fuel no longer in the core to remain in the input deck without effect on the calculation.

CARD TYPE 12 - Convergence Acceleration.

Column	Content	Description
11-12	12	
13-14		
15-16	IACCEL	Type of source acceleration

Column	Content	Description
15-16 (Cont'd)		= -1: Source over-relaxation, Equation (26). It is recommended. = 0: Point Jacobi, Equation (25). = +1: Gauss - Seidel, Equation (27).
17-80		FREE FORM DATA:
	Γ_n	Acceleration factors, n=1 to 70. n is the source iteration number for a given void loop. After the 70th iteration Γ_n is set to 0.0 by the code. If uncertain on the type of acceleration factors, use IACCEL=0 and Γ_n=0.0. For PWR, Γ_n=0.7 is recommended. $-1<\Gamma_n<0$ attenuation. $0<\Gamma_n<1$ acceleration.

CARD TYPE 13 - Moderator Density Coefficients.

11-12	13	
13-14		
15-16	KED	Source iteration debugging print option = 0: No effect. = 1: Print 3-dimensional source array after each source calculation. =-1: Print 2-dimensional (radial) source array after each source calculation.
17-80		FREE FORM DATA:

Column	Content	Description
17-80 (Cont'd)	C_n	C_1 through C_6 are used to calculate the void fraction (χ_{ijk}) according to Equation (29) these values are determined to fit U vs. enthalpy tables, to get U=1.0 at core average temperature, using the same core average temperature here, than in the k_∞ and M^2 correlations.

For PWR applications normally use:

$C_4 = 0.0$
$C_5 = -10.$
$C_6 = 1.$
$C_7 = 1. = h_{fg}$
$C_{14} = 1. = \rho_f$
$C_{15} = 0. = \rho_g$

$U = 1-\chi = 1-C_1-C_2Q-C_3Q^2 =$
$= 1-C_1-C_2(-\Delta h_s)-C_3(-\Delta h_s)^2$
using $h_{s1}=h_{inlet}$ and
$h_{s2}=0$ (card type 1)
$\rightarrow \quad -\Delta h_s = h$ and
$U = 1-C_1-C_2h-C_3h^2$

this is the thermohydraulic correlation, to be fitted using the U vs. h. tables, being $U = \frac{\rho(h)}{\rho(\bar{h})}$ the ratio between the moderator density corresponding to h and the value corresponding to the core average enthalpy or temperature.

At hot zero power, $C_2=C_3=0.0$.

C_7	Enthalpy of evaporation (h_{fg}) in Btu/lb. this is used for calculation of Q_{ex} which is used in Equation (28).
C_8	Set 0.0
C_9	Set 0.0
C_{10}	= 1: An edit of S_{ij} is given after each void iteration. ≠ 1: No effect.
C_{11}	= 1: An edit of S_{ijk} is given after each void iteration. ≠ 1: No effect.
C_{12}	= 1: An edit of U_{ij} and U_{ijk} is given after each void iteration. ≠ 1: No effect.

Column	Content	Description
17-80 (cont'd)	C_{13}	= 1: An edit of H_{ijk} (k_∞) is given after each iteracion.
		≠ 1: No effect.
	C_{14}	= ρ_f: Density of saturated moderator liquid.
	C_{15}	= ρ_g: Density of saturated moderator vapor. The units of C_{14} and C_{15} must be the same. These are used to calculate U_{ijk} by Equation (30)

Following card types 18 and 19 are supplied only when a transient calculation with NOPT=1 on card type 1 is indicated and initial value of I-135 and Xe-135 are desired. If given for NOPT ≠ 1, the concentrations will not have any effect on nodal k_∞.

CARD TYPE 18 - I-135 Concentration.

1-10		Same as type 10B
11-12	18	
13-14	I	Row designation (integer)
15-16	J	Column designation (integer)
17-80		FREE FORM DATA:
	EID_{ijk}	I-135 concentration in the same arrangement as S_{ijk} on card type 9. The unit of concentration is in 10^{15} atoms/cc, equivalent to 10^{-9} atoms/(barn.cm). These cards are allocated to i,j positions exactly the same as Exposure cards (type 10B) in regard to the Label cards (type 10A) and corresponding ID array.

CARD TYPE 19 - Xe-135 Concentration.

1-10		Same as type 10B.
11-12	19	

Column	Content	Description
13-14	I	Row designation (integer)
15-16	J	Column designation (integer)
17-80		FREE FORM DATA:
	XEN_{ijk}	Xe-135 concentration in the same arrangement as EID_{ijk} on Card type 18. All the rules for EID_{ijk} apply to this card.

CARD TYPE 33 (2A5,I2) - Reorder Card.

11-12	33	Used only to precede additional data which are out of order and not convenient to combine into basic deck. Inserted before every card whose type is lower than the preceding card.

CARD TYPE 99 (2A5,I2) - END CARD - always required.

11-12	99	The last card of each case. This card signals the end of input data for each case.

TERMINAL CARD (A1,A4) - Job Termination Card.

1	"I"	This card signals the end of a given case.
2-5	"LAST"	"LAST" is not a variable name, but it must be punched on column 2-5. Input data decks following this card will be processed as the first case, it is as reference (I) or restart (D) cases. This is useful for processing several restarts from the same restart tape 1.

TABLE 1

SUMMARY OF SIMULA-3 CASE INPUT DATA

Card Type	Dimension	Card		
			ID, JD, KD	
	Title	Card	Alphanumeric Description of Case	
1		IBURN	E_o, E_{max}, ΔE, ΔX, ΔZ, P_{th}, P_r, W_1, W_2, h_{s1}, h_{s2}, CRNR, ITAPE, IMABWR, IBUG1, IBUG2, RMAX, RMIN, RINC, NOPT, PPM,	
2	IPCH	KPCH	ISYM, KMAX, DELSX, NSMAX, DXLS, NUMAX, DXLU, NCMAX, DXLC, XLMBDA, DLP, AV_1, AV_{KMAX}, CHI, XKRNL, g_v, g_h, C_w, IHAL, IPRT, IPRT3, ICOMP.	
3		t	Constants for Fuel Type t	B_{jt} , j = 1,54 or 60
4		I	Radial Fuel Assembly Type by I,J	NFT_{IJ} , J = 1,JMAX
4	1	NFT	Axial Fuel Type by k	T_k , k = 1,KMAX
5		I	Control Position by I,J	R_{IJ} , J = 1,JMAX
5	I	I	Length of Control Rod by I,J	RH_{JI} , J = 1,JMAX
6		I	Fractional Flow by I,J	F_{IJ} , J = 1,JMAX
6	1	I	Power Dependent Flow Factor by I, J	FP_{IJ} , J = 1,JMAX
7		I	Horizontal Albedo by I,J	AH_{IJ} , J = 1,JMAX
8		I	Partial Fuel Factor by I,J or k	XK_{IJ} or XK_k , j = 1,JMAX or K = 1,KMAX
9	I	J	Source Guess by I,J,k	S_{IJk} , k = 1,KMAX
10	I	O	Fuel Labels by I,J	ID_{IJ} , J = 1,JMAX (A4 Format)
T+10	I	J	Exposure by I, J, k	E_{IJk} , k = 1,KMAX

TABLE 1 (Cont'd)

SUMMARY OF SIMULA-3 CASE INPUT DATA

Card Type				
12		IACCEL	Acceleration Factors	F_j , j = 1, 16
13		KED	Density Coefficients	C_j , j = 1, 15 or 17.
18	I	J	I-135 Concentration	EID_{IJk} , k = 1, KMAX
19	I	J	Xe-135 Concentration	XEN_{IJk} , k = 1, KMAX
33			Overlay card for basic data. Used only to precede additional (or overlay) data which is out of order and not convenient to combine (by type) into basic deck.	
99			Precedes TITLE CARD or LAST CARD. Signals end of data for this case.	

TABLE 2

SIMULA-3 INPUT DATA DECK SETUP

1. DIMENSION CARD (Only one card)
2. TITLE CARD of 1st case (It must be a Reference Case; but if a restart tape is available, it can be made a Change case)
3. Card types 1 through 33 for 1st case (Required cards only)
4. END CARD of 1st case ("99" punch on column 11-12)
5. TITLE CARD of 2nd case (Reference or Change Case)
6. Card types 1 through 33 for 2nd case (Required cards only)
7. END CARD of 2nd case ("99" punch on columns 11-12)
8. Repeat 5 through 7 for additional cases
9. TERMINAL CARD ("LAST" on columns 1-5)

NOTE: All the cases in a job must have same nodal meshes (i.e., same I, same J, and same K)

1.3. SAMPLE PROBLEM.

In the listing 1 are the input data for a three dimensional calculation of a quarter core of a PWR burnup cycle. The constants of the correlations (Section 03) were generated by MELON-3 executions, the transport and correction factors (Section 08) and horizontal albedoes (Section 07) by CONCON executions and the vertical albedoes (Card 02) and axial correction factors (Sections 08-2 and -5) by CONAXI calculations.

1.4. SIMULA-3 OUTPUT.

1.4.1. Printed Output.

Listing 1 is the printed output of the SIMULA execution with the previous sample problem input data.

For each page of the SIMULA output, the first line contains the title of a case and a page number. The page number is reset to "1" whenever a new case. (Reference or Change) is read in. A summary of items in the output of a case is given in Table 3. All the input data for a given job are printed at the beginning as they appear on input cards. Each case input data are again printed before the computed results. The fuel identification and the type of neutron transport kernel and source iteration scheme are also printed next. If the SIMULA special option parameters (NOPT on card type 1) were checked, the type of option is described inmmediately after the fuel type arrangement. The initial values of source (S_{ijk}), fuel exposure (E_{ijk}), and concentrations of I-135 and Xe-135 (EID_{ijk} and XEN_{ijk}) are printed by channel and by bank (node) only when these are provided by the input data cards.

The printing of 3D distributions and iteration can be deleted through input variable IPRT3 on card 02

The control rod positions (R_{ij}) and control rod lenght (RH_{ij}) are always printed prior to the first void (moderator density) iteration.

Results of each iteration are printed in a summary form. The symbols used for the description of iteration results in the SIMULA output are described in Table 4. Core average, channel, and nodal distributions of source, power, moderator density, and k_∞ in items 6, 7 and 8 in Table 3 are always printed regardless of the type of a problem. Note that the moderator density is not the absolute but relative density and the source and power are normalized to core averages of 1.0. The values of K are k_∞'s given by Equations (33) to (42).

The nodal concentrations of I-135 (EID) and XE-135 (XEN) are printed only for a transient Xe calculations, and they are expressed in 10^{-9} atoms/(barn-cm) which is equivalent to 10^{15} atoms/cc. The distribution of fuel exposure (E) is printed only for fuel burnup, refueling, and transient Xe calculation options. The unit of fuel exposure is the same as the unit given for E_0, E_{max}, and ΔE on card type 1 (=1,000 MWD/T).

During the control rod position or soluble poison search calculations, the results given by items, 6, 7, and 8 in Table 3 are not printed until the search is completed. That is, only the iteration data and estimated control rod positions or estimated poison are printed during the search iteration.

Additional debugging output edits of two or three-dimensional arrays are given at various stages of iteration according to input specifications for IBUG1 and IBUG2 on type 1 card, and KED and C_{10} through C_{13} on type 13 card. Use of these options for debugging edits is not recommended for normal production runs.

TABLE 3

SUMMARY OF SIMULA-3 CASE OUTPUT

1. Input card data.

2. Fuel identification and arrangement of fuel material types (NFTID, T, NFT)

3. Input source, exposure, I-135, and Xe-135 (S, E, EID, XEN) (if provided).

4. Control rod positions and rod langths (R, RH).

5. Source and void (density) iteration data.

6. Axial distributions of core average power and moderator density; core peak power, and inlet and outlet steam quality.

*7. Distribution by channel and by node of power and moderator density (SRC).

*8. Distribution of k_∞ by node (K).

*9. Distributions of fuel exposure by channel and by node (E) (for fuel burnup or transient Xe calculation only).

*10. Distribution of I-135 and Xe-135 by node (EID, XEN) (for transient Xe calculation only).

---

* For control rod position and soluble poison search problems the various nodal distributions are given only for the final, converged results.

TABLE 4

DESCRIPTION OF SYMBOLS
IN NORMAL SIMULA-3 ITERATION RESULTS (See Fig. 2)

Symbols in NUSIM-2 Output	Description
NC	Search calculation iteration count (c)
NU	Void (moderator density) iteration count (u)
NS	Source iteration count (n)
DELTA L S	$\lambda_n - \lambda_{n-1}$
DELTA L U	$\lambda_u - \lambda_{u-1}$
DELTA L C	$\lambda_c - \lambda_{c-1}$
ACCEL S TOT	Sum of normalized old sources (S_N in Section IIB.18.b)
MAX REL CHG IN SOURCE	Maximum value of $\lvert\Delta S\rvert / S$ and its location i,j,k
SOURCE TOT	Sum of unnormalized new source (S_T in Section IIB.18.a)
LAMBDA	Current value of eigenvalue (λ_n, λ_u, or λ_c)
CONVERGENCE	Convergence indicator: - 1 for $\lvert\lambda_u$ - SHANK$\rvert$ < DXLU : 0 for $\lvert$SHANK-SHANQ$\rvert$ < DXLU
SHANK	$\dfrac{\lambda_{u-2}\lambda_u - \lambda_{u-1}^2}{\lambda_{u-2} + \lambda_u - 2\lambda_{u-1}}$
SHANQ	$\dfrac{SHANK_{u-2} \cdot SHANK_u - SHANK_{u-1}^2}{SHANK_{u-2} + SHANK_u - 2 \cdot SHANK_{u-1}}$
DEL LMB	$\lvert\lambda_u$ - SHANK$\rvert$
DEL SH SQ	$\lvert$SHANK - SHANQ$\rvert$

1.4.2. Tapes Output.

When the punch card option is specified by tape 2 card, the three dimensional arrays are written in File 7 (TAPE 7) according to the input formats for these arrays. Columns 1 through 16 of punch cards contain the following information:

Column	Content
1-2	IPCH
3-6	NFTID (I,J) - Fuel label for E, EID and XEN INAME - "SIJK" - for S, "POWR" - for SRC
7-8	NFT (I,J) - Fuel material type for E, EID and XEN M - Card sequence no. - for S and SRC.
9-10	N - Card sequence no. - for E, EID, and XEN N - Card sequence no. - for S and SRC
11-12	L - Card type no. "9", "10", "18", "19", etc. - 0 for SRC (power)
13-14	I - value of I (row)
15-16	J - value of J (column)

Columns 18 through 80 contain values of S(I,J,K), SRC(I,J,K), E(I,J,K), EID(I,J,K), or XEN(I,J,K) in a 9F7.3 format starting from K=1. Thus there will be nine values per card, and the required additional cards will contain the same data on columns 1 through 16 except the card sequence number.

1.5. PROGRAM CHARACTERISTICS.

The SIMULA-3 program is written in standard FORTRAN V for UNIVAC 1100 and CYBER-835 and it can be segmented into three overlays. Segment 0 provides the control and flow of the code, segment 1 processes input data and segment 2 computes and edits the computed output. It has about 3.500 sentences.

1.5.1. I/O Unit requirements.

The SIMULA-3 code requires the following files (disk) for its operation:

File No.	Use
Tape 1	Previously written restart tape containing the variables in all the common blocks.
Tape 2	Newly written restart tape after the execution of the current case
Tape 3	Scratch file for temporary data storage used in subroutine PARTE only in transient Xenon calculations.
Tape 5	Input data file.
Tape 6	Standard output file.
Tape 7	BCD card punch file.

1.5.2. Restrictions on the complexity of the problem.

All arrays in SIMULA-3 are dimensioned through four parameter variables, which can be easily changed for recompilation. These are:

Parameter variables and given values

LI = No. of nodes in the X direction ≤ 15

LJ = No. of nodes in the Y direction ≤ 15

LK = No. of axial nodes ≤ 17

LF = No. of material or fuel assembly types ≤ 15

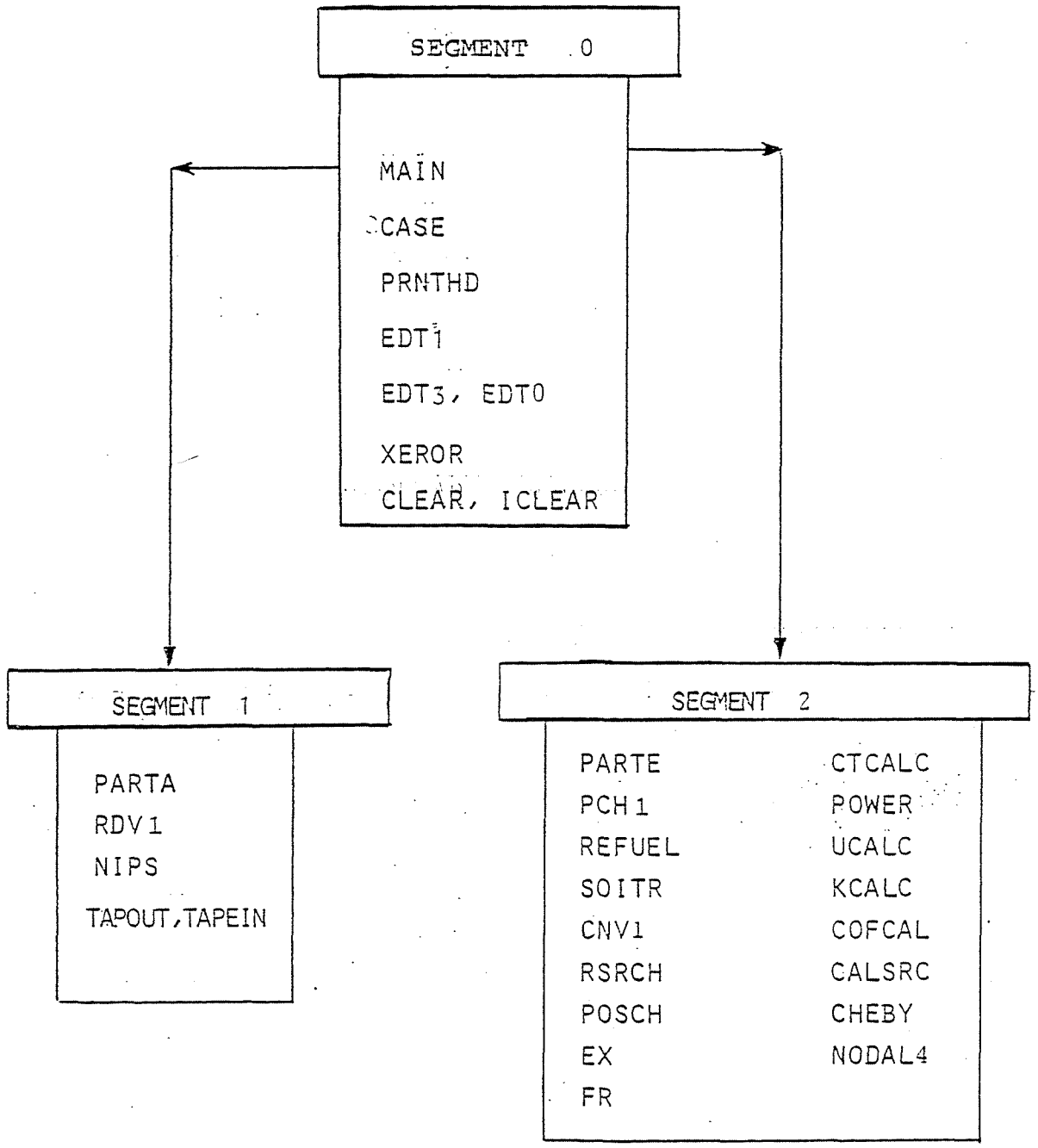
1.5.3. Program Structure.

BRIEF DESCRIPTION OF SIMULA-3 SUBROUTINES.

NAME	DESCRIPTION
MAIN	Main program of SIMULA-3.
CASE	Reads the TITLE card and prints information thereof.
PRNTHD	Prints the case title and page number on the output sheet.
EDT0	Prints output data including iteration results.
EDT1	Prints the gross or average core data after the termination of iteration and before proceeding to array editing.
EDT3	Prints two and three dimensional arrays.
XEROR	Prints error messages for programmed error stops.

NAME	DESCRIPTION
CLEAR	Initializes a floating point data array.
ICLEAR	Initializes a integer data array.
PARTA	Calls RDV1 Checks input data and processes them for computational setup. Edits the processed input arrays.
RDV1	Reads and checks input data cards, and stores the data in appropriate locations. "As read" information is listed card by card. Call NIPS, TAPEIN and TAPOUT. Reads reference power distributions.
NIPS	Converts the free form input data on columns 17 through 80 of a card, from the alphanumeric form to floating point numbers.
TAPEIN	Reads an old (previously created) restart tape (TAPE 1) and prints the identifying information.
TAPOUT	Writes a new restart tape (TAPE 2) and prints the identifying information.
PARTE	Initiates detailed setup for computation. Calls CTCALC, POWER, UCALC and KCALC to calculate nodal arrays, and NODAL4 and CNVI to calculate source terms and to control source and void iterations. Calls RSRCH and POSCH for search of control rods and poison calculations. Calls PCH1 and EDT0, EDT1, EDT3 to punch and print intermediate and final computed results.
PCH1	Punches three dimensional arrays of source, exposure, and concentrations of I-135 and Xe-135.
REFUEL	Calculates new exposure arrays and zone average exposures during the reload (Haling) calculation. Tests for convergence of the reload calculation and prints convergence data.

NAME	DESCRIPTION
CTCALC	Converts the input control rod position to control array (c_t) for use in calculation of nodal M^2 and k_∞.
POWER	Converts nodal relative source to nodal relative power.
UCALC	Computes nodal moderator relative density.
KCALC	Computes nodal k_∞.
COFCAL	Computes nodal neutron transport kernels and three dimensional source coefficients D and G.
SOITR	Calculate nodal source terms, eigenvalue, and other source iteration data for a given source loop. Forward - Brekward Solution on axial lines.
CNV1	Calculates additional void convergence data and checks for convergence of void loop.
CALSRC	Similar to SOITR except that this is used for the Chebyshev polynomial source acceleration option.
CHEBY	Applies the Chebyshev polynomial to the acceleration of sources during source iteration.
RSRCH	Determines new control rod positions during the control rod position search and checks the convergence of λ_c to λ_0. Edits the new control rod positions at each search loop.
EX	Computes exp (X).
NODAL4	Source calculation for the transport kernel type 4.
FR	Is a function for interpolation ans extrapolation calculations.
POSCH	Determines new poison during the soluble poison search iteration and checks the convergence of λ_c to λ_o. Edits the new poison concentration at each search loop.



SIMULA-3 Program Linkage

1.5.4. Machine time requirements and core storage.

The running time of a case varies widely depending upon the number of nodes, the type of problem and the convergence criteria for each type of iteration. Generalization of the running time is difficult.

As an example the running time on a CYBER-835 of a 15x15x17 nodes case, 1 burnup step, poison search, NSMAX=8, NUMAX=20, IACCEL=-1, ε=5.E-5, and 5.E-7 is about 90 seconds of central processor time.

The required memory for the main common of SIMULA-3 is:

Length of COMMON = 9.LI.LJ.LK + 17.LI.LJ (=38250).

where Li, LJ, LK are the number of nodes in I, J, K directions.

The additional central memory for code and data is 17.2 k-words in the CYBER-835 without segmentation.

1.5.5. Error Stops.

When the nodal meshes specified by the DIMENSION card are out of the range of the maximum allowable nodes by the current version, the SIMULA-3 code will not execute any of the cases in a job.

There are two types of error stops in the code: programmed and unprogrammed. The programmed stops are those resulting from specific input data checks by the code. When a programmed error stop occurs, an error message is printed with the input card type number or an error type number, and the code skips the current case to read the next case. Following programmed error stops are available in SIMULA-3.

Error Message	Cause
ERROR STOP OF TYPE 7	Fuel border type error.
ERROR STOP OF TYPE 8	Fuel border type error.
ERROR STOP OF TYPE 9	Non-positive fuel material numbers.

ERROR STOP OF TYPE 10	IMAX≤1
ERROR STOP OF TYPE 181	XLMBDA≤0 (Card type 2)
FOLLOWING CARDS OUT OF ORDER	Non-sequential card number.
FORMAT OF VALUE ON CARD NOT ACCEPTABLE	Input data format error.

There are additional programmed stops in the control rod position search or soluble poison search calculations. The reason for this type of error is usually printed in the output; however, these stops are different from the above such that all the computed results up to the stop are printed when the error occurs.

1.5.6. Restart Options

There are two ways to save the results of the current case for future use. One is to punch in unit 7 (TAPE 7) three dimensional arrays of S, E, EID, XEN in formats identical to their input data formats according to the specifications for KP, IPCH and IHAL on card type 2. These cards can be writen, from any burnup (or Xe transient) step of a case or from any or more than one case of a given job. This unit is combined with other input data and used for restart cases vith the same number of nodes. The first case in these restart cards must be an independent case.

The other is to store the current case data on a restart file (TAPE 2) for future use by specifying "SAVE" on columns 2 through 5 of the title card of the current case. The data can be saved from any case of a job on consecutive files of the unit TAPE 2. The saved data include not only the two and three dimensional arrays in the blank main COMMON, but also the remaining data on the labelled COMMONS; hence, the restart file contains much more complete data than the punch cards, requiring not additional input data for the restart case.

The restart file becomes "TAPE 1" in a restart case; and if

specified, a new restart file is created on TAPE 2 instead of TAPE 1. The restart case must be similar to the case on the restart file with respect to the number of nodes and it must be made the first dependent case of a job. Although a new restart file (TAPE 2) can be created from any case of the job as stated earlier, the old (previously generated) restart file can be reached only from the first and dependent case in the input deck or after a "ILAST" card.

2. REFERENCIAS.

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LISTING 1

SIMULA-3 - Input Data and Printed Output for a Sample Problem.

LISTING 1 SIMULA-3 INPUT DATA AND PRINTED OUTPUT FOR SAMPLE PROBLEM

```
PROGRAM SIMULA-3    VERSION IAEA-CRP (JEN-567)    J.M. ARAGONES   SEPT 84
      I = 15    J = 15    K = 17        MEMORY USED =  38250 COMMON WORDS + 17120 CODE WORDS =  55370 TOTAL WORDS


            I     SIMULA-3   INPUT DATA    BOL-ARO-HFP-EQ.XENON   ALB-V OF CONAXI

                                THIS IS AN INDEPENDENT CASE
                              THE CORRECT TIME IS  16.33.11.
                          THE CPU TIME USED THUS FAR IS     27.349 SECONDS
```

INPUT CARDS

CARD TYPE 1 INPUT

```
1  0  0   *  0.0    ,  0.0    ,  0.0  , 10.7518 , 21.5153 ,                          *   (          )
1  0  0   *  2700.0 , 2700.0  , 100.0E+6 , 0.0 , -555.4 ,0.0,0,0,1.0,               *   (          )
1  0  0   *  S5 , 3 ,  900.0 , 0   , S6                                             *   (          )
```

CARD TYPE 2 INPUT

```
2  0  0   *  -5,17,5.0E-6, 8 ,1.0E-7 , 20 ,1.0E-7,10,1.0E-5,  1.00,0               *   (          )
2  0  0   *   1.241 , 1.215 , 0 , 4 , 1.0 ,1.0, 1.0 ,0,1,3,-2                      *   (          )
```

```
KD       T   CONSTANTS  BY  FUEL  TYPE          B(J,T)  J=1,73
3  0  1   *   .207466E+03 , -.107244E+01 ,  .357318E+00 ,                          *   (B1 - B3   )
3  0  1   *  0.           , 0.           , 0.           ,                          *   (B4 - B6   )
3  0  1   *   .992825E+00 ,  .342835E+00 , -.103457E+00 ,                          *   (B7 - B9   )
3  0  1   *  0.           , 0.           , 0.           ,                          *   (B10- B12  )
3  0  1   *   .218872E+00 ,  .290909E-01 , 0.           ,                          *   (B13- B15  )
3  0  1   *   .123253E-01 , 0.           , 0.           , 0.           ,           *   (B16- B19  )
3  0  1   *  0.           , 0.           , 0.           , 0.           ,           *   (B20- B23  )
3  0  1   *     1.0000 ,    0.0000 ,    0.0000 ,    0.0000 ,    1.0000 ,          *   (B24- B28  )
3  0  1   *   .133506E-03 , -.186296E-07 ,  .196998E-11 ,                          *   (B29- B31  )
3  0  1   *  0.           , 0.           , 0.           , 0.           ,           *   (B32- B35  )
3  0  1   *  0.           , 0.           , 0.           ,  .100000E+01 ,           *   (B36- B39  )
3  0  1   *  0.           , 0.           , -.875891E-01 ,                          *   (B40- B42  )
3  0  1   *  0.           , 0.           , 0.           , 0.           ,           *   (B43- B46  )
3  0  1   *  0.           , 0.           , 0.           , 0.           ,           *   (B47- B50  )
3  0  1   *   .100000E+01 , 0.           , 0.           ,                          *   (B51- B53  )
3  0  1   *   .100000E+01 , 0.           , 0.           ,                          *   (B54- B56  )
3  0  1   *  0.           , 0.                                                      *   (B57- B58  )
3  0  2   *   .205354E+03 , -.107277E+01 ,  .357645E+00 ,                          *   (B1 - B3   )
3  0  2   *  0.           , 0.           , 0.           ,                          *   (B4 - B6   )
3  0  2   *   .103543E+01 ,  .415093E+00 , -.134013E+00 ,                          *   (B7 - B9   )
3  0  2   *  0.           , 0.           , 0.           ,                          *   (B10- B12  )
3  0  2   *   .326891E+00 ,  .295948E-01 , 0.           ,                          *   (B13- B15  )
3  0  2   *   .121284E-01 , 0.           , 0.           , 0.           ,           *   (B16- B19  )
3  0  2   *  0.           , 0.           , 0.           , 0.           ,           *   (B20- B23  )
3  0  2   *     1.0000 ,    0.0000 ,    0.0000 ,    0.0000 ,    1.0000 ,          *   (B24- B28  )
3  0  2   *   .101154E-03 , -.109487E-07 ,  .931627E-12 ,                          *   (B29- B31  )
3  0  2   *  0.           , 0.           , 0.           , 0.           ,           *   (B32- B35  )
3  0  2   *  0.           , 0.           , 0.           ,  .100000E+01 ,           *   (B36- B39  )
3  0  2   *  0.           , 0.           , -.873497E-01 ,                          *   (B40- B42  )
3  0  2   *  0.           , 0.           , 0.           , 0.           ,           *   (B43- B46  )
3  0  2   *  0.           , 0.           , 0.           , 0.           ,           *   (B47- B50  )
3  0  2   *   .100000E+01 , 0.           , 0.           ,                          *   (B51- B53  )
3  0  2   *   .100000E+01 , 0.           , 0.           ,                          *   (B54- B56  )
3  0  2   *  0.           , 0.                                                      *   (B57- B58  )
3  0  3   *   .485180E+03 , -.159532E+01 ,  .712211E+00 ,                          *   (B1 - B3   )
3  0  3   *  0.           , 0.           , 0.           ,                          *   (B4 - B6   )
3  0  3   *   .843329E+00 ,  .408147E+00 , -.108869E+00 ,                          *   (B7 - B9   )
3  0  3   *  0.           , 0.           , 0.           ,                          *   (B10- B12  )
3  0  3   *   .636219E+00 ,  .304489E-01 , 0.           ,                          *   (B13- B15  )
3  0  3   *   .138805E-01 , 0.           , 0.           , 0.           ,           *   (B16- B19  )
3  0  3   *  0.           , 0.           , 0.           , 0.           ,           *   (B20- B23  )
3  0  3   *     1.0000 ,    0.0000 ,    0.0000 ,    0.0000 ,    1.0000 ,          *   (B24- B28  )
```

INPUT CARDS

```
 3  0  3     *   .918523E-04 , -.916409E-08 ,  .741265E-12 ,                 *          (829- 831 )
 3  0  3     *  0.           , 0.           , 0.           , 0.           ,  *          (832- 835 )
 3  0  3     *  0.           , 0.           , 0.           ,  .100000E+01 ,  *          (836- 839 )
 3  0  3     *  0.           , 0.           , -.113223E+00 ,                 *          (840- 842 )
 3  0  3     *  0.           , 0.           , 0.           , 0.           ,  *          (843- 846 )
 3  0  3     *  0.           , 0.           , 0.           , 0.           ,  *          (847- 850 )
 3  0  3     *   .100000E+01 , 0.           , 0.           ,                 *          (851- 853 )
 3  0  3     *   .100000E+01 , 0.           , 0.           ,                 *          (854- 856 )
 3  0  3     *  0.           , 0.                                            *          (857- 858 )

KD       I    RADIAL FUEL ASSEMBLY ID        NFT(I,J)  J=1,JMAX
 4  0  1     *  1  3  3  1  1  3  3  1  1  3  3  1  1  2  2                  *          (          )
 4  0  2     *  3  1  1  3  3  1  1  3  3  1  1  3  3  2  2                  *          (          )
 4  0  3     *  3  1  1  3  3  1  1  3  3  1  1  3  3  2  2                  *          (          )
 4  0  4     *  1  3  3  1  1  3  3  1  1  3  3  2  2  0  0                  *          (          )
 4  0  5     *  1  3  3  1  1  3  3  1  1  3  3  2  2  0  0                  *          (          )
 4  0  6     *  3  1  1  3  3  1  1  3  3  2  2  2  2  0  0                  *          (          )
 4  0  7     *  3  1  1  3  3  1  1  3  3  2  2  2  2  0  0                  *          (          )
 4  0  8     *  1  3  3  1  1  3  3  1  1  2  2  0  0  0  0                  *          (          )
 4  0  9     *  1  3  3  1  1  3  3  1  1  2  2  0  0  0  0                  *          (          )
 4  0 10     *  3  1  1  3  3  2  2  2  2  0  0  0  0  0  0                  *          (          )
 4  0 11     *  3  1  1  3  3  2  2  2  2  0  0  0  0  0  0                  *          (          )
 4  0 12     *  1  3  3  2  2  2  2  0  0  0  0  0  0  0  0                  *          (          )
 4  0 13     *  1  3  3  2  2  2  2  0  0  0  0  0  0  0  0                  *          (          )
 4  0 14     *  2  2  2  0  0  0  0  0  0  0  0  0  0  0  0                  *          (          )
 4  0 15     *  2  2  2  0  0  0  0  0  0  0  0  0  0  0  0                  *          (          )

KD       I    HORIZONTAL ALBEDO        AH(I,J)  J=1,JHAX
 7  0  1     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0  1     *  .0000  .0000  .0000  .0000  .0000  .0000  .8000            *          (  ALBRAD  )
 7  0  2     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0  2     *  .0000  .0000  .0000  .0000  .0000  .0000  .8000            *          (  ALBRAD  )
 7  0  3     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0  3     *  .0000  .0000  .0000  .0000  .0000  .5500 1.5500            *          (  ALBRAD  )
 7  0  4     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0  4     *  .0000  .0000  .0000  .0000  .6500  .0000  .0000            *          (  ALBRAD  )
 7  0  5     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0  5     *  .0000  .0000  .0000  .0000  .8000  .0000  .0000            *          (  ALBRAD  )
 7  0  6     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0  6     *  .0000  .0000  .0000  .0000  .8000  .0000  .0000            *          (  ALBRAD  )
 7  0  7     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0  7     *  .0000  .0000  .0000  .6500 1.6000  .0000  .0000            *          (  ALBRAD  )
 7  0  8     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0  8     *  .0000  .0000  .6500  .0000  .0000  .0000  .0000            *          (  ALBRAD  )
 7  0  9     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0  9     *  .0000  .6500 1.6000  .0000  .0000  .0000  .0000            *          (  ALBRAD  )
 7  0 10     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000  .0000     *          (  ALBRAD  )
 7  0 10     *  .6500  .0000  .0000  .0000  .0000  .0000  .0000            *          (  ALBRAD  )
 7  0 11     *  .0000  .0000  .0000  .6000  .0000  .0000  .0000  .6500     *          (  ALBRAD  )
 7  0 11     * 1.6000  .0000  .0000  .0000  .0000  .0000  .0000            *          (  ALBRAD  )
 7  0 12     *  .0000  .0000  .0000  .0000  .0000  .0000  .6500  .0000     *          (  ALBRAD  )
 7  0 12     *  .0000  .0000  .0000  .0000  .0000  .0000  .0000            *          (  ALBRAD  )
```

INPUT CARDS

```
 7  0  13          *  .0000  .0000  .0000  .6500  .8000  .8000 1.6000  .0000      *          (  ALBRAD  )
 7  0  13          *  .0000  .0000  .0000  .0000  .0000  .0000  .0000             *          (  ALBRAD  )
 7  0  14          *  .0000  .0000  .5500  .0000  .0000  .0000  .0000  .0000      *          (  ALBRAD  )
 7  0  14          *  .0000  .0000  .0000  .0000  .0000  .0000  .0000             *          (  ALBRAD  )
 7  0  15          *  .8000  .8000 1.5500  .0000  .0000  .0000  .0000  .0000      *          (  ALBRAD  )
 7  0  15          *  .0000  .0000  .0000  .0000  .0000  .0000  .0000             *          (  ALBRAD  )

KD     I           PARTIAL FUEL FACTOR          XK(I,J)  J=1,JMAX
 8  5  1           * 1.0039  0.9997  R14  1.0063                                 *          (  XK-V    )
 8  5  2           * 0.9627  1.0012  R14  0.9750                                 *          (  XM-V    )
 8  5  3           * 1.0258  1.0055  R13  0.9803                                 *          (  XF-V    )

KD   ICHEBY                ACCELERATION FACTORS
12  0  -1           *   0.7,R69                                                  *          (          )

KD  K  KED                  CONSTANTS   C(J)
13  0  0            *      -0.41     0.74-4     0.102-5      0.0      -10.0       1.0     *          (          )
13  0  0            *       1.0        1.0         0.0        0.0        0.0       0.0     *          (          )
13  0  0            *       0.0        0.0         0.0        0.0        1.0       0.0     *          (          )
99  0  0            *                                                                     *          (          )
```

FUEL IDENTIFICATION

```
I     1    2    3    4    5    6    7    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24

1
2
3
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13
14
15
```

FUEL TYPE

I	1	2	3	4	5	6	7	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1	3	3	1	1	3	3	1	1	3	3	1	1	2	2										
2	3	1	1	3	3	1	1	3	3	1	1	3	3	2	2										
3	3	1	1	3	3	1	1	3	3	1	1	3	3	2	2										
4	1	3	3	1	1	3	3	1	1	3	3	2	2	0	0										
5	1	3	3	1	1	3	3	1	1	3	3	2	2	0	0										
6	3	1	1	3	3	1	1	3	3	2	2	2	2	0	0										
7	3	1	1	3	3	1	1	3	3	2	2	2	2	0	0										
8	1	3	3	1	1	3	3	1	1	2	2	0	0	0	0										
9	1	3	3	1	1	3	3	1	1	2	2	0	0	0	0										
10	3	1	1	3	3	2	2	2	2	0	0	0	0	0	0										
11	3	1	1	3	3	2	2	2	2	0	0	0	0	0	0										
12	1	3	3	2	2	2	2	0	0	0	0	0	0	0	0										
13	1	3	3	2	2	2	2	0	0	0	0	0	0	0	0										
14	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0										
15	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0										

NFT	AXIAL FUEL MATERIAL TYPE																
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

VARIABLES IN INPUT CARD 1

A1(1)= XPO	= 0.	A1(2)= XPOMAX	= 0.	A1(3)= DE	= 0.	A1(4)= DX	= 1.075180E+01
A1(5)= DZ	= 2.151530E+01	A1(6)= PTH	= 2.700000E+03	A1(7)= PRATED	= 2.700000E+03	A1(8)= FLOW1	= 1.000000E+08
A1(9)= FLOW2	= 0.	A1(10)= SUBC1	=-5.554000E+02	A1(11)= SUBC2	= 0.	A1(12)= CRIJ	= 0.
A1(13)= ITAPE	= 0.	A1(14)=	= 1.000000E+00	A1(15)= IBUG1	= 0.	A1(16)= IBUG2	= 0.
A1(17)= RMAX	= 0.	A1(18)= RMIN	= 0.	A1(19)= RINC	= 0.	A1(20)= NOPT	= 3.000000E+00
A1(21)= PPM	= 9.000000E+02	A1(22)=	= 0.	A1(23)=	= 0.	A	

VARIABLES IN INPUT CARD 2

A2(1)= ISYM	=-5.000000E+00	A2(2)= KMAX	= 1.700000E+01	A2(3)= DELSX	= 5.000000E-06	A2(4)= NSMAX	= 8.000000E+00
A2(5)= DXLS	= 1.000000E-07	A2(6)= NUMAX	= 2.000000E+01	A2(7)= DXLU	= 1.000000E-07	A2(8)= NCMAX	= 1.000000E+01
A2(9)= DXLC	= 1.000000E-05	A2(10)= XLMBDA	= 1.000000E+00	A2(11)= DLP	= 0.	A2(12)= AVB	= 1.241000E+00
A2(13)= AVT	= 1.215000E+00	A2(14)= CHI	= 0.	A2(15)=	= 4.000000E+00	A2(16)= GV	= 1.000000E+00
A2(17)= GH	= 1.000000E+00	A2(18)= CW	= 1.000000E+00	A2(19)=	= 0.	A2(20)= IPRTB	= 1.000000E+00
A2(21)= IPRT3	= 3.000000E+00	A2(22)= ICDMP	=-2.000000E+00	A			

***** SOLUBLE POISON SEARCH, INITIAL GUESS= 900.0000 PPM *****

INPUT CONSTANTS BY FUEL TYPE

TYPE =	1	2	3
1	.207466E+03	.205354E+03	.485180E+03
2	-.107244E+01	-.107277E+01	-.159532E+01
3	.357318E+00	.357645E+00	.712211E+00
40.	0.	0.	
50.	0.	0.	
60.	0.	0.	
7	.992825E+00	.103543E+01	.843329E+00
8	.342835E+00	.415093E+00	.408147E+00
9	-.103457E+00	-.134013E+00	-.108869E+00
100.	0.	0.	
110.	0.	0.	
120.	0.	0.	
13	.218872E+00	.326891E+00	.636219E+00
14	.290909E-01	.295948E-01	.304489E-01
150.	0.	0.	
16	.123253E-01	.121284E-01	.138805E-01
170.	0.	0.	
180.	0.	0.	
190.	0.	0.	
200.	0.	0.	
210.	0.	0.	
220.	0.	0.	
230.	0.	0.	
24	.100000E+01	.100000E+01	.100000E+01
250.	0.	0.	
260.	0.	0.	
270.	0.	0.	
28	.100000E+01	.100000E+01	.100000E+01
29	.133506E-03	.101154E-03	.918523E-04
30	-.186296E-07	-.109487E-07	-.916409E-08
31	.196998E-11	.931627E-12	.741265E-12
320.	0.	0.	
330.	0.	0.	
340.	0.	0.	
350.	0.	0.	
360.	0.	0.	
370.	0.	0.	
380.	0.	0.	
39	.100000E+01	.100000E+01	.100000E+01
400.	0.	0.	
410.	0.	0.	
42	-.875891E-01	-.873497E-01	-.113223E+00
430.	0.	0.	
440.	0.	0.	
450.	0.	0.	
460.	0.	0.	
470.	0.	0.	
480.	0.	0.	
490.	0.	0.	
500.	0.	0.	
51	.100000E+01	.100000E+01	.100000E+01
520.	0.	0.	
530.	0.	0.	
54	.100000E+01	.100000E+01	.100000E+01
550.	0.	0.	
560.	0.	0.	
570.	0.	0.	
580.	0.	0.	
590.	0.	0.	
600.	0.	0.	

EXPOSURE 0.0000 AH(I,J) BY CHANNEL

(0)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.800		
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.600		
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.550	1.550		
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.650	0.000	0.000		
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.800	0.000	0.000		
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.800	0.000	0.000		
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.650	1.600	0.000	0.000		
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.650	0.000	0.000	0.000	0.000		
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.650	1.600	0.000	0.000	0.000	0.000		
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.650	0.000	0.000	0.000	0.000	0.000	0.000		
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.650	1.600	0.000	0.000	0.000	0.000	0.000	0.000		
12	0.000	0.000	0.000	0.000	0.000	0.000	.650	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
13	0.000	0.000	0.000	.650	.800	.800	1.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
14	0.000	0.000	.550	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
15	.800	.800	1.550	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		

NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000

NC	NU	NS	DELTA L S	DELTA L U	DELTA L C	ACCEL S TOT	MAX REL CHG IN SOURCE			SOURCE TOT	LAMBDA
1	1	1	-.015428	-.015428	-.015428	2618.523083	.77062980	7	13 17	2639.307696	.98457204
1	1	2	.012251	-.003177	-.003177	2866.685757	.75321204	7	13 16	2785.265739	.99682344
1	1	3	.002526	-.000650	-.000650	2725.524083	26.69241048	7	12 17	2702.249460	.99934988
1	1	4	.001503	.000853	.000853	2709.194334	2.10610534	1	15 1	2692.643726	1.00085331
1	1	5	.000860	.001713	.001713	2700.068473	7.34488495	1	14 17	2687.275572	1.00171305
1	1	6	.000879	.002592	.002592	2680.662832	1.59340129	1	13 17	2675.860490	1.00259174
1	1	7	.000303	.002895	.002895	2679.535044	.65605375	1	12 17	2675.197085	1.00289512
1	1	8	-.000002	.002893	.002893	2691.877233	.30242287	1	11 17	2682.457196	1.00289328
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000								
1	2	1	-.002046	-.002046	.000847	2655.211445	.30560254	3	15 17	2660.889085	1.00084720
1	2	2	-.000549	-.002595	.000299	2664.603675	.17883352	3	9 17	2666.413926	1.00029858
1	2	3	-.000321	-.002916	-.000023	2672.303592	.12372830	3	8 17	2670.943289	.99997726
1	2	4	-.000210	-.003126	-.000233	2685.222741	.08290275	3	7 17	2678.542789	.99976704
1	2	5	-.000069	-.003195	-.000302	2685.795169	.06339103	3	6 17	2678.879511	.99969845
1	2	6	.000025	-.003170	-.000277	2677.116148	.04793073	3	6 17	2673.775381	.99972299
1	2	7	.000021	-.003149	-.000256	2676.471599	.04558418	1	6 17	2673.395059	.99974431
1	2	8	.000004	-.003145	-.000251	2678.461124	.04162700	1	2 2	2674.565367	.99974866
			ESTIMATED BOUNDS ON LAMBDA UPPER 1.02408583 LOWER .96960237								
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000								
1	3	1	-.000088	-.000088	-.000339	2669.231640	.04391279	1	1 3	2669.136259	.99966063
1	3	2	.000014	-.000074	-.000325	2665.690620	.03197372	1	4 17	2667.053306	.99967467
1	3	3	.000034	-.000040	-.000291	2656.618305	.04225708	1	1 16	2661.716650	.99970895
1	3	4	.000030	-.000009	-.000261	2662.310818	.03006129	1	1 17	2665.065187	.99973939
1	3	5	.000017	.000008	-.000243	2659.039546	.03754186	1	1 17	2663.140909	.99975664
1	3	6	-.000002	.000006	-.000245	2661.388809	.01559970	2	3 9	2664.522829	.99975450
1	3	7	-.000006	-.000001	-.000252	2662.179891	.01522232	1	3 9	2664.988171	.99974814

NC	NU	NS	DELTA L S	DELTA L U	DELTA L C	ACCEL S TOT	MAX REL CHG IN SOURCE	SOURCE TOT	LAMBDA
1	3	8	-.000002	-.000002	-.000254	2663.490123	.01522532 1 2 9	2665.758896	.99974628
CONVERGENCE 1 LAMBDA .99974628 SHANK .999746 SHANK SQ 0.000000 DEL LMB 0.000000 DEL SH SQ 0.000000									
ESTIMATED BOUNDS ON LAMBDA UPPER 1.00378492 LOWER .99097229									
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000									
1	4	1	.000018	.000018	-.000235	2667.878002	.01639043 1 1 9	2668.340001	.99976460
1	4	2	.000029	.000047	-.000206	2669.627313	.01149405 1 1 8	2669.369008	.99979350
1	4	3	-.000003	.000044	-.000210	2671.091894	.00709176 1 1 16	2670.230526	.99979017
1	4	4	-.000002	.000042	-.000212	2671.182212	.00610731 1 1 1	2670.283654	.99978819
1	4	5	.000002	.000044	-.000210	2671.582840	.00553724 1 6 9	2670.519318	.99979013
1	4	6	.000008	.000051	-.000202	2671.729655	.00573938 1 5 9	2670.605679	.99979767
1	4	7	.000009	.000060	-.000194	2671.430156	.00566121 1 4 9	2670.429504	.99980644
1	4	8	.000008	.000068	-.000186	2671.003397	.00530265 1 3 9	2670.178469	.99981411
CONVERGENCE 1 LAMBDA .99981411 SHANK .999749 SHANK SQ 0.000000 DEL LMB 0.000000 DEL SH SQ 0.000000									
ESTIMATED BOUNDS ON LAMBDA UPPER 1.00275301 LOWER .99800796									
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000									
1	5	1	-.000005	-.000005	-.000191	2670.101595	.00658882 1 2 9	2669.647997	.99980942
1	5	2	-.000007	-.000012	-.000198	2669.971414	.00676075 1 1 9	2669.571420	.99980217
1	5	3	.000004	-.000008	-.000194	2669.638765	.00483141 1 1 9	2669.375744	.99980573
1	5	4	.000002	-.000006	-.000192	2669.237516	.00305757 1 1 9	2669.139715	.99980787
1	5	5	.000000	-.000006	-.000192	2668.992652	.00202467 1 1 8	2668.995678	.99980835
1	5	6	-.000002	-.000008	-.000194	2668.731690	.00196061 1 1 1	2668.842171	.99980640
1	5	7	-.000003	-.000011	-.000197	2668.634109	.00162277 1 1 1	2668.784770	.99980338
1	5	8	-.000003	-.000014	-.000200	2668.638355	.00141134 2 3 10	2668.787268	.99980041
CONVERGENCE 1 LAMBDA .99980041 SHANK .999803 SHANK SQ .999746 DEL LMB .000002 DEL SH SQ .000057									
ESTIMATED BOUNDS ON LAMBDA UPPER 1.00086560 LOWER .99894663									
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000									
1	6	1	-.000014	-.000014	-.000213	2668.178342	.00272614 9 11 3	2668.516672	.99978655
1	6	2	-.000003	-.000017	-.000217	2668.134953	.00314428 1 1 10	2668.491149	.99978314
1	6	3	-.000004	-.000021	-.000221	2668.261727	.00263617 1 1 10	2668.565722	.99977910
1	6	4	-.000002	-.000023	-.000223	2668.521684	.00185085 1 1 10	2668.718638	.99977717
1	6	5	-.000001	-.000024	-.000224	2668.620874	.00164952 1 1 11	2668.776985	.99977641
1	6	6	.000000	-.000024	-.000223	2668.746125	.00113001 1 1 11	2668.850662	.99977665
1	6	7	.000001	-.000023	-.000223	2668.848392	.00072236 1 1 12	2668.910819	.99977741
1	6	8	.000001	-.000022	-.000222	2668.906002	.00047250 6 7 1	2668.944707	.99977827
CONVERGENCE 1 LAMBDA .99977827 SHANK .999836 SHANK SQ .999891 DEL LMB .000058 DEL SH SQ .000055									
ESTIMATED BOUNDS ON LAMBDA UPPER .99997759 LOWER .99948264									
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000									
1	7	1	.000008	.000008	-.000214	2669.309848	.00135380 3 15 10	2669.182264	.99978585
1	7	2	.000005	.000012	-.000209	2669.393746	.00097862 1 1 11	2669.231615	.99979061
1	7	3	.000002	.000015	-.000207	2669.349878	.00092128 1 1 11	2669.205811	.99979308
1	7	4	.000001	.000016	-.000206	2669.250860	.00074352 2 2 11	2669.147565	.99979431

NC	NU	NS	DELTA L S	DELTA L U	DELTA L C	ACCEL S TOT	MAX REL CHG	IN SOURCE	SOURCE TOT	LAMBDA
1	7	5	.000001	.000017	-.000205	2669.231738	.00074701	1 1 11	2669.136317	.99979490
1	7	6	.000000	.000017	-.000205	2669.202137	.00070393	1 1 11	2669.118904	.99979515
1	7	7	.000000	.000017	-.000205	2669.156709	.00052592	1 1 11	2669.092182	.99979517
1	7	8	-.000000	.000017	-.000205	2669.124810	.00041216	1 1 11	2669.073418	.99979511
CONVERGENCE 1 LAMBDA .99979511 SHANK .999788 SHANK SQ .999816 DEL LMB .000007 DEL SH SQ .000029										
ESTIMATED BOUNDS ON LAMBDA UPPER 1.00003669 LOWER .99966552										
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000										
1	8	1	-.000003	-.000003	-.000208	2668.935132	.00060675	3 15 9	2668.961842	.99979247
1	8	2	-.000003	-.000006	-.000211	2668.884814	.00033011	2 15 2	2668.932243	.99978949
1	8	3	-.000001	-.000007	-.000212	2668.898321	.00027515	1 15 1	2668.940189	.99978842
1	8	4	-.000001	-.000007	-.000212	2668.923154	.00023376	1 14 1	2668.954796	.99978789
1	8	5	-.000000	-.000007	-.000212	2668.916136	.00022630	1 2 10	2668.950668	.99978765
1	8	6	-.000000	-.000008	-.000213	2668.911196	.00024870	1 1 10	2668.947762	.99978748
1	8	7	-.000000	-.000008	-.000213	2668.920590	.00021288	1 1 10	2668.953288	.99978737
1	8	8	-.000000	-.000008	-.000213	2668.928882	.00019401	2 2 10	2668.958166	.99978729
CONVERGENCE 0 LAMBDA .99978729 SHANK .999790 SHANK SQ .999790 DEL LMB .000002 DEL SH SQ .000000										
ESTIMATED BOUNDS ON LAMBDA UPPER .99986805 LOWER .99967812										
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000										
1	9	1	.000001	.000001	-.000212	2668.991768	.00030107	3 15 16	2668.995158	.99978807
1	9	2	.000001	.000002	-.000211	2669.007037	.00015887	2 15 17	2669.004139	.99978941
1	9	3	.000000	.000002	-.000210	2669.004485	.00011953	1 15 1	2669.002638	.99978979
1	9	4	.000000	.000003	-.000210	2669.005024	.00010340	1 14 1	2669.002955	.99978996
1	9	5	.000000	.000003	-.000210	2669.013784	.00007882	1 13 1	2669.008108	.99979002
1	9	6	.000000	.000003	-.000210	2669.023979	.00006699	3 4 9	2669.014106	.99979008
1	9	7	.000000	.000003	-.000210	2669.027222	.00006643	1 4 9	2669.016013	.99979014
1	9	8	.000000	.000003	-.000210	2669.028497	.00006695	2 2 9	2669.016763	.99979019
CONVERGENCE 0 LAMBDA .99979019 SHANK .999789 SHANK SQ .999789 DEL LMB .000001 DEL SH SQ .000000										
ESTIMATED BOUNDS ON LAMBDA UPPER .99982637 LOWER .99975367										
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000										
1	10	1	-.000000	-.000000	-.000210	2669.017057	.00013219	3 15 16	2669.010034	.99978985
1	10	2	-.000000	-.000001	-.000211	2669.019280	.00009156	1 1 11	2669.011341	.99978942
1	10	3	-.000000	-.000001	-.000211	2669.018558	.00007105	1 1 11	2669.010917	.99978932
1	10	4	-.000000	-.000001	-.000211	2669.013529	.00005416	1 1 11	2669.007958	.99978928
1	10	5	.000000	-.000001	-.000211	2669.008371	.00004277	1 1 12	2669.004924	.99978928
1	10	6	-.000000	-.000001	-.000211	2669.001509	.00002714	1 12 17	2669.000888	.99978928
1	10	7	-.000000	-.000001	-.000211	2668.996723	.00002145	1 11 17	2668.998073	.99978927
1	10	8	-.000000	-.000001	-.000211	2668.993707	.00001686	1 10 17	2668.996298	.99978925
CONVERGENCE 0 LAMBDA .99978925 SHANK .999789 SHANK SQ .999789 DEL LMB .000000 DEL SH SQ .000000										
ESTIMATED BOUNDS ON LAMBDA UPPER .99980341 LOWER .99977997										
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000										
1	11	1	.000000	.000000	-.000211	2668.988065	.00004176	3 15 16	2668.992979	.99978936

NC	NU	NS	DELTA L S	DELTA L U	DELTA L C	ACCEL S TOT	MAX REL CHG	IN SOURCE	SOURCE TOT	LAMBDA
1	11	2	.000000	.000000	-.000211	2668.983060	.00004170	1 1 9	2668.990035	.99978942
1	11	3	.000000	.000000	-.000211	2668.984112	.00003639	1 1 9	2668.990654	.99978944
1	11	4	.000000	.000000	-.000211	2668.987663	.00002943	1 1 9	2668.992743	.99978944
1	11	5	-.000000	.000000	-.000211	2668.989858	.00002762	1 1 9	2668.994034	.99978943
1	11	6	-.000000	.000000	-.000211	2668.992991	.00002248	1 1 10	2668.995877	.99978942
1	11	7	-.000000	.000000	-.000211	2668.996095	.00001476	1 1 10	2668.997703	.99978942
1	11	8	-.000000	.000000	-.000211	2668.998263	.00001007	1 1 9	2668.998978	.99978941

CONVERGENCE -1 LAMBDA .99978941 SHANK .999789 SHANK SQ .999789 DEL LMB .000000 DEL SH SQ .000000

ESTIMATED BOUNDS ON LAMBDA UPPER .99979235 LOWER .99978302

**** INITIAL POISON GUESS= 880.0000 PPM CRITICAL K-EFF = 1.00000 ****

**** BORON = 900.0000 PPM K-EFF= .999789

**** FOLLOWING ARE NEW POISON AND CORRESPONDING RESULTS ****
****POISON= 880.0000 PPM ****

NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000

NC	NU	NS	DELTA L S	DELTA L U	DELTA L C	ACCEL S TOT	MAX REL CHG IN SOURCE			SOURCE TOT	LAMBDA
1	1	1	.001583	.001583	.001583	2692.149678	.02402504	7	13 1	2682.617458	1.00158326
1	1	2	.000027	.001610	.001610	2672.939018	.01514778	7	13 1	2671.317070	1.00161042
1	1	3	.000114	.001725	.001725	2672.378686	.00462670	9	11 1	2670.987462	1.00172458
1	1	4	.000024	.001748	.001748	2670.667380	.00298332	7	11 17	2669.980812	1.00174835
1	1	5	.000007	.001755	.001755	2669.948509	.00243364	1	14 17	2669.557947	1.00175514
1	1	6	-.000000	.001755	.001755	2669.375998	.00202185	1	13 17	2669.221175	1.00175505
1	1	7	.000003	.001758	.001758	2669.382447	.00168040	6	7 1	2669.224969	1.00175790
1	1	8	.000000	.001758	.001758	2669.531881	.00161959	5	7 1	2669.312871	1.00175814
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000								
1	2	1	-.000007	-.000007	.001751	2669.442312	.00129720	9	11 3	2669.260184	1.00175066
1	2	2	-.000001	-.000008	.001750	2669.308481	.00113179	4	6 1	2669.181459	1.00174992
1	2	3	.000002	-.000006	.001752	2669.322967	.00102990	3	6 1	2669.189980	1.00175196
1	2	4	.000001	-.000005	.001753	2669.398994	.00098463	3	5 1	2669.234702	1.00175308
1	2	5	-.000001	-.000006	.001752	2669.343319	.00090693	3	4 1	2669.201952	1.00175185
1	2	6	-.000000	-.000007	.001751	2669.248773	.00084290	3	3 1	2669.146337	1.00175144
1	2	7	.000001	-.000006	.001752	2669.239480	.00081205	2	3 1	2669.140871	1.00175232
1	2	8	.000000	-.000005	.001753	2669.254770	.00087272	1	3 1	2669.149865	1.00175276
			ESTIMATED BOUNDS ON LAMBDA UPPER 1.00226853 LOWER 1.00151908								
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000								
1	3	1	-.000002	-.000002	.001751	2669.006191	.00083139	1	2 1	2669.003642	1.00175120
1	3	2	-.000003	-.000004	.001748	2668.998825	.00092252	1	1 1	2668.999309	1.00174029
1	3	3	-.000000	-.000005	.001748	2668.923591	.00041122	1	1 1	2668.955054	1.00174792
1	3	4	.000000	-.000005	.001748	2668.735839	.00050015	1	1 1	2668.844611	1.00174805
1	3	5	.000000	-.000004	.001748	2668.847066	.00030431	2	5 2	2668.910039	1.00174829
1	3	6	.000000	-.000004	.001748	2668.809697	.00033095	1	5 1	2668.888057	1.00174832
1	3	7	-.000000	-.000004	.001748	2668.841759	.00031729	2	3 1	2668.906917	1.00174830
1	3	8	-.000000	-.000004	.001748	2668.860917	.00031747	1	3 1	2668.918187	1.00174829
CONVERGENCE 1 LAMBDA 1.00174829 SHANK 1.001726 SHANK SQ 0.000000 DEL LMB 0.000000 DEL SH SQ 0.000000											
			ESTIMATED BOUNDS ON LAMBDA UPPER 1.00184219 LOWER 1.00157780								
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000								
1	4	1	.000002	.000002	.001750	2668.967793	.00036372	1	2 2	2668.981055	1.00174993
1	4	2	.000001	.000003	.001751	2668.971386	.00038456	1	1 1	2668.983168	1.00175136
1	4	3	.000000	.000003	.001752	2668.991856	.00029542	1	1 1	2668.995209	1.00175157
1	4	4	-.000000	.000003	.001752	2669.016771	.00016571	1	1 1	2669.009865	1.00175156
1	4	5	-.000000	.000003	.001751	2669.025168	.00012842	1	1 1	2669.014805	1.00175146
1	4	6	-.000000	.000003	.001751	2669.043774	.00007814	2	5 5	2669.025749	1.00175141
1	4	7	-.000000	.000003	.001751	2669.046359	.00007980	2	4 5	2669.027270	1.00175140
1	4	8	-.000000	.000003	.001751	2669.045548	.00008166	2	3 5	2669.026793	1.00175140
CONVERGENCE 1 LAMBDA 1.00175140 SHANK 1.001750 SHANK SQ 0.000000 DEL LMB 0.000000 DEL SH SQ 0.000000											
			ESTIMATED BOUNDS ON LAMBDA UPPER 1.00179156 LOWER 1.00170597								
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000								
1	5	1	-.000000	-.000000	.001751	2669.040274	.00015087	2	2 3	2669.023690	1.00175098
1	5	2	-.000000	-.000001	.001751	2669.048257	.00010216	1	1 3	2669.028386	1.00175061
1	5	3	-.000000	-.000001	.001751	2669.041262	.00016417	1	1 1	2669.024272	1.00175056

NC	NU	NS	DELTA L S	DELTA L U	DELTA L C	ACCEL S TOT	MAX REL CHG IN SOURCE	SOURCE TOT	LAMBDA
1	5	4	.000000	-.000001	.001751	2669.027526	.00012314 1 1 1	2669.016192	1.00175056
1	5	5	.000000	-.000001	.001751	2669.019310	.00010785 1 1 1	2669.011359	1.00175060
1	5	6	.000000	-.000001	.001751	2669.008499	.00008408 1 1 1	2669.005000	1.00175062
1	5	7	.000000	-.000001	.001751	2669.001163	.00005713 1 1 1	2669.000684	1.00175063
1	5	8	.000000	-.000001	.001751	2668.996749	.00003862 1 1 1	2668.998088	1.00175063
CONVERGENCE 0 LAMBDA 1.00175063 SHANK 1.001751 SHANK SQ 1.001751 DEL LMB .000000 DEL SH SQ .000000									
ESTIMATED BOUNDS ON LAMBDA UPPER 1.00177894 LOWER 1.00172625									
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000									
1	6	1	-.000000	-.000000	.001750	2668.973511	.00006421 2 2 17	2668.984418	1.00175038
1	6	2	-.000000	-.000000	.001750	2668.967947	.00007321 1 1 17	2668.981145	1.00175032
1	6	3	-.000000	-.000000	.001750	2668.970925	.00006610 1 1 17	2668.982897	1.00175029
1	6	4	-.000000	-.000000	.001750	2668.977988	.00004809 1 1 17	2668.987052	1.00175029
1	6	5	-.000000	-.000000	.001750	2668.981198	.00004300 1 1 5	2668.988940	1.00175028
1	6	6	-.000000	-.000000	.001750	2668.985378	.00004220 1 1 2	2668.991399	1.00175028
1	6	7	-.000000	-.000000	.001750	2668.989962	.00003379 1 1 1	2668.994095	1.00175028
1	6	8	.000000	-.000000	.001750	2668.993185	.00002603 1 1 1	2668.995991	1.00175028
CONVERGENCE 1 LAMBDA 1.00175028 SHANK 1.001750 SHANK SQ 1.001750 DEL LMB .000000 DEL SH SQ .000000									
ESTIMATED BOUNDS ON LAMBDA UPPER 1.00175711 LOWER 1.00173621									
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000									
1	7	1	.000000	.000000	.001751	2669.009895	.00002820 7 13 15	2669.005820	1.00175051
1	7	2	.000000	.000000	.001751	2669.012778	.00003039 1 1 16	2669.007517	1.00175063
1	7	3	.000000	.000000	.001751	2669.011892	.00002991 1 1 17	2669.006995	1.00175066
1	7	4	.000000	.000000	.001751	2669.009574	.00002244 1 1 17	2669.005632	1.00175067
1	7	5	-.000000	.000000	.001751	2669.009020	.00002210 1 1 16	2669.005306	1.00175066
1	7	6	-.000000	.000000	.001751	2669.008253	.00002053 1 1 17	2669.004855	1.00175066
1	7	7	-.000000	.000000	.001751	2669.006560	.00001558 1 1 17	2669.003859	1.00175066
1	7	8	-.000000	.000000	.001751	2669.005197	.00001200 1 1 17	2669.003057	1.00175066
CONVERGENCE 1 LAMBDA 1.00175066 SHANK 1.001750 SHANK SQ 1.001750 DEL LMB .000000 DEL SH SQ .000000									
ESTIMATED BOUNDS ON LAMBDA UPPER 1.00175712 LOWER 1.00174712									
NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000									
1	8	1	-.000000	-.000000	.001751	2668.998676	.00001349 3 15 13	2668.999221	1.00175058
1	8	2	-.000000	-.000000	.001751	2668.997295	.00000747 5 5 16	2668.998409	1.00175050
1	8	3	-.000000	-.000000	.001750	2668.997399	.00000673 4 5 17	2668.998470	1.00175049
1	8	4	-.000000	-.000000	.001750	2668.997653	.00000678 4 4 16	2668.998619	1.00175048
1	8	5	.000000	-.000000	.001750	2668.997374	.00000638 3 4 17	2668.998455	1.00175049
1	8	6	.000000	-.000000	.001750	2668.997078	.00000684 1 1 16	2668.998281	1.00175049
1	8	7	.000000	-.000000	.001750	2668.997351	.00000634 1 4 17	2668.998442	1.00175049
1	8	8	.000000	-.000000	.001750	2668.997661	.00000614 2 2 16	2668.998624	1.00175049
CONVERGENCE -1 LAMBDA 1.00175049 SHANK 1.001751 SHANK SQ 1.001751 DEL LMB .000000 DEL SH SQ .000000									
ESTIMATED BOUNDS ON LAMBDA UPPER 1.00175210 LOWER 1.00174706									

BORON WORTH = -9.805 PCM/PPM INVERSE BORON WORTH = -101.98 PPM/PER CENT

**** BORON = 880.0000 PPM K-EFF= 1.001750

**** FOLLOWING ARE NEW POISON AND CORRESPONDING RESULTS ****
****POISON= 897.8523 PPM ****

NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000

NC	NU	NS	DELTA L S	DELTA L U	DELTA L C	ACCEL S TOT	MAX REL CHG	IN SOURCE	SOURCE TOT	LAMBDA
1	1	1	.000001	.000001	.000001	2668.652918	.00200819	7 13 17	2668.795834	1.00000109
1	1	2	-.000007	-.000006	-.000006	2668.774655	.00113069	3 9 1	2668.867444	.99999440
1	1	3	.000000	-.000005	-.000005	2668.869849	.00089603	4 8 1	2668.923441	.99999486
1	1	4	.000002	-.000003	-.000003	2668.764157	.00097110	1 1 1	2668.861269	.99999679
1	1	5	-.000000	-.000004	-.000004	2668.741359	.00079631	5 5 1	2668.847858	.99999650
1	1	6	-.000002	-.000005	-.000005	2668.940420	.00063268	1 7 1	2668.964953	.99999499
1	1	7	-.000000	-.000005	-.000005	2668.959807	.00058613	2 2 1	2668.976357	.99999468
1	1	8	.000000	-.000005	-.000005	2668.837555	.00069831	1 1 1	2668.904444	.99999517
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000							
1	2	1	.000004	.000004	-.000000	2668.974166	.00094250	7 13 16	2668.984804	.99999956
1	2	2	.000001	.000005	.000000	2669.050752	.00037700	6 13 17	2669.029854	1.00000029
1	2	3	.000000	.000005	.000001	2669.037762	.00029938	2 2 1	2669.022213	1.00000058
1	2	4	.000000	.000006	.000001	2668.954902	.00035635	1 1 1	2668.973472	1.00000072
1	2	5	.000000	.000006	.000001	2668.956938	.00034310	1 1 1	2668.974669	1.00000081
1	2	6	.000000	.000006	.000001	2669.006675	.00014703	7 8 17	2669.003926	1.00000085
1	2	7	-.000000	.000006	.000001	2669.015840	.00013067	1 5 17	2669.009318	1.00000084
1	2	8	-.000000	.000006	.000001	2669.014161	.00012706	2 3 17	2669.008330	1.00000083
			ESTIMATED BOUNDS ON LAMBDA UPPER 1.00008445 LOWER .99993077							
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000							
1	3	1	-.000001	-.000001	.000000	2669.034872	.00013647	6 6 1	2669.020513	1.00000030
1	3	2	.000000	-.000001	.000000	2669.045717	.00012726	1 1 17	2669.026892	1.00000033
1	3	3	-.000000	-.000001	.000000	2669.043506	.00011972	1 1 17	2669.025592	1.00000027
1	3	4	-.000000	-.000001	.000000	2669.039098	.00010956	4 5 1	2669.022999	1.00000023
1	3	5	-.000000	-.000001	.000000	2669.035956	.00010785	1 7 1	2669.021151	1.00000023
1	3	6	.000000	-.000001	.000000	2669.026408	.00010622	1 6 1	2669.015534	1.00000023
1	3	7	.000000	-.000001	.000000	2669.019453	.00010008	1 5 1	2669.011443	1.00000024
1	3	8	.000000	-.000001	.000000	2669.014815	.00009673	1 4 1	2669.008715	1.00000025
			CONVERGENCE 1 LAMBDA 1.00000025 SHANK 1.000000 SHANK SQ 0.000000 DEL LMB 0.000000 DEL SH SQ 0.000000							
			ESTIMATED BOUNDS ON LAMBDA UPPER 1.00006240 LOWER .99993996							
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000							
1	4	1	-.000001	-.000001	-.000000	2668.979566	.00011304	2 2 17	2668.987980	.99999951
1	4	2	-.000000	-.000001	-.000001	2668.979991	.00012613	1 2 17	2668.980230	.99999933
1	4	3	-.000000	-.000001	-.000001	2668.980808	.00012661	1 1 17	2668.988711	.99999926
1	4	4	-.000000	-.000001	-.000001	2668.983901	.00008555	1 1 17	2668.990530	.99999926
1	4	5	.000000	-.000001	-.000001	2668.984754	.00007906	1 1 17	2668.991032	.99999927
1	4	6	.000000	-.000001	-.000001	2668.985847	.00006231	1 1 17	2668.991675	.99999927
1	4	7	.000000	-.000001	-.000001	2668.988386	.00004244	1 1 17	2668.993168	.99999928
1	4	8	.000000	-.000001	-.000001	2668.990500	.00002951	1 1 17	2668.994412	.99999928
			CONVERGENCE 1 LAMBDA .99999926 SHANK 1.000002 SHANK SQ 0.000000 DEL LMB 0.000000 DEL SH SQ 0.000000							
			ESTIMATED BOUNDS ON LAMBDA UPPER 1.00001391 LOWER .99998218							
			NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000							
1	5	1	.000000	.000000	-.000000	2669.000343	.00003662	2 2 2	2669.000202	.99999950
1	5	2	.000000	.000000	-.000000	2669.000703	.00004454	1 1 2	2669.000413	.99999960
1	5	3	.000000	.000000	-.000000	2669.001181	.00004076	1 1 1	2669.000695	.99999963

NC	NU	NS	DELTA L S	DELTA L U	DELTA L C	ACCEL S TOT	MAX REL CHG	IN SOURCE	SOURCE TOT	LAMBDA
1	5	4	.000000	.000000	-.000000	2669.001487	.00002787	1 1 1	2669.000875	.99999963
1	5	5	-.000000	.000000	-.000000	2669.002049	.00002749	1 2 16	2669.001205	.99999962
1	5	6	-.000000	.000000	-.000000	2669.002750	.00002824	1 1 17	2669.001618	.99999961
1	5	7	-.000000	.000000	-.000000	2669.002632	.00002431	1 1 17	2669.001548	.99999961
1	5	8	-.000000	.000000	-.000000	2669.002350	.00002083	1 3 17	2669.001383	.99999960

CONVERGENCE 1 LAMBDA .99999960 SHANK 1.000000 SHANK SQ 1.000001 DEL LMB .000000 DEL SH SQ .000001

ESTIMATED BOUNDS ON LAMBDA UPPER 1.00001331 LOWER .99999197

NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000

1	6	1	.000000	.000000	-.000000	2669.003889	.00001811	1 1 16	2669.002288	.99999969
1	6	2	-.000000	.000000	-.000000	2669.002601	.00001352	1 1 17	2669.001530	.99999966
1	6	3	.000000	.000000	-.000000	2669.002301	.00000903	1 1 17	2669.001353	.99999966
1	6	4	.000000	.000000	-.000000	2669.001595	.00000698	4 5 17	2669.000938	.99999966
1	6	5	.000000	.000000	-.000000	2669.001028	.00000684	3 5 16	2669.000605	.99999967
1	6	6	.000000	.000000	-.000000	2669.000463	.00000729	1 1 2	2669.000272	.99999967
1	6	7	.000000	.000000	-.000000	2669.000124	.00000694	2 4 17	2669.000073	.99999967
1	6	8	.000000	.000000	-.000000	2668.999932	.00000683	2 3 17	2668.999960	.99999967

CONVERGENCE -1 LAMBDA .99999967 SHANK 1.000000 SHANK SQ 1.000000 DEL LMB .000000 DEL SH SQ .000000

ESTIMATED BOUNDS ON LAMBDA UPPER 1.00000334 LOWER .99999492

**** ABOVE IS CRITICAL POISON **** 897.8523 PPM

NORMALIZATION FACTOR FOR BUNDLE FLOW DISTRIBUTION = 1.000000

POWER THERMAL	POWER RELATIVE	PEAK	I	J	K
2700.0000	1.00000	1.80753	6	10	7

P(K)	LEVEL	U(K)
.28088	17	.93503
.54610	16	.93817
.76134	15	.94311
.92613	14	.94944
1.05119	13	.95681
1.14607	12	.96492
1.21793	11	.97357
1.27145	10	.98258
1.30888	9	.99181
1.33016	8	1.00115
1.33273	7	1.01045
1.31114	6	1.01959
1.25632	5	1.02835
1.15473	4	1.03649
.98794	3	1.04364
.73390	2	1.04934
.38312	1	1.05301

QUALITY INLET	QUALITY EXIT
559.4000	647.5502

AVG S	AVG U	AVG K	K EFF
1.0000000	.9927906	1.0554768	.9999997

AVERAGE MODERATOR DENSITY IS .99279

EXPOSURE 0.0000 P(I,J) BY CHANNEL

(0)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.269	1.117	1.112	1.254	1.243	1.081	1.061	1.174	1.135	.956	.895	.930	.844	.827	.534		
2	1.117	1.264	1.260	1.104	1.094	1.225	1.205	1.037	1.003	1.084	1.015	.816	.707	.744	.472		
3	1.112	1.260	1.256	1.100	1.091	1.223	1.205	1.040	1.008	1.092	1.023	.813	.655	.583	.336		
4	1.254	1.104	1.100	1.242	1.233	1.076	1.061	1.182	1.155	.983	.923	1.062	.775	0.000	0.000		
5	1.243	1.094	1.091	1.233	1.225	1.070	1.058	1.184	1.169	1.014	.949	1.064	.717	0.000	0.000		
6	1.081	1.225	1.223	1.076	1.070	1.203	1.190	1.039	1.040	1.347	1.247	1.012	.633	0.000	0.000		
7	1.061	1.205	1.205	1.061	1.058	1.190	1.172	1.013	1.003	1.287	1.122	.782	.442	0.000	0.000		
8	1.174	1.037	1.040	1.182	1.184	1.039	1.013	1.098	1.045	1.098	.825	0.000	0.000	0.000	0.000		
9	1.135	1.003	1.008	1.155	1.169	1.040	1.003	1.045	.902	.787	.503	0.000	0.000	0.000	0.000		
10	.956	1.084	1.092	.983	1.014	1.347	1.287	1.098	.787	0.000	0.000	0.000	0.000	0.000	0.000		
11	.895	1.015	1.023	.923	.949	1.247	1.122	.825	.503	0.000	0.000	0.000	0.000	0.000	0.000		
12	.930	.816	.813	1.062	1.064	1.012	.782	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
13	.844	.707	.655	.775	.717	.633	.442	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
14	.827	.744	.583	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
15	.534	.472	.336	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		

ASSEMBLY AVERAGE RELATIVE POWERS

	1	2	3	4	5	6	7	8
1	1.26933	1.11437	1.24815	1.07131	1.15448	.92530	.88702	.68059
2	1.11437	1.25993	1.09728	1.21445	1.02199	1.05353	.74755	.53373
3	1.24815	1.09728	1.23326	1.06628	1.17223	.96706	.90448	0.00000
4	1.07131	1.21445	1.06628	1.18873	1.02347	1.25075	.71730	0.00000
5	1.15448	1.02199	1.17223	1.02347	1.02236	.80348	0.00000	0.00000
6	.92530	1.05353	.96706	1.25075	.80348	0.00000	0.00000	0.00000
7	.88702	.74755	.90448	.71730	0.00000	0.00000	0.00000	0.00000
8	.68059	.53373	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

EXPOSURE 0.0000 U(I,J) BY CHANNEL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
(0)																	
1	.976	.986	.986	.977	.978	.988	.989	.982	.984	.996	1.000	.998	1.003	1.004	1.022		
2	.986	.976	.976	.987	.987	.979	.980	.991	.993	.988	.992	1.005	1.012	1.009	1.026		
3	.986	.976	.977	.987	.987	.979	.980	.991	.993	.987	.992	1.005	1.015	1.019	1.034		
4	.977	.987	.987	.978	.978	.988	.989	.981	.983	.994	.998	.989	1.007	0.000	0.000		
5	.978	.987	.987	.978	.979	.989	.989	.981	.982	.992	.996	.988	1.011	0.000	0.000		
6	.988	.979	.979	.988	.989	.980	.981	.990	.990	.969	.976	.992	1.016	0.000	0.000		
7	.989	.980	.980	.989	.989	.981	.982	.992	.992	.973	.984	1.006	1.028	0.000	0.000		
8	.982	.991	.991	.981	.981	.990	.992	.986	.990	.986	1.004	0.000	0.000	0.000	0.000		
9	.984	.993	.993	.983	.982	.990	.992	.990	.999	1.006	1.024	0.000	0.000	0.000	0.000		
10	.996	.988	.987	.994	.992	.969	.973	.986	1.006	0.000	0.000	0.000	0.000	0.000	0.000		
11	1.000	.992	.992	.998	.996	.976	.984	1.004	1.024	0.000	0.000	0.000	0.000	0.000	0.000		
12	.998	1.005	1.005	.989	.988	.992	1.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
13	1.003	1.012	1.015	1.007	1.011	1.016	1.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
14	1.004	1.009	1.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
15	1.022	1.026	1.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		

ILAST

THIS RUN HAS BEEN COMPLETED

THE CORRECT TIME IS 16.35.32.

THE CPU TIME USED THUS FAR IS 118.644 SECONDS

J.E.N. 568

Junta de Energía Nuclear. División de Cálculo y Modelos. Madrid.

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INIS CLASSIFICATION AND DESCRIPTORS: E21. S Codes. Computer Calculations. Three-Dimensional Calculations. Burnup. Reactivity Coefficients. Albedo. PWR Type Reactors. Simulators.

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