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RCT – A Code to Reconstruct Pin Power and Burnup Characteristics from Nodal Calculations in Hexagonal Geometry

by W. S. Yang

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April 1993

ANL-IFR-192

RCT - A CODE TO RECONSTRUCT PIN POWER AND BURNUP CHARACTERISTICS
FROM NODAL CALCULATIONS IN HEXAGONAL GEOMETRY

by

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RCT - A CODE TO RECONSTRUCT PIN POWER AND BURNUP CHARACTERISTICS FROM NODAL CALCULATIONS IN HEXAGONAL GEOMETRY

by

W. S. Yang

ABSTRACT

A reconstruction method has been developed for recovering pin burnup characteristics from fuel cycle calculations performed in hexagonal-z geometry using the nodal diffusion option of the DIF3D/REBUS-3 code system and implemented in a computer code RCT. Intranodal distributions of group fluxes, nuclide densities, power density, burnup, and fluence are efficiently computed using polynomial shapes constrained to satisfy nodal information. The accuracy of the method has been tested by performing several fast reactor numerical benchmark calculations and by comparing predicted local burnups to values measured for experimental assemblies in EBR-II. The results indicate that the reconstruction methods are quite accurate, yielding maximum errors in power and nuclide densities that are less than 2% for driver assemblies and typically less than 5% for blanket assemblies.

I. INTRODUCTION

Motivated by the analysis needs resulting from the Integral Fast Reactor (IFR) fuel cycle demonstration and other advanced Fast Breeder Reactor (FBR) designs, a method for recovering detailed (pinwise) information from coarse reactor representations has been developed for hexagonal-z geometry and implemented in a computer code RCT. Reconstruction methods have reached a high level of development for Light Water Reactors,[1-3] and are becoming standard analysis tools because they extend the usefulness of computationally efficient nodal schemes[4] and eliminate the need to perform fine-mesh computations. However, the existing reconstruction methods are not directly applicable to full-core FBR's because they have been designed for Cartesian geometry and macroscopic depletion calculations. Therefore, RCT has been developed to reconstruct the intranodal distributions of power density, burnup, nuclide densities, group fluxes, and fluences from nodal-diffusion/depletion calculations performed in hexagonal-z geometry using the REBUS-3/DIF3D Argonne code system.[5,6]

The spatial reconstruction techniques described in this report are based on higher order polynomial expansions of the nuclide densities as well as the group fluxes. The intranodal distribution of the power density is calculated from these flux and nuclide density distributions, while the burnup and fluence distributions are interpolated in a similar manner as the nuclide densities. The definitions of DIF3D and REBUS-3 are used for the burnup and fluence calculations.

Several important capabilities have been implemented in RCT to permit its application to a wide range of core designs and fuel management strategies. For user-defined "special pins" in assemblies with different types of fuel pins, the nuclide densities, burnup, and fluence are explicitly calculated by point depletion using the interpolated fluxes at the center of each fuel pin. In these calculations, the matrix exponential method of REBUS-3 is employed for the depletion calculation. The radioactive decay during the out-of-core storage is also considered in the nuclide density calculation. Since nonuniform intranodal distributions are considered in reconstruction calculations, the rotational shuffling of assemblies is allowed and is specified by integer multiples of 60 degrees. To permit assembly reconstitution from different types of fuel pins, pin-by-pin

shuffling is allowed for the special pins. The axial displacement of fuel (e.g., arising from the movement of the fueled portion of the control rods in EBR-II) is also treated, consistent with the data provided in the REBUS-3 input dataset A.NIP3. Multicycle reconstruction calculations are performed as a sequence of single cycle jobs of RCT.

The code RCT, which is now operational on the IBM 3033, Cray X-MP, IBM RS/6000 workstation, and Sun SparcStation computers, has been designed to require minimum input data and to use the standard interface files produced by the burnup code REBUS-3. It consists of the path driver STP034 and several calculational modules, and uses the dynamic core storage allocation provided by the BPOINTER[7] facility. It makes use of the REBUS-3 restart file (RFILES) and the Standard Interface Files[8] and thus functions as a postprocessor of REBUS-3. The Standard Interface Files defined by the Committee on Computer Code Coordination (CCCC) are stored in the STACK file in a REBUS-3 run, and they can be provided for RCT as a group through the STACK file or individually after being processed by the File Transfer Utility (FTU) program.[9] The BCD input data (A.RCT) is limited to the data that is essential for the problem, and this data may be readily specified in free format. For application to multicycle reconstruction problems, a RCT code-dependent binary file RCTDEN has been defined. This file contains the information about nonuniform nuclide density distributions in burned regions, while the CCCC file ZNATDN contains region average nuclide densities.

This report is subdivided into seven sections. Section II summarizes the mathematical development of the reconstruction method. Section III includes specific information of interest to users of RCT, and Sect. IV provides additional information concerning the programming structure of the code. In Sect. V, a description is given of a small code which has been written to extract selected information from the nuclide density file RCTDEN and the power density file RCTPWD created by RCT. The benchmarking and validation of the RCT code are discussed in Sect. VI. Finally, the current capabilities and limitations of the code are summarized along with suggestions for future work in Sect. VII.

II. RECONSTRUCTION METHODS

Reconstruction methods have been explored with the objectives of simplicity for practical applications and reconstruction accuracy comparable to the accuracy with which node-average information is predicted by the DIF3D nodal scheme. After examining several reconstruction approaches and performing various preliminary numerical tests, it was decided to use a polynomial expansion method with the assumption of the hex-planer and axial separability of the flux and burnup characteristics within a node. This section provides a brief description of this polynomial approximation for the intranodal distributions of the group flux, nuclide density, power density, burnup, and fluence.

A. Intranodal Flux Distribution

After the global solution is calculated by REBUS-3 using the nodal hexagonal-z geometry option[10] of the DIF3D code, the intranodal pointwise group flux is approximated for every node by assuming the flux within a node is separable in the hex-plane and axial directions. With this separability assumption, the axial flux distribution of a node is interpolated for every group by a cubic polynomial in a manner consistent with the DIF3D nodal formulation. The coefficients of the cubic polynomial are determined by requiring the node-average flux, the top and bottom surface-average fluxes, and the z-directional flux moment to be reproduced.

The hex-plane flux distribution is interpolated for each group g by a nonseparable polynomial of the form:

$$\phi_g(x,y) = \sum_{m,n=0}^{m+n \leq K} c_{mn}^g x^m y^n \quad (1)$$

The interpolation coefficients, c_{mn}^g , are determined by requiring this polynomial to reproduce a desired subset of the planar nodal information consisting of node-average flux, six surface-average fluxes, six surface-average net currents, and three flux moments.[10] Each of these nodal quantities can be associated with a linear functional defined on the K 'th degree

polynomial space P_K as shown in Table I. Therefore, if $L_1, L_2, \dots, L_l$ are the linear functionals associated with the nodal quantities required to be reproduced, this leads to the problem of finding an element of P_K , say p , for a given set of values $\{\omega_i\}$ such that

TABLE I. Linear Functionals Associated with Nodal Quantities

Nodal Quantity	Linear Functional
Node-averaged Flux	$L_{uv}(\phi) = \frac{1}{V} \int_V \phi(x,y) dx dy$ V = node volume
Surface-averaged Flux	$L_i^s(\phi) = \frac{1}{A} \int_{S_i} \phi [x(s),y(s)] ds \quad (i = 1,2,\dots,6)$ A = surface area
Corner Point Flux	$L_i^c(\phi) = \phi(x_i, y_i) \quad (i = 1,2,\dots,6)$ $x_i = \cos \frac{(2i-1)\pi}{6} \quad y_i = \sin \frac{(2i-1)\pi}{6}$
Surface-averaged Net Current	$L_i^J(\phi) = -\frac{D}{A} \int_{S_i} \mathbf{n}_i \cdot \nabla \phi [x(s),y(s)] ds \quad (i = 1,2,\dots,6)$ D = diffusion coefficient $\mathbf{n}_i$ = unit normal vector of surface S_i
Planar Moment	$L_i^M(\phi) = \frac{1}{V} \int_V w_i(x,y) \phi(x,y) dx dy \quad (i = x,u,v)$ $w_x(x,y) = \text{sgn}(x)$ $w_u(x,y) = \text{sgn}\left(y + \frac{x}{\sqrt{3}}\right)$ $w_v(x,y) = \text{sgn}\left(y - \frac{x}{\sqrt{3}}\right)$

$$L_i(p) = \omega_i, \quad i = 1, \dots, I \quad (2)$$

This problem can be solved only if L_i 's are independent in the algebraic conjugate space[11] of P_K , say P_K^* . That is, if $\{p_j \mid 1 \leq j \leq J = (K+1)(K+2)/2\}$ is a basis of P_K , the rank of the $I \times J$ matrix $[L_i(p_j)]$ has to be I .

In order for the rank of this $I \times J$ matrix to be I , it is necessary to choose the degree of polynomial (K) such that the dimension J of P_K is greater than or equal to I . However, this is not a sufficient condition. The I linear functionals are not always independent in P_K^* even when J is greater than I . Therefore, the minimum degree of the polynomial required to reproduce the given set of nodal quantities was first examined for several combinations of the available nodal quantities and the fluxes evaluated at the six vertices (corner points) of the hexagon. The corner fluxes are included in the constraints as has been done in Cartesian geometry,[1-3,12] since it has been shown that the flux expansion constrained only by nodal values is not sufficiently accurate.[1]

To determine the minimum polynomial degree K and the associated sets of monomials with which the given nodal information can be reproduced, the set of monomials

$$\{p_j = x^m y^n \mid j = \frac{1}{2}(m+n)(m+n+1) + n + 1, \quad 0 \leq m+n \leq K, m \geq 0, n \geq 0\} \quad (3)$$

was selected as a basis of P_K , and the following three step procedure was followed:

1. The analytic expressions for the images of monomials $x^m y^n$ with respect to the functionals (i.e., the elements of the matrix $[L_i(p_j)]$) are derived; Table II shows these expressions for the coordinate system and the numbering of the node's surfaces and corner points shown in Fig. 1,

TABLE II. Images of Monomials with Respect to Linear Functionals

$$L_{av}(x^m y^n) = \frac{[1 + (-1)^m] [1 + (-1)^n]}{4(n+1)} \left(\frac{2}{\sqrt{3}}\right)^{n+2} Z_{m(n+1)}$$

$$L_1^s(x^m y^n) = \frac{1 + (-1)^n}{2(n+1)} \left(\frac{1}{\sqrt{3}}\right)^n$$

$$L_2^s(x^m y^n) = \left(\frac{2}{\sqrt{3}}\right)^n Z_{mn}$$

$$L_3^s(x^m y^n) = (-1)^m L_2^s(x^m y^n)$$

$$L_4^s(x^m y^n) = (-1)^m L_1^s(x^m y^n)$$

$$L_5^s(x^m y^n) = (-1)^{m+n} L_2^s(x^m y^n)$$

$$L_6^s(x^m y^n) = (-1)^n L_2^s(x^m y^n)$$

$$L_1^c(x^m y^n) = \left(\frac{1}{\sqrt{3}}\right)^n$$

$$L_2^c(x^m y^n) = \delta_{m0} \left(\frac{2}{\sqrt{3}}\right)^n$$

$$L_3^c(x^m y^n) = (-1)^m L_1^c(x^m y^n)$$

$$L_4^c(x^m y^n) = (-1)^{m+n} L_1^c(x^m y^n)$$

$$L_5^c(x^m y^n) = (-1)^n L_2^c(x^m y^n)$$

$$L_6^c(x^m y^n) = (-1)^n L_1^c(x^m y^n)$$

$$L_1^J(x^m y^n) = -mD L_1^s(x^m y^n)$$

$$L_2^J(x^m y^n) = -\frac{mD}{2} L_2^s(x^{m-1} y^n) - \frac{\sqrt{3}nD}{2} L_2^s(x^m y^{n-1})$$

$$L_3^J(x^m y^n) = (-1)^m L_2^s(x^m y^n)$$

$$L_4^J(x^m y^n) = (-1)^m L_1^J(x^m y^n)$$

$$L_5^J(x^m y^n) = (-1)^{m+n} L_2^J(x^m y^n)$$

$$L_6^J(x^m y^n) = (-1)^n L_2^J(x^m y^n)$$

$$L_x^M(x^m y^n) = \frac{[1 + (-1)^{m+1}] [1 + (-1)^n]}{4(n+1)} \left(\frac{2}{\sqrt{3}}\right)^{n+2} Z_{m(n+1)}$$

$$L_u^M(x^m y^n) = \frac{[1 + (-1)^m] [1 + (-1)^{n+1}]}{4(n+1)} \left(\frac{2}{\sqrt{3}}\right)^{n+2} Z_{m(n+1)} - \frac{(-1)^m - (-1)^n}{(n+1)(n+m+2)} \left(\frac{1}{\sqrt{3}}\right)^{n+2}$$

$$L_v^M(x^m y^n) = \frac{[1 + (-1)^m] [1 + (-1)^{n+1}]}{4(n+1)} \left(\frac{2}{\sqrt{3}}\right)^{n+2} Z_{m(n+1)} - \frac{1 + (-1)^{m+n+1}}{(n+1)(n+m+2)} \left(\frac{1}{\sqrt{3}}\right)^{n+2}$$

where

$$Z_{\mu\nu} = \sum_{k=0}^{\nu} \frac{\nu!}{(\mu+k+1)(\nu-k)! k!} \left(-\frac{1}{2}\right)^k$$

$\delta_{\mu\nu}$ = Kronecker delta

Fig. 1. Numbering of Node Surfaces and Corners

2. For a given set of nodal quantities, the polynomial degree (K) is selected such that the dimension of P_K is greater than or equal to the number of nodal quantities, and the matrix $[L_i(p_j)]$ is constructed using the above elements, and
3. By reducing this matrix to the row-echelon form,[13] the rank of the matrix is determined and the dependent columns, if any exist, are identified.

If the rank of the matrix is less than the number of the given functionals, the second and the third steps are repeated with the degree of polynomial increased by one until the rank of the matrix becomes equal to the number of functionals. The results of this procedure, namely the minimum degree of polynomial and sets of monomials with which the given nodal values can be reproduced, are summarized in Table III.

Using the polynomials shown in Table III, several preliminary numerical tests have been performed to evaluate the accuracy and simplicity of interpolation schemes utilizing different subsets of the nodal and corner point quantities. Reference solutions were calculated using the triangular-z finite-difference option of DIF3D with very fine triangular and axial meshes. For the purpose of these preliminary tests, the values of node-average flux, surface-average fluxes, surface-average net currents, flux moments, and corner point fluxes were obtained by utilizing the flux and current information provided by these reference solutions. Using these nodal values and corner fluxes, the hex-plane flux distribution was interpolated with each of the polynomials shown in Table III and compared to the finite-difference reference solution.

TABLE III. Minimum Degree of Polynomial and an Example Set of Monomials for Various Combinations of Nodal Quantities

Nodal Quantities ^a	Number of Constraints	Minimum Order of Polynomial	An Example Set of Monomials
NAV, SAVs	7	3	$P_2 \cup \{x^3\}$
NAV, SAVs, CPVs	13	4	$P_3 \cup \{x^4, x^3y, x^2y^2\}$
NAV, SAVs, SNDs	13	5	$P_2 \cup \{x^3, x^2y, xy^2\} \cup \{x^4, x^3y, x^2y^2\} \cup \{x^5\}$
NAV, SAVs, CPVs, PMTs	16	5	$P_3 \cup \{x^4, x^3y, x^2y^2\} \cup \{x^5, x^4y, x^3y^2\}$
NAV, SAVs, SNDs, PMTs	16	7	$P_2 \cup \{x^3, x^2y, xy^2\} \cup \{x^4, x^3y, x^2y^2\} \cup \{x^5, x^4y, x^3y^2\} \cup \{x^7\}$
NAV, SAVs, CPVs, SNDs	19	6	$P_4 \cup \{x^5, x^4y, x^3y^2\} \cup \{x^6\}$
NAV, SAVs, CPVs, SNDs, PMTs	22	7	$P_4 \cup \{x^5, x^4y, x^3y^2, x^2y^3, xy^4\} \cup \{x^6\} \cup \{x^7\}$

^aNAV = node-averaged value

SAV = surface-averaged value

CPV = corner point value

SND = surface-averaged normal derivative

PMT = planar moment (see Ref. 10 for the definition of planar moments)

Based on these numerical tests, 13 nodal quantities (one node-average flux, six surface-average fluxes, and six surface-average net currents) and six local corner fluxes have been selected to be reproduced. The surface-average net currents (normal derivatives of the flux) are included in the constraints, since it has been found that the interpolation accuracy is improved by a factor of ~2 (for assemblies having large flux gradients) when the currents are required to be reproduced in addition to the flux information. However, the planar flux moments[10] are not included in the constraints, since they increase the required polynomial degree (K) to seven without any noticeable improvement of accuracy.

As shown in Table III, a polynomial of at least sixth degree is necessary in order to reproduce a given set of above 19 base values. By requiring this sixth degree polynomial to satisfy the 19 constraint equations, the 28 coefficients of Eq. (1) can be determined in terms of the 19 given base values and nine arbitrary constants. Using these coefficients, for a given set of node-average flux ($\bar{\phi}_g$), surface-average fluxes (ϕ_{gi}^s), corner fluxes (ϕ_{gi}^c), and surface-average net currents (J_{gi}^s), the hex-plane distribution of the g 'th group flux, $\phi_g(x,y)$, is determined as:

$$\begin{aligned} \phi_g(x,y) = & \bar{\phi}_g G^{av}(x,y) + \sum_{i=1}^6 \{ \phi_{gi}^s G_i^s(x,y) + \phi_{gi}^c G_i^c(x,y) + J_{gi}^s G_i^J(x,y) \} \\ & + \sum_{k=1}^9 a_k G_k^0(x,y) \end{aligned} \quad (4)$$

with cardinal functions[14] G^{av} , G_i^s , G_i^c , and G_i^J and with kernel functions G_k^0 . The 19 cardinal functions in Eq. (4) form a biorthonormal set for the 19 linear functionals corresponding to the base values. For example, the cardinal function G^{av} yields unity value when averaged over the node, but zero value when averaged over a surface, when evaluated at a corner, or when its normal derivative is taken and averaged over a surface. On the other hand, the kernel functions G_k^0 belong to the null space of the 19 linear functionals and produce zero for all 19 values.

The arbitrary constants (a_k) in Eq. (4) need to be eliminated in order to obtain a unique interpolation function. For physical symmetry reasons, Eq. (4) has been required to be invariant under coordinate transformations such as rotations around the origin of the hexagon by multiples of 60 degrees and reflections in lines passing through the origin and bisecting the hexagon in equal parts. In other words, Eq. (4) has been required to be invariant under the symmetry operations[15] of the hexagon so that the interpolation function for new coordinate systems may be obtained only by permuting the surface-average and corner values correspondingly. By performing 12 symmetry transformations on Eq. (4) with appropriate permutations of surface-average and corner values and by taking an average of the 12 resulting functions, the nine arbitrary constants in Eq. (4) are reduced to two, and the interpolation function can be represented as:

$$\begin{aligned} \phi_g(x,y) = & \bar{\phi}_g F^{av}(x,y) + \sum_{i=1}^6 \{ \phi_{gi}^s F_i^s(x,y) + \phi_{gi}^c F_i^c(x,y) + J_{gi}^s F_i^J(x,y) \} \\ & + \sum_{k=1}^2 c_k F_k^0(x,y) \end{aligned} \quad (5)$$

with new cardinal functions F^{av} , F_i^s , F_i^c , and F_i^J , which are obtained by combining G_k^0 's linearly with G^{av} , G_i^s , G_i^c , and G_i^J , respectively. Each of these cardinal function sets $\{F^{av}\}$, $\{F_i^s\}$, $\{F_i^c\}$, and $\{F_i^J\}$ as well as the new kernel function set $\{F_k^0\}$ forms an invariant subspace whose elements are transformed into each other by the symmetry transformations.

The remaining two arbitrary constants (c_k) in Eq. (5) are now determined by requiring Eq. (5) reproduce lower degree polynomial shapes (e.g., constant flux) exactly. By this requirement, the two constants are determined to be zeros, and a unique interpolation function is obtained, which reproduces lower degree polynomial shapes (up to fourth degree) exactly. Consequently, the interpolation function is determined by the cardinal function set $\{F^{av}, F_i^s, F_i^c, F_i^J\}$ shown in Table IV for the coordinate system which is oriented as shown in Fig. 1 and scaled such that the face to face distance of the hexagon is two.

TABLE IV. Cardinal Functions for Hex-planar Flux Interpolation

$$F^{av}(x,y) = \frac{35}{712}y^6 + \frac{735}{712}x^2y^4 + \frac{195}{89}y^4 - \frac{315}{712}x^4y^2 + \frac{390}{89}x^2y^2 - \frac{466}{89}y^2 + \frac{105}{712}x^6 \\ + \frac{195}{89}x^4 - \frac{466}{89}x^2 + \frac{7136}{2403}$$

$$F_1^s(x,y) = \frac{1295}{17088}y^6 + \frac{9065}{5696}x^2y^4 + \frac{2445}{1088}xy^4 - \frac{758}{5696}y^4 - \frac{3885}{5696}x^4y^2 - \frac{225}{544}x^3y^2 \\ - \frac{7193}{2848}x^2y^2 - \frac{93}{34}xy^2 + \frac{1561}{4272}y^2 + \frac{1295}{5696}x^6 - \frac{15}{64}x^5 - \frac{7193}{5696}x^4 + \frac{9}{34}x^3 \\ + \frac{9571}{4272}x^2 + \frac{157}{204}x - \frac{3041}{7209}$$

$$F_1^c(x,y) = -\frac{1435}{17088}y^6 + \frac{675\sqrt{3}}{34816}y^5 - \frac{10045}{5696}x^2y^4 - \frac{24705}{34816}xy^4 + \frac{7903}{22784}y^4 - \frac{8235\sqrt{3}}{17408}x^2y^3 \\ - \frac{39\sqrt{3}}{320}xy^3 + \frac{59\sqrt{3}}{2176}y^3 + \frac{4305}{5696}x^4y^2 + \frac{19845}{17408}x^3y^2 + \frac{75827}{56960}x^2y^2 + \frac{585}{2176}xy^2 \\ - \frac{6551}{17088}y^2 + \frac{6615\sqrt{3}}{34816}x^4y + \frac{123\sqrt{3}}{320}x^3y + \frac{603\sqrt{3}}{2176}x^2y - \frac{3\sqrt{3}}{32}xy - \frac{461\sqrt{3}}{6528}y \\ - \frac{1435}{5696}x^6 - \frac{405}{2048}x^5 + \frac{54467}{113920}x^4 + \frac{585}{2176}x^3 - \frac{8153}{17088}x^2 - \frac{461}{2176}x + \frac{1349}{14418}$$

$$F_1^j(x,y) = -\frac{595}{51264}y^6 - \frac{4165}{17088}x^2y^4 + \frac{2145}{8704}xy^4 + \frac{1574}{17088}y^4 + \frac{595}{5696}x^4y^2 + \frac{1755}{4352}x^3y^2 \\ + \frac{1457}{42720}x^2y^2 - \frac{273}{544}xy^2 - \frac{977}{12816}y^2 - \frac{595}{17088}x^6 - \frac{75}{512}x^5 - \frac{19903}{85440}x^4 - \frac{1}{544}x^3 \\ + \frac{3829}{12816}x^2 + \frac{251}{1632}x - \frac{746}{21627}$$

$$F_i^\alpha(x,y) = F_1^\alpha(x_i,y_i), \quad \alpha = s,c,j, \quad \text{and } i = 2,\dots,6$$

where

$$\begin{pmatrix} x_i \\ y_i \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}^{i-1} \begin{pmatrix} x \\ y \end{pmatrix} \quad \theta = \frac{\pi}{3}$$

Fig. 2. Nodal Quantities Used to Compute the Corner Flux

In order to determine the corner fluxes used in the hex-plane flux interpolation, the planar flux distribution is assumed to be biquadratic (less the x^2y^2 term) in each of the three nodes surrounding a corner point. A system of 24 equations can be obtained (to determine the eight coefficients of this expansion in each of the three nodes) by (1) requiring the node-average and surface-average fluxes (see Fig. 2) to be reproduced, (2) enforcing additional continuity conditions on the surface-average and midpoint net currents and on the flux derivative at a corner point, and (3) imposing a "source free" condition at a corner point. By determining the coefficients, an expression for a corner flux, which is analogous to that derived by Lindahl for Cartesian geometry,[12] can be obtained as:

$$\phi_{gi}^c = \sum_{n=1}^3 D_{gn} \{ 17(\phi_{gn}^s + \phi_{g(n-1)}^s) - 8\bar{\phi}_{gn} \} / \{ 26 \sum_{n=1}^3 D_{gn} \} \quad (6)$$

where D_{gn} represents the g 'th group diffusion constant of node n .

For corner points on the outer radial boundary of the core, this formula is not applicable. It is possible to derive a special formula applicable to these corner points using the specified

boundary condition. However, no such special formula for the corner fluxes on the radial boundary has yet been implemented in RCT. One reason for this is that the radial boundary is not convex in hexagonal geometry, and hence the boundary conditions available in the nodal option of DIF3D might introduce large errors in the nodal quantities for the nodes on the radial boundary. Another reason is that it is generally inappropriate to attempt the reconstruction of intranodal characteristics for the nodes on the radial boundary, because the approximations inherent in diffusion theory break down near boundaries or in the vicinity of localized sources. For these reasons, the inclusion in the REBUS-3 job of one or more rings of extra assemblies beyond any assembly in which reconstruction is to be performed is strongly recommended.

B. Intranodal Nuclide Densities

The intranodal nuclide density distributions are calculated in one of two ways. In the first way, which is applicable to conventional assemblies with nominally uniform beginning of life (BOL) densities and smooth density variation after depletion, the surface and corner densities are first calculated by solving the nuclide transmutation equations using the surface-average and corner fluxes. As in REBUS-3, the transmutation matrices are constructed with the average of the beginning and the end of time interval fluxes, and the depletion equations are solved by employing the matrix exponential method.

Using these surface-average and corner densities as well as the node-average density from the nodal solution and making the assumption of hex-planar and axial separability, the hex-plane densities are interpolated at the location coinciding with the center of each fuel pin. As shown in Table III, a minimum polynomial degree of four is necessary to reproduce these 13 nodal values. Similar to the flux interpolation functions described above, the interpolation polynomial is required to preserve these 13 base values and to be invariant under the symmetry operation of the hexagon. With these requirements, the hex-plane distribution of the nuclide density of the isotope m , $N_m(x,y)$, is uniquely determined by the given node-average density ($\bar{N}_m$), surface-average densities (N_{mi}^s), and corner densities (N_{mi}^c) as:

$$N_m(x,y) = \bar{N}_m H^{av}(x,y) + \sum_{i=1}^6 \{ N_{mi}^s H_i^s(x,y) + N_{mi}^c H_i^c(x,y) \} \quad (7)$$

with cardinal functions H^{av} , H_i^s , and H_i^c , which are shown in Table V. As in the case of flux interpolation, each of these cardinal function sets $\{H^{av}\}$, $\{H_i^s\}$, and $\{H_i^c\}$ forms an invariant subspace whose elements are transformed into each other by the symmetry operations of the hexagon. The axial density distribution is interpolated by a quadratic polynomial using the node-average density and the top and bottom surface-average densities.

TABLE V. Cardinal Functions for Hex-planar Nuclide Density Interpolation

$$\begin{aligned} H^{av}(x,y) &= \frac{135}{68}y^4 + \frac{135}{34}x^2y^2 - \frac{81}{17}y^2 + \frac{135}{68}x^4 - \frac{81}{17}x^2 + \frac{48}{17} \\ H_1^s(x,y) &= -\frac{4545}{9044}y^4 - \frac{1035}{323}x^2y^2 - \frac{9}{4}xy^2 + \frac{10449}{9044}y^2 - \frac{13725}{9044}x^4 - \frac{5}{4}x^3 + \frac{26259}{9044}x^2 \\ &\quad + 2x - \frac{11}{17} \\ H_1^c(x,y) &= \frac{5055}{9044}y^4 + \frac{75\sqrt{3}}{532}xy^3 + \frac{5\sqrt{3}}{16}y^3 + \frac{630}{323}x^2y^2 + \frac{9}{8}xy^2 - \frac{19335}{18088}y^2 + \frac{15\sqrt{3}}{28}x^3y \\ &\quad + \frac{9\sqrt{3}}{16}x^2y - \frac{177\sqrt{3}}{532}xy - \frac{5\sqrt{3}}{12}y + \frac{8565}{9044}x^4 + \frac{9}{8}x^3 - \frac{25353}{18088}x^2 - \frac{5}{4}x + \frac{35}{102} \\ H_i^\alpha(x,y) &= H_1^\alpha(x_i, y_i), \quad \alpha = s, c, \text{ and } i = 2, \dots, 6 \end{aligned}$$

where

$$\begin{pmatrix} x_i \\ y_i \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}^{i-1} \begin{pmatrix} x \\ y \end{pmatrix} \quad \theta = \frac{\pi}{3}$$

The second method of computing local nuclide densities is applied to specified "special" pins in assemblies with different types of fuel pins (e.g., experimental assemblies in EBR-II); in this case, the densities are not smooth functions of position within the assembly and cannot be determined by interpolation. The special pin nuclide densities are, therefore, calculated by point depletion, i.e., solving the depletion equations with the interpolated fluxes. For each axial pin segment contained in a given node, the top, axial-average, and bottom densities are calculated along the centerline of the segment. Using these three values, the axial density distribution is interpolated by a quadratic polynomial.

C. Intranodal Power, Burnup, and Fluence Distributions

After the intranodal nuclide density distributions are computed, the pointwise energy conversion factor (ECF) can be calculated. The intranodal power distribution is then calculated with this pointwise ECF and the reconstructed group fluxes. Even though this procedure for pointwise power "calculation" is less efficient than the direct "interpolation" of pin powers (an option for conventional assemblies) from node-average, surface-average, and corner powers, it is more accurate by a factor of ~ 2 , because the "calculated" power is obtained using group flux distributions constrained to satisfy the surface-average net currents, whereas the "interpolated" power contains no information about the currents.

The intranodal burnup and fluence distributions are calculated in a similar manner as the nuclide densities. For conventional assemblies, the surface-average and corner values as well as the node-average values of fluence and burnup are calculated using the node-average, surface-average, and corner fluxes. The burnup values are computed from the ratio of the atoms destroyed by fission over the burn step to the fissionable atoms initially present, consistent with the definition of burnup used in REBUS-3. The total fluences are calculated as the integrals of the flux over energy and time, while the fast fluences are computed as the integrals over energy greater than the fast flux energy threshold and time. For the fast fluence contribution from the energy group in which the fast flux energy threshold is located, logarithmic interpolation is used as in DIF3D. Using these node-average, surface-average, and corner values, the hex-plane

distributions of burnup and fluence are interpolated by fourth-degree polynomials, and the respective axial distributions are interpolated by quadratic polynomials; the polynomial forms and interpolation procedures are completely equivalent to those described above for the nuclide density distributions. For the special pins, the burnup and fluence values are explicitly calculated using the interpolated fluxes at the center of each fuel pin.

III. USER INFORMATION

The reconstruction techniques described in the previous section has been implemented in a computer code RCT. This code is executed in essentially the same manner as the standard Argonne Reactor Computation (ARC) codes such as DIF3D and REBUS-3. This section discusses the information needed to run a RCT problem on the Argonne computers. First, a general description of input data is provided. This is followed by detailed discussions of the binary interface files RCTDEN, RCTFLX, and RCTPWD and the BCD input dataset A.RCT. Sample jobs are also included for the Sun SparcStation and IBM RS/6000 workstation of the Reactor Analysis (RA) Division Network as well as the IBM 3033 and Cray X-MP computers. Finally, the input error checking and output edit options are presented.

A. Overview of Input Data

As in the case of DIF3D or REBUS-3, the input data for RCT are of two basic types: 1) binary interface files on disk and 2) BCD card-image files. While the BCD card-image files have to be prepared by the user as described below, the binary interface files are provided by REBUS-3 or a previous RCT run. Most of these datasets are common to those of REBUS-3, and only two datasets RCTDEN and A.RCT are specific to RCT. This subsection provides a brief overview of these input datasets (along with the ANL conventions of the BCD input structure). The datasets A.RCT and RCTDEN are described in greater detail in the next two subsections.

The binary input files used by RCT consist of the restart file (RFILES) of REBUS-3, the RCT density file RCTDEN, and the CCCC and ARC interface files. The restart file RFILES is used by RCT to obtain the burnup chain data required for the depletion calculation; this circumvents the need to process the REBUS-3 BCD input file A.BURN. The density file RCTDEN, which is written in the RCT run for the previous burn step, provides the nonuniform nuclide densities within a burn region at the beginning of the present burn step. Therefore, this file need not be included in the input datasets, if the initial nuclide densities are uniform in each burn region. This file is used by RCT to trace the nonuniform nuclide densities within a burn region from one burn step to the next. The CCCC and ARC interface files used in RCT include

microscopic cross sections (ISOTXS), geometry specifications (GEODST), zone-average nuclide densities (ZNATDN), nuclide and cross section reference (NDXSRF), region and composition labels (LABELS), and nodal flux (NHFLUX). Among these files, ZNATDN, NDXSRF, LABELS, and ISOTXS are used in the generation of the macroscopic cross section file (COMPXS), and NHFLUX is used in the flux reconstruction. The file GEODST is used in identifying the burn regions and nodes corresponding to the assemblies to be analyzed by RCT. The files ZNATDN and ISOTXS provide the assemblies with the uniform nuclide densities and the microscopic power conversion factors, respectively. These interface files (except for ISOTXS) are written on the STACK file during the REBUS-3 run and can be provided for RCT as a group through the STACK file or individually as described below.

The BCD input data is divided into two blocks of data A.HMG4C and A.RCT. The dataset A.HMG4C contains the input parameters for the cross section homogenization performed by the module HMG4C. This dataset consists of three types of cards, and all the parameters have defaults as described in the Appendices of the DIF3D and REBUS-3 user's manuals. Therefore, this dataset need not be present if default values are acceptable. The BCD input A.RCT is the dataset used in the specification of the reconstruction options and parameters. This dataset currently consists of card types 01 through 09. Among the more important input data are the input option flag for the interface datasets written on the file STACK by the REBUS-3 and the specifications of the assemblies and the fuel pins for which the reconstruction is to be performed. The interface datasets on the file STACK can be provided for RCT collectively or individually according to the option flag given in the type 02 card. If they are provided collectively through the file STACK, they will be processed by the code RCT and hence their record numbers in the STACK file have to be provided in the type 04 cards. In order to supply the interface files individually, the STACK file has to be processed by the code FTU before executing the RCT job. The specifications of the assemblies and the fuel pins to be analyzed are provided by the type 05 through 09 cards. These cards permit the user to specify reconstruction options and information about locations, compositions, and initial heavy metal densities of the assemblies and the fuel pins being analyzed.

RCT uses standard ANL conventions[7] regarding the structure of the BCD input data. Thus the input datasets are separated into two input BLOCKs as shown in Fig. 3. The name BLOCK=OLD in the input deck specifies a dataset initialization block which contains the names of the datasets which already exist at the start of a problem. Hence, the datasets ISOTXS, RFILES, and either STACK or the CCCC and ARC interface files would always be in this block. This is indicated simply by a "DATASET= dataset name" card immediately following the "BLOCK=OLD" card. If the CCCC and ARC interface files are provided, the version numbers must follow the dataset names and be separated from them by a comma. The other block of data consists of the BCD files, A.HMG4C and A.RCT, following a "BLOCK= STP034" card to indicate these files are being processed by the RCT standard path driver STP034. These datasets can be specified using the free format option (UNFORM=) or the fixed format option (DATASET=). If the free format option is specified, the input data following this card should correspond to any free field equivalent[7] of the formats specified in the various BCD dataset descriptions.

B. RCT Code-Dependent Binary Datasets

In RCT, there are three code-dependent binary datasets: RCTDEN, RCTPWD, and RCTFLX. RCTDEN is the reconstructed pin nuclide density file used to trace the nonuniform nuclide densities within a burn region from one burn step to the next. This file is employed by RCT both as an input and as an output dataset. RCTPWD and RCTFLX are output datasets containing the reconstructed pin power densities and group fluxes, respectively. The structure and contents of these three datasets are discussed in this subsection.

1. Reconstructed Pin Nuclide Density File RCTDEN

As mentioned above, the density file RCTDEN is created by RCT to transfer the (pin-by-pin and axially) nonuniform nuclide densities within a burn region from the end of one burn step to the beginning of the succeeding one. Even though this file is referred to as a density file, the nonuniform values of burnup, total fluence, and fast fluence are also contained in this file.

```
BLOCK=OLD  
DATASET=ISOTXS  
DATASET=RFILES  
DATASET=RCTDEN  
DATASET=STACK  
BLOCK=STP034  
DATASET=A.HMG4C  
  
UNFORM=A.RCT
```

OR

```
BLOCK=OLD  
DATASET=ISOTXS  
DATASET=RFILES  
DATASET=RCTDEN  
DATASET=LABELS  
DATASET=NDXSRF  
DATASET=ZNATDN, 1  
DATASET=ZNATDN, 2  
DATASET=GEODST, 1  
DATASET=GEODST, 2  
DATASET=NHFLUX, 1  
DATASET=NHFLUX, 2  
BLOCK=STP034  
DATASET=A.RCT
```

Fig. 3. Structure of Typical RCT Input Deck

In an RCT run, two versions of RCTDEN are employed to trace the nonuniform nuclide densities, burnup, total fluence, and fast fluence from one burn step to the next. The first version is the input file provided for RCT to take into account the nonuniformity of the different variables in a burn region. This file is created for the present RCT run by the RCT run performed for the preceding burn step; it contains the data at the beginning of the present burn step. If this first version of RCTDEN is not provided (e.g., in an initial run of RCT), uniform initial intranodal distributions are assumed and are obtained from the remaining input data (e.g., ZNATDN). The second version of RCTDEN is a RCT output file to be saved for the use in the next burn step. This file contains the data at the end of the burn step including the shutdown time, i.e., data at the beginning of the next burn step.

The density file RCTDEN consists of 1D through 6D records as shown in Appendix A. The 1D record specifies the number of assemblies, active isotopes, and special pins contained in

the file. The assembly label, the number of burn regions, and the number of special pins of each assembly are specified in the 2D record. The isotope and special pin labels are contained in the 3D and 4D records, respectively. The 5D and 6D records contain the assembly and special pin data of the nuclide densities, burnup, and fluences, respectively. The node-average, surface-average, and corner values are contained in the assembly data, whereas burn interval top, average, and bottom values are included in the special pin data. These 5D and 6D records are repeated for each of the assemblies specified in the 1D record.

2. Reconstructed Pin Power Density File RCTPWD

The file RCTPWD is an output file used to edit the reconstructed pin power densities. In an RCT run, two versions of RCTPWD are written: one at the beginning of burn time step, and the other at the end of burn time step. These files contain the information about nonuniform power density distributions in active regions at the corresponding time point.

The file RCTPWD consists of 1D through 5D records as shown in Appendix B. The 1D record specifies the number of assemblies, the maximum number of fuel pins in an assembly, and the number of special pins contained in the file. The assembly label, the number of fuel pin rings, the number of burn regions, and the number of special pins of each assembly are specified in the 2D record. The special pin labels are contained in the 3D record. The 4D and 5D records contain the regular pin and the special pin power densities, respectively. The regular pin power densities represent the values obtained using the interpolated nuclide densities, whereas the special pin power densities are the values obtained with the nuclide densities calculated by point depletion, i.e., solving the depletion equations with the interpolated fluxes. The burnup interval top, average, and bottom values are included in these pin power density data. These 4D and 5D records are repeated for each of the assemblies specified in the 1D record.

3. Reconstructed Neutron Flux File RCTFLX

The file RCTFLX is an output file used to edit the reconstructed neutron group fluxes. In an RCT run, two versions of RCTFLX are written: one at the beginning of the burn time step,

and the other at the end of burn time step. For each time point, RCTFLX contains the information about the intranodal neutron flux distributions in burn regions.

The file RCTFLX consists of 1D through 4D records as shown in Appendix C. The 1D record specifies the number of assemblies, the maximum number of fuel pins in an assembly, the maximum axial burn region number in an assembly, and the number of energy groups. The assembly label, the number of fuel pin rings, and the number of burn regions of each assembly are specified in the 2D record. The 3D record contains the groupwise axial-average pin fluxes in a given axial burn region. These values represent the group fluxes averaged over the axial segment of each fuel pin contained in a specified axial burn region. The 4D record contains the groupwise multiplicative factors for the bottom and top point fluxes. The bottom and top point fluxes of each fuel pin segment are obtained by multiplying the axial-average fluxes given in the 3D record by these multiplicative factors. The 3D and 4D records are repeated for each axial burn region and each assembly.

C. BCD Input Dataset A.RCT

As mentioned above, the BCD input A.RCT is the dataset used to specify the reconstruction options and parameters such the interface dataset input option, the edit options, and the assembly and fuel pin specifications. The format and usage of A.RCT are described in Appendix D, and a typical example is shown in Fig. 4.

The type 01 cards of dataset A.RCT provide the problem title. The title can consist of any alphanumeric characters, and any number of type 01 cards can be used.

The type 02 card indicates that the CCCC and ARC interface files are provided collectively on the REBUS-3 STACK file and requests RCT to process the file STACK and restore the individual files. In the example of Fig. 4, 73-day interval is specified in this card for the shutdown time between the present and the next burn step; this period is used in the radioactive decay calculation. For the assemblies specified in type 05 cards, the radioactive decay calculation is performed for this time period at the end of present burn step, and the nuclide

```

UNFORM=A.RCT
01      TEST CASE
02      0      73.0      0.11100e+06
03      1      0      1      1
04      NDXSRF      1      13
04      LABELS      1      1111
04      GEODST      1      1099
04      GEODST      2      1659
04      ZNATDN      1      1077
04      ZNATDN      2      1637
04      NHFLUX      1      1118
04      NHFLUX      2      1678
05      IB0402      4      2      5      2      0      4      3.07920E+00
05      CD0603      6      3      5      0      0      4      3.07920E+00
05      RB0703      7      3      5      4      1      4      3.07920E+00
06      IB0402 I4P01      1      1 I4P02      2      1 I4P03      2      2
06      IB0402 I4P04      2      3 I4P05      2      4 R7P01      2      5
06      CD0603 C6P01      1      1 C6P02      2      1 C6P03      2      2
06      CD0603 C6P04      2      3 C6P05      2      4 C6P06      2      5
06      RB0703 I4P06      1      1 R7P02      2      1 R7P03      2      2
06      RB0703 C6P09      2      3 R7P05      2      4 R7P06      2      5
07      MAT01 U-235 3.08883E-05 U-238 1.52161E-02
07      MAT02 U-235 1.40056E-05 U-238 6.90052E-03 PU239 2.45662E-03
07      MAT02 PU238 1.36280E-05 PU240 7.86222E-04 PU241 8.96071E-05
07      MAT02 PU242 4.07254E-05
08      MAT01 I4P01      0      0 I4P02      0      0 I4P03      0      0
08      MAT01 I4P04      0      0 I4P05      0      0 I4P06      0      0
08      MAT02 C6P01      0      0 C6P02      0      0 C6P03      0      0
08      MAT02 C6P04      0      0 C6P05      0      0 C6P06      0      0
09      IB0402      1      5 1.52470E-02
09      CD0603      0      0 1.03013E-02

```

Fig. 4. Sample BCD Input A.RCT

densities *after decay* are written on the file RCTDEN. For the assemblies in the out-of-core storage, however, the radioactive decay is taken into account for the time period of the burn step length plus the shutdown time. The assemblies present in RCTDEN are considered to be in out-of-core storage if they are not specified on type 05 cards. This type 02 card also specifies 111 KeV for the fast flux energy threshold to be used for the fast fluence calculation. A default value of 100 KeV is used if this threshold energy is not provided.

The type 03 card specifies the edit options for nuclide densities, flux, power, and burnup/fluence. The type 03 card in Fig. 4 requests the edit of nuclide densities, power, and burnup/fluence. This edit option is discussed in more detail in subsection III.F.

The type 04 cards specify the record numbers in the STACK file of the CCCC and ARC interface files. Two dataset versions have to be provided for GEODST, ZNATDN, and NHFLUX, while one version is provided for NDXSRF and LABELS. The first and second versions of the datasets represent the datasets at the beginning and the end of the burn step, respectively. The second version of GEODST is needed to treat axial fuel displacement and changes in the axial mesh structure during a burn step. Among these type 04 cards, these datasets can appear in any order. The type 04 cards are ignored if the CCCC and ARC files are provided individually (i.e., the input option flag on type 02 card is "1").

The type 05 cards provide the specifications of assemblies for which the reconstruction is to be performed; these specifications include the label, location in the core, number of axial burn regions in the REBUS-3 model, number of fuel pin rings, fuel pin pitch, and degree of rotation for each assembly. For the specification of the assembly location in the core, the hexagon numbering convention employed in the type 30 card of the A.NIP3 BCD input[6] is used to be consistent with the DIF3D nodal option. The source of the initial nuclide densities and the rotational shuffling for the present burn step are also specified for each assembly by the type 05 cards. The initial nuclide densities for each assembly can be specified through the CCCC density file ZNATDN or the RCT density file RCTDEN created in a previous RCT run. If the ZNATDN is specified as the source of the nuclide densities, it will be assumed that the initial nuclide densities are uniform in each burn region and hence the region average densities from ZNATDN will be used throughout each region. If the RCTDEN is specified, the nonuniform nuclide densities will be interpolated, as discussed in subsection II.B, for each region using the node average, surface average, and corner nuclide densities contained in RCTDEN. The rotation of an assembly is specified in the counter-clockwise sense as an integer multiple of 60 degrees with respect to the reference position at the beginning of life (BOL). In the example given in Fig. 4, the assembly RB0703 is located at the third hexagonal position in the seventh ring of hexagons and is rotated 240 degrees counter-clockwise with respect to the BOL position. Thus the burnup characteristics of this assembly will be reconstructed using the flux appropriate to the rotated position and the initial nuclide densities obtained from the density file RCTDEN.

The type 06 cards specify labels and locations of the "special pins" in each assembly; for these pins, the burnup characteristics are to be calculated by point depletion instead of interpolation. The initial nuclide densities of special pins are provided through card types 07 and 08 by defining the special pin materials with type 07 cards and assigning the materials to the special pins using type 08 cards. If the nuclide densities of a special pin are not provided by these cards, they are obtained from the file RCTDEN or the file ZNATDN depending on the existence of the special pin label in the file RCTDEN. Similarly, the heavy metal densities used for the burnup edit can be provided through the type 09 cards, the file RCTDEN, or the file ZNATDN.

It should be noted that the type 06 cards and the file RCTDEN permit the user to shuffle the special pins on a pin-by-pin base. Since the special pins are stored in RCTDEN by unique pin labels, and type 06 cards specify the special pin positions by pin labels, pin-by-pin shuffling can be performed by providing the pin labels from RCTDEN on the type 06 cards. In the example given in Fig. 4, special pin R7P01 of assembly RB0703 is interchanged with I4P06 of IB0402, and special pin R7P04 is replaced by C6P09. Thus the RCT code provides the flexibility needed to reconstitute fuel assemblies using previously irradiated and/or fresh fuel pins and to perform fuel management operations at the individual pin level.

D. Running RCT

As mentioned in the Introduction, the code RCT is operational on the Sun SparcStation and the IBM RS/6000 workstation (the systems currently making up the Reactor Analysis Division Computer Network), as well as the IBM 3033 and Cray X-MP computers. It was also mentioned that RCT functions as a postprocessor of the burnup code REBUS-3. This subsection discusses the information to be saved in a REBUS-3 run and describes sample RCT jobs for the various computing platforms.

Several REBUS-3 interface files have to be saved prior to running RCT. Among these files are the condensed microscopic cross section set ISOTXS, the restart file RFILES, and the

STACK file containing various CCCC interface files. The STACK file always has to be saved, but the files ISOTXS and RFILES need not always be saved. If the condensed version of ISOTXS was not created in a REBUS-3 job, the original ISOTXS used as input data to REBUS-3 can be used for RCT. Moreover, the file RFILES need not be explicitly saved for conventional single cycle calculations, since RFILES is automatically written by REBUS-3 at the beginning of the file STACK. It should be noted, however, that a distinct RFILES file has to be saved for each cycle of a multicycle REBUS-3 run, since REBUS-3 retains only the most recent version of RFILES and since the cycle-dependent fuel path information is contained in this file. For a RCT run, the various files must exist as disk files, and thus they have to be copied to disk files if they are stored on tapes.

Figure 5 shows a sample job-script for executing RCT on the Sun SparcStation or the IBM RS/6000 workstation of the RA Network. This job uses RASHELL shell variables and scripts.[16] RASHELL is a collection of UNIX shell variables and scripts which allows the user to utilize a tailored set of simplified commands with sensible defaults for most job functions. The capitalized commands in this job are RASHELL commands as discussed in Ref. 16. The RCT test library (*/home/salt3/b39114/lib/\$ARCH*) is included in the search path using the PREPATH command. The RASHELL parameter *\$ARCH* expands to either *sun4* or *rs6000* depending on the current host's architecture, so that job-scripts may be equivalently applied to either of two system architectures in the RA Network.

The sample job in Fig. 5 shows that the datasets STACK and RFILES are both linked to an existing REBUS-3 STACK file stored on a disk at the same time since the dataset RFILES is stored at the beginning of the STACK file. The file *input* contains all the BCD input data as shown in Figs. 3 and 4. In this example, the CCCC and ARC interface files are provided for RCT through the file STACK with the type 04 cards of A.RCT containing the record number of each interface file. In this case, the STACK file is processed by the subroutine RDSTAK of the code RCT, and the individual files are restored. If the individual files are directly provided, the second versions of datasets need to be identified by suffixing the version number "2" to the corresponding dataset name as shown in Fig. 5 for the RCT output datasets. In this example, all the RCT output datasets (second version of RCTDEN and two versions of RCTPWD and

```
#!/bin/sh
set -vx
RAJOBNAME=test1
RABANNER=test1
RABADGE=39114
RADEST=3800
RADEST2=FICHE
RAROUTE=CWD
RAMEM=6
RATIME=10
RADATASIZE=35
RAINPUT=input
RAOUTPUT=output
RAFICHETITLE1=" $RABANNER"
. RASHELL
#
#   include the modular library
#
PREPATH /home/salt3/b39114/lib/$ARCH
#
#   link or copy input datasets
#
ln -s $HOME/RCT/test1/STACK      STACK
ln -s $HOME/RCT/test1/STACK      RFILES
cp $HOME/RCT/test1/ISOTXS        ISOTXS
cp $HOME/RCT/test1/rct.input input
#
#   execute RCT
#
XRCT
IFBOMB
#
#   copy output datasets
#
cp RCTDEN2 $HOME/RCT/test1/RCTDEN
cp RCTFLX  $HOME/RCT/test1/RCTFLX
cp RCTFLX2 $HOME/RCT/test1/RCTFLX2
cp RCTPWD  $HOME/RCT/test1/RCTPWD
cp RCTPWD2 $HOME/RCT/test1/RCTPWD2
```

Fig. 5. Sample RASHELL Script for Executing RCT

RCTFLX) are saved for future use. The second version of RCTDEN contains the nuclide densities, burnups, and fluences at the end of the present burn step including the shutdown period. This file is supplied as input to the RCT run for the next burn step in order to provide it with the nonuniform initial compositions of previously irradiated burn regions. The first and second versions of RCTPWD and RCTFLX contain the reconstructed pin power densities and group fluxes at the beginning and at the end of present burn step, respectively.

Figure 6 shows a sample Cray RCT job submitted to the Cray X-MP (under the UNICOS operating system) at ANL from an IBM front end. (Operation of the ANL Cray-XMP was recently discontinued.) The *EXEC* named *CRAY* submits the *SYSUT1* file to the Cray. This job uses APSHELL shell variables and scripts.[9] APSHELL is a collection of UNICOS shell variables and scripts which allows the user to utilize a tailored set of simplified commands. The capitalized commands in this job are APSHELL commands as discussed in Ref. 9.

The sample job in Fig. 6 shows that the STACK file is supplied on tape, whereas the files ISOTXS and RCTDEN are provided on IBM disks. Since RFILES is stored at the beginning of the STACK file, the files STACK and RFILES are copied to disk files from the same tape. The Cray-format ISOTXS and RCTDEN are brought from the IBM disks to the Cray by STAGEIN commands. In the sample job shown in Fig. 6, the STACK file is processed by the file transfer code, FTU, and the individual files are provided for the RCT run. Since FTU allows only the standard file names, the second versions of ZNATDN, GEODST, and NHFLUX are processed first and copied to ZNATDN2, GEODST2, and NHFLUX2, respectively. The first versions of datasets are processed later, after the second versions are removed. In this example, all the RCT output datasets are saved and staged out from Cray to IBM disk.

Figure 7 shows a typical IBM RCT job in which the files STACK, ISOTXS, and RFILES are provided on disks. On IBM computers, all files used in a job step are described by data definition (DD) statements, and hence the JCL needed to run a problem must contain a DD card for each of the data files accessed by RCT modules. This can lead to a cumbersome amount of JCL to be included in the input deck. To simplify the RCT input deck, the datasets and parameters pertinent to RCT are added to the RA generic Fortran 77 catalogued procedure APPROC.[9] The new catalogued procedure APPROC is used by setting the *PATH* parameter to *STP034*. The user should include *PROC=AP* on the *//*MAIN* card to access this catalogued procedure. Since APPROC follows the Fortran 77 conventions, the DD cards are overwritten by using file names rather than numbered datasets *FTnnF00n*. When overwriting DD cards, the supplied cards must be in the order in which they appear in the APPROC. That is, the named files must be supplied in alphabetical order. The full listing of the catalogued procedure APPROC is shown in Appendix E.

```
//SAMPLE JOB MSGCLASS=W,REGION=400K,CLASS=C
/**MAIN ORG=PR0,PROC=AP
// EXEC CRAY
//SYSUT1 DD *
# user=
#
# QSUB -r SAMPLE
# QSUB -lT 50
# QSUB -lM 1000Kw
# QSUB -lUa 1
# QSUB -eo
# QSUB -q w
# QSUB
set -vxS
APOUTPUT=output
APDEST=PR0,FLASH=LINE
APBANNER=sample2
APFETCH=YES
APLINES=40000
. APSHELL
# *****
# COPY THE REBUS-3 FILES (STACK AND RFILES) FROM TAPE
# *****
anlrsv TAPE
anlmntp TAPE 210740 junk sl read fileseq=3 name=DCN1.STACK
anltps
cp junk RFILES
cp junk STACK
IFBOMB
anlrsls all
# *****
# EXECUTE FTU, RESTORE SECOND VERSIONS OF INTERFACE FILES
# *****
cat > input <<\EOF
    ZNATDN 1077 CRAY CRAY
    GEODST 1099 CRAY CRAY
    NHFLUX 1118 CRAY CRAY
EOF
XFTU
IFBOMB
cp ZNATDN ZNATDN2
cp GEODST GEODST2
cp NHFLUX NHFLUX2
rm input
rm ZNATDN
rm GEODST
rm NHFLUX
# *****
# EXECUTE FTU, RESTORE FIRST VERSIONS OF INTERFACE FILES
# *****
cat > input <<\EOF
    NDXSRF 13 CRAY CRAY
    ZNATDN 1077 CRAY CRAY
    GEODST 1099 CRAY CRAY
    LABELS 1111 CRAY CRAY
    NHFLUX 1118 CRAY CRAY
EOF
```

Fig. 6. Sample Cray RCT Job Using FTU


```

XFTU
IFBOMB
rm input
# *****
# STAGEIN ISOTXS AND FIRST VERSION OF RCTDEN, EXECUTE RCT
# *****
STAGEIN CRAYBINARY ISOTXS B39114.TEST2.ISOTXS
STAGEIN CRAYBINARY RCTDEN B39114.TEST2.C1E.RCTDEN
IFBOMB
cat > input <<\EOF
BLOCK=OLD
DATASET=ISOTXS
DATASET=RFILES
DATASET=LABELS
DATASET=NDXSRF
DATASET=RCTDEN
DATASET=ZNATDN,1
DATASET=ZNATDN,2
DATASET=GEODST,1
DATASET=GEODST,2
DATASET=NHFLUX,1
DATASET=NHFLUX,2
BLOCK=STP034
UNFORM=A.RCT
01 SAMPLE 2 (CCCC FILES PROCESSED BY FTU)
02 0 73.0 0.11100e+06
03 1 0 1 1
05 IB0402 4 2 5 0 1 4 3.07920E+00
05 CD0603 6 3 5 2 1 4 3.07920E+00
06 IB0402 I4P04 2 3 I4P05 2 4 I4P06 2 5
06 IB0402 I4P10 3 3 I4P11 3 4 I4P12 3 5
06 CD0603 C6P04 2 3 C6P05 2 4 C6P06 2 5
06 CD0603 C6P07 2 6 C6P08 3 1 C6P09 3 2
EOF
APTRACE='set -vxS'
XRCT input
cat sysudump >> output
# *****
# STAGEOUT OUTPUT DATASETS; RCTDEN, RCTFLX, and RCTPWD
# *****
STAGEOUT CRAYBINARY RCTDEN2 B39114.TEST2.C2E.RCTDEN\
'DISP=(NEW,CATLG),UNIT=PERM,SPACE=(TRK,(20,5),RLSE)'\
'DCB'
STAGEOUT CRAYBINARY RCTFLX B39114.TEST2.C2B.RCTFLX\
'DISP=(NEW,CATLG),UNIT=PERM,SPACE=(TRK,(20,5),RLSE)'\
'DCB'
STAGEOUT CRAYBINARY RCTFLX2 B39114.TEST2.C2E.RCTFLX\
'DISP=(NEW,CATLG),UNIT=PERM,SPACE=(TRK,(20,5),RLSE)'\
'DCB'
STAGEOUT CRAYBINARY RCTPWD B39114.TEST2.C2B.RCTPWD\
'DISP=(NEW,CATLG),UNIT=PERM,SPACE=(TRK,(20,5),RLSE)'\
'DCB'
STAGEOUT CRAYBINARY RCTPWD2 B39114.TEST2.C2E.RCTPWD\
'DISP=(NEW,CATLG),UNIT=PERM,SPACE=(TRK,(20,5),RLSE)'\
'DCB'
/*

```

Fig. 6. (Contd.)

```
//SAMPLE JOB (,F39114),USER=B39114,REGION=3000K,TIME=10,
//          CLASS=W,MSGCLASS=W
//*MAIN ORG=RADS12,PROC=AP,LINES=50
//*FORMAT PR,DDNAME=,DEST=PR0,FLASH=LINE
//*
// EXEC APPROC,PATH='STP034',
//       PRELIB1='B05317.MVS77.MODLIB'
//FT10F001 DD DUMMY
//ISOTXS DD DSN=B39114.TEST.ISOTXS,DISP=(OLD,KEEP)
//RCTDEN2 DD DSN=B39114.TEST.T1E.RCTDEN,UNIT=PERM,DISP=(NEW,CATLG)
//RCTFLX DD DSN=B39114.TEST.T1B.RCTFLX,UNIT=PERM,DISP=(NEW,CATLG)
//RCTFLX2 DD DSN=B39114.TEST.T1E.RCTFLX,UNIT=PERM,DISP=(NEW,CATLG)
//RCTPWD DD DSN=B39114.TEST.T1B.RCTPWD,UNIT=PERM,DISP=(NEW,CATLG)
//RCTPWD2 DD DSN=B39114.TEST.T1E.RCTPWD,UNIT=PERM,DISP=(NEW,CATLG)
//RFILES DD DSN=B39114.TEST.RFILES,DISP=(OLD,KEEP)
//STACK DD DSN=B39114.TEST.STACK,DISP=(OLD,KEEP)
//SYSUDUMP DD DUMMY
//SYSIN DD *
BLOCK=OLD
DATASET=STACK
DATASET=ISOTXS
DATASET=RFILES
BLOCK=STP034
UNFORM=A.RCT

< Input deck as shown in Fig. 4 >

/*
```

Fig. 7. Sample IBM RCT Job

E. Input Error Checking

During the processing of input data, an effort is made to detect user errors. The code issues self-explanatory error messages to assist the user in correcting his input. In general, a fatal error detected will terminate the processing of the input.

The input error checks performed in the various subroutines of the RCT input processor RCT1 are listed in Table VI. Typical errors are those resulting from inconsistency of data in A.RCT, RCTDEN, and REBUS-3. To avoid these errors, the labels of isotopes, assemblies, and materials, and the numbers of special pins and axial burn regions should be mutually consistent in the datasets of RCT and REBUS-3.

TABLE VI. BCD Input Error Checking of RCT

Subroutine	Checks Performed
ARCT0	1. The assembly labels on type 05 cards must not be blank. 2. The ring numbers, position numbers, numbers of burn regions, numbers of fuel pin rings, and pin pitches on type 05 cards must be positive.
ARCT06	1. The assembly labels on type 06 cards must not be blank.
ARCT07	1. The material labels on type 07 cards must not be blank.
ARCT08	1. The material labels on type 08 cards must not be blank.
CHKBCD	1. The isotopes contained in the 3D record of the first version of RCTDEN must be included in the burnup chain of the present burn step. 2. For the assembly of which type 05 card has "1" in cols. 37-42, the nuclide densities should exist in the file RCTDEN. 3. The numbers of axial burn regions given in type 05 cards must match those of the file RCTDEN. 4. The number of axial burn regions of a special pin given in type 08 cards must match that of the assembly containing this pin. 5. If a special pin is contained in the assembly whose nuclide densities come from RCTDEN, the nuclide densities of this pin should be provided through RCTDEN or type 07-08 cards. 6. If there is any assembly for which the type 05 card has "1" in cols. 37-42, the file RCTDEN should exist.
HEXREG	1. The numbers of burn regions of assemblies given in type 05 cards must match those in REBUS-3.
MAIN	1. The BCD input dataset A.RCT and the microscopic cross section dataset ISOTXS must be provided. 2. Two versions of the interface datasets GEODST, ZNATDN, and NHFLUX must be provided.
RCTIP6	1. The assembly labels on type 06 cards must match those on type 05 cards.
RCTIP7	1. The isotope names on type 07 cards must match those of REBUS-3.

TABLE VI. (Contd.)

Subroutine	Checks Performed
RCTIP8	1. The special pin and material labels on type 08 cards must match those of type 06 and 07 cards, respectively.
RCTIP9	1. The assembly labels on type 09 cards must match those on type 05 cards.
RDSTAK	1. In the STACK file, the dataset defined in cols. 7-18 of a type 04 card must begin at the record whose number is specified in cols. 19-24.

F. Output Edits

The user can exercise a fair amount of control over the information printed out during the course of a run by use of the various edit flags on the BCD input datasets. The edit flags on the type 02 card of A.HMG4C control the edits of the COMPXS and the ISOTXS files in the cross section homogenization module HMG4C, as described in Ref. 5. The ISOTXS edit is a running edit of those isotopes referenced in the homogenization. The four edit flags on the type 03 card of A.RCT control the edits of the reconstructed nuclide densities, flux, power, and burnup/fluence. The interpolated fuel pin data and calculated special pin data can be edited along with the interpolation coefficients described below. These edits are performed for each axial burn region of each assembly specified on a type 05 card of A.RCT. Since an assembly is divided into several axial burn regions, the fuel pins in that assembly are divided into corresponding axial intervals, and the edits for each fuel pin are performed over these intervals.

Certain data are always edited. Included in this category are the input data specified on the A.RCT file, the special pin materials and locations, the heavy metal densities, the information about the datasets processed by RDSTAK, the file control information of the ISOTXS and RCTDEN files, the mesh-cell ordering and region assignment of each assembly, the region average nuclide densities, the special pin characteristics, and the computing time and storage

summary for each computational module in RCT. The special pin characteristics include the nuclide densities, power, burnup, total fluence, and fast fluence of each special pin; they are edited by burn region and assembly. The top, axial-average, and bottom values are provided for each pin axial segment.

The edit flags on the type 03 card of A.RCT control the output edits of the interpolation coefficients and the interpolated data at the centers of fuel pins. The interpolation coefficients for the flux consist of the nodal values obtained from the nodal flux file NHFLUX and the corner fluxes interpolated as described in subsection II.A. The nodal values include one node-average flux, eight surface-average fluxes, and eight surface-average net currents. The corner fluxes represent the interpolated average fluxes over the six vertical corner lines of each hexagonal prism. While the interpolation coefficients for the flux thus consist of 23 numbers, those for the other variables are composed of 15 numbers; node-average, surface-average, and corner values. The interpolation coefficients for the nuclide densities and burnup at the end of a burn step are calculated by solving the depletion equations using the node-average, surface-average, and corner fluxes. In these calculations, the average of the beginning and the end of burn step flux values are used as is done in REBUS-3. The coefficients for the total and fast fluence are simply calculated by multiplying the time-step average fluxes by the burn step duration.

For the interpolated characteristics (fluxes, nuclide densities, burnup, and fluence), the axial-average value of each fuel pin is printed along with multiplicative factors for the top and bottom point values. The top and bottom point values of each fuel pin are obtained from the product of the average values and the corresponding multiplicative factors. The interpolated fluxes and nuclide densities are edited by group and by nuclide, respectively. For the power density edit, the top and bottom point values are explicitly provided for each fuel pin in addition to the axial-average values, since the power density is calculated using the interpolated fluxes and nuclide densities. The peak values and peak-to-average ratios of the flux, nuclide densities, power, burnup, and fluences are also provided for each burn region.

In an RCT run, the burnup and fluences are edited in the cumulative sense, and hence the burnup and fluences at the beginning of a burn step must be provided. For the assemblies or

special pins present in RCTDEN, the nonuniform burnup and fluences in a burn region are obtained from RCTDEN, as well as the heavy metal densities used as the burnup denominators. On the other hand, for the assemblies or special pins whose initial compositions are provided through ZNATDN, the burnup and fluences in a burn region are assumed to be initially uniform and are calculated approximately. Specifically, the total and fast fluences are assumed to be initially zero, whereas the burnup is calculated with the assumption that the heavy metal nuclei present at BOL have been destroyed only by fission. In other words, the burnup numerator is approximated by the difference between the heavy metal density at BOL and that at the beginning of the present burn step. The heavy metal density at BOL of an assembly is provided by the type 09 card of A.RCT. If the type 09 card is not provided, the initial heavy metal density is determined from the sum over all fissionable nuclide densities given through ZNATDN.

IV. PROGRAMMING INFORMATION

This section contains a detailed description of the structure and contents of the code RCT. The information provided in this section is intended to assist users who wish to make changes in the source code or who wish to understand the flow of the calculation. The modular structure, the array usage, the interface dataset usage, and the common block usage of RCT are included in the description.

A. RCT Modules

The RCT code system consists of a collection of large independent code blocks logically connected by a small "driver" program STP034. In other words, RCT is designed in a modular environment where each code block, including the driver, is organized as a separate load module. The path driver STP034 is a load module which issues initialization calls to some of the utility routines and executes the application load modules via the utility routine LINKMD.[9] The load modules in the program communicate with each other, and with STP034, by means of interface files; no problem data are passed in-core from one module to another.

The application modules consist of two types of modules; Reactor Analysis production modules and RCT calculational modules. The former includes SCAN, STUFF, and HMG4C obtained from the modular libraries of the Reactor Analysis Division, whereas the latter includes RCT1, RCT2, and RCT3 written specifically for the purpose of the reconstruction calculation. These application modules are briefly described in Table VII in the order they are invoked by the standard path driver. Each of these modules consists of a number of subroutines as listed in Table VIII for modules STP034, RCT1, RCT2, and RCT3. The standardized utility routines described in Ref. 7 are also included in each module so that each module may be independently executable.

TABLE VII. Modules Invoked by the Standard Path Driver STP034

Module	Function
SCAN	Reads the entire card-image input file and spools the card images onto a single file.
STUFF	Processes the input data associated with the data block STP034 and creates the BCD datasets.
RCT1	Processes the BCD dataset A.RCT and the interface files and sets up arrays for modules RCT2 and RCT3.
HMG4C	Generates the macroscopic cross section file COMPXS based on the data contained in CCCC files ISOTXS, NDXSRF, LABELS, and ZNATDN.
RCT2	Processes the files NHFLUX, and COMPXS and sets up flux and macroscopic cross section arrays for RCT3.
RCT3	RCT computational module; reconstructs the flux, nuclide densities, power, burnup, and fluences for each fuel pin of the specified assemblies.

TABLE VIII. Subroutine Functions in RCT Module

Module	Subroutine	Function
STP034	GOTOWS STP034	Links path driver to each application module. Main path driver.
RCT1	ARCT0 ARCT06 ARCT07 ARCT08 ARCT09 CHKBCD COMP4D COMP7D CPYF GETIK HEXREG ISOISO PNAMES RCT1 RCTIP6 RCTIP7 RCTIP8 RCTIP9 RDGEO RDSTAK RDZNA	Reads the type 01-05 cards of dataset A.RCT. Reads the type 06 cards of dataset A.RCT. Reads the type 07 cards of dataset A.RCT. Reads the type 08 cards of dataset A.RCT. Reads the type 09 cards of dataset A.RCT. Checks the consistency of the A.RCT data with the RCTDEN data. Reads the 4D records of the file ISOTXS. Reads the 7D records of the file ISOTXS. Copies a record from the file STACK to a selected file. Determines the x,y-meshes for a particular hexagon. Determines the hexagonal ordering in the file GEODST and the DIF3D nodal option for the assemblies specified on type 05 cards of A.RCT. Reads through the ISOTXS file and picks up the cross sections required for the power construction. Named block data (RCTDTA) for array names in the REBUS-3 BPOINTER. Main driver routine of the module RCT1. Checks the dataset A.RCT type 06 cards. Checks the dataset A.RCT type 07 cards. Checks the dataset A.RCT type 08 cards. Checks the dataset A.RCT type 09 cards. Reads the mesh and burn region data from the file GEODST. Main program to read selected datasets from the STACK file. Reads the region average densities of the active isotopes from the file ZNATDN.
RCT2	RCT2 RCT20 RDCXS RNHFLY	Main driver routine of the module RCT2. The driver routine for reading and processing the files NHFLUX and COMPS. Reads macroscopic cross sections from the file COMPS. Reads the node-average and surface-average fluxes from the file NHFLUX and calculates corner fluxes for each burn region of the assemblies specified in the dataset A.RCT.

TABLE VIII. (Contd.)

Module	Subroutine	Function
RCT3	ASSDEN	Calculates the node-average, surface-average, and corner nuclide densities for a given assembly.
	ASSFLU	Calculates the node-average, surface-average, and corner fluences for a given assembly.
	BOCDEN	Obtains the initial nuclide densities of the assemblies and fuel pins from the data given in the files A.RCT, RCTDEN, and ZNATDN.
	BUNNUM	Calculates the burnup numerator.
	DACON	Generates the transmutation matrices for the depletion calculation.
	DCYMTX	Generates the decay matrix.
	DENDCY	Performs the decay calculations.
	EOCDEN	Writes the final nuclide densities on the 5D and 6D records of the file RCTDEN version 2.
	MESH	Calculates the coordinates for the center of each fuel pin.
	POLY13	Evaluates the 4th order polynomial used in the nuclide density, burnup, and fluence interpolation at fuel pin centers.
	POLY19	Evaluates the 6th order polynomial used in the flux interpolation at fuel pin centers.
	PWPEAK	Searches the peak power in each burn region.
	RCT3	Main driver of the module RCT3.
	RCT30	The driver routine for performing the reconstruction calculations.
	RECONT	Reconstructs the fluxes, nuclide densities, power, burnup, and fluences of each fuel pin by interpolation.
	SPINPW	Calculates the special pin power densities.
	SPNDEN	Calculates the special pin nuclide densities.
	SPNFLU	Calculates the special pin fluences.
	SRPEAK	Searches the peak value of the given variable in each burn region by interpolation.
	TDECAY	Calculates the exponential of the given transmutation matrix.
	WRCTDN	Writes the 1D through 4D records of the file RCTDEN version 2. Calculates and writes the final densities of the assemblies and special pins in the out-of-core storage.
	WRCTFX	Writes the 1D and 2D records of the file RCTFLX.
	WRCTPW	Writes the 1D through 3D records of the file RCTPWD.
	WRFLUX	Writes the 3D and 4D records of the file RCTFLX.
	XPOWER	Writes the 4D and 5D records of the file RCTPWD.

B. RCT Array Usage

The RCT code makes use of the dynamic core storage allocation system provided by the BPOINTER[7] facility. BPOINTER is a collection of subprograms which was developed at ANL to alleviate bookkeeping chores associated with the dynamic storage allocation technique. At the start of each of the RCT modules, the size of the storage (called the container array) required in the module is estimated, and this amount of storage is allocated in the extended core memory (ECM). The use and management of this container array is carried out by calls to the various BPOINTER subroutines or entry points as explained in Ref. 7.

The ECM container array is initialized in the module RCT1 with the BPOINTER arrays of REBUS-3 located in the beginning part of the file RFILES. These arrays are later wiped out except for the arrays described in Table IX, which are used in the depletion calculation. In each module, the dimensions of all arrays needed in the module are determined, and the core storage is reserved for these arrays. In order to minimize the storage requirement, the core storage is generally reserved for a particular dimensioned array only during the time the corresponding data are required to be in-core, and the temporary arrays are maximized and used repeatedly as much as possible. The arrays used only in a particular module are wiped out at the end of the module, but the arrays used in the following modules are stored in the dataset POINTR and transferred to the next module.

TABLE IX. REBUS-3 BPOINTER Arrays Saved in RCT

Array	Pointer	Contents and Comments
AA	IP(36)	An average burn matrix for a time substep.
CSEC	IP(16)	The cross section data for each isotope and reaction type specified.
DECAY	IP(41)	Decay constants for specified decay processes.
F	IP(34)	A matrix defined by $(\exp(AA*t)-I)/(AA*t)$.
FSYLDF	IP(49)	The yield fractions.
HNNAME	IP(120)	The unique nuclide names in the library order.
ISOEQ	IP(119)	The location in the HNNAME array of each active isotope of each material.
ISONAM	IP(61)	The absolute names of the active isotopes.
LAB	IP(40)	An indexing array used in the construction of the burn matrix.
MISO	IP(97)	The location in the CSEC array of each isotope of each material type.
MPATH	IP(1)	The location in the region REGLB6 of each stage of each material type.
MSPOT	IP(17)	An indexing array used in the construction of the burn matrix.
NF	IP(54)	The index in the active isotope list of the isotopes undergoing fission.
NFPS	IP(71)	The index in the active isotope list of the fission products.
NKS	IP(2)	The number of stages in each material type.
NOA	IP(69)	The atomic mass of each active isotope.
NOR	IP(121)	The order number of a nuclide in the nuclide set for given order number in HNNAME array.
NOS	IP(122)	The order number of nuclide in the HNNAME array.
NREC	IP(39)	An indexing array used in the construction of the burn matrix.
NZNR	IP(124)	The zone number assigned to each region.
PLB	IP(96)	An array giving the path labels on the type 11 cards of dataset A.BURN.
REGLB6	IP(62)	The region labels.
W	IP(43)	A temporary array used in the calculation of the exponential of the burn matrix.
Z	IP(35)	A temporary array used in the calculation of the exponential of the burn matrix.

C. Binary Interface Dataset Usage

Communication between the various modules of RCT is accomplished by means of interface datasets. The CCCC interface datasets as well as the datasets pertinent to the RCT code system are used. Table X lists all of the datasets used by the code blocks in RCT. The first and second versions of the datasets in Table X represent the datasets at the beginning and the end of the burn step, respectively, except for RCTDEN whose second version represents the dataset at the end of shutdown time (i.e., at the beginning of next burn step). The file reference numbers are assigned in the SEEK[7] initialization call.

TABLE X. Description of Datasets Used by Code Blocks of RCT

Reference Number	File Name	File Description
11	A.HMG4C	HMG4C control file.
12	A.RCT	Reconstruction options and parameters.
13	ARC	BCD input data spool.
14	BRN	FLT and INT arrays of REBUS-3.
15	COMPXS	Macroscopic cross sections, version 1.
16	COMPXS	Macroscopic cross sections, version 2.
17	GEODST	Geometry description, version 1.
18	GEODST	Geometry description, version 2.
19	ISOTXS	Microscopic cross sections.
20	LABELS	Region and composition labels, half heights.
21	NDXSRF	Nuclide/zone reference.
22	NHFLUX	Nodal flux-moments and currents, version 1.
23	NHFLUX	Nodal flux-moments and currents, version 2.
24	POINTR	BPOINTER data.
25	RCT	RCT floating point and integer quantities.
26	RCTDEN	Nonuniform nuclide density file, version 1.
27	RCTDEN	Nonuniform nuclide density file, version 2.
28	RCTFLX	Nonuniform multigroup flux file, version 1.
29	RCTFLX	Nonuniform multigroup flux file, version 2.
30	RCTPWD	Nonuniform power density file, version 1.
31	RCTPWD	Nonuniform power density file, version 2.
32	RFILES	REBUS-3 restart file.
33	STACK	REBUS-3 STACK file.
34	ZNATDN	Zone nuclide densities, version 1
35	ZNATDN	Zone nuclide densities, version 2
46-51	SCR001-6	Scratch files.

The interface datasets accessed by a given module are summarized in Table XI. SCAN and STUFF process the card image input and write the BCD disk files, and HMG4C produces the file COMPXS using the interface files (LABELS, NDXSRF, ZNATDN, and ISOTXS) and the BCD disk file A.HMG4C. RCT1 processes RFILES and CCCC interface files and writes the data required for the ensuing calculations on the datasets POINTR. If the STACK file is provided, the CCCC interface files are retrieved from STACK. The files NHFLUX and COMPXS are processed, and the flux and power conversion data are added to the file POINTR and RCT in the module RCT2. RCT3 calculates the burnup characteristics using the data on the files POINTR, RCT, and the version 1 of RCTDEN, and later writes them on the version 2 of RCTDEN. In these modules, the file BRN is restored from the file RFILES to obtain the arrays FLT and INT.

TABLE XI. Interface File Usage by RCT

Module	Input Files	Output Files
SCAN	BLOCK=OLD and BLOCK=dsname (BCD card image input)	ARCBOD (BCD input data spool)
STUFF	BLOCK=STP034	A.RCT, A.HMG4C
RCT1	A.RCT, RFILES, ISOTXS, STACK, ZNATDN, GEODST, NHFLUX, LABELS, NDXSRF, RCTDEN	POINTR, BRN, RCT, ISOTXS, ZNATDN, GEODST, NHFLUX, LABELS, NDXSRF, RCTDEN
HMG4C	A.HMG4C, LABELS, NDXSRF, ZNATDN, ISOTXS	COMPXS
RCT2	POINTR, NHFLUX, COMPXS, RCT, BRN	POINTR, RCT
RCT3	POINTR, RCT, RCTDEN, BRN	POINTR, RCT, RCTDEN, RCTPWD, RCTFLX

D. RCT Common Block Usage

The common blocks used in the RCT modules consist of two types. The first type is the common blocks required by the utility subroutines[7] such as IOPUT, PTITLE, LOCATE, STFARC, and ARRAY. The second type is the blocks containing the various floating and integer quantities used throughout the code. There are two major common blocks of this type;

/SINGLE/ FLT(150),INT(150)

/COMRCT/ IRCT(40),FRCT(10)

The first block SINGLE is a REBUS-3 common block used to store key floating point and integer variables. The contents of this block are contained in the binary interface dataset BRN which is written on the first record of the file RFILES. The file BRN is restored from RFILES, and the variables of this block (described in Ref. 6) are retrieved in the modules of RCT.

The second block COMRCT contains two arrays, the floating point array FRCT dimensioned 10 and the integer array IRCT dimensioned 40. These arrays contain the various floating point and integer variables pertinent to the RCT code system as described in Table XII. The contents of this common block are contained in the binary interface file RCT which is written by the module RCT1 and read by the modules RCT2 and RCT3. The variables in IRCT and FRCT, which are not listed in Table XII, are reserved for future use.

TABLE XII. Contents of Arrays in RCT Common Block COMRCT

Name	Local Name	Definition and Comments
IRCT(1)	NEED	Bulk core container array length required by the module RCT1.
IRCT(2)	ICCCC	Interface dataset flag, 0.....STACK file, 1.....individual CCCC and ARC files.
IRCT(3)	NHEX	Number of assemblies for which reconstruction is to be performed.
IRCT(4)	NTOTN	Total number of burn regions.
IRCT(5)	MAXZ	Maximum number of axial burn regions of the assemblies specified on type 05 cards of A.RCT.
IRCT(6)	MAXSP	Maximum number of special pins in an assembly.
IRCT(7)	NPIN	Maximum number of fuel pins in an assembly.
IRCT(8)	NUMSP	Total number of special pins.
IRCT(9)	NUMAT	Number of special material types given by type 08 cards of A.RCT.
IRCT(11)	IEDTN	Nuclide density edit flag, 0.....no edit, 1.....print edits.
IRCT(12)	IEDTF	Flux edit flag, 0.....no edit, 1.....print edits.
IRCT(13)	IEDTP	Power density edit flag, 0.....no edit, 1.....print edits.
IRCT(14)	IEDTB	Burnup and fluence edit flag, 0.....no edit, 1.....print edits.
IRCT(15)	ISCHI	Prompt fission spectrum flag. ISCHI=0 if there is no set-wide prompt chi. ISCHI=1 if there is a set-wide prompt chi vector. ISCHI=NGROUP if there is a set-wide prompt chi matrix.
IRCT(16)	MAXUP	Maximum number of groups of upscattering.
IRCT(17)	MAXDN	Maximum number of groups of downscattering.
IRCT(18)	NSURF	Number of XY-plane surfaces per node.
IRCT(19)	NINTXY	Number of mesh cells (nodes) on XY-plane.
IRCT(20)	NPCXY	Number of XY-directed partial currents in the XY-plane.
IRCT(21)	NMOM	Number of flux moments in nodal approximation.
IRCT(22)	NSCOEF	Number of unknowns per node surface, 1.....nodal diffusion theory, 2.....nodal transport theory, isotropic transverse leakage, 3.....nodal transport theory, P1 transverse leakage.
IRCT(23)	NINTK	Number of third dimension fine mesh intervals.
IRCT(24)	NASEM	Number of assemblies in RCTDEN.
IRCT(25)	NATI	Number of active isotopes in RCTDEN.
IRCT(26)	NTSPN	Total number of special pins in RCTDEN.

TABLE XII. (Contd.)

Name	Local Name	Definition and Comments
IRCT(27)	NEWAS	Number of assemblies which are specified on type 05 cards of A.RCT, but not in RCTDEN.
IRCT(28)	NEWSP	Number of special pins which are specified on type 06 cards of A.RCT, but not in RCTDEN.
IRCT(29)	MAXZR	Maximum number of axial burn regions of the assemblies in RCTDEN.
IRCT(30)	MXABR	Maximum number of axial burn regions of assemblies (maximum of MAXZ and MAXZR).
IRCT(31)	NFST	The energy group in which the fast flux threshold energy is located.
FRCT(1)	FTF	Flat-to-flat distance (cm) of a hexagon.
FRCT(2)	TDOWN	Shutdown time in days for refueling between burn steps.
FRCT(3)	EFTHS	The fast flux threshold energy (eV).
FRCT(4)	FFST	The logarithmic fraction of the energy in group NFST less than EFTHS.

V. POSTPROCESSOR OF RCTDEN AND RCTPWD

The code RCT performs the reconstruction calculations and writes the pin burnup characteristics on the datasets RCTDEN, RCTPWD, and RCTFLX. The hex-plane distributions of the fluxes, nuclide densities, power density, burnup, and fluences are interpolated at the center of each fuel pin, and they are calculated explicitly for the special pins. However, the axial distributions cannot be calculated and edited for each axial point, and hence only the interpolation coefficients are calculated and stored in these datasets. Therefore, a small program has been developed in order to perform the axial interpolation for the specified axial positions of specified fuel pins. Although the axial interpolation for these specified positions could have been included in the code RCT, a separate program named RCTP has been created in order to avoid increasing the complexity of RCT and to give more flexibility to the user. This section provides the information about the function and structure, the input data, and the sample problems of the code RCTP.

A. Postprocessor RCTP

The program RCTP has been developed as a postprocessor of the density file RCTDEN and the power density file RCTPWD written by RCT. It is designed to process several files in a single run. For each of RCTDEN and RCTPWD, up to nine files can be processed at a time. For each of the fuel pins specified in the BCD input file A.RCTP, this program obtains the nuclide densities, burnup, and fluences and the power density from the RCTDEN files and the RCTPWD files, respectively, and performs the axial interpolation for each of these variables. The axial interpolation is performed for each of the axial positions or intervals specified by the user. The average value over the interval is calculated for an axial interval, while the point value is evaluated for an axial position.

Since a fuel pin is included in an assembly which is divided into several axial burn regions, the fuel pin is divided into corresponding axial intervals, and the interpolation is performed in each of these intervals. For each of these intervals, three values (the average over the interval, the values at the bottom and top points of the interval) are obtained for each of the

nuclide densities, burnup, fluences, and power density from RCTDEN or RCTPWD. The nuclide densities, burnup, and fluence are read from the 6D records of RCTDEN if the fuel pin exists as a special pin in RCTDEN; otherwise, they are interpolated by the fourth order polynomial using the assembly data given in the 5D records of RCTDEN. On the other hand, both the regular and the special pin power densities are read from the 4D and the 5D records of RCTPWD, respectively. Using the top, bottom, and average values of each distribution, the nuclide densities, burnup, fluences and power density are interpolated using quadratic polynomials. The values of these variables at the specified axial positions or their average values over the specified axial intervals can thus be determined for the specified fuel pins.

The program RCTP is designed to run in a stand-alone format, in contrast with RCT which has been implemented in the modular form. In this format, the entire program is organized as a single load module, and the code blocks used as modules in a modular system become subroutines. The code blocks SCAN and STUFF used to process the BCD card-image input are, therefore, executed in RCTP via Fortran CALLs instead of the utility routine LINKMD. These code blocks as well as the standard utility routines[7] have been extracted from the stand-alone version libraries. The program RCTP consists of a small driver and a number of subroutines listed in Table XIII with a brief description as to the function of each. The driver routine issues initialization calls to some of the utility routines and executes the subroutines including SCAN and STUFF similar to the driver module STP034 of RCT.

TABLE XIII. Subroutine Functions in RCTP

Subroutine	Function
ARCTP0	Reads the type 01-02 cards of dataset A.RCTP.
ARCT03	Reads the type 03 cards of dataset A.RCTP.
ARCT04	Reads the type 04 cards of dataset A.RCTP.
ARCT05	Reads the type 05 cards of dataset A.RCTP.
AXDEN	Performs the axial interpolation for nuclide densities, burnup, and fluences.
AXPWD	Performs the axial interpolation for power density.
MESH	Calculates the coordinates for the center of each fuel pin.
POLY13	Calculates the fourth order polynomial used in the nuclide density, burnup, and fluence interpolation.
RCTP	The main path driver routine.
RCTP1	The driver routine for the axial interpolation of nuclide densities, burnup, and fluences.
RCTP2	The driver routine for the axial interpolation of power density.
RCTPI2	Checks the dataset A.RCTP type 02 cards.
RCTPI3	Checks the dataset A.RCTP type 03 cards.
RCTPI4	Checks the dataset A.RCTP type 04 cards.
RCTPI5	Checks the dataset A.RCTP type 05 cards.
RCTPP	The driver routine for the calculational routines.
RDPWD1	Reads 1D-3D records of the file RCTPWD.
RDPWD2	Reads the regular and special pin power densities, from the file RCTPWD.
RDRCT1	Reads 1D-4D records of the file RCTDEN.
RDRCT2	Reads the assembly and special pin nuclide densities, burnup, and fluences from the file RCTPWD.

B. Input Data

The input data for RCTP consist of the binary interface files RCTDEN and RCTPWD and the BCD card-image file A.RCTP. As in the case of RCT, RCTP uses standard ANL conventions regarding the structure of the input data. Hence, the input datasets are separated into two blocks, BLOCK=OLD and BLOCK=RCTP, as shown in Fig. 8. The existing datasets RCTDEN and RCTPWD are provided in the first block, and the BCD input A.RCTP is provided in the second block by UNIFORM=A.RCTP or DATASET=A.RCTP depending on the input format. Since the files RCTDEN and RCTPWD were described in the earlier sections, only the BCD input A.RCTP is discussed in this subsection.

The dataset A.RCTP, described in detail in Appendix F, is the dataset used to specify the axial interpolation specifications. This dataset consists of type 01 through 05 cards. The type 01 cards provide the problem title composed of any alphanumeric characters. The type 02 cards provide the specification of assemblies in which fuel pins are to be analyzed. These specifications include the assembly label, the numbers of axial burn regions and fuel pin rings, the fuel pin pitch, and the flat-to-flat distance across the assembly. The type 03 cards specify the axial boundaries for each burn region, and type 04 cards specify the locations in an assembly of each fuel pin for which nuclide densities, burnup, and fluences are to be interpolated from the assembly data. For the special pins contained in the 4D record of RCTDEN, the data on the type 04 cards are not required and are ignored.

The specifications of the axial interpolation are provided by the type 05 cards. This type 05 card contains the pin label and the lower and upper axial positions of each interval for which the axial interpolation is to be performed. The axial positions are supplied as a fraction of the total pin length as determined from the sum over all the axial burn region heights. The fuel pin label on the type 05 cards must be consistent with those on the type 04 cards or the 4D record of RCTDEN. Moreover, if the upper axial position of an interval is positive, it must be greater than the lower position of the interval. In this case, the average values over the interval specified by the lower and upper positions are interpolated. If the upper position is negative or zero, the interpolation is performed at the point of the lower position.

```

BLOCK=OLD
DATASET=RCTDEN, 1
DATASET=RCTDEN, 2
DATASET=RCTDEN, 3
DATASET=RCTPWD, 1
DATASET=RCTPWD, 2
BLOCK=RCTP
UNFORM=A.RCTP
01      TEST CASE (HXZNEQN)
02      IB0402      5      4 3.07920E+00 1.60000E+01
02      CD0603      5      4 3.07920E+00 1.60000E+01
02      RB0703      4      4 3.07920E+00 1.60000E+01
03      IB0402      1 5.50000E+01 7.50000E+01      2 7.50000E+01 9.50000E+01
03      IB0402      3 9.50000E+01 1.15000E+02      4 1.15000E+02 1.35000E+02
03      IB0402      5 1.35000E+02 1.55000E+02
03      CD0603      1 5.50000E+01 7.50000E+01      2 7.50000E+01 9.50000E+01
03      CD0603      3 9.50000E+01 1.15000E+02      4 1.15000E+02 1.35000E+02
03      CD0603      5 1.35000E+02 1.55000E+02
03      RB0703      1 5.50000E+01 7.50000E+01      2 7.50000E+01 9.50000E+01
03      RB0703      3 9.50000E+01 1.15000E+02      4 1.15000E+02 1.35000E+02
04      IB0402 I4P12      3      5
04      CD0603 C6P06      2      5
04      RB0703 R7P18      3      11
05      I4P07      0.0      0.0      1.0      0.0
05      I4P07      0.0      2.0000E-01 4.0000E-01 6.0000E-01
05      I4P12      0.0      0.0      1.0      1.0
05      I4P12      0.0      2.0000E-01 4.0000E-01 6.0000E-01
05      I4P19      0.0      2.0000E-01
05      C6P06      2.0000E-01 0.0      4.0000E-01 0.0
05      C6P06      2.0000E-01 4.0000E-01 6.0000E-01 8.0000E-01
05      C6P13      2.0000E-01 0.0      1.0      0.0
05      C6P13      4.0000E-01 6.0000E-01 6.0000E-01 8.0000E-01
05      C6P25      4.0000E-01 4.0000E-01 1.0      1.0
05      C6P25      2.0000E-01 4.0000E-01 6.0000E-01 8.0000E-01
05      R7P18      0.0      1.0      2.5000E-01 5.0000E-01
05      R7P18      2.5000E-01 0.0      7.5000E-01 1.0
05      R7P31      0.0      2.5000E-01 5.0000E-01 0.0
05      R7P31      5.0000E-01 7.5000E-01 7.5000E-01 1.0

```

Fig. 8. Sample RCTP Input Deck

C. Sample RCTP Jobs

As in the case of RCT, RCTP is operational on the Sun SparcStation and the IBM RS/6000 workstation of the RA Network as well as the IBM 3033 and Cray X-MP computers. Figure 9 shows a sample job-script for executing RCTP on the RA Network using RASHELL shell variables and scripts. While the script XRCT is used in the execution of RCT, the executable code of RCTP, *rctp.x*, is extracted from the test library */home/salt3/b39114/lib/\$ARCH* in this job. As mentioned above, for each of RCTDEN and RCTPWD, up to nine versions of files can be processed in a single run. When multiple versions of a dataset are provided, the individual versions are identified by suffixing the version number to the dataset name (except for the first version). In the example shown in Fig. 9, three RCTDEN and two RCTPWD files are processed at the same time. The file *input* contains the BCD input data as shown in Fig. 8.

Figures 10 and 11 show the job-scripts and the job control statements required to run the problem in Fig. 8 on the Cray X-MP and the IBM 3033, respectively. In the Cray example, the Cray-format datasets RCTDEN and RCTPWD are brought from the IBM disk to the Cray by the STAGEIN commands. As in the case of the job on the RA Network, the compiled RCTP is directly extracted from the library */n1/b39114/sa_module*, and the individual versions of a dataset are identified by suffixing the version number to the dataset name. In the IBM job, the characteristics of the datasets used during the execution of RCTP are explicitly specified in the JCL instead of using a catalogued procedure. The RCTP loadmodule *B39114.RCT.POST* is provided for the *STEPLIB DD* card. The RCTDEN files are provided on logical unit numbers 12 through 20, while the RCTPWD files are provided on logical unit numbers 21 through 29. The input and output files are contained in logical unit numbers 5 and 6, respectively. The DD cards FT09F001 and FT11F001 are devoted to the BCD input data spool ARCBCD and the RCTP input dataset A.RCTP, respectively, and FT10F001 is reserved for the auxiliary output.

```
#!/bin/sh
set -vx
#
RAJOBNAME=test2
RABANNER=test2
RABADGE=39114
RADEST=3800
RADEST2=FICHE
RAHOST=
RAROUTE=CWD
RAMEM=6
RATIME=10
RADATASIZE=35
RAINPUT=input
RAOUTPUT=output
RAFICHETITLE1=" $RABANNER"
. RASHELL

#
#   include the test library
#
PREPATH /home/salt3/b39114/lib/$ARCH
#
#   copy input datasets
#
cp $HOME/RCT/test2/c1e/RCTDEN      RCTDEN
cp $HOME/RCT/test2/c2e/RCTDEN      RCTDEN2
cp $HOME/RCT/test2/c2e/RCTDEN      RCTDEN3
cp $HOME/RCT/test2/c1b/RCTPWD      RCTPWD
cp $HOME/RCT/test2/c1e/RCTPWD2     RCTPWD2
cp $HOME/RCT/test2/rctp.input      input
#
#   execute RCTP
#
rctp.x < input > output
IFBOMB
```

Fig. 9. Sample RASHELL Script for Executing RCTP


```
//SAMPLE JOB MSGCLASS=Z,REGION=400K,CLASS=C
//*MAIN ORG=PRO,PROC=AP
// EXEC CRAY
//SYSUT1 DD *
# user=
#
# QSUB -r SAMPLE
# QSUB -lT 10
# QSUB -lM 1000Kw
# QSUB -eo
# QSUB -q u
# QSUB
set -vxs
APOUTPUT=output
APDEST=PRO,FLASH=LINE
APBANNER=rctpst
APFETCH=YES
APLINES=40000
APPREPATH=/n1/b21006/debug_apshell
. APSHELL
# *****
# STAGEIN RCTDEN AND RCTPWD FILES, UP TO NINE FILES FOR EACH
# *****
STAGEIN CRAYBINARY RCTDEN B39114.TEST2.C1E.RCTDEN
STAGEIN CRAYBINARY RCTDEN2 B39114.TEST2.C2E.RCTDEN
STAGEIN CRAYBINARY RCTDEN3 B39114.TEST2.C3E.RCTDEN
STAGEIN CRAYBINARY RCTPWD B39114.TEST2.C1B.RCTPWD
STAGEIN CRAYBINARY RCTPWD2 B39114.TEST2.C1E.RCTPWD
RCTP=/n1/b39114/sa_module
IFBOMB
cat > input <<\EOF

< Input deck as shown in Fig. 8 >

EOF
$RCTP < input >> output
debug -s $RCTP
/*
```

Fig. 10. Sample Cray RCTP Job

```
//IBMPST JOB (,F39114),USER=B39114,REGION=1000K,TIME=30,  
//      CLASS=W,MSGCLASS=W  
//*MAIN ORG=RADS12,PROC=AP,LINES=50  
//*FORMAT PR,DDNAME=,DEST=PR0,FLASH=LINE  
//*  
//*   B39114.IBMPST  
//*  
// EXEC PGM=MAIN  
//STEPLIB DD DSN=B39114.RCT.POST,DISP=SHR  
//FT05F001 DD DDNAME=SYSIN  
//FT06F001 DD DCB=(RECFM=FBA,LRECL=133,BLKSIZE=133),SYSOUT=W  
//FT09F001 DD UNIT=SASCR,SPACE=(CYL,(1,1)),  
//      DCB=(RECFM=VBS,LRECL=84,BLKSIZE=3064)  
//FT10F001 DD DUMMY  
//FT11F001 DD DSN= &&ARCTP,UNIT=SASCR,SPACE=(TRK,(2,2),RLSE),  
//      DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200)  
//FT12F001 DD DSN=B39114.TEST2.C1E.RCTDEN,DISP=(OLD,KEEP)  
//FT13F001 DD DSN=B39114.TEST2.C2E.RCTDEN,DISP=(OLD,KEEP)  
//FT14F001 DD DSN=B39114.TEST2.C3E.RCTDEN,DISP=(OLD,KEEP)  
//FT21F001 DD DSN=B39114.TEST2.C1B.RCTPWD,DISP=(OLD,KEEP)  
//FT22F001 DD DSN=B39114.TEST2.C1E.RCTPWD,DISP=(OLD,KEEP)  
//SYSUDUMP DD DUMMY  
//SYSIN DD *
```

< Input deck as shown in Fig. 8 >

/*

Fig. 11. Sample IBM RCTP Job

VI. CODE VERIFICATION

Benchmark calculations have been performed for three reactor models representing 450 and 900 MWt LMR's and the Experimental Breeder Reactor (EBR-II). Static and depletion calculations for these reactors have been performed in two and three dimensions to test the accuracy of the RCT reconstruction schemes and to determine the error contributions attributable to the following:

1. Errors in the information provided by the DIF3D nodal scheme relative to a higher-order scheme (taken here to be the spatially converged diffusion theory result).
2. Various approximations in the RCT reconstruction procedure, specifically the corner flux determination, the intranodal polynomial representations, and the assumption of axial and planar separability of the intranodal distributions.

In order to identify the individual error sources, these approximations were introduced separately. The errors in the polynomial interpolation for hex-plane distributions were estimated by performing two-dimensional reconstruction calculations using the node-average, surface-average, and corner fluxes obtained from a higher-order reference solution. By replacing the reference corner fluxes by the values interpolated with the reference node and surface-average fluxes, the errors due to the corner flux interpolation were determined. The errors in the nodal solution were identified using the node-average, surface-average, and corner values obtained from the nodal solution. The assumption of axial and planar separability of the intranodal distributions was tested by performing three-dimensional reconstruction using a coarse-mesh reference solution, which is obtained by collapsing the fine-mesh reference solution over coarser axial meshes.

Since these test calculations were focused on the verification of the RCT reconstruction schemes, the reference solutions were obtained by performing nine-group diffusion calculations (rather than performing transport calculations). The triangular-z finite-difference option of DIF3D and REBUS-3 was used in these calculations with very fine triangular and axial meshes. In order to test the validity of the overall nodal diffusion and reconstruction methods, calculated values

of fuel pin burnup and heavy metal isotopics have also been compared with experimentally measured values for IFR experimental assemblies irradiated in EBR-II.[17] However, it should be emphasized that these pin burnup and heavy metal isotopics comparisons represent aggregate tests of the nuclear data, the core representation, the full-core diffusion/depletion model, and the reconstruction techniques.

A. Static Problems

Since the pinwise nuclide densities, power density, burnup, and fluence are calculated using the reconstructed neutron flux, errors in the reconstructed flux distribution were first considered. Static 2-D and 3-D benchmark calculations were performed in order to test the accuracy of the reconstructed flux and to determine the individual error sources.

The nodal and reconstruction schemes were first applied to 2-D (midplane) BOC representations of the 450 and 900 MWt LMR's shown in Figs. 12 and 13, respectively. Results were compared to spatially converged finite-difference diffusion (FDD) reference solutions obtained using 864 triangular mesh points in each hexagon (864 tri/hex). The maximum error in reconstructed power density was found to be less than 2% for driver assemblies and about 5% for blanket assemblies. The components of this error attributable to the nodal information, the corner flux calculation, and the planar flux interpolation were found to be less than 3%, 2%, and 1%, respectively. The reconstructed group fluxes showed similar errors except for the high-energy fluxes (group 1 and 2 in the nine-group model). The high-energy fluxes showed relatively high errors, especially near the core periphery, mainly due to the errors in the nodal solution and the corner flux interpolation.

RCT reconstruction results have also been obtained for a 3-D BOC model of the 450 MWt LMR, and for the simplified 3-D BOC representation of the EBR-II core (see Fig. 14). For the 450 MWt LMR (lattice pitch=16 cm), the FDD reference solution was calculated using 150 tri/hex and a 4-cm axial mesh in the active core zone; the nodal solution was obtained using a 20-cm axial mesh. Maximum errors in the reconstructed power densities for driver, internal blanket (IB), and radial blanket (RB) assemblies were 3%, 6%, and 10%, respectively. The

Fig. 12. Planar Layout of 450 MWt LMR Core

Fig. 13. Planar Layout of 900 MWt LMR Core

Fig. 14. Simplified Planar Layout of the EBR-II Core

largest contribution to these errors is made by the nodal solution errors, followed by the assumption of flux separability into hex-planar and axial distributions; the planar reconstruction scheme contributes less than 1% to the error. The maximum (net) errors are lower by a factor of ~ 2 if the regions adjacent to the top and bottom of the core, where the power density is low, are not considered. In these regions, the separability assumption is less valid and contributes a significant portion of the net error; the separability error can be reduced by use of a smaller axial nodal mesh width for the top and bottom core nodes. The error in the peak local power in each assembly is significantly lower than the maximum power error; peak powers are predicted to within 1.5% for driver assemblies and 4% for blanket assemblies.

For the simplified EBR-II 3-D model (lattice pitch=5.91 cm, active core height=34 cm), the FDD reference solution was determined using 54 tri/hex and a 2.9-cm axial mesh. The nodal solution was calculated using an axial mesh size of 11.4 cm. The reconstructed power densities agreed with the reference values to within 3% for all assemblies, with the error being largest adjacent to the core top and bottom, primarily as a result of the separability approximation. The RCT planar interpolation scheme and the nodal information are very accurate in this case, primarily because of the relatively small lattice pitch.

B. Depletion Problems

Benchmark calculations have also been performed for depletion problems in order to test the accuracy of the reconstructed burnup characteristics. The RCT reconstruction techniques have been applied to the three dimensional depletion analyses of the 450 MWt and EBR-II cores. For the 450 MWt core, the benchmark calculations were performed for both a single burnup cycle problem and a multicycle problem, and the results were compared to those of the fine-mesh (triangular-z) FDD reference solutions obtained by REBUS-3. On the other hand, for the EBR-II core, a multicycle analysis had to be performed, and local burnup and fuel isotopics predictions were compared to experimentally measured values.

The single-cycle analysis of the 450 MWt core was performed starting with the BOC configuration of an equilibrium cycle and with a cycle length of 474.5 days. The reference solution was obtained by the FDD method (using 54 tri/hex and a 4-cm axial mesh) and a "radial point depletion" model with the same radial (triangular) depletion mesh as the flux solution, but a coarser (20 cm) axial depletion mesh. The nodal solution was obtained by the block depletion of each hexagonal node using a 20-cm axial mesh. Table XIV exhibits the maximum errors (at core midplane) in the reconstructed BOC and EOC power densities and in the reconstructed EOC nuclide densities for three assemblies (driver, IB, and RB assemblies located as shown in Table XIV); the driver and RB assemblies are located in high flux-gradient positions near the core periphery where the reconstruction errors are known to be greatest. Note that the maximum error in the EOC nuclide densities is 1.65% (for ^{242}Pu in the RB assembly), indicating that pinwise nuclide masses can be accurately predicted for irradiated pins in the vicinity of the core midplane.

TABLE XIV. Maximum Errors in Reconstructed Midplane Power and Nuclide Densities for the Three-dimensional Single-cycle Problem of the 450-MW (Thermal) Core

Quantity		Driver (6,3) ^a (Error in %)	Internal Blanket (4,2) (Error in %)	Radial Blanket (7,3) (Error in %)
Power densities	BOC	1.09	-2.72	4.36
	EOC	0.79	-1.23	2.93
EOC nuclide densities	^{235}U	-0.14	0.06	-0.02
	^{238}U	-0.02	0.05	-0.02
	^{239}Pu	-0.11	0.19	0.03
	^{240}Pu	-0.07	0.50	-1.01
	^{241}Pu	-0.07	0.56	-1.29
	^{242}Pu	-0.04	0.46	-1.65

^a(Ring number, hexagon number); see Ref. 5 or 10 for a description of the numbering convention

A three-cycle depletion analysis has also been performed for the 450 MWt core; the initial core configuration represented a BOL core consisting of unirradiated driver and blanket assemblies. The cycle length was 474.5 days, and the refueling time was 73 days. Features of this calculation included blanket assembly shuffling, driver and blanket assembly rotation, control rod

movement, and transition from a BOL loading to a representative equilibrium mix of fresh and depleted assemblies. The FDD reference fluxes for this problem were obtained using 54 tri/hex and a 4-cm axial mesh, as in the case of the single-cycle problem. The reference depletion calculation again employed a "radial point depletion" option with the same radial (triangular) depletion mesh as the flux solution, but a coarser (20 cm) axial depletion mesh. The nodal solution was obtained by block depletion for each of the hexagonal prism nodes using a 20-cm axial mesh.

Table XV exhibits the maximum errors in the reconstructed BOC power densities for three test assemblies, which are initially located in the same core positions as the assemblies considered in the single-cycle problem (see Table XVI for the shuffling and rotation of these assemblies). Errors in reconstructed power densities for the driver assembly are seen to be less than 2% at any point in time. Local power density errors in blanket assemblies are less than 6%, except at BOL (prior to Pu buildup), where the error is as large as 10% because of difficulties with accurate prediction of the high-energy fluxes and because of the large power fraction attributable to (threshold) ^{238}U fission in the absence of Pu. These errors in blanket assemblies become smaller with increasing exposure and by cycle-3 are similar to the errors of the equilibrium single-cycle problem previously described; the decrease of error is attributable to the increased power level due to Pu buildup and to the increased power contribution from Pu fission.

The maximum errors in the reconstructed EOC nuclide densities are shown in Table XVII. The reconstruction errors are less than 1% for all nuclides in the driver assembly, as well as ^{235}U and ^{238}U in blanket assemblies. For blanket assemblies, the reconstruction errors for Pu isotopes are seen to be largest ($\sim 25\%$ for ^{242}Pu) in the first cycle and generally become smaller as depletion goes on. These large (relative) errors are caused mainly by the small densities and by the accumulation of the errors attributable to misprediction of the densities of the parent isotopes. For example, in assembly 3, the ^{239}Pu density is ~ 150 times smaller than ^{238}U density at the end of cycle 1 (EOC1). Since $\sim 90\%$ of ^{238}U undergoes the capture reaction, the underprediction of the ^{238}U density (i.e., overprediction of the transmutation rate during the cycle) by 0.03% results

TABLE XV. Maximum Errors in Reconstructed BOC Power Densities for the Three-dimensional Three-cycle Problem of the 450-MW (Thermal) Core

Assembly Number	Axial Region	Cycle 1 (Error in %)	Cycle 2 (Error in %)	Cycle 3 (Error in %)
1	1	-1.08	-1.14	-1.32
	2	1.00	1.05	-1.09
	3	1.24	1.06	-1.02
	4	1.45	1.42	0.95
	5	1.39	1.52	1.18
2	1	-9.58	-4.06	-1.77
	2	-8.86	-2.63	1.99
	3	-8.00	-2.68	2.13
	4	-8.09	-2.80	2.70
	5	-8.57	-3.79	3.56
3	1	-6.64	3.07	-3.83
	2	6.65	4.07	2.90
	3	6.95	4.10	3.20
	4	7.12	4.84	3.20
	5	6.97	5.25	3.80

TABLE XVI. Shuffling and Rotation of Test Assemblies for the Three-dimensional Three-cycle Problem of the 450-MW (Thermal) Core

Assembly		Location ^a (Rotation ^b)		
Number	Type	Cycle 1	Cycle 2	Cycle 3
1	Driver	6,3 (0)	6,3 (120)	6,3 (240)
2	Blanket	4,2 (0)	4,2 (0)	7,3 (180)
3	Blanket	7,3 (0)	7,3 (0)	4,2 (180)

^aRing number, hexagon number

^bCounterclockwise notation in degree

in ~ 4 % overprediction of ^{239}Pu even if the flux is known exactly. However, this error is reduced to 3.46% because of compensating errors in the reconstructed fluxes. The large errors in the other Pu isotopes can be interpreted in a similar way. On the other hand, the significant reduction of the reconstruction errors for Pu isotopes in assembly 3 (initially located in a radial blanket position) at EOC3 is mainly due to the increase in isotope densities. Because of the shuffling at EOC2, assembly 3 resides in an internal blanket position during the third cycle. Therefore, the Pu production is increased due to the higher flux level, and the relative errors are reduced. For example, the maximum relative error for ^{242}Pu in assembly 3 is reduced to 10.59% at EOC3 from 24.88% at EOC2 due to the increase of density from $(4.70 \text{ to } 6.83) \times 10^{14}$ atoms/cm³, even though the absolute error is increased from $(1.17 \text{ to } 7.24) \times 10^{14}$ atoms/cm³.

The nodal diffusion, depletion, and reconstruction techniques have also been applied to multicycle depletion analyses of experimental assemblies irradiated in EBR-II core.[17] Fuel pin burnups and heavy metal isotopics were computed at several different axial positions and compared with experimentally measured results. Detailed discussions and results of these validation tests of RCT methodologies for EBR-II core analysis can be found in Ref. 17, where it is demonstrated that RCT calculated values agree with the measured values to within combined experimental uncertainties.

TABLE XVII. Maximum Errors in Reconstructed EOC Nuclide Densities for the Three-dimensional Three-cycle Problem of the 450-MW (Thermal) Core

Isotope	Cycle Number	Assembly 1 (Error in %)	Assembly 2 (Error in %)	Assembly 3 (Error in %)
^{235}U	1	0.15	0.27	-0.40
	2	0.20	0.51	-0.81
	3	0.27	0.51	-0.77
^{238}U	1	-0.02	0.04	-0.03
	2	-0.04	0.06	-0.06
	3	-0.06	0.08	-0.07
^{239}Pu	1	-0.12	-0.98	3.46
	2	-0.18	-0.85	3.28
	3	-0.25	0.81	1.37
^{240}Pu	1	-0.12	-2.84	10.40
	2	-0.22	2.79	10.14
	3	-0.31	2.77	4.09
^{241}Pu	1	-0.19	4.31	18.42
	2	-0.32	4.46	17.94
	3	-0.39	4.06	7.07
^{242}Pu	1	-0.09	5.70	25.27
	2	-0.17	5.92	24.88
	3	-0.24	4.95	10.59

VII. SUMMARY

Techniques have been developed and implemented in a computer code, RCT, for reconstruction of LMR pin burnup characteristics from fuel cycle calculations performed using the nodal hexagonal option of the DIF3D/REBUS-3 code system. Intranodal distributions of group fluxes, nuclide densities, power density, burnup, and fluence are efficiently computed using polynomial shapes constrained to satisfy nodal information. In order to test the accuracy of the reconstruction schemes, several benchmark tests have been performed. Initial applications of these techniques have also been made to the analysis of experimental assemblies in EBR-II, enabling preliminary comparisons of predicted and measured local burnup characteristics.

The test results indicate that the reconstruction schemes are quite accurate, yielding maximum errors in power densities and nuclide densities that are less than 2% for driver assemblies and less than 5% for blanket assemblies except for the lower and upper regions where errors are somewhat larger. The calculated and measured values for local fuel pin burnups and isotopics in IFR test assemblies irradiated in EBR-II have been shown in Ref. 17 to agree to within the combined experimental uncertainties. These pin burnup and isotopics comparisons represent aggregate tests of the nuclear data, the core representation, the burn chain model, the full-core diffusion/depletion method, and the reconstruction techniques. Hence these results should be interpreted as being indicative of the predictive capability of the overall analysis approach.

In general, the largest contribution to the reconstruction error (relative to reference finite difference diffusion and point depletion calculational results) is made by the nodal solution errors, followed by the assumption of axial and planar separability of the intranodal distributions, and the corner flux interpolation approximations; the errors due to the planar and axial polynomial expansions are relatively small. Based on these observations, the following are suggested for future work to improve the accuracy of the reconstruction schemes:

1. Improvement of the nodal solution accuracy (possibly by implementation of nodal equivalence theory employing discontinuity factors[18]),

2. Elimination of the separability assumption by performing nonseparable three-dimensional interpolation instead of the synthesis of the interpolated 2-D planar and 1-D axial distributions, and
3. Improvement of the corner flux interpolation, either by employing functions other than biquadratic polynomials for the approximation of the flux in the nodes adjacent to a corner point, or by adopting other types of interpolation schemes.[3]

ACKNOWLEDGMENTS

The author wishes to acknowledge the technical advice received from H. Khalil as well as his help in performing three-cycle depletion analysis and reviewing this document. The author is also grateful to P. J. Finck for providing the static benchmark analysis, to K. L. Derstine for providing consultation and assistance with the RCT code development, and to T. A. Taiwo for reviewing this document.

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APPENDIX A

RCT CODE-DEPENDENT BINARY INTERFACE FILE RCTDEN

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C*****
C              REVISED 9/29/89 AT ANL
C
CF              RCTDEN
CE              RECONSTRUCTED NUCLIDE DENSITIES
C
C*****

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C-----
CS              FILE STRUCTURE
CS
CS              RECORD TYPE              RECORD      PRESENT IF
CS              =====              =====
CS              FILE IDENTIFICATION      ALWAYS
CS              SPECIFICATIONS            1D          ALWAYS
CS              ASSEMBLY DATA            2D          ALWAYS
CS              ISOTOPE DATA              3D          ALWAYS
CS              SPECIAL PIN DATA          4D          NUMSP.GT.0
CS
CS      ***** (REPEATED FOR ALL ASSEMBLIES)
CS      *          INTERPOLATION COEFFICIENTS      5D          ALWAYS
CS      *          SPECIAL PIN NUCLIDE DENSITIES    6D          NSPN.GT.0
CS      *****
C
C-----

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C-----
CR              FILE IDENTIFICATION
C
CL              HNAME, (HUSE(I), I=1,2), IVERS
C
CW              1+3*MULT=NUMBER OF WORDS
C
CD              HNAME              HOLLERITH FILE NAME - RCTDEN - (A6)
CD              HUSE(I)            HOLLERITH USER IDENTIFICATION (A6)
CD              IVERS              FILE VERSION NUMBER
CD              MULT                DOUBLE PRECISION PARAMETER
CD              1- A6 WORD IS SINGLE WORD
CD              2- A6 WORD IS DOUBLE PRECISION WORD
C
C-----

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C-----
CR              SPECIFICATIONS      (1D RECORD)
C
CL              NASEM, NACI, NUMSP, NSURF, MXABR, IDUM(2)
C
CW              7 = NUMBER OF WORDS
C
CD              NASEM              NUMBER OF ASSEMBLIES
CD              NACI                NUMBER OF ACTIVE ISOTOPES
CD              NUMSP              TOTAL NUMBER OF SPECIAL PINS
CD              NSURF              NUMBER OF XY-PLANE SURFACES OF ASSEMBLY
CD              MXABR              MAXIMUM AXIAL BURN REGION NUMBER

```

CD IDUM RESERVED FOR FUTURE USE

C

C-----

C-----

CR ASSEMBLY DATA (2D RECORD)

C

CL (HASNM(I), I=1, NASEM), (NZBRG(I), I=1, NASEM), (NSPIN(I), I=1, NASEM)

C

CW NASEM*MULT+2*NASEM = NUMBER OF WORDS

C

CD HASNM(I) HOLLERITH ASSEMBLY LABEL FOR ASSEMBLY I (A6)

CD NZBRG(I) NUMBER OF AXIAL BURN REGIONS IN REBUS-3

CD MODEL OF ASSEMBLY I

CD NSPIN(I) NUMBER OF SPECIAL PINS OF ASSEMBLY I

C

C-----

C-----

CR ISOTOPE DATA (3D RECORD)

C

CL (HISNM(I), I=1, NACI)

C

CW NACI*MULT = NUMBER OF WORDS

C

CD HISNM(I) HOLLERITH ISOTOPE LABEL FOR ISOTOPE I (A6)

C

C-----

C-----

CR SPECIAL PIN DATA (4D RECORD)

C

CL (HSPNM(I), I=1, NUMSP)

C

CW NUMSP*MULT = NUMBER OF WORDS

C

CD HSPNM(I) HOLLERITH PIN LABEL FOR SPECIAL PIN I (A6)

CD NUMSP TOTAL NUMBER OF SPECIAL PINS (SUMMATION OF

CD THE VALUES OF NSPIN ARRAY)

C

C-----

C-----

CR INTERPOLATION COEFFICIENTS (5D RECORD)

C

CL (HMBLA(K), K=1, NAZ), (BUN(K), K=1, NAZ),

CL 1((BUNC(J, K), J=1, NSURF), K=1, NAZ), ((BUNS(J, K), J=1, NSURF2), K=1, NAZ),

CL 2(FLU(K), K=1, NAZ), ((FLUC(J, K), J=1, NSURF), K=1, NAZ),

CL 3((FLUS(J, K), J=1, NSURF2), K=1, NAZ), ((FFL(K), K=1, NAZ),

CL 4((FFLC(J, K), J=1, NSURF), K=1, NAZ), ((FFLS(J, K), J=1, NSURF2), K=1, NAZ),

CL 5(DEN(I, K), I=1, NACI), K=1, NAZ),

CL 6(((DENC(I, J, K), I=1, NACI), J=1, NSURF), K=1, NAZ),

CL 7(((DENS(I, J, K), I=1, NACI), J=1, NSURF2), K=1, NAZ)

C

CW ((NACI+3)*(2*NSURF+3)+1)*NAZ*MULT = NUMBER OF WORDS

C

CD HMBLA(K) INITIAL HEAVY METAL DENSITY (ATOMS/BARN*CM)

CD FOR THE K-TH AXIAL BURN REGION OF THE PRESENT

CD ASSEMBLY

CD BUN(K) NODE AVERAGE BURNUP (ATOM FRACTION) FOR THE

```

CD      K-TH AXIAL BURN REGION OF THE PRESENT ASSEMBLY -
CD      BUNC(J,K)    CORNER LINE AVERAGE BURNUP OF CORNER J FOR THE -
CD      K-TH AXIAL BURN REGION OF THE PRESENT ASSEMBLY -
CD      BUNS(J,K)    SURFACE AVERAGE BURNUP OF SURFACE J FOR THE -
CD      K-TH AXIAL BURN REGION OF THE PRESENT ASSEMBLY -
CD      FLU(K)        NODE AVERAGE TOTAL FLUENCE (NEUTRON/CM**2) FOR -
CD      THE K-TH AXIAL BURN REGION OF THE PRESENT -
CD      ASSEMBLY -
CD      FLUC(J,K)    CORNER LINE AVERAGE TOTAL FLUENCE OF CORNER J -
CD      FOR THE K-TH AXIAL BURN REGION OF THE PRESENT -
CD      ASSEMBLY -
CD      FLUS(J,K)    SURFACE AVERAGE TOTAL FLUENCE OF SURFACE J -
CD      FOR THE K-TH AXIAL BURN REGION OF THE PRESENT -
CD      ASSEMBLY -
CD      FFL(K)        NODE AVERAGE FAST FLUENCE (NEUTRON/CM**2) FOR -
CD      THE K-TH AXIAL BURN REGION OF THE PRESENT -
CD      ASSEMBLY -
CD      FFLC(J,K)    CORNER LINE AVERAGE FAST FLUENCE OF CORNER J -
CD      FOR THE K-TH AXIAL BURN REGION OF THE PRESENT -
CD      ASSEMBLY -
CD      FFLS(J,K)    SURFACE AVERAGE FAST FLUENCE OF SURFACE J FOR -
CD      THE K-TH AXIAL BURN REGION OF THE PRESENT -
CD      ASSEMBLY -
CD      DEN(I,K)      NODE AVERAGE NUCLIDE DENSITY FOR THE K-TH -
CD      AXIAL BURN REGION OF THE PRESENT ASSEMBLY -
CD      (ATOMS/BARN*CM) -
CD      DENC(I,J,K)   CORNER LINE AVERAGE NUCLIDE DENSITY OF CORNER -
CD      J FOR THE K-TH AXIAL BURN REGION OF THE -
CD      PRESENT ASSEMBLY -
CD      DENS(I,J,K)   SURFACE AVERAGE NUCLIDE DENSITY OF SURFACE J -
CD      FOR THE K-TH AXIAL BURN REGION OF THE PRESENT -
CD      ASSEMBLY -
CD      NAZ           NUMBER OF AXIAL BURN REGION IN REBUS-3 MODEL -
CD      (NZBRG ARRAY VALUE) FOR THE PRESENT ASSEMBLY -
CD      NSURF2        = NSURF+2 -
C -
C -----

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C -----
CR      SPECIAL PIN NUCLIDE DENSITIES    (6D RECORD) -
C -
CL      (HMBLS(K),K=1,NAZ), (SPBNB(K),K=1,NAZ), (SPBN(K),K=1,NAZ), -
CL      1(SPBNT(K),K=1,NAZ), (SPFLB(K),K=1,NAZ), (SPFL(K),K=1,NAZ), -
CL      2(SPFLT(K),K=1,NAZ), (SPFFB(K),K=1,NAZ), (SPFF(K),K=1,NAZ), -
CL      3(SPFFT(K),K=1,NAZ), ((SPDNB(I,K),I=1,NACI),K=1,NAZ), -
CL      4((SPDN(I,K),I=1,NACI),K=1,NAZ), ((SPDNT(I,K),I=1,NACI),K=1,NAZ) -
C -
CW      (3*(NACI+3)+1)*NAZ*MULT = NUMBER OF WORDS -
C -
C      DO 1 L=1,NSPN -
C      1 READ(N) *LIST AS ABOVE* -
C -
CD      HMBLS(K)      INITIAL HEAVY METAL DENSITY (ATOMS/BARN*CM) -
CD      OF THE K-TH AXIAL BURN REGION OF THE PRESENT -
CD      SPECIAL PIN -
CD      SPBNB(K)      BOTTOM POINT BURNUP (ATOM FRACTION) OF THE K-TH -
CD      AXIAL BURN REGION OF THE PRESENT SPECIAL PIN -
CD      SPBN(K)       Z-DIRECTIONAL AVERAGE BURNUP OF THE K-TH -
CD      AXIAL BURN REGION OF THE PRESENT SPECIAL PIN -
CD      SPBNT(K)      TOP POINT BURNUP OF THE K-TH AXIAL BURN -
CD      REGION OF THE PRESENT SPECIAL PIN -
CD      SPFLB(K)      BOTTOM POINT TOTAL FLUENCE (NEUTRON/CM**2) -
CD      OF THE K-TH AXIAL BURN REGION OF THE PRESENT -

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CD		SPECIAL PIN	-
CD	SPFL(K)	Z-DIRECTIONAL AVERAGE TOTAL FLUENCE FOR THE	-
CD		K-TH AXIAL BURN REGION OF THE PRESENT SPECIAL	-
CD		PIN	-
CD	SPFLT(K)	TOP POINT TOTAL FLUENCE OF THE K-TH AXIAL BURN	-
CD		REGION OF THE PRESENT SPECIAL PIN	-
CD	SPFFB(K)	BOTTOM POINT FAST FLUENCE (NEUTRON/CM**2)	-
CD		OF THE K-TH AXIAL BURN REGION OF THE PRESENT	-
CD		SPECIAL PIN	-
CD	SPFF(K)	Z-DIRECTIONAL AVERAGE FAST FLUENCE FOR THE	-
CD		K-TH AXIAL BURN REGION OF THE PRESENT SPECIAL	-
CD		PIN	-
CD	SPFLT(K)	TOP POINT FAST FLUENCE OF THE K-TH AXIAL BURN	-
CD		REGION OF THE PRESENT SPECIAL PIN	-
CD	SPDNB(I,K)	BOTTOM POINT NUCLIDE DENSITY OF THE K-TH	-
CD		AXIAL BURN REGION OF THE PRESENT SPECIAL PIN	-
CD		(ATOMS/BARN*CM)	-
CD	SPDN(I,K)	Z-DIRECTIONAL AVERAGE NUCLIDE DENSITY OF	-
CD		THE K-TH AXIAL BURN REGION OF THE PRESENT	-
CD		SPECIAL PIN	-
CD	SPDNT(I,K)	TOP POINT NUCLIDE DENSITY OF THE K-TH AXIAL	-
CD		BURN REGION OF THE PRESENT SPECIAL PIN	-
CD	NSPN	NUMBER OF SPECIAL PIN (NSPIN ARRAY VALUE)	-
CD		FOR THE PRESENT ASSEMBLY	-
C			-
C			-

APPENDIX B

RCT CODE-DEPENDENT BINARY INTERFACE FILE RCTPWD

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C*****
C              REVISED 6/26/90 AT ANL
C
CF              RCTPWD
CE              RECONSTRUCTED POWER DENSITY
C
C*****

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C-----
CS              FILE STRUCTURE
CS
CS              RECORD TYPE              RECORD      PRESENT IF
CS              =====              =====
CS              FILE IDENTIFICATION      ALWAYS
CS              SPECIFICATIONS            1D          ALWAYS
CS              ASSEMBLY DATA            2D          ALWAYS
CS              SPECIAL PIN DATA          3D          NUMSP.GT.0
CS
CS      ***** (REPEATED FOR ALL ASSEMBLIES)
CS      *          REGULAR PIN POWER DENSITIES  4D          ALWAYS
CS      *          SPECIAL PIN POWER DENSITIES  5D          NSPN.GT.0
CS      *****
C
C-----

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C-----
CR              FILE IDENTIFICATION
C
CL      HNAME, (HUSE(I), I=1, 2), IVERS
C
CW      1+3*MULT=NUMBER OF WORDS
C
CD      HNAME          HOLLERITH FILE NAME - RCTDEN - (A6)
CD      HUSE(I)         HOLLERITH USER IDENTIFICATION (A6)
CD      IVERS          FILE VERSION NUMBER
CD      MULT            DOUBLE PRECISION PARAMETER
CD                      1- A6 WORD IS SINGLE WORD
CD                      2- A6 WORD IS DOUBLE PRECISION WORD
C
C-----

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C-----
CR              SPECIFICATIONS      (1D RECORD)
C
CL      NASEM, MNPIN, NUMSP, MXABR, IDUM(3)
C
CW      7 = NUMBER OF WORDS
C
CD      NASEM          NUMBER OF ASSEMBLIES
CD      MNPIN          MAXIMUM NUMBER OF FUEL PINS IN AN ASSEMBLY
CD      NUMSP          TOTAL NUMBER OF SPECIAL PINS
CD      MXABR          MAXIMUM AXIAL BURN REGION NUMBER
CD      IDUM           RESERVED FOR FUTURE USE
C

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C-----
C
CR      ASSEMBLY DATA      (2D RECORD)
C
CL      (HASNM(I), I=1, NASEM), (NPINR(I), I=1, NASEM), (NZBRG(I), I=1, NASEM)
CL      1, (NSPIN(I), I=1, NASEM)
C
CW      NASEM*MULT+3*NASEM = NUMBER OF WORDS
C
CD      HASNM(I)            HOLLERITH ASSEMBLY LABEL FOR ASSEMBLY I (A6)
CD      NPINR(I)            NUMBER OF FUEL PIN RINGS IN ASSEMBLY I
CD      NZBRG(I)            NUMBER OF AXIAL BURN REGIONS IN REBUS-3
CD      MODEL OF ASSEMBLY I
CD      NSPIN(I)            NUMBER OF SPECIAL PINS OF ASSEMBLY I
C-----

```

```

C-----
C
CR      SPECIAL PIN DATA   (3D RECORD)
C
CL      (HSPNM(I), I=1, NUMSP)
C
CW      NUMSP*MULT = NUMBER OF WORDS
C
CD      HSPNM(I)            HOLLERITH PIN LABEL FOR SPECIAL PIN I (A6)
CD      NUMSP                TOTAL NUMBER OF SPECIAL PINS (SUMMATION OF
CD                          THE VALUES OF NSPIN ARRAY)
C-----

```

```

C-----
C
CR      REGULAR PIN POWER DENSITIES   (4D RECORD)
C
CL      (((RPWD(I, L, K), I=1, 3), L=1, NPIN), K=1, NAZ)
C
CW      3*NPIN*NAZ*MULT = NUMBER OF WORDS
C
CD      RPWD(1, L, K)        BOTTOM POINT POWER DENSITY (W/CM**3) OF PIN L
CD                          FOR THE K-TH AXIAL BURN REGION OF THE PRESENT
CD                          ASSEMBLY
CD      RPWD(2, L, K)        Z-DIRECTIONAL AVERAGE POWER DENSITY OF PIN L
CD                          FOR THE K-TH AXIAL BURN REGION OF THE PRESENT
CD                          ASSEMBLY
CD      RPWD(3, L, K)        TOP POINT POWER DENSITY OF PIN L FOR THE K-TH
CD                          AXIAL BURN REGION OF THE PRESENT ASSEMBLY
CD      NPIN                  NUMBER OF FUEL PINS IN THE PRESENT ASSEMBLY
CD                          (NPIN=3*NR*(NR-1)+1, WHERE NR IS THE NUMBER
CD                          OF FUEL PIN RINGS GIVEN THROUGH NPINR ARRAY)
CD      NAZ                    NUMBER OF AXIAL BURN REGION IN REBUS-3 MODEL
CD                          (NZBRG ARRAY VALUE) OF THE PRESENT ASSEMBLY
C-----

```

```

C-----
C
CR      SPECIAL PIN POWER DENSITIES   (5D RECORD)
C
CL      (((SPWD(I, L, K), I=1, 3), L=1, NSPN), K=1, NAZ)
C
CW      3*NSPN*NAZ*MULT = NUMBER OF WORDS

```

C			-
CD	SPWD(1,L,K)	BOTTOM POINT POWER DENSITY OF SPECIAL PIN L	-
CD		FOR THE K-TH AXIAL BURN REGION OF THE PRESENT	-
CD		ASSEMBLY	-
CD	SPWD(2,L,K)	Z-DIRECTIONAL AVERAGE POWER DENSITY OF SPECIAL	-
CD		PIN L FOR THE K-TH AXIAL BURN REGION OF THE	-
CD		PRESENT ASSEMBLY	-
CD	SPWD(3,L,K)	TOP POINT POWER DENSITY OF SPECIAL PIN L FOR	-
CD		THE K-TH AXIAL BURN REGION OF THE PRESENT	-
CD		ASSEMBLY	-
CD	NSPN	NUMBER OF SPECIAL PIN (NSPIN ARRAY VALUE)	-
CD		FOR THE PRESENT ASSEMBLY	-
C			-
C			-

APPENDIX C

RCT CODE-DEPENDENT BINARY INTERFACE FILE RCTFLX

```

C*****
C          REVISED 1/29/91 AT ANL
C
CF          RCTFLX
CE          RECONSTRUCTED NEUTRON FLUXES
C
C*****

C-----
CS          FILE STRUCTURE
CS
CS          RECORD TYPE          RECORD    PRESENT IF
CS          =====
CS          FILE IDENTIFICATION  ALWAYS
CS          SPECIFICATIONS        1D        ALWAYS
CS          ASSEMBLY DATA        2D        ALWAYS
CS
CS          ***** (REPEATED FOR ALL ASSEMBLIES)
CS          *
CS          * ***** (REPEATED FOR ALL AXIAL BURN REGIONS)
CS          * *   AVERAGE PIN FLUXES          3D        ALWAYS
CS          * *   BOTTOM AND TOP POINT FACTORS  4D        ALWAYS
CS          * *****
CS          *
CS          *****
C
C-----

C-----
CR          FILE IDENTIFICATION
C
CL          HNAME, (HUSE(I), I=1,2), IVERS
C
CW          1+3*MULT=NUMBER OF WORDS
C
CD          HNAME          HOLLERITH FILE NAME - RCTFLX - (A6)
CD          HUSE(I)        HOLLERITH USER IDENTIFICATION (A6)
CD          IVERS          FILE VERSION NUMBER
CD          MULT           DOUBLE PRECISION PARAMETER
CD                          1- A6 WORD IS SINGLE WORD
CD                          2- A6 WORD IS DOUBLE PRECISION WORD
C
C-----

C-----
CR          SPECIFICATIONS      (1D RECORD)
C
CL          NASEM, MNPIN, MXABR, NGROUP, IDUM(3)
C
CW          7 = NUMBER OF WORDS
C
CD          NASEM          NUMBER OF ASSEMBLIES
CD          MNPIN          MAXIMUM NUMBER OF FUEL PINS IN AN ASSEMBLY
CD          MXABR          MAXIMUM AXIAL BURN REGION NUMBER
CD          NGROUP        NUMBER OF ENERGY GROUPS
CD          IDUM           RESERVED FOR FUTURE USE
C
C-----

```

```

CR          ASSEMBLY DATA      (2D RECORD)
C
CL          (HASNM(I), I=1, NASEM), (NPINR(I), I=1, NASEM), (NZBRG(I), I=1, NASEM)
C
CW          NASEM*MULT+2*NASEM = NUMBER OF WORDS
C
CD          HASNM(I)              HOLLERITH ASSEMBLY LABEL FOR ASSEMBLY I (A6)
CD          NPINR(I)              NUMBER OF FUEL PIN RINGS IN ASSEMBLY I
CD          NZBRG(I)              NUMBER OF AXIAL BURN REGIONS IN REBUS-3
CD          MODEL OF ASSEMBLY I
C
C-----

```

```

-----
CR          AVERAGE PIN FLUXES (3D RECORD)
C
CL          ((RFLX(I,J),I=1,NGROUP),J=1,NPIN)
C
CW          NGROUP*NPIN*MULT = NUMBER OF WORDS
C
CD          RFLX(I,J)          Z-DIRECTIONAL AVERAGE FLUX OF PIN J
CD          FOR ENERGY GROUP I IN THE PRESENT ASSEMBLY
CD          AND PRESENT AXIAL BURN REGION
CD          NPIN              NUMBER OF FUEL PINS IN THE PRESENT ASSEMBLY
CD          (NPIN=3*NR*(NR-1)+1, WHERE NR IS THE NUMBER
CD          OF FUEL PIN RINGS GIVEN THROUGH NPINR ARRAY)
C
C-----

```

```

-----
C          BOTTOM AND TOP POINT FACTORS (4D)
C
CL      (BFACT(I), I=1,NGROUP), (TFACT(I), I=1,NGROUP)
C
CW      2*NGROUP*MULT = NUMBER OF WORDS
C
CD      BFACT(I)          BFACT(I)*RFLX(I,J) IS THE BOTTOM POINT FLUX
CD                        FOR ENERGY GROUP I AND PIN J WHERE RFLX IS THE
CD                        AVERAGE FLUX GIVEN IN THE 3D RECORD
CD      TFACT(I)          TFACT(I)*RFLX(I,J) IS THE TOP POINT FLUX
CD                        FOR ENERGY GROUP I AND PIN J WHERE RFLX IS THE
CD                        AVERAGE FLUX GIVEN IN THE 3D RECORD
C
C
-----

```

APPENDIX D

RCT CODE-DEPENDENT BCD INPUT FILE A.RCT

```

C*****
C
C          REVISED 5/21/91 AT ANL
C
CF          A.RCT (INPUT TO RECONSTRUCTION OF NUCLIDE DENSITY)
C
CE          THIS DATA SET CAN BE INPUT EITHER IN FREE-FORMAT
CE          STYLE (UNFORM=) OR FORMATTED (DATASET=).
C
C*****
C
C-----
CR          PROBLEM TITLE (TYPE 01)
C
CL          FORMAT----- (I2,4X,11A6)
C
CD          COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD          =====
CD          1-2          01
CD
CD          7-72          ANY ALPHANUMERIC CHARACTERS.
C
CN          ANY NUMBER OF TYPE 01 CARDS MAY BE USED.
C
C-----
C
CR          PROBLEM OPTIONS AND PARAMETERS (TYPE 02)
C
CL          FORMAT----- (I2,4X,I6,2E12.5)
C
CD          COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD          =====
CD          1-2          02
CD
CD          7-12          INTERFACE DATASET SENTINEL
CD                          0...IF THERE EXIST DATASETS PROVIDED THROUGH
CD                          THE REBUS-3 STACK FILE
CD                          1...IF ALL INTERFACE DATASETS ARE PROVIDED
CD                          IN INDIVIDUAL FILES
CD
CD          13-24          REFUELING TIME (DAYS)
CD
CD          25-36          FAST FLUX ENERGY THRESHOLD (EV)
C
CN          RCT REQUIRES THE FOLLOWING TEN INTERFACE DATASETS
CN          WRITTEN BY REBUS-3 TO BE INPUT:
CN
CN          RFILES
CN          ISOTXS
CN          NDXSRF
CN          LABELS
CN          GEODST AT THE BEGINNING OF BURN STEP
CN          GEODST AT THE END OF BURN STEP
CN          NHFLUX AT THE BEGINNING OF BURN STEP
CN          NHFLUX AT THE END OF BURN STEP
CN          ZNATDN AT THE BEGINNING OF BURN STEP
CN          ZNATDN AT THE END OF BURN STEP

```

CN
CN AMONG THESE DATASETS, NDXSRF, LABELS, GEODST, NHFLUX,
CN AND ZNATDN ARE WRITTEN ON THE STACK FILE DURING THE
CN REBUS-3 RUN AND CAN BE PROVIDED FOR RCT AS A GROUP
CN THROUGH THE STACK FILE OR INDIVIDUALLY.
CN
CN IF THERE EXIST DATASETS PROVIDED THROUGH THE STACK
CN FILE, COLS. 7-12 MUST BE 0 AND THE STACK FILE HAS
CN TO BE INPUT. FOR THE DATASETS TO BE READ FROM THE
CN STACK FILE, THEIR RECORD NUMBERS IN THE STACK FILE
CN HAVE TO BE PROVIDED IN TYPE 04 CARDS.
CN
CN IF THE INITIAL NUCLIDE DENSITIES ARE NONUNIFORM IN
CN A BURN REGION (AS A RESULT OF PREVIOUS BURNUP),
CN THE NUCLIDE DENSITY FILE RCTDEN WRITTEN BY A PREVIOUS
CN RCT RUN IS ALSO REQUIRED TO BE INPUT.
CN
CN IF COLS. 13-24 IS LESS THAN 0, THE REFUELING TIME
CN IS OBTAINED FROM FILE RFILES.
CN
CN IF COLS. 25-36 IS LESS THAN 0, 0.1E+06 EV WILL BE
CN USED FOR THE FAST FLUX ENERGY THRESHOLD.
C

C-----
C

CR EDIT OPTIONS (TYPE 03)
C
CL FORMAT----- (I2,4X,4I6)
C
CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
CD =====
CD 1-2 03
CD
CD 7-12 0...NO EDIT OF NUCLIDE DENSITIES (DEFAULT)
CD 1...EDIT OF NUCLIDE DENSITIES
CD
CD 13-18 0...NO EDIT OF FLUX (DEFAULT)
CD 1...EDIT OF FLUX
CD
CD 19-24 0...NO EDIT OF POWER (DEFAULT)
CD 1...EDIT OF POWER
CD
CD 25-30 0...NO EDIT OF BURNUP (DEFAULT)
CD 1...EDIT OF BURNUP
C

C-----
C

CR FILES TO BE READ FROM THE STACK FILE (04)
C
CL FORMAT----- (I2,4X,A6,2I6)
C
CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
CD =====
CD 1-2 04
CD
CD 7-12 DATASET NAME FOR A FILE ON THE STACK FILE
CD
CD 13-18 DATASET VERSION NUMBER FOR THE FILE
CD
CD 19-24 RECORD OF THE STACK FILE WHERE THE FILE DEFINED BY
CD THE NAME AND VERSION NUMBER IN COLS. 7-18 BEGINS
C

CN EIGHT FILES CAN BE READ FROM REBUS-3 STACK FILE AS
CN THE EXAMPLE SHOWN BELOW.

CN	04	NDXSRF	1	13
CN	04	LABELS	1	1106
CN	04	GEODST	1	1094
CN	04	GEODST	2	2208
CN	04	ZNATDN	1	1072
CN	04	ZNATDN	2	2186
CN	04	NHFLUX	1	1110
CN	04	NHFLUX	2	2224

CN VERSION 1 OF NHFLUX, ZNATDN, AND GEODST CORRESPONDS
CN TO THE FILES OF THE BEGINNING OF TIME STEP, AND
CN VERSION 2 CORRESPONDS TO THE FILES OF THE END OF TIME
CN STEP.

CN THE RECORD NUMBER OF DATASET IN REBUS-3 STACK FILE
CN HAS TO BE FOUND FROM REBUS-3 OUTPUT WRITTEN BY COPYDS.

CN THE DATASETS CAN BE APPEAR IN ANY ORDER.

C
C-----
C

CR SPECIFICATION OF ASSEMBLIES FOR WHICH
CR RECONSTRUCTION IS TO BE PERFORMED (05)

C
CL FORMAT----- (I2,4X,A6,6I6,E12.5)

C	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY
CD	=====	=====
CD	1-2	05
CD	7-12	UNIQUE ASSEMBLY LABEL
CD	13-18	RING NUMBER OF ASSEMBLY
CD	19-24	POSITION NUMBER OF ASSEMBLY IN RING
CD	25-30	NUMBER OF AXIAL BURN REGIONS IN REBUS-3 MODEL FOR THIS ASSEMBLY
CD	31-36	COUNTER-CLOCKWISE ROTATION OF ASSEMBLY IN INTEGER MULTIPLE OF 60 DEGREES (0,1,...,5)
CD	37-42	INITIAL NUCLIDE DENSITY SENTINEL 0...UNIFORM NUCLIDE DENSITY FROM ZNATDN (DEFAULT) 1...NON-UNIFORM NUCLIDE DENSITY FROM INTERFACE FILE RCTDEN
CD	43-48	TOTAL NUMBER OF FUEL PIN RINGS IN THIS ASSEMBLY
CD	49-60	FUEL PIN PITCH IN THIS ASSEMBLY (CM)

CN THE NUMBERING CONVENTION OF HEXAGON (COLS. 13-24)
CN IS THE SAME AS USED IN THE TYPE 30 CARDS OF A.NIP3.

C
C-----
C

CR SPECIAL PIN SPECIFICATION (06)

C
CL FORMAT----- (I2,4X,A6,3(A6,2I6))

C	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY
CD	=====	=====
CD	1-2	06
CD	7-12	ASSEMBLY LABEL (REPEATED ON ADDITIONAL TYPE 06 CARDS)
CD	13-18	UNIQUE PIN LABEL
CD	19-24	RING NUMBER OF PIN
CD	25-30	POSITION NUMBER OF PIN IN RING
CD	31-36	UNIQUE PIN LABEL
CD	37-42	RING NUMBER OF PIN
CD	43-48	POSITION NUMBER OF PIN IN RING
CD	49-54	UNIQUE PIN LABEL
CD	55-60	RING NUMBER OF PIN
CD	61-66	POSITION NUMBER OF PIN IN RING

THE FINAL NUCLIDE DENSITIES OF SPECIAL PINS SPECIFIED IN THIS CARD WILL BE CALCULATED BY POINT DEPLETION INSTEAD OF INTERPOLATION.

THE INITIAL NUCLIDE DENSITIES OF SPECIAL PINS CAN BE PROVIDED THROUGH TYPE 07-08 CARDS, FILE RCTDEN, OR FILE ZNATDN. IF INITIAL DENSITIES ARE NOT PROVIDED THROUGH TYPE 07-08 CARDS, THEY ARE OBTAINED THROUGH RCTDEN OR ZNATDN ACCORDING TO THE EXISTENCE OF THE SPECIAL PIN IN FILE RCTDEN.

THE FIGURE BELOW ILLUSTRATES THE NUMBERING CONVENTION OF FUEL PIN RINGS AND POSITIONS IN FUEL PIN RINGS.

```

C
C-----
C
C-----
CR      SPECIAL PIN MATERIAL SPECIFICATION (07)
C
CL      FORMAT----- (I2,4X,A6,3(A6,E12.5))
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====          =====
CD      1-2              07
CD
CD      7-12            MATERIAL LABEL (REPEATED ON ADDITIONAL TYPE 07 CARDS)
CD
CD      13-18           ACTIVE ISOTOPE LABEL
CD
CD      19-30           ISOTOPE ATOM DENSITY (ATOMS/CC * 1.E-24)
CD
CD      31-36           ACTIVE ISOTOPE LABEL
CD
CD      37-48           ISOTOPE ATOM DENSITY (ATOMS/CC * 1.E-24)
CD
CD      49-54           ACTIVE ISOTOPE LABEL
CD
CD      55-66           ISOTOPE ATOM DENSITY (ATOMS/CC * 1.E-24)
C
CN      AN ACTIVE ISOTOPE LABEL IS A LABEL FROM COLS. 7-12
CN      OF THE TRANSMUTATION CHAIN SPECIFIED ON TYPE 09 CARDS
CN      OF A BURN IN REBUS-3 BCD INPUT CARDS.
C
C-----
C
C-----

```

```

CR      ASSIGNMENT OF SPECIAL PIN TO MATERIAL (08)
C
CL      FORMAT----- (I2,4X,A6,3(A6,2I6))
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====          =====
CD      1-2              08
CD
CD      7-12            MATERIAL LABEL (REPEATED ON ADDITIONAL TYPE 08 CARDS)
CD
CD      13-18           SPECIAL PIN LABEL
CD
CD      19-24           STARTING AXIAL BURN REGION NUMBER
CD
CD      25-30           FINAL AXIAL BURN REGION NUMBER
CD
CD      31-36           SPECIAL PIN LABEL
CD
CD      37-42           STARTING AXIAL BURN REGION NUMBER
CD
CD      43-48           FINAL AXIAL BURN REGION NUMBER
CD
CD      49-54           SPECIAL PIN LABEL
CD
CD      55-60           STARTING AXIAL BURN REGION NUMBER
CD
CD      61-66           FINAL AXIAL BURN REGION NUMBER
C
CN      IF THE STARTING AXIAL BURN REGION NUMBER IS BLANK
CN      OR ZERO, THE MATERIAL LABEL IS ASSIGNED TO ALL
CN      AXIAL BURN REGIONS OF THE SPECIAL PIN.

```

```

CN
CN      IF THE FINAL AXIAL BURN REGION NUMBER IS BLANK OR
CN      ZERO, THE MATERIAL LABEL IS ASSIGNED TO THE STARTING
CN      AXIAL BURN REGION OF THE SPECIAL PIN.
C
C-----
C
C-----
CR      INITIAL HEAVY METAL DENSITIES OF ASSEMBLIES (09)
C
CL      FORMAT----- (I2,4X,2(A6,2I6,E12.5))
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====
CD      1-2              09
CD
CD      7-12             ASSEMBLY LABEL
CD
CD      13-18            STARTING AXIAL BURN REGION NUMBER
CD
CD      19-24            FINAL AXIAL BURN REGION NUMBER
CD
CD      25-36            INITIAL HEAVY METAL DENSITY (ATOMS/BARN*CM)
CD
CD      37-42            ASSEMBLY LABEL
CD
CD      43-48            STARTING AXIAL BURN REGION NUMBER
CD
CD      49-54            FINAL AXIAL BURN REGION NUMBER
CD
CD      55-66            INITIAL HEAVY METAL DENSITY (ATOMS/BARN*CM)
C
CN      THE HEAVY METAL DENSITY IS USED FOR THE BURNUP EDIT,
CN      AND IT IS DEFINED AS THE SUM OVER ALL FISSIONABLE
CN      ATOMS INITIALLY PRESENT. IF THE HEAVY METAL DENSITY
CN      IS NOT PROVIDED THROUGH THIS TYPE 09 CARD, IT IS
CN      OBTAINED FROM FILE ZNATDN OR FILE RCTDEN.
CN
CN      IF THE STARTING AXIAL BURN REGION NUMBER IS BLANK
CN      OR ZERO, THE HEAVY METAL DENSITY IS ASSIGNED TO
CN      ALL AXIAL BURN REGIONS OF THE ASSEMBLY.
CN
CN      IF THE FINAL AXIAL BURN REGION NUMBER IS BLANK OR
CN      ZERO, THE HEAVY METAL DENSITY IS ASSIGNED TO THE
CN      STARTING AXIAL BURN REGION OF THE ASSEMBLY.
C
C-----
C

```

APPENDIX E

IBM CATALOGUED PROCEDURE APPROC

```
//APPROC PROC AACYL=5,AADSP='(,DELETE)',AAFLUX='&AAFLUX',
// ATCYL=5,ATDSP='(,DELETE)',
// ATFLUX='&ATFLUX',ATVOL=,DEST='*',DEST2=F,DMPDEST=F,
// BLKTYP=CYL,CMPDSP='(,DELETE)',COMPS='&COMPS',
// CXSCYL=3,DIFDSP='(,DELETE)',DIF3D='&DIF3D',
// DLADSP='(,DELETE)',DLAYXS='&DLAYXS',D3DSP='(,DELETE)',
// D3EDIT='&D3EDIT',FDCCYL=20,FLXCYL=1,
// GEODSP='(,DELETE)',GEODST='&GEODST',HALFTRK=6136,
// ISOCYL=1,ISODSP='(MOD,KEEP)',ISOVOL=,
// ISOTXS='&ISOTXS',LABDSP='(,DELETE)',LABELS='&LABELS',
// MODEDCB='(RECFM=F,BLKSIZE=23220)',
// MODLIB1='SYS1.DUMMYLIB',
// MODLIB2='C116.CCCC.MODLIB',
// NACYL=5,NADSP='(,DELETE)',NAFLUX='&NAFLUX',NAVOL=,
// NDXDSP='(,DELETE)',NDXSRF='&NDXSRF',
// NHCYL=5,NHDSP='(,DELETE)',
// NHFLUX='&NHFLUX',NHVOL=,PATH='STP021',
// PMADSP='(,DELETE)',PMATRX='&PMATRX',
// POSTLIB='SYS1.DUMMYLIB',PRELIB='SYS1.DUMMYLIB',
// PRELIB1='SYS1.DUMMYLIB',PRELIB2='SYS1.DUMMYLIB',
// PRELIB3='SYS1.DUMMYLIB',
// PSICYL=5,PSUCYL=3,PWDDSP='(,DELETE)',QRTTRK=3064,
// RACYL=5,RADSP='(,DELETE)',RAFLUX='&RAFLUX',
// RDNCYL=5,RDNDSP='(,DELETE)',RCTDEN='&RCTDEN',
// RFXCYL=5,RFXDSP='(,DELETE)',RCTFLX='&RCTFLX',
// RPWCYL=2,RPWDSP='(,DELETE)',RCTPWD='&RCTPWD',
// REGN=1000K,RFILES='&RFILES',RFDSP='(,DELETE)',RFVOL=,
// RTCYL=5,RTDSP='(,DELETE)',RTFLUX='&RTFLUX',
// RTVOL=,TIMLIM='(600,0)',RZDSP='(,DELETE)',
// RZFLUX='&RZFLUX',SFDSP='(,DELETE)',
// SFECYL=5,SFEDIT='&SFEDIT',SRFCYL=5,
// SRFCYL=12,STADSP='(,DELETE)',STACK='&STACK',
// TWELTRK=1016,UNITS=BATCHDSK,UNITSCR=SASCR,
// XSISO=NULLFILE,XSISO2=NULLFILE,XSIVOL=,XS12VOL=,
// ZNADSP='(,DELETE)',ZONCYL=1
//*
//* *****
//* *
//* * CATALOGUED PROCEDURE FOR REACTOR ANALYSIS DIVISION *
//* * FORTRAN 77 CODES. *** 02/07/91 *** *
//* *
//* *****
//*
//* CYLINDER ALLOCATIONS ARE FOR 3330 DEVICES
//* IF OTHER DEVICES ARE USED CHANGE PROC PARAMETER
//* MODEDCB=(RECFM=F,BLKSIZE=XXXXXX) TO THE APPROPRIATE
//* BLOCK SIZE (13030 ON 3330, 19069 ON 3350, 23220 ON 3380).
//* NOTE THAT THE NUMBER OF TRACKS PER CYLINDER ON THESE
//* DEVICES IS 19 ON 3330, 30 ON 3350, AND 15 ON 3380.
//* *****
//*
//* PARAMETER DEFAULT VALUE USAGE
//* =====
//*
//* PATH STP021 PROGRAM NAME (EXEC)
//* TIMLIM (600,0) STEP TIME LIMIT (EXEC)
//* REGN 1000K STEP REGION SIZE (EXEC)
//* MODLIB1 SYS1.DUMMYLIB SECOND STEP LIBRARY (STEPLIB)
```

```

/** MODLIB2      C116.CCCC.MODLIB CCCC SYSTEM LIBRARY (STEPLIB)
/** PRELIB       SYS1.DUMMYLIB  FIRST STEP LIBRARY (STEPLIB)
/** PRELIB1      SYS1.DUMMYLIB  SECOND STEP LIBRARY (STEPLIB)
/** PRELIB2      SYS1.DUMMYLIB  THIRD STEP LIBRARY (STEPLIB)
/** PRELIB3      SYS1.DUMMYLIB  FOURTH STEP LIBRARY (STEPLIB)
/** POSTLIB      SYS1.DUMMYLIB  LAST STEP LIBRARY (STEPLIB)
/** DEST         *              OUTPUT DEST. (FT06)
/** DEST2        F              OUTPUT DESTINATION (FT10)
/** DMPDEST      F              ROUTE DUMP TO FICHE (SYSUDUMP)
/** AACYL        5              NO. OF CYL. FOR AAFLUX
/** ATCYL        5              NO. OF CYL. FOR ATFLUX
/** AADSP        (,DELETE)     DISPOSITION OF AAFLUX
/** ATDSP        (,DELETE)     DISPOSITION OF ATFLUX
/** ATFLUX       &ATFLUX       DSN FOR DATASET ATFLUX
/** ATVOL        -----      VOLUME FOR ATFLUX
/** CMPDSP       (,DELETE)     DISPOSITION OF COMPTS
/** DIFDSP       (,DELETE)     DISPOSITION OF DIF3D
/** DLADSP       (,DELETE)     DISPOSITION OF DLAYXS
/** D3DSP        (,DELETE)     DISPOSITION OF D3EDIT
/** GEODSP       (,DELETE)     DISPOSITION OF GEODST
/** ISOCYL       1              NO. CYL. FOR ISOTXS
/** ISODSP       (MOD,KEEP)     DISPOSITION OF ISOTXS
/** ISOTXS       &ISOTXS       DSN FOR DATASET ISOTXS
/** ISOVOL       -----      VOLUME FOR ISOTXS
/** LABDSP       (,DELETE)     DISPOSITION OF LABELS
/** NADSP        (,DELETE)     DISPOSITION OF NAFLUX
/** NAFLUX       &NAFLUX       DSN FOR NAFLUX
/** NAVOL        -----      VOLUME FOR NAFLUX
/** NDXDSP       (,DELETE)     DISPOSITION OF NDXXSRF
/** NHCYL        5              NO. OF CYL. FOR NHFLUX
/** NHDSP       (,DELETE)     DISPOSITION OF NHFLUX
/** NHFLUX       &NHFLUX       DSN FOR NHFLUX
/** NHVOL        -----      VOLUME FOR NHFLUX
/** PMADSP       (,DELETE)     DISPOSITION OF PMATRX
/** PWDDSP       (,DELETE)     DISPOSITION OF PWDINT
/** RACYL        5              NO. OF CYL. FOR RAFLUX
/** RDNCYL       5              NO. OF CYL. FOR RCTDEN
/** RDNDSP       (,DELETE)     DISPOSITION OF RCTDEN
/** RCTDEN       &RCTDEN       DSN FOR RCTDEN
/** RFXCYL       5              NO. OF CYL. FOR RCTFLX
/** RFXDSP       (,DELETE)     DISPOSITION OF RCTFLX
/** RCTFLX       &RCTFLX       DSN FOR RCTFLX
/** RPWCYL       2              NO. OF CYL. FOR RCTPWD
/** RPWDSP       (,DELETE)     DISPOSITION OF RCTPWD
/** RCTPWD       &RCTPWD       DSN FOR RCTPWD
/** RFDSP        (,DELETE)     DISPOSITION FOR FILE RFILES
/** RFILES       &RFILES       DSN FOR DATASET RFILES
/** RTCYL        5              NO. OF CYL. FOR RTFLUX
/** RTDSP       (,DELETE)     DISPOSITION OF RTFLUX
/** RTFLUX       &RTFLUX       DSN FOR DATASET RTFLUX
/** RTVOL        -----      VOLUME FOR RTFLUX
/** SFECYL       5              NO. OF CYL. FOR SFEDIT DATA
/** SRFCYL       12             NO. OF CYL. FOR SURF. FLUXES
/** XSISO        NULLFILE      DSN FOR DATASET XS.ISO FILE 1
/** XSISO2       NULLFILE      DSN FOR DATASET XS.ISO FILE 2
/** XSIVOL       -----      VOLUME FOR XS.ISO FILE 1
/** XSI2VOL      -----      VOLUME FOR XS.ISO FILE 2
/**
/** THE FOLLOWING NINE PARAMETERS DEFINE BLOCK ALLOCATIONS
/** AND DCB'S FOR AUXILIARY FLUX, FDCOEF AND ZONMAP DATASETS
/**
/** MODEDCB (RECFM=F, BLKSIZE=23220) DCB FOR DIRECT ACCESS FILES
/** BLKTPY      CYL            ALLOCATION BY CYLINDERS
/** SEC         1              SECONDARY ALLOCATION ON DA DATASETS

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/**      FDCCYL      20      NO. OF CYL.S FOR FDCOEF DATASET
/**      FLXCYL      1      NO. CYL. FOR 1 GROUP FLUX FILES
/**      PSICYL      5      NO. CYL.S FOR FLUX DATASETS
/**      PSUCYL      3      NO. CYL.S FOR ADJ. UPSCAT. FLUX
/**      ZONCYL      1      NO. CYL.S FOR ZONMAP
/**      CXSCYL      3      NO. CYL.S FOR CXSECT
/**
/**      THE FOLLOWING SIX PARAMETERS DEFINE UNIT AND BLKSIZE FOR
/**      A VARIETY OF DATASETS
/**
/**      HALFTRK      6136      HALF TRACK BLOCKING
/**      QRTTRK      3064      QUARTER TRACK BLOCKING
/**      TWELTRK      1016      TWELFTH TRACK BLOCKING
/**      UNITS      BATCHDSK      GENERIC UNIT NAME
/**      UNITSCR      SASCR      GENERIC UNIT NAME
/**
/** *****
/**
/**APPROC EXEC PGM=&PATH,TIME=&TIMLIM,REGION=&REGN
/**STEPLIB DD DSN=&PRELIB,DISP=SHR
/**      DD DSN=&PRELIB1,DISP=SHR
/**      DD DSN=&PRELIB2,DISP=SHR
/**      DD DSN=&PRELIB3,DISP=SHR
/**      DD DSN=&MODLIB1,DISP=SHR
/**      DD DSN=&MODLIB2,DISP=SHR
/**      DD DSN=&POSTLIB,DISP=SHR
/**
/**      SYSTEM DATASETS
/**
/**FT03F001 DD DSN=&META,UNIT=&UNITSCR,SPACE=(TRK,(120,20)),
/**      DISP=(,PASS)
/**      ISSCO METAFILE DATASET
/**FT04F001 DD DISP=SHR,LABEL=(,,,IN),
/**      DSN=CA.DIS110.DRVS.GRAFPDOD.SITEDATA
/**      DISSPLA FILE
/**FT05F001 DD DDNAME=SYSIN
/**      BCD INPUT.
/**FT06F001 DD SYSOUT=&DEST,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1596)
/**      PRINTED OUTPUT.
/**FT10F001 DD DCB=(RECFM=FBA,LRECL=133,BLKSIZE=1596),SYSOUT=&DEST2
/**      ALTERNATE PRINT FILE.
/**FT61 DD DSN=&XSISO,DISP=SHR,UNIT=&UNITS,VOL=SER=&XSIVOL
/**      ARC MICROSCOPIC ISOTOPE CROSS SECTION XS.ISO FILE 1
/**FT61F002 DD DSN=&XSISO2,DISP=SHR,UNIT=&UNITS,VOL=SER=&XSIVOL
/**      ARC MICROSCOPIC ISOTOPE CROSS SECTION XS.ISO FILE 2
/**FT62 DD DSN=*.FT61F002,DISP=SHR,VOL=REF=*.FT61F002
/**      ARC MICROSCOPIC ISOTOPE CROSS SECTION XS.ISO FILE 2
/**CADYNLIB DD DISP=SHR,DSN=CA.DIS110.DRVS.DYNLIB.LOAD
/**      DISSPLA DYNAMIC LOADED DEVICE DRIVER LIBRARY
/**MODCOM DD DSN=&&MODCOM,UNIT=&UNITSCR,SPACE=(TRK,(1,5)),
/**      DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
/**      MODULAR SYSTEM INTERFACE DATA SET.
/**AAFLUX DD DSN=&AAFLUX,DISP=&AADSP,SPACE=(CYL,(&AACYL,1)),
/**      UNIT=&UNITS,VOL=SER=&ATVOL,
/**      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**      CCCC ADJOINT ANGULAR FLUX DATASET.
/**ABURN DD DSN=&&ABURN,UNIT=&UNITSCR,SPACE=(CYL,(1,1)),
/**      DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
/**      THE REBUS-3 BCD DATASET.
/**ADIF3D DD DSN=&&ADIF3D,UNIT=&UNITSCR,SPACE=(TRK,(1,5)),
/**      DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
/**      1,2 OR 3D DIFFUSION MODULE DEPENDENT BCD DATASET.
/**ADISFAC DD DSN=&&ADISFAC,UNIT=&UNITSCR,SPACE=(TRK,(1,5)),
/**      DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)

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//*          WRDFAC MODULE DEPENDENT BCD DATASET.
//ADJANG DD DSN=&ADJANG,UNIT=&UNITS,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          ADJOINT ANGULAR FLUX DATASET.
//ANGSRC DD DSN=&ANGSRC,UNIT=&UNITS,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          ANGULAR SOURCE COMPONENTS.
//AHMG4C DD DSN=&AHMG4C,UNIT=&UNITSCR,SPACE=(TRK,(1,0)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
//*          CCCC HOMOGENIZATION MODULE DEPENDENT BCD DATASET.
//AISO DD DSN=&AISO,UNIT=&UNITSCR,SPACE=(CYL,(4,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
//*          THE ISOTXS BCD DATASET.
//ALASIP3 DD DSN=&ALSIP3,UNIT=&UNITSCR,SPACE=(TRK,(3,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
//*          THE LASIP-III BCD DATASET
//AMASFLO DD DSN=&AMASFLO,UNIT=&UNITSCR,SPACE=(TRK,(1,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200)
//*          THE REBUS-3 BCD INPUT DATASET A MASFLO.
//ANIP3 DD DSN=&ANIP3,UNIT=&UNITSCR,SPACE=(CYL,(1,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
//*          THE ARC SYSTEM GENERAL NEUTRONICS BCD DATASET.
//ARC DD UNIT=&UNITSCR,SPACE=(CYL,(1,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
//*          ARC SYSTEM SPOOLED OUTPUT.
//ARCT DD DSN=&ARCT,UNIT=&UNITSCR,SPACE=(CYL,(1,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
//*          RCT MODULE DEPENDENT BCD DATASET.
//ASUMMAR DD DSN=&ASUMMAR,UNIT=&UNITSCR,SPACE=(TRK,(3,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=6000)
//*          BCD INPUT DATASET FOR EDIT MODULE - SUMMARY
//ATFLUX DD DSN=&ATFLUX,DISP=&ATDSP,SPACE=(CYL,(&ATCYL,1)),
//          UNIT=&UNITS,VOL=SER=&ATVOL,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          CCCC ADJOINT FLUX INTERFACE DATASET.
//ASTP027 DD DSN=&ASTP027,UNIT=&UNITSCR,SPACE=(TRK,(1,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200)
//*          THE REBUS-3 MODULE DEPENDENT BCD INPUT DATASET.
//AUDOIT DD DSN=&AUDOIT,UNIT=&UNITSCR,SPACE=(TRK,(3,1)),
//          DCB=(RECFM=VBS,LRECL=84,BLKSIZE=&QRTTRK)
//*          BCD INPUT DATASET FOR UDOIT MODULES.
//AUDOIT2 DD DSN=&AUDOIT2,UNIT=&UNITSCR,SPACE=(TRK,(6,2),RLSE),
//          DCB=(RECFM=VBS,LRECL=84,BLKSIZE=&QRTTRK)
//*          BCD INPUT DATASET FOR UDOIT MODULES VERSION 2.
//BCDSOB DD SYSOUT=B,DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//*          BCDSOB PUNCHED OUTPUT FOR LASIP3 CODE
//BRN DD DSN=&BRN,UNIT=&UNITS,SPACE=(TRK,(5,5)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          DATA DUMP FOR BURNUP MODULE-TO-MODULE TRANSMISSION.
//BRNFLX DD DSN=&BRNFLX,UNIT=&UNITS,SPACE=(CYL,(&SFECYL,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          MAXIMUM BURNUP AND FLUENCE FOR EACH STAGE OF EACH
//          PATH, VERSION 1.
//BRNFLX2 DD DSN=&BRNFLX2,UNIT=&UNITS,SPACE=(CYL,(&SFECYL,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          MAXIMUM BURNUP AND FLUENCE FOR EACH STAGE OF EACH
//          PATH, VERSION 2.
//COMPXS DD DSN=&COMPXS,UNIT=&UNITS,SPACE=(CYL,(3,1)),DISP=&CMPDSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          COMPOSITION MACROSCOPIC CROSS-SECTION DATASET.
//COMPXS2 DD DSN=&COMPXS2,UNIT=&UNITS,SPACE=(CYL,(3,1)),DISP=&CMPDSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          EOC MACROSCOPIC CROSS SECTION DATASET.
//DIF3D DD DSN=&DIF3D,UNIT=&UNITS,SPACE=(TRK,(1,0)),DISP=&DIFDSP,

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//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&QRTTRK)
// *          1, 2 OR 3D DIFFUSION MODULE DEPENDENT BINARY DATASET.
//DIRANG DD DSN=&DIRANG,UNIT=&UNITS,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          DIRECT ANGLUAR FLUX DATASET..
//DISFAC DD DSN=&DISFAC,UNIT=&UNITS,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          DISCONTINUITY FACTORS DATASET.
//DLAYXS DD DSN=&DLAYXS,UNIT=&UNITS,SPACE=(CYL,(3,1)),DISP=&DLADSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          PRECURSOR YELDS, EMISSION SPECTRA, AND DECAY CONSTANTS
// *          ORDERED BY ISOTOPE
//DUMISO DD DSN=&DUMISO,DISP=(,DELETE),SPACE=(CYL,(&ISOCYL,1),RLSE),
//          UNIT=&UNITS,DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          TEMPORARY DATASET FOR ISOTXS CREATED FORM XS.ISO
//D3EDIT DD DSN=&D3EDIT,UNIT=&UNITS,SPACE=(CYL,(1,1)),DISP=&D3DSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          DIF3D EDITS INTERFACE DATASET.
//EOCRF DD DSN=&EOCRF,UNIT=&UNITS,SPACE=(CYL,(&RTCYL,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          REAL FLUX DATASET AT EOC.
//FIXSRC DD DSN=&FIXSRC,UNIT=&UNITS,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          CCCC FIXED SOURCE DATASET.
//FPRINT DD DSN=&FPRINT,UNIT=&UNITSCR,SPACE=(CYL,(1,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          FPRINT FILE FOR LASIP3.
//GEODST DD DSN=&GEODST,UNIT=&UNITS,SPACE=(CYL,(01,1)),DISP=&GEODSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          CCCC GEOMETRY DESCRIPTION DATASET.
//GEODST2 DD DSN=&GEODST2,UNIT=&UNITS,SPACE=(CYL,(1,1)),DISP=&GEODSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          EOC GEOMETRY DESCRIPTION DATASET.
//GRAPHICS DD PLOTTER=G1DATA,DISP=(MOD,KEEP),DSN=&G1DATA,
//          SPACE=(TRK,(150,10)),UNIT=SASCR
// *          GRAPHICS OUTPUT DATASET
//INPTAP DD DSN=&INPTAP,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          INPTAP FILE FOR LASIP3.
//ISNTXS DD DSN=&ISNTXS,UNIT=&UNITS,SPACE=(CYL,(04,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          CCCC (ISOTXS) TYPE FILE PRODUCED BY CSE010
//ISOTXS DD DSN=&ISOTXS,DISP=&ISODSP,SPACE=(CYL,(&ISOCYL,1)),
//          UNIT=&UNITS,VOL=SER=&ISOVOL,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          CCCC NUCLIDE-ORDERED MICROSCOPIC CROSS SECTIONS.
//ISOTXS2 DD DSN=&ISOTX2,UNIT=&UNITS,SPACE=(CYL,(04,0)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          CCCC (ISOTXS) FILE USED FOR MERGING IN CSE010
//ISOTXS3 DD DSN=&ISOTX3,UNIT=&UNITS,SPACE=(CYL,(04,0)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          CCCC (ISOTXS) FILE USED FOR MERGING IN CSE010
//JONPLOT DD DSN=&JONPLOT,UNIT=&UNITS,SPACE=(TRK,(3,1),RLSE),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK),DISP=(MOD,PASS)
// *          BEITEL'S SUMMARY WORKING DATASET.
//LABELS DD DSN=&LABELS,UNIT=&UNITS,SPACE=(TRK,(3,0)),DISP=&LABDSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&TWELTRK)
// *          A.NIP3 LABELS AND AREA DEFINITIONS.
//NAFLUX DD DSN=&NAFLUX,DISP=&NADSP,SPACE=(CYL,(&NACYL,1)),
//          UNIT=&UNITS,VOL=SER=&NAVOL,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *          RESTART FILE FOR ADJOINT NODAL HEX CALCULATION.
//NBHAT DD DSN=&NBHAT,SPACE=(TRK,(5,5),RLSE),UNIT=&UNITSCR,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)

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//*          BHAT MATRIX.
//NDS1CR DD DSN=&NDS1CR, SPACE=(CYL, (2,1), RLSE), UNIT=&UNITSCR,
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          N-1 (OR N-2) FLUX ITERATE.
//NDS1 DD DSN=&NDS1, SPACE=(CYL, (7,1), RLSE, CONTIG), UNIT=&UNITSCR,
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          A1 MATRIX AND B MATRIX.
//NDS2 DD DSN=&NDS2, SPACE=(CYL, (7,1), RLSE, CONTIG),
//          UNIT=(&UNITSCR, SEP=NDS1),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          AVERAGE A1 MATRIX, AA.
//NDS3 DD DSN=&NDS3, SPACE=(CYL, (5,5), RLSE),
//          UNIT=(&UNITSCR, SEP=(NDS1, NDS2)),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          DN MATRIX.
//NDS4 DD DSN=&NDS4, SPACE=(CYL, (7,1), RLSE, CONTIG),
//          UNIT=(&UNITSCR),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          STAGE DENSITIES AT THE BEGINNING OF CYCLE.
//NDS5 DD DSN=&NDS5, SPACE=(TRK, (5,5), RLSE),
//          UNIT=(&UNITSCR, SEP=NDS1),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          STAGE DENSITIES AT THE CURRENT TIME NODE.
//NDXSRF DD DSN=&NDXSRF, UNIT=&UNITSCR, SPACE=(TRK, (03,0)), DISP=&NDXDSP,
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          CCCC NUCLIDE/CROSS SECTION REFERENCING DATA.
//NDXSRF2 DD DSN=&NDXSRF2, UNIT=&UNITSCR, SPACE=(TRK, (03,0)),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          VERSION 2 OF CCCC DATASET NDXSRF.
//NHFLUX DD DSN=&NHFLUX, DISP=&NHDS, SPACE=(CYL, (&NHCYL,1)),
//          UNIT=&UNITSCR, VOL=SER=&NHVOL,
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          RESTART FILE FOR REAL NODAL HEX CALCULATION.
//NHFLUX2 DD DSN=&NHFLUX2, DISP=&NHDS, SPACE=(CYL, (&NHCYL,1)),
//          UNIT=&UNITSCR, VOL=SER=&NHVOL,
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          EOC NHFLUX INTERFACE DATASET.
//PKEDIT DD DSN=&PKEDIT, UNIT=&UNITSCR, SPACE=(CYL, (1,1)),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          PEAK POWER DENSITY AND FLUX INTERFACE DATASET.
//POINTR DD DSN=&POINTR, UNIT=&UNITSCR, SPACE=(CYL, (2,1), RLSE),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          POINTR DATA DUMP FOR BURNUP MODULE-TO-MODULE TRANSMISSION
//PMATRX DD DSN=&PMATRX, UNIT=&UNITSCR, SPACE=(TRK, (03,0)), DISP=&PMADSP,
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          CCCC NUCLIDE/CROSS SECTION REFERENCING DATA.
//PWDINT DD DSN=&PWDINT, UNIT=&UNITSCR, SPACE=(CYL, (01,1)), DISP=&PWDDSP,
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          CCCC POWER DENSITY INTERFACE DATASET.
//RAFLUX DD DSN=&RAFLUX, DISP=&RADSP, SPACE=(CYL, (&RACYL,1)),
//          UNIT=&UNITSCR, VOL=SER=&ATVOL,
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          CCCC REAL ANGULAR FLUX DATASET.
//RCT DD DSN=&RCT, UNIT=&UNITSCR, SPACE=(TRK, (1,0)),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          RCT BINARY DATASET.
//RCTDEN DD DSN=&RCTDEN, DISP=&RDNDSP,
//          UNIT=&UNITSCR, SPACE=(CYL, (&RDNCYL,1), RLSE),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          INPUT RECONSTRUCTED NUCLIDE ATOM DENSITIES.
//RCTDEN2 DD DSN=&RCTDEN2, DISP=&RDNDSP,
//          UNIT=&UNITSCR, SPACE=(CYL, (&RDNCYL,1), RLSE),
//          DCB=(RECFM=VBS, LRECL=X, BLKSIZE=&HALFTRK)
//*          OUTPUT RECONSTRUCTED NUCLIDE ATOM DENSITIES.

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//RCTLFLX DD DSN=&RCTLFLX,DISP=&RFXDSP,
//          UNIT=&UNITS,SPACE=(CYL,(&RFXCYL,1),RLSE),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *
//          RECONSTRUCTED BOC NEUTRON FLUX
//RCTLFLX2 DD DSN=&RCTLFLX2,DISP=&RFXDSP,
//          UNIT=&UNITS,SPACE=(CYL,(&RFXCYL,1),RLSE),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *
//          RECONSTRUCTED EOC NEUTRON FLUX
//RCTPWD DD DSN=&RCTPWD,DISP=&RPWDSP,
//          UNIT=&UNITS,SPACE=(CYL,(&RPWCYL,1),RLSE),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *
//          RECONSTRUCTED BOC POWER DENSITY
//RCTPWD2 DD DSN=&RCTPWD2,DISP=&RPWDSP,
//          UNIT=&UNITS,SPACE=(CYL,(&RPWCYL,1),RLSE),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *
//          RECONSTRUCTED EOC POWER DENSITY
//RFILES DD DSN=&RFILES,UNIT=&UNITS,SPACE=(CYL,(02,1)),
//          VOL=SER=&RFVOL,DISP=&RFDSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
// *
//          RFILES RESTART/WRAPUP DATASET.
//RNDM01 DD DSN=&&PSIOLD,SPACE=(&BLKTYP,(&PSICYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FLUX ITERATE SCRATCH DATASET.
//RNDM02 DD DSN=&&PSINew,SPACE=(&BLKTYP,(&PSICYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FLUX ITERATE SCRATCH DATASET.
//RNDM03 DD DSN=&&PSIUP,SPACE=(&BLKTYP,(&PSUCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          AUXILIARY FLUX DATASET FOR ADJOINT UPSCATTER ITERATIONS
//RNDM04 DD DSN=&&FDCCOEF,SPACE=(&BLKTYP,(&FDCCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FINITE DIFFERENCE COEFFICIENTS SCRATCH DATASET.
//RNDM05 DD DSN=&&FRNOLD,SPACE=(&BLKTYP,(&FLXCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FISSION SOURCE SCRATCH DATASET
//RNDM06 DD DSN=&&FRNNEW,SPACE=(&BLKTYP,(&FLXCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FISSION SOURCE SCRATCH DATASET
//RNDM07 DD DSN=&&FRNM1,SPACE=(&BLKTYP,(&FLXCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FISSION SOURCE SCRATCH DATASET.
//RNDM08 DD DSN=&&FRNM2,SPACE=(&BLKTYP,(&FLXCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FISSION SOURCE SCRATCH DATASET.
//RNDM09 DD DSN=&&SRCNEW,SPACE=(&BLKTYP,(&FLXCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          TOTAL SOURCE SCRATCH DATASET.
//RNDM10 DD DSN=&&ZONMAP,SPACE=(&BLKTYP,(&ZONCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          ZONE MAP SCRATCH DATASET.
//RNDM11 DD DSN=&&CXSECT,SPACE=(&BLKTYP,(&CXSCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          COMPOSITION CROSS SECTIONS SCRATCH DATASET.
//RNDM12 DD DSN=&&FSRC,SPACE=(&BLKTYP,(&PSICYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FIXED SOURCE SCRATCH DATASET.
//RNDM13 DD DSN=&&PSIGO,SPACE=(&BLKTYP,(&FLXCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FLUX ITERATE SCRATCH DATASET ONE GROUP.
//RNDM14 DD DSN=&&PSIGN,SPACE=(&BLKTYP,(&FLXCYL,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
// *
//          FLUX ITERATE SCRATCH DATASET ONE GROUP.
//RNDM15 DD DSN=&&RNDM15,SPACE=(&BLKTYP,(1,1)),
//          DCB=&MODEDCB,UNIT=&UNITSCR
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/**          FLUX ITERATE SCRATCH DATASET ONE GROUP.
//RTFLUX DD DSN=&RTFLUX,DISP=&RTDSP,SPACE=(CYL,(&RTCYL,1)),
//          UNIT=&UNITS,VOL=SER=&RTVOL,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          CCCC REAL FLUX INTERFACE DATASET.
//RZFLUX DD DSN=&RZFLUX,UNIT=&UNITS,SPACE=(TRK,(01,1)),DISP=&RZDSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          CCCC ZONE AVERAGED FLUX INTERFACE DATASET.
//SCRATH DD DSN=&SCRATH,UNIT=&UNITSCR,SPACE=(CYL,(1,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATH FILE FOR LASIP3.
//SCRCH1 DD DSN=&SCRCH1,UNIT=&UNITSCR,SPACE=(CYL,(&RTCYL,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          REAL FLUX DATASET AT SECOND TIME POINT.
//SCRCH2 DD DSN=&SCRCH2,UNIT=&UNITSCR,SPACE=(CYL,(&RTCYL,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          REAL FLUX DATASET AT THIRD TIME POINT.
//SCRCH3 DD DSN=&SCRCH3,UNIT=&UNITSCR,SPACE=(CYL,(&RTCYL,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          REAL FLUX DATASET AT FOURTH TIME POINT.
//SCRCH4 DD DSN=&SCRCH4,UNIT=&UNITSCR,SPACE=(CYL,(&RTCYL,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          PRELIMINARY SEARCH AND UNPOISONED KEFF IN INTERMEDIATE
//          AND FINAL SEARCHES.
//SCR001 DD DSN=&SCR001,UNIT=&UNITSCR,SPACE=(CYL,(&SRFCYL,2)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 1.
//SCR002 DD DSN=&SCR002,UNIT=&UNITSCR,SPACE=(CYL,(&SRFCYL,2)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 2.
//SCR003 DD DSN=&SCR003,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 3.
//SCR004 DD DSN=&SCR004,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 4.
//SCR005 DD DSN=&SCR005,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 5.
//SCR006 DD DSN=&SCR006,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 6.
//SCR007 DD DSN=&SCR007,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 7.
//SCR008 DD DSN=&SCR008,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 8.
//SCR009 DD DSN=&SCR009,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 9.
//SCR010 DD DSN=&SCR010,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SCRATCH FILE 10.
//SEARCH DD DSN=&SEARCH,UNIT=&UNITSCR,SPACE=(TRK,(03,0)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          CCCC CRITICALITY SEARCH DATA.
//SFEDIT DD DSN=&SFEDIT,UNIT=&UNITS,SPACE=(CYL,(01,1)),DISP=&SFDSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SURFACE- AND CELL-AVERAGED POWER DENSITY AND FAST FLUX
//          DATASET
//SFEDIT2 DD DSN=&SFEDIT2,UNIT=&UNITS,SPACE=(CYL,(01,1)),DISP=&SFDSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
/**          SURFACE- AND CELL-AVERAGED POWER DENSITY AND FAST FLUX
```

```
//*          DATASET VERSION 2.
//SNCONS DD DSN=&SNCONS,UNIT=&UNITSCR,SPACE=(TRK,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          CCCC SN CONSTANTS DATASET.
//STACK DD DSN=&STACK,UNIT=&UNITS,SPACE=(CYL,(01,1)),DISP=&STADSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          STACK DATASET
//SYSUDUMP DD SYSOUT=&DMPDEST
//*          SYSTEM DUMP DATASET FOR ABNORMAL NJB TERMINATION.
//UDOIT1 DD DSN=&UDOIT1,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          UDOIT INTERFACE FILE VERSION 1.
//UDOIT2 DD DSN=&UDOIT2,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          UDOIT INTERFACE FILE VERSION 2.
//UDOIT3 DD DSN=&UDOIT3,UNIT=&UNITSCR,SPACE=(CYL,(01,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          UDOIT INTERFACE FILE VERSION 3.
//ZADBOC DD DSN=&ZADBOC,UNIT=&UNITS,SPACE=(TRK,(3,1),RLSE),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          CCCC ZONE NUCLIDE ATOM DENSITIES DATASET ZNATDN AT BOC.
//ZNATDN DD DSN=&ZNATDN,UNIT=&UNITS,SPACE=(CYL,(01,1)),DISP=&ZNADSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          CCCC ZONE NUCLIDE ATOM DENSITIES.
//ZNATDN2 DD DSN=&ZNATDN2,UNIT=&UNITS,SPACE=(CYL,(01,1)),DISP=&ZNADSP,
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFTRK)
//*          EOC ZONE NUCLIDE ATOM DENSITIES.
//*          *****
//          ANYONE EXPERIENCING DIFFICULTY WITH THIS PROCEDURE CONTACT
//          C. ADAMS BLDG 208, ROOM W117, EXT 4820
//          *****
//          *****
```

APPENDIX F

RCTP CODE-DEPENDENT BCD INPUT FILE A.RCTP

```

C*****
C
C                                     PREPARED 9/15/89 AT ANL
C
CF      A.RCTP  (INPUT TO RCTDEN POST-PROCESSOR)
C
CE      THIS DATA SET CAN BE INPUT EITHER IN FREE-FORMAT
CE      STYLE (UNFORM=) OR FORMATTED (DATASET=).
C
C*****
C
C-----
CR      PROBLEM TITLE (TYPE 01)
C
CL      FORMAT----- (I2,4X,11A6)
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====
CD      1-2              01
CD
CD      7-72            ANY ALPHANUMERIC CHARACTERS.
C
CN      ANY NUMBER OF TYPE 01 CARDS MAY BE USED.
C
C-----
C
C-----
CR      SPECIFICATION OF ASSEMBLIES (02)
C
CL      FORMAT----- (I2,4X,A6,2I6,2E12.5)
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====
CD      1-2              02
CD
CD      7-12            ASSEMBLY LABEL
CD
CD      13-18           NUMBER OF AXIAL BURN REGIONS IN REBUS-3 MODEL FOR
CD                      THIS ASSEMBLY
CD
CD      19-24           TOTAL NUMBER OF FUEL PIN RINGS IN THIS ASSEMBLY
CD
CD      25-36           FUEL PIN PITCH IN THIS ASSEMBLY (CM)
CD
CD      37-48           FLAT-TO-FLAT DISTANCE ACROSS THE HEXAGON (CM)
C
CN      THE ASSEMBLY LABEL MUST BE CONSISTENT WITH THE
CN      ASSEMBLY LABEL IN THE 2D RECORD OF THE FILE RCTDEN.
C
C-----
C
C-----
CR      AXIAL BURN REGION BOUNDARY COORDINATES (03)
C
CL      FORMAT----- (I2,4X,A6,2(I6,2E12.5))
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====

```

CD 1-2 03
 CD
 CD 7-12 ASSEMBLY LABEL (REPEATED ON ADDITIONAL TYPE 03 CARDS)
 CD
 CD 13-18 AXIAL BURN REGION NO.
 CD
 CD 19-30 LOWER-BOUNDARY COORDINATE
 CD
 CD 31-42 UPPER-BOUNDARY COORDINATE
 CD
 CD 43-48 AXIAL BURN REGION NO.
 CD
 CD 49-60 LOWER-BOUNDARY COORDINATE
 CD
 CD 61-72 UPPER-BOUNDARY COORDINATE
 C
 CN THE ASSEMBLY LABEL MUST BE CONSISTENT WITH THE
 CN ASSEMBLY LABEL ON TYPE 02 CARDS.
 CN
 CN IF THE ASSEMBLY LABEL IS BLANK, THE DATA ON THE CARD
 CN APPLY TO ALL ASSEMBLIES OF THE FILE RCTDEN.
 C
 C
 C

CR SPECIFICATION OF PINS FOR WHICH DENSITIES ARE
 CR TO BE INTERPOLATED FROM ASSEMBLY DENSITIES (04)
 C

CL FORMAT----- (I2,4X,A6,3(A6,2I6))
 C

CD	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY
CD	=====	=====
CD	1-2	04
CD		
CD	7-12	ASSEMBLY LABEL (REPEATED ON ADDITIONAL TYPE 04 CARDS)
CD		
CD	13-18	UNIQUE PIN LABEL
CD		
CD	19-24	RING NUMBER OF PIN
CD		
CD	25-30	POSITION NUMBER OF PIN IN RING
CD		
CD	31-36	UNIQUE PIN LABEL
CD		
CD	37-42	RING NUMBER OF PIN
CD		
CD	43-48	POSITION NUMBER OF PIN IN RING
CD		
CD	49-54	UNIQUE PIN LABEL
CD		
CD	55-60	RING NUMBER OF PIN
CD		
CD	61-66	POSITION NUMBER OF PIN IN RING

C
 CN FOR THE SPECIAL PINS WHOSE DENSITIES ARE PROVIDED
 CN THROUGH THE 6D RECORD OF THE FILE RCTDEN, THIS CARD
 CN WILL BE IGNORED.
 CN

CN THE FIGURE BELOW ILLUSTRATES THE NUMBERING CONVENTION
 CN OF FUEL PIN RINGS AND POSITIONS IN FUEL PIN RINGS.
 CN
 CN
 CN

CN			C2		
CN			=====		
CN		S3	=3,3 =	S2	- -----> X
CN			=====		
CN	C3		=3,4 =	=3,2 =	C1
CN			=====		
CN			=3,5 =	=2,2 =	=3,1 =
CN			=====		
CN			=2,3 =	=2,1 =	
CN			=====		
CN	S4		=3,6 =	=1,1 =	=3,12= S1
CN			=====		
CN			=2,4 =	=2,6 =	
CN			=====		
CN			=3,7 =	=2,5=	=3,11=
CN			=====		
CN	C4		=3,8 =	=3,10=	C6
CN			=====		
CN		S5	=3,9 =	S6	
CN			=====		
CN			C5		

C
C
C-----

CR SPECIFICATION OF AXIAL INTERPOLATION POSITION (05)

C

CL FORMAT----- (I2,4X,A6,4E12.5)

C

CD	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY
CD	=====	=====
CD	1-2	05
CD		
CD	7-12	PIN LABEL (REPEATED ON ADDITIONAL TYPE 05 CARDS)
CD		
CD	13-24	LOWER AXIAL POSITION BY THE FRACTION OF THE TOTAL PIN LENGTH
CD		
CD	25-36	UPPER AXIAL POSITION BY THE FRACTION OF THE TOTAL PIN LENGTH
CD		
CD	37-48	LOWER AXIAL POSITION BY THE FRACTION OF THE TOTAL PIN LENGTH
CD		
CD	49-60	UPPER AXIAL POSITION BY THE FRACTION OF THE TOTAL PIN LENGTH
CD		

C

CN THE PIN LABEL MUST BE CONSISTENT WITH THE SPECIAL

CN PIN LABEL IN THE 3D RECORD OF THE FILE RCTDEN OR

CN THE PIN LABEL SPECIFIED BY TYPE 04 CARDS.

CN

CN IF THE UPPER AXIAL POSITION IS LESS THAN OR EQUAL TO

CN ZERO, THE DENSITIES AT THE LOWER POSITION WILL BE

CN INTERPOLATED. OTHERWISE, THE AXIAL AVERAGE DENSITIES

CN BETWEEN THE LOWER AND THE UPPER POSITIONS WILL BE

CN INTERPOLATED.

CN

CN THE TOTAL PIN LENGTH IS DETERMINED BY SUMMING THE

CN HEIGHTS OF THE AXIAL BURN REGIONS SPECIFIED ON TYPE

CN 03 CARDS.

C

C-----