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**FX2-TH: A TWO-DIMENSIONAL
NUCLEAR REACTOR KINETICS CODE
WITH THERMAL-HYDRAULIC FEEDBACK**

by

**R. A. Shoher, T. A. Daly,
and D. R. Ferguson**

BASE TECHNOLOGY

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MASTER

ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

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by

R. A. Shober, T. A. Daly,
and D. R. Ferguson*

Applied Physics Division

October 1978

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FX2-TH: A TWO-DIMENSIONAL NUCLEAR REACTOR KINETICS CODE
WITH THERMAL AND HYDRAULICS FEEDBACK

by

R. A. Shober, D. R. Ferguson, T. A. Daly

ABSTRACT

FX2-TH is a two-dimensional, time-dependent nuclear reactor kinetics program with thermal and hydraulic feedback. The neutronics model used is multigroup neutron diffusion theory. The following geometry options are available: x, r, x-y, r-z, θ -r, and triangular. FX2-TH contains two basic thermal and hydraulic models: a simple adiabatic fuel temperature calculation, and a more detailed model consisting of an explicit representation of a fuel pin, gap, clad, and coolant. FX2-TH allows feedback effects from both fuel temperature (Doppler) and coolant temperature (density) changes. FX2-TH will calculate a consistent set of steady state conditions by iterating between the neutronics and thermal-hydraulics until convergence is reached. The time-dependent calculation is performed by the use of the improved quasistatic method. A disk editing capability is available. FX2-TH is operational on IBM system 360 or 370 computers and on the CDC 7600.

CODE ABSTRACT

1. Program Identification: FX2-TH
2. Computer for which program is designed and others on which it is operable: IBM 370/195, IBM 370/165, CDC 7600, any IBM OS System.
3. Description of Function: FX2-TH solves the steady-state and time-dependent two-dimensional multigroup neutron diffusion equations. These equations are coupled to a solution of the heat conduction equations in a fuel pin, cladding, and non-boiling coolant. The code is designed for nuclear reactor transient analysis.
4. Method of Solution: The multigroup diffusion equations are discretized in space using mesh-centered finite differences. The steady-state solution of these equations is found by accelerating a fission source iteration through the use of Chebyshev polynomials. The neutron fluxes for each energy group at each power iteration are found using the successive line over-relaxation method. The time-dependent diffusion equations are solved using the improved quasistatic method. The shape calculations required by the quasistatic method utilize the same calculational methods as described above for the steady-state calculation.

5. Restrictions: Variable dimensioning is used throughout the program so that computer core requirements depend on a variety of problem parameters. The amount of core memory required can range from 300 K bytes for a small problem up to the maximum limit of computer core for very large problems.
6. Running Time: Running times are very dependent on the number of groups, number of mesh points, length of the transient, and amount of change in the problem variables as the transient progresses.
7. Unusual Features of the Program: A consistent set of steady-state conditions are established by iterating between the steady-state neutronics and thermal-hydraulics equations. The time-dependent solution is then found using the improved quasistatic method. A wide variety of geometry options are available, such as x, r, x-y, r-z, θ -r, and triangular. Microscopic cross sections and delayed neutron data are input in the CCCC formats ISOTXS and DIAYXS, respectively. A disk editing capability is included.
8. Related and Auxiliary Programs: Input microscopic cross sections and delayed neutron data may be generated using the MC²-2 program.¹⁷
9. Status: FX2-TH is operational on the IBM 370/195 at ANL, on an IBM 370/165, and at the CDC 7600 at Lawrence Berkeley Laboratory.
10. References: R. A. Shober, D. R. Ferguson, and T. A. Daly, *FX2-TH: A Two-Dimensional Nuclear Reactor Kinetics Code with Thermal and Hydraulic Feedback*, ANL-78-97, October 1978.
11. Machine Requirements: FX2-TH will dynamically allocate problem variables either on disk or in core memory depending on the total amount of core available. For any problem, a certain minimum amount of core memory is required; this amount being dependent on the size of the problem. In general, FX2-TH operates more efficiently if sufficient core storage is available to contain most of the problem variables permanently in core. On the CDC 7600, for large problems as much SCM and LCM (up to a maximum of 131,000 words) as available should be requested.
12. Programming Language Used: FORTRAN-IV
13. Operating System or Monitor Under which Program is Executed: The IBM version of FX2-TH may be compiled under OS or VS operating systems using either FORTRAN H or Extended compilers with the highest level of optimization. The CDC 7600 version of FX2-TH has been implemented at the Lawrence Berkeley Laboratory using the COKE/SCOPE operating system. Directly addressable LCM is used in FX2-TH. The code was compiled using FORTRAN extended compiler under OPT=2 optimization.
14. Any Other Programming or Operating Information or Restrictions: None.

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16. Material Available: Separate tapes are available for the IBM and CDC versions of FX2-TH. The package includes:

- i) Source decks
- ii) Test problem input decks
- iii) Test problem input data sets
- iv) Test problem output
- v) Reference report

17. Category:

Keywords: kinetics, quasistatic method, multigroup diffusion theory,
thermal-hydraulics

I. INTRODUCTION

The FX2-TH code is designed for two-dimensional reactor transient analysis. The neutronics model used is time-dependent multigroup neutron diffusion theory. The thermal-hydraulics model used can be either an "adiabatic" calculation of the fuel temperature, or an explicit solution of the heat conduction equations through a fuel pin, gap, clad and coolant. Although FX2-TH was designed for LMFBR transient analysis, the equations solved and numerical methods used are appropriate for many reactor types.

FX2-TH solves the steady-state and time-dependent multigroup neutron diffusion equations. The steady-state calculation consists of finding both the real and adjoint multigroup neutron flux. These calculations are performed by using an accelerated iteration strategy. The time-dependent diffusion equations are solved by using the improved quasistatic method.¹ This method can be thought of as being a solution of the point kinetics equations with periodic re-calculation of the time-dependent multigroup neutron fluxes such that the resultant point kinetics solution is an acceptably accurate approximation to a full space-time solution of the diffusion equations. The neutronics equations and solution techniques are described in Chapter II.

The known multigroup neutron fluxes are then used to calculate the fission power generated in each reactor region. From this fission power, the thermal-hydraulics model calculates average fuel and coolant temperatures in this reactor region. Two basic thermal-hydraulics models are available in FX2-TH. The first is an "adiabatic" model, the second a more detailed model. The "adiabatic" model has two variations; the first assumes that no heat transfer occurs between fuel and coolant, the second assumes the rate of heat transfer to be constant over the transient. For these models, the coolant temperatures are not calculated. The second thermal-hydraulics model available in FX2-TH is an explicit representation of a fuel pin, gap, clad, and coolant for each reactor region. The heat conduction equations are solved in order to calculate the temperature distribution through the fuel pin, clad, and coolant. The coolant in each reactor region is assumed not to interact with the coolant in any other region, and it is assumed not to boil. The effect of wire wraps and the fuel assembly structure on the coolant temperature can also be calculated by defining a lumped "structure" material, and calculating its temperature during the transient. The thermal-hydraulics models present in FX2-TH are described in detail in Chapter III.

The average temperatures calculated by the thermal-hydraulics models are used in the calculation of the macroscopic cross sections for each reactor region. FX2-TH takes account of feedback effects from changes in both the average fuel and average coolant temperatures. An increase in the average fuel temperature causes Doppler broadening of resonances in fuel material, thus changing the microscopic capture and fission cross sections. In FX2-TH, this effect is represented by a general expansion of the microscopic capture and fission cross sections in terms of the average fuel temperature. An increase in the average coolant temperature causes a decrease in the atom density of the coolant. In FX2-TH, this effect is represented by a linear expansion of the atom density in terms of the average coolant temperature. Thus, the macroscopic capture, removal, scattering, and transport cross sections of the coolant are dependent on the average coolant temperature. The details of the cross section representation in FX2-TH are presented in Chapter IV.

Steady-state conditions are found by iteratively solving for the steady state neutron fluxes and steady-state fuel and coolant temperatures until a converged set of conditions is found. The transient conditions are calculated by solving the neutronics and thermal-hydraulics equations in tandem within the framework of the improved quasistatic method. The details of the overall solution strategy are presented in Chapter IV.

In Chapter V, information is presented to enable the user to successfully execute the FX2-TH program. A listing of the required input parameters is given, as well as all additional information required to run FX2-TH. Chapter VI presents detailed programming information for those who may be required to modify the code in the future.

II. NEUTRONICS EQUATIONS AND THEIR SOLUTION

A. The Multigroup Diffusion Equations

The basic neutronics model used in FX2-TH is time-dependent multigroup diffusion theory. Assuming that cross sections and material densities are known, an accurate prediction of the distribution of neutrons in a nuclear reactor requires a solution of the Boltzmann transport equation; an equation which can be derived from first principles.² However, currently available methods for solving this equation for problems in multidimensional geometry and/or which are time-dependent are extremely long-running even on today's high-speed computers. Therefore, the so-called multigroup diffusion equations are solved in the FX2-TH program. To derive these equations from the transport equation, several approximations are required.

One method of solving the transport equation involves expanding the angular flux density in Legendre polynomials.² When only the first two terms of the Legendre expansion are retained, the resulting equations are called the "P-1" equations. The solution of the diffusion equations can be thought of as an approximation to the solution of the P-1 equations. In most fast reactor problems, the error involved in reducing the Boltzmann transport equation to the P-1 equations exceeds that incurred by reducing the P-1 equations to the diffusion equations.

Diffusion theory has been historically the most widely used tool in reactor analysis. This is due to the generally simple structure of the equations, and the fact that sophisticated mathematical techniques exist for solving them. A detailed discussion of the approximations involved in reducing the transport equation to the diffusion equations is found in Ref. 2.

The time dependent multigroup diffusion equations, together with the delayed neutron precursor equations, can be written:²

$$\begin{aligned} \frac{1}{V_g} \frac{\partial}{\partial t} \phi_g(\underline{r}, t) &= \nabla \cdot D_g(\underline{r}, t) \nabla \phi_g(\underline{r}, t) - \sum_{g'=1}^G \Sigma_{gg'}(\underline{r}, t) \phi_{g'}(\underline{r}, t) \\ &+ \chi_{pg} \sum_{g'=1}^G (1 - \beta) \nu \Sigma_{fg'}(\underline{r}, t) \phi_{g'}(\underline{r}, t) \\ &+ \sum_{\ell=1}^L \chi_{dgl} \lambda_{\ell} C_{\ell}(\underline{r}, t) + Q_g(\underline{r}, t), \quad g=1, \dots, G \quad (\text{II.1a}) \end{aligned}$$

$$\begin{aligned} \frac{\partial}{\partial t} C_{\ell}(\underline{r}, t) &= -\lambda_{\ell} C_{\ell}(\underline{r}, t) + \sum_{g=1}^G \beta_g \nu \Sigma_{fg}(\underline{r}, t) \phi_g(\underline{r}, t), \quad \ell=1, \dots, L \quad (\text{II.1b}) \end{aligned}$$

where

- G is the total number of neutron energy groups
- L is the total number of delayed precursor groups
- $\phi_g(\underline{r}, t)$ is the neutron flux in group g at point $\underline{r}$ and time t ($\text{n/cm}^2 \text{ sec}$)
- $C_\ell(\underline{r}, t)$ is the density of the ℓ 'th delayed precursor at point $\underline{r}$ and time t (cm^{-3})
- $Q_g(\underline{r}, t)$ is the external neutron source in group g at point $\underline{r}$ and time t ($\text{n/cm}^3 \text{ sec}$)
- V_g is the neutron speed in group g (cm/sec)
- $D_g(\underline{r}, t)$ is the diffusion coefficient for group g at point $\underline{r}$ and time t (cm)
- $\Sigma_{gg'}(\underline{r}, t)$ is the macroscopic transfer cross section from g' to g at point $\underline{r}$ and time t (cm^{-1}), where
- $$\Sigma_{gg}(\underline{r}, t) = \Sigma_a(\underline{r}, t) + \sum_{g' \neq g} \Sigma_{s_{g'g}}(\underline{r}, t)$$
- $\Sigma_a(\underline{r}, t)$ is the macroscopic absorption cross section in group g at point $\underline{r}$ and time t (cm^{-1})
- $\Sigma_{s_{gg'}}(\underline{r}, t)$ is the macroscopic scattering cross section from group g' to g at point $\underline{r}$ and time t (cm^{-1})
- $$\Sigma_{s_{gg'}}(\underline{r}, t) = -\Sigma_{s_{gg'}}(\underline{r}, t), \quad g' \neq g$$
- χ_{pg} is the prompt fission spectrum in group g
- $\nu \Sigma_f(\underline{r}, t)$ is ν , the number of neutrons per fission, times the macroscopic fission cross section in group g at point $\underline{r}$ and time t (cm^{-1})
- β is the total fractional yield of delayed neutrons per fission
- λ_ℓ is the decay constant of the ℓ 'th group of delayed precursors
- χ_{dgl} is the fraction of group ℓ delayed neutrons which appear in neutron group g
- β_ℓ is the fraction of fissions which produce a delayed precursor of group ℓ .

If the material constants are known as a function of $\underline{r}$ and t , and if an initial flux distribution in energy and space is known, then a unique solution to Eqs. (II-1) may be obtained.

In Eqs. (II.1) above, the term $v\Sigma_{f,g}(\underline{r},t)$ should be considered as a sum over all fissionable isotopes. This summation will not be explicitly indicated for the remainder of this report.

B. Steady State Solution Strategies

B.1 Development of the Steady State Equations

The time-dependent multigroup diffusion equation (Eq.(II.1a)) constitutes a parabolic partial differential equation in space and time. To obtain a solution to this equation, the initial conditions $\phi_g(\underline{r},0)$ and $C_\ell(\underline{r},0)$ must be known. Generally, a nuclear reactor is assumed to be in a steady state condition at the time a reactor transient analysis is begun. This steady state situation can be achieved in two ways: the reactor can be exactly critical with no external source present, or it can be subcritical with an external source present. An exactly critical reactor is defined as one in which the total number of neutrons created per second by the fission process throughout the reactor exactly equals to the total number of neutrons lost per second by absorption and leakage out of the reactor. A subcritical reactor is one in which the number of the neutrons lost per second exceeds those created. Both situations (exactly critical, or subcritical with external source) lead to a steady state situation; that is one in which

$$\frac{\partial}{\partial t} \phi_g(\underline{r},0) = 0, \quad g=1, \dots, G \quad (\text{II.2a})$$

$$\frac{\partial}{\partial t} C_\ell(\underline{r},0) = 0, \quad \ell=1, \dots, L \quad (\text{II.2b})$$

Using Eqs. (II.2), we find that Eqs. (II.1) will reduce to

$$\begin{aligned} & -\nabla \cdot \underline{D}_g(\underline{r},0) \nabla \phi_g(\underline{r},0) + \sum_{g'=1}^G \Sigma_{gg'}(\underline{r},0) \phi_{g'}(\underline{r},0) \\ & = Q_g(\underline{r},0) + \chi_g \sum_{g'=1}^G v\Sigma_{f,g'}(\underline{r},0) \phi_{g'}(\underline{r},0), \quad g=1, \dots, G \end{aligned} \quad (\text{II.3})$$

where

$$\chi_g = \chi_{pg}(1-\beta) + \sum_{\ell=1}^L \chi_{dg\ell} \beta_\ell$$

If the external source $Q_g(\underline{r},0)$ is non zero, Eq. (II.3) is then an inhomogeneous equation, and possesses a unique solution provided the reactor is subcritical. If the external source $Q_g(\underline{r},0)$ is zero, Eq. (II.3) becomes a homogenous equation, and possesses a solution other than the trivial solution only if the reactor is exactly critical; or, more precisely, if the multigroup diffusion theory model used to calculate the reactor conditions predicts that the reactor is exactly critical.

In order to insure that a solution to Eq. (II.3) may always be found, if no external source is present the form of Eq. (II.3) is modified slightly by dividing ν , the number of neutrons per fission, by a number λ . The number λ can then be adjusted in such a way that the reactor model is made exactly critical; and a nontrivial solution found. Once this solution is found, a transient reactor analysis may be begun; with the adjusted value $\frac{\nu}{\lambda}$ used in place of ν in Eq. (II.1).

The value λ is included into Eq. (II.3) for the purpose of making the reactor model exactly critical. It is assumed that this operation will not grossly change the neutron flux distribution. This operation compensates for various errors in the reactor model; such as cross section errors, homogenization procedures, the use of the diffusion approximation, etc.

The equation which must be solved to determine the steady state reactor conditions is (omitting the time dependence)

$$\begin{aligned}
 & -\nabla \cdot \underline{D}_g(\underline{r}) \nabla \phi_g(\underline{r}) + \sum_{g'=1}^G \Sigma_{gg'}(\underline{r}) \phi_{g'}(\underline{r}) \\
 & = \frac{1}{\lambda} \chi_g \sum_{g'=1}^G \nu \Sigma_{fg'}(\underline{r}) \phi_{g'}(\underline{r}) + Q_g(\underline{r}), \quad g=1, \dots, G
 \end{aligned} \tag{II.4}$$

B.2. Spatial Discretization

Since the material constants in Eq. (II.4) are spatially dependent, it is generally not possible to solve Eq. (II.4) analytically over the domain of the entire reactor. To obtain a solution, Eq. (II.4) is discretized in space by the use of finite difference techniques. This procedure leads to a matrix eigenvalue problem which may be solved using conventional numerical methods.

To accomplish this discretization, a mesh is superimposed upon the two-dimensional reactor model. The mesh is constructed such that all material boundaries lie on the mesh lines. Thus, inside each mesh cell, the material is homogeneous. Eq. (II.4) is then integrated over the volume of each mesh cell. For mesh cell k , Eq. (II.4) becomes:

$$\begin{aligned}
 & \int_k \underline{J}_g(\underline{r}) \cdot d\underline{S} + \sum_{g'=1}^G \Sigma_{gg',k} \int_k \phi_{g'}(\underline{r}) dV \\
 & = \frac{1}{\lambda} \chi_g \sum_{g'=1}^G \nu \Sigma_{fg',k} \int_k \phi_{g'}(\underline{r}) dV \\
 & + \int_k Q_g(\underline{r}) dV \quad \begin{matrix} k=1, \dots, K; \\ g=1, \dots, G \end{matrix}
 \end{aligned}$$

where

$$\underline{J}_g(\underline{r}) = -D_g(\underline{r})\nabla\phi_g(\underline{r})$$

$D_{g,k}$ is the value of $D_g(\underline{r})$ in mesh cell k

$\Sigma_{gg',k}$ is the value of $\Sigma_{gg'}(\underline{r})$ in mesh cell k

$v\Sigma_{f,g,k}$ is the value of $v\Sigma_f(\underline{r})$ in mesh cell k (representing a sum over all fissionable isotopes)

The additional definitions are now made:

$$\bar{\phi}_{g,k} = \frac{1}{V_k} \int_k \phi_g(\underline{r}) dV$$

$$\bar{Q}_{g,k} = \frac{1}{V_k} \int_k Q_g(\underline{r}) dV$$

$$V_k = \int_k dV$$

From these definitions, the following equation is obtained:

$$\begin{aligned} \int_k \underline{J}_g(\underline{r}) \cdot d\underline{S} + \sum_{g'=1}^G V_k \Sigma_{gg',k} \bar{\phi}_{g',k} \\ = \frac{1}{\lambda} \chi_g \sum_{g'=1}^G V_k v\Sigma_{f,g',k} \bar{\phi}_{g',k} + \bar{Q}_{g,k} \quad k=1, \dots, K; \\ g=1, \dots, G \quad (\text{II.5}) \end{aligned}$$

To solve Eq. (II.5), relationships must be specified between the current

$\underline{J}_g(\underline{r})$ and the average fluxes $\bar{\phi}_{g,k}$. The technique used in FX2-TH leads to the "mesh-centered difference equations," which are the difference equations used in the computer programs VENTURE,³ DIF2D,⁴ DIF3D,⁵ and MEKIN.⁶ The difference equations for all geometries are derived in Ref. 4. The resulting equations can be written in the following matrix form:

$$\begin{aligned} [L_g] [\bar{\phi}_g] + [\Sigma_{r_g}] [\bar{\phi}_g] - \sum_{\substack{g'=1 \\ g' \neq g}}^G [\Sigma_{s_{gg'}}] [\bar{\phi}_{g'}] \\ = \frac{1}{\lambda} \chi_g \sum_{g'=1}^G [v\Sigma_{f,g'}]^T [\bar{\phi}_{g'}] + [\bar{Q}_g], \quad g=1, \dots, G \quad (\text{II.6}) \end{aligned}$$

Where

$[\bar{\phi}_g]$ is a column vector of length K consisting of the average neutron fluxes at every mesh cell for group g

$[\Sigma_{rg}]$ is a diagonal $K \times K$ matrix consisting of the macroscopic removal cross sections at all mesh cells for group g times the volume of the respective mesh cell.

$[\Sigma_{sgg'}]$ is a diagonal $K \times K$ matrix consisting of the macroscopic scattering cross sections at all mesh cells for scattering from group g' into group g times the volume of the respective mesh cell

$[v\Sigma_{fg}]$ is a column vector of length K consisting of ν , the number of neutrons per fission, times the macroscopic fission cross section at all mesh cells for group g times the volume of the respective mesh cell (this term represents a sum over all fissionable isotopes)

$[\bar{Q}_g]$ is a column vector of length K consisting of the integrated external source at all mesh cells for group g.

L_g is a banded $K \times K$ matrix consisting of the finite difference coefficients at all mesh cells for group g.

K is the total number of mesh cells.

B.3. Outer Iteration Strategies

If $[\bar{Q}_g]$ is zero, Eq. (II.6) is a homogeneous matrix eigenvalue problem. This problem may be solved by using the power method, in which we define:

$$[S_{g,\ell}] = \frac{1}{\lambda_\ell} \chi_g \sum_{g'=1}^G [v\Sigma_{fg'}]^T [\bar{\phi}_{g'}^\ell] \quad (II.7)$$

Where ℓ is the outer iteration index, and λ_ℓ and $[\bar{\phi}_{g'}^\ell]$ represent the current estimate of the eigenvalue and average fluxes, respectively, at the ℓ th outer iteration. Eq. (II.6) then becomes:

$$[L_g] [\bar{\phi}_g] + [\Sigma_{rg}] [\bar{\phi}_g] - \sum_{\substack{g'=1 \\ g' \neq g}}^G [\Sigma_{sgg'}] [\bar{\phi}_{g'}] = [S_{g,\ell}], \quad g=1, \dots, G \quad (II.8)$$

For outer iteration l , the sequence of calculations is then:

- a) Calculate $[S_{g,l}]$ for all groups g
- b) Solve the resulting inhomogeneous matrix equation (II.8) for all groups g
- c) Calculate a new estimate of the eigenvalue λ_l .

In FX2-TH, this convergent iterative process is accelerated by the use of Chebyshev polynomials applied to the fission source. This strategy has proven very successful for fast reactor problems, and is described in detail in Ref. 5.

For problems in which $[\bar{Q}_g]$ is not zero, the parameter λ is set to a user-specified value (whose default value is one). Eq. (II.6) is then solved as an inhomogeneous problem. The solution strategy, however, is very similar to the one used for the homogeneous problem. A fission source is calculated at each "outer" iteration, the fixed source is added, and the resulting matrix equations are solved. The iteration is accelerated by applying Chebyshev polynomials to the fission sources, as was done for the homogeneous case. The solution strategies are described in detail in Ref. 5.

B.4. Inner Iteration Strategies

In FX2-TH, no "up-scattering" is allowed (that is, $[\Sigma_{s_{gg'}}]$ is zero for all groups $g' > g$). Thus the solution of Eq. (II.8) involves a single sweep through the energy groups $g=1, \dots, G$. At each group g , an inhomogeneous matrix equation must be solved. The particular structure of the $[L_g]$ matrix depends on the geometry of the problem, however $[L_g]$ is always a very sparse, symmetric matrix with a regular structure. For two dimensional orthogonal geometries, for example, $[L_g]$ is a five striped block tri-diagonal matrix. Due to the sparseness of the matrix and the large number of unknowns, iterative methods are generally used to solve matrix problems such as (II.8). The particular technique used in FX2-TH is called the "successive line over-relaxation" method, and is a variant of the accelerated Gauss-Seidel iterative method. The same technique is used in the DIF3D⁵ program; the details of this scheme are fully described in Ref. 5.

B.5. Solution of the Adjoint Flux Equations

FX2-TH uses the improved quasistatic method¹ to calculate the time dependent neutron fluxes. This method requires that the adjoint neutron fluxes be calculated. The adjoint flux required, $[\bar{\phi}_g^*]$, is the solution of the following equation:

$$\begin{aligned}
& [L_g] [\bar{\phi}_g^*] + [\Sigma_{r_g}] [\bar{\phi}_g^*] - \sum_{\substack{g'=1 \\ g' \neq g}}^G [\Sigma_{s_{g'g}}] [\bar{\phi}_{g'}^*] \\
& = \frac{1}{\lambda^*} [\nu \Sigma_{f_g}] \sum_{g'=1}^G \chi_{g'} [\bar{\phi}_{g'}^*], \quad g=1, \dots, G
\end{aligned} \tag{II.9}$$

The same adjoint flux $[\bar{\phi}_g^*]$ is calculated independent of whether or not a fixed source is present. It can be seen that Eq. (II.9) is obtained by taking the transpose of the matrix operator which Eq. (II.6) represents. This is called the "physicist's adjoint" (the complex conjugate of the transpose) rather than the "mathematician's adjoint" (the transpose of the matrix of co-factors). This adjoint operator was first introduced by Wigner. The motivation behind the use of this particular form of the adjoint will be discussed in Section C of this Chapter.

C. Time Dependent Solution Strategies

C.1. Characteristics of the Time Dependent Problem

The solution of the time dependent multigroup diffusion equations is a very formidable problem. Once a steady-state flux distribution has been obtained, Eqs. (II.1) must be integrated in time to determine the transient solution. One immediate difficulty with this procedure is the non-linearity introduced by the presence of thermal and hydraulic feedback. This non-linearity will be discussed in detail in Chapter IV. Another major difficulty lies in the range of time constants present in Eqs. (II.1). The very short time constants present in the neutron flux equations requires that small time steps be taken to integrate them accurately. However, very often the interesting period of a reactor transient can stretch over a period of seconds, thus requiring a very large number of time steps.

The time dependent multigroup diffusion equations are thus difficult to solve first because of the large number of unknowns to be calculated, and secondly because of the large number of time steps for which these unknowns must be calculated.

A number of methods have been proposed for solving the time-dependent multigroup diffusion equations. These methods can be divided into two major categories. The first class of solution methods, here called synthesis methods, attempt to dramatically reduce the number of unknowns in the problem by using expansions of the solution in known functions. The second class of solution methods, here called space-time methods, retain the full structure of the equations and attempt to directly integrate them by one scheme or another.

Several space-time methods have been developed which have proven successful for solving the diffusion equations. These methods often are long-running even on today's high-speed computers; therefore, where applicable the less costly synthesis methods are preferable. For use in FX2-TH, a method

called the Improved Quasistatic Method is used. This method will be shown to be a variation of the Points Kinetics Method.

The Point Kinetics Method is one of the simplest of the synthesis methods. This method, which will be developed in the next section, assumes that the shape of the neutron flux distribution (in space and energy) does not change significantly over the course of a reactor transient. If this assumption is valid, the full space-time equations can be reduced to $(1 + L)$ coupled ordinary differential equations in time.

Unfortunately, very few reactor transients involve no significant spatial or spectral changes. However, it is possible to significantly improve the Point Kinetics Method by using different approximations to the neutron flux shape at different times during the reactor transient. If these shape functions are the result of a series of static calculations representing various reactor conditions during the transient, the resulting method is called the Adiabatic Method.⁷ If the shape functions are calculated in tandem with the actual point kinetics solution, the method is called the Quasistatic Method.¹ This method, used in the FX2-TH code, will be described in the next two sections.

C.2. Development of the Point Kinetics Equations

To begin the derivation of the point kinetics equations, Eqs. (II.1) will be rewritten in a more compact matrix notation:

$$\begin{aligned} \underline{\nabla} \cdot [\underline{D}(\underline{r}, t)] \underline{\nabla} [\underline{\phi}(\underline{r}, t)] - [\underline{A}(\underline{r}, t)] [\underline{\phi}(\underline{r}, t)] \\ + \frac{1}{\lambda_k} (1-\beta) [\chi_p] [\nu \Sigma_f(\underline{r}, t)]^T [\underline{\phi}(\underline{r}, t)] + \sum_{\ell=1}^L \lambda_{\ell} C_{\ell}(\underline{r}, t) [\chi_{\ell}] + [\underline{Q}(\underline{r}, t)] \\ = [\underline{V}]^{-1} \frac{\partial}{\partial t} [\underline{\phi}(\underline{r}, t)] \end{aligned} \quad (\text{II.10a})$$

$$\frac{1}{\lambda_k} \beta_{\ell} [\nu \Sigma_f(\underline{r}, t)]^T [\underline{\phi}(\underline{r}, t)] - \lambda_{\ell} C_{\ell}(\underline{r}, t) = \frac{\partial}{\partial t} C_{\ell}(\underline{r}, t), \quad \ell=1, \dots, L \quad (\text{II.10b})$$

where

$$[\underline{D}(\underline{r}, t)] = \text{diag} \{ D_1(\underline{r}, t), D_2(\underline{r}, t), \dots, D_G(\underline{r}, t) \}$$

$$[\underline{\phi}(\underline{r}, t)] = \text{col} \{ \phi_1(\underline{r}, t), \phi_2(\underline{r}, t), \dots, \phi_G(\underline{r}, t) \}$$

$$[A(\underline{r}, t)] = \begin{bmatrix} \Sigma_{11}(\underline{r}, t) & 0 & \dots & 0 \\ -\Sigma_{s21}(\underline{r}, t) & \Sigma_{22}(\underline{r}, t) & \dots & \dots \\ \vdots & \vdots & \ddots & \vdots \\ -\Sigma_{sG1}(\underline{r}, t) & \dots & \dots & \Sigma_{GG}(\underline{r}, t) \end{bmatrix}$$

$$[\chi_p] = \text{col} \{ \chi_{p1}, \chi_{p2}, \dots, \chi_{pG} \}$$

$$[v\Sigma_f(\underline{r}, t)] = \text{col} \{ v\Sigma_{f1}(\underline{r}, t), v\Sigma_{f2}(\underline{r}, t), \dots, v\Sigma_{fG}(\underline{r}, t) \}$$

$$[\chi_\ell] = \text{col} \{ \chi_{d1\ell}, \chi_{d2\ell}, \dots, \chi_{dG\ell} \}$$

$$[Q(\underline{r}, t)] = \text{col} \{ Q_1(\underline{r}, t), Q_2(\underline{r}, t), \dots, Q_G(\underline{r}, t) \}$$

$$[V] = \text{diag} \{ V_1, V_2, \dots, V_G \}$$

$$\lambda_k \begin{cases} \text{is the critical eigenvalue } \lambda \text{ of Eq. (II.4) if no external} \\ \text{source is present} \\ \text{is unity if an external source is present} \end{cases}$$

The term $v\Sigma_f(\underline{r}, t)$ represents a sum over all the fissionable isotopes.

An arbitrary column vector weight function $[W(\underline{r})]$ is now defined:

$$[W(\underline{r})] \equiv \text{col} \{ W_1(\underline{r}), W_2(\underline{r}), \dots, W_G(\underline{r}) \}$$

Next define $T(t)$ to be the following weighted integral:

$$T(t) \equiv \int [W(\underline{r})]^T [V]^{-1} [\phi(\underline{r}, t)] dV \quad (\text{II.11})$$

The function $T(t)$ is often referred to as the "amplitude function", since it is anticipated that it will determine the primary time dependence of the solution $[\phi(\underline{r}, t)]$.

A column vector shape function is now defined:

$$[S(\underline{r}, t)] \equiv T(t)^{-1} [\phi(\underline{r}, t)] \quad (\text{II.12})$$

such that

$$\int [W(\underline{r})]^T [V]^{-1} [S(\underline{r}, t)] dV = 1 \quad (\text{II.13})$$

To obtain an equation for $T(t)$, replace $[\phi(\underline{r}, t)]$ by $T(t) [S(\underline{r}, t)]$, multiply the row vector $[W(\underline{r})]^T$ into Eq. (II.10a), and integrate over the volume of the vector. To reduce the precursor equations (II.10b), multiply by $[W(\underline{r})]^T [\chi_\ell]$ and integrate over the volume of the reactor. These operations lead to the following equations:

$$\begin{aligned} \frac{d}{dt} T(t) = & \left\{ \frac{\rho(t) - \beta(t)}{\Lambda(t)} - \frac{\lambda_s^{-1}}{\lambda_s \Lambda(t)} \right\} T(t) \\ & + \sum_{\ell=1}^L \lambda_\ell C_\ell(t) + Q(t) \end{aligned} \quad (\text{II.14a})$$

$$\frac{d}{dt} C_\ell(t) = \frac{\beta_\ell(t)}{\Lambda(t)} T(t) - \lambda_\ell C_\ell(t), \quad \ell=1, \dots, L \quad (\text{II.14b})$$

where

$$\lambda_s \begin{cases} \text{is unity if there is no external source} \\ \text{is the critical eigenvalue } \lambda^* \text{ of Eq. (II.9) if} \\ \text{an external source is present} \end{cases}$$

$$C_\ell(t) = \frac{\int [W(\underline{r})]^T [\chi_\ell] C_\ell(\underline{r}, t) dV}{\int [W(\underline{r})]^T [V]^{-1} [S(\underline{r}, t)] dV} \quad (\text{II.14c})$$

$$Q(t) = \frac{\int [W(\underline{r})]^T [Q(\underline{r}, t)] dV}{\int [W(\underline{r})]^T [V]^{-1} [S(\underline{r}, t)] dV} \quad (\text{II.14d})$$

$$\begin{aligned} F(t) = & \int [W(\underline{r})]^T \left\{ (1-\beta) [\chi_p] + \sum_{\ell=1}^L \beta_\ell [\chi_\ell] \right\} \\ & \frac{1}{\lambda_k} [\nu \Sigma_f(\underline{r}, t)]^T [S(\underline{r}, t)] dV \end{aligned} \quad (\text{II.14e})$$

$$\rho(t) = \frac{1}{F(t)} \int [W(\underline{r})]^T \left\{ \underline{\nabla} \cdot [D(\underline{r}, t)] \underline{\nabla} [S(\underline{r}, t)] - [A(\underline{r}, t)] [S(\underline{r}, t)] + \left((1-\beta) [\chi_p] + \sum_{\ell=1}^L \beta_{\ell} [\chi_{\ell}] \right) \frac{1}{\lambda_k \lambda_s} [v\Sigma_f(\underline{r}, t)]^T [S(\underline{r}, t)] \right\} dV \quad (\text{II.14f})$$

$$\Lambda(t) = \frac{1}{F(t)} \int [W(\underline{r})]^T [V]^{-1} [S(\underline{r}, t)] dV \quad (\text{II.14g})$$

$$\beta_{\ell}(t) = \frac{1}{F(t)} \int [W(\underline{r})]^T \frac{1}{\lambda_k} \beta_{\ell} [\chi_{\ell}] [v\Sigma_f(\underline{r}, t)]^T [S(\underline{r}, t)] dV \quad (\text{II.14h})$$

$$\beta(t) = \sum_{\ell=1}^L \beta_{\ell}(t) \quad (\text{II.14i})$$

The term λ_s was introduced such that the reactivity $\rho(0)$ would equal zero for the case with an external source.

In most reactor transients, spatial and spectral changes in $[S(\underline{r}, t)]$ have a fairly small effect on the value of terms such as $\beta_{\ell}(t)$ and $\Lambda(t)$.

The reactivity ($\rho(t)$), however, is sensitive to such changes since its numerator is a difference of two quantities which are almost equal. Therefore, it is of prime importance to minimize errors in $\rho(t)$ resulting from the fact that an approximation to the shape function will be used in practice. The weight function $[W(\underline{r})]$ is chosen in such a way that first order errors in $[S(\underline{r}, t)]$ are eliminated. This is accomplished by using the time-independent adjoint flux $[\bar{\phi}_g^*]$ (the solution of Eq. (II.9)) as the weight function.²

The Point Kinetics Equations derived in this section are the most widely used equations in the field of reactor kinetics. They can be derived from the multigroup diffusion equations (or from the transport equation) with no approximations. In practice, their accuracy depends on the method used to calculate $\beta_{\ell}(t)$, $\Lambda(t)$, and especially $\rho(t)$. The accuracy of $\rho(t)$ is primarily dependent on the accuracy of the shape function $[S(\underline{r}, t)]$. In the next section, an accurate method for the calculation of the shape function will be described.

C.3. Development of the Quasistatic Method

The Quasistatic Method¹⁸ can be thought of as a solution to the point kinetics equations in which the shape functions used to calculate the point kinetics parameters are calculated in tandem with the point kinetics solution. This method will be shown to be derived from the factorization defined in Eq. (II.12), and to be capable of reproducing the results of an exact temporal integration of Eqs. (II.10) in the limit of small time steps. Therefore, the quasistatic method achieves the dramatic reduction in the number of unknowns characteristic of a synthesis method, and also possesses the reliability of a full space-time method.

The following factorization is defined:

$$[\phi(\underline{r}, t)] \equiv T(t) [S(\underline{r}, t)] \quad (\text{II.12})$$

This equation is substituted into Eq. (II.10a) to yield:

$$\begin{aligned} \underline{\nabla} \cdot [D(\underline{r}, t)] \underline{\nabla} [S(\underline{r}, t)] - [A(\underline{r}, t)] [S(\underline{r}, t)] \\ - [V]^{-1} T(t)^{-1} \frac{\partial}{\partial t} T(t) [S(\underline{r}, t)] + \frac{1}{\lambda_k} (1-\beta) [\chi_p] [v\Sigma_f(\underline{r}, t)]^T [S(\underline{r}, t)] \\ + \sum_{\ell=1}^L \lambda_{\ell} T(t)^{-1} C_{\ell}(\underline{r}, t) [\chi_{\ell}] + T(t)^{-1} [Q(\underline{r}, t)] \\ = [V]^{-1} \frac{\partial}{\partial t} [S(\underline{r}, t)] \end{aligned} \quad (\text{II.15})$$

In the quasistatic method, Eqs. (II.14) are solved to determine the primary temporal behavior of the solution. At various times during the transient, Eq. (II.15) is solved to calculate a new shape function $[S(\underline{r}, t)]$. Therefore, two basic time step units are required. A reactivity step is a unit of time over which Eqs. (II.14) are solved given a certain known set of point kinetics parameters. A shape step is a unit of time, typically several reactivity steps long, which elapses between solutions of Eq. (II.15); that is, between shape re-calculations. The next sections will describe these calculations in more detail.

C.4. Reactivity Step Calculation Sequence

C.4.a. Reactivity Step Initialization

Across a reactivity step, the point kinetics equations (Eqs. (II.14a, b)) and the thermal-hydraulics equations (see Chapter III) are solved. Although these equations are nonlinear, they are solved in tandem across each reactivity step. This approach has proved successful for several multidimensional space-time kinetics programs.^{6,9,10} In addition to these computations, several other initialization procedures are performed at the beginning of each reactivity step. These computations are described below. Figure 1 shows a flow chart of the calculations performed at each reactivity step.

Fig. 1

Sequence of Calculations During a Reactivity Step

The length of the reactivity step is first calculated. The selection of the step sizes is based on how rapidly system parameters are changing. The selection criteria for both shape steps and reactivity steps are discussed in Section II.C.6. The first reactivity step in a transient is computed as a user-specified factor times the prompt neutron lifetime. The first shape step is chosen to be this same length, thus forcing a shape calculation at the end of the first reactivity step of the transient.

C.4.b. Shape Function Estimation

In order to evaluate the point kinetics parameters (Eqs. (II.14 f,g,h,i)), an estimate of the shape function is required. In FX2-TH, the shape is assumed to vary linearly between shape calculations. Therefore, the shape functions obtained by the solution of Eq. (II.15) at two previous shape calculations are linearly extrapolated to obtain the required shape function. Let t_j be the time at the beginning of shape step j . The shapes $[S(\underline{r},t)]$ calculated at times t_{j-1} and t_j are used to extrapolate the shape to form the shape estimate at $t_{j,i+1}$ used for reactivity step i . Figure 2 shows the relationship of these time step levels.

To calculate the thermal-hydraulic conditions at the end of the reactivity step, an estimate of the amplitude function during the reactivity step is required. The amplitude values calculated at times $t_{j,i-2}$, $t_{j,i-1}$, and $t_{j,i}$ are fit to a quadratic function; and this quadratic is integrated from $t_{j,i}$ to $t_{j,i+1}$ to calculate the average value of the amplitude over this reactivity step.

Δt_s = SHAPE STEP LENGTH

$\Delta t_{s,r}$ = REACTIVITY STEP LENGTH

Fig. 2. Time Step Levels

C.4.c. Volume Fraction Calculation

The volume fractions appropriate for this reactivity step are next calculated. Volume fractions can be changed during the transient by use of driving functions. A driving function forces the volume fraction of some material m in a region e , $VF(e, m, t)$ to change over a time interval from t_{ST} to t_{SP} according to the formula

$$VF(e, m, t) = VF(e, m, t_{ST}) + CL \cdot (t - t_{ST}) + CQ \cdot (t - t_{ST})^2, (t_{ST} \leq t \leq t_{SP}).$$

The user may set $t_{ST} = t_{SP}$, in which case CL is added to VF in a stepwise fashion at time t_{ST} , as $VF(e, m, t) = VF(e, m, t_{ST}) + CL, (t > t_{ST})$.

The driving functions are used to start and modify a transient.

The thermal-hydraulic conditions for this reactivity step are next calculated. The details of the thermal-hydraulic models are given in Chapter III. Next, with the volume fractions and thermal-hydraulic conditions known, the macroscopic cross sections for this reactivity step can be calculated. Details of the dependence of the macroscopic cross sections on temperatures are given in Chapter IV.

C.4.d. Point Kinetics Equation Solution

Using the estimated shape function, the cross sections, and volume fractions, the point kinetics parameters (Eqs. (II.14 f,g,h,i)) are then calculated. The point kinetics equations (Eqs. (II.14a,b)) may then be integrated over this reactivity step. The integration technique used is an extension¹¹ of a method originally devised by Kaganove.¹² The method involves a scheme for integrating the point kinetics equations over subdivisions of the reactivity step. An automatic time step halving and doubling scheme is used to achieve a specified precision.

C.4.e. Pointwise Precursor Density

After the amplitude function has been calculated, the pointwise precursor densities may be updated. Rewriting Eq. (II.10b):

$$\frac{\beta_\ell}{\lambda_k} [\nu \Sigma_f(\underline{r}, t)]^T [\phi(\underline{r}, t)] - \lambda_\ell C_\ell(\underline{r}, t) = \frac{\partial}{\partial t} C_\ell(\underline{r}, t), \quad \ell=1, \dots, L \quad (\text{II.10b})$$

where

L is the total number of delayed precursor groups

This equation is integrated from $t_{j,i}$ to $t_{j,i+1}$ to obtain:

$$\begin{aligned} C_\ell(\underline{r}, t_{j,i+1}) &= C_\ell(\underline{r}, t_{j,i}) \exp(-\lambda_\ell \Delta t_{j,i}) \\ &+ \int_{t_{j,i}}^{t_{j,i+1}} \frac{\beta_\ell}{\lambda_k} [\nu \Sigma_f(\underline{r}, t)]^T [S(\underline{r}, t)] T(t) \cdot \\ &\quad \exp[\lambda_\ell(t_{j,i+1} - t)] dt, \quad \ell=1, \dots, L \end{aligned} \quad (\text{II.16})$$

where

$$\Delta t_{j,i} = t_{j,i+1} - t_{j,i}$$

$$[\phi(\underline{r}, t)] = [S(\underline{r}, t)] T(t)$$

In order to evaluate the integral in Eq. (II.16), it is assumed that the product $[\nu \Sigma_f(\underline{r}, t)]^T [S(\underline{r}, t)]$ is a linear function of time over the reactivity step. Therefore, the integral can be replaced by a sum of two terms each involving a known estimate of $[\nu \Sigma_f(\underline{r}, t)]^T [S(\underline{r}, t)]$ at an endpoint of $\Delta t_{j,i}$; therefore:

$$\begin{aligned} C_\ell(\underline{r}, t_{j,i+1}) &= C_\ell(\underline{r}, t_{j,i}) \exp(-\lambda_\ell \Delta t_{j,i}) \\ &+ I_1^\ell + I_2^\ell, \quad \ell=1, \dots, L \end{aligned} \quad (\text{II.17a})$$

where

$$\begin{aligned} I_1^\ell &= \frac{\beta_\ell}{\Delta t_{j,i} \lambda_k} [\nu \Sigma_f(\underline{r}, t_{j,i})]^T [S(\underline{r}, t_{j,i})] \cdot \\ &\quad \int_{t_{j,i}}^{t_{j,i+1}} T(t) \exp[-\lambda_\ell(t_{j,i+1} - t)] \cdot (t_{j,i+1} - t) dt \end{aligned} \quad (\text{II.17b})$$

$$I_2^{\ell} = \frac{\beta_{\ell}}{\Delta t_{j,i} \lambda_k} [\nu \Sigma_f(\underline{r}, t_{j,i+1})]^T [S(\underline{r}, t_{j,i+1})] \cdot$$

$$\int_{t_{j,i}}^{t_{j,i+1}} T(t) \exp [-\lambda_{\ell}(t_{j,i+1} - t)] (t - t_{j,i}) dt \quad (II.17c)$$

The integrals in Eqs. (II.17b,c) are evaluated by numerical integration in which $T(t)$ is expressed as a piecewise quadratic function over the subsets.¹¹ This completes the calculations required for this reactivity step.

C.5. Shape Step Calculation Sequence

After each reactivity step is completed, FX2-TH determines if a shape calculation should be performed at this point. These tests are described in Section II.C.6. To calculate a new shape function, Eq. (II.15) must be solved. This is done by using the fully implicit time integration method.¹³

When this method is applied to Eq. (II.15), the following equation is obtained:

$$[B] [S] - [F] [S] = [W] \quad (II.18a)$$

where

$$[S] = [S(\underline{r}, t_{j+1})] \quad (II.18b)$$

$$[B] = \left\{ \begin{array}{l} -\underline{\nabla} \cdot [D(\underline{r}, t_{j+1})] \underline{\nabla} + [A(\underline{r}, t_{j+1})] \\ + [V]^{-1} T(t_{j+1})^{-1} \frac{\partial}{\partial t} T(t_{j+1}) + \frac{1}{\Delta t_j} [V]^{-1} \end{array} \right\} \quad (II.18c)$$

$$[F] = \frac{1}{\lambda_k} (1-\beta) [\chi_p] [\nu \Sigma_f(\underline{r}, t_{j+1})]^T \quad (II.18d)$$

$$[W] = \sum_{\ell=1}^L \lambda_{\ell} T(t_{j+1})^{-1} C_{\ell}(\underline{r}, t_{j+1}) [\chi_{\ell}] \\ + T(t_{j+1})^{-1} [Q(\underline{r}, t_{j+1})] + \frac{1}{\Delta t_j} [V]^{-1} [S(\underline{r}, t_j)] \quad (II.18e)$$

and L is the total number of delayed neutron families.

The amplitude function $T(t_{j+1})$ is known from the solution of the point kinetics equations, its time derivative at t_{j+1} is known from evaluating the right hand side of Eq. (II.14a). The pointwise precursor densities are known from the solution of Eqs. (II.17). Therefore, Eq. (II.18a) can be solved for the shape function $[S]$.

For the remainder of this Section, the variables of interest will be written as continuous functions of $\underline{r}$. In the FX2-TH program; these variables are spatially discretized as described in Section II.B.2. This leads to matrix problems which are solved numerically.

During the sequence of reactivity steps, the estimate of the shape function used to calculate the point kinetics parameters was made by linearly extrapolating the results of two preceding shape function calculations. The new shape function $[S(\underline{r}, t_{j+1})]$ will not, in general, be equal to the linearly extrapolated shape function used to calculate the point kinetics parameters.

Therefore, an iterative procedure called the "shape step iteration" will be performed. This iteration will consist of first re-calculating the point kinetics solution at each reactivity step within this shape step. This re-calculation is performed by approximating the time dependence of the

point kinetics parameters $\frac{\rho}{\Lambda}$, $\frac{\beta}{\Lambda}$, $\frac{1}{\Lambda}$, and $\frac{\beta \lambda}{\Lambda}$ as being linear over the shape step. Let n denote the shape step iteration index; and h^n denote the n iteration value of any of the above ratios. Then

$$h^n(t_{j,i}) = h^1(t_{j,i}) + \alpha(t_{j,i}) [h^n(t_{j+1}) - h^1(t_{j+1})]$$

where

$$\alpha(t_{j,i}) = \frac{t_{j,i} - t_j}{t_{j+1} - t_j}$$

The ratios $h^1(t_{j,i})$ and $h^1(t_{j+1})$ are already known and $h^n(t_{j+1})$ is found using the n^{th} shape estimate $[S^n(\underline{r}, t_{j+1})]$. For the purposes of the shape step iteration, it is assumed that the thermal-hydraulic effects and pointwise precursor densities calculated during the first sequence of reactivity steps are sufficiently accurate.

The second portion of the shape step iteration is a recalculation of the shape function using the newly calculated values of $T(t_{j+1})$ and its time derivative. Eq. (II.18a) is solved to calculate the $(n+1)^{\text{th}}$ estimate of the shape function.

In the development of the quasistatic method, it was observed that for some problems the solution of Eq. (II.18a) poses numerical difficulties. When the system approaches prompt critical, $T(t_{j+1})$ becomes very large.

In addition, for typical shape step sizes the operator $\frac{1}{\Delta t_j} [V]^{-1}$ is small compared to the magnitude of $[B]$ and $[F]$. Therefore, the term $[W]$ becomes very small, and Eq. (II.18a) becomes almost homogeneous. In that case, the coefficient matrix $([B] - [F])$ becomes almost singular, and the iterative convergence very slow.

To mitigate these effects, Eq. (II.18a) is modified to resemble an eigenvalue problem

$$[B] [S] = \frac{1}{\gamma} [F] [S] + [W]$$

where γ is a scalar.

Letting m be the outer iteration index, the equation solved to calculate the $(n+1)^{th}$ shape estimate is:

$$[B^n] [S^{n+1,m}] = \frac{1}{\gamma^{n+1,m}} [F^n] [S^{n+1,m}] + [W^n] \quad (II.19a)$$

where

$$\gamma^{n+1,m} = \int_V [\phi^*(\underline{r})]^T [V]^{-1} [S^{n+1,m}] dV \quad (II.19b)$$

The converged solution of Eq. (II.19a), divided by γ^{n+1} (to satisfy the constraint condition), is used as the new shape estimate.

The solution of Eq. (II.19a) uses the same numerical strategies as the steady-state solution with a nonzero external source. These solution strategies are described in detail in Ref. 5.

After the new shape function is calculated by solving Eq. (II.19a), the point kinetics equations are re-solved over each reactivity step in this shape step as described above. When this calculation is complete, the value γ^n calculated for the n^{th} shape step iteration is examined. If the amplitude $T(t_{j+1})$ and its time derivative used in forming $[B]$ and $[W]$ are "correct" (in the sense that they form a correct solution to the coupled set of equations (II.14) and (II.15)), then the value γ^n calculated above will be unity. If γ^n is within a user-specified value of being unity, then this shape step is completed; and a new shape step is begun. If γ^n is not sufficiently close to unity, Eq. (II.19a) is re-solved using the newly calculated values of $T(t_{j+1})$ and its time derivative. The shape step iteration procedure then continues until either a converged value γ^n is found, or until a user-specified number of shape step iterations are

completed. The convergence of γ^n to unity with shape step iteration is generally very rapid; the quantity $|\gamma^n - 1|$ is usually reduced by an order of magnitude with each iteration. Figure 3 shows a detailed flowchart of the transient solution strategy for FX2-TH.

Fig. 3. Flowchart of Transient Calculations

The shape step iteration procedure can be seen to be a convergent method of simultaneously solving Eqs. (II.14) and (II.15). The only approximations made are those previously noted; that the thermal-hydraulic effects and pointwise precursor densities calculated during the first reactivity steps pass are sufficiently accurate. In the limit of small reactivity and shape step lengths, FX2-TH can be expected to reproduce the results of an exact temporal numerical integration.

In summary, the calculational sequence at a shape step is divided into two sections. First, for each reactivity step within this shape step the point kinetics equations and thermal-hydraulics equations are solved in tandem (see Figure 1). The second part involves only solutions of the point kinetics equations (Eq.(II.14a,b)) and the shape equation (Eq.(II.19a)). These equations are solved until a converged solution is reached; that is, until γ^n is acceptably close to unity (see Figure 3).

C.6. Selection of Time Steps

The purpose of the time step selection algorithm is to provide acceptably accurate results for the lowest computation cost. Ultimately, the user must determine the acceptability of a certain solution. Therefore, FX2-TH allows the user to input a number of parameters which determine maximum allowable changes in certain system parameters. Through these input variables, the user is able to control the time step selection.

In the vicinity of prompt critical, it has been found desirable to reduce the user-specified limits by a calculated factor. This factor is

$$f = 1.0 - (1.0 - f_{\min}) \exp \left[-\frac{1}{2} \left(\frac{\rho - \beta}{\beta \sigma} \right)^2 \right]$$

where $f_{\min}$, the minimum value of f , is an input parameter. The constant σ is such that the exponential equals 0.5 when

$$\frac{|\rho - \beta|}{\beta} = 0.277.$$

C.6.a. Shape Step Selection Criteria

The shape step criteria are tested at two points in the program; at the beginning of each shape step, and at the end of each reactivity step. The shape step length is then taken as the largest time interval which meets all of the required constraints.

At the beginning of each shape step (other than the first) the program computes three step lengths implied by maximum allowable parameter magnitudes or changes. The smallest of these values is found, and tested for compliance with two more constraints.

The shape step size, $\Delta t_j^{(1)}$, implied by the maximum allowed change in the flux shape is estimated by assuming that the shape function is a linear function from t_{j-1} to t_{j+1} . The expression for $\Delta t_j^{(1)}$ is

$$\frac{\max_{\underline{r}, g} \left| \frac{[S(\underline{r}, t_j)] - [S(\underline{r}, t_{j-1})]}{\bar{S}} \right|}{\Delta t_{j-1}} = \frac{\delta S_{SH} f}{\Delta t_j (1)}$$

where $[S(\underline{r}, t_j)]$ is the shape function at $\underline{r}$ at time t_j for all groups $g=1, \dots, G$, $\bar{S}$ is the average shape element over all groups and points, and δS_{SH} is the maximum allowed change over a shape step in the point and group-dependent relative shape function.

The second shape step length is $\Delta t_j^{(2)} = \delta t_{SH}$, where δt_{SH} an input maximum shape step length. Finally, the shape step must not be more than ten times the previous shape step length; more precisely

$$\Delta t_j^{(3)} = 10 \Delta t_{j-1} \frac{f_j}{f_{j-1}}$$

where f_{j-1} is the reduction factor at the last shape step selection.

If the problem end time, $t=t_{END}$, falls within the smallest of the three step lengths, Δt_j , then this step length is reduced such that $t_{j+1} = t_{END}$. Finally, if t_{ST} and t_{SP} of a driving function are equal and if this time falls within Δt_j , then the shape step is made to end at t_{ST} . Thus, stepwise driving functions can be used to force shape steps to end at predetermined times.

The shape step will be terminated at the end of a reactivity step if any of five constraints are violated at that point. First, the shape step is ended if the current time coincides with the end time predicted at the beginning of the shape step. Second, a fuel temperature change over the step exceeding an input maximum will terminate the step. Third, the step is ended if the amplitude change thus far over the shape step does not satisfy the inequality:

$$-\frac{10}{\delta T_{SH}} \leq \frac{T(t_{j+1})}{T(t_j)} \leq \frac{10}{\delta T_{SH}},$$

where δT_{SH} is an input parameter. Fourth, the step is ended if the fixed source was altered at the beginning of this reactivity step. Finally, the number of reactivity steps in the shape step must not exceed an input maximum number.

C.6.b. Reactivity Step Selection Criteria

To determine the reactivity step length, the program computes four step lengths implied by maximum allowed magnitudes or changes

in parameters. The smallest of these lengths is selected and is checked against four additional constraints.

The first step length is two times the previous step length,

$$\Delta t_{j,i}^{(1)} = 2 \Delta t_{j,i-1} \frac{f}{f_{i,j-1}}.$$

The second limit is an input maximum reactivity step length.

The fuel temperature rise over the reactivity step is restricted to be not more than the input value δT_{RH} . For the purposes of calculating the reactivity step length, the temperature rise is assumed to be proportional to the fission energy released over the time interval. The energy released is approximated by a constant times the amplitude at the beginning of the interval times the time interval. The expression for the fuel-temperature limited step length is

$$\frac{\max_k [T_{f,k}(t_{j,i}) - T_{f,k}(t_{j,i-1})]}{T(t_{j,i-1}) (t_{j,i} - t_{j,i-1})} = \frac{\delta T_{RH} f}{T(t_{j,i}) \Delta t_{j,i}}$$

where $T_{f,k}(t_{j,i})$ is the fuel temperature in mesh cell k at time $t_{j,i}$.

An amplitude-limited step length is determined by the requirement that the amplitude change over the reactivity step must satisfy the inequality

$$-\frac{10}{\delta N_{RH}} \leq \frac{T(t_{j,i+1})}{T(t_{j,i})} \leq \frac{10}{\delta N_{RH}}$$

where δN_{RH} is an input parameter. The time step required is obtained by approximating the amplitude function by a quadratic and linearizing the resulting expression.

The smallest of the four limiting step lengths is used as the reactivity step if it does not contain any of the following times:

- 1) t_{ST} or t_{SP} of a driving function,
- 2) the endpoint of a shape step predicted at the beginning of the shape step,
- 3) the time that the external source is to be modified, and
- 4) the problem end time.

If the time step contains any of these times, then the step length is adjusted so that the smallest of the times which fell within the step becomes the endpoint of the step.

III. THERMAL-HYDRAULICS EQUATIONS AND THEIR SOLUTION

The objective of the thermal-hydraulics models present in FX2-TH is to provide realistic reactor feedback calculations for off-normal conditions. For LMFBR applications, accurate pre-disassembly feedback is desired. The models described in this chapter are intended to provide the required feedback without a large expense in computation time.

Two basic models will be described in this chapter. The first model, called the "adiabatic" model, has two variations; and is used to calculate transient fuel temperatures only. The second model, called the "detailed" model, calculates steady-state and transient fuel and coolant temperatures.

In order to solve the multigroup diffusion equations, the reactor volume was divided into "mesh cells" (Section III.B.2). For the solution of the thermal-hydraulics equations, an additional spatial grid is placed over the mesh cell grid to define thermal-hydraulics regions. A thermal-hydraulic region may consist of one spatial mesh cell, or more than one mesh cell; and a region need not be contiguous. For each thermal-hydraulic region, it is assumed that accurate feedback effects can be obtained by using a single average value of fuel and coolant temperature.

Generally, a thermal-hydraulic region is chosen to correspond to a volume in the reactor taken up by a fuel assembly (with appropriate axial subdivision). The user may elect to place more than one thermal-hydraulic region within each fuel assembly; however for most problems this corresponds to a negligible increase in accuracy. The user may also choose to define a thermal-hydraulic region over more than one fuel assembly; however this practice may be dangerous, as significant spatial effects may be overlooked.

In FX2-TH, the thermal-hydraulic regions are considered to be completely separate; that is, there is no heat or mass transfer between them. The particular thermal-hydraulic model chosen is used to calculate the average thermal-hydraulic conditions within each thermal-hydraulic region.

A. The Adiabatic Fuel Temperature Models

The thermal-hydraulic models present in FX2-TH are designed to calculate an accurate value of the average fuel and coolant temperature in this thermal-hydraulic region. For the adiabatic models, the coolant temperature is assumed to be independent of time; therefore, no coolant temperatures are calculated. During the entire calculation, the coolant temperatures remain at their user-specified initial values. Within the adiabatic model, there are two alternate methods for calculating the transient fuel temperatures. These methods will now be described.

A.1 Zero Heat Transfer Method

In the first method, it is assumed that no heat transfer exists between the fuel and coolant. The heat conduction equation¹⁴ then reduces to

$$\rho_f C_f \frac{\partial T_f(r, t)}{\partial t} = q(r, t) \quad (\text{III.1})$$

where

$T_f(\underline{r}, t)$	is the average fuel temperature at point $\underline{r}$ and time t ($^{\circ}\text{C}$)
ρ_f	is the density of the fuel (g/cm^3)
C_f	is the specific heat of the fuel ($\text{watt-sec}/\text{g}^{\circ}\text{C}$)
$q(\underline{r}, t)$	is the volumetric power generation rate in the fuel (watts/cm^3)

Since no unique steady-state condition exists for Eq. (III.1), the user must enter the initial fuel temperatures $T_f(\underline{r}, 0)$. The quantities ρ_f and C_f are both dependent on the fuel temperature, therefore in FX2-TH the following correlation is made

$$\rho_f C_f(T_f) = \rho_f C_f^0 + \rho_f C_f^1 (T_f) + \rho_f C_f^2 (T_f)^2 + \rho_f C_f^3 (T_f)^3 + \rho_f C_f^4 (T_f)^4 \quad (\text{III.2})$$

where

$\rho_f C_f(T_f)$	is the specific heat density of the fuel ($\text{watt-sec}/\text{cm}^3 \text{ } ^{\circ}\text{C}$)
T_f	is the fuel temperature in this thermal-hydraulic region ($^{\circ}\text{C}$)

At each reactivity step, Eq. (III.1) must be solved to calculate the fuel temperature at the end of the reactivity step. First, the temperature T_f at the beginning of the reactivity step is used in Eq. (III.2) to evaluate $\rho_f C_f$. This value is assumed to hold for this reactivity step. Then, Eq. (III.1) is integrated from $t_{j,i}$ to $t_{j,i+1}$ to obtain

$$T_f(\underline{r}, t_{j,i+1}) = T_f(\underline{r}, t_{j,i}) + \frac{\int_{t_{j,i}}^{t_{j,i+1}} q(\underline{r}, t) dt}{\rho_f C_f} \quad (\text{III.3})$$

To evaluate the integral in Eq. (III.3), the amplitude function $T(t)$ is fit to a quadratic function from its values at $t_{j,i}$, $t_{j,i-1}$, and $t_{j,i-2}$. This quadratic function is then integrated numerically from $t_{j,i}$ to $t_{j,i+1}$ to obtain the required integral. The calculation of $q(\underline{r}, t)$ is described in Sec. III.A.3.

A.2 Constant Heat Transfer Method

In the second method, it is assumed that the rate of heat transfer from fuel to coolant remains constant during the transient. In this case, the heat conduction equation¹⁴ becomes

$$\rho_f C_f \frac{\partial T_f(\underline{r}, t)}{\partial t} = q(\underline{r}, t) - q(\underline{r}, 0) \quad (\text{III.4})$$

where

$q(\underline{r}, 0)$ is the volumetric power generation rate in the fuel at point $\underline{r}$ and time zero.

All other terms are as defined for Eq. (III.1).

To solve this equation over a reactivity step, the same methods are used as for Eq. (III.1). The quantity $\rho_f C_f$ is calculated from Eq. (III.2), then the equation integrated from $t_{j,i}$ to $t_{j,i+1}$ to obtain

$$T_f(\underline{r}, t_{j,i+1}) = T_f(\underline{r}, t_{j,i}) + \frac{\int_{t_{j,i}}^{t_{j,i+1}} q(\underline{r}, t) dt - q(\underline{r}, t) \Delta t_{j,i}}{\rho_f C_f} \quad (\text{III.5})$$

The first integral in Eq. (III.5) is evaluated exactly as was done in Eq. (III.3).

A.3 Calculation of Volumetric Power Generation Rate

In the above two methods, the volumetric power generation rate $q(\underline{r}, t)$ is required. In practice, FX2-TH calculates an average value of $q(\underline{r}, t)$ over each thermal-hydraulic region. Let $q_k(t)$ be the average volumetric power generation rate in thermal-hydraulic region k . Then

$$q_k(t) = \frac{(3.20 \times 10^{-11}) \sum_{g=1}^G \int_{V_k} \sum_g (\underline{r}, t) \phi_g(\underline{r}, t) dV}{VF_f \int_{V_k} dV} \quad (\text{III.6})$$

where

V_k is the volume of thermal-hydraulic region k

VF_f is the volume fraction of fuel within thermal-hydraulic region k

and 3.20×10^{-11} is a conversion factor converting fissions/second to watts. The fuel volume fraction VF_f is a user-input number.

A.4 Summary of the Adiabatic Model

The adiabatic fuel temperature models described above are capable of calculating transient fuel temperatures very inexpensively. The assumptions made to derive these models are most likely to be satisfied by a very rapid transient in which the primary feedback mechanism is Doppler feedback. The drawback of these methods is that they require the user to supply the steady-state solution. It is suggested that a steady-state calculation using the detailed model (to be described in the next Section) could be used to obtain estimates of the initial fuel and coolant temperatures.

B. The Detailed Fuel and Coolant Temperature Model

This model is designed to calculate realistic fuel and coolant temperatures for both steady-state and transient conditions. The heat conduction equations in both the fuel and coolant are solved to calculate the required temperatures. It is assumed that within each thermal-hydraulic region, an average fuel pin is defined. This fuel pin is assumed to be cylindrical; with a gas gap, cladding, and surrounding coolant flowing in the +z direction. The following additional assumptions are made:

- 1) The coolant is assumed not to boil.
- 2) The coolant specific heat, density, and thermal conductivity are taken as polynomial functions of the average coolant temperature.
- 3) No coolant flow reversal is allowed.
- 4) The fuel thermal conductivity and specific heat density are taken as polynomial functions of the fuel temperature.
- 5) All heat is deposited in the fuel pin.
- 6) No fuel motion is allowed, nor is fuel (or clad) expansion.
- 7) Heat generation in the fuel is radially uniform.
- 8) Axial and azimuthal heat transfer in the fuel pin are neglected.

The reactor is assumed to be made up of fuel pins which traverse the entire length of the axial (Z) direction. Each fuel pin is referred to as a thermal-hydraulic channel. Each channel contains the fuel pin and its associated coolant, flowing upwards in the +Z direction. The axial direction is divided into axial mesh regions. An axial mesh region may be composed of one or more fine-mesh intervals (neutronics mesh intervals), and must be contiguous. The reactor core is therefore divided into thermal-hydraulic channels, and each channel into axial mesh regions. A thermal-hydraulic region (within which a single value of average fuel and coolant temperatures are used for feedback purposes) is therefore a particular axial mesh region within a particular thermal-hydraulic channel.

When FX2-TH is run using r-Z geometry, the region of solution is inherently three-dimensional, and the above scheme for dividing the reactor core is appropriate. When any other geometry is used, the one- or two-dimensional region of solution is assumed to be perpendicular to the axial direction. In this case, the one- or two-dimensional region of solution is divided into thermal-hydraulic channels as described above, however only one axial mesh region is used. The height of this axial mesh region is taken as the height of the active core.

B.1 Derivation of the Fuel Temperature Equations

For the purpose of calculating the temperature distribution within the fuel pin and cladding, first assume that the cladding outer surface temperature, T_{cs} , is known. The details of this calculation will be presented in Section III.B.3. Then, I equally spaced nodes are placed within the fuel pin, one node at the inside of the clad, and one node at the middle of the clad. I is a user-specified parameter. There are, therefore, $(I+2)$ unknowns to be found. Figure 4 shows the mesh point placement with a fuel pin.

Fig. 4. Mesh Point Placement Within a Fuel Pin

The heat conduction equation in the fuel can be written¹⁴

$$\rho_f C_f \frac{\partial}{\partial t} T_f(r,t) = \frac{1}{r} \frac{\partial}{\partial r} r k_f \frac{\partial}{\partial r} T_f(r,t) + q(r,t) \quad (\text{III.7})$$

where

$T_f(r,t)$	is the fuel temperature at point r along the fuel pin radius and time t ($^{\circ}\text{C}$)
k_f	is the fuel thermal conductivity (watts/cm $^{\circ}\text{C}$)
$q(r,t)$	is the volumetric power generation rate at point r along the fuel pin radius and time t (watts/cm 3)
$\rho_f C_f$	is the fuel specific heat density (watt-sec/cm 3 $^{\circ}\text{C}$)

In the FX2-TH program, the fuel thermal conductivity and specific heat density are correlated as polynomial functions of the fuel temperature. The specific heat density correlation is given in Eq. (III.2), evaluated at

each point r along the fuel pin radius. The thermal conductivity is correlated as

$$k_f(r) = k_f^0 + k_f^1 (T_f(r,t)) + k_f^2 (T_f(r,t))^2 \quad (\text{III.8})$$

where $T_f(r,t)$ is in $^{\circ}\text{C}$. The calculation of $q(r,t)$ will be described in Section III.B.5.

It is desired to form difference equations over each region ($r_i < r < r_{i+1}$), where $T_{f,i}(t)$ denotes the average temperature within this interval. This is accomplished by multiplying Eq. (III.7) by r , and integrating it from r_i to r_{i+1} :

$$\begin{aligned} & \frac{\partial}{\partial t} \int_{r_i}^{r_{i+1}} r \rho_f C_f(r) T_f(r,t) dr \\ &= \int_{r_i}^{r_{i+1}} \frac{\partial}{\partial r} r k_f(r) \frac{\partial}{\partial r} T_f(r,t) dr + \int_{r_i}^{r_{i+1}} r q(r,t) dr \end{aligned} \quad (\text{III.9})$$

To obtain difference equations from Eq. (III.9), the same technique is used as was done in Section II.B.2. The difference equations derived inside the fuel pin are the "mesh-centered difference equations."^{3,4,5,6} These equations are derived in the following manner.

Let $T_{f,i}(t)$ denote the average fuel temperature in region i , $\rho_f C_{f,i}$ denote $\rho_f C_f(r)$ in region i , and $k_{f,i}$ denote $k_f(r)$ in region i . Then Eq. (III.9) becomes

$$\begin{aligned} \rho_f C_{f,i} \frac{(r_{i+1}^2 - r_i^2)}{2} \frac{\partial}{\partial t} T_{f,i}(t) &= r_{i+1} k_{f,i} \frac{\partial}{\partial r} T_f(r,t) \Big|_{r_{i+1}} \\ &- r_i k_{f,i} \frac{\partial}{\partial r} T_f(r,t) \Big|_{r_i} + q_i \frac{(r_{i+1}^2 - r_i^2)}{2} \end{aligned} \quad (\text{III.10})$$

where the calculation of q_i is described in Section III.B.5. To obtain difference equations, a relationship must be found between the derivative of the fuel temperature at a point and the adjacent average temperatures. The following coupling relationship is obtained:

$$k_{f,i-1} \frac{\partial}{\partial r} T_f(r,t) \Big|_{r_{i-1}} = \frac{2 k_{f,i-1} k_{f,i}}{\Delta r_f (k_{f,i-1} + k_{f,i})} (T_{f,i}(t) - T_{f,i-1}(t)) \quad (\text{III.11})$$

The difference equation for the innermost fuel node is therefore

$$\rho_f C_{f,1} \frac{\Delta r_f^2}{2} \frac{\partial}{\partial t} T_{f,1}(t) = \frac{2 k_{f,1} k_{f,2}}{(k_{f,1} + k_{f,2})} \cdot \left\{ T_{f,2}(t) - T_{f,1}(t) \right\} + q_1 \frac{\Delta r_f^2}{2} \quad (\text{III.12a})$$

The difference equation for an internal fuel node is

$$\rho_f C_{f,i} \frac{(r_{i+1}^2 - r_i^2)}{2} \frac{\partial}{\partial t} T_{f,i}(t) = \frac{2 k_{f,i} k_{f,i+1} r_{i+1}}{\Delta r_f (k_{f,i} + k_{f,i+1})} \left\{ T_{f,i+1}(t) - T_{f,i}(t) \right\} - \frac{2 k_{f,i-1} k_{f,i} r_i}{\Delta r_f (k_{f,i-1} + k_{f,i})} \left\{ T_{f,i}(t) - T_{f,i-1}(t) \right\} + q_i \frac{(r_{i+1}^2 - r_i^2)}{2} \quad (\text{III.12b})$$

To obtain the difference equation for $T_{f,I}(t)$, the derivative at $r = r_f$ must be evaluated. Note that $T_{f,I}(t)$ is located in the middle of the last fuel node. Beginning with Fourier's equation

$$q''(r_f) = -k_f \frac{\partial T}{\partial r} \Big|_{r_f}$$

To evaluate q'' at r_f , the following equation is used

$$q''(r_f) = \frac{T_{f,I}(t) - T_{ci}(t)}{R_g}$$

where R_g is the effective gap resistance

$$R_g = \frac{1}{h_{\text{gap}}} + \frac{\Delta r_f}{2k_{f,I}}$$

Therefore

$$\left. \frac{\partial T}{\partial r} \right|_{r_f} = - \frac{T_{f,I}(t) - T_{ci}(t)}{k_{f,I} R_g}$$

Therefore the difference equation for $T_{f,I}(t)$ is

$$\begin{aligned} \rho_f C_{f,I} \frac{(r_f^2 - r_{I-1}^2)}{2} \frac{\partial}{\partial t} T_{f,I}(t) = & - \frac{r_f}{R_g} (T_{f,I}(t) - T_{ci}(t)) \\ & - \frac{2r_{I-1}k_{f,I-1}k_{f,I}}{\Delta r_f(k_{f,I-1} + k_{f,I})} (T_{f,I}(t) - T_{f,I-1}(t)) + q_i \frac{(r_f^2 - r_{I-1}^2)}{2} \end{aligned} \quad (\text{III.12c})$$

where $r_f = r_I$ and $r_{I-1} = r_f - \Delta r_f$.

Inside the cladding, the analog to Eq. (III.7) is

$$\rho_c C_c \frac{\partial}{\partial t} T_{cl}(r, t) = \frac{1}{r} \frac{\partial}{\partial r} k_c \frac{\partial}{\partial r} T_{cl}(r, t) \quad (\text{III.13})$$

where

$T_{cl}(r, t)$ is the cladding temperature at radius r and time t ($^{\circ}\text{C}$)

and the subscript cl denotes cladding.

The cladding is divided into three unknown temperatures; $T_{ci}(t)$ at the inside of the cladding, $T_{cm}(t)$ at the middle of the cladding, and $T_{cs}(t)$ at the outside of the clad (assumed known). Using the same techniques as described above, the difference equations for the unknown cladding temperatures will now be written:

$$\begin{aligned} \rho_c C_c \frac{(r_{cm}^2 - r_{ci}^2)}{2} \frac{\partial}{\partial t} T_{ci}(t) = & \frac{2r_{cm}k_c}{\Delta r_c} (T_{cm}(t) - T_{ci}(t)) \\ & + \frac{r_{ci}}{R_g} (T_{f,I}(t) - T_{ci}(t)) \end{aligned} \quad (\text{III.14a})$$

$$\rho_c C_c \frac{(r_{cm2}^2 - r_{cm1}^2)}{2} \frac{\partial}{\partial t} T_{cm}(t) = \frac{2 r_{cm2} k_c}{\Delta r_c} (T_{cs}(t) - T_{cm}(t))$$

$$- \frac{2 r_{cm1} k_c}{\Delta r_c} (T_{cm}(t) - T_{ci}(t)) \quad (\text{III.14b})$$

where

$$r_{cm1} = r_{ci} + .25 (r_{cs} - r_{ci})$$

$$r_{cm2} = r_{ci} + .75 (r_{cs} - r_{ci})$$

B.2 Solution of the Fuel Temperature Equations

The fuel thermal conductivity and specific heat density are polynomial functions of the average fuel temperature in this fuel region. In steady state, the fuel temperatures are solved iteratively until a converged solution is found. For the transient solution, the equations derived above are differenced according to the fully implicit method. The value q used in the difference equations is calculated from the integral over this reactivity step of a quadratic function of the amplitude $T(t)$ (as described in Section III.A.1). Initially, the values $\rho_f C_f$ and k_f are estimated by solving Eqs. (III.2) and (III.8) using the fuel temperatures present at the beginning of the reactivity step. These values are then used for the remainder of this reactivity step. The equations are then solved using the above-described modification of the fully implicit method.

The fuel and cladding equations comprise a set of $(I+2)$ equations in $(I+2)$ unknowns, whose matrix structure is tridiagonal. This matrix problem is easily factorized and solved.⁶

For feedback purposes, the average fuel temperature is required. This temperature is calculated from

$$T_{f,av}(t) = \frac{\sum_{i=1}^I (r_{i-1} + r_i) T_{f,i}(t)}{\sum_{i=1}^I (r_{i-1} + r_i)} \quad (\text{III.15})$$

B.3 Derivation of Coolant Temperature Equations

The development of the coolant temperature equations follows closely the development given in Ref. 15. The average coolant properties for each axial mesh region will be calculated; and if the user requests, the average structure temperature also.

As described above, the axial dimension is split into a series of axial mesh regions, with the assumption being made that the material properties are uniform over each segment. If some segment k has zero fission power, the fluid simply transports upward with no change in temperature.

The fuel temperatures calculated above represent average fuel temperatures over each axial mesh region. It will be convenient, however, to calculate coolant temperatures only at the interfaces k and $k+1$ below and above segment k . To obtain the average coolant temperature, the below and above temperatures are averaged.

The development begins with the continuity of mass and energy equations:¹⁵

$$\frac{\partial \rho_l(z,t)}{\partial t} + \frac{\partial G(z,t)}{\partial z} = 0 \quad (\text{III.16})$$

$$\frac{\partial}{\partial t} [\rho_l(z,t) H(z,t)] + \frac{\partial}{\partial z} [G(z,t) H(z,t)] = \gamma \psi(z,t) \quad (\text{III.17})$$

where

$\rho_l(z,t)$ is the coolant density (g/cm^3)

$G(z,t)$ is the coolant mass flow rate for this channel
($\text{g/cm}^2 \text{ sec}$)

$H(z,t)$ is the coolant enthalpy (watt-sec/g)

γ is the ratio of the surface area of cladding
to the volume of the coolant (cm^{-1})

$\psi(z,t)$ is the heat flux (watts/cm^2)

The assumptions are made that $G(z,t)$ and $\rho_l(z,t)$ are constant within this axial mesh region, therefore combining the above equations gives

$$\rho_l \frac{\partial}{\partial t} H(z,t) + G \frac{\partial}{\partial z} H(z,t) = \gamma \psi(z,t) \quad (\text{III.18})$$

For a non-boiling coolant,

$$dH(z,t) = C_\ell dT_c(z,t) \quad (\text{III.19})$$

where

C_ℓ is the coolant specific heat
(watt-sec/g°C)

$T_c(z,t)$ is the coolant temperature (°C)

The quantity C_ℓ is also assumed to be a constant over this axial mesh region. Combining Eqs. (III.18) and (III.19) yields

$$\rho_\ell C_\ell \frac{\partial}{\partial t} T_c(z,t) + G C_\ell \frac{\partial}{\partial z} T_c(z,t) = \gamma \psi(z,t) \quad (\text{III.20})$$

The time dependent equation for the structure temperature is¹⁵

$$\tau_s \rho_s C_s \frac{\partial}{\partial t} T_s(z,t) = h_s [T_c(z,t) - T_s(z,t)] \quad (\text{III.21})$$

where

$T_s(z,t)$ is the structure temperature (°C)

τ_s is the ratio of structure volume to surface
area in contact with coolant (cm)

$\rho_s C_s$ is the specific heat density for the structure
(watt-sec/cm³ °C)

$$h_s = \left(\frac{1}{h_c} + R_{st} \right)^{-1}$$

R_{st} is the thermal resistance of the structure
(cm² °C/watt)

h_c is the convection-film heat transfer coefficient
(watt/cm² °C)

FX2-TH allows the user to specify a time dependence for the coolant mass flow rate $G(z,t)$.

Let

$$G(z,t) = G_m \cdot f$$

where

G_m is the initial mass flow rate for thermal-
hydraulic channel m

and

$$f = 1.0 + \alpha_1(t - t_s) + \alpha_2(t - t_s)^2$$

where

α_1, α_2 are input variables

t_s is the time the coolant flow rate variation is to begin.

For all times $t < t_s$, f is set to unity.

In the steady-state, Eq. (III.20) reduces to

$$G C_\ell \frac{\partial}{\partial z} T_c(z, 0) = \gamma \psi(z, 0) \quad (\text{III.22})$$

In steady-state, all power goes toward heating the coolant. Therefore the following expression is correct:

$$\gamma \psi(z, 0) = \frac{P(j)}{\Delta Z_j A_c} \quad (\text{III.23})$$

where

$P(j)$ is the total power produced in this fuel pin in axial mesh region j (watts)

ΔZ_j is the length of axial mesh region j

A_c is the coolant flow area (cm^2)

All the data required to solve Eq. (III.22) are now known, therefore integrate it from Z_k to Z_{k+1} to obtain:

$$T_c(Z_{k+1}, 0) = T_c(Z_k, 0) + \frac{\Delta Z_k \gamma \psi(Z, 0)}{G C_\ell} \quad (\text{III.24})$$

where $\gamma \psi(Z, 0)$ is given by Eq. (III.23). The steady-state average coolant temperature in axial mesh region k is then

$$T_{c,k}(0) = \frac{T_c(Z_{k+1}, 0) + T_c(Z_k, 0)}{2}$$

and the steady-state average structure temperature is

$$T_{s,k}(0) = T_{c,k}(0)$$

During a transient, the heat flux has components from both the fuel pin and the structure:

$$\psi(Z, t) = \psi_c(Z, t) + \gamma_2 \psi_s(Z, t) \quad (\text{III.25})$$

where

$$\psi_c(Z, t) = \frac{T_{cm}(Z, t) - T_c(Z, t)}{R_{ec}(Z, t)} \quad (\text{III.26})$$

$$\psi_s(Z, t) = \frac{T_s(Z, t) - T_c(Z, t)}{R_{sc}(Z, t)} \quad (\text{III.27})$$

and

$T_{cm}(Z, t)$ is the clad midpoint temperature at Z and t ($^{\circ}\text{C}$)

$T_c(Z, t)$ is the coolant bulk temperature at Z and t ($^{\circ}\text{C}$)

$$R_{ec}(Z, t) = \frac{1}{h_c} + \frac{\Delta r_c}{2k_c}$$

h_c is the convection-film heat transfer coefficient (watts/cm² $^{\circ}\text{C}$)

Δr_c is the clad thickness (cm)

k_c is the clad thermal conductivity (watt/cm $^{\circ}\text{C}$)

$T_s(Z, t)$ is the structure temperature at Z and t ($^{\circ}\text{C}$)

$$R_{sc}(Z, t) = \frac{1}{h_c} + R_{st}$$

R_{st} is the thermal resistance of the structure (cm² $^{\circ}\text{C}/\text{watt}$)

γ_2 is the ratio of the surface area of structure to the surface area of cladding.

Eqs. (III.20) and (III.21) are now solved for this reactivity step. The values ρ_l and C_l are each expanded as polynomial functions of the average coolant temperature, as

$$\rho_{l,k}(t) = \rho_l^0 + \rho_l^1 (T_{c,k}(t)) + \rho_l^2 (T_{c,k}(t))^2$$

$$C_{l,k}(t) = C_l^0 + C_l^1 (T_{c,k}(t)) + C_l^2 (T_{c,k}(t))^2$$

The average coolant temperature used to evaluate these expressions is extrapolated from past history. Let $T_{c,k}^i$ be the coolant temperature at axial level k and reactivity step i . Then the extrapolated average coolant temperature at reactivity step $i+1$ is:

$$T_{c,k+\frac{1}{2}}^{i+1} = T_{c,k}^{i+1} + \frac{1}{2} \left\{ T_{c,k+1}^i - T_{c,k}^i \right\}$$

Eqs. (III.20) and (III.21) are then solved using the fully implicit method, to yield:

$$T_{c,k+1}^{i+1} = \left\{ \frac{\rho_l C_l}{\Delta t_{j,i}} + \frac{G C_l}{\Delta Z_k} \right\}^{-1} \cdot \left\{ \frac{\rho_l C_l}{\Delta t_{j,i}} T_{c,k+1}^i + \frac{G C_l}{\Delta Z_k} T_{c,k}^{i+1} + \gamma \psi(k,i+1) \right\} \quad (\text{III.28})$$

$$T_{s,k}^{i+1} = \left\{ \frac{\tau_s \rho_s C_s}{\Delta t_{j,i}} + h_s \right\}^{-1} \left\{ \frac{\tau_s \rho_s C_s}{\Delta t_{j,i}} T_{s,k}^i + h_s T_{c,k}^{i+1} \right\} \quad (\text{III.29})$$

The fuel temperature and coolant temperature calculations are linked by two properties, the heat flux and the clad surface temperature. The clad surface temperature is found from

$$T_{cs}(Z,t) = T_c(Z,t) + \psi_c(Z,t)/h_c \quad (\text{III.30})$$

The heat flux $\psi_c(Z,t)$ calculated above can be used with the calculated value of $T_c(Z,t)$ to calculate the new clad surface temperature $T_{cs}(Z,t)$. The fuel temperature equations can then be solved.

To calculate the heat transfer coefficient h_c , a general correlation is used which is applicable to several coolants. Let

$$Nu = C_1 + C_2 (Re)^{C_3} (Pr)^{C_4} \quad (\text{III.31})$$

where

C_1, C_2, C_3, C_4 are user-specified constants

Nu is the Nusselt number

Re is the Reynolds number

Pr is the Prandtl number

These dimensionless quantities are defined as

$$Nu = \frac{h_c D_e}{k}$$

$$Re = \frac{D_e G}{\mu}$$

$$Pr = \frac{C_p \mu}{k}$$

where

h_c is the heat transfer coefficient
(watt/cm² °C)

D_e is the hydraulic diameter (cm)

k is the thermal conductivity of the coolant (watt/cm °C)

G is the mass flow rate of the coolant (g/cm² sec)

μ is the viscosity of the coolant (g/cm sec)

C_p is the specific heat of the coolant (watt-sec/g °C)

The hydraulic diameter D_e is calculated from

$$D_e = \frac{4 A_c}{2\pi r_{cs}(1+\gamma_2)}$$

where

A_c is the area of the coolant (cm²)

$$A_c = \frac{V_{fc} \pi r_{cs}^2}{1-V_{fc}}$$

V_{fc} is the volume fraction of the coolant.

The coolant viscosity is also represented as a polynomial function of the average coolant temperature, as

$$\mu_k(t) = \mu^{(0)} + \mu^{(1)}(T_{c,k}(t)) + \mu^{(2)}(T_{c,k}(t))^2$$

B.4 Steady State and Transient Calculation of Fuel and Coolant Temperatures

In steady state, the heat flux is calculated from Eq. (III.23). This is an analytical (and therefore exact) relationship. Once the transient begins, Eqs. (III.25, 26, 27) are used to calculate the heat flux. These expressions are dependent on the cladding midpoint temperature, which is found using a finite difference approximation to the heat conduction equation. Therefore, the two expressions are not in complete agreement. In order for there to be no spurious "drift" when the transient is begun, the steady state solution strategy has been devised such that the fuel temperatures and coolant temperatures are iterated to convergence, using Eqs. (III.25, 26, 27) to calculate the heat flux.

For the transient calculation, the heat flux at this reactivity step is first found. This is done by assuming that the heat flux determined by Eqs. (III. 25, 26, 27) using temperatures present at the beginning of the reactivity step is sufficiently accurate for the calculation of the coolant temperatures across this reactivity step. The SAS2A code¹⁵ uses an extrapolated value of heat flux based on past history. Numerical tests performed on the FX2-TH detailed model using such an extrapolation demonstrated that when large reactivity steps were taken, the coolant temperatures calculated could be significantly in error. therefore, an extrapolation of this kind is not performed in FX2-TH. Once the coolant properties for this reactivity step are found, the heat transfer coefficient (h_c) and cladding surface temperature (T_{cs}) are calculated, and the resulting fuel temperatures calculated.

Figure 5 shows a flowchart of the overall thermal-hydraulic solution strategy. Figure 6 shows a flowchart of the steady-state solution strategy for the detailed model. Figure 7 shows a flowchart of the transient solution strategy for the detailed model.

Fig. 5.

Overall Flowchart for
Thermal-Hydraulic Calculation

Fig. 5. (Contd)

Fig. 6. Flowchart of Steady-State Calculation of Fuel and Coolant Temperatures for One Thermal-Hydraulic Channel of the Detailed Model

Fig. 7. Flowchart of Transient Calculation of Fuel and Coolant Temperatures for One Thermal-Hydraulic Channel of the Detailed Model

B.5. Calculation of Volumetric Power Generation Rate

In the fuel temperature equations for the detailed model, the volumetric power generation rate $q(r,t)$ is required. For each thermal-hydraulic region k , the following equation is used

$$q_k(t) = \frac{(3.20 \times 10^{-11}) \sum_{g=1}^G \int_{V_k} \Sigma_{fg}(r,t) \phi_g(r,t) dV}{NPIN \cdot h_k \cdot \pi r_f^2} \quad (\text{III.32})$$

where

NPIN is the total number of fuel pins in thermal-hydraulic region k

h_k is the height (axially) of thermal-hydraulic region k

r_f is the radius of the fuel pin

In equations such as (III.10) and (III.12), the value q_i is required, where q_i is the volumetric power generation rate in fuel node i . Since the power is assumed to be generated uniformly in the fuel pin, $q_i = q_k$ for all fuel nodes i .

B.6 Accuracy Considerations of the Detailed Model

In the development of the detailed thermal-hydraulic model for FX2-TH, an extensive model verification procedure was undertaken. The results of this procedure will be summarized in this Section. Errors present in the detailed model can come from two basic sources; errors introduced due to the assumptions made to derive the model, and errors introduced due to the approximate solution of the equations. The most significant errors discovered in this investigation will now be discussed.

The most significant error inherent in the model generally comes from the restriction that no fuel or cladding motion due to thermal expansion is allowed. Comparison of results between FX2-TH and SAS2A¹⁵ reveals that care must be taken in setting up the thermal-hydraulic model in FX2-TH so that the results using FX2-TH will be in good agreement with more detailed calculations. The most significant parameters which must be matched between FX2-TH and a more accurate thermal-hydraulics calculation are the width of the gap (τ_{gap}) and the conductivity of the gap (h_{gap}). In particular, a fuel pin located in a very high-power region of the reactor core will probably have a smaller τ_{gap} (and hence a large h_{gap}) than a similar pin located in a low-power region of the core. FX2-TH has the capability of allowing more than one set of thermal-hydraulic input parameters, and this is useful in matching the proper fuel pin dimensions to their appropriate position in the core.

In addition, the power distribution of a reactor can have significant axial variations; thus a fuel pin's outer radius can vary axially. To account for this variation, FX2-TH allows the user to input a set of "axial correction factors" to the gap conductivity h_{gap} . The value of h_{gap} used for axial location k is then

$$h_{gap,k} = h_{gap} / h_{corr,k}$$

where

h_{gap} is the input value of h_{gap} for this fuel pin

$h_{corr,k}$ is the correction factor for axial level k

One set of correction factors is entered for all fuel pins. Therefore, through the combination of adjusting the fuel pin dimensions and the axial correction factors, the user can adjust the FX2-TH input parameters to match more detailed calculations. Also, these input values can be set in such a way as to guarantee a conservative safety analysis result.

The most significant error incurred in the numerical solution of the thermal-hydraulic equations is the effect of a finite difference approximation to the heat conduction equation inside the fuel pin. It has been found that four or five radial fuel nodes are sufficient to keep errors in average fuel temperature below one or two percent for the duration of the transient.

IV. REPRESENTATION OF THERMAL-HYDRAULIC FEEDBACK EFFECTS

A. Homogenization of Cross Sections

The FX2-TH program accepts microscopic cross section data from the CCCC standard interface files ISOTXS and DLAYXS.¹⁶ If upscatter cross sections are present in the ISOTXS file, they will be read correctly by the FX2-TH input processor; however the calculation will not use the upscatter cross sections. Neither a set matrix nor an isotope matrix for the fission spectrum is allowed. Also, no co-ordinate dependent transport cross sections are read by FX2-TH.

The FX2-TH homogenization routines use information from the files ISOTXS, DLAYXS, and FXHMOG to generate the unique material macroscopic cross sections and the temperature correction coefficients. The material cross sections are mixed in the usual way

$$\Sigma_{m,g} = \sum_{i=1}^{NISO} \sigma_{i,g} N_{i,m} \quad (IV-1)$$

i.e. the product of the atom density and microscopic cross section are summed over all isotopes comprising that unique material. The specific form of the terms $\Sigma_{m,g}$ and $N_{i,m}$ in the presence of temperature feedback will be discussed in the next section. The material prompt fission spectrum is computed as follows

$$\chi_{m,g} = \frac{\sum_{i=1}^{NISO} \chi_{i,g} N_{i,m} \sum_{g'=1}^{NG} (v\sigma_f)_{g'}^i}{N_{i,m} \sum_{g'=1}^{NG} (v\sigma_f)_{m,g'}} \quad (IV.2)$$

This weighting assumes that the flux is constant in each region. m is the unique material number, i is the isotope number, and g, g' are energy group indices.

B. Temperature Effects Upon Cross Sections

In FX2-TH, feedback effects due to both fuel and coolant temperature changes are calculated. These feedback effects will be discussed separately.

The fuel temperatures calculated in FX2-TH affect the microscopic cross sections through Doppler broadening of the resonances.² In FX2-TH, Doppler broadening is assumed to affect only the microscopic capture and fission cross sections. FX2-TH requires that the ISOTXS file contain cross sections for a particular isotope at four different values of fuel temperature. From these values, a general correlation relating the microscopic cross section to the fuel temperature is evaluated:

$$\begin{aligned} \Sigma_{m,g}^P(T_f) = & \Sigma_{m,g_{base}}^P + C_{m,g}^{P,1} \cdot (\sqrt{T_f} - \sqrt{T_{f_{base}}}) \\ & + C_{m,g}^{P,2} \cdot \ln(T_f/T_{f_{base}}) + C_{m,g}^{P,3} \cdot \left(\frac{1}{T_f} - \frac{1}{T_{f_{base}}} \right) \end{aligned} \quad (IV.3)$$

where

$\Sigma_{m,g}^P(T_f)$ is the macroscopic cross section for process P (capture or fission) for material m and group g at temperature T_f

$\Sigma_{m,g_{base}}^P$ is the macroscopic cross section $\Sigma_{m,g}^P(T_{f_{base}})$ evaluated at $T_{f_{base}}$

$C_{m,g}^{P,i}$ is the i^{th} fuel temperature feedback coefficient for process P, material m and group g.

$T_{f_{base}}$ is the base fuel temperature

The feedback coefficients are calculated from the known values of $\Sigma_{m,g}^P(T_f)$ at four values of T_f . Each such value $\Sigma_{m,g}^P(T_f)$ represents a sum over all isotopes in this material, such as Eq. (IV.1).

To represent changes in the coolant temperature, the atom density ($N_{i,m}$) of each coolant isotope is allowed to be a function of the coolant temperature, as

$$N_{i,m}(T_c) = N_{i,m}^0 + N_{i,m}^1 (T_c - T_{c_{base}}) \quad (IV.4)$$

where

$N_{i,m}(T_c)$ is the atom density for isotope i in material m at temperature T_c

$N_{i,m}^0$ is the atom density $N_{i,m}(T_{c_{base}})$ evaluated at $T_{c_{base}}$

$N_{i,m}^1$ is the first derivative of the atom density with respect to coolant temperature for isotope i in material m. This value is user input.

$T_{c_{base}}$ is the base coolant temperature

The macroscopic cross section and coolant temperature feedback coefficient are then calculated as:

$$\Sigma_{m,g}^P(T_c) = \Sigma_{m,g_{base}}^P + D_{m,g}^P \cdot (T_c - T_{c_{base}}) \quad (IV.5)$$

where

$\Sigma_{m,g}^P(T_c)$ is the macroscopic cross section for process P (capture, scattering), material m, group g, at temperature T_c

$$\Sigma_{m,g_{base}}^P = \sum_{i=1}^{NISO} \sigma_{i,g}^P N_{i,m}^0$$

$$D_{m,g}^P = \sum_{i=1}^{NISO} \sigma_{i,g}^P N_{i,m}^1$$

Therefore, for materials m representing fuel material, the macroscopic capture and fission cross sections are functions of the fuel temperature through Eq. (IV.3). For materials m representing coolant material, the macroscopic capture and scattering cross sections are functions of the coolant temperature through Eq. (IV.5).

To calculate the temperature dependent transport cross section, the variations from capture and fission from both fuel and temperature are added to the base transport cross section. The diffusion coefficient is then calculated from $D = 1/3 \Sigma_{tr}$.

C. Overall Solution Strategies for FX2-TH

C.1 Steady State Calculation

FX2-TH must calculate the steady-state real and adjoint neutron fluxes, and the steady state thermal-hydraulic conditions. As a result of the thermal-hydraulic feedback equations given in Chapter III, the calculation of a consistent set of steady-state conditions is, in general, an iterative process. A flowchart of the steady-state solution strategy used in FX2-TH is given in Figure 8.

If no thermal-hydraulics calculations are being performed, or if one of the adiabatic fuel temperature models are being used, then the steady-state fuel and coolant temperatures are known from the problem input; and an iteration is not necessary (see Figure 8). If the detailed model is being used, however, then the steady-state real neutron fluxes and thermal-hydraulic conditions are solved consecutively until the pointwise reactor powers from two successive iterations agree to within a user-specified amount. When this occurs, the final set of real and adjoint neutron fluxes and thermal-hydraulic conditions are calculated.

During this steady-state iterative process, the neutron fluxes are being calculated from macroscopic cross sections which were found from the previous (approximate) set of thermal-hydraulic conditions. Therefore, there is no need to converge the neutron flux equations to a high degree of convergence during this iterative process. Before the start of the steady-state iteration, the steady-state convergence criteria are modified. The criterion which determines the maximum change in pointwise fission source vector, the most restrictive of the convergence criteria, is set as

$$\epsilon_{fs} = 0.5 \epsilon_{th}$$

where

ϵ_{fs} is the pointwise fission source vector convergence criterion

ϵ_{th} is the user-specified pointwise power convergence criterion for the steady-state iteration

After a converged set of steady-state conditions are found, the steady-state convergence criteria are returned to their user-specified values. The tightly converged real and adjoint neutron fluxes are then calculated, as well as the final set of thermal-hydraulic conditions (see Figure 8).

It has been assumed that the iterative process described above is a convergent one. If this is not the case, then no unique steady-state condition exists for the given set of FX2-TH input. The iterative process can be guaranteed to converge if the temperature coefficients

$\frac{\partial \rho}{\partial T_f}$ and $\frac{\partial \rho}{\partial T_c}$ are both negative (these temperature coefficients are assumed

to represent the overall response of the reactor to changes in temperature). It is possible, however, for a reactor to have one of the above coefficients,

for instance $\frac{\partial \rho}{\partial T_c}$, be positive; while the other be negative. This situation

could occur in a PWR at beginning-of-life with a relatively high initial concentration of soluble boron present in the coolant. Such a reactor could still exhibit an overall negative temperature coefficient if the negative of the fuel temperature coefficient was dominant over that of the coolant temperature. To determine this, a "power coefficient" is helpful,

where $\frac{\partial \rho}{\partial P_i}$ represents the change in ρ for a change in reactor power P_i at

any point i in the reactor. This quantity, which includes the effects of fuel and coolant temperature feedback, must be negative for the iterative strategy to converge. (It also must be negative for the reactor to be licensable).

Fig. 8. Flowchart for the Steady-State Calculation in FX2-TH

Fig. 8. (Contd)

B.2 Time-Dependent Calculation

During the transient calculation, the point kinetics equations and thermal-hydraulics equations are solved in tandem at each reactivity step, thus eliminating the need for costly iterations between the neutronics and thermal-hydraulics equations. This approach has proven to work well for several other multidimensional space-time kinetics programs.^{6,9,10}

V. A GUIDE TO USER APPLICATIONS

A. Description of the Cataloged Procedure ARCSP024

The FX2-TH program is a stand-alone load module. To assist the user in executing this program, the cataloged procedure ARCSP024 has been written to relieve much of the burden of coding job control language when using FX2-TH on an IBM 360 or 370 series computer. A listing of this procedure is given in Figure 9. A description of the symbolic parameters in this procedure is given in Table I.

```

//ARCSP024 PROC APLXDSP=(,DELETE)',APLXVOL=,AISO='&AISO',
//      ADLA='&ADLA',AISODSP=(,DELETE)',AISOVOL=,ATFLUX='&ATFLUX',
//      DLAYVOL=,DLAYXS='&DLAYXS',FULLBLK=12280,
//      FXEDIT='&FXEDIT',FXEDSP=(,DELETE)',FXEVOL=,
//      HALFBK=6136,ISOTDSP=(,DELETE)',ISOTVOL=,
//      ISOTXS='&ISOTXS',PATH=FX2,POSTLIB='SYS1.DUMMYLIB',
//      PRELIB='SYS1.DUMMYLIB',RFLXDSP=(,DELETE)',RFLXVOL=,
//      RSTRDSP=(,DELETE)',RSTRT1='&RSTRT1',
//      RSTRT2='&RSTRT2',RSTRVL1=,RSTRVL2=,RTFLUX='&RTFLUX',
//      SEP1='FT25F001,FT26F001',
//      THDATA='&THDATA',THDDSP=(,DELETE)',
//      THDVOL=,TIMLIM='(600,0)',UNITS=BATCHDSK,
//      XSCNDSP=(,DELETE)',XSCNVOL=,XSCON='&XSCON'
//
//*****
//*
//*   CATALOGUED PROCEDURE FOR THE FX2-TH CODE
//*
//*****
//
//FX2      EXEC PGM=&PATH,TIME=&TIMLIM
//STEPLIB DD DSN=&PRELIB,DISP=SHR
//      DD DSN=C116.B20219.FX2TH.MODLIB,DISP=SHR
//      DD DSN=&POSTLIB,DISP=SHR
//DUMMY1 DD DSN=&&BCD,UNIT=SASCR,SPACE=(CYL,(1,1)),
//      DCB=(RECFM=VBS,LRECL=84,BLKSIZE=&HALFBK)
//DUMMY2 DD DSN=&&DUMMY2,UNIT=SASCR,SPACE=(CYL,(2,1),,CONTIG),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFBK)
//DUMMY3 DD DSN=&&DUMMY3,UNIT=SASCR,SPACE=(CYL,(9,1),,CONTIG),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//DUMMY4 DD DSN=&&DUMMY4,UNIT=SASCR,SPACE=(CYL,(10,1),,CONTIG),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//DUMMY5 DD DSN=&&DUMMY5,UNIT=SASCR,SPACE=(CYL,(5,1),,CONTIG),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//DUMMY6 DD DSN=&&DUMMY6,UNIT=(SASCR,SEP=(DUMMY3,DUMMY4,DUMMY5)),
//      SPACE=(CYL,(3,1),,CONTIG),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//DUMMY7 DD DSN=&&DUM7,UNIT=(SASCR,SEP=(DUMMY3,DUMMY4,DUMMY5,DUMMY6)),
//      SPACE=(CYL,(2,1),,CONTIG),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//FT05F001 DD DDNAME=SYSIN
//      *
//      *
//      *
//FT06F001 DD SYSOUT=A,DCB=(RECFM=FB,LRECL=133,BLKSIZE=1596)
//      *
//      *
//      *
//FT09F001 DD UNIT=SASCR,SPACE=(TRK,(10,10),,RLSE),
//      DCB=(RECFM=VBS,LRECL=84,BLKSIZE=&HALFBK)
//FT11F001 DD DDNAME=&&AFX2,SUBALLOC=(TRK,(7,1),DUMMY1),
//      DCB=&.FT09F001
//      *
//      *
//      *
//FT12F001 DD DDNAME=&&AFNIP,SUBALLOC=(TRK,(6,1),DUMMY1),
//      DCB=&.FT09F001
//FT13F001 DD DDNAME=&&ATHRM,SUBALLOC=(TRK,(6,1),DUMMY1),
//      DCB=&.FT09F001
//FT14F001 DD DDNAME=&&AFOUT,UNIT=SASCR,
//      SPACE=(TRK,(3,1)),DCB=(RECFM=FB,LRECL=133,BLKSIZE=1596)
//FT15F001 DD DDNAME=&&FXCTRL,SUBALLOC=(TRK,(11,1),DUMMY2),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFBK)
//      *
//      *
//      *
//FT16F001 DD DDNAME=&&GEODST,SUBALLOC=(TRK,(9,1),DUMMY2),
//      DCB=&.FT15F001
//FT17F001 DD DDNAME=&&FXHMOG,SUBALLOC=(TRK,(9,1),DUMMY2),
//      DCB=&.FT15F001
//FT18F001 DD DDNAME=&&FXTH,SUBALLOC=(TRK,(9,1),DUMMY2),

```

Fig. 9. Listing of Cataloged Procedure ARCSP024

```

//      DCB=*.FT15F001
//FT19F001 DD DSN=&ISOTXS,DISP=&ISOTDSP,UNIT=&UNITS,
//      VOL=SER=&ISOTVOL,SPACE=(CYL,(5,1)),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFBLK)
//FT20F001 DD DSN=&DLAYXS,DISP=&ISOTDSP,UNIT=&UNITS,
//      VOL=SER=&DLAYVOL,SPACE=(CYL,(1,1)),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFBLK)
//FT21F001 DD DSN=&XSCON,DISP=&XSCNDSP,UNIT=&UNITS,
//      VOL=SER=&XSCNVOL,SPACE=(CYL,(1,1)),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFBLK)
//FT22F001 DD DSN=&RTFLUX,DISP=&RFLXDSP,VOL=SER=&RFLXVOL,
//      UNIT=&UNITS,SPACE=(CYL,(2,1)),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//FT23F001 DD DSN=&ATFLUX,DISP=&AFLXDSP,VOL=SER=&AFLXVOL,
//      UNIT=&UNITS,SPACE=(CYL,(2,1)),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFBLK)
//FT24F001 DD DSNAME=&&FIXSRC,UNIT=SASCR,
//      SPACE=(TRK,(5,5)),DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFBLK)
//FT25F001 DD DSNAME=&&VFRACM,SUBALLOC=(CYL,(1,1),DUMMY3),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//*      ALSO USED BY TPSORC(30),FDCOEF(38),SCRXS(41),DELFNS(43),
//*      AND SCRFS1(44)
//FT26F001 DD DSNAME=&&POWDNM,SUBALLOC=(CYL,(2,1),DUMMY4),
//      DCB=*.FT25F001
//*      ALSO USED BY SHPES(31),XSPGRP(36),DELFSO(42),SCRFS2(45),
//*      AND SCR001(46)
//FT27F001 DD DSNAME=&THDATA,DISP=&THDDSP,VOL=SER=&THDVOL,
//      UNIT=&UNITS,SPACE=(CYL,(1,1)),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&HALFBLK)
//FT28F001 DD DSN=&&POWOLD,SUBALLOC=(CYL,(1,1),DUMMY6),
//      DCB=*.FT25F001
//*      ALSO USED BY FRIP1(33)
//FT29F001 DD DSNAME=&FXEDIT,DISP=&FXEDSP,VOL=SER=&FXEVOL,
//      UNIT=&UNITS,SPACE=(CYL,(2,1)),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//FT30F001 DD DSNAME=&&TPSORC,SUBALLOC=(CYL,(1,1),DUMMY3),
//      DCB=*.FT25F001
//FT31F001 DD DSNAME=&&SHPES,SUBALLOC=(CYL,(2,1),DUMMY4),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//FT32F001 DD DSNAME=&&FRI,SUBALLOC=(CYL,(2,1),DUMMY5),
//      DCB=*.FT31F001
//FT33F001 DD DSNAME=&&FRIP1,SUBALLOC=(CYL,(2,1),DUMMY6),
//      DCB=*.FT31F001
//FT34F001 DD DSNAME=&&FRJM1,SUBALLOC=(CYL,(2,1),DUMMY7),
//      DCB=*.FT31F001
//FT35F001 DD DSNAME=&&XSPSCT,SPACE=(CYL,(5,1)),
//      UNIT=(3330,SEP=(FT25F001,FT26F001)),
//      DCB=*.FT31F001
//FT36F001 DD DSNAME=&&XSPGRP,SUBALLOC=(CYL,(3,1),DUMMY4),
//      DCB=*.FT31F001
//FT37F001 DD DSNAME=&&XSPFIS,
//      UNIT=(3330,SEP=(FT35F001,&SEP1)),
//      SPACE=(CYL,(1,1)),DCB=*.FT31F001
//FT38F001 DD DSNAME=&&FDCOEF,SUBALLOC=(CYL,(4,1),DUMMY3),
//      DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//FT39F001 DD DSNAME=&&ADJFLX,
//      UNIT=(3330,SEP=(FT35F001,FT37F001,&SEP1)),
//      SPACE=(CYL,(2,1)),DCB=*.FT31F001

```

Fig. 9. (Contd)

```

//FT40F001 DD DSNAME=&&PREC2M,SUBALLOC=(CYL,(1,1),DUMMY5),
//          DCB=*.FT31F001
//FT41F001 DD DSNAME=&&SCRXS,SUBALLOC=(CYL,(1,1),DUMMY3),
//          DCB=*.FT31F001
//FT42F001 DD DSNAME=&&DELFSO,SUBALLOC=(CYL,(1,1),DUMMY4),
//          DCB=*.FT31F001
//FT43F001 DD DSNAME=&&DELFSN,SUBALLOC=(CYL,(1,1),DUMMY3),
//          DCB=*.FT31F001
//FT44F001 DD DSNAME=&&SCRFS1,SUBALLOC=(CYL,(1,1),DUMMY3),
//          DCB=*.FT31F001
//FT45F001 DD DSNAME=&&SCRFS2,SUBALLOC=(CYL,(1,1),DUMMY4),
//          DCB=*.FT31F001
//FT46F001 DD DSNAME=&&SCR001,SUBALLOC=(CYL,(1,1),DUMMY4),
//          DCB=*.FT31F001
//FT47F001 DD DSNAME=&&SCR002,SUBALLOC=(CYL,(2,1),DUMMY5),
//          DCB=*.FT31F001
//FT48F001 DD DSNAME=&&SCR003,UNIT=SASCR,
//          SPACE=(TRK,(5,5)),DCB=*.FT31F001
//FT49F001 DD DSN=&RSTRT1,DISP=&RSTRDSP,UNIT=&UNITS,
//          VOL=SER=&RSTRVL1,SPACE=(CYL,(4,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//FT50F001 DD DSN=&RSTRT2,DISP=&RSTRDSP,UNIT=&UNITS,
//          VOL=SER=&RSTRVL2,SPACE=(CYL,(4,1)),
//          DCB=(RECFM=VBS,LRECL=X,BLKSIZE=&FULLBLK)
//FT51F001 DD DSNAME=&AISO,DISP=&AISODSP,UNIT=&UNITS,
//          VOL=SER=&AISOVOL,SPACE=(CYL,(6,1)),
//          DCB=(RECFM=VBS,LRECL=84,BLKSIZE=&HALFBLK)
//FT52F001 DD DSNAME=&ADLA,DISP=&AISODSP,UNIT=&UNITS,
//          VOL=SER=&AISOVOL,SPACE=(CYL,(2,1)),
//          DCB=(RECFM=VBS,LRECL=84,BLKSIZE=&HALFBLK)
//
//
//*****
//
//
//*      IN CASE OF DIFFICULTY WITH THIS PROCEDURE      *
//*      CONTACT:  R. A. SHOBER  BLDG. 208 ROOM L-114      *
//*      EXTENSION 5583                                     *
//*
//*****

```

Fig. 9. (Contd)

TABLE I. Symbolic Parameters for ARCSP024

Parameters	Description	Default	FTNNF001
AFLXDSP	disposition for ATFLUX	(,DELETE)	23
AFLXVOL	volume for ATFLUX	no volume	23
AISO	DSN for A.ISO	&AISO	51
ADLA	DSN for A.DLA	&ADLA	52
AISODSP	disposition for A.ISO	(,DELETE)	51,52
AISOVOL	volume for A.ISO	no volume	51,52
ATFLUX	DSN for ATFLUX	&ATFLUX	23
DLAYVOL	volume for DLAYXS	no volume	20
DLAYXS	DSN for DLAYXS	(,DELETE)	20
FULLBLK	block length for full-track blocking	12280	
FXEDIT	DSN for FXEDIT	&FXEDIT	29
FXEDSP	disposition for FXEDIT	(,DELETE)	29
FXEVOL	volume for FXEDIT	no volume	29
HALFBLK	block length for half-track blocking	6136	
ISOTDSP	disposition for DLAYXS and ISOTXS	SHR	19,20
ISOTVOL	volume for ISOTXS	no volume	19
ISOTXS	DSN for ISOTXS	(,DELETE)	19
PATH	name of member to be executed	FX2	EXEC
POSTLIB	step library	SYS1.DUMMYLIB	STEPLIB
PRELIB	step library	SYS1.DUMMYLIB	STEPLIB
RFLXDSP	disposition for RTFLUX	(,DELETE)	22
RFLXVOL	volume for RTFLUX	no volume	22
RSTRDSP	disposition for FX2RS1 and FX2RS2	(,DELETE)	49,50
RSTR1	DSN for FX2RS1	&RSTR1	49
RSTR2	DSN for FX2RS2	&RSTR2	50
RTFLUX	DSN for RTFLUX	&RTFLUX	22
SEP1	separation parameter	FT25F001,FT26F001	
THDATA	DSN for THDATA	&THDATA	27
THDDSP	disposition for THDATA	(,DELETE)	27
THDVOL	volume for THDATA	no volume	27
TIMLIM	time limit	(600,0)	EXEC
UNITS	generic unit name	BATCHDSK	
XSCNDSP	disposition for XSCON	(,DELETE)	21
XSCNVOL	volume for XSCON	no volume	21
XSCON	DSN for XSCON	&XSCON	21

The parameters HALFBLK, FULLBLK, and UNITS which are used in many of the datasets are defined with the other symbolic parameters. The block size defaults of 6136 and 12280 for HALFBLK and FULLBLK are consistent with the use of 3330 disk packs. The use of SASCR and BATCHDSK for the UNIT parameter in the procedure correspond to ANL conventions for generic names. SASCR is used to designate permanently resident disk packs for scratch purposes. BATCHDSK corresponds to both permanently resident and setup disk packs, and is used for those files which may be saved on user option for later use. The PRELIB and POSTLIB parameters allow the user to access other load modules than the one permanently referred to. They default to empty partitioned data sets.

The use of the cataloged procedure allows FX2-TH problems to be executed with a minimum of job control language requirements. Examples of the necessary JCL are given in Section V.D.

B. Input Data Specifications

Input data for FX2-TH may be entered as either BCD input files or as binary interface files stored on disk. If desired, all the input data may be on BCD input files, or all the input data may be on binary interface files. In practice, neither of these modes of operation is very convenient. In general, cross section input resides on binary interface files, while the rest of the input resides on BCD input files.

B.1 Overall Structure of Input Data

The input deck for FX2-TH is divided into two parts, or "blocks". The first block is labeled "BLOCK=OLD", while the second block is labeled "BLOCK=STP014". In the BLOCK=OLD section, the user specifies files, by their FX2-TH file name, which have previously been saved and are now resident on disk as binary files. Such files generally include microscopic or macroscopic cross sections. The files are specified with a card which says, starting in column 1, DATASET=filename. There is one such data card for each file so specified.

The cross sections may be input in either microscopic or macroscopic form. If microscopic cross sections are to be entered, two data sets must be present; one containing the microscopic cross sections (ISOTXS), the other containing the delayed neutron parameters (DLAYXS). These files must be in the format specified by the CCCC,¹⁶ although they may be present as binary interface files (ISOTXS and DLAYXS), or as BCD input files (A.ISO and A.DLA). If the files are entered as binary files, FX2-TH will use them directly. If they are entered as BCD input files FX2-TH will first convert them to binary files, and then use them directly. These files can be obtained by running a code such as MC²-2.¹⁷ If macroscopic cross sections are to be entered, the data set XSCON must be present as a binary file on disk. The XSCON file contains the result of the cross section homogenization procedure. It also contains the fuel and coolant temperature feedback coefficients. This data set may be obtained in one of two ways. The user may construct it himself and write it on disk using a user-written program. Or, the XSCON file written by FX2-TH after successful completion of the cross section homogenization procedure of Section IV.A and calculation of the required temperature coefficients may be saved on disk.

This file may then be used for future cases instead of FX2-TH performing the cross section homogenization again.

In BLOCK=STP014, the user inputs the BCD input cards, broken into files. Each BCD input file is preceded by a card which says, starting in column 1, DATASET=filename. The file A.FX2 contains various control parameters and convergence criteria. The file A.FNIP describes the geometry of the problem and specifies the homogenization of the microscopic cross sections. The file A.THRM provides input for the thermal-hydraulics calculation.

As stated above, some data required by FX2-TH can originate either as BCD input files or as binary interface files. Figure 10 shows a diagram illustrating the data flow between these input data files. Any file listed under the column "Files Used Directly by FX2-TH" may be saved on disk for a future run, where it would be placed in BLOCK=OLD. The user must determine the mode of operation which is most convenient for himself.

If BCD input data sets A.ISO and A.DLA are present in the input job stream, they must be preceded by a card which says NOSORT=A.ISO, or NOSORT=A.DLA. This takes the place of the DATASET=A.ISO or DATASET=A.DLA.

Fig. 10. Input Data Files to FX2-TH

B.2 Cross Section Representation

A multigroup representation of a nuclear reactor requires a great deal of data manipulation and storage. The strategies used in FX2-TH were designed to provide full user flexibility while at the same time making optimal use of available core storage. The various cross section homogenization schemes in FX2-TH will now be discussed.

The cross sections in FX2-TH undergo two stages of homogenization. In the first stage, microscopic cross sections representing each physical isotope are smeared together to form a unique material. Then, the unique materials are smeared together to form compositions. These two stages will be discussed separately.

In the first stage of homogenization, isotopes are mixed together to form unique materials. This homogenization stage is performed when FX2-TH accepts ISOTXS and DLAYXS files, homogenizes them, and writes an XSCON file. The type 13 cards of the BCD input file A.FNIP controls this homogenization stage.

FX2-TH allows the user to enter any number of physical isotopes which then will be homogenized into a unique material. For example, the fuel in a specific region of the reactor might be composed of the isotopes ^{235}U , ^{238}U , and ^{239}Pu . FX2-TH would then allow the user to define a specific type of fuel material, consisting of a specific isotopic content of the above three isotopes. This isotopic content is assumed fixed for the duration of the FX2-TH calculation. The cross sections and chi vectors are calculated as shown in Eqs. (IV.1, 2). Each unique material also has a set of fuel and coolant temperature coefficients. To calculate the fuel temperature coefficients, FX2-TH allows the user to enter sets of microscopic cross sections representing the same physical isotope at different values of fuel temperature. The general correlation shown in Eq. (IV.3) is then evaluated by considering the cross section values at the four temperatures. To calculate the coolant temperature coefficients, FX2-TH allows the user to enter, for each physical coolant isotope, the first derivative of the atom density of this isotope with respect to coolant temperature. The coolant temperature feedback coefficient is then calculated as in Eq. (IV.5). When the cross section homogenization and feedback coefficient calculation has been accomplished for each unique material, the XSCON file is written with all of this information written on it.

At this point, further clarification of the unique material concept is required. In FX2-TH, the reactor is thought of as being composed of physical materials such as uranium oxide, plutonium oxide, stainless steel, etc. Each of these materials represents one of the "unique materials" described above. However, it is recognized that the cross sections for a particular physical material at one point in the reactor core may not be the same as the cross sections of the same physical material at another point in the core (from reactor burnup, for example). In an attempt to minimize computer storage requirements, FX2-TH employs a generic material - unique material concept. That is, a number of generic materials are defined (such as plutonium oxide, stainless steel, etc.). At a specific point in the reactor core, the generic material is composed of a specific unique material (which may be different from the unique material present at a different point in the core). Therefore, there are several unique

materials, each with a separate cross section set and unique material label, all of which however share the same generic material label. Under this scheme, uranium oxide in the inner and outer core regions might be represented as UO2-IC and UO2-OC, respectively, with both sharing the generic material label UO2. Since core storage requirements and computing times are much more dependent on the number of generic materials than on the number of unique materials, it is in the user's interest to attempt to minimize the number of generic materials.

In the second stage of homogenization, the unique materials which make up the actual reactor material at a specific point in the reactor are homogenized. This is performed by FX2-TH when it reads in the XSCON file and multiplies the unique material cross sections and temperature coefficients by the appropriate volume fractions. The volume fractions are input on the type 14 cards of the BCD input file A.FNIP. The composition so generated, represented by a particular region label, can then be placed at any point in the reactor as the user desires.

For materials in which Doppler feedback is present, the macroscopic cross section for process P in group g is calculated as follows. First, the cross sections $\Sigma_{m,g}^P(T_f)$ are evaluated from Eq. (IV.3) using the fuel temperature present in this region. Then, these cross sections are summed over each material m making up this composition:

$$\Sigma_g^P(T_f) = \sum_{m=1}^M VF_m \Sigma_{m,g}^P(T_f) \quad (V.1)$$

where

M is the total number of unique materials in this composition

VF_m is the volume fraction of unique material m in this composition

For materials in which coolant temperature feedback is present, the required macroscopic cross section is calculated in a similar manner.

First, the cross sections $\Sigma_{m,g}^P(T_c)$ are evaluated from Eq. (IV.5) using the coolant temperature present in this region. Then, the cross sections are summed over each material m making up this composition:

$$\Sigma_g^P(T_c) = \sum_{m=1}^M VF_m \Sigma_{m,g}^P(T_c) \quad (V.2)$$

For materials in which neither fuel nor coolant feedback is present, the following expression is used

$$\Sigma_g^P = \sum_{m=1}^M VF_m \Sigma_{m,g_{base}}^P \quad (V.3)$$

In FX2-TH, perturbations are initiated by allowing the user to alter the values of VF_m for any m in any composition. This modification can be a step, ramp, or quadratic function. The modifications to VF_m are controlled by the type 10 cards of the BCD input file A.FX2.

B.3 Geometry and Boundary Condition Input

The FX2-TH code allows a variety of one- and two-dimensional geometric configurations. These are

- a) slab (x)
- b) cylinder (r)
- c) x-y
- d) r-z
- e) θ -r
- f) triangular

For the one-dimensional geometries and all two-dimensional geometries, except the triangular mesh, the region and mesh data are supplied on type 06 or 09 cards of dataset A.FNIP. For the triangular mesh geometries, the region and mesh data are supplied on type 29, 30, and 31 cards of dataset A.FNIP. The transverse half-height and extrapolation distance are specified on a type 12 card of A.FNIP.

The boundary condition types that can be specified are

- a) $\phi=0$
- b) $\phi'=0$
- c) $\phi' + \frac{A}{D} \phi=0$
- d) repeating periodic with next adjacent face

where D is the diffusion coefficient in the mesh interval immediately within the reactor boundary. For orthogonal geometries (except θ -r); options a), b), and c) above may be used. For θ -r geometry and triangular geometry, any of the above options may be used.

The above boundary conditions can be dependent on the neutron energy group. The data are supplied on the type 04 and 05 cards of dataset A.FNIP.

B.4 External Neutron Source

If there is an external isotropic neutron source, the data are supplied on the type 29 card of dataset A.FNIP. The external source is allowed to be time dependent in FX2-TH. A very simple time dependence is specified; the user is allowed to multiply the fixed source (at all mesh points and energy groups) by an input number at a specific time during the transient. This time, which can be equal to zero, is also input by the user.

B.5 Flux Input

If no flux files are specified as being in BLOCK=OLD, FX2-TH uses a flat flux guess (for each mesh point and energy group) to begin the steady state calculation. At the conclusion of the steady state calculation, the real

and adjoint fluxes are written on the standard interface files RTFLUX and ATFLUX respectively. If files RTFLUX and ATFLUX are specified in BLOCK=OLD, they will be used as the initial flux estimates for the steady-state calculation.

B.6 Thermal-Hydraulics Input

The input to the thermal-hydraulics models in FX2-TH is given in dataset A.THRM. In this dataset, the user selects which thermal-hydraulics model is to be used, and the relevant input data for that model.

For the purposes of the thermal-hydraulic calculation, the reactor core is broken into thermal-hydraulic channels, and each channel into axial mesh regions. In the dataset A.THRM, the correspondence between the neutronics mesh and the thermal-hydraulics mesh is specified in a very general manner. The user is given three options:

- a) each neutronics region may become one thermal-hydraulics region, or
- b) each neutronics mesh cell may become one thermal-hydraulics region, or
- c) the thermal-hydraulics mesh structure may be defined in an arbitrary manner.

These options are accomplished by using type 03, 04, and 05 cards of A.THRM.

In FX2-TH, it is recognized that different regions of the core may contain different thermal-hydraulics data values. Each thermal-hydraulics channel is assigned a data type number, and the user inputs different sets of input data values for each data type. The input data are read on card type 06 of A.THRM. Each "set" of data (corresponding to a particular data type number) consists of an entire set of data values given in the list under card type 06 of dataset A.THRM (6 values for the simple models, 34 for the detailed model). All data for thermal-hydraulics data set IT must be entered before any data from data set (IT+1) can be entered. Within a particular data set IT, the individual datum values may be input in any order. Before each datum value, the datum number (either 1 to 6 or 1 to 34, depending on which model is being used) is entered. When all of the data for any particular data set IT have been entered, a new type 06 card should be used to begin to specify the data for data set (IT+1). When any particular data set IT has been completely entered, the code will "copy" the data of data set IT into the locations reserved for data set (IT+1). Then, only those values for data set (IT+1) which are different from those of data set IT need be entered. The correspondence between the thermal-hydraulic channels and the data types is made on the type 09 cards of dataset A.THRM.

On card types 13 and 14 of A.THRM, the user may enter the initial values of the average coolant and fuel temperatures. If one of the simple thermal-hydraulic models is being used, these temperatures represent the steady-state temperatures. A coolant and fuel temperature may be entered for every thermal-hydraulic channel and axial mesh region. If the detailed thermal-hydraulic model is being used, these temperatures are used to begin the steady-state iteration between neutronics and thermal-hydraulics. If type 13 and 14 cards are not entered, the initial coolant and fuel temperatures are taken to be the base coolant and fuel temperatures, respectively.

C. Computer Core Requirements

Previous versions of the FX2 code used one large block of core memory to contain the problem variables. When FX2 was executed on a two-level storage computer such as the CDC 7600, only a small amount of small core memory (SCM) was available for data storage, requiring FX2 to perform a great deal of disk I/O. To relieve this problem and also allow for larger problems to be executed on the CDC 7600, a two-level data storage technique has been implemented into FX2-TH. In this technique, FX2-TH uses two levels of core storage, a "small core" block, and a "large core" block. On the CDC 7600, this corresponds to SCM and LCM, respectively. On IBM 360 or 370 series computers, both blocks are contained in directly addressable core memory. The user must input the amount of small core and the amount of large core required for this calculation. FX2-TH provides edits of the amount of core storage required for both the small core and the large core blocks. A small test run can be used together with these edits to determine the amount of storage required.

The small core storage block is used to contain small blocks of data. A certain minimum amount of large core storage is required for each problem. FX2-TH then examines the amount of additional large core storage remaining and determines which additional data blocks may be kept permanently in core. There are eight blocks of data which FX2-TH will attempt to fit into the large core block; in the following order:

- a) Thermal-hydraulic data
- b) Fission cross sections
- c) Scattering cross sections
- d) Removal and transport cross sections
- e) Flux file
- f) Volume fractions
- g) Precursor densities
- h) Finite difference coefficients.

If insufficient room is available for a particular file, then that file is read from and written to the disk as needed. Generally, FX2-TH is more cost efficient if as many of the above files are permanently contained in large core as are possible. On the CDC 7600, storage in the large core block is accessed directly using LEVEL 2 statements. In order to execute FX2-TH, the CDC 7600 system must support this directly addressable LCM concept.

The overall core requirements of FX2-TH will now be discussed. On IBM 360 or 370 series computers, the FX2-TH overlayed program requires 150 K of core. In-core buffers require from 105 K to 156 K, depending on the problem. If all files are permanently contained in large core, 105 K of buffer space is required. If none of the above files can be core contained, 156 K of buffer space is required. The core taken up by the small core and large core blocks are then added to determine the total FX2-TH requirement.

For the CDC 7600 computer, the core requirements of both SCM and LCM must be considered. The FX2-TH overlayed program plus SCM buffers requires 28,700 words of SCM. This leaves roughly 20,000 words of SCM for the small core block (this is dependent on the particular operating system). The large core storage block must not exceed 131,000 words.

D. Sample Problems

Three sample problems have been defined to demonstrate the use of the FX2-TH code. The first sample problem is an r-z model of an LMFBR in four neutron energy groups. No feedback is included in this sample problem. The transient is induced by removing some stainless steel from the inner core. A listing of the input data for this sample problem is given in Figure 11. The output for this sample problem is given in Appendix VI.

```
// EXEC ARCSP024,
// XSCON='C116.B20219.XSCON.PROB1',XSCNDSP='SHR'
//SYSIN DD *
BLOCK=OLD
DATASET=XSCON
BLOCK=STP014
DATASET=A.FX2
01      FX2-TH TEST PROBLEM 1
02      2000 13000 0
03      0 0 0 0 1 0 0 0
04      1 0 0 3 0 50 10 10000
05      2 0 0 0 0 0 1 0 1 0
06      0.5 0.05 -0.01 0.0 1000.0
07      0.0 0.001 1.0E-6 0.0 0.8
07      1.0E-7 1.0E-6 1.0E-7 1.0E2 0.0
08      120.0 30.0 0.5 0.25 1.0
08      2.0 0.1 0.0 0.0
09      5.0E8 1.0 1.0 0.01
09      0.0
10      INCORE SS 0.0 1.0 -0.1 0.0
DATASET=A.FNIP
03      50
04      3 2 2 2
06      AXREFL 0. 80. 0. 130.
06      RDREFL 80. 100. 0. 130.
06      AXBLKT 0. 65. 20. 110.
06      RDBLKT 65. 80. 20. 110.
06      INCORE 0. 45. 30. 100.
06      OUCORE 45. 65. 30. 100.
09      X 8 45.0 3 65.0 2 80.0
09      X 3 100.0
09      Y 3 20.0 2 30.0 10 100.
09      Y 2 110. 3 130.
14      INCORE UO2 0.25 PUO2 0.05 SS 0.25
14      INCORE NA 0.45
14      OUCORE UO2 0.24 PUO2 0.06 SS 0.25
14      OUCORE NA 0.45
14      RDBLKT UO2 0.30 SS 0.25 NA 0.45
14      AXBLKT UO2 0.30 SS 0.30 NA 0.40
14      RDREFL SS 0.60 NA 0.28 NI 0.12
14      AXREFL SS 0.30 NA 0.40 NI 0.30
/*
```

Fig. 11. Sample Problem 1 Input

Sample problem 2 is an x-y model of a BWR in two neutron energy groups. The feedback model used is the adiabatic model with the constant heat transfer option. The steady-state coolant and fuel temperatures are input in the dataset A.THRM. These temperatures were obtained by running a steady-state FX2-TH solution using the detailed thermal-hydraulics model. The temperatures input into sample problem 2 are the converged coolant and fuel temperatures found from the detailed model. The results of the steady-state and transient calculations in sample problem 2 are almost identical to the same problem when using the detailed model. A listing of the input data for sample problem 2 is given in Figure 12.

```
// EXEC ARCSPO24,
// XSCON='C116.B20219.XSCON.PROB2',XSCNDSP='SHR'
//SYSIN DD *
BLOCK=OLD
DATASET=XSCON
BLOCK=STP014
DATASET=A.FX2
01      FX2-TH TEST PROBLEM 2
02      1500 13000 0
03      0 0 1 1 1 0 0 0
04      0 0 0 3 0 200 20 7000
05      2 1 2 0 0 0 1 0
06      0.2 0.05 -0.01 0.0 1.0E+10
07      0.01 0.001 0.000001 0.0 0.5
08      1.0E-06 1.0E-06 1.0E-06 1.0E+02 0.0
09      80. 20. .1 .01
10      0.05 0.0 0.0
11      7.5 E+0 1.107361480 1.0 0.01 0.002
12      0.0
13      REG7 COMP1 0.0 0.0 -1.0 0.0
14      REG7 COMP5 0.0 0.0 +1.0 0.0
15      REG55 COMP1 0.0 0.0 -1.0 0.0
16      REG55 COMP5 0.0 0.0 +1.0 0.0
DATASET=A.FNIP
03      40
04      3 2 3 2
05      REGREF 0.0 180. 18 18 0.0 100.
06      REG1 0.0 20. 2 2 0.0 20.
06      REG2 20.0 40. 2 2 0.0 20.
06      REG3 40.0 60. 2 2 0.0 20.
06      REG4 60. 80. 2 2 0.0 20.
06      REG5 80. 100. 2 2 0.0 20.
06      REG6 100. 120. 2 2 0.0 20.
06      REG7 120. 140. 2 2 0.0 20.
06      REG8 140. 160. 2 2 0.0 20.
06      REG10 0.0 20. 2 2 20. 40.
06      REG11 20. 40. 2 2 20. 40.
06      REG12 40. 60. 2 2 20. 40.
06      REG13 60. 80. 2 2 20. 40.
06      REG14 80. 100. 2 2 20. 40.
06      REG15 100. 120. 2 2 20. 40.
06      REG16 120. 140. 2 2 20. 40.
06      REG17 140. 160. 2 2 20. 40.
06      REG19 0.0 20. 2 2 40. 60.
06      REG20 20. 40. 2 2 40. 60.
06      REG21 40. 60. 2 2 40. 60.
06      REG22 60. 80. 2 2 40. 60.
06      REG23 80. 100. 2 2 40. 60.
06      REG24 100. 120. 2 2 40. 60.
06      REG25 120. 140. 2 2 40. 60.
06      REG26 140. 160. 2 2 40. 60.
06      REG28 0.0 20. 2 2 60. 80.
06      REG29 20. 40. 2 2 60. 80.
06      REG30 40. 60. 2 2 60. 80.
06      REG31 60. 80. 2 2 60. 80.
06      REG32 80. 100. 2 2 60. 80.
06      REG33 100. 120. 2 2 60. 80.
06      REG34 120. 140. 2 2 60. 80.
06      REG35 140. 160. 2 2 60. 80.
06      REG37 0.0 20. 2 2 80. 100.
06      REG38 20. 40. 2 2 80. 100.
06      REG39 40. 60. 2 2 80. 100.
06      REG40 60. 80. 2 2 80. 100.
```

Fig. 12. Sample Problem 2 Input

06	REG41	80.	100.	2	2	80.	100.
06	REG42	100.	120.	2	2	80.	100.
06	REG43	120.	140.	2	2	80.	100.
06	REG46	0.0	20.	2	2	100.	120.
06	REG47	20.	40.	2	2	100.	120.
06	REG48	40.	60.	2	2	100.	120.
06	REG49	60.	80.	2	2	100.	120.
06	REG50	80.	100.	2	2	100.	120.
06	REG51	100.	120.	2	2	100.	120.
06	REG52	120.	140.	2	2	100.	120.
06	REG55	0.0	20.	2	2	120.	140.
06	REG56	20.	40.	2	2	120.	140.
06	REG57	40.	60.	2	2	120.	140.
06	REG58	60.	80.	2	2	120.	140.
06	REG59	80.	100.	2	2	120.	140.
06	REG60	100.	120.	2	2	120.	140.
06	REG64	0.0	20.	2	2	140.	160.
06	REG65	20.	40.	2	2	140.	160.
06	REG66	40.	60.	2	2	140.	160.
06	REG67	60.	80.	2	2	140.	160.
14	REGREFCOMP4		1.0				
14	REG1 COMP1		1.0				
14	REG2 COMP2		1.0				
14	REG3 COMP1		1.0				
14	REG4 COMP2		1.0				
14	REG5 COMP1		1.0				
14	REG6 COMP2		1.0				
14	REG7 COMP1		1.0				
14	REG8 COMP3		1.0				
14	REG10 COMP2		1.0				
14	REG11 COMP1		1.0				
14	REG12 COMP2		1.0				
14	REG13 COMP1		1.0				
14	REG14 COMP2		1.0				
14	REG15 COMP1		1.0				
14	REG16 COMP3		1.0				
14	REG17 COMP3		1.0				
14	REG19 COMP1		1.0				
14	REG20 COMP2		1.0				
14	REG21 COMP1		1.0				
14	REG22 COMP2		1.0				
14	REG23 COMP1		1.0				
14	REG24 COMP2		1.0				
14	REG25 COMP1		1.0				
14	REG26 COMP3		1.0				
14	REG28 COMP2		1.0				
14	REG29 COMP1		1.0				
14	REG30 COMP2		1.0				
14	REG31 COMP1		1.0				
14	REG32 COMP2		1.0				
14	REG33 COMP1		1.0				
14	REG34 COMP3		1.0				
14	REG35 COMP3		1.0				
14	REG37 COMP1		1.0				
14	REG38 COMP2		1.0				
14	REG39 COMP1		1.0				
14	REG40 COMP2		1.0				
14	REG41 COMP2		1.0				
14	REG42 COMP2		1.0				
14	REG43 COMP3		1.0				
14	REG46 COMP2		1.0				
14	REG47 COMP1		1.0				
14	REG48 COMP2		1.0				
14	REG49 COMP1		1.0				
14	REG50 COMP2		1.0				
14	REG51 COMP3		1.0				
14	REG52 COMP3		1.0				
14	REG55 COMP1		1.0				
14	REG56 COMP3		1.0				
14	REG57 COMP1		1.0				
14	REG58 COMP3		1.0				
14	REG59 COMP3		1.0				
14	REG60 COMP3		1.0				
14	REG64 COMP3		1.0				
14	REG65 COMP3		1.0				
14	REG66 COMP3		1.0				
14	REG67 COMP3		1.0				

Fig. 12. (Contd)

DATASET=A.THRM

```

02      2      0      0      1      1
04      365.76
06      1      1      .4757      2      3.432      3      0.0      4      0.0      5      0.0
06      1      6      0.0
13      549.2      578.7      582.9      579.0      582.0
13      577.0      578.3      571.3      567.5      582.9
13      579.4      582.5      578.4      580.4      575.3
13      576.8      568.0      579.0      582.5      578.9
13      581.7      577.2      578.1      571.3      566.7
13      582.0      578.4      581.7      578.2      580.8
13      575.0      574.6      564.3      577.0      580.4
13      577.2      580.8      580.7      577.4      571.6
13      578.3      575.3      578.1      575.0      577.4
13      575.3      565.6      571.3      576.8      571.3
13      574.6      571.6      565.6      567.5      568.0
13      566.7      564.3
14      884.0      944.4      1016.2      950.6      1000.0
14      918.1      938.0      832.0      777.9      1016.2
14      956.7      1018.7      941.1      973.2      891.5
14      915.4      785.1      950.6      1008.7      948.1
14      994.7      921.1      935.6      831.3      767.2
14      1000.0      941.1      994.7      937.4      980.0
14      886.6      881.2      734.1      918.1      973.2
14      921.1      980.0      978.8      925.1      835.6
14      938.0      891.5      935.6      886.6      925.1
14      891.3      752.0      832.0      915.4      831.3
14      881.2      835.6      752.0      777.9      785.1
14      767.2      734.1
/*

```

Fig. 12. (Contd)

Sample problem 3 is an r-z model of an LMFBR in nine neutron energy groups. The detailed thermal-hydraulics model is used for this problem. For the steady-state solution, a converged set of coolant and fuel temperatures and power densities are found. A short transient is then run. This problem demonstrated the generally rapid convergence of the overall steady-state iterative process which appears to be typical of LMFBR problems. A listing of the BCD input data for sample problem 3 is given in Figure 13. The BCD input data sets A.ISO and A.DLA are not shown in Figure 13.

E. Error Messages

A list of the error messages provided by FX2-TH is given in Table II. The error messages are arranged by subroutine, which are grouped in alphabetical order.

There are two main types of errors in FX2-TH; non-fatal and fatal errors. In a non-fatal error, the subroutine ERROR is called with a non-negative integer argument. In a fatal error, the integer input is negative. When a fatal error occurs, processing is generally ended.

```

BLOCK=OLD
DATASET=A.ISO
DATASET=A.DIA
BLOCK=STP014
DATASET=A.FX2
01  FX2-TH TEST PROBLEM 3.  9 GROUP, 25 X 40 LMFBR
02      6000 60000      0
03      0      0      1      1      1      1      0      0
04
05      2      0      2      0      0      0      0      0      1      1
06      .05      3.20      -0.01      0.0      1.0E+30
07      0.0      0.001      0.000001      0.0      0.5
08      1.0E-07      1.0E-06      1.0E-07      1.0E+02      .0001
08      120.0      30.0      .10      .02      0.5
08      2.0      0.05      59.0      59.0
09      1.05      E+09      1.0 1.0      0.01      0.01
09      0.0
10      ICCH13NA800      0.0      0.1      -4.077
10      ICCH23NA800      0.0      0.1      -4.077
10      ICCH33NA800      0.0      0.1      -4.077
10      ICCH43NA800      0.0      0.1      -4.077
10      ICCH63NA800      0.0      0.1      -4.077
10      ICCH73NA800      0.0      0.1      -4.077
10      OCCH93NA800      0.0      0.1      -4.077
10      AXBKC1NA800      0.0      0.1      4.077
10      AXBKC2NA800      0.0      0.1      4.077
10      AXBKC3NA800      0.0      0.1      4.077
10      AXBKC4NA800      0.0      0.1      4.077
10      AXBKC6NA800      0.0      0.1      4.077
10      AXBKC7NA800      0.0      0.1      4.077
10      AXBKC9NA800      0.0      0.1      4.077
10      ICCH14PU02      0.0      2.0      -.028525
10      ICCH24PU02      0.0      2.0      -.028525
10      ICCH34PU02      0.0      2.0      -.028525
10      ICCH44PU02      0.0      2.0      -.028525
10      ICCRD7PU02      0.0      2.0      -.021375
10      ICCH64PU02      0.0      2.0      -.028525
10      ICCH74PU02      0.0      2.0      -.028525
10      OCCRD7PU02      0.0      2.0      -.0380775
10      OCCH94PU02      0.0      2.0      -.0439645
10      ICCH13PU02      0.0      2.0      .028525
10      ICCH23PU02      0.0      2.0      .028525
10      ICCH33PU02      0.0      2.0      .028525
10      ICCH43PU02      0.0      2.0      .028525
10      ICCRD6PU02      0.0      2.0      .021375
10      ICCH63PU02      0.0      2.0      .028525
10      ICCH73PU02      0.0      2.0      .028525
10      OCCRD6PU02      0.0      2.0      .0380775
10      OCCH93PU02      0.0      2.0      .0439645
10      ICCH14U02C      0.0      2.0      -.148525
10      ICCH24U02C      0.0      2.0      -.148525
10      ICCH34U02C      0.0      2.0      -.148525
10      ICCH44U02C      0.0      2.0      -.148525
10      ICCRD7U02C      0.0      2.0      -.111285
10      ICCH64U02C      0.0      2.0      -.148525
10      ICCH74U02C      0.0      2.0      -.148525
10      OCCRD7U02C      0.0      2.0      -.1153165
10      OCCH94U02C      0.0      2.0      -.133085
10      ICCH13U02C      0.0      2.0      .148525
10      ICCH23U02C      0.0      2.0      .148525
10      ICCH33U02C      0.0      2.0      .148525
10      ICCH43U02C      0.0      2.0      .148525
10      ICCRD6U02C      0.0      2.0      .111285
10      ICCH63U02C      0.0      2.0      .148525
10      ICCH73U02C      0.0      2.0      .148525
10      OCCRD6U02C      0.0      2.0      .1153165
10      OCCH93U02C      0.0      2.0      .133085

```

Fig. 13. Sample Problem 3 Input

DATASET=A.FNIP

03		50					
04		3	2	2	2		
06	ICCH11	0.0		6.2879		50.8000	76.2000
06	ICCH12	0.0		6.2879		76.2000	96.5200
06	ICCH13	0.0		6.2879		96.5200	116.8400
06	ICCH14	0.0		6.2879		116.8400	142.2400
06	ICCH21	6.2879		16.6362		50.8000	76.2000
06	ICCH22	6.2879		16.6362		76.2000	96.5200
06	ICCH23	6.2879		16.6362		96.5200	116.8400
06	ICCH24	6.2879		16.6362		116.8400	142.2400
06	ICCH31	16.6362		27.4083		50.8000	76.2000
06	ICCH32	16.6362		27.4083		76.2000	96.5200
06	ICCH33	16.6362		27.4083		96.5200	116.8400
06	ICCH34	16.6362		27.4083		116.8400	142.2400
06	ICCH41	27.4083		38.2478		50.8000	76.2000
06	ICCH42	27.4083		38.2478		76.2000	96.5200
06	ICCH43	27.4083		38.2478		96.5200	116.8400
06	ICCH44	27.4083		38.2478		116.8400	142.2400
06	ICCRD1	38.2478		49.1101		50.8000	66.0400
06	ICCRD2	38.2478		49.1101		66.0400	76.2000
06	ICCRD3	38.2478		49.1101		76.2000	86.3600
06	ICCRD4	38.2478		49.1101		86.3600	96.5200
06	ICCRD5	38.2478		49.1101		96.5200	106.6800
06	ICCRD6	38.2478		49.1101		106.6800	116.8400
06	ICCRD7	38.2478		49.1101		116.8400	127.0000
06	ICCRD8	38.2478		49.1101		127.0000	142.2400
06	ICCH61	49.1101		59.9828		50.8000	76.2000
06	ICCH62	49.1101		59.9828		76.2000	96.5200
06	ICCH63	49.1101		59.9828		96.5200	116.8400
06	ICCH64	49.1101		59.9828		116.8400	142.2400
06	ICCH71	59.9828		70.0191		50.8000	76.2000
06	ICCH72	59.9828		70.0191		76.2000	96.5200
06	ICCH73	59.9828		70.0191		96.5200	116.8400
06	ICCH74	59.9828		70.0191		116.8400	142.2400
06	OCCRD1	70.0191		81.7427		50.8000	66.0400
06	OCCRD2	70.0191		81.7427		66.0400	76.2000
06	OCCRD3	70.0191		81.7427		76.2000	86.3600
06	OCCRD4	70.0191		81.7427		86.3600	96.5200
06	OCCRD5	70.0191		81.7427		96.5200	106.6800
06	OCCRD6	70.0191		81.7427		106.6800	116.8400
06	OCCRD7	70.0191		81.7427		116.8400	127.0000
06	OCCRD8	70.0191		81.7427		127.0000	142.2400
06	OCC91	81.7427		92.6266		50.8000	76.2000
06	OCC92	81.7427		92.6266		76.2000	96.5200
06	OCC93	81.7427		92.6266		96.5200	116.8400
06	OCC94	81.7427		92.6266		116.8400	142.2400
06	AXBKC1	0.0		6.2879		142.2400	180.3400
06	AXBKC2	6.2879		16.6362		142.2400	180.3400
06	AXBKC3	16.6362		27.4083		142.2400	180.3400
06	AXBKC4	27.4083		38.2478		142.2400	180.3400
06	AXBKC5	38.2478		49.1101		142.2400	180.3400
06	AXBKC6	49.1101		59.9828		142.2400	180.3400
06	AXBKC7	59.9828		70.0191		142.2400	180.3400
06	AXBKC8	70.0191		81.7427		142.2400	180.3400
06	AXBKC9	81.7427		92.6266		142.2400	180.3400
06	AXBKLO	0.0		92.6266		12.7000	50.8000
06	AXREFI	0.0		124.8113		0.0	12.7000
06	AXREFI	0.0		124.8113		180.3400	193.0400
06	RDBNKT	92.6266		124.8113		12.7000	180.3400
06	RDRFPL	124.8113		135.7372		0.0000	193.0400
09	X	1	6.2879	2	16.6362	2	27.4083
09	X	2	38.2479	2	49.1101	2	59.9828
09	X	2	70.0191	2	81.7427	2	92.6266
09	X	6	124.8113	2	135.7372		
09	Y	3	12.7000	8	50.8000	3	66.0400
09	Y	2	76.2000	2	86.3600	2	96.5200
09	Y	2	106.6800	2	116.8400	2	127.0000
09	Y	3	142.2400	8	180.3400	3	193.0400

Fig. 13. (Contd)

14	ICCPD7NA800	0.531394	B4C	0.						
14	ICCRD8PU02	0.042750	U02C	0.222570	SS316	0.202531				
14	ICCRD8NA800	0.531394	B4C	0.						
14	ICCH61PU02	0.05705	U02C	0.29705	SS316	0.2382				
14	ICCH61NA800	0.4077								
14	ICCH62PU02	0.05705	U02C	0.29705	SS316	0.2382				
14	ICCH62NA800	0.4077								
14	ICCH63PU02	0.05705	U02C	0.29705	SS316	0.2382				
14	ICCH63NA800	0.4077								
14	ICCH64PU02	0.05705	U02C	0.29705	SS316	0.2382				
14	ICCH64NA800	0.4077								
14	ICCH71PU02	0.05705	U02C	0.29705	SS316	0.2382				
14	ICCH71NA800	0.4077								
14	ICCH72PU02	0.05705	U02C	0.29705	SS316	0.2382				
14	ICCH72NA800	0.4077								
14	ICCH73PU02	0.05705	U02C	0.29705	SS316	0.2382				
14	ICCH73NA800	0.4077								
14	ICCH74PU02	0.05705	U02C	0.29705	SS316	0.2382				
14	ICCH74NA800	0.4077								
14	OCCRD1PU02	0.076155	U02C	0.230633	SS316	0.219205				
14	OCCRD1NA800	0.473718	B4C	0.						
14	OCCRD2PU02	0.076155	U02C	0.230633	SS316	0.219205				
14	OCCRD2NA800	0.473718	B4C	0.						
14	OCCRD3PU02	0.076155	U02C	0.230633	SS316	0.219205				
14	OCCRD3NA800	0.473718	B4C	0.						
14	OCCPD4PU02	0.076155	U02C	0.230633	SS316	0.219205				
14	OCCRD4NA800	0.473718	B4C	0.						
14	OCCRD5PU02	0.076155	U02C	0.230633	SS316	0.219205				
14	OCCRD5NA800	0.473718	B4C	0.						
14	OCCPD6PU02	0.076155	U02C	0.230633	SS316	0.219205				
14	OCCRD6NA800	0.473718	B4C	0.						
14	OCCRD7PU02	0.076155	U02C	0.230633	SS316	0.219205				
14	OCCRD7NA800	0.473718	B4C	0.						
14	OCCRD8PU02	0.076155	U02C	0.230633	SS316	0.219205				
14	OCCRD8NA800	0.473718	B4C	0.						
14	OCCH91PU02	0.087929	U02C	0.266170	SS316	0.238200				
14	OCCH91NA800	0.4077								
14	OCCH92PU02	0.087929	U02C	0.266170	SS316	0.238200				
14	OCCH92NA800	0.4077								
14	OCCH93PU02	0.087929	U02C	0.266170	SS316	0.238200				
14	OCCH93NA800	0.4077								
14	OCCH94PU02	0.087929	U02C	0.266170	SS316	0.238200				
14	OCCH94NA800	0.4077								
14	AXBKC1U02B	0.3541	SS316	0.2382	NA800	0.4077				
14	AXBKC2U02B	0.3541	SS316	0.2382	NA800	0.4077				
14	AXBKC3U02B	0.3541	SS316	0.2382	NA800	0.4077				
14	AXBKC4U02B	0.3541	SS316	0.2382	NA800	0.4077				
14	AXBKC5U02B	0.3541	SS316	0.2382	NA800	0.4077				
14	AXBKC6U02B	0.3541	SS316	0.2382	NA800	0.4077				
14	AXBKC7U02B	0.3541	SS316	0.2382	NA800	0.4077				
14	AXBKC8U02B	0.3541	SS316	0.2382	NA800	0.4077				
14	AXBKC9U02B	0.3541	SS316	0.2382	NA800	0.4077				
14	AXBKLCU02B	0.3541	SS316	0.2382	NA800	0.4077				
14	RDBNKTU02B	0.5525	SS316	0.1639	NA800	0.2836				
14	AXREFLSS316R	0.2382	NA800R	0.4077	IN600R	0.3179				
14	RDREFLSS316R	0.2216	NA800R	0.1401	IN600R	0.6383				
15		750.								
DATASET=A.THRM										
02		3	5	0	2	1				
03		1	2	2	3	3	4	4	5	5
03		6	7	7	8	8	9	9	10	10
03		11	11	11	12	12				10
04		1	1	1	2	2	2	2	3	3
04		3	4	4	4	5	5	6	6	7
04		8	8	9	9	10	10	11	11	12
04		12	12	12	13	13	13	13	14	14
06	1	1	.235	2	.256	3	.295	4	.2076	5
06	1	6	.3	7	.43	8	.0958	9	.54707	10
06	1	20	5.0	21	.025	22	.8	23	.8	24
06	1	27	.02	28	0.0	29	0.0	30	3.518	31
06	1	32	0.0							
07			430.							
08			600.							
10		150	910	1830	2730	3670	4580	5010	6840	7320
										12490

Fig. 13. (Contd)

13	PU02	PUFUEL	0.01312	0.0	PU39C1PU39C2PU39C3PU39C4
13	PU02	PUFUEL	0.004710	0.0	PU40C1PU40C2PU40C3PU40C4
13	PU02	PUFUEL	0.002771	0.0	PU41C1PU41C2PU41C3PU41C4
13	PU02	PUFUEL	0.00085	0.0	PU42C1PU42C2PU42C3PU42C4
13	PU02	PUFUEL	0.04225	0.0	O-16C1
13	U02C	UFUEL	0.0000627	0.0	U-35C1U-35C2U-35C3U-35C4
13	U02C	UFUEL	0.02058	0.0	U-38C1U-38C2U-38C3U-38C4
13	U02C	UFUEL	0.04067	0.0	O-16B1
13	U02B	UFUEL	0.0000701	0.0	U-35B1U-35B2U-35B3U-35B4
13	U02B	UFUEL	0.02301	0.0	U-38B1U-38B2U-38B3U-38B4
13	U02B	UFUEL	0.04545	0.0	O-16B1
13	SS316	STEEL	0.05910	0.0	FEC1
13	SS316	STEEL	0.009849	0.0	NIC1
13	SS316	STEEL	0.01545	0.0	CRC1
13	SS316	STEEL	0.001356	0.0	MOC1
13	SS316RSTEEL		0.05910	0.0	FER1
13	SS316RSTEEL		0.009849	0.0	NIR1
13	SS316RSTEEL		0.01545	0.0	CRP1
13	SS316RSTEEL		0.001356	0.0	MOP1
13	NA800	NACOO	0.022	-6.5E-6NAC1	
13	NA800RNACOO		0.022	-6.5E-6NAP1	
13	B4C	CONT	0.01843	0.0	B-10C1
13	B4C	CONT	0.07468	0.0	B-11C1
13	B4C	CONT	0.02324	0.0	CC1
13	IN600RREFL		0.007287	0.0	FER1
13	IN600RREFL		0.06579	0.0	NIR1
13	IN600RREFL		0.01439	0.0	CHK1
14	ICCH11PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH11NA800		0.4077		
14	ICCH12PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH12NA800		0.4077		
14	ICCH13PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH13NA800		0.4077		
14	ICCH14PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH14NA800		0.4077		
14	ICCH21PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH21NA800		0.4077		
14	ICCH22PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH22NA800		0.4077		
14	ICCH23PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH23NA800		0.4077		
14	ICCH24PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH24NA800		0.4077		
14	ICCH31PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH31NA800		0.4077		
14	ICCH32PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH32NA800		0.4077		
14	ICCH33PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH33NA800		0.4077		
14	ICCH34PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH34NA800		0.4077		
14	ICCH41PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH41NA800		0.4077		
14	ICCH42PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH42NA800		0.4077		
14	ICCH43PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH43NA800		0.4077		
14	ICCH44PU02		0.05705	U02C 0.29705	SS316 0.2382
14	ICCH44NA800		0.4077		
14	ICCRD1PU02		0.042750	U02C 0.222570	SS316 0.202531
14	ICCRD1NA800		0.531394	B4C 0.	
14	ICCRD2PU02		0.042750	U02C 0.222570	SS316 0.202531
14	ICCRD2NA800		0.531394	B4C 0.	
14	ICCRD3PU02		0.042750	U02C 0.222570	SS316 0.202531
14	ICCRD3NA800		0.531394	B4C 0.	
14	ICCRD4PU02		0.042750	U02C 0.222570	SS316 0.202531
14	ICCRD4NA800		0.531394	B4C 0.	
14	ICCRD5PU02		0.042750	U02C 0.222570	SS316 0.202531
14	ICCRD5NA800		0.531394	B4C 0.	
14	ICCRD6PU02		0.042750	U02C 0.222570	SS316 0.202531
14	ICCRD6NA800		0.531394	B4C 0.	
14	ICCRD7PU02		0.042750	U02C 0.222570	SS316 0.202531

Fig. 13. (Contd)

TABLE II. Summary of Error Messages for FX2-TH

Subroutine AFX210

Error	-100.	A driving function was assigned a blank region label.
Error	-110.	A driving function was assigned a blank material label.
Error	-120.	A driving function was assigned an ending time less than zero
Error	-130.	A driving function was assigned an ending time less than its starting time.

Subroutine ANIPHX

Error	100.	No type 29 cards were entered.
Error	110.	Distance along hex flat cannot be non-positive
Error	120.	No type 30 cards entered.
Error	130.	A blank region label was entered.
Error	140.	Hex ring number entered as negative
Error	150.	Initial and/or final hex position entered as negative
Error	160.	Background region label identical to another region label already entered.
Error	170.	Zone label entered as blank
Error	180.	Region label entered on type 33 card does not match any region label on a type 30 card.

Subroutine ANIP03

Error	100.	No type 03 card entered.
Error	110.	Invalid geometry type entered.

Subroutine ANIP04

Error	100.	No type 04 card entered.
Error	110.	Invalid boundary condition on type 04 card.

TABLE II. (Contd.)

Subroutine ANIP05

Error	110.	Invalid boundary designator on type 05 card.
Error	120.	Negative energy group number entered on type 05 card.
Error	130.	Same as error 120.
Error	140.	Lower energy group number is less than the higher energy group number.

Subroutine ANIP06

Error	110.	Blank region label entered on type 06 card.
Error	120.	Invalid x-coordinate region boundary on type 06 card.
Error	130.	Invalid y-coordinate region boundary on type 06 card.
Error	140.	Negative number of intervals specified on type 06 card.

Subroutine ANIP08

Error	100.	Blank zone label on type 08 card.
Error	110.	Region label given on type 08 card does not match any label given on type 06 card.

Subroutine ANIP09

Error	110.	Invalid coordinate entered on type 09 card.
Error	120.	Discrepancy in number of mesh intervals on type 09 card.
Error	130.	Zero or negative value was given for first lower coordinate on type 09 card.
Error	140.	Zero or negative value was given for number of intervals on type 09 card.
Error	150.	Negative value given as number of intervals on the type 09 card.
Error	160.	Upper coordinates on type 09 cards are not monotonically increasing.
Error	170.	Two successive upper coordinates on type 09 cards are equal.
Error	180.	Same as Error 120.
Error	190.	Same as Error 130.
Error	200.	Same as Error 140.

TABLE II. (Contd.)

Subroutine ANIP09 (Contd.)

Error	210.	Same as Error 150.
Error	220.	Same as Error 160.
Error	230.	Same as Error 170.

Subroutine ANIP12

Error	110.	Region label on type 12 card does not match any region label on type 06 or 30 card.
Error	120.	Region label is blank, so only one type 12 card is allowed. More than one was entered.
Error	130.	Non-positive value given for transverse half-height.
Error	140.	Negative value given for transverse extrapolation distance.

Subroutine ANIP13

Error	110.	Blank material label on type 13 card.
Error	120.	Blank absolute material label on type 13 card.
Error	130.	First isotope label on type 13 card is blank.
Error	140.	Identical label found on type 13 card.
Error	150.	Input atom density is negative.

Subroutine ANIP14

Error	110.	Material label given on type 14 card does not match any label given on type 13 card.
Error	120.	Material label given on type 14 card does not match any label on UMNAM array of XSCON file.
Error	130.	Negative volume fraction entered on type 14 card.
Error	140.	Same as Error 110.
Error	150.	Region label appears more than once in the set of type 14 cards.

Subroutine ANIP19

Error	120.	Negative value entered for an energy group number on type 19 cards.
Error	130.	Label entered on type 19 cards does not match any region label.

TABLE II. (Contd.)

Subroutine ANIP19 (Contd.)

Error	140.	Same as Error 120.
Error	150.	Higher energy group number is greater than lower energy group number on type 19 cards.
Error	160.	Negative value given for lower coordinate on type 19 card.
Error	170.	Same as Error 160.

Subroutine ANIP34

Error	100.	Cannot have blank zone label on type 34 card if more than one type 34 card is entered.
Error	110.	Zone label on type 34 card does not match any zone label on type 08 or 33 cards.
Error	120.	Higher group number on type 34 card is negative.
Error	130.	Lower group number on type 34 card is negative.
Error	140.	Lower group number is less than higher group number on this type 34 card.

Subroutine CHKHOM

Error	-100.	Region label is blank, not allowed.
Error	-110.	Label for unique material from FXHMOG is blank, not allowed.
Error	-120.	Label for generic material from FXHMOG is blank, not allowed.
Error	-130.	Label from material mixing table not found in list of unique material labels.
Error	-140.	A geometry region has not had its composition specified.
Error	-150.	Entry in volume fraction array is negative - not allowed.
Error	-160.	Sum of elements of MRSPEC array does not equal material mixing table length.

Subroutine CHKXSC

Error	-100.	Decay constant less than zero.
Error	-110.	Neutron velocity less than zero.
Error	-120.	Error in LTOLP array.
Error	-130.	Error in LPTOL array.
Error	-140.	Unique material in FXHMOG not found in XSCON.

TABLE II. (Contd.)

Subroutine CHKXSC (Contd.)

Error	-150.	Generic material in FXHMOG not found in XSCON.
Error	-160.	Material number is too large.

Subroutine CRED

Error	-110.	Request to read negative number of words.
Error	-130.	No LCM storage available.

Subroutine CRIT

Error	-120.	Request to write negative number of words.
Error	-140.	No LCM storage available.

Subroutine DIMXCK

Error	-100.	Inconsistency in isotopes - do not share same common absolute isotope label.
-------	-------	--

Subroutine DRIVEF

Error	-100.	Driving function material label not a valid cross section label.
Error	-110	Driving function region label not a valid region label.

Subroutine EXTBC

Error	100.	Must specify boundary conditions for upper and lower x-boundaries for one-dimensional geometries.
Error	110.	Boundary condition at x-boundary is incorrect.
Error	120.	Boundary condition at x+boundary is incorrect.
Error	130.	Must specify boundary conditions for four boundaries in two-dimensional geometries.
Error	140.	Same as Error 110.
Error	150.	Same as Error 120.
Error	160.	Boundary condition at y-boundary is incorrect.
Error	170.	Boundary condition at y+boundary is incorrect.

TABLE II. (Contd.)

Subroutine FFIXSR

Error -100. Insufficient storage to allocate arrays.

Subroutine FFXHMO

Error -100. Insufficient storage to allocate arrays.
 Error -110. Same as Error -100.
 Error -120. Insufficient large core storage available to
 allocate arrays.
 Error -130. Same as Error -120.

Subroutine FGEODS

Error (-110) to (-180). Insufficient storage to allocate arrays.

Subroutine FORMSH

Error -100. Total number of fine-mesh intervals specified
 cannot be less than 2.
 Error -110. Same as Error -100.
 Error -120. Zero or negative interval number not allowed.
 Error -130. Coarse-mesh interval assigned negative width.
 Error -140. Same as Error -120.
 Error -150. Same as Error -130.

Subroutine FXINIT

Error -100. Fatal error in processing input binary files.
 Error -110. Fatal error in initializing steady-state calculation.
 Error -120. Fatal error in initializaing transient calculation.

Subroutine FXINPD

Error (-100) to (-120). Insufficient storage to allocate arrays.

TABLE II. (Contd.)

Subroutine FXINPR

Error	-100.	Neither ISOTXS or XSCON exist.
Error	-110.	Dataset A.FNIP does not exist and it should.
Error	-120.	Fatal error in reading A.FNIP.
Error	-130.	Same as Error -120.
Error	-140.	Cannot find GEODST in SEEK tables while preparing to write it.
Error	-150.	Error in forming GEODST file.
Error	-160.	Cannot find FXHMOG in SEEK tables while preparing to write it.
Error	-170.	Error in forming FXHMOG file.
Error	-180.	Cannot find RTFLUX in SEEK tables while preparing to write it.
Error	-190.	Cannot find ATFLUX in SEEK tables while preparing to write it.
Error	-200.	Cannot find FIXSRC in SEEK tables while preparing to write it.
Error	-210.	Error in forming FIXSRC file.
Error	-220.	BCD dataset A.THRM is not present and should be.
Error	-230.	Cannot find FXTH in SEEK tables while preparing to write it.
Error	-240.	Error in A.THRM input.
Error	-250.	Error in forming FXTH file.
Error	-260.	File FXTH must be in BLOCK=OLD and it is not.
Error	-300.	BCD dataset A.FX2 is needed but does not exist.
Error	-310.	Cannot find FXCTRL in SEEK tables while preparing to write it.
Error	-320.	Error in A.FX2 input make it impossible to write FXCTRL.
Error	-330.	Same as Error -320.

Subroutine FXINXS

Error	-100.	File FXHMOG must exist and it does not.
Error	-110.	File DLAYXS must exist and it does not.
Error	-120.	File ISOTXS must exist and it does not.
Error	-130.	File XSCON must exist and it does not.
Error	-140.	File FXCTRL must exist and it does not.
Error	-150.	Error in processing cross section input.

TABLE II. (Contd.)

Subroutine FXOV31

Error -100. Insufficient space to allocate arrays.

Subroutine FXOV32

Error -100. Insufficient large core space to allocate arrays.

Error -110. Same as Error -100.

Error -120. Same as Error -110.

Subroutine FXOV33

Error -100. Insufficient large core space to allocate arrays.

Subroutine FXOV41

Error (-110) to (-180). File is required but has not been supplied.

Error (-120) to (-280). Error incurred while reading and checking file.

Subroutine FXOV42

Error -100. Insufficient space to allocate arrays.

Subroutine FXPTXS

Error (-100) to (-130). Insufficient large core space to allocate arrays.

Subroutine FXSHAP

Error -100. Insufficient space to perform shape calculation.

Subroutine INITSS

Error -100. Insufficient space to perform steady-state calculation.

Subroutine INITT1

Error -100. Insufficient space to perform transient calculation.

TABLE II. (Contd.)

Subroutine ISOR48

Error	-100.	Isotope in FXHMOG was not found in ISOTXS.
Error	-110.	Isotope CHI matrix is not allowed.
Error	-120.	Isotope requested a set CHI but no set CHI was provided.

Subroutine I2SORD

Error	100.	Input data does not match mesh structure.
-------	------	---

Subroutine MATSRT

Error	100.	Region has not had its composition specified on a type 14 card of A.FNIP.
-------	------	---

Subroutine PKCALC

Error	-100.	Insufficient small core storage to allocate arrays.
-------	-------	---

Subroutine PKSTEP

Error	-100.	Point kinetics substep is too fine.
-------	-------	-------------------------------------

Subroutine PKUPDT

Error	-100.	Insufficient small core storage to allocate arrays.
-------	-------	---

Subroutine PNTMAT

Error	-100.	No material is present in a particular mesh cell.
-------	-------	---

Subroutine PRECUP

Error	-100.	Insufficient large core storage to allocate arrays.
-------	-------	---

Subroutine RAFNIP

Error	110.	No type 06 cards supplied in A.FNIP.
Error	120.	No type 13 cards supplied in A.FNIP.

TABLE II. (Contd.)

Subroutine RAFNIP (Contd.)

Error	130.	Insufficient small core storage space to allocate arrays.
Error	-100.	Insufficient core storage space to allocate arrays.

Subroutine RAFX2

Error	-100.	No type 01 card in A.FX2.
Error	-120.	Unacceptable input variable.
Error	-140.	Insufficient core storage space to allocate arrays.

Subroutine RATFLX

Error	-100.	Number of intervals inconsistent with GEODST.
Error	-110.	ATFLUX supplied is not one- or two-dimensional.

Subroutine RATHRM

Error	-100.	No type 01 card present in A.THRM.
-------	-------	------------------------------------

Subroutine RCMESH

Error	100.	X coordinate specified on type 06 card is inconsistent with XMESH array.
Error	110.	Same as Error 100.
Error	130.	Y coordinate specified on type 06 card is inconsistent with the YMESH array.
Error	140.	A mesh point did not receive a region specification.

Subroutine RDLYR4

Error	-100.	Isotope does not occur in DLAYXS.
-------	-------	-----------------------------------

Subroutine RESTRT

Error	-100.	Insufficient large core storage space to allocate arrays.
Error	-120.	Old and new values of amount of small and large core available are not compatible.
Error	-130.	Same as Error -100.

TABLE II. (Contd.)

Subroutine RESTRT (Contd.)

Error	-150.	Insufficient small core storage space to allocate arrays.
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Subroutine RFIXSR

Error	-100.	FIXSRC file inconsistent with GEODST file.
Error	-120.	FIXSRC supplied is not one- or two-dimensional.
Error	-130.	FIXSRC supplied is not for P-0 diffusion theory.
Error	-140.	Insufficient core storage space for allocating arrays.

Subroutine RFXCTL

Error	-100.	Input variable IPK has incorrect value.
Error	-110.	Input variable NTHF has incorrect value.
Error	-120.	Input variable NFDBK has incorrect value.
Error	-130.	Input variable ICMPFL has incorrect value.
Error	-140.	Input variable NTMPCR has incorrect value.
Error	-150.	Input variable IPTYPE has incorrect value.
Error	-160.	Input value NDOSS has incorrect value.
Error	-180.	Input value NGAMNX or NOUTMX has incorrect value.
Error	-190.	Input array IEDF has an incorrect value.
Error	-200.	Record 4 of FXCTRL has an incorrect value.
Error	-210.	Insufficient core storage space to allocate arrays.
Error	-220.	Starting time for a driving function is less than zero.
Error	-230.	Ending time for a driving function is less than starting time.

Subroutine RFXHMO

Error	-100.	Number of regions for which materials have been specified is less than number of geometry regions.
Error	-110.	Number of regions from FXHMOG is not equal to number of geometry regions.
Error	-120.	Number of zones from FXHMOG is not equal to number of geometry zones.
Error	-130.	Insufficient core storage space to allocate arrays.

TABLE II. (Contd.)

Subroutine RFXH35

Error	-110.	Length of material mix table is not greater than zero.
Error	-120.	Number of isotopes in FXHMOG is not greater than zero.
Error	-130.	Number of generic materials in FXHMOG is not greater than zero.
Error	-140.	Number of unique materials in FXHMOG is not greater than zero.
Error	-150.	Number of unique and generic materials are not compatible.
Error	-160.	Insufficient core storage space to allocate arrays.
Error	-170.	Same as Error -160.

Subroutine RFXTH

Error	-100.	Insufficient core storage space to allocate arrays.
-------	-------	---

Subroutine RGEODS

Error	-100.	Insufficient core storage space to allocate arrays.
-------	-------	---

Subroutine RHOBEG

Error	-100.	Insufficient core storage space to allocate arrays.
Error	-110.	Same as Error -100.

Subroutine ROMBI

Error	1.	Order 15 exceeded in Romberg integration.
-------	----	---

Subroutine RRTFLX

Error	-100.	Number of first or second dimension intervals or number of groups of RTFLUX is inconsistent.
Error	-110.	RTFLUX specified is not one- or two-dimensional.

Subroutine RWISOT

Error	-600.	Insufficient small core storage space to perform A.ISO to ISOTXS transformation.
-------	-------	--

TABLE II. (Contd.)

Subroutine RXSCON

Error	-100.	Number of generic materials on XSCON is inconsistent.
Error	-110.	Number of unique materials on XSCON is inconsistent.
Error	-120.	Variables NFMAT or NTFMAT are inconsistent with NMAT.
Error	-130.	NFAM is greater than six.
Error	-140.	Insufficient core storage space to allocate arrays.

Subroutine SCAN

Error	-18.	Error in BCD input cards.
Error	-22.	Same as Error -18.
Error	24.	File is not in SEEK tables.

Subroutine SHPEND

Error	100.	Number of gamma factor iterations exceeded.
-------	------	---

Subroutine START

Error	-100.	Unable to allocate the requested number of words.
-------	-------	---

Subroutine STUFF

Error	1.	Error in subroutine STUFF.
-------	----	----------------------------

Subroutine STUFF1

Error	- 8.	End of file encountered on ARC input file.
Error	- 14.	Record containing the word end was expected.
Error	- 22.	Subroutine STUFF1 expects a keyword.
Error	- 48.	Error in subroutine STUFF1.

Subroutine TIMDEP

Error	-100.	Insufficient core storage space to allocate arrays.
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TABLE II. (Contd.)

Subroutine TRIGOM

Error	100.	A row in the MR array has no non-zero entries.
Error	110.	A row in the MR array has a hole in it.

Subroutine XDENCK

Error	-100.	Energy bounds of ISOTXS and DLAYXS do not agree.
Error	-110.	Same as Error -100.

Subroutine XDRDR2

Error	-100.	Number of energy groups in ISOTXS is not greater than zero.
Error	-110.	Number of isotopes in ISOTXS is not greater than zero.
Error	-120.	Maximum scattering order must not be less than zero.
Error	-130.	Error in blocking of scattering data.
Error	-140.	Number of isotopes in DLAYXS must be positive.
Error	-150.	Number of energy groups of ISOTXS and DLAYXS must agree.
Error	-160.	Number of delayed families in DLAYXS is not positive and less than 7.
Error	-170.	Set fission spectrum is a matrix - not allowed.

Subroutine XDRDR3

Error	-100.	Insufficient core storage space to allocate arrays.
Error	-110.	Same as Error -100.

Subroutine XSCTSV

Error	-100.	Scattering matrix type must be 0, 1, 2, or 3.
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Subroutine XSFLPR

Error	-100.	Denominator on term for prompt chi was zero.
Error	-110.	Denominator in term for prompt nu was zero.
Error	-120.	Denominator in term for delayed nu was zero.

TABLE II. (Contd.)

Subroutine XSUPDT

Error	-100.	Array in SPEC was inconsistent.
Error	-110.	Temperature of isotope is not within five percent of required temperature.

After a fatal error occurs, a flag is set in subroutine ERROR. Subsequently if a call is made to ERROR with FATAL substituted for the subroutine name, the flag is checked to see if a fatal error has occurred. If such an error has occurred, then processing is terminated.

F. Restart Capabilities

FX2-TH has two different ways in which a problem may be restarted. These will be discussed separately.

F.1 Bypass Steady-State Calculation

FX2-TH allows the user to bypass the steady-state calculation if the converged steady state real and adjoint fluxes and thermal-hydraulic conditions are available as binary files. Therefore, the files RTFLUX, ATFLUX, and (if thermal-hydraulics is being used) THDATA must have been previously saved and available as binary files in BLOCK=OLD. The FX2-TH code will then begin the calculation with the time-dependent section. The cross sections may be input in the same manner on both runs.

F.2 Transient Restart

A transient FX2-TH problem may be restarted at a certain time in the transient. A restart file is written periodically (under user control) during the transient. Periodic dumps are written every C minutes of computing time and P seconds of problem time. A restart dump is also written at normal problem termination time. The restart file is written alternately on two datasets; a message appears in the printed edit to indicate which dataset the file was last written on.

To submit a problem which begins from a restart file, the dataset XSCON must be placed in BLOCK=OLD, and the dataset FX2RS1 or FX2RS2 must also be placed in BLOCK=OLD. Use FX2RS1 if the restart file is written on file 49, and FX2RS2 if the restart file is written on file 50. In dataset A.FX2 the restart flag on the type 03 card must be set to unity. Other input data in the dataset A.FX2 may be changed on a restart (see the input data description). If a fixed source file (FIXSRC) is written using the type 19 cards of A.FNIP, that file must be saved and the name FIXSRC placed in BLOCK=OLD for the restart case.

Table III shows the status of the files for a hypothetical set of runs. The first run calculates the steady-state conditions with the microscopic cross sections originating on BCD input data sets. The second run bypasses the steady-state calculation and performs part of a transient. The final restart file was written on FT49F001. The third run restarts the transient using the restart file written above.

G. Edits and Output Options

The edits produced by the FX2-TH program are controlled entirely by the type 05 card of BCD input data set A.FX2. There are three kinds of edits produced. The first is the standard printed edit file printed as the

TABLE III STATUS OF BINARY FILES FOR A SET OF RESTART CASES

	INITIAL STEADY - STATE SOLUTION	FIRST TRANSIENT CASE	TRANSIENT RESTART CASE
A. ISO	OLD	TEMPORARY	TEMPORARY
A. OLA	OLD	TEMPORARY	TEMPORARY
ISOTXS	NEW, KEEP	OLD, DELETE	TEMPORARY
DLAYXS	NEW, KEEP	OLD, DELETE	TEMPORARY
XSCON	NEW, DELETE	OLD, KEEP	OLD
RTFLUX	NEW, KEEP	OLD, DELETE	TEMPORARY
ATFLUX	NEW, KEEP	OLD, DELETE	TEMPORARY
THDATA	NEW, KEEP	OLD, DELETE	TEMPORARY
FX2RS1	TEMPORARY	NEW, KEEP	OLD
FX2RS2	TEMPORARY	NEW, KEEP	TEMPORARY
FIXSRC	NEW, KEEP	OLD, KEEP	OLD

calculation proceeds. The second is a log of certain key parameters during the transient which is written on data set A.FOUT in BCD format. When the problem reaches a normal termination, the file A.FOUT is printed out as a summary of the transient. This edit tabulates several key variables as a function of reactivity step, and flags each shape step with an asterisk. The third is a binary edit file, FXEDIT. This file can be written in brief, standard, or extended edit form. This file is written to assist the user in interpreting FX2-TH output, and allow the user to plot key variables easily. With the extended edit, the user has available a summary of various problem parameters, the pointwise powers, regionwise temperatures, and multigroup neutron fluxes. The FXEDIT description in Appendix III shows the format of this binary file. The output from the standard printed output for Sample Problem 1 is shown in Appendix VI.

If an FXEDIT file is being written and a transient restart case is performed, the edit files may be concatenated from the two jobs. This may be done by specifying DISP=(MOD,KEEP) on the restart job for the FXEDIT dataset. Care should be taken to insure that the restart file taken to begin the restart job was the last such file written by the initial job and that the calculation of the initial job terminated immediately after writing the restart file. This will insure that duplicate entries for the same time step do not appear on the FXEDIT file. On the CDC 7600, the FXEDIT file should be skipped to the end of information at the beginning of the restart job.

VI. PROGRAMMING INFORMATION

A. Program Structure

The FX2-TH program is structured along the lines of the overlays which compose it. The program consists of a root segment, and ten primary overlays. Four of the primary overlays are further subdivided into secondary overlays. A general chart showing the overlay structure is given in Figure 14. A detailed Table listing all subroutines contained in each overlay is given in Table IV.

Fig. 14. General Overlay Structure of FX2-TH

TABLE IV. Detailed Overlay Structure of FX2-TH

LEVEL (0,0)

MAIN	
START	
SSTATE	
TIMDEP	
SSEDIT	
CALFSP	
SUMARY	
TIMSUM	
BUOPEN	BUCLOS
IEQUAT	
FEQUAT	
FLTSET	
INTSET	
LINES	
DSKEDT	
ERROR	
TWODPR	
TWOPR2	
VOLUME	
PAR	
EDTFTC	
IEQUT2	
FEQUT2	
INTST2	
FLTST2	
SQUEZ2	
LCOPEN	
LCREED	LCRITE
LCCLOS	
FEQUT4	
IEQUT4	
CODE	
SEEK	
REED	RITE
TIMER	
CRED	CRIT
ECMV	
LRED	LRIT
ABEND	ABSTOP
POINTR	
PUTPNT	PUTBLK
BULK	
FREE	
WIPOUT	CLEAR
GETPNT	GETN
IGET	
IPT2	
PUTM	PUTB
IPTRR	NNAMSF
ILAST	ILASTB
REDEF	
REDEFM	REDEFB
PURGE	PURGB
STATUS	
PRTI1	
PRTI2	
PRTR1	PRTA1
PRTR2	PRTA2
PRTECM	
SPACE	
SQUEZE	GOWEST
ALLOCL	
ALLOC2	
FREE1	
FREE2	

TABLE IV. (Contd.)

LEVEL (1,0)

FXOV10
 RHOBEG
 RHOEND
 SHPEND
 TIMSTP
 DRIVEF
 EXTFLX
 EDITS
 PRECUP
 PRCUPD
 PRCMAP
 PKCALC
 PKSTEP
 PKSTOR
 PKUPDT

LEVEL (2,0)

FXINPR
 FRTFLX
 FATFLX

LEVEL (2,1)

RAFX2
 AFX210
 WFXCTL

LEVEL (2,2)

RAFNIP
 REPORT
 ANIP03
 ANIPHX
 ANIP04
 ANIP05
 ANIP06
 ANIP08
 ANIP09
 ANIP12
 ANIP13
 ANIP14
 ANIP19
 ANIP34
 GSCAN

LEVEL (2,3)

FGEODS
 NUMREG
 MESH
 MESHV
 MSHORD
 RCMESH
 LOCHEX
 TRIGOM
 DZONE
 BUCK
 VOLREG
 EXTBC
 WGEODS

LEVEL (2,4)

FFXHMO
 ISOSRT
 MATSRT
 WFXHMO

TABLE IV. (Contd.)

LEVEL (2,5)

FFIXSR
I2SORD
GRPSOR

LEVEL (2,6)

RATHRM
THMRZ
THRM03
THRM04
THRM05
THRM06
WFXTH

LEVEL (2,7)

BCDXST
RWISOT
RWDELY
RWDY1
RWDY2

LEVEL (3,0)

FXINXS
SDEQT
SDSEQT
SINEQT
SINSET
FARSET
SDRCST
IPT3
PRNTEL
PRNT1A
PRNT1I
PRNT1E
PRNT2E
PRNT1D
PRNT2D
SINST2
SDEQT4
SDSEQ4
3INEQ4

LEVEL (3,1)

FXOV31
FHEADR
RFXH35
XDRDR2
XDRDR3
XDENCK

LEVEL (3,2)

FXOV32
XSCTSV
XSUPDT
DIMXCK
ISOR48

TABLE IV. (Contd.)

LEVEL (3,3)

FXOV33
 RDLYR4
 DLUPDT
 DLY23
 EDLYR4
 XSURDR
 DCRNCH
 XSFIPR
 DOPCAL

LEVEL (3,4)

FXOV34
 XSCTL
 XSCTL1

LEVEL (4,0)

FXINIT

LEVEL (4,1)

FXOV41
 RFXCTL
 RGEODS
 FORMSH
 RFXHMO
 CHKHOM
 RFXTH
 RXSCON
 CHKXSC
 RRTFLX
 RATFLX
 RFXSR

LEVEL (4,2)

FXOV42
 INEDIT
 EDXSCU
 REGMAP
 INITSS

LEVEL (4,3)

FXOV43
 INITT1
 MAXMNF

LEVEL (4,5)

FXOV45
 RESTRT
 COPYDS
 CHNGIN

LEVEL (5,0)

FXTHRM
 PWCAL
 SIMPL
 DETAL
 THCALC
 THFT
 HCALC
 ROMBI

TABLE IV. (Contd.)

LEVEL (7,0)

FXPTXS
PNTMAT
FISSON
SCTTER
FISFIX
XSFIX

LEVEL (8,0)

FXINPD
PASS1
PASS2
NROTAT
LEKIP
TLEKIP
GETBND
AREAP

LEVEL (9,0)

FXSHAP
CHEBE
DACOSH
HYPCOS
ROWSRC
TRISRC
INVRT
NGSUB
SOLVP

LEVEL (9,1)

FXOV91
SRCCAL
SRCMOD

LEVEL (9,2)

FXOV92
SFDGEN
SFDCEL
TFDCEL
SGTBND
AREAS

LEVEL (9,3)

FXOV93
FISINT
OMEGCA
OMEGIN
INNDS
TOMEGN

LEVEL (9,4)

FXOV94
OUTERS
GSORC1
GSORC2
INNERS
INNDO
INNEKT
GNDOTS
UPDFS
EXTRPO

TABLE IV. (Contd.)

LEVEL (9,5)

FXOV95
SHPOUT
WRTFLX
WATFLX

LEVEL (10,0)

SCAN

LEVEL (11,0)

STUFF
STUFF1

In the root segment, routines such as the main program, SSTATE, and TIMDEP reside. In addition, the BPOINTER and REED/RITE routines as well as various other common subroutines reside there. Overlay level (1,0) performs the solution of the neutronics equations at each reactivity step. Overlay level (2,0) reads BCD input cards, and writes binary interface files. Overlay level (3,0) converts the files ISOTXS and DLAYXS to macroscopic form, and writes the file XSCON. Overlay level (4,0) performs various initializing functions for the steady state and transient, as well as restart capability. Overlay level (5,0) solves the steady state and transient thermal-hydraulics equations. Overlay level (7,0) calculates the temperature-dependent macroscopic cross sections present at this time. Overlay level (8,0) calculates the inner products required to evaluate the point kinetics parameters. Overlay level (9,0) calculates the multigroup neutron flux distribution. Overlay levels (10,0) and (11,0) read the input data and form the BCD input data sets.

In Appendix I, a listing is provided of all subroutines in FX2-TH. In addition, a brief objective is present, as well as a listing of all other routines called by and called from this routine.

B. Program Flow Charts

In Figure 15, macroscopic flow charts for FX2-TH are provided. These flow charts show the overall program logic for FX2-TH.

C. Description of Dynamically Allocated Arrays

C.1 BPOINTER, A Dynamic Storage Allocation Program

BPOINTER is a FORTRAN subprogram package which was developed to alleviate bookkeeping chores associated with the use of dynamic storage allocation techniques.

Programs which use the BPOINTER capability tend to be structured in subroutine form. A control routine is used to define one or two large blocks of storage (called the container arrays), and make the appropriate calls to BPOINTER to control the allocation of storage within these block(s). Calls to calculational subroutines transmit pointers corresponding to appropriate array locations through the calling sequences. All BPOINTER

Fig. 15. Macroscopic Flow Diagram

Fig. 15. (Contd)

Fig. 15. (Contd)

Fig. 15. (Contd)

FXINIT

Fig. 15. (Contd)

Fig. 15. (Contd)

Fig. 15. (Contd)

TIMDEP

Fig. 15. (Contd)

Fig. 15. (Contd)

Fig. 15. (Contd)

capabilities are accessed through an appropriate call to an entry point, subroutine, or function subprogram. The following capabilities are available in the BPOINTER system:

- (a) Storage of data in and retrieval of data from the container array, via user defined variable arrays.
- (b) Purge of variable arrays stored in the container array.
- (c) Automatic "cleanup" of the container array when more storage is required.
- (d) Re-definition of array sizes without loss of data already stored in the array.
- (e) Array dump of selected integer, floating point or BCD arrays in a prescribed format.
- (f) Trace dumps of BPOINTER activities.
- (g) Status reports of the BPOINTER tables.

Detailed program documentation including flow charts, common block information and subprogram descriptions is available in Reference 18. This Section is intended to provide a brief description of how the program package operates. The major differences between the IBM and CDC standalone versions of the program package are also noted.

The short example listed in Figure 16 is intended to illustrate the structure of a program using the BPOINTER package. This example demonstrates the manner in which a container is allocated, pointers defined and used, and the container released.

Brief descriptions of the BPOINTER subroutines and functions are given in the subroutines descriptions in Appendix I.

All dynamically allocated arrays are addressed relative to the common block /ARRAY/ which contains a single array element, BLK(1). In the IBM version of the code the element must be declared as DOUBLE PRECISION. A second common block /ARRAY2/ is used in the CDC version of BPOINTER to address arrays allocated to a large core memory container. This common block also contains a single array element BLK2(1) which must be declared a LEVEL 2 variable. The equivalent of the large core memory container on IBM equipment is a second container which may be given a HIARCHY 1 location but is addressed in precisely the same manner as the first (SCM) container. The one word assigned to the container by the source language program provides a reference address. At execution time machine language routines (ALLOC1, ALLOC2 on IBM, MEMGET1, MEMGET2 on CDC) are used to obtain the addresses of core which are available to the program for the allocation of data arrays. These blocks of core are allocated in the following manner.

(a) IBM allocation

The standard IBM macro instructions GETMAIN and FREEMAIN are used to allocate and free consecutive words of core which are available to the program. The designations subpool 1 and 2 are assigned to the bulk (LCM) and fast (SCM) containers respectively. Since allocations are performed in units of 256 (eight byte) words, it is most efficient to request blocks of core in such multiples.

```

C BPOINTER EXAMPLE
C DEFINE CONTAINER COMMON BLOCK
C
    REAL*8 BLK, FLUX, POWER
    COMMON/ARRAY/BLK(1)
    DIMENSION BLK4(1)
    EQUIVALENCE (BLK(1),BLK4(1))
    DATA FLUX/6HFLUX /, POWER/6HPOWER /, MAXSIZ/10000/
    DATA I4/4/, I8/8/, I0/0/, NG/27/
C
C ALLOCATE CONTAINER WITH MAXSIZ WORDS OF SCM AND NO LCM
C
    CALL BULK(I0)
    CALL POINTR(BLK,MAXSIZ,I0)
C
C ALLOCATE SPACE FOR ARRAYS POWER, FLUX AND CURRENT
C
    CALL PUTM(POWER,I8,NG,IPOWER)
    CALL PUTM(FLUX,I4,2*NG,IFLUX)
C
C DETERMINE POINTER FOR SUB-ARRAY CURRENT WHICH FOLLOWS THE
C NG SINGLE PRECISION WORDS FOR THE ARRAY FLUX
C
    ICURNT=IPT2(IFLUX,NG,I0)
C
C CHECK ON BPOINTER ERROR
C
    IF( IPTERR(DUM).GT.0 ) PRINT 500
500 FORMAT(1H0,14HBPOINTER ERROR)
C
C CALL SUBROUTINE INIT TO USE THESE ARRAYS
C
    CALL INIT(DLK(IFLUX),BLK(IPOWER),BLK4(ICURNT),NG)
C
C FREE CONTAINER AND RETURN
C
    CALL FREE
    RETURN
    END
    SUBROUTINE INIT(PHI,POWER,CURRENT,NG)
C
C USE BPOINTER ARRAYS JUST AS ANY OTHER VARIABLES
C
    REAL*8 POWER
    DIMENSION PHI(1),POWER(1),CURRENT(1)
    DO 10 I=1,NG
    PHI(I)=1.0
    POWER(I)=3.1E+06
    CURRENT(I)=.333
10 CONTINUE
    RETURN
    END

```

Fig. 16. BPOINTER Example

(b) CDC allocation

The COMPASS routine MEMGET uses the standard CDC macro instruction MEMORY to determine the jobs SCM and LCM field length. The core available as a container for BPOINTER SCM arrays is determined by subtracting the address of blank common from the SCM field length. Thus a program using the CDC version of BPOINTER should not use blank common. Blank common is used for this purpose because of the CDC loader convention which places blank common after all other program sections in core. Although blank common is used in this manner to determine the available core for a container, arrays in the container are addressed relative to the common block/ARRAY/ as noted above. The BPOINTER program package accounts for the offsets between the address of /ARRAY/ in core and the address of the container. It should also be noted that the conventions used by BPOINTER are such that the first word of the container is not in general set to the first word of blank common. This is important since the loader convention noted above is not adhered to by all CDC Systems. The user is therefore responsible for providing enough SCM memory to accommodate the program, any SCM buffers, and the BPOINTER container as there is currently no effective check to make sure that data stored in the BPOINTER container do not overlap code. It is assumed by the CDC version of BPOINTER that the LEVEL 2 common block /ARRAY2/ is addressed as the first word of LCM and the entire LCM field length is assumed to be available to BPOINTER for its LCM container.

The letters M and B are used as neumonics within BPOINTER to designate routines which operate on the SCM and LCM containers respectively. Thus PUTM allocates an array in the SCM container while PUTB allocates an array which must be referenced on CDC equipment as a LEVEL 2 array. On IBM equipment without HIARCHY support (e.g. 370/195) the two containers are equivalent. The distinctions noted above between the two dynamic containers are important on CDC equipment where the containers are addressed quite differently and on IBM equipment with HIARCHY support where access to the BULK core container (HIARCHY 1, subpool 1) is significantly slower than access to the MAIN core container (HIARCHY 0, subpool 2).

C.2 Arrays Permanently In-Core

In FX2-TH, arrays are allocated for three basic purposes:

- a) Permanently in-core arrays
- b) Arrays which may be in-core depending on the data management scheme
- c) Temporary arrays

Arrays which reside permanently in-core are discussed in this Section, and arrays which may be in-core depending on the data management scheme are discussed in the next Section.

In each FX2-TH run, a certain number of arrays are allocated permanently in-core. These arrays are described in Figure 17. The name, arguments, function, word length, and core block indicator are given for each array. Most of these arrays are allocated in overlay (4,1) and remain throughout the rest of the calculation. These arrays can be divided into the following categories:

- a) Driving function (DFRLAB, DFMLAB, DRF)
- b) Geometry (NZNR, MR, XMesh, YMesh, IS, IE, ZONLAB, REGLAB)
- c) Materials (BSQ, BNDC, CHIP, PNU, CHID, DNU, VEL, NDN, LTOLP, LPTOL, UMNAM, AMNAME, NUMAM, MATREG)
- d) Thermal-Hydraulics (MTH, TF, TC, ITYP, DAT, NPIN, TCIN, FLOW, AXTH, HCORR, PWOLD)
- e) Neutronics (NINGR, OMER, POWERM, PKBUF)

Categories a), b), c), and e) are present for all cases. If no thermal-hydraulic feedback is used, category d) is not present. If one of the adiabatic thermal-hydraulic models is used, the following arrays are present in category d): MTH, TF, TC, ITYP, DAT, AXTH, PWOLD. The entire category d) listed above is present if the detailed model is used.

Name	Function	Word Length (Bytes)	Small/Large (0/1)
DFRLAB(NREGD)	Region labels for diving functions	8	0
DFMLAB(NREGD)	Material labels for driving functions	8	0
DRF(4,NREGD)	Driving function data ($T_{ST}, T_{END}, C_1, C_2$)	8	0
BSQ(NZONE,NGROUP)	Values of B^2	8	1
BNDC(NBCS)	Boundary condition constants	8	1
NZNR(NREG)	Region to zone assignment	4	1
MR(NINTI,NINTJ)	Neutronics mesh region assignments	4	1
XMesh(NINTI)	X-direction mesh locations	8	0
YMesh(NINTJ)	Y-direction mesh locations	8	0
IS(NINTJ)	Mesh starting locations (if triangular)	4	0
IE(NINTJ)	Mesh ending locations (if triangular)	4	0
REGLAB(NREG)	Region labels	8	1
ZONLAB(NZONE)	Zone labels	8	1
CHIP(NTFMAT,NGROUP)	Prompt CHI values	8	1
PNU(NTFMAT,NGROUP)	Prompt NU values	8	1
CHID(NFAM,NGROUP)	Delayed CHI values	8	1
DNU(NFAM,NTFMAT,NGROUP)	Delayed NU values	8	1
VEL(NGROUP)	Neutron velocities	8	1
NDN(NGROUP)	Number of downscatter groups	4	1
LTOLP(NMAT)	Generic material numbers	4	1
LPTOL(NFMAT)	Generic fissionable material number	4	1
UMNAME(NTMAT)	Unique material label	8	1
AMNAME(NMAT)	Generic material label	8	1
NUMAM(NTMAT)	Position in AMNAME array of unique material m	4	1
MATREG(NMAT,NREG)	Unique material number assigned to a generic material in a specific material	4	1
MTH(NINTI,NINTJ)	Thermal-Hydraulics mesh region assignment	4	1
TF(NAX,NCH)	Average fuel temperature	8	1
TC(NAX,NCH)	Average coolant temperature	8	1
ITYP(NCH)	Data type number	4	1
DAT(LEN,ITYPE)	Thermal-Hydraulics data array	8	1
NPIN(NCH)	Number of pins	4	1
TCIN(NCH)	Inlet coolant temperature	8	1
FLOW(NCH)	Mass flow rate	8	1
AXTH(NAX)	Axial mesh spacing	8	1
HCORR(NAX)	H-gap correction factor	8	1
NINGR(NGROUP)	Number of inner iterations	4	0
OMER(NGROUP)	Over relaxation-factor	8	0
POWERM(NINTI,NINTJ)	Pointwise power density	8	1
PKBUF(NPKM)*	Storage for point kinetics update parameters	8	0
PWOLD(NAX,NCH)	Old thermal-hydraulics power	8	1

*NPKM=67+(NROSMX-1)*24

Fig. 17. Arrays Permanently In-Core During Steady-State and Transient

C.3 Arrays Which May Be In-Core

Depending on the amount of core memory provided to FX2-TH, the data management strategy decides which files may be contained in core while they are being used, and which must be read from and written to the disk as the calculation progresses. These files are described in Figure 18.

Name	Function	Alternate Definitions	Conditions
SIGF	Fission Cross Sections	a) (NFMAT,MNFPTS,NGROUP)	LOCFIL(2)=0 (file core contained)
		b) (NFMAT,MNFPTS,2)	LOCFIL(2)=1 (file not core contained)
TSCATD	Downscatter Cross Sections	a) (NCMP,NDSCT)	LOCFIL(3)=0 (file core contained)
		b) (NCMP,2)	LOCFIL(3)=1 (file not core contained)
TSIGTR	Removal and Transport Cross Sections	a) (NCMP,2,NGROUP)	LOCFIL(4)=0 (file core contained)
		b) (NCMP,2,2)	LOCFIL(4)=1 (file not core contained)
THSTOR	Thermal-Hydraulics Data	a) FT(NFR+2,NAX,NCH), TC(NAX+1,NCH),TST (NAX,NCH)	LOCFIL(7)
	FT Detailed fuel temperatures in fuel pin		
	TC Coolant temperatures at each axial level		
	TST Structure temperatures in each axial region		
PSI	Multigroup Neutron Fluxes	a) (NCELLS,NGROUP)	INCPST=0 (file core contained)
		b) (NCELLS,MAXDN+1)	INCPST=1 (scattering band core contained)
		c) (NCELLS,2)	INCPST=2 (file not core contained) LOCFIL(1)
ZETAM	Delayed Precursors	a) (NCELLS,NFAM)	LOCFIL(6)
VFRACM	Volume Fractions	a) (NMAT,NCELLS)	LOCFIL(5)
FDC	Finite Difference Coefficients	a) (3*NCELLS,NGROUP)	INCFDC=0 (file core contained)
		b) (4*NCELLS,1)	INCFDC=1 (file not core contained)

Fig. 18. Arrays Whose Dispositions are Determined by the Data Management Strategy

The arrays SIGF, TSCATD, and TSIGTR have different structures depending on the data management decisions. If sufficient storage is available to contain them, the entire record (all NGROUP or NDSCT records) are allocated. This mode is indicated by the appropriate entry in the LOCFIL array being set to zero. If insufficient space is available, two records are allocated, so that the file may be double buffered as it is read from or written to the disk.

If sufficient space exists to permanently contain the THSTOR array, then it is allocated at the beginning of the steady state calculations. Regardless of the data management decision, THSTOR is written to disk and deleted at the end of the steady state calculation. It is then read from the disk and re-allocated at the beginning of the transient. The array THSTOR is made up of the arrays FT, TC, and TST; consisting of the detailed fuel temperatures, coolant temperature at each axial level, and structure temperatures in each axial region. If the detailed thermal-hydraulics model is not used, this file is not present.

The array PSI has three different configurations depending on available core space. If sufficient core is available, the entire array will be allocated in core. If a scattering band of fluxes can only be contained, then that will be allocated. Finally, if a scattering band cannot be allocated, then two records will be allocated to provide double buffering of the file.

The files ZETAM and VFRACM have only one configuration. They are either present in core or read from and written to the disk depending on the appropriate LOCFIL entry. The array FDC also has two configurations, a full array if INCFDC = 0, and a reduced array if INCFDC = 1. The extra NCELLS array is to provide double buffering of the file.

Figure 19 is a glossary of the various terms used in Figures 17 and 18.

In addition to the arrays mentioned in Figures 17 and 18, a large number of other files are allocated to temporarily contain data. These files are later deleted, and the space purged. Descriptions of these arrays can be found in the comments at the beginning of each subroutine.

D. Use of Standard Subprograms

The FX2-TH code uses the BPOINTER routines to manage core memory. The BPOINTER routines are described in Section VI.C.1. The BCD input data follows the ARC system conventions,¹⁸ and is discussed in Section V.B. The FORTRAN routines SCAN and STUFF read and process the input as discussed in Reference 18.

The Committee on Computer Code Coordination has specified a number of standard routines¹⁶ to be used in RRD funded code development. In principle these routines may be installation dependent. The FX2-TH code uses the standard routines REED, RITE, LRED, LRIT, TIMER and SEEK as specified in Reference 16. While it is possible to substitute installation dependent code, simple versions of these routines are provided with both the IBM and CDC versions of FX2-TH.

Name	Description
NREGD	Number of regions which have driving functions
NZONE	Number of zones
NGROUP	Number of neutron energy groups
NBCS	Number of entries in BNDC array
NREG	Number of regions
NINTI	Number of X-dimension mesh intervals
NINTJ	Number of Y-dimension mesh intervals
NTFMAT	Number of fissionable unique materials
NFAM	Number of delayed neutron families
NMAT	Number of generic materials
NFMAT	Number of fissionable generic materials
NTMAT	Number of unique materials
NAX	Number of axial thermal-hydraulic regions
NCH	Number of thermal-hydraulic channels
LEN	Length of one set of thermal-hydraulic data
ITYPE	Number of different thermal-hydraulic data types
NROSMX	Maximum number of reactivity steps per shape step
MNFPTS	Number of mesh cells with fissionable material in them
NCMP	Number of compositions
NDSCT	Number of downscatter components
NFR	Number of regions in fuel pin
NCELLS	Number of mesh cells
MAXDN	Number of downscatter groups

Fig. 19. Glossary of Terms Used in Figs. 17 and 18

D.1 SEEK

The subroutine SEEK is used by FX2-TH to return the logical unit number associated with a named data file. With only two exceptions, all files referenced by FX2-TH are assigned unit numbers through calls to subroutine SEEK. The two exceptions are the BCD files input (5) and printed output (6). While it should be possible to use installation dependent versions of SEEK, it is obvious that any changes in unit allocation must also be reflected in the Job Control Language required for the IBM version of FX2-TH or the program card of the CDC version. A single initialization call to SEEK is made from the main program driver of FX2-TH.

D.2 REED/RITE

The standard routines REED and RITE are used to perform the non-formatted (binary) I/O operations for FX2-TH. The ARC system version of REED/RITE make use of three access methods, standard FORTRAN, asynchronous FORTRAN, and a special random access I/O package SIO.¹⁹ The IBM and CDC standalone versions of FX2-TH contain far simpler versions of REED/RITE which use standard FORTRAN I/O. REED and RITE are designed to read data directly into the small core container (SCM on the CDC 7600). To allow data to be read into the large core container (LCM) directly,

the routines LRED and LRIT were written. These routines are identical to REED and RITE except that they directly address the large core container. All records of a file must be read (or written) using the same subroutine; i.e., calls to REED (or RITE) and LRED (or LRIT) may not be intermixed in a particular processing of a file. A file may be processed using one set of routines at one point in the code, and later processed using the other set of routines; as long as all records of the file are processed in the same way.

D.3 TIMER

The standard subroutine TIMER is used by FX2-TH to provide timing and problem identification information. These data are not essential to the execution of the FX2-TH program. As a consequence, the CDC version of TIMER is in large part a dummy program. It calls only the standard CDC system code SECOND to provide CPU timing data. The IBM version of TIMER makes use of a number of assembler language routines to provide time and edit information.

E. Program Implementation

Both the IBM and CDC versions of the program FX2-TH are available from the Argonne Code Center. A description of the tapes along with a step-by-step implementation strategy for each version of the program is described below.

E.1 IBM Code Implementation

The IBM program tape is written as described in Table V. The source code for FX2-TH is written on Files 1 and 2 of the program tape. The FORTRAN routines are contained on File 1, while the ASSEMBLER routines are contained on File 2. File 3 contains the SYSIN data cards for the linkage editor; this defines the overlay structure. The cataloged procedure ARCSP024 is contained in File 4. Files 5 - 7 contain the input data for Sample Problem 3. File 8 contains the output from Sample Problem 3. File 9 contains documentation information found in this manual.

To implement FX2-TH, first the object code should be created, then the cataloged procedure obtained, finally Sample Problem 3 should be executed. To create the object code, the job shown in Figure 20 should be executed. This job is composed of five steps:

- i) Allocation of disk space for the compiled and link-edited source code from File 1.
- ii) Compilation and link-edit of FORTRAN source code from File 2.
- iii) Assembly and link-edit of ASSEMBLER source code from File 2.
- iv) Allocation of disk space for the object program.
- v) Link-edit of compiled code from steps ii) and iii).


```

//STEP1 EXEC PGM=IEFBR14
//OBJECT DD DSN=C116.B20219.FX2ACC.SEGLIB,DISP=(NEW,CATLG) ,
// UNIT=SHRT3330,DCB=BLKSIZE=6144,SPACE=(CYL,(6,3,1))
//STEP2 EXEC FTXCEP,OPTIONS='OPT=2,XREF',EDTOPTS='LET,NCAL',
// OBJROOM='(CYL,(10,2))',LSIZE='(500K,100K)'
//FTX.SYSPRINT DD UNIT=TAPE1600,LABEL=(1,NL) ,
// DISP=(NEW,PASS),VOL=SER=135706,
// DCB=(RECFM=FB,LRECL=133,BLKSIZE=1596,DEN=2)
//FTX.SYSIN DD UNIT=TAPE800,VOL=SER=135536,
// LABEL=(1,NL),DISP=(OLD,KEEP),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,DEN=2)
//EDT.SYSLMOD DD DSN=C116.B20219.FX2ACC.SEGLIB(FORT),DISP=(OLD,KEEP)
//EDT.STEPLIB DD DISP=SHR,DSN=B99960.SYS1.LINKLIB
//STEP3 EXEC ASMCEP,EDTOPTS='LIST,MAP,DCBS'
//ASM.SYSIN DD UNIT=TAPE800,VOL=SER=135536,
// LABEL=(2,NL),DISP=(OLD,KEEP),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,DEN=2)
//EDT.SYSLMOD DD DSN=C116.B20219.FX2ACC.SEGLIB(ASM),DISP=(OLD,KEEP)
//STEP4 EXEC PGM=IEFBR14
//DD1 DD DSN=C116.B20219.FX2ACC.MODLIB,DISP=(NEW,CATLG) ,
// UNIT=LONG3330,DCB=BLKSIZE=6144,SPACE=(CYL,(4,1,1),RLSE)
//STEP5 EXEC FTXEP,EDTOPTS=OVLY,LSIZE='(250K,64K)'
//EDT.SYSLMOD DD DSN=C116.B20219.FX2ACC.MODLIB,DISP=(OLD,KEEP)
//EDT.SEGLIB DD DSN=C116.B20219.FX2ACC.SEGLIB,DISP=(OLD,KEEP)
//EDT.SYSIN DD UNIT=TAPE800,VOL=SER=135536,
// LABEL=(3,NL),DISP=(OLD,KEEP),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,DEN=2)

```

Fig. 20. Creation of FX2-TH Object Code

The user may specify certain JCL parameters to correspond to his particular installation. The compilation of File 1 is performed using FORTRAN IV EXTENDED compiler using OPT=2 optimization. If this compiler is not available, FORTRAN IV H with OPT=2 optimization is adequate. The assembly of File 2 coding is performed in the usual manner.

Next, the cataloged procedure ARCSP024 should be removed from File 4 of the program tape. The job shown in Figure 21 should be executed to remove this procedure from the tape and punch cards. The cataloged procedure may then be added to the PROCLIB of the user's installation.

Finally, Sample Problem 3 should be executed. The problem can be run without having to transfer the data from the program tape. This is done by overriding certain of the DD cards. The necessary JCL is shown in Figure 22. This problem will execute in 5 minutes (CPU plus WAIT time) on a 370/195 and requires 900K of core storage.

The output from Sample Problem 3 is stored on File 8. This output may be printed by using the same JCL as shown in Figure 21, with two exceptions: substitute LABEL=(8,NL), and let

```
//SYSUT2 DD SYSOUT=A,DCB=(RECFM=FB, // LRECL=133,BLKSIZE=1596)
```

File 9 contains a description of the BCD input files, the binary interface files, and the COMMON blocks. This file may be printed as in the example above except that LRECL=80, BLKSIZE=3200, and LABEL=(9,NL).

```
// EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD UNIT=TAPE800,VOL=SER=135536,
// LABEL=(4,NL),DISP=(OLD,PASS),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,
// DEN=2)
//SYSUT2 DD SYSOUT=B
```

Fig. 21. Removal of ARCSP024 from IBM Program Tape

```
//STEP1 EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSIN DD DUMMY
//STEP1.SYSUT1 DD UNIT=TAPE800,VOL=SER=135536,
// LABEL=(6,NL),DISP=(OLD,PASS),
// DCB=(RECFM=VBS,LRECL=84,BLKSIZE=6136,DEN=2)
//STEP1.SYSUT2 DD DSN=88SRAISO,DISP=(NEW,PASS),UNIT=SASCR,
// SPACE=(CYL,(5,2)),
// DCB=(RECFM=VBS,LRECL=84,BLKSIZE=6136)
//STEP2 EXEC PGM=IEBGENER
//SYSPRINT DD SYSOUT=A
//SYSIN DD DUMMY
//STEP2.SYSUT1 DD UNIT=TAPE800,VOL=SER=135536,
// LABEL=(7,NL),DISP=(OLD,PASS),
// DCB=(RECFM=VBS,LRECL=84,BLKSIZE=6136,DEN=2)
//STEP2.SYSUT2 DD DSN=88SRADLA,DISP=(NEW,PASS),UNIT=SASCR,
// SPACE=(CYL,(2,1)),
// DCB=(RECFM=VBS,LRECL=84,BLKSIZE=6136)
//STEP3 EXEC ARCSP024
//FT05F001 DD UNIT=TAPE800,VOL=SER=135536,
// LABEL=(5,NL),DISP=(OLD,PASS),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,DEN=2)
//FT51F001 DD DSN=*.STEP1.SYSUT2,DISP=(OLD,PASS)
//FT52F001 DD DSN=*.STEP2.SYSUT2,DISP=(OLD,PASS)
```

Fig. 22. IBM JCL to Execute Sample Problem 3

E.2 CDC Code Implementation

The FX2-TH code has been implemented on a CDC 7600 computer at the Lawrence Berkeley Laboratory. The 7600 at LBL has 65,636 (60-bit) words of small core memory and 512,000 (60-bit) words of large core memory. The examples given in this Section use the control cards suitable at LBL. The essential nature of each step should be system independent.

The CDC program tape is written as described in Table V. The source has intermixed COMPASS routines with the FORTRAN. The FORTRAN EXTENDED Version 4 compiler (FTN4) available at LBL is capable of processing coding mixed in this way. If the FORTRAN compiler available at a particular installation is not capable of this, the COMPASS routines must be separated out, assembled, and then replaced in their original position in the LGO file. The FORTRAN EXTENDED compiler is required since FX2-TH makes use of LEVEL 2 statements. Full optimization (OPT=2) is recommended.

TABLE V. IBM Code Center Tape Description
 Program Tape (Non-labelled, 9 track, 800 bpi)

File	Description	RECFM	LRECL	BLKSIZE
1	Fortran Source (EBCDIC)	FB	80	3200
2	Assembler Source (EBCDIC)	FB	80	3200
3	Linkage Editor Directive Cards (EBCDIC)	FB	80	3200
4	Cataloged Procedure ARCSPO24 (EBCDIC)	FB	80	3200
5	Sample Problem 3 Input Data (EBCDIC)	FB	80	3200
6	Sample Problem 3 A.ISO (EBCDIC)	VBS	84	6136
7	Sample Problem 3 A.DLA (EBCDIC)	VBS	84	6136
8	Sample Problem 3 Output (EBCDIC)	FB	133	1596
9	Manual Documentation	FB	80	3200

The required PROGRAM and OVERLAY cards are positioned as required for the CDC overlay structure, therefore no special overlay control cards are required. The source file may be compiled, loaded, and executed without special instructions. In Figure 23, the CDC control cards required to process the program tape, compile and load FX2-TH, and execute Sample Problem 3 are given. The control cards are specific to the LBL installation, however, their general function may be duplicated at any installation.

JOB 1 PROCESS PROGRAM TAPE

SCF,R=TAPE1,RL=80,BF=40,D5,FC=4,29381. PLEASE USE ST TAPE DRIVE
 COPY,TAPE1/FB,1F,SOURCE/RR.
 COPY,TAPE1,1F,BCD/RR.
 COPY,TAPE1,1F,AISO/RR.
 COPY,TAPE1,1F,ADLA/RR.
 STAGE,SOURCE,D9,NT,P3,W,6395.
 STAGE,BCD,D9,NT,P3,W,2217.
 STAGE,AISO,D9,NT,P3,W,2219.
 STAGE,ADLA,D9,NT,P3,W,2444.

JOB 2 COMPILE AND LOAD FX2-TH

STAGE,SOURCE,D9,NT,P3,R,6395.
 SPL,120000,100000.
 FTN4(I=SOURCE,R=1,OPT=2,B=LGO)
 LINK,F=LGO,RF.
 STAGE,FX2,W,NT,10347.

JOB 3 EXECUTE SAMPLE PROBLEM 3

STAGE,FX2,R,NT,10347.
 STAGE,INP,D9,NT,P3,R,2217.
 STAGE,TAPE51,D9,NT,P3,R,2219.
 STAGE,TAPE52,D9,NT,P3,R,2444.
 FBSIZE,FX2=150.
 SPL,140000,200000.
 FX2,LC=50000,INP.

Fig. 23. CDC Control Cards

TABLE VI. CDC Code Center Tape Description
Program Tape (7-track, 556 bpi)

File	Description	RECFM	LRECL	BLKSIZE
1	FX2-TH Source	FB	80	3200
2	Sample Problem 3 Input Data (BCD)	FB	80	3200
3	Sample Problem 3 A.ISO (BCD)	FB	80	3200
4	Sample Problem 3 A.DLA (BCD)	FB	80	3200
5	Manual Documentation	FB	80	3200

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A number of people have contributed significantly to the development of the FX2-TH code. The original development of the quasistatic method used in this code is due to Dan Meneley and his associates at Argonne. An internal report (FRA-TM-87) was prepared by D. Ferguson, T. Daly, and R. W. Schaefer in 1976 documenting a version of FX2 coupled with hydrodynamics calculations. This work was guided in large measure by W. M. Stacey, Jr. The capability to solve problems on a triangular mesh was added by H. Henryson, II. The work of Lyn Young in typing this report is greatly appreciated also.

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APPENDIX A

Description of FX2-TH Subroutines

SUBPROGRAM NAME: ABEND
OBJECTIVE: CALLS SUBROUTINE EXIT
CALLS TO : EXIT
CALLED FROM: ERROR
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: AFX210
OBJECTIVE: READS TYPE 10 CARDS OF A.FX2 AND CHECKS DATA
CALLS TO : ERROR LINES SQUEZE
CALLED FROM: RAFX2
OVERLAY LEVEL: 2, 1

SUBPROGRAM NAME: ALLOC1
OBJECTIVE: ALLOCATE MEMORY IN SMALL CORE
CALLS TO : MEMGET
CALLED FROM: POINTR
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: ALLOC2
OBJECTIVE: ALLOCATE MEMORY IN LARGE CORE
CALLS TO : MEMGT1
CALLED FROM: POINTR
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: ANIPHX
OBJECTIVE: READS CARD TYPES 29,30,31 AND 33 OF A.FNIP
(HEX. GEOMETRY) AND CHECKS DATA
CALLS TO : ERROR LINES REPORT SPACE SQUEZE SQUEZ2
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP03
OBJECTIVE: READS TYPE 03 CARD OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR LINES REPORT SPACE
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP04
OBJECTIVE: READS TYPE 04 CARD OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR LINES REPORT SPACE
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP05
OBJECTIVE: READS TYPE 05 CARDS OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR LINES REPORT
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP06
OBJECTIVE: READS TYPE 06 CARDS OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR LINES REPORT SQUEZ2
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP08
OBJECTIVE: READS TYPE 08 CARDS OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR LINES REPORT SQUEZ2
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP09
OBJECTIVE: READS TYPE 09 CARDS OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR LINES REPORT
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP12
OBJECTIVE: READS TYPE 12 CARDS OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR LINES REPORT SQUEZ2
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP13
OBJECTIVE: READS TYPE 13 CARDS OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR GSCAN LINES REPORT SQUEZ2
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP14
OBJECTIVE: READS TYPE 14 CARDS OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR GSCAN LINES REPORT SQUEZ2
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP19
OBJECTIVE: READS TYPE 19 CARDS OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR LINES REPORT SQUEZ2
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: ANIP34
OBJECTIVE: READS TYPE 34 CARDS OF A.FNIP AND CHECKS DATA
CALLS TO : ERROR LINES REPORT SQUEZ2
CALLED FROM: RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: AREAP
OBJECTIVE: CALCULATES SURFACE AREAS OF EACH MESH CELL
CALLS TO : FEQUAT FLTSET FLTST2
CALLED FROM: PASS2
OVERLAY LEVEL: 8, 0

SUBPROGRAM NAME: AREAS
OBJECTIVE: CALCULATES SURFACE AREA OF EACH MESH CELL
CALLS TO : FEQUAT FLTSET FLTST2
CALLED FROM: SFDGEN
OVERLAY LEVEL: 9, 2

SUBPROGRAM NAME: BCDXST
OBJECTIVE: CONTROLS TRANSFORMATION FROM A.ISO AND A.DLA
TO ISOTXS AND DIAYXS
CALLS TO : ERROR ILAST PURGE PUTM RWDELY RWISOT SEEK WIPOUT
CALLED FROM: NONE
OVERLAY LEVEL: 2, 7

SUBPROGRAM NAME: BLOCKS
OBJECTIVE: DUMMY SUBFOJTINE CONTAINING COMMON BLOCK
DESCRIPTIONS
CALLS TO : NONE
CALLED FROM: NONE
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: BUCK
OBJECTIVE: CALCULATES ZONE AND GROUPWISE BUCKLINGS
CALLS TO : NONE
CALLED FROM: FGEODS
OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: BUCLOS

OBJECTIVE: DUMMY ROUTINE, USED TO CLOSE DISK BUFFERS

CALLS TO : NONE

CALLED FROM: CHNGIN COPYDS DRIVEF DSKEDT EXTFLX FATFLX FISINT FISSON FRTFLX FXINPR FXOV31
FXOV33 FXOV34 FXPTXS FXTHRM GNDOTS INITSS INITT1 ISOR48 I2SORD LRED LRIT
MAXMNF OMEGCA OUTERS PASS1 PASS2 PRCMAP PRCUPD RAFNIP RAFX2 RATFLX RATHRM
REED RESTRT RFIXSR RFXCTL RFXHMO RFXH35 RFXTH RGEODS RHOBEG RITE RRTFLX
RXSCON SCTTER SFDGEN SHPOUT SRCCAL SRCMOD SSTATE START SUMARY WFXCTL WFXHMO
WFXTH WGEODS XSFIX

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: BUOPEN

OBJECTIVE: DUMMY ROUTINE, USED TO OPEN DISK BUFFERS

CALLS TO : NONE

CALLED FROM: CHNGIN COPYDS DRIVEF DSKEDT EXTFLX FATFLX FISINT FISSON FRTFLX FXINPR FXOV31
FXOV34 FXOV41 FXPTXS FXTHRM GNDOTS GSORC2 INITSS INITT1 I2SORD LRED LRIT
MAXMNF OMEGCA OUTERS PASS1 PASS2 PRCMAP PRCUPD RATHRM REED RESTRT RFXH35
RHOBEG RITE SCTTER SFDGEN SHPOUT SRCCAL SRCMOD SSTATE START SUMARY WATFLX
WFXCTL WFXHMO WFXTH WGEODS WRTFLX XDRDR2 XSFIX

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: CALFSP

OBJECTIVE: COMPUTES NUMBER OF FISSIONABLE COMPOSITIONS
PRESENT

CALLS TO : NONE

CALLED FROM: INITSS

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: CHEBE
OBJECTIVE: COMPUTES CHEBYSHEV ACCELERATION COEFFICIENTS
CALLS TO : DACOSH HYPCOS
CALLED FROM: GNDOTS
OVERLAY LEVEL: 9, 0

SUBPROGRAM NAME: CHKHOM
OBJECTIVE: CHECKS FILE FXHMOG FOR CONSISTENCY
CALLS TO : ERROR LINES
CALLED FROM: RFXHMO
OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: CHKXSC
OBJECTIVE: CHECKS FILE XSCON FOR CONSISTENCY
CALLS TO : ERROR FLTST2 INTST2 LINES
CALLED FROM: RXSCON
OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: CHNGIN
OBJECTIVE: CHANGES VALUE OF CERTAIN VARIABLES FOR
A RESTART PROBLEM
CALLS TO : BUCLOS BUOPEN REED
CALLED FROM: RESTRT
OVERLAY LEVEL: 4, 5

SUBPROGRAM NAME: CODE
OBJECTIVE: READS A CARD IMAGE FOR A SPECIFIC FILE
CALLS TO : NONE
CALLED FROM: SCAN STUFF1
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: COPYDS
OBJECTIVE: COPIES DISK FILES TO OR FROM RESTART FILE
CALLS TO : BUCLOS BUOPEN LRED LRIT
CALLED FROM: RESTRT
OVERLAY LEVEL: 4, 5

SUBPROGRAM NAME: CRED
OBJECTIVE: TRANSFERS DATA FROM LARGE CORE TO SMALL CORE
CALLS TO : ERROR LINES READEC WRITEC
CALLED FROM: ECMV PRTECM REDEFB REDEFM
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: CRIT
OBJECTIVE: TRANSFERS DATA FROM SMALL CORE TO LARGE CORE
CALLS TO : ERROR LINES READEC WRITEC
CALLED FROM: ECMV ECZERO FATFLX FRTFLX REDEFB REDEFM
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: DACOSH
OBJECTIVE: COMPUTES INVERSE HYPERBOLIC COSINE
CALLS TO : DLOG DSQRT
CALLED FROM: CHEBE GNDOTS
OVERLAY LEVEL: 9, 0

SUBPROGRAM NAME: DCRNCH
OBJECTIVE: COMPRESSES DIMENSIONS OF CHIP,PNU,SFIST,DNU
CALLS TO : NONE
CALLED FROM: XSORDR
OVERLAY LEVEL: 3, 3

SUBPROGRAM NAME: DETAL
OBJECTIVE: CONTROLS CALCULATION FOR DETAILED
THERMAL-HYDRAULIC MODEL
CALLS TO : PUTM THCALC WIPOUT
CALLED FROM: FXTHRM
OVERLAY LEVEL: 5, 0

SUBPROGRAM NAME: DIMXCK
OBJECTIVE: CHECK ISOTOPE LABELS FOR DOPPLER CALCULATION
CALLS TO : ERROR LINES
CALLED FROM: ISOR48
OVERLAY LEVEL: 3, 2

SUBPROGRAM NAME: DLUPDT
OBJECTIVE: CALCULATES DELAYED NU VALUES
CALLS TO : NONE
CALLED FROM: RDLYR4
OVERLAY LEVEL: 3, 3

SUBPROGRAM NAME: DLY23
OBJECTIVE: PRINTS SUMMARY OF RECORDS 2 AND 3 OF DLAYXS
CALLS TO : LINES PENTEL PRNT1A PRNT1D PRNT1I PRNT2D
CALLED FROM: RDLYR4
OVERLAY LEVEL: 3, 3

SUBPROGRAM NAME: DOPCAL
OBJECTIVE: COMPUTES FISSION AND CAPTURE DOPPLER
COEFFICIENTS
CALLS TO : DLOG DSQRT
CALLED FROM: FXOV33
OVERLAY LEVEL: 3, 3

SUBPROGRAM NAME: DRIVEP
OBJECTIVE: CALCULATES NEW VOLUME FRACTIONS AT
EACH REACTIVITY TIME STEP
CALLS TO : BUCLOS BUOPEN ERROR LINES LRED LRIT SEEK
CALLED FROM: RHOBEG
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: DSKEDT
OBJECTIVE: WRITES DISK EDIT FILE FXEDIT AT EACH
REACTIVITY TIME STEP
CALLS TO : BUCLOS BUOPEN IGET LRED PURGE PURGEB PUTB WIPOUT
CALLED FROM: SSTATE TINDEP
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: DZONE
OBJECTIVE: SORTS THROUGH ZONE LABEL ARRAY
CALLS TO : NONE
CALLED FROM: FGEODS
OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: ECMV
OBJECTIVE: TRANSFERS DATA FROM LARGE CORE TO LARGE CORE
CALLS TO : CRED CRIT
CALLED FROM: PURGE PURGEB REDEFB REDEFM
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: ECZERO
OBJECTIVE: ZEROES A BLOCK OF STORAGE IN LARGE CORE
CALLS TO : CRIT
CALLED FROM: POINTR PURGE PURGEB WIPOUT
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: EDITS
OBJECTIVE: EDITS INFORMATION AFTER EACH TIME STEP
CALLS TO : EDTFTC IGET LINES PURGE PUTM TIMER INDDR2 WIPOUT
CALLED FROM: PKUPDT RHOEND SHPEND
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: EDLYR4
OBJECTIVE: EDITS OUT RECORD TYPE 04 OF DLAYXS
CALLS TO : LINES
CALLED FROM: RDLYR4
OVERLAY LEVEL: 3, 3

SUBPROGRAM NAME: EDTFTC
OBJECTIVE: EDIT OUT FUEL AND COOLANT TEMPERATURES
CALLS TO : LINES TWODPR
CALLED FROM: EDITS INEDIT SSEDIT
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: EDXSCO
OBJECTIVE: EDIT XSCON FILE
CALLS TO : LINES
CALLED FROM: INEDIT
OVERLAY LEVEL: 4, 2

SUBPROGRAM NAME: ERROR

OBJECTIVE: PRINTS ERROR SUMMARY

CALLS TO : ABEND LINES

CALLED FROM: AFX210 ANIPHX ANIP03 ANIP04 ANIP05 ANIP06 ANIP08 ANIP09 ANIP12 ANIP13 ANIP14
ANIP19 ANIP34 BCDXS2 CHKHOM CHKXSC CRED CRIT DIMXCK DRIVEF EXTBC FFXSR
FFXHMO FGEODS FORMSE FXINIT FXINPD FXINPR FXINXS FXOV31 FXOV32 FXOV33 FXOV41
FXOV42 FXPTXS FXSHAP INITSS INITT1 ISOR48 I2SORD MATSRT PKCALC PKSTEP PKUPDT
PNTMAT PRECUP RAFNIP RAFX2 RAIFLX RATHRM RCMESH RDLYR4 RESTRT RFXSR RFXCTL
RFXHMO RFXH35 RFXTH RGEODS RHOBEG ROMBI RRTFLX RWISOT RXSCON SCAN SHPEND
START STUFF STUFF1 TIMDEP TRIGOM XDENCK XDRDR2 XDRDR3 XSCTSV XSFIPR XSUPDT

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: EXTBC

OBJECTIVE: FORMS THE BOUNDARY CONDITION CONSTANTS ARRAY

CALLS TO : ERROR LINES

CALLED FROM: FGEODS

OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: EXTFLX

OBJECTIVE: EXTRAPOLATES FLUX SHAPE AT END OF EACH
REACTIVITY STEP

CALLS TO : BUCLOS BUOPEN LRED LRIT SEEK

CALLED FROM: RHOBEG

OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: EXTRPO
OBJECTIVE: EXTRAPOLATES FISSION SOURCE IN CHEBYSHEV
ACCELERATION
CALLS TO : NONE
CALLED FROM: GNDOTS
OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: FARSET
OBJECTIVE: STORES SINGLE PRECISION ARRAY IN REVERSE ORDER
INTO A DOUBLE SUBSCRIPTED ARRAY
CALLS TO : NONE
CALLED FROM: XSCTSV
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: FATFLX
OBJECTIVE: WRITES ADJOINT FLUX FILE ATFLUX
CALLS TO : BUCLOS BUOPEN CRIT IGET IPT2 LRED LRIT
CALLED FROM: FXINPR
OVERLAY LEVEL: 2, 0

SUBPROGRAM NAME: FEQUAT
OBJECTIVE: TRANSFERS CONTENTS OF ONE FLOATING POINT
ARRAY INTO ANOTHER FLOATING POINT ARRAY
(SMALL CORE TO SMALL CORE)
CALLS TO : NONE
CALLED FROM: AREAP AREAS FFXHMO FGEODS OMEGIN RAFX2 START TIMDEP
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: FEQUT2
OBJECTIVE: TRANSFERS CONTENTS OF ONE FLOATING POINT
ARRAY INTO ANOTHER FLOATING POINT ARRAY
(SMALL CORE TO LARGE CORE)
CALLS TO : NONE
CALLED FROM: WFXHMO WGEODS
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: FEQUT4
OBJECTIVE: TRANSFERS CONTENTS OF ONE FLOATING POINT
ARRAY INTO ANOTHER FLOATING POINT ARRAY
(LARGE CORE TO LARGE CORE)
CALLS TO : NONE
CALLED FROM: RGEODS TOMEGR XDRDR3
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: FFIYSR
OBJECTIVE: CONTROLS WRITING OF FIXSRC FILE
CALLS TO : ERROR GRPSOR IGET IPTERR I2SORD LINES PURGE PURGEB PUTB PUTM WIPOUT
CALLED FROM: FXINPR
OVERLAY LEVEL: 2, 5

SUBPROGRAM NAME: FFXHMO
OBJECTIVE: CONTROLS WRITING OF FILE FXHMOG
CALLS TO : ERROR FEQUAT FLTSET FLTST2 IGET INTSET IPTERR IPT2 ISOSFT LINES MATSRT
PURGE PURGEB PUTB PUTM REDEF REDEFB WFXHMO WIPOUT
CALLED FROM: FXINPR
OVERLAY LEVEL: 2, 4

SUBPROGRAM NAME: FGEODS
OBJECTIVE: CONTROLS WRITING OF FILE GEODST
CALLS TO : BUCK DZONE ERROR EXTBC FEQUAT IGET INTSET INTST2 IPTERR IPT2 LINES
LOCHEX MESBC MESHV NUMREG PURGE PURGEB PUTB PUTM RCMESH REDEFB TRIGOM
VOLREG WGEODS WIPOUT
CALLED FROM: FXINPR
OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: PHEADR

OBJECTIVE: PRINTS SUMMARY OF ISOTOPE-TO-MATERIAL MIXING
TABLE

CALLS TC : LINES

CALLED FROM: FXOV31

OVERLAY LEVEL: 3, 1

SUBPROGRAM NAME: FILES1

OBJECTIVE: DUMMY SUBROUTINE CONTAINING DESCRIPTION OF BCD
AND BINARY INTERFACE FILES

CALLS TC : NONE

CALLED FROM: NONE

OVERLAY LEVEL: 0, 0

SUBPROGFAM NAME: FILES2

OBJECTIVE: DUMMY SUBROUTINE CONTAINING DESCRIPTION OF
SCRATCH FILES

CALLS TC : NONE

CALLED FROM: NONE

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: FISFIX
OBJECTIVE: CALCULATES MACROSCOPIC FISSION CROSS SECTIONS
FOR EACH MATERIAL
CALLS TO : LRIT F LTST2
CALLED FROM: FISSON
OVERLAY LEVEL: 7, 0

SUBPROGRAM NAME: FISINT
OBJECTIVE: CALCULATES INITIAL FISSION SOURCE
CALLS TO : BUCLOS BUOPEN DSQRT FLTST2 LRED LRIT
CALLED FROM: FXOV93
OVERLAY LEVEL: 9, 3

SUBPROGRAM NAME: FISSON
OBJECTIVE: CONTROLS CALCULATION OF MACROSCOPIC FISSION
CROSS SECTIONS
CALLS TO : BUCLOS BUOPEN FISFIX LRIT
CALLED FROM: FXPTXS
OVERLAY LEVEL: 7, 0

SUBPROGRAM NAME: FLTSET

OBJECTIVE: STORES A SCALAR INTO A FLOATING POINT ARRAY
(ARRAY IN SMALL CORE)

CALLS TO : NONE

CALLED FROM: AREAP AREAS FFXHMO INITSS INITT1 INNERT MAIN OMEJCA PASS2 PWCAL RAFX2
SRCCAL START TIMDEP TOMEKN TRIGOM

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: FLTST2

OBJECTIVE: STORES A SCALAR INTO A FLOATING POINT ARRAY
(ARRAY IN LARGE CORE)

CALLS TO : NONE

CALLED FROM: AREAP AREAS CHKXSC FFXHMO FISINT FXOV32 FXOV33 FXTHRM GNDOTS ISOR48 OMEGCA
PASS1 PNTMAT RATHRM RFXTH SCTTER SHPOUT SSTATE TFDCEL XSFIX

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: FORMSH

OBJECTIVE: CHECKS FILE GEODST FOR CONSISTENCY

CALLS TO : ERROR LINES

CALLED FROM: RGEODS

OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: FREE
OBJECTIVE: RELEASES CORE STORAGE
CALLS TO : FREE1 FREE2
CALLED FROM: STUFF
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: FREE1
OBJECTIVE: FREE CORE ALLOCATED BY ALLOC1
CALLS TO : NONE
CALLED FROM: FREE
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: FREE2
OBJECTIVE: FREE CORE ALLOCATED BY ALLOC2
CALLS TO : NONE
CALLED FROM: FREE
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: FRTFLX
OBJECTIVE: WRITES REAL FLUX FILE RTFLUX
CALLS TO : BUCLOS BUOPEN CRIT IGET IPT2 LRED LRIT
CALLED FROM: FXINPR
OVERLAY LEVEL: 2, 0

SUBPROGRAM NAME: FXINIT
OBJECTIVE: BINARY INPUT FILE PROCESSOR AND PROGRAM
INITIALIZER
CALLS TO : ERROR FXOV41 FXOV42 FXOV43 FXOV45 LINES SEEK
CALLED FROM: MAIN TIMDEP
OVERLAY LEVEL: 4, 0

SUBPROGRAM NAME: FXINPD
OBJECTIVE: CONTROLS INNER PRODUCT CALCULATION
CALLS TO : ERROR IGET ILASTB IPTERR LINES PASS PASS2 PURGE PURGEB PUTB PUTM
SEEK VOLUME WIPOUT
CALLED FROM: SSTATE TIMDEP
OVERLAY LEVEL: 8, 0

SUBPROGRAM NAME: FXINPR
OBJECTIVE: DRIVER SUBROUTINE FOR BCD INPUT PROCESSOR
CALLS TO : BUCLOS BUOPEN ERROR FATFLX FFIYSR FFXHMO FGEODS FRIFLX IGET INTSET IPT2
LINES PURGE PURGEB PUTB PUTM RAFNIP RAFX2 RATHRM REED SEEK WIPOUT

CALLED FROM: MAIN

OVERLAY LEVEL: 2, 0

SUBPROGRAM NAME: FXINKS

OBJECTIVE: DRIVER SUBROUTINE FOR MICROSCOPIC CROSS SECTION
PROCESSOR

CALLS TO : ERROR FXOV31 FXOV32 FXOV33 FXOV34 LINES SEEK

CALLED FROM: MAIN

OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: FXOV10

OBJECTIVE: DRIVER SUBROUTINE FOR ALL ROUTINES IN OVERLAY
(1,0)

CALLS TO : IGET PKCALC RHOBEG RHOEND SHPEND

CALLED FROM: NONE

OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: FXOV31

OBJECTIVE: CONTROLS READING RECORDS 2-3 OF ISOTXS AND
 DLAYXS AND RECCRDs 2-5 OF FXHMOG

CALLS TO : BUCLOS BUCPEN ERROR FHEADR IEQUAT IGET IPTERR IPT2 LINES PURGE PURGEB
 PUTB PUTM REED RFXH35 WIPOUT XDRDR2 XDRDF3

CALLED FROM: FXINXS

OVERLAY LEVEL: 3, 1

SUBPROGRAM NAME: FXOV32

OBJECTIVE: CONTROLS READING RECORDS 5 AND 6 FROM ISOTXS

CALLS TO : ERROR FLTST2 IGET INTST2 IPTERR IPT2 IPT3 ISOR48 LINES PURGE PURGEB
 PUTB WIFOUT

CALLED FROM: FXINXS

OVERLAY LEVEL: 3, 2

SUBPROGRAM NAME: FXOV33

OBJECTIVE: CONTROLS FEADING DLAYXS AND CALCULATING
 TEMPERATUEE COEFFICIENTS

CALLS TO : BUCLOS DOFCAL ERROR FLTST2 IGET IPTERR IPT2 LINES LRED PURGE PURGEB
 PUTB RDLYR4 WIPOUT XSFIPR XSORDR

CALLED FROM: FXINXS

OVERLAY LEVEL: 3, 3

SUBPROGRAM NAME: FXOV34

OBJECTIVE: DRIVER ROUTINE TO CALCULATE AND WRITE
XSCON FILE

CALLS TO : BUCLOS BUOPEN IGET IPT2 LRED LRIT PURGE PURGEB PUTB REDEFB SINEQ4
WIPOUT XSCIL

CALLED FROM: FXINXS

OVERLAY LEVEL: 3, 4

SUBPROGRAM NAME: FXOV41

OBJECTIVE: CONTROLS READING IN BINARY INPUT FILES

CALLS TO : BUOPEN ERROR IGET LINES LRED PURGE PURGEB PUTB RATFLX REED RFXSR
RFXCTL RFXHMO RFXTH RGEODS RRTFLX RXSCON WIPOUT

CALLED FROM: FXINIT

OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: FXOV42

OBJECTIVE: CONTROLS EDITING INPUT DATA AND PERFORMING
STEADY STATE INITIALIZATION

CALLS TO : ERROR IGET INEDIT INITSS IPTERR LINES PURGE PURGEB PUTB PUTM WIPOUT

CALLED FROM: FXINIT

OVERLAY LEVEL: 4, 2

SUBPROGRAM NAME: FXOV43
OBJECTIVE: CONTROLS TIME DEPENDENT INITIALIZATION
CALLS TO : IGET INITT1 MAXMNF PURGE PURGEB PUTB PUTM WIPOUT
CALLED FROM: FXINIT
OVERLAY LEVEL: 4, 3

SUBPROGRAM NAME: FXOV45
OBJECTIVE: CONTROLS READING AND WRITING RESTART FILE
CALLS TO : RESTRT
CALLED FROM: FXINIT
OVERLAY LEVEL: 4, 5

SUBPROGRAM NAME: FXOV91
OBJECTIVE: CONTROLS CALCULATION OF SOURCE FOR TIME
DEPENDENT CALCULATION
CALLS TO : IGET PURGE PURGEB PUTB PUTM SRCCAL SRCMOD WIPOUT
CALLED FROM: FXSHAP
OVERLAY LEVEL: 9, 1

SUBPROGRAM NAME: FXOV92
OBJECTIVE: CONTROLS CALCULATION OF FINITE DIFFERENCE
COEFFICIENTS
CALLS TO : IGET SFDGEN VOLUME
CALLED FROM: FXSHAP
OVERLAY LEVEL: 9, 2

SUBPROGRAM NAME: FXOV93
OBJECTIVE: CONTROLS CALCULATION OF OVER-RELAXATION FACTORS
CALLS TO : FISINT IGET LCOPEN OMEGCA
CALLED FROM: FXSHAP
OVERLAY LEVEL: 9, 3

SUBPROGRAM NAME: FXOV94
OBJECTIVE: CONTROLS CALCULATION OF FLUX SHAPE
CALLS TO : IGET OUTERS
CALLED FROM: FXSHAP
OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: FXOV95
OBJECTIVE: CONTROLS WRITING OUTPUT FLUX FILES
CALLS TO : IGET SHPOUT
CALLED FROM: FXSHAP
OVERLAY LEVEL: 9, 5

SUBPROGRAM NAME: FXPTXS
OBJECTIVE: CONTROLS CALCULATION OF MACROSCOPIC CROSS
SECTIONS
CALLS TO : BUCLOS BUOPEN ERROR FISSON IGET IPTERR IPT2 LINES LRED PNTMAT PURGE
PURGEB PUTB PUTM SCATTER SEEK VOLUME WIPOUT XSFIX
CALLED FROM: SSTATE TIMDEP
OVERLAY LEVEL: 7, 0

SUBPROGRAM NAME: FXSHAP
OBJECTIVE: CONTROLS OVERALL CALCULATION OF FLUX SHAPE
CALLS TO : ERROR FXOV91 FXOV92 FXOV93 FXOV94 FXOV95 IGET LCCLOS LINES PURGE PURGEB
PUTB PUTM SEEK WIPOUT
CALLED FROM: SSTATE TIMDEP
OVERLAY LEVEL: 9, 0

SUBPROGRAM NAME: FXTHRM
OBJECTIVE: CONTROLS THERMAL-HYDRAULIC CALCULATION
CALLS TO : BUCLOS BUOPEN DETAL FLTST2 IGET LRED LRIT PURGE PURGES PUTB PUTM
PWCAL REED RITE ROMBI SEEK SIMPL VOLUME WIPOUT
CALLED FROM: SSTATE TIMDEP
OVERLAY LEVEL: 5, 0

SUBPROGRAM NAME: GETBND
OBJECTIVE: RETURNS THE APPROPRIATE BOUNDARY CONDITION
CONSTANT
CALLS TO : NONE
CALLED FROM: LEKIP TLEKIP
OVERLAY LEVEL: 8, 0

SUBPROGRAM NAME: GETPNT
OBJECTIVE: RETURN POINTR FOR A GIVEN BLOCK
CALLS TO : PRTA1 PRTA2 PRTECM PRTI1 PRTI2 PRTR1 PRTR2
CALLED FROM: NONE
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: GNDOTS

OBJECTIVE: CONTROLS THE CHEBYSHEV ACCELERATION AT EACH
OUTER ITERATION

CALLS TO : BUCLOS BUCPEN CHEBE DACOSH DARCOS DCOS DSQRT EXTRPO FLTST2 HYPCOS LRED
LRIT UPIFS

CALLED FROM: OUTERS

OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: GRPSOR

OBJECTIVE: COMPUTES GROUP LIMITS FOR FIXED SOURCE

CALLS TO : NONE

CALLED FROM: PFIJSR

OVERLAY LEVEL: 2, 5

SUBPROGRAM NAME: ESCAN

OBJECTIVE: SCANS ALPHANUMERIC NAME LIST

CALLS TO : LINES

CALLED FROM: ANIP13 ANIP14

OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: GSORC1
OBJECTIVE: COMPUTES FISSION AND SCATTERING SOURCE
FOR A GROUP IF CROSS SECTIONS ARE IN CORE
CALLS TO : NONE
CALLED FROM: OUTERS
OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: GSORC2
OBJECTIVE: COMPUTES FISSION AND SCATTERING SOURCE
FOR A GROUP IF CROSS SECTIONS ARE ON DISK
CALLS TO : BUOPEN LRED NGSUB
CALLED FROM: OUTERS
OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: HCALC
OBJECTIVE: CALCULATE SURFACE HEAT TRANSFER COEFFICIENT
CALLS TO : NONE
CALLED FROM: THCALC
OVERLAY LEVEL: 5, 0

SUBPROGRAM NAME: HYPCOS
OBJECTIVE: CALCULATES HYPERBOLIC COSINE OF ARGUMENT
CALLS TO : DEXP
CALLED FROM: CHEBE GNDOTS
OVERLAY LEVEL: 9, 0

SUBPROGRAM NAME: IEQUAT
OBJECTIVE: TRANSFERS ONE INTEGER ARRAY INTO ANOTHER
(SMALL CORE TO SMALL CORE)
CALLS TO : NONE
CALLED FROM: FXOV31 RAFX2 RFXCTL
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: IEQUT2
OBJECTIVE: TRANSFERS ONE INTEGER ARRAY INTO ANOTHER
(SMALL CORE TO LARGE CORE)
CALLS TO : NONE
CALLED FROM: WFXHMO
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: IEQUT4
OBJECTIVE: TRANSFERS ONE INTEGER ARRAY INTO ANOTHER
(LARGE CORE TO LARGE CORE)
CALLS TO : NONE
CALLED FROM: RGEODS RXSCON XDRDR3
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: IGET
OBJECTIVE: RETURNS PCINTER ASSOCIATED WITH AN ARRAY NAME
CALLS TO : GETN
CALLED FROM: DSKEDT EDITS FATFLX FFI XSR FFXHMO FGEODS FRIFLX FXINPD FXINPR FXOV10 FXOV31
FXOV32 FXOV33 FXOV34 FXOV41 FXOV42 FXOV43 FXOV91 FXOV92 FXOV93 FXOV94 FXOV95
FXPTXS FXSHAP FXTHRM ISOR48 PKUPDT PRECUP RAFNIP RATHRM RHOEBEG RHOEND RXSCON
SHPEND SSEDIT SSTATE TIMDEP XDRDR3
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: INEDIT
OBJECTIVE: EDITS INPUT BINARY FILES AS REQUESTED
CALLS TO : EDTFTC EDXSCO LINES REGMAP
CALLED FROM: FXOV42
OVERLAY LEVEL: 4, 2

SUBPROGRAM NAME: INITSS
OBJECTIVE: INITIALIZES THE STEADY STATE CALCULATION
CALLS TO : BUCLOS BUOPEN CALFSP ERROR FLTSET ILAST ILASTB INTSET LINES LRED LRIT
CALLED FROM: FXOV42
OVERLAY LEVEL: 4, 2

SUBPROGRAM NAME: INITT1
OBJECTIVE: INITIALIZES THE TRANSIENT CALCULATION
CALLS TO : BUCLOS BUOPEN ERROR FLTSET ILAST ILASTB LINES LRED LRIT
CALLED FROM: FXOV43
OVERLAY LEVEL: 4, 3

SUBPROGRAM NAME: INNDO
OBJECTIVE: CONTROLS CALCULATION OF ONE INNER ITERATION FOR
PERIODIC OR NON-PERIODIC CONDITIONS FOR
ORTHOGONAL GEOMETRIES
CALLS TO : INVRT LCREED BOWSRC SOLVP
CALLED FROM: INNERS
OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: INNDS
OBJECTIVE: CONTROLS CALCULATION OF ONE LINE OF MESH FOR
ORTHOGONAL GEOMETRY IN CALCULATION OF OVER-
RELAXATION PARAMETERS
CALLS TO : INVRT ROWSRC SOLVP
CALLED FROM: OMEGIN
OVERLAY LEVEL: 9, 3

SUBPROGRAM NAME: INNERS
OBJECTIVE: CARRIES OUT REQUIRED NUMBER OF INNER ITERATIONS
FOR ORTHOGONAL GEOMETRIES
CALLS TO : INNDO
CALLED FROM: OUTERS
OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: INNERT
OBJECTIVE: CARRIES OUT REQUIRED NUMBER OF INNER ITERATIONS
FOR TRIANGULAR GEOMETRIES
CALLS TO : FLTSET TRISRC
CALLED FROM: OUTERS
OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: INTSET
OBJECTIVE: INITIALIZES AN INTEGER ARRAY IN SMALL CORE
CALLS TO : NONE
CALLED FROM: PFXHMO FGEODS FXINPR INITSS MAIN OMEGCA RAFX2
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: INTST2
OBJECTIVE: INITIALIZES AN INTEGER ARRAY IN LARGE CORE
CALLS TO : NONE
CALLED FROM: CHKXSC FGEODS FXOV32 ISOR48 PNTMAT RDLYR4 TRIGOM WGEODS
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: INVRT
OBJECTIVE: INVERTS A TRIDIAGONAL MATRIX AND PERFORMS
OVER-RELAXATION
CALLS TO : NONE
CALLED FROM: INNDO INNDS
OVERLAY LEVEL: 9, 0

SUBPROGRAM NAME: IPTERR
OBJECTIVE: RETURNS NUMBER OF ERRORS IN BPOINTER ROUTINES
CALLS TO : NONE
CALLED FROM: FFI XSR FFXHMO FGEODS FXINPD FXOV31 FXOV32 FXOV33 FXOV42 FXPTXS PKCALC PKUPDT
PRECUP RAFNIP RAFX2 RESTRT RFI XSR RFXCTL RFXHMO RFXH35 RFXTH RGEODS RHOBEG
RXSCON START TIMDEP XDRDR3
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: IPT2
OBJECTIVE: RETURNS POINTER TO A SUBARRAY WITHIN A BLOCK
CALLS TO : NONE
CALLED FROM: FATFLX FFXHMO FGEODS FRTFLX FXINPR FXOV31 FXOV32 FXOV33 FXOV34 FXPTXS ISOR48
POINTR PRTECM PURGE PURGEB RAFX2 RATFLX RATHRM REDEFB REDEFM RFI XSR RFXCTL
RFXHMO RFXTH RGEODS RRTFLX RXSCON WIPOUT XDRDR3
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: IPT3
OBJECTIVE: RETURNS A POINTER IN THE BLK ARRAY
CALLS TO : NONE
CALLED FROM: FXOV32 XDRDR3
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: ISOR48

OBJECTIVE: READS RECORD TYPES 5, 6, AND 8 OF ISOTXS
FOR EACH ISOTOFE

CALLS TO : BUCLOS DIMXCK ERROR FLTST2 IGET INTST2 IPT2 LINES LRED SINEQ4 SINST2
SQUEZ2 XSCTSV XSUPDT

CALLED FROM: FXOV32

OVERLAY LEVEL: 3, 2

SUBPROGRAM NAME: ISOSRT

OBJECTIVE: SORTS DATA ON CARD TYPE 13 OF A.FNIP

CALLS TO : NONE

CALLED FROM: FFXHMO

OVERLAY LEVEL: 2, 4

SUBPROGRAM NAME: I2SORD

OBJECTIVE: SORTS DATA ON CARD TYPE 19 OF A.FNIP AND
WRITES THE FILE FIXSRC

CALLS TO : BUCLOS BUOPEN ERROR LINES LRED LRIT

CALLED FROM: FFIXSR

OVERLAY LEVEL: 2, 5

SUBPROGRAM NAME: LCCLOS
OBJECTIVE: PERFORMS A WIPOUT ON FILE FILNAM
CALLS TO : WIPOUT
CALLED FROM: FXSHAP
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: LCOPEN
OBJECTIVE: CALLS PUTM TO OPEN A FILE IN SMALL CORE
CALLS TO : PUTM
CALLED FROM: FXOV93
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: LCREED
OBJECTIVE: READS DATA FROM LARGE CORE TO SMALL CORE
CALLS TO : NONE
CALLED FROM: INNDO
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: LCRITE

OBJECTIVE: WRITES DATA FROM SMALL CORE TO LARGE CORE

CALLS TO : NONE

CALLED FROM: NONE

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: LEKIP

OBJECTIVE: COMPUTES LEAKAGE PLUS REMOVAL INNER PRODUCT FOR ORTHOGONAL GEOMETRIES

CALLS TO : DCOS DSIN GETBND

CALLED FROM: PASS2

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: LINES

OBJECTIVE: KEEPS TRACK OF LINES PRINTED ON THE PAGE

CALLS TO : NONE

CALLED FROM: AFX210 ANIPHX ANIP03 ANIP04 ANIP05 ANIP06 ANIP08 ANIP09 ANIP12 ANIP13 ANIP14
 ANIP19 ANIP34 CHKHM CHKXSC CRED CRIT DIMXCK DLY23 DRIVEF EDITS EDLYR4
 EDTFTC ELXSCO ERROR EXTBC FFIYSR FFXHMO FGEODS FHEADR FORMSH FXINIT FXINPD
 FXINPR FXINXS FXOV31 FXOV32 FXOV33 FXOV41 FXOV42 FXPIXS FXSHAP GSCAN INEDIT
 INITSS IFITT1 ISOR48 I2SORD MAIN MATSR OUTERS PKSTEP PNTMAT PRECUP PRNTEL
 PRNT1A PRNT1D PRNT1E PRNT1I PRNT2D PRNT2E RAFNIP RAFX2 RATFLX RCMESH RDLYR4
 REGMAP REPORT RESTRT RFIYSR RFXCTL RFXHMO RFXH35 RGEODS RHOBEG ROMBI RRTFLX
 RWDELY RWISOT RXSCON SHPEND SPACE SSEDIT START SUMARY TIMDEP TIMSIP TRIGOM
 TWDP2 TWODPR XDENCK XDRDR2 XDRDR3 XSCTSV XSFIPR XSUPDT

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: LOCHEX
OBJECTIVE: LOCATES A PARTICULAR HEX CELL IN A
PARTICULAR RING
CALLS TO : NONE
CALLED FROM: FGEODS TRIGOM
OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: LRED
OBJECTIVE: GENERAL PURPOSE FILE READ SUBROUTINE (TO
LARGE CORE). MEETS CCCC SPECIFICATIONS
CALLS TO : BUCLOS BUOPEN ZEROIO
CALLED FROM: COPYDS DRIVEF DSKEDT EXTFLX FATFLX FISINT FRTFLX FXOV33 FXOV34 FXOV41 FXPTXS
FXTHRM GNDOTS GSORC2 INITSS INITT1 ISOE48 I2SORD MAXMNF OMEGCA OUTERS PASS1
PASS2 PRCUPD RATFLX RATHRM RDLYR4 RESTRI RFIXSR RFXHMO RFXTH RGEODS RTTFLX
RXSCON SFDGEN SHPOUT SRCCAL SRCMOD SSTATE WFXHMO WFXTH WGEODS XDRDR2 XDRDR3
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: LRIT
OBJECTIVE: GENERAL PURPOSE FILE READ SUBROUTINE (FROM
LARGE CORE). MEETS CCCC SPECIFICATIONS
CALLS TO : BUCLOS BUOPEN ZEROIO
CALLED FROM: COPYDS DRIVEF EXTFLX FATFLX FISINT FISSON FRTFLX FXOV34 FXTHRM GNDOTS INITSS
INITT1 I2SORD OUTERS PASS2 PRCMAP RESTRT SCTTER SFDGEN SHPOUT SSTATE WFXHMO
WFXTH WGEODS XSFIX
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: MAIN
OBJECTIVE: MAIN PROGRAM FOR FX2-TH
CALLS TO : FLTSET FXINIT FXINPR FXINKS INTSET LINES SCAN SEEK SSTATE START STUFF
SUMARY TIMDEP TIMER TIMSUM
CALLED FROM: NONE
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: MATSRT
OBJECTIVE: SORTS DATA FROM TYPE 14 CARDS OF A.FNIP
CALLS TO : ERROR LINES
CALLED FROM: FFXHMO
OVERLAY LEVEL: 2, 4

SUBPROGRAM NAME: MAXMNF
OBJECTIVE: COMPUTES MAX. NUMBER OF CELLS CONTAINING
FISSIONABLE MATERIAL DURING TRANSIENT
CALLS TO : BUCLOS BUOPEN LRED
CALLED FROM: FXOV43
OVERLAY LEVEL: 4, 3

SUBPROGRAM NAME: MESH C

OBJECTIVE: FORMS XMESH AND YMESH ARRAYS IF TYPE 09 CARDS
NOT PRESENT IN A.FNIP

CALLS TO : MSHORD

CALLED FROM: FGEODS

OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: MESH V

OBJECTIVE: FORMS XMESH AND YMESH ARRAYS IF TYPE 09 CARDS
ARE PRESENT IN A.FNIP

CALLS TO : NONE

CALLED FROM: FGEODS

OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: MSHORD

OBJECTIVE: ORDERS ELEMENTS OF A FLOATING POINT ARRAY

CALLS TO : NONE

CALLED FROM: MESH C

OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: NGSUB
OBJECTIVE: COMPUTES POINTER TO LOCATION IN PSI ARRAY
IF SCATTERING BAND OF FLUXES IS IN CORE
CALLS TO : NONE
CALLED FROM: GSORC2 OUTERS
OVERLAY LEVEL: 9, 0

SUBPROGRAM NAME: NROTAT
OBJECTIVE: COMPUTES POINTER TO LOCATION IN PSI ARRAY
IF ALL FLUXES ARE IN CORE
CALLS TO : NONE
CALLED FROM: PASS1 PASS2
OVERLAY LEVEL: 8, 0

SUBPROGRAM NAME: NUMREG
OBJECTIVE: SORTS THROUGH REGION LABEL ARRAY RLABEL
CALLS TO : NONE
CALLED FROM: FGEO DS
OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: OMEGCA
OBJECTIVE: CONTROLS CALCULATION OF OPTIMAL OVER-RELAXATION
PARAMETERS
CALLS TO : BUCLOS BUOPEN FLTSET FLTST2 INTSET LRED OMEGIN TOME3N
CALLED FROM: FXOV93
OVERLAY LEVEL: 9, 3

SUBPROGRAM NAME: OMEGIN
OBJECTIVE: CALCULATES OVER-RELAXATION PARAMETERS FOR
ORTHOGONAL GEOMETRIES
CALLS TO : DSQRT FEQUAT INNDS
CALLED FROM: OMEGCA
OVERLAY LEVEL: 9, 3

SUBPROGRAM NAME: OUTERS
OBJECTIVE: CONTROLS OUTER (FISSION SOURCE) ITERATIONS
CALLS TO : BUCLOS BUOPEN GNDOTS GSORC1 GSORC2 INNERS INNERT LINES LRED LRIT NGSUB
CALLED FROM: FXOV94
OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: PAR
OBJECTIVE: COMPUTES A PARABOLIC FIT TO THREE DATA POINTS
CALLS TO : NONE
CALLED FROM: PKCALC PKSTEP PKUPDT
OVERLAY LEVEL: 0, 0

SUBPROGEAM NAME: PASS1
OBJECTIVE: CALCULATES PROMPT AND RELAYED FISSION SOURCES
CALLS TO : BUCLOS BUOPEN FLTST2 LRED NROTAT
CALLED FROM: FXINPD
OVERLAY LEVEL: 8, 0

SUBPROGRAM NAME: PASS2
OBJECTIVE: CALCULATES DELAYED AND PROMPT FISSION SOURCES,
SCATTERING SOURCE, FIXED SCURCE, LEAKAGE AND
REMOVAL INNER PRODUCTS
CALLS TO : AREAP BUCLOS BUOPEN FLTSET LEKIP LRED LRIT NROTAT REED TLEKIP
CALLED FROM: FXINPD
OVERLAY LEVEL: 8, 0

SUBPROGRAM NAME: PKCALC
OBJECTIVE: CONTROLS CALCULATION OF POINT KINETICS AT
EACH REACTIVITY STEP
CALLS TO : DLOG ERROR IPTERR PAR PKSTEP PURGE PUTM WIPOUT
CALLED FROM: FXOV10 TIMDEP
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: PKSTEP
OBJECTIVE: INTEGRATES POINT KINETICS EQUATIONS ACROSS
ONE REACTIVITY STEP
CALLS TO : DEXP DLOG ERROR LINES PAR
CALLED FROM: PKCALC PKUPDT
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: PKSTOR
OBJECTIVE: STORES DATA FROM EACH REACTIVITY STEP INTO
PKBUF ARRAY
CALLS TO : NONE
CALLED FROM: RHOEND
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: PKUPDT
OBJECTIVE: CONTROLS POINT KINETICS UPDATE SWEEP
CALLS TO : EDITS ERROR IGET IFTERR PAR PKSTEP PURGE PUTM WIPOUT
CALLED FROM: SHPEND
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: PNTMAT
OBJECTIVE: SETS UP ARRAY MATPNT TO POINT TO FISSIONABLE
MATERIALS ON THE MESH
CALLS TO : DLOG DSQRT ERROR FLTST2 INTST2 LINES
CALLED FROM: FXPTXS
OVERLAY LEVEL: 7, 0

SUBPROGRAM NAME: POINTR
OBJECTIVE: INITIALIZES DATA MANAGEMENT ROUTINES
CALLS TO : ALLOC1 ALLOC2 BULK ECZERO IPT2
CALLED FROM: START STUFF
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PRCMAP
OBJECTIVE: WRITES THE DELAYED PRECURSOR FILE PREC2M
CALLS TO : BUCLOS BUOPEN LRIT
CALLED FROM: PRECUP
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: PRCUPD
OBJECTIVE: CALCULATES THE DELAYED PRECURSORS AFTER EACH
REACTIVITY STEP
CALLS TO : BUCLOS BUOPEN DEXP LRED
CALLED FROM: PRECUP
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: PRECUP
OBJECTIVE: CONTROLS UPDATING OF PRECURSORS AFTER EACH
REACTIVITY STEP
CALLS TO : ERROR IGET IPTERR LINES PRCMAP PRCUPD PURGE PURGEB PUTB SEEK WIPOUT
CALLED FROM: RHOEND
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: PRNTEL
OBJECTIVE: PRINTS A ONE-DIMENSIONAL ARRAY IN A6 FCRMAT
CALLS TO : LINES
CALLED FROM: DLY23 XDRDR3
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: PRNT1A
OBJECTIVE: PRINTS ONE-DIMENSIONAL ARRAY WITH INDEXING
CALLS TO : LINES
CALLED FROM: DLY23 XDRDR3
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: PRNT1D
OBJECTIVE: PRINTS ONE-DIMENSIONAL ARRAY WITH INDEXING
CALLS TO : LINES
CALLED FROM: DLY23
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: PRNT1E
OBJECTIVE: PRINTS ONE-DIMENSIONAL ARRAY WITH INDEXING
CALLS TO : LINES
CALLED FROM: XDRDR3
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: PRNT1I
OBJECTIVE: PRINTS ONE-DIMENSIONAL ARRAY WITH INDEXING
CALLS TO : LINES
CALLED FROM: DLY23
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: PRNT2D
OBJECTIVE: PRINTS TWO-DIMENSIONAL ARRAY WITH INDEXING
CALLS TO : LINES
CALLED FROM: DLY23
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: PRNT2E
OBJECTIVE: PRINTS TWO-DIMENSIONAL ARRAY WITH INDEXING
CALLS TO : LINES
CALLED FROM: NONE
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: PRTI1
OBJECTIVE: PRINTS HALF WORD INTEGER FROM SMALL CORE
CALLS TO : NONE
CALLED FROM: GETPNT
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PRTI2
OBJECTIVE: PRINTS FULLWORD INTEGER FROM SMALL CORE
CALLS TO : NONE
CALLED FROM: GETPNT
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PRTA1

OBJECTIVE: PRINTS SINGLE PRECISION ARRAY FROM SMALL
CORE IN A4 FORMAT

CALLS TO : NONE

CALLED FROM: GETPNT

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PRTA2

OBJECTIVE: PRINTS DOUBLE PRECISION ARRAY FROM SMALL
CORE IN A8 FORMAT

CALLS TO : NONE

CALLED FROM: GETPNT

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PRTECM

OBJECTIVE: MANAGES PRINTING OF DATA IN LARGE CORE

CALLS TO : CRED IPT2 PRTECM

CALLED FROM: GETPNT

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PRTR1
 OBJECTIVE: PRINTS SINGLE PRECISION REAL ARRAY FROM SMALL
 CORE IN E15.7 FORMAT
 CALLS TO : NONE
 CALLED FROM: GETPNT
 OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PRTR2
 OBJECTIVE: PRINTS DCUBLE PRECISION REAL ARRAY FROM SMALL
 CORE IN E15.7 FORMAT
 CALLS TO : NONE
 CALLED FROM: GETPNT
 OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PURGE
 OBJECTIVE: COMPRESSES UNUSED SPACE IN SMALL CORE
 CALLS TO : ECMV ECZERO IPT2 STATUS
 CALLED FROM: BCDXST DSKEDT EDITS FFI XSR FFXHMO FGEODS FXINPD FXINPR FXOV31 FXOV32 FXOV33
 FXOV34 FXOV41 FXOV42 FXOV43 FXOV91 FXPTXS FXSHAP FXTHRM PKCALC PKUPDT PRECUP
 PUTM RAFNIP RAFX2 RATFLX BATHRM RESTET RFI XSR RFXCTL RFXHMO RFXH35 RFXTH
 RGEODS RHOBEG RRTFLX RXSCON SSEDIT SSTATE TIMDEP XDRDR3
 OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PURGEB

OBJECTIVE: COMPRESSES UNUSED SPACE IN LARGE CORE

CALLS TO : ECMV ECZERO IPT2 STATUS

CALLED FROM: DSKEDT FFI XSR FFXHMO FGEODS FXINPD FXINPR FXOV31 FXOV32 FXOV33 FXOV34 FXOV41
FXOV42 FXOV43 FXOV91 FXPTXS FXSHAP FXTHRM PRECUP PUTB RAFNIP RAFX2 RATFLX
RATHRM RESTRT RFI XSR RFXHMO RFXH35 RFXTH RGEODS RHOBE3 RRTFLX RXSCON SSTATE
TIMDEP XDRDR3

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PUTB

OBJECTIVE: ALLOCATES SPACE IN LARGE CORE

CALLS TO : PURGEB

CALLED FROM: DSKEDT FFI XSR FFXHMO FGEODS FXINPD FXINPR FXOV31 FXOV32 FXOV33 FXOV34 FXOV41
FXOV42 FXOV43 FXOV91 FXPTXS FXSHAP FXTHRM PRECUP PUTBLK RAFNIP RATFLX RATHRM
REDEFB REDEFM RESTRT RFI XSR RFXHMO RFXTH RGEODS RHOBE3 RRTFLX RXSCON SSTATE
TIMDEP XDRDR3

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PUTBLK

OBJECTIVE: ASSIGN AN ARRAY TO LARGE CORE

CALLS TO : PUTB

CALLED FROM: NONE

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PUTM

OBJECTIVE: ALLOCATES SPACE IN SMALL CORE

CALLS TO : PURGE

CALLED FROM: BCDXST DETAL EDITS FFI XSR FFXHMO FGEODS FXINPD EXINPR FXOV31 FXOV42 FXOV43
FXOV91 FXPTXS FXSHAP FXTHRM LCOPEN PKCALC PKUPDT PUTPNT RAFNIP RAFX2 RATHRM
REDEFB REDEFM RESTRT RFXCTL RFXHMO RFXH35 RGEODS RHOBEG SSEDIT SSTATE STUFF

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PUTPNT

OBJECTIVE: ASSIGN AN ARRAY TO SMALL CORE

CALLS TO : PUTM

CALLED FROM: NONE

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: PWCAL

OBJECTIVE: CALCULATES SPECIFIC POWER IN EACH THERMAL-
HYDRAULIC REGION

CALLS TO : FLTSET

CALLED FROM: FXTHRM

OVERLAY LEVEL: 5, 0

SUBPROGRAM NAME: RAFNIP

OBJECTIVE: ALLOCATES SPACE FOR AND READS THE A.FNIP
DATA SET

CALLS TO : ANIPHX ANIP03 ANIP04 ANIP05 ANIP06 ANIP08 ANIP09 ANIP12 ANIP13 ANIP14 ANIP19
ANIP34 BUCLOS ERROR IGET IPTERR LINES PURGE PURGEB PUTB PUTM REDEFB
REED REPORT SPACE SQUEZE WIPOUT

CALLED FROM: FXINPR

OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: RAFX2

OBJECTIVE: ALLOCATES SPACE FOR AND READS CARD TYPES 01 THRU
09 OF A.FX2

CALLS TO : AFX210 BUCLOS ERROR FEQUAT FLTSET IEQUAT INTSEI IPIERR IPT2 LINES PURGE
PURGEB PUTM SPACE TIMER WFXCTL WIPOUT

CALLED FROM: FXINPR

OVERLAY LEVEL: 2, 1

SUBPROGRAM NAME: RATFLX

OBJECTIVE: READS RECORD 02 OF FILE ATFLUX

CALLS TO : BUCLOS ERROR IPT2 LINES LRED PURGE PURGEB PUTB WIPOUT

CALLED FROM: FXOV41

OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: RATHRM
OBJECTIVE: ALLOCATES SPACE AND READS DATA SET A.THFM
CALLS TO : BUCLOS BJOPEN ERROR FLTST2 IGET IPT2 LRED PURGE PURGEB PUTE PUTM
SEEK SPACE THRMZ THRM03 THRM04 THRM05 THRM06 WFXTH WIPOUT
CALLED FROM: FXINPR
OVERLAY LEVEL: 2, 6

SUBPROGRAM NAME: RCMESH
OBJECTIVE: CHECKS REGION BOUNDARY COORDINATES ON TYPE 06
CARDS
CALLS TO : ERROR LINES
CALLED FROM: FGEODS
OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: RDLYR4
OBJECTIVE: READS RECORD 04 OF FILE DLAYXS FOR EACH ISOTCPE
CALLS TO : DLUPDT DLY23 EDLYR4 ERROR INTST2 LINES LRED
CALLED FROM: FXOV33
OVERLAY LEVEL: 3, 3

SUBPROGRAM NAME: READEC
OBJECTIVE: TRANSFER FROM LARGE CORE TO SMALL CORE
CALLS TO : NONE
CALLED FROM: CRED CRIT
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: REDEF
OBJECTIVE: REDEFINES LENGTH OF ARRAY IN SMALL CORE
CALLS TO : REDEFM
CALLED FROM: FFXHMO
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: REDEFB
OBJECTIVE: REDEFINES LENGTH OF ARRAY IN LARGE CORE
CALLS TO : CRED CRIT ECMV GETN IPT2 PUTB PUTM
CALLED FROM: FFXHMO FGEODS FXOV34 RAFNIP
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: REDEFM
OBJECTIVE: REDEFINES LENGTH OF ARRAY IN SMALL CORE
CALLS TO : CRED CRIT ECMV GETN IPT2 PUTB PUTM
CALLED FROM: REDEF
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: REED
OBJECTIVE: GENERAL PURPOSE FILE READ SUBROUTINE (TO
SMALL CORE). MEETS CCCC SPECIFICATIONS
CALLS TO : BUCLOS BUOPEN ZEROIO
CALLED FROM: CHNGIN FXINPR FXOV31 FXOV41 FXTHRM PASS2 RAFNIP RESIRT RFXCTL RFXH35 RHOBEG
RRTFLX RWDELY RWISOT SRCCAL SRCMOD SSTATE START WAITFLX WFXCTL WRTFLX
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: REGMAP
OBJECTIVE: PRINTS A MAP OF THE REGION ASSIGNMENTS
CALLS TO : LINES
CALLED FROM: INEDIT
OVERLAY LEVEL: 4, 2

SUBPROGRAM NAME: REPORT
OBJECTIVE: ISSUES REPORT ON TRIVIAL AND FATAL ERRORS IN
AN INPUT BCD DATASET
CALLS TO : LINES
CALLED FROM: ANIPHX ANIP03 ANIP04 ANIP05 ANIP06 ANIP08 ANIP09 ANIP12 ANIP13 ANIP14 ANIP19
ANIP34 RAFNIP
OVERLAY LEVEL: 2, 2

SUBPROGRAM NAME: RESTRT
OBJECTIVE: READS OR WRITES THE FX2 RESTART FILE
CALLS TO : BUCLOS BUOPEN CHNGIN COPYDS ERROR IPTERR LINES LRED LRIT PURGE PURGEB
PUTB PUTM REED RITE SEEK WIPOUT
CALLED FROM: FXOV45
OVERLAY LEVEL: 4, 5

SUBPROGRAM NAME: RFIXSR
OBJECTIVE: READS AND CHECKS RECORD 02 OF FIXSRC
CALLS TO : BUCLOS ERROR IPTERRIPT2 LINES LRED PURGE PURGEB PUTB WIPOUT
CALLED FROM: FXOV41
OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: RFXCTL

OBJECTIVE: READS AND CHECKS FILE FXCTRL

CALLS TO : BUCLOS ERROR IEQUAT IPTERR IPT2 LINES PURGE PUTM REED WIPOUT

CALLED FROM: FXOV41

OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: RFXHMO

OBJECTIVE: READS AND CHECKS FILE FXHMOG

CALLS TO : BUCLOS CHKHOM ERROR IPTERR IPT2 LINES LRED PURGE PURGEB PUTB PUTM
WIPOUT

CALLED FROM: FXOV41

OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: RFXH35

OBJECTIVE: READS DATA IN RECORDS 02-05 OF FXHMOG

CALLS TO : BUCLOS BUOPEN ERROR IPTERR LINES PURGE PURGEB PUTM REED WIPOUT

CALLED FROM: FXOV31

OVERLAY LEVEL: 3, 1

SUBPROGRAM NAME: RFXTH
 OBJECTIVE: READS BINARY INPUT FILE FXTH
 CALLS TO : BUCLOS ERROR FLTST2 IPTERR IPT2 LRED PURGE PURGEB PUTB WIPOUT
 CALLED FROM: FXOV41
 OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: RGEODS
 OBJECTIVE: READS IN FILE GEODST
 CALLS TO : BUCLOS ERROR FEQUT4 FORMSH IEQUT4 IPTERR IPT2 LINES LRED PURGE PURGEB
 PUTB PUTM WIPOUT
 CALLED FROM: FXOV41
 OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: RHOBEG
 OBJECTIVE: SETS UP REACTIVITY STEP. CALLS TIMSTP,
 EXTRAPOLATES FLUXES AND APPLIES DRIVING
 FUNCTIONS
 CALLS TO : BUCLOS BUOPEN DEXP DRIVEF ERROR EXTFLX IGET IPTERR LINES PURGE PURGEB
 PUTB PUTM REED RITE SEEK TIMSTP WIPOUT
 CALLED FROM: FXOV10 TIMDEP
 OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: RHOEND
OBJECTIVE: END OF REACTIVITY STEP. UPDATES PRECURSORS
AND PRINTS EDIT
CALLS TO : EDITS IGET PKSTOR PRECUP TIMSTP TIMSUM
CALLED FROM: FXOV10
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: RITE
OBJECTIVE: GENERAL PURPOSE FILE WRITE SUBROUTINE (FROM
SMALL CORE). MEETS CCCC SPECIFICATIONS
CALLS TO : BUCLOS BUOPEN ZERGIO
CALLED FROM: FXTHRM BESTRT RHOEG EWDELY RWISOT SRCCAL SRCMOD WATFLX WFXCTL WRTFLX
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: ROMBI
OBJECTIVE: INTEGRATES AMPLITUDE FUNCTION EXPRESSED
AS A QUADRATIC
CALLS TO : DEXP ERROR LINES
CALLED FROM: FXTHRM
OVERLAY LEVEL: 5, 0

SUBPROGRAM NAME: ROWSRC
OBJECTIVE: COMPUTES Y-DIRECTION LEAKAGE FOR ORTHOGONAL
GEOMETRY CASES
CALLS TO : NONE
CALLED FROM: INNDO INNDS
OVERLAY LEVEL: 9, 0

SUBPROGRAM NAME: BRTFLX
OBJECTIVE: READS AND CHECKS RECORD 02 OF FILE RTFLUX
CALLS TO : BUCLOS ERROR IPT2 LINES LRED PURGE PURGEB PUTB REED WIPOUT
CALLED FROM: FXOV41
OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: RWDELY
OBJECTIVE: CONVERTS A.DLA TO A.ISO
CALLS TO : LINES REED RITE RWDY1 RWDY2
CALLED FROM: BCDXST
OVERLAY LEVEL: 2, 7

SUBPROGRAM NAME: RWDY1

OBJECTIVE: EDITS PRECURSOR DECAY CONSTANTS, DELAYED CHI'S,
AND ENERGY BOUNDS

CALLS TO : NONE

CALLED FROM: RWDELY

OVERLAY LEVEL: 2, 7

SUBPROGRAM NAME: RWDY2

OBJECTIVE: EDITS DELAYED NU'S

CALLS TO : NONE

CALLED FROM: RWDELY

OVERLAY LEVEL: 2, 7

SUBPROGRAM NAME: RWISOT

OBJECTIVE: CONVERTS A.ISO TO ISOTXS

CALLS TO : ERROR LINES REED RITE SQUEZE

CALLED FROM: BCDXST

OVERLAY LEVEL: 2, 7

SUBPROGRAM NAME: RXSCON
OBJECTIVE: READS AND CHECKS THE FILE XSCON
CALLS TO : BUCLOS CHKXSC ERROR IEQUT4 IGET IPTERR IPT2 LINES LRED PURGE PURGEB
PUTB WIPOUT
CALLED FROM: FXOV41
OVERLAY LEVEL: 4, 1

SUBPROGRAM NAME: SCAN
OBJECTIVE: READS ENTIRE ECD INPUT, SPOOLS DATA ONTO FILE
ARC FOR PROCESSING BY SUBROUTINE STUFF
CALLS TO : CODE ERROR SEEK
CALLED FROM: MAIN
OVERLAY LEVEL: 10, 0

SUBPROGRAM NAME: SCTTER
OBJECTIVE: CALCULATES MACROSCOPIC SCATTERING CROSS SECTIONS
CALLS TO : BUCLOS BUCPEN FLTST2 LRIT
CALLED FROM: FXPTXS
OVERLAY LEVEL: 7, 0

SUBPROGRAM NAME: SDEQT

OBJECTIVE: STORES SINGLE PRECISION VECTOR INTO A DOUBLE
PRECISION VECTOR
(SMALL CORE TO SMALL CORE)

CALLS TO : NONE

CALLED FROM: NONE

OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: SDEQT4

OBJECTIVE: STORES SINGLE PRECISION VECTOR INTO A DOUBLE
PRECISION VECTOR
(LARGE CORE TO LARGE CORE)

CALLS TO : NONE

CALLED FROM: XDRDR3

OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: SDRGST

OBJECTIVE: STORES SINGLE PRECISION ARRAY INTO A COLUMN OF
A DOUBLE-SUBSCRIPTED, DOUBLE PRECISION ARRAY

CALLS TO : NONE

CALLED FROM: NONE

OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: SDSEQT
OBJECTIVE: STORES THE TRANSPOSE OF A SINGLE PRECISION
ARRAY INTO A DOUBLE PRECISION ARRAY
(SMALL CORE TO SMALL CORE)
CALLS TO : NONE
CALLED FROM: NONE
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: SDSEQ4
OBJECTIVE: STORES THE TRANSPOSE OF A SINGLE PRECISION
ARRAY INTO A DOUBLE PRECISION ARRAY
(LARGE CORE TO LARGE CORE)
CALLS TO : NONE
CALLED FROM: XDRDR3
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: SEEK
OBJECTIVE: RETURNS LUN VALUE OF FILE. ROUTINE FUNCTION
DESCRIBED IN LA-5486-MS
CALLS TO : NONE
CALLED FROM: BCDXST DRIVEF EXTFLX FXINIT FXINPD FXINPR FXINXS FXPIXS FXSHAP FXTHRM MAIN
PRECUP RATHRM RESTRT RHOBEG SCAN SSTATE START STUFF STUFF1
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: SFDCEL
OBJECTIVE: COMPUTES THE FINITE DIFFERENCE COEFFICIENTS
IN ORTHOGONAL GEOMETRY
CALLS TO : DCOS DSIN SGTBND
CALLED FROM: SFDGEN
OVERLAY LEVEL: 9, 2

SUBPROGRAM NAME: SFDGEN
OBJECTIVE: CONTROLS COMPUTATION OF FINITE DIFFERENCE
COEFFICIENTS
CALLS TO : AREAS BUCLOS. BUOPEN LRED LRIT SFDCEL TFDCEL
CALLED FROM: FXOV92
OVERLAY LEVEL: 9, 2

SUBPROGRAM NAME: SGTBND
OBJECTIVE: RETURNS BOUNDARY CONDITION CONSTANT FOR
EXTERNAL MESH CELL
CALLS TO : NONE
CALLED FROM: SFDCEL TFDCEL
OVERLAY LEVEL: 9, 2

SUBPROGRAM NAME: SHPEND
OBJECTIVE: COMPLETES GAMMA FACTOR ITERATION BY CALLING
PKUPDT AND CHECKING GAMMA CONVERGENCE
CALLS TO : EDITS ERROR IGET LINES PKUPDT TIMSUM
CALLED FROM: FXOV10 TIMDEP
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: SHPOUT
OBJECTIVE: NORMALIZES FLUXES AFTER SHAPE CALCULATION
CALLS TO : BUCLOS BUOPEN FLTST2 LRED LRIT TWDPR2 WATFLX WRIFLX
CALLED FROM: FXOV95
OVERLAY LEVEL: 9, 5

SUBPROGRAM NAME: SIMPL
OBJECTIVE: CALCULATES FUEL TEMPERATURES FOR SIMPLE
THERMAL-HYDRAULIC MODEL
CALLS TO : NONE
CALLED FROM: FXTHRM
OVERLAY LEVEL: 5, 0

SUBPROGRAM NAME: SINEQT

OBJECTIVE: STORES ONE SINGLE PRECISION VECTOR INTO ANOTHER
SINGLE PRECISION VECTOR
(SMALL CORE TO SMALL CORE)

CALLS TO : NONE

CALLED FROM: NONE

OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: SINEQ4

OBJECTIVE: STORES ONE SINGLE PRECISION VECTOR INTO ANOTHER
SINGLE PRECISION VECTOR
(LARGE CORE TO LARGE CORE)

CALLS TO : NONE

CALLED FROM: FXOV34 ISOR48 XDRDR3

OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: SINSET

OBJECTIVE: STORES SCALAR INTO A SINGLE PRECISION VECTOR
(IN SMALL CORE)

CALLS TO : NONE

CALLED FROM: NONE

OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: SINST2
OBJECTIVE: STORES SCALAR INTO A SINGLE PRECISION VECTOR
(IN LARGE CORE)
CALLS TO : NONE
CALLED FROM: ISOR48 XSCTSV
OVERLAY LEVEL: 3, 0

SUBPROGRAM NAME: SOLVP
OBJECTIVE: SOLVES ONE ROW OF FLUXES WITH PERIODIC
BOUNDARY CONDITIONS (THETA-R GEOMETRY)
CALLS TO : NONE
CALLED FROM: INNDO INNDS
OVERLAY LEVEL: 9, 0

SUBPROGRAM NAME: SPACE
OBJECTIVE: SPACES PAST UNNEEDED CARDS IN A BCD DATA SET
CALLS TO : LINES
CALLED FROM: ANIPHX ANIP03 ANIP04 RAFNIP RAFX2 RATHRM
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: SQUEZE
OBJECTIVE: LEFT JUSTIFIES AN ARRAY IN SMALL CORE
CALLS TO : NONE
CALLED FROM: AFX210 ANIPHX EAFNIP RWISOT SQUEZ2
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: SQUEZ2
OBJECTIVE: SQUEZE AN ARRAY IN LARGE CORE CONTAINER
CALLS TO : SQUEZE
CALLED FROM: ANIPHX ANIP06 ANIP08 ANIP12 ANIP13 ANIP14 ANIP19 ANIP34 ISOR48 XDRDR3
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: SRCCAL
OBJECTIVE: COMPUTES SOURCE FOR TIME-DEPENDENT SHAPE
CALCULATION
CALLS TO : BUCLOS BUOPEN FLTSET LREL REED RITE
CALLED FROM: FXOV91
OVERLAY LEVEL: 9, 1

SUBPROGRAM NAME: SRCMOD
OBJECTIVE: COMPUTES TIME-DEPENDENT SOURCE FOR SECOND AND
SUBSEQUENT GAMMA-FACTOR ITERATIONS
CALLS TO : BUCLOS BUOPEN LRED REED RITE
CALLED FROM: FXOV91
OVERLAY LEVEL: 9, 1

SUBPROGRAM NAME: SSEDIT
OBJECTIVE: EDIT STEADY-STATE CALCULATION
CALLS TO : EDTFTC IGET LINES PURGE PUTM TIMER TWDPR2 WIPOUT
CALLED FROM: SSTATE
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: SSTATE
OBJECTIVE: CONTROLS STEADY-STATE CALCULATION
CALLS TO : BUCLOS BUOPEN DSKEDT FLTST2 FXINPD FXPTXS FXSHAP FXTHRM IGET LRED LRIT
PURGE PURGEB PUTB PUTM REED SEEK SSEDIT TIMER TINSUM WIPOUT
CALLED FROM: MAIN
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: START

OBJECTIVE: INITIALIZES CERTAIN PARAMETERS AND REQUESTS
CORE STORAGE ALLOCATION

CALLS TO : BUCLOS BULK BUOPEN ERROR FEQUAT FLTSET IPTERR LINES POINTR REED SEEK
TIMER

CALLED FROM: MAIN

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: STATUS

OBJECTIVE: PRINTS CURRENT STATUS OF BPOINTER TABLES

CALLS TO : NONE

CALLED FROM: PURGE PURGEB

OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: STUFF

OBJECTIVE: PROCESSES BCD INPUT CARDS FOR EACH BLOCK

CALLS TO : BULK ERROR FREE POINTR PUTM SEEK STUFF1

CALLED FROM: MAIN

OVERLAY LEVEL: 11, 0

SUBPROGRAM NAME: STUFF1
OBJECTIVE: PROCESSES THE PARTICULAR DATA BLOCK
CALLS TO : CODE ERROR SEEK
CALLED FROM: STUFF
OVERLAY LEVEL: 11, 0

SUBPROGRAM NAME: SUMMARY
OBJECTIVE: READS THE SUMMARY BCD DATA SET AND WRITES IT
CALLS TO : BUCLOS BUOPEN LINES
CALLED FROM: MAIN
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: TFDCEL
OBJECTIVE: COMPUTES FINITE DIFFERENCE COEFFICIENTS FOR
TRIANGULAR GEOMETRY
CALLS TO : FLTST2 SGTBND
CALLED FROM: SFDGEN
OVERLAY LEVEL: 9, 2

SUBPROGRAM NAME: THCALC
OBJECTIVE: CONTROLS THERMAL-HYDRAULIC CALCULATION USING
DETAILED MODEL FOR ONE CHANNEL
CALLS TO : HCALC THFT
CALLED FROM: DETAL
OVERLAY LEVEL: 5, 0

SUBPROGRAM NAME: THFT
OBJECTIVE: CALCULATES FUEL TEMPERATURES FOR DETAILED MODEL
CALLS TO : NONE
CALLED FROM: THCALC
OVERLAY LEVEL: 5, 0

SUBPROGRAM NAME: THMRZ
OBJECTIVE: CONSTRUCTS THERMAL-HYDRAULICS MAP FROM DATA ON
TYPE 03 AND 04 CARDS OF A.THRM
CALLS TO : NONE
CALLED FROM: RATHRM
OVERLAY LEVEL: 2, 6

SUBPROGRAM NAME: THRM03
OBJECTIVE: READ TYPE 03 CARD OF A.THRM
CALLS TO : NONE
CALLED FROM: RATHRM
OVERLAY LEVEL: 2, 6

SUBPROGRAM NAME: THRM04
OBJECTIVE: READ TYPE 04 CARD OF A.THRM
CALLS TO : NONE
CALLED FROM: RATHRM
OVERLAY LEVEL: 2, 6

SUBPROGRAM NAME: THRM05
OBJECTIVE: READ TYPE 05 CARD OF A.THRM
CALLS TO : NONE
CALLED FROM: RATHRM
OVERLAY LEVEL: 2, 6

SUBPROGRAM NAME: THRM06
OBJECTIVE: READ TYPE 06 CARD OF A.THRM
CALLS TO : NONE
CALLED FROM: RATHRM
OVERLAY LEVEL: 2, 6

SUBPROGRAM NAME: TIMDEP
OBJECTIVE: CONTROLS TRANSIENT CALCULATION IN FX2-TH
CALLS TO : CALFSF DSKEDT ERROR FEQUAT PLTSET FXINIT FXINPD FXPTXS FXSHAP FXTHRM IGET
IPTERR LINES PKCALC PURGE PURGEB PUTB RHOEG SHPEND TIMER TIMSUM WIPOUT
CALLED FROM: MAIN
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: TIMER
OBJECTIVE: GENERAL PURPOSE TIMING ROUTINE. MEETS CCCC
SPECIFICATIONS
CALLS TO : SECOND
CALLED FROM: EDITS MAIN RAPX2 SSEDIT SSTATE START TIMDEP TIMSUM
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: TIMSTP
OBJECTIVE: SELECT TIME STEP SIZES
CALLS TO : DEXP DLOG LINES
CALLED FROM: RHOBEG RHOEND
OVERLAY LEVEL: 1, 0

SUBPROGRAM NAME: TIMSUM
OBJECTIVE: COMPUTES ELAPSED TIME BETWEEN CALLS TO IT
CALLS TO : TIMER
CALLED FROM: MAIN RHOEND SHPEND SSTATE TIMDEP
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: TLEKIP
OBJECTIVE: COMPUTES LEAKAGE PLUS REMOVAL INNER PRODUCT
FOR TRIANGULAR GEOMETRY
CALLS TO : GETBND
CALLED FROM: PASS2
OVERLAY LEVEL: 8, 0

SUBPROGRAM NAME: TOMEQN
OBJECTIVE: COMPUTES OVER-RELAXATION FACTORS FOR TRIANGULAR
GEOMETRY
CALLS TO : FEQUT4 FLTSET TRISRC
CALLED FROM: OMEGCA
OVERLAY LEVEL: 9, 3

SUBPROGRAM NAME: TRIGOM
OBJECTIVE: CONSTRUCTS GEOMETRY FOR TRIANGULAR GEOMETRY
CALLS TO : ERROR FLTSET INTST2 LINES LOCHX
CALLED FROM: FGEODS
OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: TRISRC
OBJECTIVE: COMPUTES THE Y-LEAKAGE FOR A ROW IN
TRIANGULAR GEOMETRY
CALLS TO : NONE
CALLED FROM: INNERT TOMEQN
OVERLAY LEVEL: 9, 0

SUBPROGRAM NAME: TWDP2
OBJECTIVE: PRINTS A TWO-DIMENSIONAL ARRAY FROM LARGE CORE
CALLS TO : LINES
CALLED FROM: EDITS SHPOUT SSEDIT
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: TWODPR
OBJECTIVE: PRINTS A TWO-DIMENSIONAL ARRAY FROM SMALL CORE
CALLS TO : LINES
CALLED FROM: EDTFTC
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: UPDFS
OBJECTIVE: COMPUTES PROMPT AND DELAYED FISSION SOURCE
FROM ONE GROUP
CALLS TO : NONE
CALLED FROM: GNDOTS
OVERLAY LEVEL: 9, 4

SUBPROGRAM NAME: VOLREG
OBJECTIVE: COMPUTES THE REGION VOLUMES
CALLS TO : NONE
CALLED FROM: FGEODS
OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: VOLUME
OBJECTIVE: COMPUTES THE VOLUME OF EACH MESH CELL
CALLS TO : NONE
CALLED FROM: FXINPD FXMOV92 FXPTXS FXTHRM
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: WATFLX
OBJECTIVE: WRITES RECORDS 01 AND 02 OF ATFLUX
CALLS TO : BUOPEN REED RITE
CALLED FROM: SHPOUT
OVERLAY LEVEL: 9, 5

SUBPROGRAM NAME: WFXCTL
OBJECTIVE: WRITES THE FILE FXCTRL
CALLS TO : BUCLOS BUOPEN REED RITE
CALLED FROM: RAFX2
OVERLAY LEVEL: 2, 1

SUBPROGRAM NAME: WFXHMO
OBJECTIVE: WRITES THE FILE FXHMOG
CALLS TO : BUCLOS BUOPEN FEQUT2 IEQUT2 LRED LRIT
CALLED FROM: FFXHMO
OVERLAY LEVEL: 2, 4

SUBPROGRAM NAME: WFXTH
OBJECTIVE: WRITES THE FILE FXTH
CALLS TO : BUCLOS BUOPEN LRED LRIT
CALLED FROM: RATHRM
OVERLAY LEVEL: 2, 6

SUBPROGRAM NAME: WGEODS
OBJECTIVE: WRITES THE FILE GEODST
CALLS TO : BUCLOS BUOPEN FEQUT2 INTST2 LRED LRIT
CALLED FROM: FGEODS
OVERLAY LEVEL: 2, 3

SUBPROGRAM NAME: WIPOUT
OBJECTIVE: RELEASES A BLOCK OF STORAGE
CALLS TO : ECZERO GETN IPT2
CALLED FROM: BCDXST DETAL DSKEDT EDITS FFIXSR PFXHMO FGEODS FXINPD FXINPR FXOV31 FXOV32
FXOV33 FXOV34 FXOV41 FXOV42 FXOV43 FXOV91 FXPTXS FXSHAP FXTHRM LCCLOS PKCALC
PKUPDT PPECUP RAFNIP RAFX2 RAIFLX RATHRM RESORT RFIXSR RFXCTL RFXHMO RFXH35
RFXTH RGEODS RHOBEG RRTFLX RXSCON SSEDIT SSTATE TIMDEP XDRDR3
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: WRITEC
OBJECTIVE: TRANSFER FROM SMALL CORE TO LARGE CORE
CALLS TO : NONE
CALLED FROM: CRED CEIT
OVERLAY LEVEL: 0, 0

SUBPROGRAM NAME: WRTFLX
OBJECTIVE: WRITES RECORDS 01 AND 02 OF FILE RTFLUX
CALLS TO : BUOPEN REED RITE
CALLED FROM: SHPOUT
OVERLAY LEVEL: 9, 5

SUBPROGRAM NAME: XDENCK
OBJECTIVE: CHECKS ENERGY GROUP CUT POINTS
CALLS TO : ERROR LINES
CALLED FROM: XDRDR3
OVERLAY LEVEL: 3, 1

SUBPROGRAM NAME: XDRDR2
OBJECTIVE: READS RECORD 02 OF ISOTXS AND DLAYXS
CALLS TO : BUOPEN ERROR LINES LRED
CALLED FROM: FXOV31
OVERLAY LEVEL: 3, 1

SUBPROGRAM NAME: XDRDR3

OBJECTIVE: READS RECORD 03 OF ISOTXS AND DLAYXS

CALLS TO : ERROR FEQUT4 IEQUT4 IGET IPTERR IPT2 IPT3 LINES LRED PRNTEL PRNT1A
PRNT1E PURGE PURGEB PUTB SDEQT4 SDSEQ4 SINEQ4 SQJEZ2 WIPOUT XDENCK

CALLED FROM: FXOV31

OVERLAY LEVEL: 3, 1

SUBPROGRAM NAME: XSCTL

OBJECTIVE: COMPACTS THE SCATTERING CROSS SECTION ARRAY

CALLS TO : XSCTL1

CALLED FROM: FXOV34

OVERLAY LEVEL: 3, 4

SUBPROGRAM NAME: XSCTL1

OBJECTIVE: COMPACTS THE SCATTERING CROSS SECTION ARRAY

CALLS TO : NONE

CALLED FROM: XSCTL

OVERLAY LEVEL: 3, 4

SUBPROGRAM NAME: XSCTSV
OBJECTIVE: PLACE SCATTERING CROSS SECTIONS INTO APPROPRIATE
FUEL SCATTERING MATRIX
CALLS TO : ERROR FARSET LINES SINST2
CALLED FROM: ISOR48
OVERLAY LEVEL: 3, 2

SUBPROGRAM NAME: XSFIPR
OBJECTIVE: COMPUTES PNU, CHIP, AND DNU ARRAYS
CALLS TO : ERROR LINES
CALLED FROM: FXOV33
OVERLAY LEVEL: 3, 3

SUBPROGRAM NAME: XSFIX
OBJECTIVE: CALCULATES MACROSCOPIC REMOVAL AND TRANSPORT
CROSS SECTIONS
CALLS TO : BUCLOS BUOPEN FLTST2 LRIT
CALLED FROM: FXPTXS
OVERLAY LEVEL: 7, 0

SUBPRCGRAM NAME: XSORDR
OBJECTIVE: REORDERS MACROSCOPIC CROSS SECTION ARRAY
CALLS TO : DCRNCH
CALLED FROM: FXOV33
OVERLAY LEVEL: 3, 3

SUBPRCGRAM NAME: XSUPDT
OBJECTIVE: UPDATES MACROSCOPIC CROSS SECTIONS
CALLS TO : ERROR LINES
CALLED FROM: ISOR48
OVERLAY LEVEL: 3, 2

SUBPRCGRAM NAME: ZEROIO
OBJECTIVE: INITIALIZES I/O FLAGS
CALLS TO : NONE
CALLED FROM: LRED LRIT REED RITE
OVERLAY LEVEL: 0, 0

APPENDIX B

Listing of BCD Input Files

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CODE-DEPENDENT BINARY INTERFACE FILES ARE DESCRIBED. THE
 CCCC BINARY INTERFACE FILES ARE THOROUGHLY DESCRIBED IN THE
 PUBLICATION LA-5486-MS. IF XSCON IS NOT PRESENT AS AN OLD FILE,
 THE MICROSCOPIC CROSS SECTIONS AND DELAYED NEUTRON DATA MUST BE
 INPUT. THIS MAY BE DONE BY INPUTTING THE BCD FILES A.ISO AND
 A.DLA, OR THEIR CORRESPONDING BINARY VERSIONS ISOTXS AND DLAYXS.
 IF A.ISO AND A.DLA ARE ENTERED, THEY ARE CONVERTED TO ISOTXS AND
 DLAYXS FORMAT. GEODST MAY BE USED TO INPUT GEOMETRY DATA. IF IT IS
 PRESENT AS AN OLD FILE, A GEODST FILE WILL NOT BE WRITTEN
 BY THE BCD INPUT PROCESSOR, EVEN IF A.FNIP IS PRESENT.
 INITIAL FLUX GUESSES ARE PROVIDED BY RTFLUX AND ATFLUX. IF
 THEY ARE NOT PRESENT AS OLD FILES, FLAT FLUX GUESSES ARE
 WRITTEN BY THE BCD INPUT PROCESSOR. THE CONVERGED STEADY
 STATE FLUXES ARE WRITTEN BACK ON THEM. IF THE STEADY STATE
 CALCULATION IS TO BE SKIPPED, RTFLUX AND ATFLUX MUST PROVIDE
 THE CONVERGED STEADY STATE FLUXES FOR THE PROBLEM TO BE SOLVED.
 IF THERMAL FEEDBACK IS BEING USED, STEADY STATE FUEL AND
 COOLANT TEMPERATURES AND INITIAL POWERS MUST BE PROVIDED
 AS INPUT. THIS IS DONE BY INPUTTING THE FILE THDATA
 ON A CARD DATASET=THDATA. FIXSRC IS USED TO PROVIDE AN
 INHOMOGENEOUS VOLUMETRIC FIXED SOURCE IF ONE IS PRESENT.

A.FX2
 MODULE-DEPENDENT BCD INPUT FOR FX2, TWO-DIMENSIONAL
 SPACE-DEPENDENT REACTOR KINETICS CODE WITH FEEDBACK

THIS IS A USER-SUPPLIED BCD DATA SET.
 THE LIST FOR EACH RECORD IS GIVEN IN TERMS OF
 THE BCD FORMAT OF THE DATA CARD.
 COLUMNS 1-2 NORMALLY CONTAIN THE CARD TYPE
 NUMBER.

ONLY CARD TYPE 01 IS REQUIRED. IF ANY OTHER
 CARD TYPE IS MISSING, DEFAULT VALUES WILL BE
 USED FOR THE VARIABLES NORMALLY READ FROM IT.
 A BLANK FIELD ON A CARD ALSO PRODUCES A
 DEFAULT VALUE.

FX2 REQUIRES THAT A.FX2 BE PRESENT UNLESS THE
 BINARY FILE, FXCTRL, IS AVAILABLE AND HAS BEEN
 INCLUDED IN THE BLOCK=OLD.

 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
C-----

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C-----
CR          BPOINTER DYNAMIC STORAGE SPECIFICATIONS (TYPE 02)
C
CL   FORMAT----- (I2,10X,3I6)
C
CD   COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD   =====
CD   1-2                02
CD
CD   13-18              SIZE OF FAST CORE STORAGE ARRAY IN REAL*8 WORDS
CD                      (SINGLE WORDS ON CDC SYSTEMS) (DEFAULT VALUES ARE
CD                      10000 ON IBM AND 20000 ON CDC).
CD
CD   19-24              SIZE OF BULK CORE STORAGE ARRAY IN REAL*8 WORDS.
CD                      (SINGLE LCM WORDS ON CDC SYSTEMS) (DEFAULT VALUES
CD                      ARE 30000 ON IBM AND 80000 ON CDC).
CD
CD   25-30              BPOINTER DEBUGGING EDIT.
CD                      0...NO DEBUGGING EDIT (DEFAULT).
CD                      1...DEBUGGING DUMP PRINTOUT.
CD                      2...DEBUGGING TRACE PRINTOUT.
CD                      3...FULL DEBUGGING PRINTOUT.
C
C-----

```

```

C-----
CR          PROBLEM OPTIONS (TYPE 03)
C
CL   FORMAT----- (I2,10X,8I6)
C
CD   COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD   =====
CD   1-2                03
CD
CD   13-18              RESTART PROBLEM INDICATOR.
CD                      0...NOT A RESTART PROBLEM (DEFAULT).
CD                      1...IS A RESTART PROBLEM.
CD
CD   19-24              KINETICS OPTIONS.
C

```


CD		0...SPACE-TIME KINETICS (DEFAULT).	-
CD		1...POINT KINETICS WITH LINEARIZED DIFFUSION.	-
CD		2...POINT KINETICS WITH NONLINEAR DIFFUSION.	-
CD		3...POINT KINETICS WITH PERTURBED SHAPE AND	-
CD		NONLINEAR DIFFUSION.	-
CD			-
CD	25-30	THERMAL FEEDBACK OPTION	-
CD		0...DO NOT DO THERMAL-HYDRAULIC CALCULATION OF	-
CD		TEMPERATURES (DEFAULT)	-
CD		1...DO THERMAL-HYDRAULIC CALCULATION OF TEMPERATURES	-
CD			-
CD	31-36	TEMPERATURE FEEDBACK OPTION.	-
CD		0...DO NOT TEMPERATURE-CORRECT CROSS SECTIONS	-
CD		(DEFAULT).	-
CD		1...TEMPERATURE-CORRECT CROSS SECTIONS.	-
CD			-
CD	37-42	COMPOSITION OPTION.	-
CD		0...EACH MESH CELL IS A COMPOSITION (DEFAULT).	-
CD		1...EACH REGION IS A COMPOSITION	-
CD			-
CD	43-48	TEMPERATURE FEEDBACK ITERATION OPTION.	-
CD		0...DO NOT ITERATE BETWEEN NEUTRONICS AND THERMAL-	-
CD		HYDRAULICS AT STEADY STATE.	-
CD		1...ITERATE NEUTRONICS AND THERMAL-HYDRAULICS TO	-
CD		CONVERGENCE IN STEADY STATE	-
CD			-
CD	49-54	PROBLEM TYPE.	-
CD		0...HOMOGENEOUS PROBLEM (DEFAULT).	-
CD		1...INHOMOGENEOUS VOLUMETRIC FIXED SOURCE PRESENT.	-
CD			-
CD	55-60	STEADY STATE OPTION.	-
CD		0...DO STEADY STATE REAL AND ADJOINT FLUX CALCULATION	-
CD		(DEFAULT).	-
CD		1...BYPASS STEADY STATE REAL AND ADJOINT FLUX	-
CD		CALCULATION.	-

C

C-----

C	-----		
CR	ITERATION LIMITS (TYPE 04)		-
C			-
CL	FORMAT----- (I2,10X,8I6)		-
C			-
CD	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY	-
CD	=====	=====	-
CD	1-2	04	-
CD			-
CD	13-18	MAXIMUM NUMBER OF NEUTRONICS/FEEDBACK ITERATIONS	-
CD		ALLOWED AT STEADY STATE (DEFAULT=10)	-

CD		
CD	19-24	UNUSED AT PRESENT
CD		
CD	25-30	UNUSED AT PRESENT
CD		
CD	31-36	MAXIMUM NUMBER OF SHAPE STEP ITERATIONS ALLOWED
CD		AT ANY SHAPE STEP (DEFAULT=3).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	37-42	UNUSED AT PRESENT
CD		
CD	43-48	MAXIMUM NUMBER OF OUTER (FISSION SOURCE) ITERATIONS
CD		ALLOWED DURING ANY FLUX SHAPE CALCULATION (DEFAULT=25).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	49-54	MAXIMUM NUMBER OF REACTIVITY STEPS ALLOWED IN ANY
CD		SHAPE STEP (DEFAULT=20).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	55-60	LENGTH OF INITIAL TIME STEP IN GENERATION TIMES
CD		(DEFAULT=1000).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
C		
C		

C		
CR	EDIT OPTIONS (TYPE 05)	
C		
CL	FORMAT----- (I2,10X,10I6)	
C		
CD	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY
CD	=====	=====
CD	1-2	05
CD		
CD	13-16	INPUT BINARY FILE EDIT.
CD		0...NO EDIT OF INPUT BINARY FILES (DEFAULT).
CD		1...EDIT INPUT BINARY FILES EXCEPT FOR MACROSCOPIC
CD		CROSS SECTIONS AND REGION MAP.
CD		2...EDIT ALL INPUT BINARY FILES.
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	19-24	MICROSCOPIC CROSS SECTION EDIT.
CD		0...PARTIAL EDIT OF MICROSCOPIC CROSS SECTION
CD		HOMOGENIZATION (DEFAULT).
CD		1...ALSO EDIT INPUT MICROSCOPIC CROSS SECTIONS DURING
CD		MICROSCOPIC CROSS SECTION HOMOGENIZATION.
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	25-30	THERMAL HYDRAULICS INPUT EDIT FLAG

CD		0...DO NOT EDIT THERMAL HYDRAULICS (DEFAULT).	-
CD		1...PARTIAL EDIT OF THERMAL HYDRAULICS INPUT	-
CD		2...FULL EDIT OF THERMAL HYDRAULICS INPUT	-
CD		THIS DATUM CAN BE CHANGED FOR A FESTART PROBLEM	-
CD			-
CD	31-36	UNUSED AT PRESENT	-
CD			-
CD	37-42	DISK EDIT FLAG	-
CD		0...NO DISK EDIT	-
CD		1...BRIFF DISK EDIT	-
CD		2...DETAILED DISK EDIT	-
CD		(POINTWISE POWERS, COOLANT AND FUEL TEMPERATURES)	-
CD		3...EXTENDED DETAILED DISK EDIT	-
CD		(ALL EDITS ABOVE PLUS POINTWISE FLUXES)	-
CD			-
CD	43-48	FUEL AND COOLANT TEMPERATURE EDIT FLAG	-
CD		0...DO NOT EDIT FUEL AND COOLANT TEMPERATURES	-
CD		1...EDIT FUEL AND COOLANT TEMPERATURES AFTER	-
CD		EACH SHAPE STEP	-
CD			-
CD	49-54	REACTIVITY STEP SUMMARY EDIT.	-
CD		0...BRIEF EDIT (DEFAULT).	-
CD		1...NORMAL EDIT.	-
CD		2...DETAILED EDIT.	-
CD		THIS DATUM CAN BE CHANGED FOR A FESTART PROBLEM	-
CD			-
CD	55-60	POWER DENSITY EDIT (REACTIVITY STEP)	-
CD		0...DO NOT EDIT POWER DENSITY AFTER	-
CD		REACTIVITY STEPS (DEFAULT).	-
CD		N...EDIT POWER DENSITY AFTER EVERY	-
CD		N REACTIVITY STEPS.	-
CD		THIS DATUM CAN BE CHANGED FOR A FESTART PROBLEM	-
CD			-
CD	61-66	FLUX SHAPE CALCULATION EDIT.	-
CD		0...MINIMUM EDIT OF EACH FLUX SHAPE CALCULATION	-
CD		(DEFAULT).	-
CD		1...EDIT ITERATION HISTORY AT EACH FLUX SHAPE	-
CD		CALCULATION.	-
CD		2...EDIT ITERATION HISTORY AND MULTIGROUP FLUX SHAPE	-
CD		AT EACH FLUX SHAPE CALCULATION.	-
CD			-
CD	67-72	POWER DENSITY EDIT (SHAPE STEPS)	-
CD		0...DO NOT EDIT POWER DENSITIES AFTER	-
CD		SHAPE STEPS (DEFAULT).	-
CD		N...EDIT POWER DENSITIES AFTER	-
CD		EVERY N SHAPE STEPS.	-
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM	-
C			-
C			-

```

C-----
CR          PROBLEM LIMITS (TYPE 06)
C
CL  FORMAT----- (I2,10X,5E12.5)
C
CD  COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD  =====
CD  1-2              06
CD
CD  13-24            END OF PROBLEM TIME (SEC) (DEFAULT=20.0).
CD                    THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD
CD  25-36            MINIMUM ALLOWED VALUE OF AMPLITUDE, N(T)
CD                    (DEFAULT=0.05).
CD                    THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD
CD  37-48            MINIMUM ALLOWED VALUE OF REACTIVITY (DEFAULT=-0.01).
CD                    THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD
CD  49-60            UNUSED AT PRESENT
CD
CD  61-72            MAXIMUM ALLOWED VALUE OF AMPLITUDE, N(T)
CD                    (DEFAULT=1.0E+30).
CD                    THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
C-----

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C-----
CR          TIME-DEPENDENT CONVERGENCE CRITERIA (TYPE 07)
C
CL  FORMAT----- (I2,10X,5E12.5)
C
CD  COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD  =====
CD  1-2              07
CD
CD  13-24            UNUSED AT PRESENT
CD
CD  25-36            CONVERGENCE CRITERION FOR GAMMA FACTOR ITERATION AT
CD                    EACH SHAPE STEP (DEFAULT=0.001).
CD                    THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD
CD  37-48            CONVERGENCE CRITERION FOR AMPLITUDE FUNCTION EQUATION
CD                    SOLUTION (DEFAULT=1.0E-6).
CD                    THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD
CD  49-60            UNUSED AT PRESENT
CD

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CD 61-72 FACTOR BY WHICH TIME STEP SELECTOR TESTS ARE TIGHTENED -
 CD AT OR NEAR PROMPT CRITICAL (DEFAULT=0.5). -
 C -
 C -----

C -----
 CR STEADY STATE CONVERGENCE CRITERIA (TYPE 07) -
 C -
 CL FORMAT----- (I2,10X,5E12.5) -
 C -
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY -
 CD ===== -
 CD 1-2 07 -
 CD -
 CD 13-24 EIGENVALUE CONVERGENCE CRITERION FOR STEADY STATE -
 CD CALCULATION (DEFAULT=1.0E-7). -
 CD -
 CD 25-36 POINTWISE FISSION SOURCE CONVERGENCE CRITERION FOR -
 CD STEADY STATE SHAPE CALCULATION (DEFAULT=1.0E-6). -
 CD -
 CD 37-48 AVERAGE FISSION SOURCE CONVERGENCE CRITERION FOR -
 CD STEADY STATE SHAPE CALCULATION (DEFAULT=1.0E-7). -
 CD -
 CD 49-60 FACTORS BY WHICH POINTWISE AND AVERAGE FISSION SOURCE -
 CD CONVERGENCE CRITERIA WILL BE INCREASED FOR TIME- -
 CD DEPENDENT CALCULATION (DEFAULT=100.0). -
 CD -
 CD 61-72 POINTWISE POWER DENSITY CONVERGENCE CRITERION -
 CD FOR STEADY STATE NEUTRONICS/FEEDBACK ITERATION -
 CD (DEFAULT=.001) -
 C -
 CN THIS SECOND CARD TYPE 07 MUST ALWAYS FOLLOW THE FIRST -
 CN CARD TYPE 07. -
 C -
 C -----

C -----
 CR TIME STEP SELECTION CRITERIA (TYPE 08) -
 C -
 CL FORMAT----- (I2,10X,5E12.5) -
 C -
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY -
 CD ===== -
 CD 1-2 08 -
 CD -
 CD 13-24 MAXIMUM ALLOWABLE FUEL TEMPERATURE CHANGE (DEG. K) -
 CD OVER A SHAPE STEP (DEFAULT=120.0). -
 CD THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM -
 C -

CD		
CD	25-36	MAXIMUM ALLOWABLE FUEL TEMPERATURE CHANGE (DEG. K)
CD		OVER A REACTIVITY STEP (DEFAULT=30.0).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	37-48	MAXIMUM ALLOWABLE SHAPE STEP LENGTH (SEC)
CD		(DEFAULT=0.2).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	49-60	MAXIMUM ALLOWABLE REACTIVITY STEP LENGTH (SEC)
CD		(DEFAULT=0.05).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	61-72	MINIMUM NUMBER OF SHAPE STEPS ALLOWED PER DECADE OF
CD		AMPLITUDE FUNCTION CHANGE (DEFAULT=0.5).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
C		
C		

C		
CR		TIME STEP SELECTION AND RESTART DUMP CRITERIA (TYPE 08)
C		
CL	FORMAT-----	(I2, 10X, 4E12.5)
C		
CD	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY
CD	=====	=====
CD	1-2	08
CD		
CD	13-24	MINIMUM NUMBER OF REACTIVITY STEPS ALLOWED PER DECADE
CD		OF AMPLITUDE FUNCTION CHANGE (DEFAULT=2.0).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	25-36	MAXIMUM ALLOWABLE CHANGE IN GROUP- AND POINT-
CD		DEPENDENT LINEARLY-EXTRAPOLATED SHAPE FUNCTION DURING
CD		A SHAPE STEP (DEFAULT=0.10).
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	37-48	TOTAL COMPUTING TIME (MIN.) WHICH WILL BE ALLOWED TO
CD		ELAPSE BETWEEN RESTART DUMPS.
CD		(DEFAULT=TIME SPECIFIED FOR ESTIMATED RUNNING OF JOB)
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
CD		
CD	49-60	TOTAL PROBLEM TIME (SEC) WHICH WILL BE ALLOWED TO
CD		ELAPSE BETWEEN RESTART DUMPS
CD		(DEFAULT=END OF PROBLEM TIME(SEC).) SEE TYPE 06 CARD
CD		OF DATASET A.FX2
CD		THIS DATUM CAN BE CHANGED FOR A RESTART PROBLEM
C		
CN		THIS SECOND TYPE 08 CARD MUST ALWAYS FOLLOW THE FIRST

CN TYPE 08 CARD.

C

C-----

C-----

CR ADDITIONAL FLOATING POINT PARAMETERS (TYPE 09)

C

CL FORMAT----- (I2,10X,5E12.5)

C

CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY

CD =====

CD 1-2 09

CD

CD 13-24 INITIAL POWER (WATTS) (DEFAULT=1.0).

CD

CD 25-36 K-EFFECTIVE FOR REACTOR FOR USE IN A PROBLEM WITH A
 CD FIXED INHOMOGENEOUS SOURCE AND IN ANY PROBLEM IN
 CD WHICH THE REAL AND ADJOINT STEADY STATE CALCULATION
 CD IS BYPASSED (DEFAULT=1.0).

CD

CD 37-48 K-EFFECTIVE FOR THE SOURCE-FREE ADJOINT CALCULATION
 CD OF A REACTOR IN WHICH A FIXED INHOMOGENEOUS SOURCE IS
 CD PRESENT, NEEDED ONLY IF THE REAL AND ADJOINT STEADY
 CD STATE CALCULATION IS BYPASSED (DEFAULT=1.0). MUST USE
 CD 1.0 UNLESS INHOMOGENEOUS SOURCE IS PRESENT.

CD

CD 49-60 ANY POINTWISE FISSION SOURCE WILL BE NEGLECTED IN THE
 CD POINTWISE FISSION SOURCE CONVERGENCE TEST IF IT IS
 CD LESS THAN THIS FACTOR TIMES THE AVERAGE FISSION SOURCE
 CD (DEFAULT=0.01).

CD

CD 61-72 ERROR REDUCTION FACTOR TO BE ACHIEVED BY EACH SERIES
 CD OF INNER ITERATIONS FOR EACH GROUP DURING A SHAPE
 CD CALCULATION - STRONGLY RECOMMENDED THAT THE DEFAULT
 CD VALUE OF 0.03 BE USED.

C

C-----

C-----

CR ADDITIONAL FLOATING POINT PARAMETERS (TYPE 09)

C

CL FORMAT----- (I2,10X,2E12.5)

C

CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY

CD =====

CD 1-2 09

CD

CD 13-24 INITIAL ESTIMATE OF SPECTRAL RADIUS FOR OUTER

CD ITERATION OF TIME-DEPENDENT SHAPE CALCULATION -
 CD STRONGLY RECOMMENDED THAT DEFAULT VALUE OF 0.0
 CD BE USED.
 C
 CN THIS SECOND TYPE 09 CARD MUST ALWAYS FOLLOW THE FIRST
 CN TYPE 09 CARD.
 C
 C-----

C-----
 CR TIME-DEPENDENT DRIVING FUNCTION (TYPE 10)
 C
 CL FORMAT----- (I2,10X,2A6,4E12.5)
 C
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
 CD =====
 CD 1-2 10
 CD
 CD 13-18 REGION LABEL OF REGION TO WHICH THIS DRIVING FUNCTION
 CD IS TO BE APPLIED.
 CD
 CD 19-24 UNIQUE MATERIAL LABEL TO WHICH THIS DRIVING FUNCTION
 CD IS TO BE APPLIED.
 C
 CD 25-36 PROBLEM TIME (SEC) AT WHICH THIS DRIVING FUNCTION
 CD BEGINS TO APPLY (TSTART).
 CD
 CD 37-48 PROBLEM TIME (SEC) AT WHICH THIS DRIVING FUNCTION
 CD CEASES TO APPLY (TSTOP).
 CD
 CD 49-60 LINEAR COEFFICIENT FOR THIS DRIVING FUNCTION (CL)
 CD (OR STEP CHANGE IF TSTART=TSTOP).
 CD
 CD 61-72 QUADRATIC COEFFICIENT FOR THIS DRIVING FUNCTION (CQ)
 CD (NOT USED IF TSTART=TSTOP).
 C
 CN ONE TYPE 10 CARD IS REQUIRED FOR EACH DRIVING FUNCTION.
 CN THESE DRIVING FUNCTIONS ARE APPLIED IN THE FOLLOWING
 CN MANNER:
 CN
 CN LET $VF(R,M,TSTART)$ BE THE VOLUME FRACTION OF MATERIAL
 CN M IN REGION R AT TIME TSTART. THEN, IF THE ABOVE
 CN DRIVING FUNCTION APPLIES TO MATERIAL M AND REGION R,
 CN
 CN $VF(R,M,T) = VF(R,M,TSTART) + CL * (T - TSTART)$
 CN $+ CQ * (T - TSTART) ** 2$, TSTART.LE.T.LE.TSTOP
 CN
 CN IF, HOWEVER, TSTOP=TSTART, THEN A SHAPE STEP IS FORCED
 CN TO END AT T=TSTART, AND, AT THE START OF THE NEXT

CN REACTIVITY STEP, $VF(R,M,T)$ IS MODIFIED IN A STEP
 CN FASHION AS FOLLOWS:
 CN
 CN $VF(R,M,T) = VF(R,M,TSTART) + CL \cdot (T - GE.TSTART)$
 CN
 CN THIS SECOND OPTION IS INTENDED TO BE USED PRIMARILY
 CN TO FORCE A SHAPE STEP TO BE DONE AT A SPECIFIED TIME
 CN (CL=0.0).

C-----
 C-----
 CR TIME-DEPENDENT FIXED SOURCE (TYPE 11)
 C
 CL FORMAT----- (I2,10X,2E12.5)
 C
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
 CD =====
 CD 1-2 11
 CD
 CD 13-24 TIME DURING TRANSIENT AT WHICH FIXED SOURCE WILL BE
 CD MODIFIED (SEC.)
 CD
 CD 25-36 FACTOR BY WHICH FIXED SOURCE VALUES (FOR EACH MESH
 CD POINT AND ENERGY GROUP) WILL BE MULTIPLIED.
 C
 CN IF NO FIXED SOURCE IS PRESENT, THIS CARD SHOULD NOT
 CN BE ENTERED. IF FIXED SOURCE IS PRESENT AND THIS CARD
 CN IS NOT ENTERED, THE FIXED SOURCE IS ASSUMED TO BE
 CN INDEPENDENT OF TIME
 C-----
 C-----

CEOF

C*****

C
 C PREPARED 9/15/75 AT ANL
 C
 CF A.FNIP
 CE MODULE-DEPENDENT BCD INPUT FOR FX2, TWO-DIMENSIONAL
 CE SPACE-DEPENDENT REACTOR KINETICS CODE WITH FEEDBACK
 C
 CN THIS IS A USER-SUPPLIED BCD DATA SET.
 CN THE LIST FOR EACH RECORD IS GIVEN IN TERMS OF
 CN THE BCD FORMAT OF THE DATA CARD.
 CN COLUMNS 1-2 NORMALLY CONTAIN THE CARD TYPE
 CN NUMBER.
 CN
 CN IF ANY OF THE BINARY FILES GEODST, FXHMOG,
 CN XSCON, OR FIXSRC IS NOT AVAILABLE AS AN OLD
 CN FILE, ALL CARD TYPES OF A.FNIP WHICH ARE

CN REQUIRED TO DESCRIBE THE PROBLEM ARE REQUIRED -
 CN TO BE PRESENT. THE ONE EXCEPTION IS THAT IF -
 CN THE MACROSCOPIC CROSS SECTION FILE, XSCON, IS -
 CN PRESENT AS OLD FILE, CARD TYPE 13 MAY BE -
 CN OMITTED FROM A.FNIP IF IT IS NEEDED TO CON- -
 CN STRUCT GEODST, FXHMOG, AND/OR FIXSRC. -
 C -
 C*****

C-----
 CR BASIC PROBLEM IDENTIFICATION (TYPE 03) -
 C -
 CL FORMAT----- (I2,10X,I6) -
 C -
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY. -
 CD ===== -
 CD 1-2 03 -
 CD -
 CD 13-18 GEOMETRY TYPE. -
 CD 10...SLAB. -
 CD 20...CYLINDER. -
 CD 40...X-Y. -
 CD 50...R-Z. -
 CD 60...THETA-R -
 CD 70...TRIANGULAR, RHOMBIC BOUNDARY, CORE CENTER AT -
 CD 60 DEGREE ANGLE (SIXTH CORE SYMMETRY). -
 CD 72...TRIANGULAR, RECTANGULAR BOUNDARY, HALF CORE -
 CD SYMMETRY. -
 CD 74...TRIANGULAR, RHOMBIC BOUNDARY, CORE CENTER AT -
 CD 120 DEGREE ANGLE (THIRD CORE SYMMETRY). -
 CD 78...TRIANGULAR, RECTANGULAR BOUNDARY, QUARTER -
 CD CORE SYMMETRY. -
 CD 80...TRIANGULAR, RECTANGULAR BOUNDARY, FULL CORE. -
 C -
 C-----

C-----
 CR EXTERNAL BOUNDARY CONDITIONS (TYPE 04) -
 C -
 CL FORMAT----- (I2,10X,4I6) -
 C -
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY -
 CD ===== -
 CD 1-2 04 -
 CD -
 CD 13-18 BOUNDARY CONDITION AT LOWER "X" BOUNDARY OF REACTOR. -
 CD -
 CD 19-24 BOUNDARY CONDITION AT UPPER "X" BOUNDARY OF REACTOR. -
 C -
 C-----

CD
 CD 25-30 BOUNDARY CONDITION AT LOWER "Y" BOUNDARY OF REACTOR. -
 CD
 CD 31-36 BOUNDARY CONDITION AT UPPER "Y" BOUNDARY OF REACTOR. -
 CD
 CD 2...PHI=0. -
 CD 3...PHI PRIME=0. -
 CD 4...PHI PRIME + A/D * PHI=0. -
 CD 7...REPEATING (PERIODIC) WITH NEXT ADJACENT FACE. -
 CD 8...INVERTED REPEATING ALONG THIS FACE -
 CD (180 DEGREE ROTATION). -
 C -
 CN PHI PRIME IS THE DERIVATIVE OF THE FLUX IN THE -
 CN DIRECTION OF THE REACTOR OUTWARD NORMAL. D IS THE -
 CN DIFFUSION COEFFICIENT IN THE MESH INTERVAL -
 CN IMMEDIATELY INSIDE THE REACTOR BOUNDARY. -
 CN
 CN NOTE FOR REPEATING CONDITIONS (7 AND 8) - LET XL DENOTE -
 CN LOWER "X"-BOUNDARY, XU DENOTE UPPER "X"-BOUNDARY, -
 CN YL DENOTE LOWER "Y"-BOUNDARY, AND YU DENOTE UPPER -
 CN "Y"-BOUNDARY. THEN THESE REPEATING CONDITIONS ONLY -
 CN APPLY TO BOUNDARIES XL, XU, YL, AND YU. GOING IN THE -
 CN ORDER OF XL, YL, XU, YU, THE FIRST BOUNDARY WHICH IS -
 CN INVOLVED CARRIES THE DESIGNATOR DEFINING THE REPEATING -
 CN CONDITION. THE BOUNDARY CONDITION SPECIFIED FOR THE -
 CN SECOND BOUNDARY INVOLVED WILL BE IGNORED. -
 CN
 CN FOR TRIANGULAR GEOMETRIES USING 60 OR 120 DEGREE -
 CN OPTIONS, THE REPEATING PERIODIC -
 CN BOUNDARY CONDITION (7) IS PERMITTED ON THE LEFT AND -
 CN BOTTOM BOUNDARIES. IN THE 180 DEGREE GEOMETRY, THE -
 CN INVERTED REPEATING BOUNDARY CONDITION IS PERMITTED -
 CN ON THE BOTTOM BOUNDARY. -
 CN
 CN FOR THETA-R GEOMETRY, IN THE THETA DIRECTION, OPTIONS -
 CN 2, 3, 4, OR 7 ARE ALLOWED. THE PERIODIC BOUNDARY -
 CN CONDITION IS SPECIFIED BY 7. AT BOUNDARY YU, -
 CN OPTIONS 2, 3, OR 4 ARE ALLOWED. -
 CN
 CN "X" REPRESENTS THE FIRST DIMENSION COORDINATE (X IN -
 CN X-Y GEOMETRY, R IN R-Z, ETC.). "Y" REPRESENTS THE -
 CN SECOND DIMENSION COORDINATE (Y IN X-Y GEOMETRY, Z IN -
 CN R-Z, ETC.). -
 C -
 C-----

C-----
 CR EXTERNAL BOUNDARY CONDITION CONSTANTS (TYPE 05) -
 C

CL FORMAT----- (I2,8X,A2,E12.5,12X,2I6)
C
CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
CD ===== =====

CD 1-2	05
CD 11-12	BOUNDARY DESIGNATOR. XL..."X" LOWER. XU..."X" UPPER. YL..."Y" LOWER. YU..."Y" UPPER.
CD 13-24	VALUE OF CONSTANT A REFERRED TO ON CARD TYPE 04.
CD 37-42	HIGHER-ENERGY GROUP NUMBER FOR WHICH CONSTANTS APPLY.
CD 43-48	LOWER-ENERGY GROUP NUMBER FOR WHICH CONSTANTS APPLY.

C
CN AS MANY TYPE 05 CARDS AS NECESSARY MAY BE USED TO
CN SPECIFY THE EXTERNAL BOUNDARY CONDITIONS.
CN
CN IF NO "HIGHER-ENERGY GROUP NUMBER" IS SUPPLIED (COLS.
CN 37-42 ARE BLANK), THE CONSTANTS GIVEN APPLY TO ALL
CN ENERGY GROUPS. IF NO "LOWER-ENERGY GROUP NUMBER" IS
CN SUPPLIED (COLS. 43-48 ARE BLANK), THE CONSTANTS GIVEN
CN APPLY TO THE "HIGHER-ENERGY GROUP" ONLY. IF NO GROUP
CN NUMBERS ARE SUPPLIED (COLS. 37-48 ARE BLANK), THE
CN CONSTANTS GIVEN APPLY TO ALL ENERGY GROUPS.
CN
CN DATA ON THIS CARD MAY BE OVERLAYED. THAT IS, BOUNDARY
CN CONSTANTS DEFINED ON LATER TYPE 5 CARDS SUPERCEDE DATA
CN FOR ENERGY RANGES PREVIOUSLY SPECIFIED.
CN
CN "X" REPRESENTS THE FIRST DIMENSION COORDINATE (X IN
CN X-Y GEOMETRY, R IN R-Z, ETC.). "Y" REPRESENTS THE
CN R-Z, ETC.).
C
C-----

C-----
CR REGION BOUNDARY COORDINATES AND CONSTANT MESH STRUCTURE
CR (TYPE 06)
C
CL FORMAT----- (I2,4X,A6,2E12.5,2I6,2E12.5)
C
CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
CD ===== =====

CD 1-2	06
------------	----

CD

CD	7-12	REGION LABEL (REPEATED ON ADDITIONAL TYPE 06 CARDS).	-
CD			-
CD	13-24	"X"-DIRECTION LOWER-BOUNDARY COORDINATE.	-
CD			-
CD	25-36	"X"-DIRECTION UPPER-BOUNDARY COORDINATE.	-
CD			-
CD	37-42	NUMBER OF INTERVALS IN "X" DIRECTION.	-
CD			-
CD	43-48	NUMBER OF INTERVALS IN "Y" DIRECTION.	-
CD			-
CD	49-60	"Y"-DIRECTION LOWER-BOUNDARY COORDINATE.	-
CD			-
CD	61-72	"Y"-DIRECTION UPPER-BOUNDARY COORDINATE.	-
C			-
CN		"X" REPRESENTS X OR R. "Y" REPRESENTS Y OR Z.	-
CN			-
CN		CARD TYPE 06 IS NOT PERTINENT FOR TRIANGULAR	-
CN		GEOMETRIES.	-
CN			-
CN		REGIONS MAY BE DEFINED USING THE OVERLAY PROCEDURE,	-
CN		WITH THE LATEST REGION ASSIGNMENT OVERLAYING THE	-
CN		PREVIOUS CONFIGURATION, OR USING THE USUAL PROCEDURE,	-
CN		WITH EACH REGION'S BOUNDARIES GIVEN EXPLICITLY.	-
CN		REGION LABELS MUST BE NON-BLANK.	-
CN		THE MESH FOR A DIRECTION MUST BE COMPLETELY	-
CN		SPECIFIED EITHER ON THE TYPE 06 OR 09 CARDS. IF MESH	-
CN		DATA ARE SUPPLIED ON BOTH TYPE 06 AND 09 CARDS, THE	-
CN		TYPE 09 DATA WILL BE USED. FOR ONE-DIMENSIONAL	-
CN		PROBLEMS, ONLY THE "X"-DIRECTION UPPER BOUNDARIES NEED	-
CN		BE GIVEN FOR REGIONS AFTER THE FIRST.	-
C			-
C			-

C	-----		
CR	ZONE SPECIFICATIONS (TYPE 08)		
C			
CL	FORMAT----- (I2,4X,11A6)		
C			
CD	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY	
CD	=====	=====	
CD	1-2	OR	
CD			
CD	7-12	ZONE LABEL (REPEATED ON ADDITIONAL TYPE 08 CARDS).	
CD			
CD	13-18	LABEL OF REGION COMPRISING ZONE.	
CD			
CD	19-24	LABEL OF REGION COMPRISING ZONE.	
CD			
CD	25-30	LABEL OF REGION COMPRISING ZONE.	

CD		
CD	31-36	LABEL OF REGION COMPRISING ZONE.
CD		
CD	37-42	LABEL OF REGION COMPRISING ZONE.
CD		
CD	43-48	LABEL OF REGION COMPRISING ZONE.
CD		
CD	49-54	LABEL OF REGION COMPRISING ZONE.
CD		
CD	55-60	LABEL OF REGION COMPRISING ZONE.
CD		
CD	61-66	LABEL OF REGION COMPRISING ZONE.
CD		
CD	67-72	LABEL OF REGION COMPRISING ZONE.
C		
CN		ZONE LABELS MUST BE NON-BLANK. THE FIRST BLANK REGION
CN		LABEL ENCOUNTERED TERMINATES READING OF THE DATA ON
CN		THAT PARTICULAR TYPE 08 CARD.
CN		
CN		CARD TYPE 08 IS NOT PERTINENT FOR TRIANGULAR
CN		GEOMETRIES.
C		

C	-----	
CR	VARIABLE-MESH STRUCTURE (TYPE 09)	
C		
CL	FORMAT----- (I2,9X,A1,3(I6,E12.5))	
C		
CD	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY
CD	=====	=====
CD	1-2	09
CD		
CD	12	COORDINATE DIRECTION.
CD		X..."X" COORDINATE DIRECTION.
CD		Y..."Y" COORDINATE DIRECTION.
CD		
CD	13-18	NUMBER OF INTERVALS.
CD		
CD	19-30	UPPER COORDINATE.
CD		
CD	31-36	NUMBER OF INTERVALS.
CD		
CD	37-48	UPPER COORDINATE.
CD		
CD	49-54	NUMBER OF INTERVALS.
CD		
CD	55-66	UPPER COORDINATE.
C		

CN "X" REPRESENTS X OR R; "Y" REPRESENTS Y, Z, OR THETA. -
 CN EACH NUMBER PAIR IS OF THE FORM (N(I), X(I)). THERE -
 CN ARE N(I) INTERVALS BETWEEN X(I-1) AND X(I), WHERE X(0) -
 CN IS THE LOWER REACTOR BOUNDARY IN THIS DIRECTION. -
 CN NUMBER PAIRS MUST BE GIVEN IN ORDER OF INCREASING MESH -
 CN COORDINATES. ALL REGION BOUNDARIES MUST COINCIDE WITH -
 CN THE MESH LINES THAT BOUND MESH INTERVALS. -
 CN
 CN CARD TYPE 09 IS NOT PERTINENT FOR TRIANGULAR -
 CN GEOMETRIES. -
 C -
 C -----

C -----
 CR FINITE-GEOMETRY TRANSVERSE DISTANCE (TYPE 12) -
 C -
 CL FORMAT----- (I2,4X,A6,2E12.5) -
 C -
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY -
 CD =====
 CD 1-2 12 -
 CD -
 CD 7-12 REGION LABEL. -
 CD -
 CD 13-24 ACTUAL TRANSVERSE HALF-HEIGHT OR RADIUS. -
 CD -
 CD 25-36 TRANSVERSE EXTRAPOLATION DISTANCE. -
 C -
 CN IF THERE IS NO REGION LABEL (COLS. 7-12 ARE BLANK), -
 CN THE DATA ON THE CARD APPLY TO ALL REGIONS OF THE -
 CN REACTOR. IF THERE IS NO REGION LABEL AND IF THERE ARE -
 CN NO TYPE 34 CARDS (ZONE AND GROUP DEPENDENT BUCKLING -
 CN SPECIFICATIONS), THE DATA ON THIS CARD WILL BE USED -
 CN TO CALCULATE A SPACE- AND ENERGY-INDEPENDENT BUCKLING -
 CN AND TO CALCULATE REGION VOLUMES. IN THIS MODE OF INPUT -
 CN ONLY ONE TYPE 12 CARD SHOULD BE SUPPLIED. -
 CN -
 CN IF MORE THAN ONE TYPE 12 CARD IS PRESENT (EACH CARD -
 CN WITH A VALID REGION LABEL IN COLS. 7-12), THE -
 CN DATA ON THE CARDS WILL BE USED TO CALCULATE REGION -
 CN VOLUMES. IF BUCKLINGS ARE REQUIRED, THEY MUST BE -
 CN SPECIFIED ON TYPE 34 CARDS. -
 CN -
 CN REGION VOLUMES ARE CALCULATED USING THE HALF-HEIGHT -
 CN (EXCLUDING THE EXTRAPOLATION DISTANCE). -
 CN -
 CN DATA ON THIS CARD MAY BE OVERLAYED. THAT IS, -
 CN TRANSVERSE DISTANCES DEFINED ON LATER TYPE 12 -
 CN CARDS SUPERCEDE DATA FOR REGIONS PREVIOUSLY -
 CN

CN SPECIFIED.
 CN
 CN IF TYPE 34 CARDS ARE PRESENT, BUCKLINGS WILL BE TAKEN
 CN FROM TYPE 34 CARD DATA AND NOT FROM TYPE 12 CARDS.
 CN
 CN IN THE ABSENCE OF TYPE 12 AND TYPE 34 CARDS NO
 CN BUCKLINGS WILL BE USED AND REGION VOLUMES WILL BE
 CN CALCULATED USING UNIT TRANSVERSE HEIGHTS.
 C
 C-----

C-----
 CR ISOTOPE-TO-MATERIAL SPECIFICATIONS (TYPE 13)
 C
 CL FORMAT----- (I2,10X,A6,A6,E12.5,4A6)
 C
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
 CD =====
 CD 1-2 13
 CD
 CD 13-18 UNIQUE MATERIAL LABEL (REPEATED FOR EACH ISOTOPE
 CD IN THIS MATERIAL).
 CD
 CD 19-24 LABEL OF GENERIC MATERIAL WITH WHICH THIS UNIQUE
 CD MATERIAL IS ASSOCIATED.
 CD
 CD 25-36 ISOTOPE ATOM DENSITY (ATOMS/CC * 1.E-24).
 CD
 CD 37-48 FIRST DERIVATIVE OF ATOM DENSITY WITH RESPECT TO
 CD COOLANT TEMPERATURE (ATOMS/CC * 1.0E-24)
 CD (DEFAULT=ZERO)
 CD
 CD 49-54 UNIQUE ISOTOPE NAME OF ISOTOPE AT TEMPERATURE
 CD TFBASE FROM FILE ISOTXS
 CD
 CD 55-60 UNIQUE ISOTOPE NAME OF ISOTOPE AT TEMPERATURE T2
 CD
 CD 61-66 UNIQUE ISOTOPE NAME OF ISOTOPE AT TEMPERATURE T3
 CD
 CD 67-72 UNIQUE ISOTOPE NAME OF ISOTOPE AT TEMPERATURE T4
 C
 CN FOR EACH ISOTOPE USED IN FORMING THE CROSS SECTIONS
 CN FOR A UNIQUE MATERIAL, ONE TYPE 13 CARD IS REQUIRED.
 CN ONCE SPECIFICATION OF A UNIQUE MATERIAL IS BEGUN, ALL
 CN REMAINING ISOTOPES COMPRISING THIS UNIQUE MATERIAL
 CN MUST BE SPECIFIED ON CONSECUTIVE TYPE 13 CARDS. IN
 CN ORDER TO CLARIFY THE UNIQUE MATERIAL-GENERIC MATERIAL
 CN CONCEPT, IT MUST BE UNDERSTOOD THAT WITHIN FX2, THE
 CN REACTOR IS VIEWED AS BEING COMPOSED OF PHYSICAL

CN MATERIALS SUCH AS URANIUM OXIDE, PLUTONIUM OXIDE, -
 CN STAINLESS STEEL, BORON CARBIDE, ETC. EACH PHYSICAL -
 CN MATERIAL IS ASSUMED TO HAVE A FIXED ISOTOPIC CONTENT -
 CN DURING A TRANSIENT. -
 CN
 CN SINCE FX2 EMPLOYS THE MULTIGROUP APPROXIMATION, IT -
 CN WILL OFTEN BE DESIRABLE TO USE DIFFERENT CROSS -
 CN SECTIONS FOR A PARTICULAR PHYSICAL MATERIAL IN -
 CN DIFFERENT REGIONS OF THE REACTOR. THIS IS ACCOMPLISHED -
 CN IN FX2 BY CREATING SEVERAL UNIQUE MATERIALS, EACH WITH -
 CN ITS OWN CROSS SECTIONS AND UNIQUE MATERIAL LABEL, -
 CN BUT ALL SHARING THE SAME GENERIC MATERIAL LABEL. THUS, -
 CN URANIUM OXIDE IN THE INNER AND OUTER CORE REGIONS -
 CN MIGHT BE DESIGNATED BY THE UNIQUE MATERIAL LABELS -
 CN UO2-IC AND UO2-OC, RESPECTIVELY, WITH BOTH SHARING THE -
 CN GENERIC MATERIAL LABEL UO2. BECAUSE CORE STORAGE -
 CN REQUIREMENTS AND COMPUTING TIMES ARE DEPENDENT ON THE -
 CN NUMBER OF GENERIC MATERIALS MUCH MORE STRONGLY THAN -
 CN ON THE NUMBER OF UNIQUE MATERIALS, IT IS IN THE USER'S -
 CN INTEREST TO ATTEMPT TO MINIMIZE THE NUMBER OF GENERIC -
 CN MATERIALS. -
 CN
 CN IN CONSTRUCTING EACH UNIQUE MATERIAL, ISOTOPES ARE -
 CN IDENTIFIED BY THEIR UNIQUE ISOTOPE NAMES (FROM THE -
 CN HISONM ARRAY) ON THE ISOTXS FILE. EITHER ONE UNIQUE -
 CN ISOTOPE NAME OR FOUR UNIQUE ISOTOPE NAMES MUST APPEAR -
 CN ON EACH TYPE 13 CARD. IF FOUR APPEAR ON A CARD, THEY -
 CN MUST SHARE A COMMON ABSOLUTE ISOTOPE NAME (HABSID) ON -
 CN ISOTXS. -
 CN
 CN IF THE CAPTURE AND FISSION CROSS SECTIONS OF A -
 CN PARTICULAR UNIQUE MATERIAL ARE TO BE TEMPERATURE- -
 CN DEPENDENT, AT LEAST ONE OF THE ISOTOPES COMPRISING -
 CN IT MUST HAVE FOUR UNIQUE ISOTOPE NAMES SPECIFIED ON -
 CN ITS TYPE 13 CARD. FX2 CONSTRUCTS MACROSCOPIC CAPTURE -
 CN AND FISSION CROSS SECTIONS AT TEMPERATURES TBASE, T2, -
 CN T3, AND T4 FOR THIS UNIQUE MATERIAL AND EXTRACTS THEIR -
 CN TEMPERATURE DEPENDENCE IN THE FORM OF FITTING CO- -
 CN EFFICIENTS. FOR EACH GROUP, G, COEFFICIENTS A1, A2, -
 CN A3, A4, A5, AND A6 ARE COMPUTED SO THAT THE CAPTURE -
 CN AND FISSION CROSS SECTIONS FOR THIS GROUP AT SOME -
 CN TEMPERATURE T, SIGCAP(G,T) AND SIGFIS(G,T), CAN BE -
 CN COMPUTED AS FOLLOWS: -
 CN
 CN
$$\text{SIGCAP}(G,T) = \text{SIGCAP}(G, \text{TBASE}) + A1 * (\text{DSQRT}(T) - \text{DSQRT}(\text{TBASE}))$$
 CN
$$+ A2 * (\text{DLOG}(T/\text{TBASE})) + A3 * (\text{TBASE} - T) / (\text{TBASE} * T)$$
 CN
 CN
$$\text{SIGFIS}(G,T) = \text{SIGFIS}(G, \text{TBASE}) + A4 * (\text{DSQRT}(T) - \text{DSQRT}(\text{TBASE}))$$
 CN
$$+ A5 * (\text{DLOG}(T/\text{TBASE})) + A6 * (\text{TBASE} - T) / (\text{TBASE} * T)$$
 CN

CN AS EACH UNIQUE ISOTOPE IS READ IN FROM ISOTXS, ITS
 CN TEMPERATURE AS SPECIFIED ON ISOTXS IS CHECKED AGAINST
 CN THE APPROPRIATE REFERENCE TEMPERATURE (TBASE, T2, T3,
 CN OR T4). IT MUST BE WITHIN + OR - 5 PERCENT OF THAT
 CN REFERENCE TEMPERATURE. THE VALUES USED FOR THE FOUR
 CN REFERENCE TEMPERATURES ARE TAKEN AS THE TEMPERATURES
 CN PICKED UP FROM THE FIRST ISOTOPES READ FROM ISOTXS
 CN WHICH ARE SPECIFIED AS BEING AT EACH OF THE FOUR
 CN TEMPERATURES.
 CN
 CN THE ATOM DENSITY OF THE COOLANT MATERIAL CAN BE
 CN EXPANDED AS A LINEAR FUNCTION OF THE COOLANT
 CN TEMPERATURE, AS
 CN
 CN $RHO(TC) = RHO(TCBASE) + RHO1 * (TC - TCBASE)$
 CN
 CN TCBASE IS ENTERED ON CARD TYPE 15. THE COOLANT
 CN TEMPERATURE FEEDBACK COEFFICIENT IS CONSTRUCTED
 CN FROM THE BASE AND FIRST DERIVATIVE OF THE ATOM
 CN DENSITY. ISOTOPES WHOSE NUMBER DENSITIES ARE NOT
 CN DEPENDENT ON COOLANT TEMPERATURE SHOULD HAVE THE
 CN FIRST DERIVATIVE SET TO ZERO.
 C
 C-----

C-----
 CR ASSIGNMENT OF MATERIALS TO REGION (TYPE 14)
 C
 CL FORMAT----- (I2,10X,A6,3(A6,E12.5))
 C
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
 CD =====
 CD 1-2 14
 CD
 CD 13-18 REGION LABEL (REPEATED ON ADDITIONAL TYPE 14 CARDS).
 CD
 CD 19-24 UNIQUE MATERIAL LABEL.
 CD
 CD 25-36 MATERIAL VOLUME FRACTION.
 CD
 CD 37-42 UNIQUE MATERIAL LABEL.
 CD
 CD 43-54 MATERIAL VOLUME FRACTION.
 CD
 CD 55-60 UNIQUE MATERIAL LABEL.
 CD
 CD 61-72 MATERIAL VOLUME FRACTION.
 C
 CN REGION LABELS MUST BE NON-BLANK.

CN THE UNIQUE MATERIAL LABELS ARE USED TO SPECIFY -
 CN MATERIAL VOLUME FRACTIONS FOR EACH REGION. ONLY ONE -
 CN UNIQUE MATERIAL ASSOCIATED WITH EACH GENERIC MATERIAL -
 CN MAY BE PLACED IN ANY GIVEN REGION. ALL UNIQUE MATERIAL -
 CN LABELS USED MUST APPEAR ON TYPE 13 CARDS OR, IF DATA -
 CN SET XSCON IS OLD, IN THE UMNAM ARRAY OF XSCON. -
 C -
 C-----

C-----
 CR BASE COOLANT TEMPERATURE (TYPE 15) -
 C -
 CL FORMAT----- (I2,10X,E12.5) -
 C -
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY -
 CD ===== -
 CD 1-2 15 -
 CD -
 CD 13-24 BASE COOLANT TEMPERATURE (DEG. K) -
 CD -
 CD IF THE CROSS SECTIONS ARE CHOSEN TO BE DEPENDENT -
 CD ON COOLANT TEMPERATURE, THIS CARD IS REQUIRED -
 C -
 C-----

C-----
 CR DISTRIBUTED ISOTROPIC INHOMOGENEOUS SOURCE DATA DEFINED -
 CR EITHER BY REGION OR MESH INTERVAL (TYPE 19) -
 C -
 CL FORMAT----- (I2,4X,A6,2I6,3E12.5) -
 C -
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY -
 CD ===== -
 CD 1-2 19 -
 CD -
 CD 7-12 LABEL OF REGION (BLANK IF DATA ARE GIVEN BY MESH -
 CD INTERVALS). -
 CD -
 CD 13-18 HIGHER-ENERGY GROUP NUMBER. -
 CD -
 CD 19-24 LOWER-ENERGY GROUP NUMBER. -
 CD -
 CD 25-36 ISOTROPIC SOURCE VALUE IN THE SPECIFIED MESH INTERVAL -
 CD FOR THIS ENERGY RANGE. (NEUTRONS PER SECOND PER -
 CD UNIT VOLUME). -
 CD -
 CD 37-48 LOWER "X" DIRECTION COORDINATE OF MESH INTERVAL -
 CD CONTAINING THIS SOURCE. -
 C-----

CD
 CD 49-60 LOWER "Y" DIRECTION COORDINATE OF MESH INTERVAL
 CD CONTAINING THIS SOURCE.
 C
 CN IF THERE IS NO REGION LABEL (COLS. 7-12 ARE BLANK),
 CN THE SOURCE SPECIFIED IN COLS. 25-36 IS PLACED IN THE
 CN MESH BOX DEFINED BY COLS. 37-48 AND 49-60.
 CN
 CN IF THERE IS A REGION LABEL (COLS. 7-12 ARE NON-BLANK),
 CN THE MESH COORDINATE FIELDS (COLS. 37-48 AND 49-60)
 CN ARE IGNORED AND THE SOURCE SPECIFIED IN COLS. 25-36
 CN IS PLACED IN EVERY MESH BOX IN THE REGION.
 CN
 CN "X" REPRESENTS THE FIRST DIMENSION COORDINATE (X IN
 CN X-Y GEOMETRY, R IN R-Z, ETC.). "Y" REPRESENTS THE
 CN SECOND DIMENSION COORDINATE (Y IN X-Y GEOMETRY, Z IN
 CN R-Z, ETC.).
 CN
 CN IF NO "HIGHER-ENERGY GROUP NUMBER" IS SUPPLIED (COLS.
 CN 13-18 ARE BLANK), THE SOURCE VALUE GIVEN APPLIES TO
 CN ALL ENERGY GROUPS. IF NO "LOWER-ENERGY GROUP NUMBER"
 CN IS SUPPLIED (COLS. 19-24 ARE BLANK), THE SOURCE VALUE
 CN GIVEN APPLIES TO THE "HIGHER-ENERGY GROUP" ONLY. IF
 CN NO GROUP NUMBERS ARE SUPPLIED (COLS. 13-24 ARE BLANK),
 CN THE SOURCE VALUE GIVEN APPLIES TO ALL ENERGY GROUPS.
 CN
 CN DATA ON THIS CARD MAY BE OVERLAPPED. THAT IS, SOURCE
 CN VALUES DEFINED ON LATER TYPE 19 CARDS SUPERCEDE DATA
 CN FOR REGIONS AND GROUPS PREVIOUSLY SPECIFIED.
 C
 C-----
 C-----
 CR HEXAGON DIMENSION (TYPE 29)
 C
 CL FORMAT----- (I2,10X,E12.5,2I6)
 C
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
 CD =====
 CD 1-2 29
 CD
 CD 13-24 DIMENSION OF HEXAGON ACROSS FLATS.
 CD
 CD 25-30 TOTAL NUMBER OF HEXAGONAL RINGS IN THE REGION OF
 CD SOLUTION.
 CD
 CD 31-36 NUMBER OF EQUAL PARTS INTO WHICH EACH SIDE OF THE
 CD BASIC EQUILATERAL TRIANGLES MAKING UP THE HEXAGONS ARE
 CD SUBDIVIDED. THUS E.G., IF COLS 31-36 CONTAIN 3, THE
 CD HEXAGON CONTAINS 54 MESH POINTS INSTEAD OF THE NORMAL
 CD 6.

C
 CN IF THE NUMBER OF RINGS IS NOT PROVIDED IN COLS. 25-30, -
 CN IT IS DERIVED FROM THE TYPE 30 CARDS. -
 CN
 CN IF COLS. 31-36 ARE BLANK, THE TRIANGLES ARE NOT -
 CN SUBDIVIDED. -
 CN
 CN THE TYPE 29 CARD IS PERTINENT ONLY IF COLS. 13-18 ON -
 CN CARD TYPE 03 ARE GREATER THAN 61 (TRIANGULAR GEOMETRY). -
 C
 C-----

C-----
 CR LOCATIONS OF REGIONS FOR TRIANGULAR GEOMETRIES (TYPE 30) -
 C
 CL FORMAT----- (I2,4X,A6,3I6) -
 C
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY -
 CD =====
 CD 1-2 30 -
 CD
 CD 7-12 REGION LABEL (REPEATED ON ADDITIONAL TYPE 30 CARDS). -
 CD
 CD 13-18 HEXAGONAL RING NUMBER WHERE REGION IS LOCATED. -
 CD
 CD 19-24 STARTING HEXAGONAL POSITION NUMBER WHERE REGION IS -
 CD LOCATED. -
 CD
 CD 25-30 FINAL HEXAGONAL POSITION WHERE REGION IS LOCATED. -
 C
 CN REGION LABELS MUST BE NON-BLANK. -
 CN
 CN IF THE STARTING POSITION (COLS. 19-30) IS BLANK OR -
 CN ZERO, THE REGION LABEL IS ASSIGNED TO THE WHOLE RING. -
 CN
 CN IF THE FINAL POSITION (COLS. 25-30) IS BLANK OR ZERO, -
 CN THE REGION LABEL IS ASSIGNED TO THE POSITION IN 19-24 -
 CN OF THE RING IN 13-18. -
 CN
 CN DATA ON THIS CARD MAY BE OVERLAYED. THAT IS, REGION -
 CN ASSIGNMENTS DEFINED ON LATER TYPE 30 CARDS SUPERCEDE -
 CN DATA FOR RINGS AND POSITIONS PREVIOUSLY SPECIFIED. -
 CN
 CN THE FIGURE BELOW ILLUSTRATES THE ORDER OF NAMING -
 CN RINGS AND HEXAGONS IN THE RINGS. THE FIRST NUMBER OF -
 CN EACH NUMBERED PAIR IS THE RING NUMBER, AND THE SECOND -
 CN NUMBER IS THE HEXAGON NUMBER IN THAT RING. -
 CN THE REGION OF SOLUTION DEPENDS ON THE VALUE IN COLS. -
 CN 13-18 ON CARD TYPE 03 AS FOLLOWS. -

[illegible]

```

C-----
CR          BACKGROUND REGION NAME FOR TRIANGULAR GEOMETRIES (TYPE 31)
C
CL  FORMAT----- (I2,4X,A6)
C
CD  COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD  =====
CD  1-2              31
CD
CD  7-12             BACKGROUND REGION NAME.

```

C
 CN ANY PORTION OF THE REACTOR NOT SPECIFIED ON THE
 CN TYPE 30 CARDS WILL BE IN THE BACKGROUND REGION.
 CN
 CN IF THE BACKGROUND REGION NAME (COLS. 7-12) IS BLANK,
 CN OR IF THERE IS NO TYPE 31 CARD, THE BACKGROUND REGION
 CN WILL BE ASSIGNED A REGION NUMBER 0 (ZERO). SOME CCCC
 CN CODES EXCLUDE SUCH A REGION FROM THE REGION OF
 CN SOLUTION. OTHER CCCC CODES MAY NOT ALLOW ZERO
 CN REGION NUMBERS.
 C
 C-----

C-----
 CR ZONE SPECIFICATIONS FOR TRIANGULAR GEOMETRIES (TYPE 33)
 C
 CL FORMAT----- (I2,4X,11A6)
 C
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
 CD =====
 CD 1-2 33
 CD
 CD 7-12 ZONE LABEL (REPEATED ON ADDITIONAL TYPE 33 CARDS).
 CD
 CD 13-18 LABEL OF REGION COMPRISING ZONE.
 CD
 CD 19-24 LABEL OF REGION COMPRISING ZONE.
 CD
 CD 25-30 LABEL OF REGION COMPRISING ZONE.
 CD
 CD 31-36 LABEL OF REGION COMPRISING ZONE.
 CD
 CD 37-42 LABEL OF REGION COMPRISING ZONE.
 CD
 CD 43-48 LABEL OF REGION COMPRISING ZONE.
 CD
 CD 49-54 LABEL OF REGION COMPRISING ZONE.
 CD
 CD 55-60 LABEL OF REGION COMPRISING ZONE.
 CD
 CD 61-66 LABEL OF REGION COMERISING ZONE.
 CD
 CD 67-72 LABEL OF REGION COMPRISING ZONE.
 C
 CN ZONE LABELS MUST BE NON-BLANK. THE FIRST BLANK REGION
 CN LABEL ENCOUNTERED TERMINATES READING OF THE DATA ON
 CN THAT PARTICULAR TYPE 33 CARD. A REGION CAN BE PLACED
 CN IN ONLY ONE ZONE.
 C

```

C-----
CP          ZONE AND GROUP DEPENDENT BUCKLING SPECIFICATIONS (TYPE 34)
C
CL  FORMAT----- (I2,4X,A6,2(E12.5,2I6))
C
CD  COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD  =====
CD  1-2              34
CD
CD  7-12             ZONE LABEL.
CD
CD  13-24            BUCKLING (B**2) .
CD
CD  25-30            HIGHER ENERGY BROAD GROUP NUMBER TO WHICH BUCKLING
CD                    IN COLS. 13-24 APPLIES.
CD
CD  31-36            LOWER ENERGY BROAD GROUP NUMBER TO WHICH BUCKLING
CD                    IN COLS. 13-24 APPLIES.
CD
CD  37-48            BUCKLING (B**2) .
CD
CD  49-54            HIGHER ENERGY BROAD GROUP NUMBER TO WHICH BUCKLING
CD                    IN COLS. 37-48 APPLIES.
CD
CD  55-60            LOWER ENERGY BROAD GROUP NUMBER TO WHICH BUCKLING
CD                    IN COLS. 37-48 APPLIES.
C
CN          IF THERE IS NO ZONE LABEL (COLS. 7-12 ARE BLANK), THE
CN          BUCKLINGS ON THIS CARD WILL APPLY TO ALL ZONES (IN
CN          THIS CASE THERE SHOULD BE ONLY ONE CARD). IF ONE OR
CN          MORE ZONES ARE NAMED, UNNAMED ZONES WILL HAVE NO
CN          BUCKLINGS.
CN
CN          IF NO "HIGHER-ENERGY GROUP NUMBER" IS SUPPLIED IN
CN          COLS. 25-30, THE BUCKLING GIVEN IN COLS. 13-24 APPLIES
CN          TO ALL ENERGY GROUPS NOT PREVIOUSLY SPECIFIED FOR THIS
CN          ZONE, AND ANY REMAINING TYPE 34 DATA FOR THIS ZONE ARE
CN          IGNORED. IF NO "LOWER-ENERGY GROUP NUMBER" IS SUPPLIED
CN          IN COLS. 31-36, THE BUCKLING GIVEN IN COLS. 13-24
CN          APPLIES TO THE "HIGHER-ENERGY GROUP" ONLY.
CN
CN          IF NO "HIGHER-ENERGY GROUP NUMBER" IS SUPPLIED IN
CN          COLS. 49-54, THE DATA IN COLS. 37-60 ARE IGNORED. IF
CN          THERE IS A "HIGHER-ENERGY GROUP NUMBER" IN COLS. 49-54,
CN          BUT NO "LOWER-ENERGY GROUP NUMBER" IN COLS. 55-60,
CN          THE BUCKLING GIVEN IN COLS. 37-48 APPLIES TO THE
CN          "HIGHER-ENERGY GROUP" ONLY.

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CN
 CN BUCKLINGS CAN BE OVERLAYED. THAT IS, BUCKLINGS DEFINED
 CN ON LATER TYPE 34 CARDS SUPERCEDE DATA FOR ZONES
 CN AND/OR ENERGY RANGES PREVIOUSLY DEFINED. THE EXCEPTION
 CN TO THIS RULE IS THE SITUATION DESCRIBED IN THE PRE-
 CN CEDING PARAGRAPHS WHERE DATA IS SPECIFICALLY IGNORED.
 CN
 CN WHEN ANY TYPE 34 CARDS EXIST, BUCKLINGS WILL NOT BE
 CN CALCULATED FROM FINITE GEOMETRY DATA ON TYPE 12 CARDS.
 C
 C-----

CEOF

C*****
 C
 C PREPARED 11/08/77 AT ANL
 C
 CF A.THRM
 CE MODULE-DEPENDENT BCD INPUT FILE FOR THERMAL-HYDRAULICS
 CE CALCULATION (FX2-TH)
 C
 CN THIS IS A USER-SUPPLIED BCD DATA SET.
 CN THE LIST FOR EACH RECORD IS GIVEN IN TERMS
 CN OF THE BCD FORMAT OF THE DATA CARD.
 CN COLUMNS 1-2 NORMALLY CONTAIN THE CARD TYPE
 CN NUMBER.
 CN
 CN CARD TYPE 02, CARD TYPE 04, CARD TYPE 13 AND
 CN CARD TYPE 14 ARE ALWAYS PRESENT.
 CN CARD TYPE 03 IS PRESENT IF R-Z GEOMETRY
 CN IS USED.
 CN CARD TYPE 05 IS PRESENT IF OTHER THAN R-Z
 CN GEOMETRY IS USED
 CN CARD TYPE 06 AND CARD TYPE 09 ARE PRESENT
 CN IF NTHF.EQ.1.
 CN CARD TYPE 07, CARD TYPE 08, CARD TYPE 10,
 CN CARD TYPE 11 AND CARD TYPE 12 ARE PRESENT IF
 CN NTHF.EQ.1 .AND. IFTH.EQ.3
 CN
 CN FX2-TH REQUIRES THAT A.THRM BE PRESENT IF A-
 CN THERMAL-HYDRAULICS CALCULATION IS REQUIRED OR
 CN IF INPUT TEMPERATURES ARE REQUIRED. A.THRM IS
 CN NOT REQUIRED IF BINARY FILE FXTH IS AVAILABLE
 CN AND HAS BEEN INCLUDED IN THE BLOCK=OLD.
 C
 C*****

C-----
 CR INTEGER CONTROL (TYPE 02)

```

C
CL  FORMAT----- (I2,10X,5I6)
C
CD  COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD  =====
CD  1-2                02
CD
CD  13-18              IFTH, CALCULATION FLAG.
CD                      1...SIMPLE MODEL WITH TOTAL POWER AS SOURCE
CD                      2...SIMPLE MODEL WITH TOTAL POWER MINUS INITIAL
CD                      POWER AS SOURCE
CD                      3...DETAILED MODEL (DEFAULT)
CD
CD  19-24              NFR, THE NUMBER OF REGIONS THE FUEL IS TO BE DIVIDED
CD                      INTO TO SOLVE HEAT CONDUCTION EQUATION (DEFAULT=5).
CD
CD  25-30              IST, STRUCTURE CALCULATION FLAG.
CD                      0...NO STRUCTURE CALCULATION (DEFAULT).
CD                      1...STRUCTURE CALCULATION.
CD
CD  31-36              IMAP, THERMAL-HYDRAULICS MAP FLAG.
CD                      1...EACH NEUTRONICS REGION IS ONE THERMAL-HYDRAULIC
CD                      REGION (DEFAULT). NOT AVAILABLE IF R-Z GEOMETRY.
CD                      2...EACH NEUTRONICS MESH CELL IS ONE THERMAL-HYDRAULIC
CD                      REGION. NOT AVAILABLE IF R-Z GEOMETRY.
CD                      3...READ CARD TYPES 03, 04, OR 05 TO DETERMINE MAP.
CD
CD  37-42              ITYPE, NUMBER OF DIFFERENT THERMAL-HYDRAULIC DATA
CD                      TYPES (DEFAULT=1).
C
CN                      NFR AND IST ARE NOT APPLICABLE FOR THE SIMPLE MODEL
CN                      (IFTH.LT.3)
C
C-----

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C-----
CR          "R"-DIRECTION MESH STRUCTURE (TYPE 03).
C
CL  FORMAT----- (I2,10X,10I6)
C
CD  COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD  =====
CD  1-2                03
CD
CD  13-18              IRMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS
CD                      ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL.
CD
CD  19-24              IRMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS
CD                      ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL.

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```

CD
CD 25-30      IRMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS -
CD            ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL. -
CD
CD 31-36      IPMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS -
CD            ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL. -
CD
CD 37-42      IRMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS -
CD            ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL. -
CD
CD 43-48      IPMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS -
CD            ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL. -
CD
CD 49-54      IRMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS -
CD            ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL. -
CD
CD 55-60      IRMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS -
CD            ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL. -
CD
CD 61-66      IRMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS -
CD            ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL. -
CD
CD 67-72      IRMESH, THE THERMAL-HYDRAULIC CHANNEL NUMBER THAT IS -
CD            ASSIGNED TO THIS FINE-MESH "R"-DIRECTION INTERVAL. -
C
CN            TYPE 03 CARDS ARE ONLY READ IF R-Z GEOMETRY IS USED -
CN            AND IMAP IS ENTERED AS 3. IF NO TYPE 03 CARDS ARE -
CN            PRESENT (AND GEOMETRY IS R-Z), THEN USE ONE THERMAL- -
CN            HYDRAULIC CHANNEL FOR EACH FINE MESH INTERVAL. IF -
CN            IRMESH IS INPUT AS 0, THEN THIS "R"-DIRECTION INTERVAL -
CN            DOES NOT BELONG TO ANY THERMAL-HYDRAULIC CHANNEL. -
CN
CN            AS MANY TYPE 03 CARDS ARE USED AS ARE NECESSARY TO -
CN            SPECIFY THE "R"-DIRECTION MESH STRUCTURE FOR ALL -
CN            MESH INTERVALS IN THE "R"-DIRECTION. -
C
C-----

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```

C-----
C
C *****
C *
C=====*      FIRST CONFIGURATION      *=====
C *
C *****
C
CR            USE THE FIRST CONFIGURATION FOR R-Z GEOMETRY.
CR            "Z"-DIRECTION MESH STRUCTURE (TYPE 04)
C

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```

CL    FORMAT----- (I2,10X,10I6)
C
CD    COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD    =====
CD    1-2              04
CD
CD    13-18            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
CD
CD    19-24            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
CD
CD    25-30            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
CD
CD    31-36            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
CD
CD    37-42            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
CD
CD    43-48            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
CD
CD    49-54            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
CD
CD    55-60            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
CD
CD    61-66            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
CD
CD    67-72            IZMESH, THE AXIAL MESH REGION THAT IS ASSIGNED TO
CD                      THIS "Z"-DIRECTION FINE-MESH INTERVAL.
C
CN    ALL ENTRIES MUST BE .GT.0 AND IN INCREASING ORDER.
CN
CN    TYPE 04 CARDS ARE ONLY READ IF R-Z GEOMETRY IS "SPD
CN    AND IMAP IS ENTERED AS 3. IF NO TYPE 04 CARDS ARE
CN    PRESENT (AND GEOMETRY IS R-7), THEN USE ONE AXIAL
CN    THERMAL-HYDRAULIC REGION FOR EVERY FINE MESH INTERVAL.
CN
CN    AS MANY TYPE 04 CARDS ARE USED AS ARE NECESSARY TO
CN    SPECIFY THE "Z"-DIRECTION MESH STRUCTURE FOR ALL MESH
CN    INTERVALS IN THE "Z"-DIRECTION.
C
C    *****
C    *
C=====*    SECOND CONFIGURATION    *=====

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```

C      *
C      *****
C
CR      USE SECOND CONFIGURATION FOR NON R-Z GEOMETRIES.
CR      HEIGHT OF ACTIVE CORE (TYPE 04)
C
CL      FORMAT----- (I2,10X,E12.4)
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====
CD      1-2              04
CD
CD      13-24            AXHT, THE HEIGHT OF THE ACTIVE CORE (CM).
C
CN      AXHT IS REQUIRED SO THAT THE SPECIFIC POWER
CN      (WATTS/CM**3) MAY BE CALCULATED.
CN      FOR GEOMETRIES OTHER THAN R-Z, THIS CARD IS REQUIRED.
C
C-----

```

```

C-----
CR      THERMAL-HYDRAULICS MAP DESCRIPTION (TYPE 05)
C
CL      FORMAT----- (I2,10X,I6,6X,4I6)
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====
CD      1-2              05
CD
CD      13-18            NC, THE THERMAL-HYDRAULICS CHANNEL NUMBER. THIS
CD                        CHANNEL IS COMPOSED OF THE SQUARE DEFINED BY
CD                        "X"-DIRECTION INTERVALS IXL TO IXR (INCLUSIVE) AND
CD                        "Y"-DIRECTION INTERVALS JYD TO JYT (INCLUSIVE).
CD
CD      25-30            IXL, "X"-DIRECTION LEFT BOUNDARY.
CD
CD      31-36            IXR, "X"-DIRECTION RIGHT BOUNDARY.
CD
CD      37-42            JYD, "Y"-DIRECTION BOTTOM BOUNDARY
CD
CD      43-48            JYT, "Y"-DIRECTION TOP BOUNDARY.
C
CN      FOR ONE-DIMENSIONAL PROBLEMS, LET JYD=JYT=1.
CN
CN      THESE TYPE 05 CARDS DEFINE THE MESH FOR GEOMETRIES
CN      OTHER THAN R-Z. IF IMAP.EQ.3 AND NO TYPE 05 CARDS ARE
CN      ENTERED, THEN THE DEFAULT (IMAP.EQ.1) OPTION IS TAKEN.
CN
CN      AS MANY TYPE 05 CARDS MAY BE USED AS ARE NECESSARY

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CN      TO DEFINE THE THERMAL-HYDRAULIC CHANNELS.
C
C-----
C
CR      THERMAL-HYDRAULICS DATA (TYPE 06)
C
CL      FORMAT----- (I2,4X,I4,2X,5(I2,E10.4))
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====
CD      1-2              06
CD
CD      7-10             IT, THE DATA TYPE NUMBER.
CD                        ALL CARDS FOR TYPE IT MUST BE PROCESSED BEFORE ANY
CD                        TYPE (IT+1) CARDS.
CD
CD      13-14            IN, THE DATA NUMBER, FROM 1 TO 6 (IF IFTH.LT.3),
CD                        OR FROM 1 TO 34 (IF IFTH.EQ.3)
CD
CD      15-24            DATA VALUE FOR DATA TYPE SPECIFIED.
CD
CD      25-26            IN, THE DATA NUMBER, FROM 1 TO 6 (IF IFTH.LT.3),
CD                        OR FROM 1 TO 34 (IF IFTH.EQ.3)
CD
CD      27-36            DATA VALUE FOR DATA TYPE SPECIFIED.
CD
CD      37-38            IN, THE DATA NUMBER, FROM 1 TO 6 (IF IFTH.LT.3),
CD                        OR FROM 1 TO 34 (IF IFTH.EQ.3)
CD
CD      39-48            DATA VALUE FOR DATA TYPE SPECIFIED.
CD
CD      49-50            IN, THE DATA NUMBER, FROM 1 TO 6 (IF IFTH.LT.3),
CD                        OR FROM 1 TO 34 (IF IFTH.EQ.3)
CD
CD      51-60            DATA VALUE FOR DATA TYPE SPECIFIED.
CD
CD      61-62            IN, THE DATA NUMBER, FROM 1 TO 6 (IF IFTH.LT.3),
CD                        OR FROM 1 TO 34 (IF IFTH.EQ.3)
CD
CD      63-72            DATA VALUE FOR DATA TYPE SPECIFIED.
C
CN      AS MANY TYPE 06 CARDS MAY BE USED AS ARE NECESSARY TO
CN      SPECIFY ALL THE DATA REQUIRED FOR THE CALCULATION.
CN
CN      *****
CN      *
CN===== * FIRST CONFIGURATION *=====
CN      *

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CN      *****
CN
CN      DATA REQUIRED IF IFTH.LT.3
CN
CN      IN  DATA NAME      DATA DEFINITION
CN      =====
CN      ( 1) VF              FUEL VOLUME FRACTION.
CN      ( 2) RHOF(1)         FUEL SPECIFIC HEAT DENSITY CORRELATION.
CN      ( 3) RHOF(2)          $RHOF(T) = RHOF(1) + RHOF(2) * T + RHOF(3) * T**2$ 
CN      ( 4) RHOF(3)          $+ RHOF(4) * T**3 + RHOF(5) * T**4$ 
CN      ( 5) RHOF(4)          $RHOF = (WATT-SEC/CM**3 \text{ DEG. C})$ 
CN      ( 6) RHOF(5)         TEMPERATURE (T) IS IN DEG. C.
CN
CN      *****
CN      *
CN      =====* SECOND CONFIGURATION *=====
CN      *
CN      *****
CN
CN      DATA REQUIRED IF IFTH.EQ.3
CN
CN      IN  DATA NAME      DATA DEFINITION
CN      =====
CN      ( 1) RF              FUEL OUTER RADIUS (CM).
CN      ( 2) RG              GAP OUTER RADIUS (CM).
CN      ( 3) RC              CLAD OUTER RADIUS (CM).
CN      ( 4) XKC             CLAD THERMAL CONDUCTIVITY (WATTS/CM DEG. C).
CN      ( 5) RCP            CLAD SPECIFIC HEAT DENSITY
CN                        (WATT-SEC/CM**3 DEG. C).
CN      ( 6) HGAF           GAP HEAT TRANSFER COEFFICIENT
CN                        (WATT/CM**2 DEG. C).
CN      ( 7) VFC            VOLUME FRACTION OF COOLANT.
CN      ( 8) GAM2           SURFACE AREA OF STRUCTURE/
CN                        SURFACE AREA OF CLADDING.
CN      ( 9) RST            THERMAL RESISTANCE OF STRUCTURE
CN                        (CM**2 DEG. C/WATT).
CN      (10) TRC            RATIO OF STRUCTURE VOLUME TO SURFACE AREA (CM)
CN                        TIMES SPECIFIC HEAT DENSITY OF STRUCTURE
CN                        (WATT-SEC/CM**2 DEG. C).
CN      (11) CP(1)          COOLANT SPECIFIC HEAT CORRELATION.
CN      (12) CP(2)           $CP(T) = CP(1) + CP(2) * T + CP(3) * T**2$ 
CN      (13) CP(3)           $T = \text{DEG. C}, CP = (WATT-SEC/G \text{ DEG. C})$ 
CN      (14) RHOC(1)        COOLANT DENSITY CORRELATION.
CN      (15) RHOC(2)         $RHOC(T) = RHOC(1) + RHOC(2) * T + RHOC(3) * T**2$ 
CN      (16) RHOC(3)         $T = \text{DEG. C}, RHOC = (G/CM**3)$ 
CN      (17) KC(1)          COOLANT THERMAL CONDUCTIVITY CORRELATION.
CN      (18) KC(2)           $KC(T) = KC(1) + KC(2) * T + KC(3) * T**2$ 
CN      (19) KC(3)           $T = \text{DEG. C}, KC = (WATTS/CM \text{ DEG. C})$ 
CN      (20) C(1)           HEAT TRANSFER COEFFICIENT CORRELATION.
CN      (21) C(2)            $NU = C(1) + C(2) * (PE**C(3)) * (PR**C(4))$ 

```

CN (22) C(3) NU, RE, AND PR ARE DIMENSIONLESS.
 CN (23) C(4) NU IS NUSSELT NUMBER, RE IS REYNOLDS NUMBER,
 CN AND PR IS PRANDTL NUMBER.
 CN (24) MUC(1) COOLANT VISCOSITY CORRELATION.
 CN (25) MUC(2) $MUC(T) = MUC(1) + MUC(2) * T + MUC(3) * T^2$
 CN (26) MUC(3) $T = \text{DEG. C, } MUC = (G/CM-SEC).$
 CN (27) KF(1) FUEL THERMAL CONDUCTIVITY CORRELATION.
 CN (28) KF(2) $KF(T) = KF(1) + KF(2) * T + KF(3) * T^2$
 CN (29) KF(3) $T = \text{DEG. C, } KF = (\text{WATTS}/CM \text{ DEG. C}).$
 CN (30) RHOF(1) FUEL SPECIFIC HEAT DENSITY CORRELATION.
 CN (31) RHOF(2) $RHOF(T) = RHOF(1) + RHOF(2) * T + RHOF(3) * T^2$
 CN (32) RHOF(3) $+ RHOF(4) * T^3 + RHOF(5) * T^4$
 CN (33) RHOF(4) $T = \text{DEG. C, } RHOF = (\text{WATT-SEC}/CM^3 \text{ DEG. C}).$
 CN (34) RHOF(5)

DATA VALUES 11 THROUGH 34 HAVE BUILT-IN DEFAULT
 VALUES WHICH REPRESENT TYPICAL VALUES OF A SODIUM-
 COOLED FAST BREEDER REACTOR. THESE DEFAULT VALUES
 ARE OVERRIDEN BY ENTERING A VALUE FOR THIS
 PARTICULAR DATUM ON CAPD TYPE 06.

C-----
 CR INLET COOLANT TEMPERATURES (DEGREES C) (TYPE 07)
 C
 CL FORMAT----- (I2,10X,5E12.4)
 C
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
 CD =====
 CD 1-2 07
 CD
 CD 13-24 TCIN, INLET COOLANT TEMPERATURE BY THERMAL-HYDRAULIC
 CD CHANNEL.
 CD
 CD 25-36 TCIN, INLET COOLANT TEMPERATURE BY THERMAL-HYDRAULIC
 CD CHANNEL.
 CD
 CD 37-48 TCIN, INLET COOLANT TEMPERATURE BY THERMAL-HYDRAULIC
 CD CHANNEL.
 CD
 CD 49-60 TCIN, INLET COOLANT TEMPERATURE BY THERMAL-HYDRAULIC
 CD CHANNEL.
 CD
 CD 61-72 TCIN, INLET COOLANT TEMPERATURE BY THERMAL-HYDRAULIC
 CD CHANNEL.
 C
 CN AS MANY TYPE 07 CARDS MAY BE USED AS ARE NECESSARY TO
 CN ASSIGN AN INLET COOLANT TEMPERATURE FOR EACH

CN THERMAL-HYDRAULIC CHANNEL. -
 CN IF ONLY ONE INLET COOLANT TEMPERATURE IS READ IN, -
 CN THAT VALUE IS USED FOR ALL INLET TEMPERATURES. -
 CN TYPE 07 CARDS ARE NOT REQUIRED IF IFTH.LT.3 -
 C -----

C -----
 CR MASS FLOW RATE (G/CM**3 SEC) (TYPE 08) -
 C -
 CL FORMAT----- (I2,10X,5E12.4) -
 C -
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY -
 CD ===== -
 CD 1-2 08 -
 CD -
 CD 13-24 G, MASS FLOW RATE BY THERMAL-HYDRAULIC CHANNEL. -
 CD -
 CD 25-36 G, MASS FLOW RATE BY THERMAL-HYDRAULIC CHANNEL. -
 CD -
 CD 37-48 G, MASS FLOW RATE BY THERMAL-HYDRAULIC CHANNEL. -
 CD -
 CD 49-60 G, MASS FLOW RATE BY THERMAL-HYDRAULIC CHANNEL. -
 CD -
 CD 61-72 G, MASS FLOW RATE BY THERMAL-HYDRAULIC CHANNEL. -
 C -
 CN AS MANY TYPE 08 CARDS MAY BE USED AS ARE NECESSARY TO -
 CN ASSIGN A MASS FLOW RATE FOR EACH THERMAL-HYDRAULIC -
 CN CHANNEL. -
 CN IF ONLY ONE MASS FLOW RATE IS READ IN, THAT VALUE IS -
 CN USED FOR ALL MASS FLOW RATES. -
 CN TYPE 08 CARDS ARE NOT REQUIRED IF IFTH.LT.3 -
 C -----

C -----
 CR THERMAL-HYDRAULICS DATA TYPE (TYPE 09) -
 C -
 CL FORMAT----- (I2,10X,10I6) -
 C -
 CD 1-2 09 -
 CD -
 CD 13-18 ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL. -
 CD -

CD	43-48	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC	-
CD		CHANNEL.	-
CD			-
CD	49-54	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC	-
CD		CHANNEL.	-
CD			-
CD	55-60	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC	-
CD		CHANNEL.	-
CD			-
CD	61-66	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC	-
CD		CHANNEL.	-
CD			-
CD	67-72	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC	-
CD		CHANNEL.	-
C			-
CN		AS MANY TYPE 10 CARDS MAY BE USED AS ARE NECESSARY TO	-
CN		ASSIGN A VALUE FOR EACH THERMAL-HYDRAULIC CHANNEL.	-
CN			-
CN		IF ONLY ONE VALUE OF NPIN IS READ IN, THAT VALUE IS	-
CN		USED FOR ALL VALUES OF NPIN.	-
CN			-
CN		TYPE 10 CARDS ARE NOT REQUIRED IF IFTH.LT.3	-
C			-
C			-

C	-----			-
CR	H-GAP CORRECTION FACTORS (TYPE 11)			-
C				-
CL	FORMAT----- (I2,10X,5E12.4)			-
C				-
CD	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY		-
CD	=====	=====		-
CD	1-2	11		-
CD				-
CD	13-24	HCORR, THE H-GAP CORRECTION FACTOR BY AXIAL SEGMENT.		-
CD				-
CD	25-36	HCORR, THE H-GAP CORRECTION FACTOR BY AXIAL SEGMENT.		-
CD				-
CD	37-48	HCORR, THE H-GAP CORRECTION FACTOR BY AXIAL SEGMENT.		-
CD				-
CD	49-60	HCORR, THE H-GAP CORRECTION FACTOR BY AXIAL SEGMENT.		-
CD				-
CD	61-72	HCORR, THE H-GAP CORRECTION FACTOR BY AXIAL SEGMENT.		-
C				-
CN		THE TYPE 11 CARD IS NOT REQUIRED IF IFTH.LT.3 OR		-
CN		IF THE GEOMETRY IS NOT R-Z.		-
C				-
CN		AS MANY TYPE 11 CARDS MAY BE USED AS ARE NECESSARY TO		-
CN		SPECIFY A H-GAP CORRECTION FACTOR FOR EACH AXIAL		-

CD	19-24	ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL.	-
CD			-
CD	25-30	ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL.	-
CD			-
CD	31-36	ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL.	-
CD			-
CD	37-42	ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL.	-
CD			-
CD	43-48	ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL.	-
CD			-
CD	49-54	ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL.	-
CD			-
CD	55-60	ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL.	-
CD			-
CD	61-66	ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL.	-
CD			-
CD	67-72	ITHTYP, THE THERMAL-HYDRAULICS DATA TYPE BY CHANNEL.	-
C			-
CN		AS MANY TYPE 09 CARDS MAY BE USED AS ARE NECESSARY TO	-
CN		ASSIGN A DATA TYPE TO EACH THERMAL-HYDRAULIC CHANNEL.	-
CN			-
CN		TYPE 09 CARDS ARE NOT REQUIRED IF ITYPE.EQ.1.	-
C			-
C			-

C	-----		-
CR	NUMBER OF PINS (TYPE 10)		-
C			-
CL	FORMAT----- (I2,10X,10I6)		-
C			-
CD	COLUMNS	CONTENTS...IMPLICATIONS, IF ANY	-
CD	=====	=====	-
CD	1-2	10	-
CD			-
CD	13-16	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC CHANNEL.	-
CD			-
CD	19-24	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC CHANNEL.	-
CD			-
CD	25-30	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC CHANNEL.	-
CD			-
CD	31-36	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC CHANNEL.	-
CD			-
CD	37-42	NPIN, THE NUMBER OF FUEL PINS BY THERMAL-HYDRAULIC CHANNEL.	-
CD			-
CD			-

CN SEGMENT.
CN
CN THE SAME SET OF H-GAP CORRECTION FACTORS ARE USED FOR
CN EACH THERMAL-HYDRAULICS CHANNEL.
C
C

```

C-----
CR      MASS FLOW RATE TIME DEPENDENCE (TYPE 12)
C
CL      FORMAT----- (I2,10X,3E12.4)
C
CD      COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD      =====
CD      1-2              12
CD
CD      13-24            TST, TIME TO BEGIN MASS FLOW RATE CHANGE (SEC)
CD
CD      25-36            A1      MASS FLOW RATE CORRELATION
CD                        (BEGINS AT TIME TST) .
CD      37-48            A2       $G(T) = G(0) * (1 + A1 * (T - TST) + A2 * (T - TST) ** 2)$ 
C
CN      THE MASS FLOW RATES AT EACH THERMAL-HYDRAULIC
CN      CHANNEL (G) IS UNCHANGED UNTIL T.GT.TST, THEN
CN       $G(T) = G(0) * (1 + A1 * (T - TST) + A2 * (T - TST) ** 2)$ 
CN      ALL G VALUES ARE EFFECTED THE SAME WAY.
CN
CN      THE TYPE 12 CARD IS NOT REQUIRED IF IFTH.LT.3
CN
CN      IF NO TYPE 12 CARDS ARE ENTERED, SET TST=A1=A2=0.0.
C-----

```

```

C
CR          INITIAL AVERAGE COOLANT TEMPERATURES (DEGREES K)
CF          (TYPE 13)
C
CL  FORMAT----- (I2,10X,5E12.4)
C
CD  COLUMNS          CONTENTS...IMPLICATIONS, IF ANY
CD  =====
CD  1-2                13
CD
CD  13-24              TC, INITIAL AVERAGE COOLANT TEMPERATURE BY THERMAL-
CD                      HYDRAULIC REGION.
CD
CD  25-36              TC, INITIAL AVERAGE COOLANT TEMPERATURE BY THERMAL-
CD                      HYDRAULIC REGION.

```

CD
 CD 37-48 TC, INITIAL AVERAGE COOLANT TEMPERATURE BY THERMAL-
 CD HYDRAULIC REGION.
 CD
 CD 49-60 TC, INITIAL AVERAGE COOLANT TEMPERATURE BY THERMAL-
 CD HYDRAULIC REGION.
 CD
 CD 61-72 TC, INITIAL AVERAGE COOLANT TEMPERATURE BY THERMAL-
 CD HYDRAULIC REGION.
 C
 CN IF R-Z GEOMETRY, INITIAL AVERAGE COOLANT TEMPERATURES
 CN ARE GIVEN IN ORDER TC(NAX,NCH). IF NOT R-Z GEOMETRY,
 CN THEY ARE GIVEN IN ORDER TC(NCH).
 CN
 CN IF CARD TYPE 13 IS NOT ENTERED, INITIAL AVERAGE
 CN COOLANT TEMPERATURES ARE SET TO THE BASE COOLANT
 CN TEMPERATURE.
 C
 C-----

C-----
 CR INITIAL AVERAGE FUEL TEMPERATURES (DEGREES K)
 CR (TYPE 14)
 C
 CL FORMAT----- (I2,10X,5E12.4)
 C
 CD COLUMNS CONTENTS...IMPLICATIONS, IF ANY
 CD =====
 CD 1-2 14
 CD
 CD 13-24 TF, INITIAL AVERAGE FUEL TEMPERATURE BY THERMAL-
 CD HYDRAULIC REGION.
 CD
 CD 25-36 TF, INITIAL AVERAGE FUEL TEMPERATURE BY THERMAL-
 CD HYDRAULIC REGION.
 CD
 CD 37-48 TF, INITIAL AVERAGE FUEL TEMPERATURE BY THERMAL-
 CD HYDRAULIC REGION.
 CD
 CD 49-60 TF, INITIAL AVERAGE FUEL TEMPERATURE BY THERMAL-
 CD HYDRAULIC REGION.
 CD
 CD 61-72 TF, INITIAL AVERAGE FUEL TEMPERATURE BY THERMAL-
 CD HYDRAULIC REGION.
 C
 CN IF R-Z GEOMETRY, INITIAL AVERAGE FUEL TEMPERATURES
 CN ARE GIVEN IN ORDER TF(NAX,NCH). IF NOT R-Z GEOMETRY,
 CN THEY ARE GIVEN IN ORDER TF(NCH).
 CN
 CN

CN	IF CARD TYPE 14 IS NOT ENTERED, INITIAL AVERAGE FUEL	-
CN	TEMPERATURES ARE SET TO THE BASE FUEL TEMPERATURE.	-
C		-
C	-----	

APPENDIX C

Listing of Binary Interface Files

```

C*****
C
C          PREPARED 2/8/74 AT ANL
C
CF          FXCTRL
CE          CODE-DEPENDENT BINARY INPUT FILE FOR FX2
C
CN          THIS FILE IS ALWAYS REQUIRED BY FX2.
CN          IT CONTAINS PROBLEM CONTROL INFORMATION AND
CN          DRIVING FUNCTION INFORMATION FOR THE TRANSIENT.
CN
CN          NOTE THAT THIS IS A DOUBLE PRECISION FILE ON
CN          SYSTEMS WHERE MULT=2.
C
C*****

```

```

C-----
CS          FILE STRUCTURE
CS
CS          RECORD TYPE                                PRESENT IF
CS          =====
CS          FILE IDENTIFICATION                        ALWAYS
CS          FILE CONTROL AND PROBLEM TITLE            ALWAYS
CS          FX2 INTEGER CONTROL INPUT                 ALWAYS
CS          FX2 FLOATING POINT CONTROL INPUT          ALWAYS
CS          TRANSIENT DRIVING FUNCTIONS               NREGD.GT.0
CS          TIME DEPENDENT FIXED SOURCE              ALWAYS
C
C-----

```

CD NREGD NUMBER OF DRIVING FUNCTIONS.

```

C-----
CR          FILE IDENTIFICATION (TYPE 1)
C
CC          ALWAYS PRESENT
C
CL          HNAME, (HUSE(I), I=1,2), IVERS
C
CW          1+3*MULT
C
CD          HNAME                      HOLLERITH FILE NAME - FXCTRL - (A6).
CD          HUSE                      HOLLERITH USER IDENTIFICATION (2A6).
CD          IVERS                      FILE VERSION NUMBER.
CD          MULT                      DOUBLE PRECISION PARAMETER.
CD          MULT=1, A6 WORD IS SINGLE WORD.

```


CD =2, A6 WORD IS DOUBLE WORD.

C

C-----

C-----

CR FILE CONTROL AND PROBLEM TITLE (TYPE 2)

C

CC ALWAYS PRESENT

C

CL (TITLE(I), I=1, 11), MAXSIZ, MAXBLK, IPEDT, NREST, NREGD

C

CW 5+11*MULT

C

CD TITLE HOLLERITH PROBLEM TITLE (A6).

CD MAXSIZ SIZE OF FAST CORE STORAGE ARRAY IN REAL*8

CD WORDS (SINGLE WORDS ON CDC SYSTEMS).

CD MAXBLK SIZE OF BULK CORE STORAGE ARRAY IN REAL*8

CD WORDS. (SINGLE LCM WORDS ON CDC SYSTEMS)

CD IPEDT BPOINTER DEBUGGING EDIT.

CD IPEDT=0, NO DEBUGGING EDIT.

CD =1, DEBUGGING DUMP PRINTOUT.

CD =2, DEBUGGING TRACE PRINTOUT.

CD =3, FULL DEBUGGING PRINTOUT.

CD NREST RESTART PROBLEM INDICATOR.

CD NREST=0, NOT A RESTART PROBLEM.

CD =1, IS A RESTART PROBLEM.

C

C-----

C-----

CR FX2 INTEGER CONTROL INPUT (TYPE 3)

C

CC ALWAYS PRESENT

C

CL IPK, NTHF, NFDBK, ICMPFL, NIMPCR, IPTYPE, NDOSS, LOOPSS, NAMPMX, NRHOB, C,

CL 1NGAMMX, NIROMX, NOUTMX, NROSMX, NITSTP, (IEDF(I), I=1, 10)

C

CW 25

C

CD IPK KINETICS OPTIONS.

CD IPK=0, SPACE-TIME KINETICS.

CD =1, POINT KINETICS.

CD NTHF THERMAL HYDRAULICS OPTION

CD NTHF=0, DO NOT DO THERMAL HYDRAULICS

CD =1, DO THERMAL HYDRAULICS

CD NFDBK TEMPERATURE FEEDBACK OPTION.

CD NFDBK=0, DO NOT TEMPERATURE-CORRECT CROSS

CD SECTIONS.

CD		=1, TEMPERATURE-CORRECT CROSS SECTIONS.	-
CD	ICMPFL	COMPOSITION OPTION.	-
CD		ICMPFL=0, EACH MESH CELL IS A COMPOSITION.	-
CD		=1, EACH REGION IS A COMPOSITION. THIS	-
CD		OPTION IS TURNED OFF ONCE THE MESH	-
CD		STARTS TO MOVE DURING THE HYDRO-	-
CD		DYNAMICS CALCULATION.	-
CD	NTMPCR	TEMPERATURE FEEDBACK ITERATION OPTION.	-
CD		NTMPCR=0, DO NOT ITERATE BETWEEN NEUTRONICS	-
CD		AND THERMAL-HYDRAULICS AT	-
CD		STEADY STATE.	-
CD		=1, ITERATE NEUTRONICS AND THERMAL-	-
CD		HYDRAULICS TO CONVERGENCE IN	-
CD		STEADY STATE.	-
CD	IPTYPE	PROBLEFM TYPE.	-
CD		IPTYPE=0, HOMOGENEOUS PROBLEM.	-
CD		=1, INHOMOGENEOUS VOLUMETRIC FIXED	-
CD		SOURCE PRESENT.	-
CD	NDOSS	STEADY STATE OPTION.	-
CD		NDOSS=0, DO STEADY STATE REAL AND ADJOINT	-
CD		FLUX CALCULATION.	-
CD		=1, BYPASS STEADY STATE REAL AND ADJOINT	-
CD		FLUX CALCULATION.	-
CD	LOOPSS	MAXIMUM NUMBER OF NEUTRONICS/FEEDBACK	-
CD		ITERATIONS ALLOWED AT STEADY STATE.	-
CD	NAMPMX	UNUSED AT PRESENT	-
CD	NRHOBC	UNUSED AT PRESENT	-
CD	NGAMMX	MAXIMUM NUMBER OF GAMMA FACTOR ITERATIONS	-
CD		ALLOWED AT ANY SHAPE STEP.	-
CD	NTROMX	MAXIMUM NUMBER OF TEMPERATURE CORRECTION TO	-
CD		REACTIVITY ITERATIONS ALLOWED AT ANY REACTIVITY-	-
CD		STEP DURING UPDATE SWEEP.	-
CD	NOUTMX	MAXIMUM NUMBER OF OUTER (FISSION SOURCE)	-
CD		ITERATIONS ALLOWED DURING ANY FLUX SHAPE	-
CD		CALCULATION.	-
CD	NROSMX	MAXIMUM NUMBER OF REACTIVITY STEPS ALLOWED	-
CD		IN ANY SHAPE STEP (1.LE.NROSMX.LE.20).	-
CD	NITSTP	LENGTH OF INITIAL TIME STEP IN GENERATION	-
CD		TIMES.	-
CD	IEDF(1)	INPUT BINARY FILE EDIT.	-
CD		IEDF(1)=0, NO EDIT OF INPUT BINARY FILES.	-
CD		=1, EDIT INPUT BINARY FILES EXCEPT FOR	-
CD		MACROSCOPIC CROSS SECTIONS AND	-
CD		REGION MAP.	-
CD		=2, EDIT ALL INPUT BINARY FILES.	-
CD	IEDF(2)	MICROSCOPIC CROSS SECTION EDIT.	-
CD		IEDF(2)=0, PARTIAL EDIT OF MICROSCOPIC CROSS	-
CD		SECTION HOMOGENIZATION.	-
CD		=1, ALSO EDIT INPUT MICROSCOPIC CROSS	-
CD		SECTIONS DURING MICROSCOPIC CROSS	-

```

CD          SECTION HOMOGENIZATION.
CD          IEDF (3)  THERMAL-HYDRAULICS INPUT EDIT FLAG.
CD          IEDF (3)=0, DO NOT EDIT THERMAL-HYDRAULICS
CD          =1, PARTIAL EDIT OF THERMAL-HYDRAULICS
CD          INPUT
CD          =2, FULL EDIT OF THERMAL-HYDRAULICS
CD          INPUT
CD          IEDF (4)  UNUSED AT PRESENT
CD          IEDF (5)  DISK EDIT FLAG.
CD          IEDF (5)=0, NO DISK EDIT
CD          =1, BRIEF DISK EDIT
CD          =2, DETAILED DISK EDIT
CD          POINTWISE POWERS, COOLANT AND
CD          FUEL TEMPERATURES.
CD          IEDF (6)  FUEL AND COOLANT TEMPERATURE EDIT FLAG
CD          IEDF (6)=0, DO NOT EDIT FUEL AND COOLANT
CD          TEMPERATURES.
CD          =1, EDIT FUEL AND COOLANT TEMPERATURES
CD          AFTER EACH SHAPE STEP.
CD          IEDF (7)  REACTIVITY STEP SUMMARY EDIT
CD          IEDF (7)=0, BRIEF EDIT.
CD          =1, NORMAL EDIT.
CD          =2, DETAILED EDIT.
CD          IEDF (8)  POWER DENSITY EDIT (REACTIVITY STEP)
CD          IEDF (8)=0, DO NOT EDIT POWER DENSITY AFTER
CD          REACTIVITY STEPS.
CD          =N, EDIT POWER DENSITY AFTER EVERY
CD          N REACTIVITY STEPS.
CD          IEDF (9)  FLUX SHAPE CALCULATION EDIT
CD          IEDF (9)=0, MINIMUM EDIT OF EACH FLUX SHAPE
CD          CALCULATION.
CD          =1, EDIT ITERATION HISTORY AT EACH FLUX
CD          SHAPE CALCULATION.
CD          =2, EDIT ITERATION HISTORY AND
CD          MULTIGROUP FLUX SHAPE AT EACH FLUX
CD          SHAPE CALCULATION.
CD          IEDF (10) POWER DENSITY EDIT (SHAPE STEP).
CD          IEDF (10)=0, DO NOT EDIT POWER DENSITIES
CD          AFTER SHAPE STEPS
CD          =N, EDIT POWER DENSITIES AFTER EVERY
CD          N SHAPE STEPS.
C
C-----

```

```

C-----
CR          FX2 FLOATING POINT CONTROL INPUT (TYPE 4)
C
CC          ALWAYS PRESENT
C

```

CL	TEND, AMPMIN, RHOMIN, TMPMAX, AMPMAX, EPSAMP, EPSGAM, EPSPK, EPSTRO,	-
CL	1EPCLOW, EPSKEF, EPSLAM, EPSFLN, EPSINC, EPSTMP, DTMP SH, DTMPRH, DTSHMX,	-
CL	2DTRHMX, DAMPSH, DAMPRH, DPSISH, DCTRST, DPTRST, POWIN, RKEFF, OKEFF,	-
CL	3FLNMON, PSINRM, OUTRHO	-
C		-
CW	30*MULT	-
C		-
CD	TEND	END OF PROBLEM TIME (SEC).
CD	AMPMIN	MINIMUM ALLOWED VALUE OF AMPLITUDE, N(T).
CD	PHOMIN	MINIMUM ALLOWED VALUE OF REACTIVITY.
CD	TMPMAX	MAXIMUM ALLOWED FUEL TEMPERATURE (DEG. K).
CD	AMPMAX	MAXIMUM ALLOWED VALUE OF AMPLITUDE, N(T).
CD	EPSAMP	UNUSED AT PRESENT
CD	EPSGAM	CONVERGENCE CRITERION FOR GAMMA FACTOR
CD		ITERATION AT EACH SHAPE STEP.
CD	EPSPK	CONVERGENCE CRITERION FOR AMPLITUDE FUNCTION
CD		EQUATION SOLUTION.
CD	EPSTRO	CONVERGENCE CRITERION FOR TEMPERATURE
CD		CORRECTION TO REACTIVITY ITERATION.
CD	EPCLOW	FACTOR BY WHICH TIME STEP SELECTOR TESTS ARE
CD		TIGHTENED AT OR NEAR PROMPT CRITICAL.
CD	EPSKEF	EIGENVALUE CONVERGENCE CRITERION FOR STEADY
CD		STATE CALCULATION.
CD	EPSLAM	POINTWISE FISSION SOURCE CONVERGENCE CRITERION
CD		FOR STEADY STATE SHAPE CALCULATION.
CD	EPSFLN	AVERAGE FISSION SOURCE CONVERGENCE CRITERION
CD		FOR STEADY STATE SHAPE CALCULATION.
CD	EPSINC	FACTORS BY WHICH POINTWISE AND AVERAGE FISSION
CD		SOURCE CONVERGENCE CRITERIA WILL BE INCREASED
CD		FOR TIME-DEPENDENT CALCULATION.
CD	EPSTMP	POINTWISE POWER DENSITY CONVERGENCE CRITERIA
CD		FOR STEADY-STATE NEUTRONICS/THERMAL-HYDRAULICS
CD		FEEDBACK ITERATION.
CD	DTMP SH	MAXIMUM ALLOWABLE FUEL TEMPERATURE CHANGE
CD		(DEG. K) OVER A SHAPE STEP.
CD	DTMPRH	MAXIMUM ALLOWABLE FUEL TEMPERATURE CHANGE
CD		(DEG. K) OVER A REACTIVITY STEP.
CD	DTSHMX	MAXIMUM ALLOWABLE SHAPE STEP LENGTH (SEC).
CD	DTRHMX	MAXIMUM ALLOWABLE REACTIVITY STEP LENGTH (SEC).
CD	DAMPSH	MINIMUM NUMBER OF SHAPE STEPS ALLOWED PER
CD		DECADE OF AMPLITUDE FUNCTION CHANGE.
CD	DAMPRH	MINIMUM NUMBER OF REACTIVITY STEPS ALLOWED PER
CD		DECADE OF AMPLITUDE FUNCTION CHANGE.
CD	DPSISH	MAXIMUM ALLOWABLE CHANGE IN GROUP- AND POINT-
CD		DEPENDENT LINEARLY-EXTRAPOLATED SHAPE FUNCTION
CD		DURING A SHAPE STEP.
CD	DCTRST	TOTAL COMPUTING TIME (MIN.) WHICH WILL BE
CD		ALLOWED TO ELAPSE BETWEEN RESTART DUMPS. THIS
CD		OPTION IS OVER-RIDDEN IF A NON-ZERO VALUE IS
CD		ENTERED FOR DPTRST (SEE BELOW).

```

CD   DPTRST      TOTAL PROBLEM TIME (SEC) WHICH WILL BE ALLOWED -
CD               TO ELAPSE BETWEEN RESTART DUMPS.             -
CD   POWIN       INITIAL POWER (WATTS).                        -
CD   RKEFF       K-EFFECTIVE FOR REACTOR FOR USE IN A PROBLEM -
CD               WITH A FIXED INHOMOGENEOUS SOURCE AND IN ANY -
CD               PROBLEM IN WHICH THE REAL AND ADJOINT STEADY -
CD               STATE CALCULATION IS BYPASSED.                 -
CD   OKEFF       K-EFFECTIVE FOR THE SOURCE-FREE ADJOINT       -
CD               CALCULATION OF A REACTOR IN WHICH A FIXED     -
CD               INHOMOGENEOUS SOURCE IS PRESENT, NEEDED ONLY -
CD               IF THE REAL AND ADJOINT STEADY STATE           -
CD               CALCULATION IS BYPASSED.                       -
CD   FLNMON      ANY POINTWISE FISSION SOURCE WILL BE NEGLECTED -
CD               IN THE POINTWISE FISSION SOURCE CONVERGENCE -
CD               TEST IF IT IS LESS THAN THIS FACTOR TIMES THE -
CD               AVERAGE FISSION SOURCE.                       -
CD   PSINRM      ERROR REDUCTION FACTOR TO BE ACHIEVED BY EACH -
CD               SERIES OF INNER ITERATIONS FOR EACH GROUP    -
CD               DURING A SHAPE CALCULATION - STRONGLY        -
CD               RECOMMENDED THAT A VALUE OF 0.08 BE USED.     -
CD   GUTRHO      INITIAL ESTIMATE OF SPECTRAL RADIUS FOR OUTER -
CD               ITERATION OF TIME-DEPENDENT SHAPE CALCULATION -
CD               - STRONGLY RECOMMENDED THAT A VALUE OF 0.0    -
CD               BE USED.                                       -
C-----

```

```

C-----
CR               TRANSIENT DRIVING FUNCTIONS (TYPE 5)         -
C               -
CC               PRESENT IF NREGD.GT.0                         -
C               -
CL               (DFRLAB(I),I=1,NREGD),(DFMLAB(I),I=1,NREGD), -
CL               1((DRF(J,I),J=1,4),I=1,NREGD)                -
C               -
CW               6*NREGD*MULT                                  -
C               -
CD   DFRLAB(I)    REGION LABEL OF REGION TO WHICH I-TH DRIVING -
CD               FUNCTION IS TO BE APPLIED (HOLLERITH - A6).    -
CD   DFMLAB(I)    UNIQUE MATERIAL LABEL TO WHICH I-TH DRIVING -
CD               FUNCTION IS TO BE APPLIED (HOLLERITH - A6).    -
CD   DRF(1,I)     PROBLEM TIME (SEC) AT WHICH I-TH DRIVING    -
CD               FUNCTION BEGINS TO APPLY.                      -
CD   DRF(2,I)     PROBLEM TIME (SEC) AT WHICH I-TH DRIVING    -
CD               FUNCTION CEASES TO APPLY.                      -
CD   DRF(3,I)     LINEAR COEFFICIENT FOR I-TH DRIVING FUNCTION -
CD               (OR STEP CHANGE IF DRF(1,I)=DRF(2,I)).         -
CD   DRF(4,I)     QUADRATIC COEFFICIENT FOR I-TH DRIVING      -
CD               FUNCTION (NOT USED IF DRF(1,I)=DRF(2,I)).      -

```

```

C
CN      LET THE I-TH DRIVING FUNCTION APPLY TO UNIQUE
CN      MATERIAL M IN REGION R. ALSO, LET
CN
CN      TS=DRF(1,I),
CN      TE=DRF(2,I).
CN
CN      IF VF(R,M,TS) IS THE VOLUME FRACTION OF UNIQUE
CN      MATERIAL M IN REGION R AT TIME TS, THEN
CN
CN      VF(R,M,T)=VF(R,M,TS)+DRF(3,I)*(T-TS)
CN      +DRF(4,I)*(T-TS)**2,
CN      TS.LE.T.LE.TE.
CN
CN      IF, HOWEVER, TS=TE, THEN A SHAPE STEP IS
CN      FORCED TO END AT T=TS, AND, BEFORE THE START
CN      OF THE NEXT REACTIVITY STEP, VF(R,M,T) IS
CN      MODIFIED IN A STEP FASHION AS FOLLOWS:
CN
CN      VF(R,M,T)=VF(R,M,TS)+DRF(3,I), T.GE.TS.
CN
CN      THIS SECOND OPTION IS INTENDED TO BE USED
CN      PRIMARILY TO FORCE A SHAPE STEP TO END AT A
CN      SPECIFIED TIME, TS (DRF(3,I)=0.0).
C
C-----
CR      TIME DEPENDENT FIXED SOURCE INFORMATION (TYPE 6).
C
CC      ALWAYS PRESENT
C
CL      ITDSRC,TISHCH,FCSHCH
C
CW      3*MULT
C
CD      ITDSRC      FLAG TO INDICATE IF FIXED SOURCE IS TO BE
CD                  CONSIDERED TIME DEPENDENT (0/1) (NO/YES)
CD      TISHCH      TIME AT WHICH FIXED SOURCE IS ALTERED (SEC.)
CD      FCSHCH      FACTOR BY WHICH FIXED SOURCE (ALL GROUPS
CD                  AND MESH POINTS) IS MULTIPLIED
C
C-----
CEOF
C*****
C
C      PREPARED 2/15/74 AT ANL
C
CF      FXHMOG
CE      CODE-DEPENDENT BINARY INPUT FILE FOR FX2

```

C
 CN RECORDS 1-3 AND 6 OF FXHMOG ARE ALWAYS
 CN REQUIRED BY FX2. RECORDS 4 AND 5 ARE REQUIRED
 CN IF THE MACROSCOPIC CROSS SECTION FILE, XSCON,
 CN DOES NOT EXIST AS AN OLD FILE. FXHMOG CONTAINS
 CN ISOTOPE-TO-MATERIAL AND MATERIAL-TO-REGION
 CN CROSS SECTION HOMOGENIZATION INFORMATION.
 CN
 CN NOTE THAT THIS IS A DOUBLE PRECISION FILE ON
 CN SYSTEMS WHERE MULT=2.
 C
 C*****

CS	FILE STRUCTURE	
CS	RECORD TYPE	PRESENT IF
CS	=====	=====
CS	FILE IDENTIFICATION	ALWAYS
CS	FILE CONTROL	ALWAYS
CS	MATERIAL, REGION, AND ZONE LABELS	ALWAYS
CS	LIST OF ISOTOPE LABELS	ALWAYS
CS	ISOTOPE-TO-MATERIAL HOMOGENIZATION	ALWAYS
CS	INFORMATION	
CS	MATERIAL-TO-REGION HOMOGENIZATION	ALWAYS
CD	INFORMATION	

CD	MISLTH	LENGTH OF ISOTOPE-TO-MATERIAL CROSS SECTION HOMOGENIZATION TABLE.
CD	NISOU	IF .GT.0, NUMBER OF DIFFERENT UNIQUE ISOTOPES APPEARING IN THE DIMIX ARRAY AND, HENCE, THE LENGTH OF THE DITBL ARRAY.
CD		IF .LT.0, RECORDS 4 AND 5 ARE DUMMY RECORDS AND IABS(NISOU) IS THE LENGTH OF THE DUMMY DITBL ARRAY.
CD	MMSLTH	LENGTH OF MATERIAL-TO-REGION CROSS SECTION HOMOGENIZATION TABLE.
CD	NREGM	NUMBER OF REGIONS FOR WHICH HOMOGENIZATION SPECIFICATIONS HAVE BEEN GIVEN, .GE.NREG.
CD	NMATU	NUMBER OF GENERIC MATERIALS USED IN FXHMOG, .LE.NMAT FROM XSCON.
CD	NMATU	NUMBER OF UNIQUE MATERIALS USED IN FXHMOG, .LE.NMAT FROM XSCON.
CD	NREG	NUMBER OF REGIONS USED TO DESCRIBE PROBLEM GEOMETRY (MUST BE CONSISTENT WITH NREG FROM GEODST).

CD NZONE NUMBER OF ZONES USED TO DESCRIBE PROBLEM
 CD GEOMETRY (MUST BE CONSISTENT WITH NZONE FROM
 CD GEODST).

C-----
 CR FILE IDENTIFICATION (TYPE 1) =
 C - - - - -
 CC ALWAYS PRESENT - - - - -
 C - - - - -
 CL HNAME, (HUSE(I), I=1,2), IVERS - - - - -
 C - - - - -
 CW 1+3*MULT - - - - -
 C - - - - -
 CD HNAME HOLLERITH FILE NAME - FXHMOG - (A6). - - - - -
 CD HUSE HOLLERITH USER IDENTIFICATION (2A6). - - - - -
 CD IVERS FILE VERSION NUMBER. - - - - -
 CD MULT DOUBLE PRECISION PARAMETER. - - - - -
 CD MULT=1, A6 IS SINGLE WORD. - - - - -
 CD =2, A6 IS DOUBLE WORD. - - - - -
 C - - - - -
 C-----

C-----
 CR FILE CONTROL (TYPE 2) - - - - -
 C - - - - -
 CC ALWAYS PRESENT - - - - -
 C - - - - -
 CL MISLTH, NISOU, MMSLTH, NREGM, NMATU, NTMATU, NREG, NZONE - - - - -
 C - - - - -
 CW 8 - - - - -
 C - - - - -
 CN FXHMOG MUST BE CONSISTENT WITH THE XSCON AND - - - - -
 CN GEODST FILES BEING USED FOR A PARTICULAR - - - - -
 CN PROBLEM. IN THAT SENSE, NREGM, THE NUMBER OF - - - - -
 CN REGIONS FOR WHICH MIXING INSTRUCTIONS ARE - - - - -
 CN GIVEN ON FXHMOG, MUST BE .GE.NREG, WHILE NMATU - - - - -
 CN AND NTMATU MUST BE .LE.THE VALUES OF NMAT AND - - - - -
 CN NTMAT, RESPECTIVELY, GIVEN ON XSCON. - - - - -
 C - - - - -
 C-----

C-----
 CR MATERIAL, REGION, AND ZONE LABELS (TYPE 3) - - - - -
 C - - - - -
 CC ALWAYS PRESENT - - - - -
 C - - - - -
 CL (UMNAM1(M), M=1, NTMATU), (AMNAM1(N), N=1, NMATU), - - - - -


```

CL 1 (REGLAB(I), I=1, NREG), (ZONLAB(I), I=1, NZONE),
CL 2 (NUMAM1(M), M=1, NTMATU)
C
CW NTMATU+ (NTMATN+NMATU+NREG+NZONE) *MULT
C
CD UMNAM1          HOLLERITH UNIQUE MATERIAL LABELS (A6) OF THE
CD                  UNIQUE MATERIALS SPECIFIED IN FXHMOG.
CD AMNAM1          HOLLERITH GENERIC MATERIAL LABELS (A6) ASSIGNED
CD                  TO THE MATERIALS WHICH ARE SPECIFIED IN FXHMOG.
CD REGLAB          REGLAB(I) IS THE REGION LABEL ASSIGNED TO THE
CD                  I-TH REGION ON THE FILE GEODST.
CD ZONLAB          ZONLAB(I) IS THE ZONE LABEL ASSIGNED TO THE
CD                  I-TH ZONE ON THE FILE GEODST.
CD NUMAM1          NUMAM1(M) IS THE GENERIC MATERIAL NUMBER
CD                  (POSITION IN THE AMNAM1 ARRAY) OF THE M-TH
CD                  UNIQUE MATERIAL IN UMNAM1.
C
CN                FOR THE SAKE OF CONSISTENCY WITH THE MACRO-
CN                SCOPIC MATERIAL CROSS SECTION FILE, XSCON,
CN                EACH ELEMENT IN THE ARRAYS UMNAM1 AND AMNAM1
CN                MUST BE PRESENT IN THE ARRAYS UMNAM1 AND
CN                AMNAME FROM XSCON, RESPECTIVELY. THAT IS,
CN                XSCON CAN CONTAIN CROSS SECTIONS FOR MORE
CN                UNIQUE MATERIALS THAN ARE SPECIFIED ON FXHMOG
CN                AND USED IN FX2 FOR A PARTICULAR PROBLEM.
C
CN                FOR THE SAKE OF CONSISTENCY WITH THE GEOMETRY
CN                FILE, GEODST, THE ORDERING OF THE LABELS IN
CN                THE REGLAB AND ZONLAB ARRAYS MUST BE
CN                CONSISTENT WITH THE NUMBERING OF THE REGIONS
CN                AND ZONES, RESPECTIVELY, AS USED IN GEODST.
C
C-----

```

```

C-----
CR          LIST OF ISOTOPE LABELS (TYPE 4)
C
CC          ALWAYS PRESENT (DUMMY IF NISOU.LT.0).
C
CL          (DITBL(I), I=1, IABS(NISOU))
C
CW          IABS(NISOU) *MULT
C
CD DITBL          DITBL IS THE LIST OF THE UNIQUE ISOTOPE LABELS
CD                  (A6) OF THE ISOTOPES WHICH APPEAR IN THE DIMIY
CD                  ARRAY, WITH EACH UNIQUE ISOTOPE LABEL
CD                  APPEARING ONCE.
CD                  IF NISOU.LT.0, DITBL IS A DUMMY ARRAY WITH ALL
CD                  BLANK ENTRIES.

```

```

C
CN      RECORDS 4 (DITBL) AND 5 WILL BE DUMMY RECORDS
CN      IF THIS FXHMOG WAS WRITTEN BY THE FX2 BCD
CN      INPUT PROCESSOR FOR A PROBLEM WHERE THE FILE
CN      XSCON HAD BEEN SPECIFIED AS AN OLD FILE. IN
CN      THIS CASE, THIS ISOTOPE-TO-MATERIAL HOMO-
CN      GENIZATION INFORMATION WILL NOT BE NEEDED
CN      BY FX2.
C
C-----

```

```

C-----
CR      ISOTOPE-TO-MATERIAL HOMOGENIZATION INFORMATION (TYPE 5)
C
CC      ALWAYS PRESENT (DUMMY IF NISOU.LT.0)
C
CL      ((DIMIX(K,I),K=1,4),I=1,MISLTH),((ATMDEN(K,I),K=1,2),I=1,MISLTH),
CL      1(DMTBL(M),M=1,NTMATU),(MSPEC(M),M=1,NTMATU),
CL      2(IFTMP(M),M=1,NTMATU)
C
CW      2*NTMATU+(NTMATU+6*MISLTH)*MULT
C
CD      DIMIX      ISOTOPE-TO-MATERIAL MIXING TABLE CONSISTING
CD                  OF 4*MSPEC(M) ENTRIES FOR EACH UNIQUE
CD                  MATERIAL, M. THESE ENTRIES ARE THE LABELS OF
CD                  THE UNIQUE ISOTOPES WHICH COMPISE UNIQUE
CD                  MATERIAL M AT FOUR TEMPERATURES.
CD      ATMDEN      ATOMIC DENSITIES (ATOMS/BARN-CC) FOR THE
CD                  MIXING TABLE. IT CONSISTS OF 2*MSPEC(M) ENTRIES-
CD                  FOR EACH UNIQUE MATERIAL M, CORRESPONDING TO
CD                  THE 4*MSPEC(M) ENTRIES IN DIMIX. FOR A
CD                  PARTICULAR UNIQUE ISOTOPE IN MATERIAL M, THE
CD                  SAME ATOM DENSITY IS USED AT ALL FOUR
CD                  TEMPERATURES.
CD      DMTBI      DMTBL(M) IS THE UNIQUE MATERIAL LABEL (A6) OF
CD                  THE M-TH UNIQUE MATERIAL BEING SPECIFIED BY
CD                  DIMIX AND ATMDEN.
CD      MSPEC      MSPEC(M) IS THE NUMBER OF UNIQUE ISOTOPES USED
CD                  TO CONSTRUCT UNIQUE MATERIAL M AT EACH
CD                  TEMPERATURE.
CD      IFTMP      IFTMP(M)=1 IF THE M-TH UNIQUE MATERIAL IS
CD                  TEMPERATURE-DEPENDENT; =0 IF IT IS NOT.
C
CN      THE UNIQUE MATERIAL LABELED DMTBL(M) IS
CN      COMPOSED OF MSPEC(M) UNIQUE ISOTOPES AT EACH
CN      TEMPERATURE. THESE ISOTOPES AND THE CORRE-
CN      SPONDING ATOMIC DENSITIES ARE GIVEN IN ORDER
CN      IN THE ARRAYS DIMIX AND ATMDEN, RESPECTIVELY.
CN      THE FIRST ISOTOPE LABELS AND ATOMIC DENSITIES

```

CN FOR MATERIAL M ARE FOUND AT DIMIX(1,I) AND -
 CN ATMDEN(I), WHERE I=1 + SUM OF THE FIRST (M-1) -
 CN VALUES IN MSPEC. -
 CN IF IFIMP(M)=1, THEN ONE OR MORE OF THE ISOTOPES -
 CN USED TO CONSTRUCT UNIQUE MATERIAL M WILL HAVE -
 CN NON-BLANK UNIQUE ISOTOPE LABELS IN THE K=2, 3, -
 CN AND 4 POSITIONS OF DIMIX(I,K). FISSION AND -
 CN CAPTURE CROSS SECTIONS WILL BE GENERATED AT -
 CN FOUR TEMPERATURES FOR THIS MATERIAL. -
 CN IF NISOU IS NEGATIVE, THEN RECORD 5 IS A -
 CN DUMMY RECORD. -
 C -
 C -----

C-----
 CR MATERIAL-TO-REGION HOMOGENIZATION INFORMATION (TYPE 6) -
 C -
 CC ALWAYS PRESENT -
 C -
 CL (DMMIX(I), I=1, MMSLTH), (VOLFR(I), I=1, MMSLTH), -
 CL 1 (DRTBL(N), N=1, NREGM), (MRSPEC(N), N=1, NREGM) -
 C -
 CW NREGM + (2*MMSLTH + NREGM) * MULT -
 C -
 CD DMMIX DMMIX IS THE MATERIAL-TO-REGION MIXING TABLE. -
 CD FOR THE REGION WHOSE LABEL IS THE N-TH ENTRY -
 CD IN DRTBL, THERE ARE MRSPEC(N) ENTRIES IN -
 CD DMMIX, EACH ENTRY BEING THE LABEL OF A UNIQUE -
 CD MATERIAL TO BE PLACED IN THIS REGION. -
 CD VOLFR VOLFR CONTAINS THE VOLUME FRACTIONS FOR THE -
 CD MATERIAL-TO-REGION MIXING TABLE. FOR THE -
 CD MRSPEC(N) ENTRIES IN DMMIX FOR THE REGION -
 CD WHOSE LABEL IS THE N-TH ENTRY IN DRTBL, THERE -
 CD ARE MRSPEC(N) CORRESPONDING ENTRIES IN VOLFR. -
 CD DRTBL DRTBL IS THE LIST OF THE LABELS (A6) OF THE -
 CD REGIONS IN THE ORDER THAT THEY ARE BEING -
 CD SPECIFIED IN DMMIX AND VOLFR. -
 CD MRSPEC MRSPEC(N) IS THE NUMBER OF ENTRIES IN THE -
 CD DMMIX AND VOLFR ARRAYS FOR THE REGION WHOSE -
 CD LABEL IS THE N-TH ENTRY IN DRTBL. -
 C -
 CN AS WITH THE ISOTOPE-TO-MATERIAL MIXING TABLE, -
 CN THE REGION LABELED DRTBL(N) IS COMPOSED OF -
 CN MRSPEC(N) UNIQUE MATERIALS. THE UNIQUE -
 CN MATERIAL LABELS OF THESE UNIQUE MATERIALS AND -
 CN THE CORRESPONDING VOLUME FRACTIONS ARE GIVEN -
 CN IN ORDER IN THE ARRAYS DMMIX AND VOLFR, -

CN RESPECTIVELY. THE FIRST UNIQUE MATERIAL LABEL
CN AND VOLUME FRACTION FOR MATERIAL M ARE FOUND
CN AT DMMIX(I) AND VOLFR(I), WHERE I=1 + SUM OF
CN THE FIRST (N-1) VALUES IN MRSPEC.

C

CEOF

C*****

C

C PREPARED 11/08/77 AT ANL

G

CF FXTH -

CE CODE-DEPENDENT BINARY INTERFACE FILE FOR FX2-TH -

CN THIS IS THE THERMAL-HYDRAULICS INTERFACE -

CN DATA FILE. ONLY RECORDS 1, 2 AND 3 EXIST IF -

CN THERE IS NO EXPLICIT THERMAL-HYDRAULIC -

CN CALCULATION BUT THERE ARE TEMPERATURE-CORRECI -

CN CROSS SECTIONS (IF NFDBK.GT.0 PUT NTHF.EQ.0). -

CN RECOFDS 1 THROUGH 5 AND 11 THROUGH 13 ONLY -

CN EXIST IF THE SIMPLE MODEL IS INDICATED -

CN (IFTH. LT. 3) .

CN

CN NOTE THAT THIS IS A DOUBLE PRECISION FILE ON -

CN SYSTEMS WHERE MULT=2.

C

C-----

CS FILE STRUCTURE -

CS

CS	RECORD TYPE	PRESENT IF	-
----	-------------	------------	---

CS

CS	FILE IDENTIFICATION	ALWAYS PRESENT	-
----	---------------------	----------------	---

CS	FILE CONTROL	ALWAYS PRESENT	-
----	--------------	----------------	---

CS THERMAL-HYDRAULICS MAP ALWAYS PRESENT -

CS THERMAL-HYDRAULICS DATA TYPE NTHF.EQ.1 -

CS MATERIAL CONSTANTS FILE NTHF.EO.1

CS	NUMBER OF PTNS	NTHF. EQ. 1. AND.	-
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	10
11	11	11	11
12	12	12	12
13	13	13	13
14	14	14	14
15	15	15	15
16	16	16	16
17	17	17	17
18	18	18	18
19	19	19	19
20	20	20	20
21	21	21	21
22	22	22	22
23	23	23	23
24	24	24	24
25	25	25	25
26	26	26	26
27	27	27	27
28	28	28	28
29	29	29	29
30	30	30	30
31	31	31	31
32	32	32	32
33	33	33	33
34	34	34	34
35	35	35	35
36	36	36	36
37	37	37	37
38	38	38	38
39	39	39	39
40	40	40	40
41	41	41	41
42	42	42	42
43	43	43	43
44	44	44	44
45	45	45	45
46	46	46	46
47	47	47	47
48	48	48	48
49	49	49	49
50	50	50	50
51	51	51	51
52	52	52	52
53	53	53	53
54	54	54	54
55	55	55	55
56	56	56	56
57	57	57	57
58	58	58	58
59	59	59	59
60	60	60	60
61	61	61	61
62	62	62	62
63	63	63	63
64	64	64	64
65	65	65	65
66	66	66	66
67	67	67	67
68	68	68	68
69	69	69	69
70	70	70	70
71	71	71	71
72	72	72	72
73	73	73	73
74	74	74	74
75	75	75	75
76	76	76	76
77	77	77	77
78	78	78	78
79	79	79	79
80	80	80	80
81	81	81	81
82	82	82	82
83	83	83	83
84	84	84	84
85	85	85	85
86	86	86	86
87	87	87	87
88	88	88	88
89	89	89	89
90	90	90	90
91	91	91	91
92	92	92	92
93	93	93	93
94	94	94	94
95	95	95	95
96	96	96	96
97	97	97	97
98	98	98	98
99	99	99	99
100	100	100	100

CS IFTH.EO.3

CS INLET COOLANT TEMPERATURES NTHF.EQ.1.AND. -

CS IFTH. EO. 3

CS MASS FLOW RATES NTHF.EQ.1.AND. -

CS IFTH.EO.3 -

CS AXIAL MESH LENGTHS NTHF.EQ.1 -

CS H-GAP CORRECTION FACTORS NTHF.EO.1.AND. -

CS IFTH.EO.3

CS	NUMBER OF TYPE 13 AND TYPE 14	NTHF.EO.1	-
----	-------------------------------	-----------	---

```

CS      INPUT CARDS
CS      INITIAL AVERAGE COOLANT          NTHF.EQ.1
CS      TEMPERATURES
CS      INITIAL AVERAGE FUEL TEMPERATURES  NTHF.EQ.1
C
C-----

```

```

CD      IFTH          MODEL FLAG.
CD                        IFTH=1, SIMPLE MODEL WITH TOTAL POWER
CD                        AS SOURCE
CD                        =2, SIMPLE MODEL WITH TOTAL POWER MINUS
CD                        INITIAL POWER AS SOURCE
CD                        =3, DETAILED MODEL
CD      ITYPEF        NUMBER OF DIFFERENT DATA TYPES.
CD      NAX           NUMBER OF AXIAL SEGMENTS.
CD      NCH           NUMBER OF THERMAL-HYDRAULIC CHANNELS.
CD      NFDBK         TEMPERATURE FEEDBACK OPTION.
CD                        NFDBK=0, DO NOT TEMPERATURE-CORRECT
CD                        CROSS SECTIONS.
CD                        =1, TEMPERATURE-CORRECT CROSS SECTIONS.
CD      NINTI         NUMBER OF MESH INTERVALS IN THE "X"-DIRECTION.
CD      NINTJ         NUMBER OF MESH INTERVALS IN THE "Y"-DIRECTION.
CD      NTHF          THERMAL-HYDRAULICS OPTION.
CD                        NTHF=0, NO THERMAL-HYDRAULICS CALCULATION.
CD                        =1, DO THERMAL-HYDRAULICS CALCULATION.

```

```

C-----
CR      FILE IDENTIFICATION (TYPE 1)
C
CC      ALWAYS PRESENT
C
CL      FXTH, (HUSE (I), I=1,2), NVERSN
C
CW      1+3*MULT
C
CD      FXTH          HOLLERITH FILE NAME - FXTH - (A6).
CD      HUSE          HOLLERITH USER IDENTIFICATION (2A6).
CD      NVERSN        FILE VERSION NUMBER.
CD      MULT          DOUBLE PRECISION PARAMETER.
CD                        MULT=1, A6 WORD IS SINGLE WORD.
CD                        2, A6 WORD IS DOUBLE WORD.
C
C-----

```

```

C-----
CR      FILE CONTROL (TYPE 2)
C

```

```

CC          ALWAYS PRESENT
C
CL      IFTH,NCH,NFR,NAX,IST,ITYPE
C
CW      6
C
CD      NFR          NUMBER OF NODES IN FUEL.
CD      IST          STRUCTURE CALCULATION FLAG.
CD                      IST=0, NO CALCULATION.
CD                      =1, DO STRUCTURE CALCULATION.
C
C-----

```

```

C-----
CR          THERMAL-HYDRAULICS MAP (TYPE 3)
C
CC          ALWAYS PRESENT
C
CL      MTH(NINTI,NINTJ)
C
CW      NINTI*NINTJ
C
CD      MTH          MTH IS THE THERMAL-HYDRAULIC CHANNEL NUMBER
CD                      THAT IS ASSIGNED TO THIS FINE MESH REGION.
C
C-----

```

```

C-----
CR          THERMAL-HYDRAULICS DATA TYPE (TYPE 4)
C
CC          PRESENT IF NTHF.EQ.1
C
CL      ITHTYP(NCH)
C
CW      NCH
C
CD      ITHTYP          ITHTYP IS THE DATA TYPE OF THIS
CD                      THERMAL-HYDRAULICS CHANNEL.
C
C-----

```

```

C-----
CR          MATERIAL CONSTANTS FILE (TYPE 5)
C
CC          PRESENT IF NTHF.EQ.1
C
C          *****

```

```

C      *
C=====*      FIRST CONFIGURATION      *=====
C      *
C      *****
C
CL     VF, (RHOFCE(I), I=1,5), (DUMMY(I), I=1,4)
C
CW     ITYPE*10*MULT                      FOR IFTH.IT.3
C
CD     VF                      FUEL VOLUME FRACTION.
CD     RHOFCE(1)              FUEL SPECIFIC HEAT DENSITY CORRELATION.
CD     RHOFCE(2)              RHOFCE(T) = RHOFCE(1) + RHOFCE(2)*T + RHOFCE(3)*T**2
CD     RHOFCE(3)              + RHOFCE(4)*T**3 + RHOFCE(5)*T**4
CD     RHOFCE(4)              RHOFCE = (WATT-SEC/CM**3 DEG. C)
CD     RHOFCE(5)              TEMPERATURE (T) IS IN DEG. C.
CD     DUMMY(1)              UNUSED AT PRESENT.
CD     DUMMY(2)              UNUSED AT PRESENT.
CD     DUMMY(3)              UNUSED AT PRESENT.
CD     DUMMY(4)              UNUSED AT PRESENT.
C
CN                      THIS RECORD WILL CONTAIN ITYPE SETS OF DATA.
C
C      *****
C      *
C=====*      SECOND CONFIGURATION      *=====
C      *
C      *****
C
CL     RF, RG, RC, XKC, RCPC, HGAP, VFC, GAM2, RST, TPC, (CP(I), I=1,3),
CL     1 (RHOC(I), I=1,3), (KC(I), I=1,3), (C(I), I=1,4), (MUC(I), I=1,3),
CL     2 (KF(I), I=1,3), (RHOFCE(I), I=1,5), DRF, DRG, DRC, AC, GAM, DE, TST,
CL     3A1, A2, (DUMMY(I), I=1,7)
C
CW     ITYPE*50*MULT                      FOR IFTH.EQ.3
C
CD     RF                      FUEL OUTER RADIUS (CM).
CD     RG                      GAP OUTER RADIUS (CM).
CD     RC                      CLAD OUTER RADIUS (CM).
CD     XKC                     CLAD THERMAL CONDUCTIVITY (WATTS/CM DEG. C).
CD     RCPC                    CLAD SPECIFIC HEAT DENSITY
CD                             (WATT-SEC/CM**3 DEG. C).
CD     HGAP                    GAP HEAT TRANSFER COEFFICIENT
CD                             (WATT/CM**2 DEG. C).
CD     VFC                     VOLUME FRACTION OF COOLANT.
CD     GAM2                    SURFACE AREA OF STRUCTURE/
CD                             SURFACE AREA OF CLADDING.
CD     RST                     THERMAL RESISTANCE OF STRUCTURE
CD                             (CM**2 DEG. C/WATT).
CD     TRC                     RATIO OF STRUCTURE VOLUME TO SURFACE AREA (CM)
CD                             TIMES SPECIFIC HEAT DENSITY OF STRUCTURE

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CD      (WATT-SEC/CM**2 DEG. C).
CD      CP(1)      COOLANT SPECIFIC HEAT CORRELATION.
CD      CP(2)      CP(T)=CP(1)+CP(2)*T+CP(3)*T**2
CD      CP(3)      T=DEG. C, CP=(WATT-SEC/G DEG. C).
CD      RHOC(1)     COOLANT DENSITY CORRELATION.
CD      RHOC(2)     RHOC(T)=RHOC(1)+RHOC(2)*T+RHOC(3)*T**2
CD      RHOC(3)     T=DEG. C, RHOC=(G/CM**3).
CD      KC(1)      COOLANT THERMAL CONDUCTIVITY CORRELATION.
CD      KC(2)      KC(T)=KC(1)+KC(2)*T+KC(3)*T**2
CD      KC(3)      T=DEG. C, KC=(WATTS/CM DEG. C).
CD      C(1)      HEAT TRANSFER COEFFICIENT CORRELATION.
CD      C(2)      NU=C(1)+C(2)*(RE**C(3))*(PR**C(4))
CD      C(3)      NU, RE, AND PR ARE DIMENSIONLESS.
CD      C(4)      NU IS NUSSELT NUMBER, RE IS REYNOLDS NUMBER,
CD               AND PR IS PRANDTL NUMBER.
CD      MUC(1)     COOLANT VISCOSITY CORRELATION.
CD      MUC(2)     MUC(T)=MUC(1)+MUC(2)*T+MUC(3)*T**2
CD      MUC(3)     T=DEG. C, MUC=(G/CM-SEC).
CD      KF(1)      FUEL THERMAL CONDUCTIVITY CORRELATION.
CD      KF(2)      KF(T)=KF(1)+KF(2)*T+KF(3)*T**2
CD      KF(3)      T=DEG. C, KF=(WATTS/CM DEG. C).
CD      RHOF(1)     FUEL SPECIFIC HEAT DENSITY CORRELATION.
CD      RHOF(2)     RHOF(T)=RHOF(1)+RHOF(2)*T+RHOF(3)*T**2
CD      RHOF(3)     +RHOF(4)*T**3+RHOF(5)*T**4
CD      RHOF(4)     T=DEG. C, RHOF=(WATT-SEC/CM**3 DEG. C).
CD      RHOF(5)
CD      DRF        MESH SPACING IN FUEL (CM).
CD      DRG        MESH SPACING OF GAP (CM).
CD      DRC        CLAD THICKNESS (CM).
CD      AC         COOLANT FLOW AREA (CM**2).
CD      GAM        SURFACE TO VOLUME RATIO OF COOLANT CM**-1.
CD      DE         COOLANT HYDRAULIC DIAMETER (CM).
CD      TST        TIME TO BEGIN MASS FLOW RATE CHANGE (SEC).
CD      A1         MASS FLOW RATE CORRELATION
CD      A2         (BEGINS AT TIME TST).
CD               G(T)=G(0)*(1+A1*(T-TST)+A2*(T-TST)**2)
CD      DUMMY(1)   UNUSED AT PRESENT.
CD      DUMMY(2)   UNUSED AT PRESENT.
CD      DUMMY(3)   UNUSED AT PRESENT.
CD      DUMMY(4)   UNUSED AT PRESENT.
CD      DUMMY(5)   UNUSED AT PRESENT.
CD      DUMMY(6)   UNUSED AT PRESENT.
CD      DUMMY(7)   UNUSED AT PRESENT.
C
CN      THIS RECORD WILL CONTAIN ITYPE SETS OF DATA.
C
C-----
C-----

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```

CR          NUMBER OF PINS (TYPE 6)
C
CC          PRESENT IF NTHF.EQ.1 .AND. IFTH.EQ.3
C
CL          NPIN(NCH)
C
CW          NCH
C
CD          NPIN          NPIN IS THE NUMBER OF FUEL PINS IN THIS
CD                      THERMAL-HYDPAULIC CHANNEL.
C
C-----

```

```

C-----
CR          INLET COOLANT TEMPERATURES (TYPE 7)
C
CC          PRESENT IF NTHF.EQ.1 .AND. IFTH.EQ.3
C
CL          TEMP(NCH)
C
CW          NCH*MULT
C
CD          TEMP          INLET COOLANT TEMPERATURES AT EACH
CD                      THERMAL-HYDRAULIC CHANNEL (DEG. C).
C
C-----

```

```

C-----
CR          MASS FLOW RATES (TYPE 8)
C
CC          PRESENT IF NTHF.EQ.1 .AND. IFTH.EQ.3
C
CL          G(NCH)
C
CW          NCH*MULT
C
CD          G             MASS FLOW RATES AT EACH THERMAL-HYDRAULIC
CD                      CHANNEL.
C
C-----

```

```

C-----
CR          AXIAL MESH LENGTHS (TYPE 9)
C
CC          PRESENT IF NTHF.EQ.1
C
CL          DZ(NAX)

```

```

C
CW      NAX*MULT
C
CD      DZ                AXIAL THERMAL-HYDRAULIC MESH SPACINGS..
C
C-----

```

```

C-----
CR      H-GAP CORRECTION FACTORS (TYPE 10)
C
CC      -- PRESENT-IF NTHF.EQ.1 AND LETH.EQ.3 --
C
CL      HCORR(NAX)
C
CW      NAX*MULT
C
CD      HCORR              AXIAL CORRECTION FACTORS TO H-GAP.
C
C-----

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```

C-----
CR      NUMBER OF TYPE 13 AND TYPE 14 INPUT CARDS (TYPE 11)
C
CC      PRESENT IF NTHF.EQ.1
C
CL      N13,N14
C
CW      2
C
CD      N13                NUMBER OF TYPE 13 INPUT CARDS ENTERED.
CD      N14                NUMBER OF TYPE 14 INPUT CARDS ENTERED.
C
C-----

```

```

C-----
CR      INITIAL AVERAGE COOLANT TEMPERATURES (TYPE 12)
C
CC      PRESENT IF NTHF.EQ.1
C
CL      TC(NCH,NAX)
C
CW      MULT*NCH*NAX
C
CD      TC                INITIAL AVERAGE COOLANT TEMPERATURE FOR EACH
CD                        THERMAL-HYDRAULIC REGION (DEG. K).
CD      TCBASE            BASE COOLANT TEMPERATURE (DEG. K).
C

```

CN N13 IS THE NUMBER OF TYPE 13 CARDS ENTERED. -
 CN IF N13.EQ.0, TEMPERATURES ARE ZERO AND ARE -
 CN LATER SET TO TCBASE. -
 C -
 C-----

C-----
 CR INITIAL AVERAGE FUEL TEMPERATURES (TYPE 13) -
 C -
 CC PRESENT IF NTHF.EQ.1 -
 C -
 CL TF (NCH,NAX) -
 C -
 CW MULT*NCH*NAX -
 C -
 CD TF INITIAL AVERAGE FUEL TEMPERATURE FOR EACH -
 CD THERMAL-HYDRAULIC REGION (DEG. K). -
 CD TFBASE BASE FUEL TEMPERATURE (DEG. K). -
 C -
 CN N14 IS THE NUMBER OF TYPE 14 CARDS ENTERED. -
 CN IF N14.EQ.0, TEMPERATURES ARE ZERO AND ARE -
 CN LATER SET TO TFBASE. -
 C -
 C-----

CEOF
 C*****
 C
 C PREPARED 2/20/74 AT ANL -
 C -
 CF XSCON -
 CE CODE-DEPENDENT BINARY INPUT FILE FOR FX2 -
 C -
 CN XSCON CONTAINS THE UNIQUE MATERIAL MACROSCOPIC -
 CN CROSS SECTIONS AND TEMPERATURE CORRECTION -
 CN COEFFICIENTS. IT IS CONSTRUCTED BY FX2 FROM -
 CN INFORMATION ON THE FILES ISOTXS, DLAYXS, AND -
 CN FXHMO3. ONCE FORMED, IT CAN BE USED REPEATEDLY -
 CN BY FX2. IF IT IS PROVIDED TO FX2 AS AN OLD -
 CN FILE, ISOTXS AND DLAYXS NEED NOT BE PROVIDED. -
 CN
 CN NOTE THAT THIS IS A DOUBLE PRECISION FILE ON -
 CN SYSTEMS WHERE MULT=2. -
 C -
 C*****

C-----
 CS FILE STRUCTURE -

CS			
CS	RECORD TYPE	PRESENT IF	-
CS	=====	=====	-
CS	FILE IDENTIFICATION	ALWAYS	-
CS	FILE CONTROL	ALWAYS	-
CS	GROUP VELOCITIES, DECAY CONSTANTS,	ALWAYS	-
CS	PROMPT AND DELAYED FISSION SPECTRA		-
CS	AND NU VALUES		-
CS	UNIQUE MATERIAL MACROSCOPIC CROSS	ALWAYS	-
CS	SECTIONS AND TEMPERATURE CORRECTION		-
CS	COEFFICIENTS		-
CS	MATERIAL LABELS	ALWAYS	-
CS			-
C	-----		

CD	NGROUP	NUMBER OF ENERGY GROUPS.
CD	NMAT	NUMBER OF GENERIC MATERIALS.
CD	NTMAT	NUMBER OF UNIQUE MATERIALS, .GE.NMAT.
CD	NFMAT	NUMBER OF GENERIC MATERIALS WHICH ARE
CD		FISSIONABLE, .LE.NMAT.
CD	NTFMAT	NUMBER OF UNIQUE MATERIALS WHICH ARE
CD		FISSIONABLE, .LE.NTMAT.
CD	NFAM	NUMBER OF DELAYED PRECURSOR FAMILIES, .LE.6.
CD	MSCT	LENGTH OF SCTXS ARRAY.
CD	MAXDN	MAXIMUM NUMBER OF GROUPS WHICH DOWNSCATTER
CD		INTO ANY GROUP.

C	-----		
CR	FILE IDENTIFICATION (TYPE 1)		-
C			-
CC	ALWAYS PRESENT		-
C			-
CL	HNAME, (HUSE(I), I=1, 2), IVERS		-
C			-
CW	1+3*MULT		-
C			-
CD	HNAME	HOLLERITH FILE NAME - XSCON - (A6).	-
CD	HUSE	HOLLERITH USER IDENTIFICATION (2A6).	-
CD	IVERS	FILE VERSION NUMBER.	-
CD	MULT	DOUBLE PRECISION PARAMETER.	-
CD		MULT=1, A6 IS A SINGLE WORD.	-
CD		=2, A6 IS A DOUBLE WORD.	-
C			-
C	-----		

C	-----		
CR	FILE CONTROL (TYPE 2)		-

```

C
CC      ALWAYS PRESENT
C
CL      NGROUP,NMAT,NTMAT,NFMAT,NTFMAT,NFAM,MSCT,MAXDN,(T(I),I=1,5)
C
CW      13
C
CD      T(1)          TEMPERATURE TFBASE(DEGREES K) SINGLE PRECISION
CD      T(2)          TEMPERATURE T2 (DEGREES K)    SINGLE PRECISION
CD      T(3)          TEMPERATURE T3 (DEGREES K)    SINGLE PRECISION
CD      T(4)          TEMPERATURE T4 (DEGREES K)    SINGLE PRECISION
CD      T(5)          TEMPERATURE TCBASE(DEGREES K) SINGLE PRECISION
C
CN      THE APPRAY T IS ALWAYS SINGLE PRECISION
CN      TEMPERATURES T(1-4) ARE THE FOUR REFERENCE
CN      TEMPERATURES OVER WHICH THE MACROSCOPIC FISSION-
CN      AND CAPTURE CROSS SECTIONS WERE FITTED.
CN      TEMPERATURE T(5) IS THE BASE COOLANT
CN      TEMPERATURE FOR THE NUMBER DENSITY CORRELATION
C
C-----

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C-----
CR      GROUP VELOCITIES, DECAY CONSTANTS, PROMPT AND DELAYED
CR      FISSION SPECTRA AND NU VALUES (TYPE 3)
C
CC      ALWAYS PRESENT
C
CL      ((CHIP(M,NG),M=1,NTFMAT),NG=1,NGROUP),
CL      1((PNU(M,NG),M=1,NTFMAT),NG=1,NGROUP),
CL      2((CHID(L,NG),L=1,NFAM),NG=1,NGROUP),
CL      3(((DNU(L,M,NG),L=1,NFAM),M=1,NTFMAT),NG=1,NGROUP),
CL      4(DECCON(L),L=1,NFAM),(VEI(NG),NG=1,NGROUP)
C
CW      (NGROUP*(1+NFAM+NTFMAT*(2+NFAM))+NFAM)*MULT
C
CD      CHIP          CHIP(M,NG) IS THE PROMPT FISSION SPECTRUM
CD                      COMPONENT INTO GROUP NG FOR THE M-TH UNIQUE
CD                      FISSIONABLE MATERIAL.
CD      PNU           PNU(M,NG) IS THE NUMBER OF PROMPT NEUTRONS
CD                      BORN PER FISSION IN GROUP NG IN UNIQUE
CD                      FISSIONABLE MATERIAL M.
CD      CHID          CHID(L,NG) IS THE DELAYED FISSION SPECTRUM
CD                      COMPONENT INTO GROUP NG FOR DELAYED PRECURSOR
CD                      FAMILY L.
CD      DNU           DNU(L,M,NG) IS THE NUMBER OF DELAYED
CD                      PRECURSORS BORN INTO FAMILY L DUE TO FISSIONS
CD                      IN GROUP NG IN UNIQUE FISSIONABLE MATERIAL M.
CD      DECCON        DECCON(L) IS THE DECAY CONSTANT (SEC-1) FOR

```

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CD          DELAYED PRECURSOR FAMILY L.
CD  VEL      VEL(NG) IS THE VELOCITY FOR GROUP NG.
C
C-----

C-----
CR          UNIQUE MATERIAL MACROSCOPIC CROSS SECTIONS AND
CR          TEMPERATURE CORRECTION COEFFICIENTS (TYPE 4)
C
CC          ALWAYS PRESENT
C
CL          (((DOPCOF(M,NG,I),M=1,NTMAT),NG=1,NGROUP),I=1,6),
CL          1(((SFIST(M,NG,I),M=1,NTFMAT),NG=1,NGROUP),I=1,2),
CL          2(((SCAPT(M,NG,I),M=1,NTMAT),NG=1,NGROUP),I=1,2),
CL          3(((SIGTR(M,NG),M=1,NTMAT),NG=1,NGROUP),
CL          4(((SCTXS(I,I),L=1,MSCT),I=1,2),
CL          5(((SIGR(M,NG,I),M=1,NTMAT),NG=1,NGROUP),I=1,2),
CL          6(LMSCT(M),M=1,NTMAT), (LCSCT(NG),NG=1,NGROUP),
CL          7(NDN(NG),NG=1,NGROUP), (LTOLP(M),M=1,NTMAT),
CL          8(LPTOL(M),M=1,NTMAT)
C
CW          (NGROUP*(11*NTMAT+NTFMAT)+2*MSCT)*MULT+2*NGROUP+
CW          NTMAT+NTMAT+NTMAT
C
CD  DOPCOF      DOPCOF(M,NG,I) IS THE I-TH TEMPERATURE
CD              CORRECTION COEFFICIENT FOR GROUP NG CROSS
CD              SECTIONS IN UNIQUE MATERIAL M, WHERE I=1-3
CD              APPLY TO CAPTURE CROSS SECTIONS AND I=4-6
CD              APPLY TO FISSION CROSS SECTIONS.
CD  SFIST      SFIST(M,NG,I) ARE THE FISSION CROSS SECTIONS
CD              (I=1) AND COOLANT TEMPERATURE FEEDBACK
CD              COEFFICIENTS (I=2) FOR GROUP NG IN UNIQUE
CD              FISSIONABLE MATERIAL M
CD  SCAPT      SCAPT(M,NG,I) ARE THE CAPTURE CROSS SECTIONS
CD              (I=1) AND COOLANT TEMPERATURE FEEDBACK
CD              COEFFICIENTS (I=2) FOR GROUP NG IN UNIQUE
CD              MATERIAL M
CD  SIGTR      SIGTR(M,NG) IS THE TRANSPORT CROSS SECTION FOR
CD              GROUP NG IN UNIQUE MATERIAL M.
CD  SCTXS      SCTXS(M,ND,I) ARE THE SCATTERING CROSS SECTIONS-
CD              (I=1) AND COOLANT TEMPERATURE FEEDBACK
CD              COEFFICIENTS (I=2) FOR THE ND-TH DOWNSCATTER
CD              FOR UNIQUE MATERIAL M. THE NDN(NG)
CD              DOWNSCATTERS FOR SCATTERING INTO GROUP NG
CD              BEGIN AT SCTXS(M,NP,1), WHERE NP=LCSCT(NG)+1
CD  SIGR      SIGR(M,NG,I) ARE THE REMOVAL CROSS SECTIONS
CD              (I=1) AND COOLANT TEMPERATURE FEEDBACK
CD              COEFFICIENTS (I=2) FOR GROUP NG IN UNIQUE
CD              MATERIAL M

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CD      LMSCT      LMSCT(M) IS THE MAXIMUM NUMBER OF DOWNSCATTER -
CD              GROUPS INTO ANY GROUP FOR UNIQUE MATERIAL M -
CD              (=MAXDN) . -
CD      LCSCT      LCSCT IS A POINTER INTO THE ARRAY SCTXS. THE -
CD              NDN(NG) CROSS SECTIONS FOR SCATTERING INTO -
CD              GROUP NG IN UNIQUE MATERIAL M ARE FOUND AT -
CD              SCTXS(M,ND), ND=LCSCT(NG)+1,..., -
CD              LCSCT(NG)+NDN(NG) . -
CD      NDN         NDN(NG) IS THE NUMBER OF GROUPS WHICH DOWN- -
CD              SCATTER INTO GROUP NG. -
CD      LTOLP      LTOLP(M) IS THE GENERIC MATERIAL NUMBER OF THE -
CD              M-TH MATERIAL IN THE AMNAME ARRAY; LTOLP(M)=M. -
CD      LPTOL      LPTOL(M) IS THE GENERIC FISSIONABLE MATERIAL -
CD              NUMBER OF THE M-TH MATERIAL IN THE AMNAME -
CD              ARRAY; LPTOL(M)=M, M.LE.NFMAT. -
C
CN
CN      THE COEFFICIENTS IN THE DOPCOF ARRAY ARE USED -
CN      IN THE FOLLOWING MANNER: LET THE FISSION AND -
CN      CAPTURE CROSS SECTIONS FOR GROUP NG IN MATERIAL- -
CN      M AT SOME FUEL TEMPERATURE, T, BE REPRESENTED AS -
CN      SIGFIS(NG,M,T) AND SIGCAP(NG,M,T) . -
CN      WITHIN FX2, THEY WOULD BE COMPUTED AS FOLLOWS: -
CN
CN      SIGCAP(NG,M,T)=SCAPT(M,NG) -
CN      +DOPCOF(M,NG,1)*(DSQRT(T)-DSQRT(TBASE)) -
CN      +DOPCOF(M,NG,2)*(DLOG(T/TBASE)) -
CN      +DOPCOF(M,NG,3)*(TBASE-T)/(TBASE*T) -
CN
CN      SIGFIS(NG,M,T)=SFIST(M,NG) -
CN      +DOPCOF(M,NG,4)*(DSQRT(T)-DSQRT(TBASE)) -
CN      +DOPCOF(M,NG,5)*(DLOG(T/TBASE)) -
CN      +DOPCOF(M,NG,6)*(TBASE-T)/(TBASE*T) , -
CN      M.LE.NTFMAT -
CN
CN      HERE, T IS IN DEGREES KELVIN, AND TBASE IS -
CN      THE LOWEST OF THE FOUR TEMPERATURES AT WHICH -
CN      MATERIAL MACROSCOPIC CROSS SECTIONS WERE -
CN      FORMED IN ORDER TO EXTRACT THE COEFFICIENTS -
CN      IN THE DOPCOF ARRAY. -
CN
CN      IN FX2-TH, THE NUMBER DENSITY FOR CERTAIN -
CN      ISOTOPES IS CORRELATED AS A LINEAR FUNCTION -
CN      OF THE COOLANT TEMPERATURE. THEREFORE, ALL -
CN      MACROSCOPIC CROSS SECTIONS (SCATTERING,CAPTURE, -
CN      TRANSPORT, AND FISSION) ARE CORRELATED TO THE -
CN      COOLANT TEMPERATURE AS FOLLOWS: -
CN
CN      SIG(NG,M,TC)=SIG0(NG,M)+SIG1(NG,M)*(TC-TCBASE) -
CN
CN      WHERE SIG0(NG,M) IS THE BASE CROSS SECTION, AND-

```

CN SIG1(NG,M) IS THE COOLANT TEMPERATURE FEEDBACK -
 CN COEFFICIENT FOR THIS PARTICULAR NUCLEAR PROCESS-
 C
 C-----

C-----
 CR MATERIAL LABELS (TYPE 5) -
 C
 CC ALWAYS PRESENT -
 C
 CL (UMNAME(M),M=1,NTMAT), (AMNAME(M),M=1,NMAT), (NUMAM(M),M=1,NTMAT) -
 C
 CW (NTMAT+NMAT)*MULT+NTMAT -
 C
 CD UMNAME UMNAME(M) IS THE HOLLERITH LABEL (A6) OF -
 CD UNIQUE MATERIAL M. -
 CD AMNAME AMNAME(M) IS THE HOLLERITH LABEL (A6) OF -
 CD GENERIC MATERIAL M. -
 CD NUMAM NUMAM(M) IS THE POSITION IN THE AMNAME ARRAY -
 CD OF THE GENERIC MATERIAL LABEL (AND HENCE -
 CD GENERIC MATERIAL NUMBER) ASSIGNED TO UNIQUE -
 CD MATERIAL M. -
 C
 CN IN ORDER TO CLARIFY THE UNIQUE MATERIAL- -
 CN GENERIC MATERIAL CONCEPT, IT MUST BE UNDER- -
 CN STOOD THAT WITHIN FX2, THE REACTOR IS VIEWED -
 CN AS BEING COMPOSED OF PHYSICAL MATERIALS SUCH -
 CN AS URANIUM OXIDE, PLUTONIUM OXIDE, STAINLESS -
 CN STEEL, BORON CARBIDE, ETC. EACH PHYSICAL -
 CN MATERIAL IS ASSUMED TO HAVE A FIXED ISOTOPIC -
 CN CONTENT DURING A TRANSIENT. SINCE FX2 EMPLOYS -
 CN THE MULTIGROUP APPROXIMATION, IT WILL OFTEN -
 CN BE DESIRABLE TO USE DIFFERENT CROSS SECTIONS -
 CN FOR A PARTICULAR PHYSICAL MATERIAL IN DIFFERENT -
 CN REGIONS OF THE REACTOR. THIS IS ACCOMPLISHED -
 CN IN FX2 BY CREATING SEVERAL UNIQUE MATERIALS, -
 CN EACH WITH ITS OWN CROSS SECTIONS AND UNIQUE -
 CN MATERIAL LABEL, BUT ALL SHARING THE SAME -
 CN GENERIC MATERIAL LABEL. THUS, URANIUM OXIDE -
 CN IN THE INNER AND OUTER CORE REGIONS MIGHT BE -
 CN DESIGNATED BY THE UNIQUE MATERIAL LABELS -
 CN UO2-IC AND UO2-OC, RESPECTIVELY, WITH BOTH -
 CN SHARING THE GENERIC MATERIAL LABEL, UO2. -
 CN BECAUSE CORE STORAGE REQUIREMENTS AND COM- -
 CN PUTING TIMES ARE DEPENDENT ON THE NUMBER OF -
 CN GENERIC MATERIALS MUCH MORE STRONGLY THAN ON -
 CN THE NUMBER OF UNIQUE MATERIALS, IT IS IN THE -
 CN USER'S INTEREST TO ATTEMPT TO MINIMIZE THE -
 CN NUMBER OF GENERIC MATERIALS. -


```

C
C-----
CEOF
C*****
C
C      PREPARED 01/05/78 AT ANL
C
CF      THDATA
CE      CODE-DEPENDENT BINARY INTERFACE FILE FOR FX2-TH
C
CN      THERE ARE TWO CONFIGURATIONS OF THIS
CN      CODE-DEPENDENT BINARY INTERFACE FILE.
CN
CN      THE FIRST CONFIGURATION IS USED IF IFTH.LT.3.
CN      THE SECOND CONFIGURATION IS USED IF IFTH.EQ.3.
CN
CN      NOTE THAT THIS IS A DOUBLE PRECISION FILE ON
CN      SYSTEMS WHERE MULT=2.
C
C*****

C      *****
C      *
C=====*      FIRST CONFIGURATION      *=====
C      *
C      *****

C*****
C
CN      THIS CODE-DEPENDENT BINARY INTERFACE FILE
CN      CONTAINS THE STEADY-STATE POWER DENSITIES
CN      ON THE THERMAL-HYDRAULIC GRID.
CN
CN      THIS FILE IS WRITTEN AT THE CONCLUSION OF THE
CN      STEADY-STATE CALCULATION. IT IS READ AT THE
CN      BEGINNING OF THE FIRST REACTIVITY STEP OF
CN      THE TRANSIENT.
C
C*****

C-----
CS      FILE STRUCTURE
CS
CS      RECORD TYPE      PRESENT IF
CS      =====
CS      STEADY-STATE POWER DENSITIES      ALWAYS PRESENT

```

C-----

C-----

CR	STEADY-STATE POWER DENSITIES (TYPE 1)	
C		
CC	ALWAYS PRESENT	
C		
CL	PWOLD (NAX, NCH)	
C		
CW	MULT*NAX*NCH	
C		
CD	NAX	NUMBER OF AXIAL SEGMENTS.
CD	NCH	NUMBER OF THERMAL-HYDRAULIC CHANNELS.
CD	PWOLD	STEADY-STATE POWER DENSITIES FOR EACH
CD		THERMAL-HYDRAULIC REGION.
C		

C-----

C *****

C *

C-----* SECOND CONFIGURATION -----*

C *

C *****

C*****

C

CN	THIS CODE-DEPENDENT BINARY INTERFACE FILE
CN	CONTAINS THE FUEL AND COOLANT TEMPERATURES
CN	FOR THE DETAILED THERMAL-HYDRAULIC MODEL.
CN	
CN	THIS FILE IS WRITTEN AT THE CONCLUSION OF THE
CN	STEADY STATE CALCULATION. DURING A TRANSIENT,
CN	ONLY RECORD TYPE 1 IS WRITTEN, AND THEN ONLY
CN	IF INSUFFICIENT CORE STORAGE IS AVAILABLE TO
CN	CORE CONTAIN THE TEMPERATURES FOR THE ENTIRE
CN	TRANSIENT CALCULATION. RECORD TYPES 2 AND 3
CN	ARE NEVER RE-WRITTEN DURING THE TRANSIENT.
CN	
CN	RECORDS 1, 2 AND 3 ARE ALWAYS REQUIRED
CN	BY FX2-TH.
C	

C*****

C-----

CS FILE STRUCTURE

CS			
CS	RECORD TYPE	PRESENT IF	-
CS	=====	=====	-
CS	FUEL, COOLANT AND STRUCTURE	ALWAYS PRESENT	-
CS	TEMPERATURES		-
CS	STEADY-STATE AVERAGE FUEL	ALWAYS PRESENT	-
CS	TEMPERATURES		-
CS	STEADY-STATE AVERAGE COOLANT	ALWAYS PRESENT	-
CS	TEMPERATURES		-
C			-
C			-

CD	NAX	NUMBER OF AXIAL SEGMENTS.
CD	NCH	NUMBER OF THERMAL-HYDRAULIC CHANNELS.

C			
CR	FUEL, COOLANT AND STRUCTURE TEMPERATURES (TYPE 1)		-
C			-
CC	ALWAYS PRESENT		-
C			-
CL	(FT(NFR+2,NAX,I),TC(NAX+1,I),TST(NAX,I),I=1,NCH)		-
C			-
CW	MULT*NCH*(NAX*(NFR+4)+1)		-
C			-
CD	FT	DETAILED FUEL TEMPERATURES WITHIN FUEL	-
CD		ROD AND CLAD.	-
CD	NFR	NUMBER OF REGIONS IN FUEL.	-
CD	TC	COOLANT TEMPERATURES AT EACH AXIAL ELEVATION.	-
CD	TST	STRUCTURE TEMPERATURE AT EACH AXIAL LEVEL.	-
C			-
C			-

C			
CR	STEADY-STATE AVERAGE FUEL TEMPERATURES (TYPE 2)		-
C			-
CC	ALWAYS PRESENT		-
C			-
CL	TFAV(NAX,NCH)		-
C			-
CW	MULT*NAX*NCH		-
C			-
CD	TFAV	AVERAGE FUEL TEMPERATURES FOR EACH CHANNEL	-
CD		AND AXIAL LEVEL.	-
C			-
C			-

```

C-----
CR      STEADY-STATE AVERAGE COOLANT TEMPERATURES (TYPE 3)
C
CC      ALWAYS PRESENT
C
CD      TCAV (NAX,NCH)
C
CW      MULT*NAX*NCH
C
CD      TCAV              AVERAGE COOLANT TEMPERATURES FOR EACH
CD                        CHANNEL AND AXIAL LEVEL.
C
C-----

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CEOF
C
C      PREPARED 1/24/78 AT ANL
C
CF      FXEDIT
C
CE      CODE-DEPENDENT BINARY EDIT FILE FOR FX2-TH
C
CN      THIS FILE IS WRITTEN TO DISK UNIT NFXEDT.  THE
CN      WRITING OF THIS FILE IS CONTROLLED BY AN
CN      INPUT PARAMETER, IEDF(5), READ IN ON CARD
CN      TYPE 05 OF A.FX2.  IF IEDF(5) .EQ. 0, NO
CN      FILE IS WRITTEN.  IF IEDF(5) .EQ. 1, ONLY
CN      THE BASIC EDIT IS WRITTEN.  IF IEDF(5) .EQ.
CN      2, BOTH THE BASIC EDIT AND THE EXTENDED
CN      EDIT (REGION POWERS, FUEL AND COOLANT
CN      TEMPERATURES) ARE EDITED.  IF IEDF(5) .EQ. 3,
CN      THE POINTWISE FLUXES ARE ALSO EDITED.  DURING
CN      THE TRANSIENT, THE POINTWISE FLUXES ARE ONLY
CN      WRITTEN IF A SHAPE CALCULATION HAS JUST BEEN
CN      PERFORMED.  THE POWER DENSITIES AND POINTWISE
CN      FLUXES ARE WRITTEN IN NORMALIZED FORM, THAT
CN      IS, THEY MUST BE MULTIPLIED BY THE AMPLITUDE
CN      FUNCTION (AMPTI) TO OBTAIN THE CORRECT VALUES.
CN
CN      TO OBTAIN VALUES OF THE POINTWISE FLUXES
CN      AT TIME POINTS BETWEEN THE PLACES WHERE THE
CN      FULL SET OF FLUXES ARE WRITTEN, THE FLUXES AT
CN      THE TIME POINTS IMMEDIATELY BEFORE AND AFTER
CN      THE TIME POINT OF INTEREST SHOULD BE LINEARLY
CN      INTERPOLATED.  THEN, TO OBTAIN THE CORRECT
CN      FLUX VALUES AT THIS TIME POINT, THE
CN      INTERPOLATED FLUXES SHOULD BE MULTIPLIED
CN      BY THE VALUE OF THE AMPLITUDE FUNCTION AT
CN      THIS TIME POINT (SEE ABOVE).
C

```

```

C*****
C-----
CS  STRUCTURE FOR STEADY STATE EDIT -
CS -
CS  RECORD TYPE                      PRESENT IF -
CS -
CS  ===== -
CS -
CS  TITLE                          ALWAYS PRESENT -
CS  CONTROL                        ALWAYS PRESENT -
CS  SUMMARY                        ALWAYS PRESENT -
CS  POINT KINETICS                 ALWAYS PRESENT -
CS  POWER DENSITY                  IEDF(5) .GE. 2 -
CS  FUEL TEMPERATURES              IEDF(5) .GE. 2 .AND. -
CS                                  NTHF.EQ.1 -
CS  COOLANT TEMPERATURES          IEDF(5) .GE. 2 .AND. -
CS                                  NTHF.EQ.1 .AND. -
CS                                  IFTH.EQ.3 -
CS  POINTWISE FLUXES (NGROUP RECORDS) IEDF(5) .EQ. 3 -
CS -
C-----
C-----
CS  STRUCTURE FOR EDIT AT EACH REACTIVITY STEP -
CS -
CS  RECORD TYPE                      PRESENT IF -
CS -
CS  ===== -
CS -
CS  TRANSIENT CONTROL              ALWAYS PRESENT -
CS  SUMMARY                        ALWAYS PRESENT -
CS  POINT KINETICS                 ALWAYS PRESENT -
CS  POWER DENSITY                  IEDF(5) .GE. 2 -
CS  FUEL TEMPERATURES              IEDF(5) .GE. 2 .AND. -
CS                                  NTHF.EQ.1 -
CS  COOLANT TEMPERATURES          IEDF(5) .GE. 2 .AND. -
CS                                  NTHF.EQ.1 .AND. -
CS                                  IFTH.EQ.3 -
CS  POINTWISE FLUXES (NGROUP RECORDS) IEDF(5) .EQ. 3 .AND. -
CS                                  ISHP .EQ. 1 -
CS -
C-----
C-----
CD  NCELLS=NINTI*NINTJ -
CD  NINTI      NUMBER OF MESH INTERVALS IN THE X DIRECTION -
CD  NINTJ      NUMBER OF MESH INTERVALS IN THE Y DIRECTION -
CD  NR=NAX*NCH -
CD  NAX        NUMBER OF AXIAL THERMAL-HYDRAULIC INTERVALS -
CD  NCH        NUMBER OF THERMAL-HYDRAULIC CHANNELS -
CD  NTHF       FLAG TO DETERMINE IF THERMAL-HYDRAULICS MODEL -
CD             IS BEING USED (0 = NO), (1 = YES) -

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```

CD      IFTH          FLAG TO DETERMINE WHICH THERMAL-HYDRAULICS
CD                      MODEL IS BEING USED (1 OR 2 = SIMPLE MODEL),
CD                      (3 = DETAILED MODEL).
CD      ISHP          FLAG TO DETERMINE IF SHAPE CALCULATION HAS
CD                      JUST BEEN MADE (0 = NO), (1 = YES).
C-----
C-----
CR      TITLE
C
CC      ALWAYS PRESENT
C
CL      (TITLE(I), I=1, 12), IEDF(5)
C
CW      12*MULT+1
C
CD      TITLE          PROBLEM TITLE (IN 12A6 FORMAT)
CD      IEDF(5)         CONTROLS EDITING
CD      MULT            DOUBLE PRECISION PARAMETER.
CD                      MULT=1, A6 IS A SINGLE WORD.
CD                      =2, A6 IS A DOUBLE WORD.
C-----
C-----
CR      CONTROL
C
CC      ALWAYS PRESENT
C
CW      27
C
CD      NCH,NAX,NINTI,NINTJ,NGROUP,NMAT,NTMAT,NFMAT,NTFMAT,NFAM,MSCT,
CD      1MAXDN,NREG,NREGD,NCMP,MNFPTS,NDSCCT,NGEOM,NZONE,IMBL,JMBT,
CD      2IMBR,JMBB,MAXSIZ,NTHF,IFTH
CD
CD      NINTI           NO. OF X-DIRECTION MESH INTERVALS
CD      NINTJ           NO. OF Y-DIRECTION MESH INTERVALS
CD      NGROUP          NO. OF NEUTRON ENERGY GROUPS
CD      NMAT            NO. OF GENERIC MATERIALS
CD      NTMAT           NO. OF UNIQUE MATERIALS
CD      NFMAT           NO. OF GENEPIC MATERIALS WHICH ARE FISSIONABLE
CD      NTFMAT          NO. OF UNIQUE MATERIALS WHICH ARE FISSIONABLE
CD      NFAM            NO. OF DELAYED PRECURSOR FAMILIES
CD      MSCT            MATERIAL SCATTERING CROSS SECTION ARRAY LENGTH
CD      MAXDN           MAX. NO. OF DOWNSCATTER GROUPS FOR A GROUP
CD      NREG            NO. OF REGIONS
CD      NREGD           NO. OF REGIONS IN WHICH DRIVING FUNCTIONS
CD                      ARE USED.
CD      NCMP            NO. OF COMPOSITIONS
CD      MNFPTS          NO. OF MESH INTERVALS WITH FISSIONABLE MATERIAL
CD      NDSCCT          TOTAL NUMBER OF DOWNSCATTER GROUPS
CD      NGEOM           GEOMETRY TYPE

```

CD	NZONE	NUMBER OF ZONES	-
CD	IMBL	LEFT BOUNDARY ON FIRST DIMENSION	-
CD	JMBT	TOP BOUNDARY ON SECOND DIMENSION	-
CD	IMBR	RIGHT BOUNDARY ON FIRST DIMENSION	-
CD	JMBB	BOTTOM BOUNDARY ON SECOND DIMENSION	-
CD	NBCS	NO. OF CONSTANTS FOR EXTERNAL BOUNDARIES	-
CD		1 - SINGLE VALUE USED EVERYWHERE	-
CD		6 - INDIVIDUAL VALUES FOR EACH POSSIBLE SURFACE	-
CD		GT 6 - SIX VALUES ARE GIVEN FOR THE FIRST	-
CD		ENERGY GROUP, THEN FOR THE NEXT GROUP,	-
CD		TO END OF LIST - IF THERE ARE MORE	-
CD		GROUPS, LAST GROUP DATA GIVEN IS USED.	-
CD	MAXSIZ	SIZE OF FAST CORE STORAGE	-
CD		(IN DOUBLE PRECISION WORDS ON IBM)	-
CD		(IN SINGLE PRECISION WORDS ON CDC)	-

C-----

C-----

CR	SUMMARY	-
C		-
CC	ALWAYS PRESENT	-
C		-
CL	TI,TIM1,TJP1,TJ,DTI,AMPTI,ALPHA,ETOT,RKEFF,OKEFF,POWIN,POWTOT,	-
CL	GENTIM,BETAT,RHOT,QLAM	-
C		-
CW	16*MULT	-
C		-
CD	TI	TIME AT END OF CURRENT REACTIVITY STEP
CD	TIM1	TIME AT BEGINNING OF CURRENT REACTIVITY STEP
CD	TJP1	TIME AT END OF CURRENT SHAPE STEP
CD	TJ	TIME AT BEGINNING OF CURRENT SHAPE STEP
CD	DTI	LENGTH OF CURRENT REACTIVITY STEP
CD	AMPTI	AMPLITUDE (N) AT END OF CURRENT REACTIVITY
CD	ALPHA	N DOT/N AT END OF CURRENT REACTIVITY STEP
CD	ETOT	TOTAL ENERGY GENERATED DURING TRANSIENT
CD		(WATT-SEC)
CD	RKEFF	KEFF OF REACTOR-INITIAL
CD	OKEFF	K0 - EIGENVALUE OF SOURCE-FREE ADJOINT EQUATION-
CD		FOR REACTOR WITH FIXED SOURCE
CD	POWIN	INITIAL TOTAL POWER OF REACTOR (WATTS)
CD	POWTOT	TOTAL REACTOR POWER (WATTS)
CD	GENTIM	NEUTRON GENERATION TIME, CAPITAL LAMBDA
CD	BETAT	TOTAL DELAYED NEUTRON FRACTION, BETA
CD	RHOT	REACTIVITY AT END OF CURRENT REACTIVITY
CD		STEP, RHO
CD	QLAM	(EXTERNAL SOURCE/NEUTRON GENERATION TIME)

C-----

C-----

CR TRANSIENT CONTROL

```

C
CC      ALWAYS PRESENT
C
CL      NRHOST,ISHP
C
CW      2
C
CD      NRHOST      REACTIVITY STEP COUNTER
C
-----
C
CR      POINT KINETICS
C
CC      ALWAYS PRESENT
C
CL      (BETAP (I) ,I=1,6) , (PREC (I) ,I=1,6) , (DECCON (I) ,I=1,6)
C
CW      18*MULT
C
CD      BETAP (1)      SIX VALUES, BY FAMILY, OF BETA PRIME(S)/NEUTRON
CD                      GENERATION TIME, S=1,...,6, AT END OF CURRENT
CD                      REACTIVITY STEP
CD      (2)
CD      (3)
CD      (4)
CD      (5)
CD      (6)
CD      PREC (1)      SIX VALUES, BY FAMILY, OF THE POINT KINETICS
CD                      PRECURSORS, AT END OF CURRENT REACTIVITY STEP.
CD      (2)
CD      (3)
CD      (4)
CD      (5)
CD      (6)
CD      DECCON (1)      SIX VALUES, BY FAMILY, OF LAMBDA (S) , S=1,...,6,
CD                      - PRECURSOR DECAY CONSTANTS
CD      (2)
CD      (3)
CD      (4)
CD      (5)
CD      (6)
C
-----
C
CR      POWER DENSITY
C
CC      PRESENT IF IEDF (5) .GT. 2
C
CL      (POWER (I) ,I=1,NCELLS)
C

```



```

CW      NCELLS*MULT
C
CD      POWER(I)          POWER DENSITIES FOR EACH MESH CELL
CD                        THESE ARE NORMALIZED POWER DENSITIES - TO
CD                        OBTAIN CORRECT POWER DENSITIES YOU MUST
CD                        MULTIPLY BY THE AMPLITUDE FUNCTION.
C
C-----
C
CR      FUEL TEMPERATURES
C
CS      PRESENT IF IEDF(5) .GE. 2 .AND. NTHF .EQ. 1
C
CL      (TF(I),I=1,NR)
C
CW      NR*MULT
C
CD      TF(I)             AVERAGE FUEL TEMPERATURES AT EACH
CD                        THERMAL-HYDRAULIC REGION.
C
C-----
C
CR      COOLANT TEMPERATURES
C
CS      PRESENT IF IEDF(5) .GE. 2 .AND. NTHF .EQ. 1 .AND.
CS      IFTH .EQ. 3
C
CL      (TC(I),I=1,NR)
C
CW      NR*MULT
C
CD      TC(I)             AVERAGE COOLANT TEMPERATURES AT EACH
CD                        THERMAL-HYDRAULIC REGION.
C
C-----
C
CR      POINTWISE FLUXES (NGROUP RECORDS)
C
CC      PRESENT IF IEDF(5) .EQ. 3 .AND. ISHP .EQ. 1
C
CL      (PSI(NG,I),I=1,NCELLS) FOR EACH RECORD NG
C
CW      NCELLS*MULT FOR EACH RECORD NG
C
CD      PSI(NG,I)         POINTWISE FLUX FOR GROUP (RECORD) NG AT
CD                        MESH CELL I (NORMALIZED).
C
C-----
CEOF

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APPENDIX D

Listing of Scratch Files

SUBROUTINE FILES2

MULT=1 FOR CDC
MULT=2 FOR IBM

FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
VFRACH	NVFRAC	IVFRAC
(25)		
LOCFIL(5) EQ 0, MEANS DATA IS HELD IN CORE		
LOCFIL(5) NE 0, MEANS DATA IS ON DISK		
READ	FXPTXS (TIME=0.0), DRIVEF, MAXNMF, COPYDS	
WRITTEN	DRIVEF, INITSS, COPYDS	
DESCRIPTION	VOLUME FRACTIONS OF GENERIC MATERIALS BY MESH CELL	
NMAT	NO. OF GENERIC MATERIAL	
NCELLS	NO. OF MESH CELLS	
VFRACH	VFRACH(M,I) IS THE VOLUME FRACTION OF GENERIC MATERIAL M AT MESH CELL I	
RECORD TYPE 01	((VFRACH(M,I), M=1, NMAT), I=1, NCELLS)	
LENGTH	NMAT*NCELLS*MULT	SINGLE PRECISION WORDS
FILE SIZE	NMAT*NCELLS*MULT	SINGLE PRECISION WORDS

FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
POWDNM	NPOWDN	IPOWDN
(26)		
WRITTEN	SHPOUT	
DESCRIPTION	POWER DENSITY (WATTS/CC) BY MESH CELL	
NCELLS	NO. OF MESH CELLS	
POWER	POWER(I) ARE THE POWER DENSITIES ON THE EULERIAN MESH (WATTS/CM**3)	
RECORD TYPE 01	(POWER(I), I=1, NCELLS)	
LENGTH	NCELLS*MULT	SINGLE PRECISION WORDS
FILE SIZE	NCELLS*MULT	SINGLE PRECISION WORDS

```

C
C
C  FILE NAME      LOGICAL UNIT NUMBER      RECORD POINTER
C  =====      =====
C  POWOLD          NPWOLD                    IPWOLD
C                      (28)
C  WRITTEN          SSTATE
C  READ             SSTATE
C  DESCRIPTION      OLD POWER DENSITY FOR USE IN CHECKING
C                   CONVERGENCE OF NEUTRONICS / THERMAL-HYDRAULICS
C                   ITERATION
C  NCELLS           NUMBER OF MESH CELLS
C  POWER            POWER DENSITY(WATTS/CC) BY MESH CELL
C  RECORD TYPE 01   (POWER(I),I=1,NCELLS)
C  LENGTH           NCELLS*MULT             REAL*4 WORDS
C  FILE SIZE        NCELLS*MULT             REAL*4 WORDS
C  -----
C
C
C
C
C
C
C
C  FILE NAME      LOGICAL UNIT NUMBER      RECORD POINTER
C  =====      =====
C  TPSORC          NTPSRC                    ITPSRC
C                      (30)
C  READ             RHOBEG
C  WRITTEN          RHOBEG
C  DESCRIPTION      TEMPORARY FILE FOR MODIFYING FIXED SOURCE
C  NGROUP           NUMBER OF NEUTRON ENERGY GROUPS
C  NCELLS           NUMBER OF MESH CELLS
C                   NGROUP RECORDS
C  RECORD TYPE 01   (SORC(I),I=1,NCELLS)
C                   LENGTH           NCELLS*MULT             REAL *4 WORDS
C                   FILE SIZE        NCELLS*NGROUP*MULT      REAL *4 WORDS
C  -----
C
C
C
C
C
C
C
C  FILE NAME      LOGICAL UNIT NUMBER      RECORD POINTER
C  =====      =====
C  SHPES           NSHPES                    ISHPES
C                      (31)
C  READ            SRCMOD,OUTERS
C  WRITTEN          SRCCAL,SRCMOD
C  DESCRIPTION      SOURCE TERM IN TIME DEPENDENT SOLUTION OF THE
C                   SHAPE FUNCTION
C

```

C	NGROUP	NO. OF NEUTRON ENERGY GROUPS
C	NCELLS	NO. OF MESH CELLS
C		NGROUP RECORDS
C	RECORD TYPE 01	(TIMSRC(I),I=1,NCELLS)
C	LENGTH	NCELLS*MULT SINGLE PRECISION WORDS
C	FILE SIZE	NCELLS*NGROUP*MULT SINGLE PRECISION WORDS

C	FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
C	=====	=====	=====
C	FRI	NPRI	IFRI
C		(32)	
C	READ	OUTERS,GSOPC2,GNDOTS,SHPOUT,EXTFLX	
C	WRITTEN	OUTERS,GSORC2,GNDOTS,SHPOUT	
C	DESCRIPTION	REAL NEUTRON FLUX BY MESH CELL AND ENERGY GROUP	
C		AT REACTIVITY TIME STEP(I)	
C	NGROUP	NO. OF NEUTRON ENERGY GROUPS	
C	NCELLS	NO. OF MESH CELLS	
C		NGROUP RECORDS	
C	RECORD TYPE 01	(PSI(I),I=1,NCELLS)	
C	LENGTH	NCELLS*MULT	SINGLE PRECISION WORDS
C	FILE SIZE	NCELLS*NGROUP*MULT	SINGLE PRECISION WORDS.

C	FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
C	=====	=====	=====
C	FRIP1	NFRIP1	IFRIP1
C		(33)	
C		LOCFIL(1) EQ 0, MEANS DATA IS HELD IN CORE	
C		LOCFIL(1) NE 0, MEANS DATA IS ON DISK	
C	READ	PASS1,PASS2,FISINT,OUTERS,GSORC2,GNDOTS,SHPOUT	
C		INITT1,COPYDS	
C	WRITTEN	OUTERS,GSORC2,GNDOTS,SHPOUT,EXTFLX,INITSS	
C	DESCRIPTION	REAL NEUTRON FLUX BY MESH CELL AND ENERGY GROUP	
C		AT REACTIVITY TIME STEP(I+1)	
C	NGROUP	NO. OF NEUTRON ENERGY GROUPS	
C	NCELLS	NO. OF MESH CELLS	
C		NGROUP RECORDS	
C	RECORD TYPE 01	(PSI(I),I=1,NCELLS)	
C	LENGTH	NCELLS*MULT	SINGLE PRECISION WORDS
C	FILE SIZE	NCELLS*NGROUP*MULT	SINGLE PRECISION WORDS

```

-----
FILE NAME      LOGICAL UNIT NUMBER    RECORD POINTER
=====
FRJM1          NFRJM1                 IFRJM1
              (34)
READ          SRCCAL,SRCMOD,OUTERS,GSORC2,GNDOTS,SHPOUT,EXTFLX
READ          COPYDS
WRITTEN       OUTERS,GSORC2,GNDOTS,SHPOUT,INITT1,INITSS,COPYDS
DESCRIPTION   REAL NEUTPON FLUX BY MESH CELL AND ENERGY GROUP
              AT SHAPE TIME STEP (J-1)
NGROUP        NO. OF NEUTRON ENERGY GROUPS
NCELLS        NO. OF MESH CELLS
              NGROUP RECORDS
RECORD TYPE 01 (PSI(I),I=1,NCELLS)
              LENGTH      NCELLS*MULT      SINGLE PRECISION WORDS
              FILE SIZE   NCELLS*NGROUP*MULT SINGLE PRECISION WORDS
-----

```

```

FILE NAME      LOGICAL UNIT NUMBER    RECORD POINTER
=====
XSPSCT        NXSPSC                 IXSPSC
              (35)
              LOCFIL(3) EQ 0, MEANS DATA IS HEID IN CORE
              LOCFIL(3) NE 0, MEANS DATA IS ON DISK
READ          PASS2,FISINT,OUTERS,GSORC2
WRITTEN       SCTTER
DESCRIPTION   MACROSCOPIC SCATTERING CROSS-SECTIONS BY MESH CELL
              OR AVERAGED BY VOLUME OVER REGIONS
              NDSCT=SUMMATION FROM G=1 TO NGROUP OF
              THE ARRAY NDN(G)
NCMP          NO. OF COMPOSITIONS
NDSCT         TOTAL NUMBER OF DOWNSCATTER GROUPS
NDN           NDN(G) IS THE NUMBER OF GROUPS WHICH
              DOWNSCATTER INTO GROUP G
              NDSCT RECORDS
RECORD TYPE 01 (TSCATD(I),I=1,NCMP)
              LENGTH      NCMP*MULT      SINGLE PRECISION WORDS

```

FILE SIZE	NCMP*SUM*MULT	SINGLE PRECISION WORDS
FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
=====	=====	=====
XSPGRP	NXSPGR (36)	IXSPGR
	LOCFIL(4) EQ 0, MEANS DATA IS HELD IN CORE	
	LOCFIL(4) NE 0, MEANS DATA IS ON DISK	
READ	PASS2, SFDGEN	
WRITTEN	XSFIX	
DESCRIPTION	MACROSCOPIC REMOVAL AND TRANSPORT CROSS SECTIONS BY MESH CELL OR AVERAGED BY VOLUME OVER REGIONS	
NGROUP	NO. OF NEUTRON ENERGY GROUPS	
NCMP	NO. OF COMPOSITIONS	
TSIGTR	TSIGTR(NC,1) IS THE REMOVAL CROSS SECTION FOR COMPOSITION NC, WHILE TSIGTR(NC,2) IS THE TRANSPORT CROSS SECTION FOR COMPOSITION NC, BOTH FOR ONE GROUP.	
RECORD TYPE 01	NGROUP RECORDS ((TSIGTR(I,K), I=1, NCMP), K=1, 2)	
LENGTH	NCMP*2*MULT	SINGLE PRECISION WORDS
FILE SIZE	NCMP*NGROUP*2	SINGLE PRECISION WORDS
	*MULT	
=====	=====	=====
FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
=====	=====	=====
XSPFIS	NXSPFI (37)	IXSPFI
	LOCFIL(2) EQ 0, MEANS DATA IS HELD IN CORE	
	LOCFIL(2) NE 0, MEANS DATA IS ON DISK	
READ	PASS1, PASS2, FISINT, OUTERS, GNDOTS, SHPOUT	
WRITTEN	FISISSON, FISFIX	
DESCRIPTION	MACROSCOPIC FISSION CROSS-SECTIONS AND POINTERS BY MESH CELL OR AVERAGED BY VOLUME OVER REGIONS	
NGROUP	NO. OF NEUTRON ENERGY GROUPS	
NCELLS	NO. OF MESH CELLS	


```

C      NFMAT          NO. OF GENERIC MATERIALS WHICH ARE FISSIONABLE
C      MNFPTS        NO. OF MESH INTERVALS WITH FISSIONABLE MATERIALS
C      MATPNT        MATPNT(I) IS THE FISSIONABLE COMPOSITION NO.
C                      ASSIGNED TO MESH CELL I ON EULERIAN MESH
C      RECORD TYPE 01      (MATPNT(I),I=1,NCELLS)
C          LENGTH          NCELLS          SINGLE PRECISION WORDS
C                      NGROUP RECORDS
C      RECORD TYPE 02      ((SIGF(L,I),L=1,NFMAT),I=1,MNFPTS)
C          LENGTH          NFMAT*MNFPTS*MULT    SINGLE PRECISION WORDS
C          FILE SIZE       (NGROUP*NFMAT*      SINGLE PRECISION WORDS
C                          MNFPTS*MULT)+
C                          NCELLS
C      -----

```

```

C      FILE NAME      LOGICAL UNIT NUMBER      RECORD POINTER
C      =====
C      FDCCOF          NFDCOF          IFDCOF
C                      (38)
C                      INCFDC=0, DATA IS HELD IN CORE
C      READ            OMEGCA,OUTERS,GSORC2
C      WRITTEN          SFDGEN
C      DESCRIPTION     POINTWISE FINITE DIFFERENCE CO-EFFICIENTS FOR EACH
C                      ENERGY GROUP
C      NGROUP          NO. OF NEUTRON ENERGY GROUPS
C      NCELLS          NO. OF MESH CELLS
C      A               FINITE DIFFERENCE CO-EFFICIENT A AT CELL I
C      B               FINITE DIFFERENCE CO-EFFICIENT B AT CELL I
C      E               FINITE DIFFERENCE CO-EFFICIENT E AT CELL I
C                      NGROUP RECORDS
C      RECORD TYPE 01      (A(I),I=1,NCELLS),
C                          (B(I),I=1,NCELLS),
C                          (E(I),I=1,NCELLS)
C          LENGTH          NCELLS*3*MULT    SINGLE PRECISION WORDS
C          FILE SIZE       NCELLS*NGROUP*3    SINGLE PRECISION WORDS
C                          *MULT
C      -----

```

```

C      FILE NAME      LOGICAL UNIT NUMBER      RECORD POINTER
C      =====
C      ADJFLX          NADJFI          IADJFL

```

FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
=====	=====	=====
SCRXS	NSCRXS	ISCRXS
	(41)	

C READ PASS2
 C WRITTEN XSFIX
 C DESCRIPTION MACROSCOPIC TRANSPORT CROSS-SECTION BY MESH CELL
 C OR AVERAGED BY VOLUME OVER REGIONS
 C THIS DATA IS WRITTEN ONLY WHEN THE POINT KINETICS
 C OPTIONS ARE USED
 C NGROUP NO. OF NEUTRON ENERGY GROUPS
 C NCMP NO. OF COMPOSITIONS
 C NGROUP RECORDS
 C RECCRD TYPE 01 (TSIGTR(I), I=1, NCMP)
 C LENGTH NCMP*MULT SINGLE PRECISION WORDS
 C FILE SIZE NCMP*NGROUP*MULT SINGLE PRECISION WORDS
 C -----

C FILE NAME LOGICAL UNIT NUMBER RECORD POINTER
 C =====
 C DELFSO NDLSO IDLSO
 C (42)
 C READ PRCPD
 C DESCRIPTION DELAYED FISSION SOURCE INTO A FAMILY S BY MESH CELL
 C AT BEGINING OF CURRENT REACTIVITY STEP
 C NFAM NO. OF DELAYED PRECURSOR FAMILIES
 C NCELLS NO. OF MESH CELLS
 C NFAM RECORDS
 C RECORD TYPE 01 (DL(I), I=1, NCELLS)
 C LENGTH NCELLS*MULT SINGLE PRECISION WORDS
 C FILE SIZE NFAM*NCELLS*MULT SINGLE PRECISION WORDS
 C -----

C FILE NAME LOGICAL UNIT NUMBER RECORD POINTER
 C =====
 C DELFSN NDLSN IDLSN
 C (43)
 C READ COPYDS
 C WRITTEN PASS2 (TIME=0.0), COPYDS
 C DESCRIPTION DELAYED FISSION SOURCE INTO A FAMILY S BY MESH CELL
 C AT END OF CURRENT REACTIVITY STEP

NFAM	NO. OF DELAYED PRECURSOR FAMILIES	
NCELLS	NO. OF MESH CELLS	
	NFAM RECORDS	
RECORD TYPE 01	(DL(I), I=1, NCELLS)	
LENGTH	NCELLS*MULT	SINGLE PRECISION WORDS
FILE SIZE	NFAM*NCELLS*MULT	SINGLE PRECISION WORDS

FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
=====	=====	=====
SCRFS1	NSCFS1	ISCFS1
	(44)	
READ	GNDOTS	
WRITTEN	FISINT	
DESCRIPTION	PROMPT FISSION SOURCE	
NCELIS	NO. OF MESH CELLS	
NFMAT	NO. OF GENERIC MATERIALS WHICH ARE FISSIONABLE	
	NFMAT RECORDS	
RECORD TYPE 01	(FLNM1(I), I=1, NCELLS),	
	(FLNM2(I), I=1, NCELLS)	
LENGTH	NCELLS*2*MULT	SINGLE PRECISION WORDS
FILE SIZE	NCELLS*2*MULT	SINGLE PRECISION WORDS

FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
=====	=====	=====
SCRFS2	NSCFS2	ISCFS2
	(45)	
WRITTEN	GNDOTS	
DESCRIPTION	PROMPT FISSION SOURCE	
	THIS DATASET IS INTERCHANGEABLE WITH SCRFS1	
NCELLS	NO. OF MESH CELLS	
NFMAT	NO. OF GENERIC MATERIALS WHICH ARE FISSIONABLE	
	NFMAT RECORDS	
FILE SIZE	NCELLS*2*MULT	SINGLE PRECISION WORDS

FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
SCR002	NSCR02 (47)	ISCP02
READ	SRCMOD	
WRITTEN	SRCMOD	
DESCRIPTION	SOURCE TERM IN TIME DEPENDENT SOLUTION OF THE SHAPE FUNCTION (UPDATED)	
NGROUP	NO. OF NEUTRON ENERGY GROUPS	
NCELIS	NO. OF MESH CELLS	
	NGROUP RECORDS	
RECORD TYPE 01	(TIMSRC(I), I=1, NCELIS)	
LENGTH	NCELLS*MULT	SINGLE PRECISION WORDS
FILE SIZE	NCELLS*NGROUP*MULT	SINGLE PRECISION WORDS

FILE NAME	LOGICAL UNIT NUMBER	RECORD POINTER
RSTRT1	NRSTR1 (49)	IREC
READ	RESTR1,COPYDS	
WRITTEN	RESTR1,COPYDS	
DESCRIPTION	THIS DATASET IS WRITTEN SO THAT A PX2 CALCULATION MAY BE CONTINUED IN A LATER JOB AT SOME TIME INTO THE CALCULATION	
RECORD TYPE 01	LABELLED COMMON	/ TABLES /
LENGTH	MAXNAM*(MULT+1)	SINGLE PRECISION WORDS
RECORD TYPE 02	LABELLED COMMON	/ BFLAGS /
LENGTH	100	SINGLE PRECISION WORDS
RECORD TYPE 03	LABELLED COMMON	/ LOCATE /
LENGTH	7	SINGLE PRECISION WORDS
RECORD TYPE 04	LABELLED COMMON	/ SPECS /
LENGTH	27	SINGLE PRECISION WORDS
RECORD TYPE 05	LABELLED COMMON	/ FXCOM /
LENGTH	150*MULT+80	SINGLE PRECISION WORDS
RECORD TYPE 06	LABELLED COMMON	/ LUNAM /
LENGTH	47	SINGLE PRECISION WORDS
RECORD TYPE 07	LABELLED COMMON	/ RCPNT /
LENGTH	35	SINGLE PRECISION WORDS
RECORD TYPE 08	LABELLED COMMON	/ PTITLE /
LENGTH	46*MULT	SINGLE PRECISION WORDS
RECORD TYPE 09	LABELLED COMMON	/ VERNUM /
LENGTH	12	SINGLE PRECISION WORDS

C	RECORD TYPE 10	LABELLED COMMON / PKFLT /	
C	LENGTH	96*MULT	SINGLE PRECISION WORDS
C	RECORD TYPE 11	LABELLED COMMON / ARRAY / (SMALL	
C		CORE CONTAINER)	
C	LENGTH	LASTSCM*MULT	SINGLE PRECISION WORDS
C	RECORD TYPE 12	DATASET DELFSN	
C	LENGTH	NCELLS*MULT	SINGLE PRECISION WORDS
C		NFAM RECORDS	
C	RECORD TYPE 13	DATASET PREC2M (LOCFIL(6) NE 0)	
C	RECORD TYPE 14	DATASET VFRACM (LOCFIL(5) NE 0)	
C		NGROUP RECORDS	
C	RECORD TYPE 15	DATASET FRJM1	
C	LENGTH	NCELLS*MULT	SINGLE PRECISION WORDS
C		NGROUP RECORDS	
C	RECORD TYPE 16	DATASET ADJFLX	
C	LENGTH	NCELLS*MULT	SINGLE PRECISION WORDS
C		NGROUP RECORDS	
C	RECORD TYPE 17	DATASET FRIP1 (LOCFIL(1) NE 0)	
C	LENGTH	NCELLS*MULT	SINGLE PRECISION WORDS
C		2 RECORDS	
C	RECORD TYPE 18	DATASET THDATA (IF NECESSARY)	
C		FIRST RECORD OF THDATA ONLY	
C	RECORD TYPE 19	LABELLED COMMON / ARPAY2 / (PULK	
C		CORE CONTAINER)	
C	LENGTH	LASTLCM*MULT	SINGLE PRECISION WORDS

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FILE NAME      LOGICAL UNIT NUMBER      RECORD POINTER
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RSTRT2         NFSTR2                     IPEC
                (50)
DESCRIPTION    THIS DATASET IS INTERCHANGEABLE WITH RSTRT1
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APPENDIX E

Listing of Common Blocks

SUBROUTINE BLOCKS

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COMMON/APRAY/   BLK(1)
BLK(1)          STARTING ADDRESS FOR SMALL CORE ARRAY
COMMON/ARRAY2/  BLK2(1)
BLK2(1)         STARTING ADDRESS FOR LARGE CORE ARRAY

COMMON/FXCOM/FLT(150),INT(80)
FLT( 1) TI      TIME AT END OF CURRENT REACTIVITY STEP
( 2) TIM1      TIME AT BEGINNING OF CURRENT REACTIVITY STEP
( 3) TIM2      TIME AT BEGINNING OF PREVIOUS REACTIVITY STEP
( 4) TJP1      TIME AT END OF CURRENT SHAPE STEP
( 5) TJ        TIME AT BEGINNING OF CURRENT SHAPE STEP
( 6) TJM1      TIME AT BEGINNING OF PREVIOUS SHAPE STEP
( 7) DTJ       LENGTH OF CURRENT SHAPE STEP
( 8) DTI       LENGTH OF CURRENT REACTIVITY STEP
(11) AMPTI     AMPLITUDE (N) AT END OF CURRENT REACTIVITY STEP
(12) AMPTM1    AMPLITUDE (N) AT BEGINNING OF CURRENT REACTIVITY STEP
(13) AMPCOF(1) QUADRATIC COEFFICIENTS FOR FITTING LN (N) OVER TWO REACTIVITY STEPS
(14)          (2)
(15)          (3)
(16) ALPHA     N DOT/N AT END OF CURRENT REACTIVITY STEP
(17) TEND      TIME AT END OF TRANSIENT
(18) AMPERR     CURRENT AMPLITUDE FUNCTION CONVERGENCE
(19)           (RESERVED FOR FUTURE USE)
(20) GENTIM     NEUTRON GENERATION TIME, CAPITAL LAMBDA
(21) BETAT     TOTAL DELAYED NEUTRON FRACTION, BETA
(22) RHOT      REACTIVITY AT END OF CURRENT REACTIVITY STEP,  $\rho$ 
(23) PTJ        $\rho = (\rho_0 - \beta + (K_0 - 1)/K_0) / (\text{NEUTRON GENERATION TIME})$  AT END OF CURRENT REACTIVITY STEP
(24) QLAM      (EXTERNAL SOURCE/NEUTRON GENERATION TIME) AT END OF CURRENT REACTIVITY STEP
(25) BETAP(1)  SIX VALUES, BY FAMILY, OF BETA PRIME(S)/NEUTRON GENERATION TIME,  $S=1, \dots, 6$ , AT END OF CURRENT REACTIVITY STEP
(26)          (2)
(27)          (3)
(28)          (4)
(29)          (5)
(30)          (6)
(31) PRCMOV(1) SIX VALUES, BY FAMILY, OF  $\lambda_i(S)$ /NEUTRON GENERATION TIME,  $S=1, \dots, 6$ , AT END OF CURRENT REACTIVITY STEP

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C	(32)	(2)	.
C	(33)	(3)	.
C	(34)	(4)	.
C	(35)	(5)	.
C	(36)	(6)	.
C	(37)	PREC(1)	SIX VALUES, BY FAMILY, OF C(S), S=1,...,6, AT END OF CURRENT REACTIVITY STEP
C	(38)	(2)	.
C	(39)	(3)	.
C	(40)	(4)	.
C	(41)	(5)	.
C	(42)	(6)	.
C	(43)	PRECM1(1)	SIX VALUES, BY FAMILY, OF C(S), S=1,...,6, AT BEGINNING OF CURRENT REACTIVITY STEP
C	(44)	(2)	.
C	(45)	(3)	.
C	(46)	(4)	.
C	(47)	(5)	.
C	(48)	(6)	.
C	(49)	AH(1)	SIX VALUES, BY FAMILY, OF A HAT(S), S=1,...,6, FOR CURRENT REACTIVITY STEP. INTEGRAL EVALUATED IN POINT KINETICS AND USED TO CALCULATE POINT- WISE PRECURSOR DENSITIES
C	(50)	(2)	.
C	(51)	(3)	.
C	(52)	(4)	.
C	(53)	(5)	.
C	(54)	(6)	.
C	(55)	BH(1)	SIX VALUES, BY FAMILY, OF B HAT(S), S=1,...,6, FOR CURRENT REACTIVITY STEP. INTEGRAL EVALUATED IN POINT KINETICS AND USED TO CALCULATE POINT- WISE PRECURSOR DENSITIES
C	(56)	(2)	.
C	(57)	(3)	.
C	(58)	(4)	.
C	(59)	(5)	.
C	(60)	(6)	.
C	(61)	DECCON(1)	SIX VALUES, BY FAMILY, OF LAMBDA(S), S=1,...,6, - PRECURSOR DECAY CONSTANTS
C	(62)	(2)	.
C	(63)	(3)	.
C	(64)	(4)	.
C	(65)	(5)	.
C	(66)	(6)	.
C	(67)	DKAPPA(1)	SIX VALUES, BY FAMILY, OF KAPPA(S), S=1,...,6, - PRECURSOR LOSS COEFFICIENTS
C	(68)	(2)	.
C	(69)	(3)	.
C	(70)	(4)	.
C	(71)	(5)	.

C	(72)	(6)	
C	(73)	EPSPK	POINT KINETICS CONVERGENCE PARAMETERS
C	(74)	EPSTRO	REACTIVITY TEMPERATURE CORRECTION CONVERGENCE
C			PARAMETER
C	(75)	DELTRO	COEFFICIENT USED IN REACTIVITY TEMPERATURE
C			CORRECTION ITERATION
C	(76)	ETOT	TOTAL ENERGY GENERATED DURING TRANSIENT
C			(WATT-SEC)
C	(77)	DTDT	FIRST DERIVATIVE OF MAXIMUM TEMPERATURE
C			CHANGE WITH RESPECT TO TIME
C	(78)	TFBASE	BASE FUEL TEMPERATURE (DEG.K) FOR TEMPERATURE
C			DEPENDENT CROSS SECTIONS
C	(79)	TCBASE	BASE COOLANT TEMPERATURE (DEG.K) FOR TEMPERATURE
C			DEPENDENT CROSS SECTIONS
C	(80)	RKEFF	KEFF OF REACTOR-INITIAL
C	(81)	OKEFF	KU - EIGENVALUE OF SOURCE-FREE ADJOINT EQUATIONS
C			FOR REACTOR WITH FIXED SOURCE
C	(82)	GAMMA	GAMMA FACTOR FROM SHAPE CALCULATION
C	(83)	POWIN	INITIAL TOTAL POWER OF REACTOR (WATTS)
C	(84)	POWTOT	TOTAL REACTOR POWER (WATTS)
C	(85)	EPSKEF	CONVERGENCE CRITERIA OF KEFF DURING INITIAL
C			STEADY STATE SHAPE CALCULATION
C	(86)	EPSLAM	CONVERGENCE CRITERIA ON RELATIVE POINT ERROR
C			OF FISSION SOURCES IN SHAPE CALCULATION
C	(87)	EPSFLN	CONVERGENCE CRITERIA ON RELATIVE SUM ERROR
C			OF FISSION SOURCES IN SHAPE CALCULATION
C	(88)	FLNMON	RATIO OF MINIMUM FISSION SOURCE VALUE AT A
C			POINT WHICH WILL BE CONSIDERED IN RELATIVE
C			POINT ERROR CALCULATION TO AVERAGE FISSION
C			SOURCE
C	(89)	PSINRM	DESIRED ERROR REDUCTION FACTOR FOR INNER
C			ITERATIONS ON A GROUP DURING AN OUTER
C			ITERATION IN THE SHAPE CALCULATION
C	(90)	OUTRHO	SPECTRAL RADIUS OF OUTER ITERATION MATRIX
C			IN THE SHAPE CALCULATION
C	(91)	AMPMIN	MINIMUM ALLOWED VALUE OF AMPLITUDE
C	(92)	PHOMIN	MINIMUM ALLOWED VALUE OF REACTIVITY
C	(93)	TMPMAX	MAXIMUM ALLOWED FUEL TEMPERATURE
C	(94)	AMPMAX	MAXIMUM ALLOWED AMPLITUDE FUNCTION VALUE
C	(95)		(RESERVED FOR FUTURE USE)
C	(96)	EPSEGAM	CONVERGENCE CRITERIA FOR GAMMA FACTOR ITERATION
C	(97)	EPCLOW	REACTIVITY STEP FACTOR BY WHICH TIME STEP
C			SELECTION TESTS ARE TIGHTENED AT OR NEAR
C			PROMPT CRITICAL
C	(98)	EPSINC	FACTOR BY WHICH EPSFLN AND EPSLAM ARE TO BE
C			INCREASED FOR TIME-DEPENDENT CALCULATION
C	(99)	EPSTMP	CONVERGENCE CRITERIA FOR POINTWISE POWER
C			DENSITY, STEADY STATE NEUTRONICS FEEDBACK
C			ITERATION
C	(100)	DTMPSH	MAXIMUM ALLOWED FUEL TEMPERATURE CHANGE

C		(DEG. K) OVER A SHAPE STEP
C	(101) DTMPRH	MAXIMUM ALLOWED FUEL TEMPERATURE CHANGE
C		(DEG. K) OVER A REACTIVITY STEP
C	(102) DTSHMX	MAXIMUM ALLOWED SHAPE STEP LENGTH (SEC)
C	(103) DTRHMX	MAXIMUM ALLOWED REACTIVITY STEP LENGTH (SEC)
C	(104) DAMPSH	MAXIMUM ALLOWED AMPLITUDE FUNCTION CHANGE
C		OVER A SHAPE STEP
C	(105) DAMPRH	MAXIMUM ALLOWED AMPLITUDE FUNCTION CHANGE
C		OVER A REACTIVITY STEP
C	(106) DCTRST	TOTAL COMPUTING TIME (MIN.) WHICH WILL BE
C		ALLOWED TO ELAPSE BEFORE ANOTHER RESTART DUMP
C		IS TAKEN
C	(107) DPTRST	TOTAL PROBLEM TIME (SEC.) WHICH WILL BE ALLOWED
C		TO ELAPSE BETWEEN THE TIMES THAT RESTART DUMPS
C		ARE TAKEN
C	(108) DPSISH	MAXIMUM ALLOWABLE CHANGE IN GROUP- AND POINT-
C		DEPENDENT LINEARLY EXTRAPOLATED SHAPE FUNCTION
C		DURING A SHAPE STEP
C	(109)	(RESERVED FOR FUTURE USE)
C	(110) DPSIDT	MAXIMUM OF THE ABSOLUTE VALUES OF DELTA PSI
C		OVER ALL MESH POINTS AND GROUPS/(AVERAGE
C		FLUXES*DELTA T), WHERE PSI IS THE NEUTRON
C		FLUX, AVERAGE FLUX IS THE SUM OF THE FLUXES/
C		(NO. OF MESH POINTS*NO. OF GROUPS), AND DELTA
C		T IS THE PREVIOUS SHAPE STEP LENGTH
C	(111) TMPSUM	SUM OF MAXIMUM FUEL TEMPERATURE CHANGES OVER
C		A SHAPE STEP
C	(112) EFACRO	FACTOR USED TO REDUCE REACTIVITY STEP SIZE
C		GOING THROUGH PROMPT CRITICAL
C	(113) EFACSH	FACTOR USED TO REDUCE SHAPE STEP SIZE GOING
C		THROUGH PROMPT CRITICAL
C	(114) TDRVRH	WILL BE THE SMALLEST TIME AFTER THE END OF
C		THIS REACTIVITY STEP AT WHICH A DRIVING
C		FUNCTION BEGINS OR ENDS
C	(115) TDRVSH	WILL BE THE SMALLEST TIME AFTER THE END OF
C		THIS SHAPE STEP AT WHICH A DRIVING FUNCTION
C		BEGINS OR ENDS
C	(116) TFMAX	MAXIMUM FUEL TEMPERATURE OVER ALL THERMAL -
C		HYDRAULIC REGIONS AT THIS REACTIVITY STEP
C	(117) DTIM1S	PREVIOUS REACTIVITY TIME STEP SIZE
C	(118) DTJM1S	PREVIOUS SHAPE TIME STEP SIZE
C	(119) DTHMAX	MAXIMUM FUEL TEMPERATURE CHANGE OVER ALL MESH
C		POINTS FOR THIS REACTIVITY STEP
C	(120) AMPEXT	EXTRAPOLATED AMPLITUDE
C	(121) CPUT	CPU TIME
C	(122) WAIT	PERIPHERAL PROCESSOR TIME
C	(123) TJOB	TIME IN SECONDS TO RUN JOB
C	(124) RHOTO	INITIAL REACTIVITY SUBTRACTED FROM RHOT(FLT(22))
C		WHEN IPK(INT(1)) = 3. THE PURPOSE IS TO START
C		THE TRANSIENT WITH REACTIVITY IDENTICALLY EQUAL

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C
C
C      (125) T2      ZERO
C                  ISOTOPE FUEL TEMPERATURES FOR WHICH CROSS
C                  SECTIONS WERE CURVE-FITTED TO GIVE DOPPLER
C                  COEFFICIENTS
C                  READ FROM DATA SET XSCON
C
C      (126) T3
C      (127) T4
C      (128) TPSTOR  MAXIMUM FUEL TEMPERATURE AT BEGINNING OF THIS
C                  SHAPE STEP
C
C      (131) TISHCH  TIME AT WHICH FIXED SOURCE IS TO BE ALTERED
C      (132) FCSHCH  FACTOR BY WHICH FIXED SOURCE (ALL MESH POINTS
C                  AND GROUPS) WILL BE MULTIPLIED
C
C      INT( 1) IPK   =0, SPACE-TIME CALCULATION
C                  =1, POINT KINETICS CALCULATION
C                  =2,
C                  =3, INITIAL REACTIVITY DUE TO PERTURBED FLUX
C                  SHAPE IS SUBTRACTED FROM COMPUTED
C                  REACTIVITIES
C
C      ( 2) NSHPST  SHAPE STEP COUNTER
C      ( 3) NRHOST  REACTIVITY STEP COUNTER
C      ( 4)          (RESERVED FOR FUTURE USE)
C      ( 5) ITGAM   GAMMA FACTOR ITERATION COUNTER
C      ( 6) NTHF    0 - NO FEEDBACK CALCULATION
C                  1 - DO FEEDBACK CALCULATION
C
C      ( 7)          (RESERVED FOR FUTURE USE)
C      ( 8) NDOSHP  0 - NO SHAPE CALCULATION AT END OF CURRENT
C                  REACTIVITY STEP
C                  1 - DO SHAPE CALCULATION AT END OF CURRENT
C                  REACTIVITY STEP
C
C      ( 9) NTMPCR  0 - DO NOT ITERATE BETWEEN NEUTRONICS AND
C                  THERMAL-HYDRAULICS IN STEADY STATE
C                  1 - ITERATE NEUTRONICS AND THERMAL-HYDRAULICS
C                  TO CONVERGENCE IN STEADY STATE
C
C      (10) ICMPFL  0 - POINT-WISE COMPOSITIONS
C                  1 - REGION-WISE COMPOSITIONS
C                  (RESERVED FOR FUTURE USE)
C      (11)
C      (12) NFDBK   0 - NO TEMPERATURE FEEDBACK
C                  1 - TEMPERATURE FEEDBACK
C      (13) NITSTP  LENGTH OF INITIAL SHAPE STEP IN GENERATION
C                  TIMES
C      (14) IOVFLG  CONTROLS LOGIC IN SUBROUTINE FXINIT
C                  1 - BINARY INPUT PROCESSOR
C                  2 - FIXED MESH TIME DEPENDENT INITIALIZER
C                  3 - UNUSED AT PRESENT
C                  4 - WRITE RESTART
C                  5 - READ RESTART
C                  CONTROLS LOGIC IN SUBROUTINE FXOV10
C                  1 - CALL PKCALC
C                  2 - CALL RHOBEG

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C      3 - CALL RHOEND
C      4 - CALL SHPEND
C      5 - CALL PKCALC
C      (15) NOSTEP REACTIVITY STEP COUNTER IN CURRENT SHAPE STEP
C      (16) ITRO TEMPERATURE CORRECTION TO REACTIVITY
C      ITERATION COUNTER
C      (17) IPKPT POINTER IN POINT KINETICS UPDATE INFORMATION
C      BUFFER
C      (18) MAXORD CURRENT ORDER OF SUBDIVISION OF REACTIVITY
C      TIME STEP INTO POINT KINETICS SUBINTERVALS
C      (19) NERF ERROR FLAG
C      (20) NOUTMN MINIMUM NUMBER OF OUTER ITERATIONS TO BE DONE
C      DURING A SHAPE CALCULATION
C      (21) NOUTMX MAXIMUM NUMBER OF OUTER ITERATIONS TO BE DONE
C      DURING A SHAPE CALCULATION
C      (22) (RESERVED FOR FUTURE USE)
C      (23) ISHPOU OUTPUT EDIT SELECTOR FROM SHAPE CALCULATION
C      (24) IPROB CALCULATION TYPE FOR SHAPE CALCULATION
C      1 - INHOMOGENEOUS (FIXED SOURCE)
C      2 - EIGENVALUE (KEFF)
C      3 - TIME-DEPENDENT
C      (25) MKRTHY SOLUTION TYPE FOR SHAPE CALCULATION
C      0 - REAL
C      1 - ADJOINT
C      (26) IPTYPE =0, HOMOGENEOUS PROBLEM
C      =1, FIXED SOURCE PRESENT
C      (27) NDOSS 0 - DO STEADY STATE CALCULATION
C      1 - BYPASS STEADY STATE CALCULATION
C      (28) LOOPSS MAXIMUM NUMBER OF ITERATIONS BETWEEN NEUTRONICS
C      AND FEEDBACK CALCULATIONS AT STEADY STATE
C      (29) MAXSCM NUMBER OF WORDS OF SCM AVAILABLE
C      (30) MAXLCM NUMBER OF WORDS OF LCM AVAILABLE
C      (31) NGAMMX MAXIMUM NUMBER OF GAMMA FACTOR ITERATIONS
C      ALLOWED AT A SHAPE STEP
C      (32) NTROMX MAXIMUM NUMBER OF TEMPERATURE CORRECTION TO
C      REACTIVITY ITERATIONS TO BE DONE AT A
C      REACTIVITY STEP DURING UPDATE SWEEP
C      (33) NROSMX MAXIMUM NUMBER OF REACTIVITY STEPS ALLOWED
C      IN A SHAPE STEP
C      (34) IEDF( 1) INPUT BINARY FILE EDIT
C      0 - NO EDIT OF THE INPUT BINARY FILES
C      1 - EDIT INPUT BINARY FILES EXCEPT FOR
C      MACROSCOPIC CROSS SECTIONS AND REGION MAP
C      2 - EDIT ALL INPUT BINARY FILES
C      (35) ( 2) MICROSCOPIC CROSS SECTION EDIT
C      0 - PARTIAL EDIT OF MICROSCOPIC CROSS SECTION
C      HOMOGENIZATION
C      1 - ALSO EDIT INPUT MICROSCOPIC CROSS SECTIONS
C      DURING MICROSCOPIC CROSS SECTION
C      HOMOGENIZATION

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C      (36)      ( 3)  THERMAL HYDRAULICS INPUT EDIT FLAG
C                      0 - DO NOT EDIT THERMAL-HYDRAULICS INPUT
C                      1 - PARTIAL EDIT OF THERMAL-HYDRAULICS INPUT
C                      2 - FULL EDIT OF THERMAL-HYDRAULICS INPUT
C      (37)      ( 4)          (RESERVED FOR FUTURE USE)
C      (35)      ( 5)  DISK EDIT OPTIONS
C                      0 - NO DISK EDITING PERFORMED
C                      1 - BASIC EDIT WRITTEN TO DISK
C                      2 - BASIC EDIT AND POWERS AND TEMPERATURES
C                      3 - BASIC EDIT AND POWERS AND TEMPERATURES
C                        PLUS POINTWISE FLUXES
C      (37)      ( 6)  FUEL AND COOLANT TEMPERATURE EDIT FLAG
C                      0 - DO NOT EDIT FUEL AND COOLANT TEMPERATURES
C                      1 - EDIT FUEL AND COOLANT TEMPERATURES AFTER
C                        EVERY SHAPE STEP
C      (40)      ( 7)  REACTIVITY STEP SUMMARY EDIT
C                      0 - BRIEF EDIT
C                      1 - NORMAL EDIT
C                      2 - DETAILED EDIT
C      (41)      ( 8)  POWER DENSITY EDIT
C                      (REACTIVITY STEP)
C                      0 - DO NOT EDIT POWER DENSITY
C                        AFTER REACTIVITY STEPS
C                      N - EDIT POWER DENSITY AFTER
C                        EVERY N REACTIVITY STEPS
C      (42)      ( 9)  FLUX SHAPE CALCULATION EDIT
C                      0 - MINIMUM EDIT OF EACH FLUX SHAPE CALCULATION
C                      1 - EDIT ITERATION HISTORY AT EACH FLUX SHAPE
C                        CALCULATION
C                      2 - EDIT ITERATION HISTORY AND MULTIGROUP FLUX
C                        SHAPE AT EACH FLUX SHAPE CALCULATION
C      (43)      (10)  POWER DENSITY EDIT (SHAPE STEP)
C                      0 - DO NOT EDIT POWER DENSITY
C                        AFTER SHAPE STEPS
C                      N - EDIT POWER DENSITY AFTER
C                        EVERY N SHAPE STEPS
C      (44) LOCFIL (1)  PSI STORAGE FLAG
C      (45)          (2)  TSIGF, MATPNT STORAGE FLAG
C      (46)          (3)  TSCATD STORAGE FLAG
C      (47)          (4)  TSIGF, TSIGTR STORAGE FLAG
C      (48)          (5)  VFRACM STORAGE FLAG
C      (49)          (6)  ZETAM STORAGE FLAG
C      (50)          (7)  THDATA FILE STORAGE FLAG
C      (51)          (8)          (RESERVED FOR FUTURE USE)
C      (52)          (9)          (RESERVED FOR FUTURE USE)
C      (53)          (10)         (RESERVED FOR FUTURE USE)
C      (54)          (RESERVED FOR FUTURE USE)
C      (57) IRGOTO    LOGIC FLOW FLAG (TIMDEP)
C      (58)          (RESERVED FOR FUTURE USE)
C      (59) NREST     RESTART FLAG

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C
C
C      0 - NO RESTART
C      1 - RESTART PROBLEM
C      (60) INITV      INITIALIZE THERMAL HYDRAULICS
C      (61) NBS        BOUNDARY CONDITIONS
C      (62) NTRIAG     TRIANGULAR GEOMETRY TYPE
C      (63) NTRIPT     LOWER TRIANGLE ORIENTATION
C      (64) IPERB      PERIODIC TRIANGULAR GEOMETRY
C                      ALSO THETA - R PERIODICITY FLAG
C      (65) IFTH       THERMAL-HYDRAULICS CALCULATION FLAG
C                      1 - SIMPLE MODEL WITH ZERO HEAT FLOW APPROX.
C                      2 - SIMPLE MODEL WITH CONSTANT HEAT FLOW APPROX.
C                      3 - DETAILED MODEL
C      (66) NCH        NUMBER OF THERMAL-HYDRAULIC CHANNELS
C      (67) NFR        NUMBER OF REGIONS INSIDE THE FUEL PIN
C      (68) NAX        NUMBER OF AXIAL THERMAL-HYDRAULIC SEGMENTS
C      (69) IST        STRUCTURE CALCULATION FLAG
C                      0 = NO STRUCTURE, 1 = STRUCTURE
C      (70)           (RESERVED FOR FUTURE USE)
C      (71) ITYPE      NUMBER OF DIFFERENT THERMAL-HYDRAULIC DATA TYPES
C      (72) IEN        IF IFTH=1, LEN=10. IF IFTH=2, LEN=50.
C      (73) ITDSRC     FLAG TO INDICATE IF FIXED SOURCE IS TIME
C                      DEPENDENT (0/1) (NO/YES)
C      (74) ITDHAP     FLAG TO INDICATE IF MODIFICATION TO FIXED SOURCE
C                      HAS BEEN MADE YET (0/1) (NO/YES)
C      (75) ITDNO      FLAG TO INDICATE IF FIXED SOURCE IS TO BE
C                      MODIFIED THIS REACTIVITY STEP (0/1) (NO/YES)
C      (76) LSTSCM     LENGTH OF SMALL CORE CONTAINER WHEN RESTART
C                      FILE WAS WRITTEN
C      (77) LSTLCM     LENGTH OF LARGE CORE CONTAINER WHEN RESTART
C                      FILE WAS WRITTEN
C
C      COMMON/SPECS /  NPTI , NPTJ , NINTI , NINTJ , NGROUP, NMAT ,
C      1 NTMAT , NPMAT , NTFMAT, NFAM , MSCT , MAXDN , NREG , NREGD ,
C      2 NCMP , MNFPTS, NDSCT , NGEOM , NZONE , IMBL , JMBT , IMBR ,
C      3 JMBS , NBCS , MAXSIZ, LW4 , LW8
C      NPTI           NO. OF X-DIRECTION MESH LINES
C      NPTJ           NO. OF Y-DIRECTION MESH LINES
C      NINTI          NO. OF X-DIRECTION MESH INTERVALS
C      NINTJ          NO. OF Y-DIRECTION MESH INTERVALS
C      NGROUP         NO. OF NEUTRON ENERGY GROUPS
C      NMAT           NO. OF GENERIC MATERIALS
C      NTMAT          NO. OF UNIQUE MATERIALS
C      NPMAT          NO. OF GENERIC MATERIALS WHICH ARE FISSIONABLE
C      NTFMAT         NO. OF UNIQUE MATERIALS WHICH ARE FISSIONABLE
C      NFAM           NO. OF DELAYED PRECURSOR FAMILIES
C      MSCT           MATERIAL SCATTERING CROSS SECTION ARRAY LENGTH
C      MAXDN          MAX. NO. OF DOWNSCATTER GROUPS FOR A GROUP
C      NREG           NO. OF REGIONS
C      NREGD          NO. OF REGIONS IN WHICH DRIVING FUNCTIONS
C                      ARE USED.

```

C	NCMP	NO. OF COMPOSITIONS
C	MNFPTS	NO. OF MESH INTERVALS WITH FISSIONABLE MATERIALS
C	NDSCT	TOTAL NUMBER OF DOWNSCATTER GROUPS
C	NGEOM	GEOMETRY TYPE
C	NZONE	NUMBER OF ZONES
C	IMBL	LEFT BOUNDARY ON FIRST DIMENSION
C	JMBT	TOP BOUNDARY ON SECOND DIMENSION
C	IMBR	RIGHT BOUNDARY ON FIRST DIMENSION
C	JMBB	BOTTOM BOUNDARY ON SECOND DIMENSION
C	NBCS	NO. OF CONSTANTS FOR EXTERNAL BOUNDARIES
C		1 - SINGLE VALUE USED EVERYWHERE
C		6 - INDIVIDUAL VALUES FOR EACH POSSIBLE SURFACE
C		GT 6 - SIX VALUES ARE GIVEN FOR THE FIRST ENERGY
C		GROUP, THEN FOR THE NEXT GROUP, TO END OF
C		LIST- IF THERE ARE MORE GROUPS, LAST GROUP
C		DATA GIVEN IS USED
C	MAXSIZ	SIZE OF FAST CORE STORAGE
C		(IN DOUBLE PRECISION WORDS ON IBM)
C		(IN SINGLE PRECISION WORDS ON CDC)
C	LW4	IBM-NO. OF BYTES IN A SINGLE PRECISION WORD
C	LW8	IBM-NO. OF BYTES IN A DOUBLE PRECISION WORD
C		
C	COMMON/LUNAM /	NRTFLX, NATFLX, NFIXSR, NISOTX, NGEODS, NFXHMO,
C	1 NFRI , NFRIP1,	NFRJM1, NADJFL, NSHPES, NSCFS1, NSCFS2, NFDCOF,
C	2 NPWDNM, NXSCON,	NXSPGR, NXSPFI, NXSPSC, NSCRXS, NPRECM, NDLFSN,
C	3 NDLFSO, NVFRAC,	NRSTR1, NRSTR2, NTHDAT, NPWOLD, NFXEDT, NFXCTL,
C	4 NFXTH , NSCR01,	NSCR02, NSCR03, NWDS0 , NWDS1 , NWDS2 , NWDS3 ,
C	5 NWDS4 , NWDS5 ,	LDW , MODE0 , MODE1 , MODE2 , IRWD , NIN
C	NRTFLX-NSCR03	THESE ARE THE LOGICAL UNIT NUMBERS OF THE FX2
C		BINARY FILES. THEY ARE MANAGED BY SUBROUTINE
C		SEEK. THEIR VALUES WILL BE -1,0, OR THE LOGICAL
C		UNIT NUMBER OF THE FILE.
C	NWDS0	NWDS0=0. NO. OF WORDS TO BE TRANSFERRED IN
C		SUBROUTINE REED/RITE. (USED TO SKIP RECORDS)
C	NWDS1	NO. OF SINGLE PRECISION WORDS TO BE TRANSFERRED
C		IN SUBROUTINE REED/RITE
C	NWDS2	NO. OF SINGLE PRECISION WORDS TO BE TRANSFERRED
C		IN SUBROUTINE REED/RITE
C	NWDS3	NO. OF SINGLE PRECISION WORDS TO BE TRANSFERRED
C		IN SUBROUTINE REED/RITE
C	NWDS4	NO. OF SINGLE PRECISION WORDS TO BE TRANSFERRED
C		IN SUBROUTINE REED/RITE
C	NWDS5	NO. OF SINGLE PRECISION WORDS TO BE TRANSFERRED
C		IN SUBROUTINE REED/RITE
C	LDW	NO. OF WORDS IN A DOUBLE PRECISION WORD
C		LDW=2. IBM
C		LDW=1. CDC
C	MODE0	MODE0=0. USED FOR ASYNCHRONOUS I/O IN
C		SUBROUTINE REED/RITE


```

C      MODE1          MODE1=1. USED TO INITIATE SYNCHRONOUS I/O
C                      IN SUBROUTINE REED/RITE
C      MODE2          MODE2=2. USED TO WAIT FOR COMPLETION OF
C                      SYNCHRONOUS I/O IN SUBROUTINE REED/RITE
C      IRWD           IRWD=0. PASSED TO SUBROUTINE REED/RITE TO
C                      REWIND A FILE
C      NIN            LOGICAL UNIT NUMBER FOR CARD INPUT FILE
C                      NIN=5 IS DEFAULT VALUE
C
C      COMMON/RCPNT /  IRTFLX, IATFLX, IFIXSR, IISOTX, IGEODS, IFXHMO,
C 1 IFRI , IFRIPI, IFRJM1, IADJFL, ISHPES, ISCFS1, ISCFS2, IPDCOF,
C 2 IPWDNM, IXSCON, IXSPGR, IXSPFI, IXSPSC, ISCRXS, IPRECM, IDLFSN,
C 3 IDLFSO, IVFRAC, IRSTR1, IRSTR2, ITHDAT, IPWOLD, IFXEDT, IFXCTL,
C 4 IFXTH , ISCR01, ISCR02, ISCR03
C      IRTFLX-ISCRO3   THESE ARE THE RECORD NUMBER POINTERS FOR THE FX2
C                      BINARY FILES. THEY ARE PASSED TO SUBROUTINE
C                      REED/RITE.
C
C      COMMON/PTITLE/ TITLE(12),TIMES(10),ESTIM(2,7),ERTIM(2,5)
C      TITLE(12)       AN ARRAY FOR PROBLEM TITLE
C      TIMES(10)       AN ARRAY PASSED TO SUBROUTINE TIMER
C      ESTIM(2,7)      AN ARRAY FOR SHAPE STEP TIMES
C                      ESTIM(1,*)-CPU TIME(SECONDS) .
C                      ESTIM(2,*)-PERIPHERAL PROCESSOR TIME(SECONDS) .
C                      ESTIM(*,1)- ERTIM(*,1) SUMMED OVER A SHAPE STEP
C                      ESTIM(*,2)- ERTIM(*,2) SUMMED OVER A SHAPE STEP
C                      ESTIM(*,3)- ERTIM(*,3) SUMMED OVER A SHAPE STEP
C                      ESTIM(*,4)- ERTIM(*,4) SUMMED OVER A SHAPE STEP
C                      +NEW AMPLITUDE FUNCTION EQUATION
C                      ESTIM(*,5)- SHAPE CALCULATION (FXSHAP)
C                      +GAMMA ITEFATION TIME.
C                      ESTIM(*,6)- ERTIM(*,5) SUMMED OVER A SHAPE STEP
C                      ESTIM(*,7)- INITIALIZE THERMAL HYDRAULICS
C                      MODEL (FXTHRM)
C                      +AMPLITUDE EQUATIONS CO-EFFICIENTS
C                      GENERATION (FXINPD)
C      ERTIM(2,5)      AN ARRAY FOR RE-ACTIVITY STEP TIMES.
C                      ERTIM(1,*)-CPU TIME(SECONDS) .
C                      ERTIM(2,*)-PERIPHERAL PROCESSOR TIME(SECONDS) .
C                      ERTIM(*,1) - THERMAL-HYDRAULICS (FXTHRM)
C                      ERTIM(*,2)- UNUSED AT PRESENT
C                      ERTIM(*,3)- POINT MACROSCOPIC CROSS-SECTION
C                      GENERATION (FXPTXS)
C                      ERTIM(*,4)- AMPLITUDE EQUATION CO-EFFICIENT
C                      GENERATION (FXINPD)
C                      ERTIM(*,5)- REACTIVITY STEP INITIALIZATION.

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C      COMMON/VERNUM/  IVISOT, IVDLAY, IVFXCT, IVGEOD, IVFXHM, IVXSCO,
C      1 IVFIXS, IVFXTH, IVRTFL, IVATFL, IVRST1, IVRST2
C      IVISOT          CCCC FILE VERSION NUMBER FOR FILE ISOTXS
C      IVDLAY          CCCC FILE VERSION NUMBER FOR FILE DLAYXS
C      IVFXCT          FX2 FILE VERSION NUMBER FOR FILE FXCTRL
C      IVGEOD          CCCC FILE VERSION NUMBER FOR FILE GEODST
C      IVFXHM          FX2 FILE VERSION NUMBER FOR FILE FXHMUG
C      IVXSCO          FX2 FILE VERSION NUMBER FOR FILE XSCON
C      IVFIXS          CCCC FILE VERSION NUMBER FOR FILE FIXSRC
C      IVFXTH          FX2 FILE VERSION NUMBER FOR FILE FXTH
C      IVRTFL          CCCC FILE VERSION NUMBER FOR FILE RTFLUX
C      IVATFL          CCCC FILE VERSION NUMBER FOR FILE ATFIUX
C      IVRST1          FX2 FILE VERSION NUMBER FOR FILE RSTRT1
C      IVRST2          FX2 FILE VERSION NUMBER FOR FILE RSTRT2
C
C      COMMON/PKFLT /  AMPI , AMPO , ALFA , DT , DT1 , BUPT ,
C      1 PHINT , PUP , STORHO, STORPR, RUP , STRUP , TRUP , TMIN ,
C      2 TMAX , TPREV , AMPVA(3) , BETVA(3,6) , BUP(6) ,
C      3 EXVA(3) , PRAC(6) , PPOLVA(3) , ROVA(3) ,
C      4 STOREB(6) , STOREX(6) , XSVA(3,6) , XUP(6) ,
C      5 STOPBT , TBETA
C      AMPI            AMPLITUDE AT CURRENT REACTIVITY STEP
C      AMPO            AMPLITUDE AT PREVIOUS REACTIVITY STEP
C      ALFA            NDOT/N. DERIVATIVE OF AMPLITUDE/AMPLITUDE
C      DT             TMAX-TMIN
C      DT1            TMIN-TPREV
C      BUPT           (BETA-POINT KINETICS ESTIMATE OF BETA)/
C                   SHAPE STEP LENGTH (DTJ)
C                   BETA=TOTAL DELAYED NEUTRON FRACTION
C      PHINT          AMPLITUDE INTEGRAL
C      PUP            (NEUTRON GENERATION-POINT KINETICS ESTIMATE OF
C                   NEUTRON GENERATION TIME)/SHAPE STEP LENGTH (DTJ)
C      STORHO         (RHO-BETA+(K0-1)/K0)/
C                   (NEUTRON GENERATION TIME)
C                   POINT KINETICS ESTIMATE AT END OF SHAPE STEP
C      STORPR         NEUTRON GENERATION TIME
C                   POINT KINETICS ESTIMATE AT END OF SHAPE STEP
C      RUP            (PTI-POINT KINETICS ESTIMATE OF PTI)/
C                   SHAPE STEP LENGTH (DTJ)
C                   PTI=(RHO-BETA+(K0-1)/K0)/NEUTRON GEN. TIME
C      STRUP
C      TRUP
C      TMIN           TIME AT REACTIVITY STEP (I-1)
C      TMAX           TIME AT REACTIVITY STEP (I)
C      TPREV          TIME AT REACTIVITY STEP (I-2)
C      AMPVA(3)       LN(AMPLITUDE)
C                   (THREE MOST RECENT VALUES)
C      BETVA(3,6)     (BETA(S))/(NEUTRON GENERATION TIME)
C                   WHERE S=1 TO NFAM

```

```

C      (THREE MOST RECENT VALUES)
C      BUP(6)      (BETA(S))-POINT KINETICS ESTIMATE OF BETA(S) ')/
C                   SHAPE STEP LENGTH (DTJ)
C                   WHERE S = 1 TO NFAM
C      EXVA(3)      (EXTERNAL SOURCE)/(NEUTRON GENERATION TIME)
C                   (THREE MOST RECENT VALUES)
C      PRAC(6)      PRECURSORS(S) AT BEGINING OF SHAPE STEP
C                   WHERE S = 1 TO NFAM
C      PROLVA(3)     NEUTRON GENERATION TIME
C                   (THREE MOST RECENT VALUES)
C      ROVA(3)      (RHO-BETA+(K0-1)/K0)/
C                   (NEUTRON GENERATION TIME)
C                   (THREE MOST RECENT VALUES)
C      STOREB(6)     BETA(S) '/(NEUTRON GENERATION TIME)
C                   WHERE S=1 TO NFAM
C                   POINT KINETICS ESTIMATE AT END OF SHAPE STEP
C      STOPEX(6)     PRECURSORS(S)/(NEUTRON GENERATION)
C                   WHERE S=1 TO NFAM
C                   POINT KINETICS ESTIMATE AT END OF SHAPE STEP
C      XSVA(3,6)     PRECURSORS(S)/(NEUTRON GENERATION TIME)
C                   WHERE S=1 TO NFAM
C                   (THREE MOST RECENT VALUES)
C      XUP(6)        (PRECURSORS(S)-POINT KINETICS ESTIMATE OF
C                   PRECURSORS(S))/SHAPE STEP LENGTH (DTJ)
C                   WHERE S = 1 TO NFAM
C      STORBT        TOTAL DELAYED NEUTRON FRACTION, BETA
C                   POINT KINETICS ESTIMATE AT END OF SHAPE STEP
C      TBETA         TOTAL DELAYED NEUTRON FRACTION, BETA
C
C      COMMON/OUTPUT/NOU
C      NOU           LOGICAL UNIT NUMBER FOR PRINT OUTPUT FILE
C                   NOU=6 IS DEFAULT VALUE
C
C      COMMON/TABLES/NAMLST(150),LENLST(150),IPTLST(150),LEN(150),
C      1            MLT(150),NNAMS
C      NAMLST        LIST OF ARRAY NAMES STORED IN CONTAINER ARRAY
C      LENLST        LENGTH OF EACH ARRAY
C      IPTLST        POINTERS FOR EACH ARRAY
C      LEN           ORIGINAL LENGTH OF EACH ARRAY
C      MLT           VARIABLE TYPE OF EACH ARRAY
C                   2 - 2 BYTE WORD
C                   4 - 4 BYTE WORD
C                   8 - 8 BYTE WORD
C      NNAMS         NUMBER OF NAMES STORED IN BPOINTER TABLES
C
C      COMMON/LOCATE/LSTM,MAXM,1STB,MAXB,INDXM,INDXB,IPRINT
C      LSTM          INDEX OF FIRST AVAILABLE LOCATION IN PRIMARY

```

```

C      STORAGE ARRAY
C      MAXM      MAXIMUM LENGTH OF THE PRIMARY STORAGE ARRAY
C      LSTB      INDEX OF FIRST AVAILABLE LOCATION IN SECONDARY
C                STORAGE ARRAY
C      MAXB      MAXIMUM LENGTH OF SECONDARY STORAGE ARRAY
C      INDXM      ADDRESS (INDEX) ' ' OFFSET OF PRIMARY STORAGE
C                IN WORDS
C      INDXB      ADDRESS (INDEX) ' ' OFFSET OF SECONDARY STORAGE
C                IN WORDS
C      IPRINT     EDIT FLAG FOR POINTR ROUTINE
C                0 - NO PRINTOUT
C                1 - DUMPS ONLY
C                2 - TRACE ONLY
C                DUMPS AND TRACE
C
C      COMMON /ICMSIZ/ ILOCM,ILOCB,MAXBLK,MAXFM,MAXFB,MULT,MAXNAM,
C      1             MULT3,JLOCM,JLOCB
C      ILOCM      STARTING ADDRESS OF PRIMARY STORAGE ARRAY
C      ILOCB      STARTING ADDRESS OF SECONDARY STORAGE APRAY
C      MAXBLK     LENGTH OF SECONDARY STORAGE ARPAY REQUESTED
C      MAXFM      LENGTH OF PRIMARY STORAGE ARRAY BEFORE
C                EXTENSION BY ADDRESS OFFSET
C      MAXFB      LENGTH OF SECONDARY STORAGE ARRAY BEFORE
C                EXTENSION BY ADDRESS OFFSET
C      MULT       NO. OF WORDS IN A DOUBLE PRECISION WORD.
C                MULT=2. IBM
C                MULT=1. CDC
C      MAXNAM     MAXIMUM NO. OF NAMES WHICH CAN BE HELD IN POINTR
C                TABLES (MAXNAM=150)
C      MULT3      MULT3=MULT**3
C      JLOCM      ADDRESS OF LABELLED COMMON BLOCK ARRAY
C      JLOCB      ADDRESS OF ECM CONTAINER ARRAY
C
C      COMMON/BFLAGS/IFLAG (150)
C      IFLAG      MEMORY FLAG FOR EACH ARRAY
C                0 - PRIMARY STORAGE APAY
C                1 - SECONDARY STORAGE ARRAY
C

```

APPENDIX F

Sample Problem 1 Output

BCD INPUT

BLOCK=CID

DATASET=XSCON

BLOCK=STP014

DATASET=A.FX2

```

01      FX2-TH TEST PROBLEM 1
02      2000 13000
03      0      0      0      0      1      0      0      0
04      1      0      0      3      0      50      10 10000
05      2      0      0      0      0      0      1      0      1      0
06      0.5      0.05      -0.01      0.0      1000.0
07      0.0      0.001      1.0E-6      0.0      0.8
07      1.0E-7      1.0E-6      1.0E-7      1.0E2      0.0
08      120.0      30.0      0.5      0.25      1.0
08      2.0      0.1      0.0      0.0
09      5.0E8      1.0 1.0      0.01
09      0.0
10      INCORE      SS      0.0      1.0      -0.1      2.0

```

DATASET=A.FNIP

```

03      50
04      3      2      2      2
06      AXFEFL      0.      80.      0.      130.
06      RDREFL      80.      100.      0.      120.
06      AXBLKT      0.      65.      20.      110.
06      RDBLKT      65.      80.      20.      110.
06      INCORE      0.      45.      30.      100.
06      OUCORE      45.      65.      30.      100.
09      X      8      45.0      3      65.0      2      80.0
09      X      3      100.0
09      Y      3      20.0      2      30.0      10      100.
09      Y      2      110.      3      130.
14      INCORE      UO2      9.25      PUC2      0.05      SS      0.25
14      INCORE      NA      0.45
14      OUCORE      UO2      0.24      PUO2      0.06      SS      0.25
14      OUCORE      NA      0.45
14      RDBLKT      UO2      0.30      SS      0.25      NA      0.45
14      AXBLKT      UO2      0.30      SS      0.30      NA      0.40
14      RDREFL      SS      0.60      NA      0.28      NI      0.12
14      AXFEFL      SS      0.30      NA      0.40      NI      0.30

```

BCD FILES FORMED FROM BLOCK STP014

A.FX2 VERSION = 1, MAXIMUM CARD TYPE = 10, NOSORT CARDS = 0
 CARDS-PER-CARD-TYPE = 1 1 1 1 1 1 2 2 2 1

01 FX2-TH TEST PROBLEM 1
 02 2000 13000 0
 03 0 0 0 0 1 0 0 0
 04 1 0 0 3 0 50 10 10000
 05 2 0 0 0 0 0 1 0 1 0
 06 0.5 0.05 -0.01 0.0 1000.0
 07 0.0 0.001 1.0E-6 0.0 0.8
 07 1.0E-7 1.0E-6 1.0E-7 1.0E2 0.0
 08 120.0 30.0 0.5 0.25 1.0
 08 2.0 0.1 0.0 0.0
 09 5.0E8 1.0 1.0 0.01
 09 0.0
 10 INCORE SS 0.0 1.0 -0.1 0.0

A.FNIP VERSION = 1, MAXIMUM CARD TYPE = 14, NOSORT CARDS = 0
 CARDS-PER-CARD-TYPE = 0 0 1 1 0 6 0 0 4 0 0 0 0 8

03 50
 04 3 2 2 2
 06 AXREFL 0. 80. 0. 130.
 06 RDREFL 80. 100. 0. 130.
 06 AXBLKT 0. 65. 20. 110.
 06 RDBLKT 65. 80. 20. 110.
 06 INCORE 0. 45. 30. 100.
 06 OUCORE 45. 65. 30. 100.
 09 X 8 45.0 3 65.0 2 80.0
 09 X 3 100.0
 09 Y 3 20.0 2 30.0 10 100.
 09 Y 2 110. 3 130.
 14 INCORE U02 0.25 PU02 0.05 SS 0.25
 14 INCORE NA 0.45
 14 OUCORE U02 0.24 PU02 0.06 SS 0.25
 14 OUCORE NA 0.45
 14 RDBLKT U02 0.30 SS 0.25 NA 0.45
 14 AXBLKT U02 0.30 SS 0.30 NA 0.40
 14 RDREFL SS 0.60 NA 0.28 NI 0.12
 14 AXREFL SS 0.30 NA 0.40 NI 0.30

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FX2-TH TEST PROBLEM 1

2/01/78 19.49.31

*** FX2 BCD INPUT PROCESSOR ***

THE FOLLOWING BINARY DATASETS HAVE BEEN WRITTEN-
NAME VERSION USER IDENTIFICATION

FXCTRL	1	B20219FX2PRO
GEODST	1	B20219FX2PRO
FXHMOG	1	B20219FX2PRO
RTFLUX	1	B20219FX2PRO
ATFLUX	1	B20219FX2PRO

BCD INPUT PROCESSING COMPLETED

CENTRAL PROCESSOR TIME (SEC) = 0.27
PERIPHERAL PROCESSOR TIME (SEC) = 2.16

FX2-TH 07/77

FX2-TH TEST PROBLEM 1

2/01/78 19.49.31

*** THIS CASE IS ENTITLED ***

FX2-TH TEST PROBLEM 1

INPUT FILE FXCTRL, VERSION 1, USER IDENTIFICATION = B20219FX2PRO HAS BEEN PROCESSED.
INPUT FILE GEODST, VERSION 1, USER IDENTIFICATION = B20219FX2PRO HAS BEEN PROCESSED.
INPUT FILE FXHMOG, VERSION 1, USER IDENTIFICATION = B20219FX2PRO HAS BEEN PROCESSED.
INPUT FILE XSCON, VERSION 1, USER IDENTIFICATION = TEST.PROB. 1 HAS BEEN PROCESSED.
INPUT FILE RTFLUX, VERSION 1, USER IDENTIFICATION = B20219FX2PRO HAS BEEN PROCESSED.
INPUT FILE ATFLUX, VERSION 1, USER IDENTIFICATION = B20219FX2PRO HAS BEEN PROCESSED.

*** USER INPUT SPECIFICATIONS FOR THIS PROBLEM ***

0	NREST	0/1 NO/YES FSTART PROBLEM
0	IPK	0/1/2/3 SPACE-DEPENDENT/POINT (LINEARIZED D)/POINT (NONLINEAR D)/ POINT (PERTURBED SHAPE) NEUTRONICS
0	NTHF	0/1 NO/YES DO THERMAL HYDRAULICS
0	NFDBK	0/1 NO/YES MODIFY CROSS SECTIONS FOR TEMPERATURE DEPENDENCE
1	ICMPFL	0/1 POINTWISE/REGIONWISE MATERIAL COMPOSITIONS
0	IPTYPE	0/1 NO/YES INHOMOGENEOUS FIXED SOURCE PRESENT
0	NDOSS	0/1 YES/NO DO STEADY STATE CALCULATION
0	NTMPCR	0/1 NO/YES ITERATE BETWEEN NEUTRONICS AND THERMAL HYDRAULICS IN STEADY STATE
0	ITDSRC	0/1 NO/YES FIXED SOURCE IS TIME DEPENDENT

STORAGE, ITERATION LIMITS

2000	MAXSCM	NO. OF WORDS REQUESTED FOR SMALL CORE CONTAINER
13000	MAXLCM	NO. OF WORDS REQUESTED FOR LARGE CORE CONTAINER
1	LOOPSS	MAX. NO. OF NEUTRONICS/FEEDBACK ITERATIONS AT STEADY STATE
3	NGAMMX	MAX. NO. OF GAMMA FACTOR ITERATIONS AT A SHAPE STEP
50	NOUTMY	MAX. NO. OF OUTER ITERATIONS DURING A FLUX SHAPE CALCULATION
10	NROSMX	MAX. NO. OF REACTIVITY STEPS IN A SHAPE STEP
10000	NITSTP	NO. OF GENERATION TIMES IN INITIAL TIME STEP

EDIT OPTIONS

2	IEDF(1)	0/1/2 NONE/PARTIAL/COMPLETE EDIT OF PROBLEM DESCRIPTION
0	(2)	0/1 PARTIAL/COMPLETE EDIT OF CROSS SECTION HOMOGENIZATION
0	(3)	0/1/2 NONE/PARTIAL/COMPLETE EDIT OF THERMAL-HYDRAULICS INPUT
0	(5)	0/1/2 NONE/SIMPLE/DETAILED EDIT WRITTEN TO EDIT DISK
0	(6)	0/1 NONE/EVERY SHAPE STEP EDIT FUEL AND COOLANT TEMPERATURES
1	(7)	0/1/2 BRIEF/NORMAL/DETAILED REACTIVITY STEP SUMMARY EDIT
0	(8)	0/N NONE/EVERY N REACTIVITY STEPS POWER DENSITY EDIT
1	(9)	0/1/2 NONE/PARTIAL/COMPLETE EDIT OF EACH FLUX SHAPE CALCULATION
0	(10)	0/N NONE/EVERY N SHAPE STEPS POWER DENSITY EDIT

PROBLEM LIMITS

0.500000D+00	TEND	PROBLEM END TIME (SEC)
0.500000D-01	AMPMIN	MIN. ALLOWED VALUE OF AMPLITUDE
0.100000D+04	AMPMAX	MAX. ALLOWED VALUE OF AMPLITUDE
-0.100000D-01	RHOMIN	MIN. ALLOWED VALUE OF REACTIVITY

CONVERGENCE CRITERIA

0.100000D-02	EPGAM	GAMMA FACTOR CONVERGENCE CRITERIA
0.100000D-05	EPSPK	AMPLITUDE FUNCTION EQUATION SOLUTION ACCURACY
0.800000D+00	EPCLOW	FACTOR USED TO TIGHTEN TIME STEP SELECTORS NEAR PROMPT CRITICAL
0.100000D-06	EPSKEP	EIGENVALUE CONVERGENCE CRITERIA, STEADY STATE FLUX CALCULATION
0.100000D-05	EPSLAM	POINTWISE FISSION SOURCE CONVERGENCE CRITERIA FOR SHAPE CALCULATION
0.100000D-06	EPSFLN	AVERAGE FISSION SOURCE CONVERGENCE CRITERIA FOR SHAPE CALCULATION
0.100000D+03	EPSINC	FACTOR FOR LOOSENING EPSLAM AND EPSFLN FOR TIME-DEPENDENT CALCULATION
0.100000D-02	EPSTMP	POINTWISE POWER DENSITY CONVERGENCE CRITERIA, STEADY STATE ITERATION

TIME STEP SELECTION CRITERIA

0.120000D+03	DTMPSH	MAX. ALLOWED FUEL TEMPERATURE CHANGE OVER SHAPE STEP (DEG. K)
0.300000D+02	DTMPRH	MAX. ALLOWED FUEL TEMPERATURE CHANGE OVER REACTIVITY STEP (DEG. K)
0.500000D+00	DTSHMX	MAX. ALLOWED SHAPE STEP LENGTH (SEC)
0.200000D+00	DTRHMX	MAX. ALLOWED REACTIVITY STEP LENGTH (SEC)
0.500000D+09	DAMPSH	NO. OF SHAPE STEPS/DECADE OF AMPLITUDE CHANGE
0.200000D+01	DAMERH	NO. OF REACTIVITY STEPS/DECADE OF AMPLITUDE CHANGE
0.100000D+00	DPSISH	MAX. ALLOWED POINTWISE FLUX SHAPE CHANGE OVER SHAPE STEP

OTHER FLOATING POINT PARAMETERS

0.500000D+09	POWIN	STEADY STATE REACTOR POWER (WATTS)
1.000000000	RKEFF	K-EFFECTIVE (INITIAL GUESS IF NDOSS=1)
1.000000000	OKEFF	EIGENVALUE OF SOURCE-FREE ADJOINT PROBLEM (USED IF IPTYPE=1)
0.100000D-01	FLNMON	MIN./AVE. CRITERIA FOR POINTWISE FISSION SOURCE TEST
0.300000D-01	PSINRM	ERROR REDUCTION FACTOR FOR SHAPE CALCULATION INNER ITERATIONS
0.0	OUTRHO	INPUT ESTIMATE OF SHAPE CALCULATION DOMINANCE RATIO
0.700000D+03	TFBASE	BASE FUEL TEMPERATURE (DEG. K)
0.500000D+03	TCBASE	BASE COOLANT TEMPERATURE (DEG. K)
0.694650D+01	DCTRST	COMPUTING TIME INTERVAL BETWEEN RESTART DUMPS (MIN)
0.150000D+01	DPTRST	PROBLEM TIME INTERVAL BETWEEN RESTART DUMPS (SEC)
0.0	TISHCH	TIME THAT FIXED SOURCE WILL BE ALTERED (SEC)
0.100000D+01	FCSHCH	FACTOR BY WHICH FIXED SOURCE WILL BE MULTIPLIED

*** PROBLEM DESCRIPTION ***

NO. OF FIRST DIMENSION MESH INTERVALS = 16
 NO. OF SECOND DIMENSION MESH INTERVALS = 20
 NO. OF REGIONS = 6
 NO. OF ZONES = 1
 NO. OF ENERGY GROUPS = 4
 MAX. NO. OF DOWNSCATTER GROUPS = 2
 NO. OF DELAYED PRECURSOR FAMILIES = 6
 NO. OF GENERIC MATERIALS = 5
 NO. OF GENERIC FISSIONABLE MATERIALS = 2
 NO. OF UNIQUE MATERIALS = 5
 NO. OF UNIQUE FISSIONABLE MATERIALS = 2

PROBLEM GEOMETRY - 2-DIMENSIONAL R - Z

R - DIRECTION MESH INTERVAL BOUNDARIES

1	0.0	2	0.562500D+01	3	0.112500D+02	4	0.168750D+02	5	0.225000D+02	6	0.281250D+02
7	0.337500D+02	8	0.393750D+02	9	0.450000D+02	10	0.516667D+02	11	0.583333D+02	12	0.650000D+02
13	0.725000D+02	14	0.800000D+02	15	0.866667D+02	16	0.933333D+02	17	0.100000D+03		

Z - DIRECTION MESH INTERVAL BOUNDARIES

1	0.0	2	0.666667D+01	3	0.133333D+02	4	0.200000D+02	5	0.250000D+02	6	0.300000D+02
7	0.370000D+02	8	0.440000D+02	9	0.510000D+02	10	0.580000D+02	11	0.650000D+02	12	0.720000D+02
13	0.790000D+02	14	0.860000D+02	15	0.930000D+02	16	0.100000D+03	17	0.105000D+03	18	0.110000D+03
19	0.116667D+03	20	0.123333D+03	21	0.130000D+03						

BOUNDARY CONDITIONS (ORIGIN AT LOWER LEFT)

0 - ZERO FLUX 1 - ZERO CURRENT 2 - EXTRAPOLATED 3 - PERIODIC OPPOSITE FACE
 4 - PERIODIC NEXT ADJACENT FACE 5 - INVERTED PERIODIC ALONG FACE

R	= 0.0	R	= 0.100000D+03	Z	= 0.0	Z	= 0.130000D+03
1		0		0		0	

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REGION NUMBER, LABEL, AND ASSIGNMENT TO ZONE

REGION NO.	ZONE LABEL NO.	REGION NO.	ZONE LABEL NO.	REGION NO.	ZONE LABEL NO.	REGION NO.	ZONE LABEL NO.	REGION NO.	ZONE LABEL NO.
1	AXREFL 1	2	RDREFL 1	3	AXBLKT 1	4	RDELKT 1	5	INCORE 1
								6	OCORE 1

BUCKLINGS BY ZONE AND GROUP
(CM-2 , LAST VALUE FOR ZONE USED FOR REMAINING GROUPS)

BUCKLING FOR ALL ZONES, ALL GROUPS 0.0

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REACTOR REGIONS BY MESH POINT

Z	-DIM/R	-DIM																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		

20	*	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	*	20
	*													*				*	
19	*	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	*	19
	*													*				*	
18	*	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	*	18
	*	*****																	
17	*	3	3	3	3	3	3	3	3	3	3	3	4	4	2	2	2	*	17
	*												*					*	
16	*	3	3	3	3	3	3	3	3	3	3	3	4	4	2	2	2	*	16
	*	*****																	
15	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	15
	*									*			*					*	
14	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	14
	*									*			*					*	
13	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	13
	*									*			*					*	
12	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	12
	*									*			*					*	
11	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	11
	*									*			*					*	
10	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	10
	*									*			*					*	
9	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	9
	*									*			*					*	
8	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	8
	*									*			*					*	
7	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	7
	*									*			*					*	
6	*	5	5	5	5	5	5	5	5	6	6	6	4	4	2	2	2	*	6
	*	*****																	
5	*	3	3	3	3	3	3	3	3	3	3	3	4	4	2	2	2	*	5
	*									*			*					*	
4	*	3	3	3	3	3	3	3	3	3	3	3	4	4	2	2	2	*	4
	*	*****																	
3	*	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	*	3
	*									*			*					*	
2	*	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	*	2
	*									*			*					*	
1	*	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	*	1
	*	*****																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		

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ASSIGNMENT OF MATERIALS TO REGIONS

NO.	REGION LABEL	UNIQUE LABEL	MATERIAL GENERIC LABEL	VOLUME FRACTION	UNIQUE LABEL	MATERIAL GENERIC LABEL	VOLUME FRACTION,
1	AXREFL	SS NA	SS NA	0.300000D+00 0.400000D+00	NI	NI	0.300000D+00
2	RDREFL	SS NA	SS NA	0.600000D+00 0.280000D+00	NI	NI	0.120000D+00
3	AXBLKT	UO2 NA	UO2 NA	0.300000D+00 0.400000D+00	SS	SS	0.300000D+00
4	RDBLKT	UO2 NA	UO2 NA	0.300000D+00 0.450000D+00	SS	SS	0.250000D+00
5	INCORE	PUO2 SS	PUO2 SS	0.500000D-01 0.250000D+00	UO2 NA	UO2 NA	0.250000D+00 0.450000D+00
6	OUCORE	PUO2 SS	PUO2 SS	0.600000D-01 0.250000D+00	UO2 NA	UO2 NA	0.240000D+00 0.450000D+00

*** EDIT OF MACROSCOPIC CROSS SECTION DATASET XSCON ***

NO. OF GROUPS	=	4
NO. OF GENERIC MATERIALS	=	5
NO. OF UNIQUE MATERIALS	=	5
NO. OF GENERIC FISSIONABLE MATERIALS	=	2
NO. OF UNIQUE FISSIONABLE MATERIALS	=	2
NO. OF PRECURSOR FAMILIES	=	6
MAXIMUM NO. OF DOWNSCATTER GROUPS	=	2

TEMPERATURES TO WHICH CROSS-SECTIONS WERE FILLED (DEG.K)

	700.00	700.00	700.00	700.00
GROUP	NEUTRON VELOCITY		MAX DOWNSCATTER	
1	2.1245599D+09		0	
2	5.9584633D+08		1	
3	1.5327296D+08		2	
4	3.6674375D+07		2	

*** DELAYED FISSION SPECTRUM ***

L, N, NUMBER OF NEUTRONS EMITTED INTO GROUP N FROM FAMILY L

1	1	5.881500D-01	1	2	4.081900D-01	1	3	3.638300D-03	1	4	1.947200D-05
2	1	5.881500D-01	2	2	4.081900D-01	2	3	3.638300D-03	2	4	1.947200D-05
3	1	5.881500D-01	3	2	4.081900D-01	3	3	3.638300D-03	3	4	1.947200D-05
4	1	5.881500D-01	4	2	4.081900D-01	4	3	3.638300D-03	4	4	1.947200D-05
5	1	5.881500D-01	5	2	4.081900D-01	5	3	3.638300D-03	5	4	1.947200D-05
6	1	5.881500D-01	6	2	4.081900D-01	6	3	3.638300D-03	6	4	1.947200D-05

*** PRECURSOR DECAY CONSTANTS ***

FAMILY, DELAYED NEUTRON PRECURSOR DECAY CONSTANT FOR FAMILY

1	1.300000D-02	2	3.140000D-02	3	1.360000D-01	4	1.400000D-01	5	1.320000D+00
6	3.500000D+00								

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***** EDIT OF FISSIONABLE MATERIAL PU02 IN XSCON *****

UNIQUE MATERIAL LABEL - PU02
 GENERIC MATERIAL LABEL - PU02

GROUP	CAPTURE CROSS SECTION	TRANSPORT CROSS SECTION	REMOVAL CROSS SECTION	FISSION CROSS SECTION	FISSION SPECTRUM (CHI)	PROMPT NEUTRONS (PNU)
1	4.219672D-02	1.944012D-01	9.102020D-02	4.882348D-02	5.881532D-01	3.237050D+00
2	1.053368D-02	4.040335D-01	4.603569D-02	3.550201D-02	4.081901D-01	2.912616D+00
3	2.410943D-02	5.535035D-01	7.088877D-02	4.677934D-02	3.638321D-03	2.865921D+00
4	1.188673D-01	8.261834D-01	3.012388D-01	1.823716D-01	1.947201D-05	2.863793D+00

SCATTERING CROSS SECTION (TOTAL)

INTO GROUP	FROM GROUP	
2	1	4.143188D-02
3	1	1.445823D-04
4	2	0.0
	2	6.033036D-03
	3	1.300986D-03

NO. OF DELAYED PRECURSORS BORN PER FISSION

L, N, PRECURSORS BORN IN FAMILY L PER FISSION IN GROUP N

1	1	2.401067D-04	1	2	2.395995D-04	1	3	2.394461D-04	1	4	2.394071D-04
2	1	1.828452D-03	2	2	1.782198D-03	2	3	1.768204D-03	2	4	1.764643D-03
3	1	1.393995D-03	3	2	1.370173D-03	3	3	1.362965D-03	3	4	1.361131D-03
4	1	2.168732D-03	4	2	2.095293D-03	4	3	2.073075D-03	4	4	2.067421D-03
5	1	6.971079D-04	5	2	6.625115D-04	5	3	6.520447D-04	5	4	6.493811D-04
6	1	2.240033D-04	6	2	2.214891D-04	6	3	2.207285D-04	6	4	2.205350D-04

*** THIS MATERIAL HAS ZERO DOPPLER COEFFICIENTS ***

*** COOLANT TEMPERATURE COEFFICIENTS ***

CAPTURE, REMOVAL, AND FISSION COEFFICIENTS ARE ALL ZERO

SCATTERING COEFFICIENTS ARE ALL ZERO

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***** EDIT OF FISSIONABLE MATERIAL UO2 IN XSCON *****

UNIQUE MATERIAL LABEL - UO2
GENERIC MATERIAL LABEL - UO2

GROUP	CAPTURE CROSS SECTION	TRANSPORT CROSS SECTION	REMOVAL CROSS SECTION	FISSION CROSS SECTION	FISSION SPECTRUM(CHI)	PROMPT NEUTRONS(PNG)
1	7.592895D-02	1.849744D-01	8.944729D-02	1.251835D-02	5.881532D-01	2.791577D+00
2	1.075132D-02	3.865024D-01	1.107492D-02	3.236011D-04	4.087901D-01	2.444791D+00
3	1.562200D-02	5.052336D-01	1.617540D-02	5.534008D-04	3.638321D-03	2.414096D+00
4	2.916624D-02	4.310034D-01	3.112641D-02	1.960172D-03	1.947201D-05	2.413162D+00

SCATTERING CROSS SECTION (TOTAL)

INTO GROUP	FROM GROUP	
2	1	7.534785D-02
3	1	5.131849D-04
4	2	4.037523D-07
	2	6.396771D-03
	3	1.256890D-03

NO. OF DELAYED PRECURSORS BORN PER FISSION

L , N , PRECURSORS BORN IN FAMILY L PER FISSION IN GROUP N

1	1	5.374499D-04	1	2	6.162775D-04	1	3	6.352500D-04	1	4	6.352500D-04
2	1	5.604860D-03	2	2	3.920014D-03	2	3	3.514500D-03	2	4	3.514500D-03
3	1	6.608081D-03	3	2	3.782153D-03	3	3	3.102000D-03	3	4	3.102000D-03
4	1	1.581351D-02	4	2	8.480445D-03	4	3	6.715500D-03	4	4	6.715500D-03
5	1	9.137117D-03	5	2	3.474820D-03	5	3	2.112000D-03	5	4	2.112000D-03
6	1	3.040601D-03	6	2	9.356309D-04	6	3	4.290000D-04	6	4	4.290000D-04

*** THIS MATERIAL HAS ZERO DOPPLER COEFFICIENTS ***

*** COOLANT TEMPERATURE COEFFICIENTS ***

CAPTURE, REMOVAL, AND FISSION COEFFICIENTS ARE ALL ZERO

SCATTERING COEFFICIENTS ARE ALL ZERO

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***** EDIT OF NON-FISSIONABLE MATERIAL SS IN XSCGN *****

UNIQUE MATERIAL LABEL - SS
GENERIC MATERIAL LABEL - SS

GROUP	CAPTURE CROSS SECTION	TRANSPORT CROSS SECTION	REMOVAL CROSS SECTION
1	5.654370D-02	1.948022D-01	5.654370D-02
2	3.606285D-03	2.832556D-01	3.606285D-03
3	3.642032D-03	6.715761D-01	3.642032D-03
4	9.163083D-03	7.879999D-01	9.163083D-03

SCATTERING CROSS SECTION (TOTAL)

INTO GROUP	FROM GROUP	
2	1	5.503979D-02
3	1	1.525620D-04
4	2	0.0
2	3	3.137153D-03
3	3	1.214004D-03

*** THIS MATERIAL HAS ZERO DOPPLER COEFFICIENTS ***

*** COOLANT TEMPERATURE COEFFICIENTS ***

CAPTURE, REMOVAL, AND FISSION COEFFICIENTS ARE ALL ZERO

SCATTERING COEFFICIENTS ARE ALL ZERO

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***** EDIT OF NON-FISSIONABLE MATERIAL NI IN XSCON *****

UNIQUE MATERIAL LABEL - NI
GENEFIC MATERIAL LABEL - NI

GROUP	CAPTURE CROSS SECTION	TRANSPORT CROSS SECTION	REMOVAL CROSS SECTION
1	7.553295D-02	2.170758D-01	7.553295D-02
2	4.634934D-03	4.120737D-01	4.634934D-03
3	3.896842D-03	1.630028D+00	3.896842D-03
4	2.589156D-03	1.388670D+00	2.589156D-03

SCATTERING CROSS SECTION (TOTAL)

INTO GROUP	FROM GROUPE	
2	1	6.459791D-02
3	1	2.536110D-04
4	2	0.0
2		3.786622D-03
3		2.469709D-03

*** THIS MATERIAL HAS ZERO DOPPLER COEFFICIENTS ***

*** COOLANT TEMPERATURE COEFFICIENTS ***

CAPTURE, REMOVAL, AND FISSION COEFFICIENTS ARE ALL ZERO

SCATTERING COEFFICIENTS ARE ALL ZERO

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***** EDIT OF NON-FISSIONABLE MATERIAL NA IN XSCON *****

UNIQUE MATERIAL LABEL - NA
GENERIC MATERIAL LABEL - NA

GROUP	CAPTURE CROSS SECTION	TRANSPORT CROSS SECTION	REMOVAL CROSS SECTION
1	8.411797D-03	4.038637D-02	8.411797D-03
2	1.903396D-03	8.124305D-02	1.903396D-03
3	5.518917D-04	1.520316D-01	5.518917D-04
4	1.402493D-04	7.751120D-02	1.402493D-04

SCATTERING CROSS SECTION (TOTAL)

INTO GROUP	FROM GROUP	
2	1	8.335418D-03
3	1	8.739242D-07
4	2	0.0
	2	1.891439D-03
	3	4.684741D-04

*** THIS MATERIAL HAS ZERO DOPPLER COEFFICIENTS ***

*** COOLANT TEMPERATURE COEFFICIENTS ***

CAPTURE, REMOVAL, AND FISSION COEFFICIENTS ARE ALL ZERO

SCATTERING COEFFICIENTS ARE ALL ZERO

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*** FX2 STEADY STATE STORAGE ALLOCATION ***

CORE REQUIREMENTS SUMMARY FOR SMALL CORE CONTAINER

NUMBER OF WORDS IN CONTAINER	=	2000
NUMBER OF WORDS REQUIRED FOR PERMANENT IN-CORE ARRAYS	=	51
NUMBER OF WORDS REQUIRED FOR SCRATCH ARRAYS FOR THIS PROBLEM	=	350
TOTAL NUMBER OF WORDS REQUIRED IN THIS CONTAINER	=	451

CORE REQUIREMENTS SUMMARY FOR LARGE CORE CONTAINER

NUMBER OF WORDS IN CONTAINER	=	13000
NUMBER OF WORDS REQUIRED FOR PERMANENT IN-CORE ARRAYS	=	299
NUMBER OF WORDS REQUIRED FOR SCRATCH ARRAYS FOR THIS PROBLEM	=	5372
TOTAL NUMBER OF WORDS REQUIRED IN THIS CONTAINER	=	5671

NUMBER OF ADDITIONAL WORDS REQUIRED TO STORE SCATTERING BAND OF FLUXES = 616

LOCATION OF SCRATCH FILES IN LARGE CORE CONTAINER FOR THIS RUN-

NAME	LENGTH	LOCATION	TOTAL WORDS REQUIRED
FISS. XSECT.	192	CORE	6303
SCAT. XSECT.	30	CORE	6321
FLUX ITERATE	1280	CORE	6641
P.D. COEFS.	3340	CORE	10481

BINARY INPUT PROCESSING COMPLETED

CENTRAL PROCESSOR TIME (SEC)	=	0.43
PERIPHERAL PROCESSOR TIME (SEC)	=	2.43

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OUTER ITERATION SUMMARY REAL SOLUTION K-EFF. PROBLEM PROBLEM TIME = 0.0 SECONDS

OPTIMIZED INNER ITERATION STRATEGY FOR ROW RELAXATION		
GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS
1	0.12025D+01	5
2	0.14041D+01	7
3	0.13048D+01	6
4	0.12177D+01	5

OUTER IT. NO.	REL. POINT ERROR	REL. SUM ERROR	EIGENVALUE CHANGE	POLY. ORDER	DOM. RATIO USED	DOM. RATIO ESTIMATED	K-EFFECTIVE
1	5.860194D-01	2.208075D-01	9.981942D-02	0	0.0	1.000000D+00	1.09931942D+00
2	3.667570D-01	9.947798D-02	8.058272D-02	0	0.0	4.858579D-01	1.01923670D+00
3	1.421619D-01	4.265778D-02	1.213567D-02	0	0.0	4.438236D-01	1.00710104D+00
4	6.540523D-02	2.376582D-02	8.151514D-03	1	4.438236D-01	4.438236D-01	9.98949523D-01
5	2.667389D-02	1.107148D-02	6.917453D-03	2	4.438236D-01	5.840939D-01	9.92032070D-01
6	1.001710D-02	4.507151D-03	4.217437D-03	3	4.438236D-01	5.886334D-01	9.87814633D-01
7	4.686409D-03	1.898209D-03	1.745476D-03	1	5.886334D-01	5.886334D-01	9.86069158D-01
8	1.759259D-03	7.722590D-04	7.388348D-04	2	5.886334D-01	5.812644D-01	9.85330323D-01
9	3.861034D-04	1.687815D-04	3.946075D-04	3	5.886334D-01	5.836411D-01	9.84935716D-01
10	2.283492D-04	4.555432D-05	1.020057D-04	4	5.886334D-01	5.934229D-01	9.84833710D-01
11	4.310894D-05	1.095908D-05	2.171636D-05	1	5.934229D-01	5.934229D-01	9.84811994D-01
12	2.836701D-05	6.101554D-06	4.662580D-06	2	5.934229D-01	6.882735D-01	9.84807331D-01
13	5.623216D-06	1.603012D-06	1.862369D-06	3	5.934229D-01	6.282662D-01	9.84805469D-01
14	2.802173D-06	6.021848D-07	5.458346D-07	1	6.282662D-01	6.282662D-01	9.84804923D-01
15	9.642767D-07	2.588365D-07	5.043881D-08	2	6.282662D-01	6.089385D-01	9.84804872D-01
16	1.319379D-07	7.237383D-08	4.974121D-08	3	6.282662D-01	6.302766D-01	9.84804823D-01

OUTER ITERATIONS COMPLETED AT ITERATION 16, ITERATIONS HAVE CONVERGED

K-EFFECTIVE = 0.98480482264

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FX2-TH TEST PROBLEM 1

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OUTER ITERATION SUMMARY ADJOINT SOLUTION K-EFF. PROBLEM PROBLEM TIME = 0.0 SECONDS

OPTIMIZED INNER ITERATION STRATEGY FOR ROW RELAXATION		
GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS
1	0.12177D+01	5
2	0.13048D+01	6
3	0.14041D+01	7
4	0.12025D+01	5

OUTER IT. NO.	REL. POINT ERROR	REL. SUM ERROR	EIGENVALUE CHANGE	POLY. ORDER	DOM. RATIO USED	DOM. RATIO ESTIMATED	K-EFFECTIVE
1	5.224818D-01	2.811394D-01	2.512517D-02	0	0.0	1.000000D+00	1.00993000D+00
2	2.696021D-01	1.154570D-01	3.784814D-03	0	0.0	4.315092D-01	1.01371481D+00
3	9.572635D-02	4.585588D-02	5.607785D-03	0	0.0	4.177880D-01	1.00810702D+00
4	4.750759D-02	2.284266D-02	8.125406D-03	1	4.177880D-01	4.177830D-01	9.99978618D-01
5	2.007093D-02	1.053601D-02	7.306571D-03	2	4.177880D-01	5.733248D-01	9.92672047D-01
6	8.164430D-03	4.437133D-03	4.426852D-03	3	4.177880D-01	5.816931D-01	9.88251195D-01
7	3.943311D-03	1.951627D-03	1.931220D-03	1	5.816931D-01	5.816931D-01	9.86319974D-01
8	1.512425D-03	8.025597D-04	8.815078D-04	2	5.816931D-01	5.824214D-01	9.85438466D-01
9	3.449929D-04	1.855892D-04	4.718365D-04	3	5.816931D-01	5.842387D-01	9.84966580D-01
10	2.087823D-04	5.098654D-05	1.227715D-04	1	5.842337D-01	5.842387D-01	9.84843808D-01
11	4.536647D-05	2.094129D-05	2.353381D-05	2	5.842337D-01	5.828569D-01	9.84820275D-01
12	1.077760D-05	5.325515D-06	1.146676D-05	3	5.842337D-01	5.930329D-01	9.84808808D-01
13	9.891478D-06	1.926115D-06	3.077365D-06	1	5.930329D-01	5.930329D-01	9.84805730D-01
14	1.903832D-06	8.505360D-07	5.495056D-07	2	5.930329D-01	6.071548D-01	9.84805181D-01
15	4.911510D-07	2.573011D-07	2.827718D-07	3	5.930329D-01	6.193124D-01	9.84804898D-01
16	3.970087D-07	9.050388D-08	6.374419D-08	1	6.193124D-01	6.193124D-01	9.84804834D-01

OUTER ITERATIONS COMPLETED AT ITERATION 16, ITERATIONS HAVE CONVERGED

K-EFFECTIVE = 0.98480483447

*** EDIT OF CONVERGED STEADY STATE CONDITIONS ***

CONVERGED REACTOR K-EFFECTIVE = 0.98480482
 TOTAL REACTOR POWER (WATTS) = 0.50000000D+09
 INITIAL RESIDUAL REACTIVITY = -0.66986561D-09
 EFFECTIVE DELAYED NEUTRON FRACTION = 0.36874056D-02
 NEUTRON GENERATION TIME (SEC) = 0.40998670D-06
 FIXED INHOMOGENEOUS SOURCE = 0.0

FAMILY	DELAYED NEUTRON FRACTION	INTEGRATED PRECURSOR CONC.
1	0.99449447D-04	0.18659038D+05
2	0.78763142D-03	0.61181993D+05
3	0.70183055D-03	0.12587040D+05
4	0.13251076D-02	0.95061017D+04
5	0.58273858D-03	0.10767877D+04
6	0.19064798D-03	0.13286005D+03

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COMPUTING TIME SUMMARY	CENTRAL PROCESSOR (SEC)	PERIPHERAL PROCESSOR (SEC)
BCD CARD INPUT PROCESSING	0.27	2.16
CROSS SECTION HOMOGENIZATION	0.0	0.0
BINARY FILE INPUT PROCESSING AND INITIALIZATION	0.43	2.48
GENERATE CROSS SECTIONS	0.60	3.62
COMPUTE REAL AND ADJOINT NEUTRON FLUX	5.26	18.44
COMPUTE AMPLITUDE FUNCTION EQUATION COEFFICIENTS	0.27	1.61
COMPUTE THERMAL/HYDRAULIC FEEDBACK	0.0	0.0
TOTAL FOR STEADY STATE CALCULATION	6.83	28.31
TOTAL ELAPSED COMPUTING TIME (SEC) =	35.29 (CP + PP)	

INITIAL POWER DENSITY (WATTS/CM3) ON FIXED MESH

Z-AXIS	R-AXIS 1	R-AXIS 2	R-AXIS 3	R-AXIS 4	R-AXIS 5	R-AXIS 6	R-AXIS 7	R-AXIS 8	R-AXIS 9
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	3.5463D+01	3.5084D+01	3.4332D+01	3.3222D+01	3.1774D+01	3.0015D+01	2.7974D+01	2.5667D+01	2.2808D+01
16	5.2339D+01	5.1780D+01	5.0675D+01	4.9043D+01	4.6920D+01	4.4353D+01	4.1406D+01	3.8137D+01	3.4179D+01
15	5.2845D+02	5.2276D+02	5.1147D+02	4.9475D+02	4.7284D+02	4.4668D+02	4.1488D+02	3.7972D+02	3.9371D+02
14	6.4952D+02	6.4255D+02	6.2872D+02	6.0824D+02	5.8143D+02	5.4869D+02	5.1056D+02	4.6763D+02	4.8432D+02
13	7.4833D+02	7.4031D+02	7.2441D+02	7.0086D+02	6.7004D+02	6.3241D+02	5.8856D+02	5.3916D+02	5.5808D+02
12	8.7771D+02	8.0896D+02	7.9160D+02	7.5590D+02	7.3225D+02	6.9115D+02	6.4327D+02	5.8928D+02	6.0978D+02
11	8.5341D+02	8.4429D+02	8.2618D+02	7.9936D+02	7.6425D+02	7.2139D+02	6.7140D+02	6.1504D+02	6.3635D+02
10	8.5341D+02	8.4429D+02	8.2618D+02	7.9936D+02	7.6425D+02	7.2139D+02	6.7140D+02	6.1504D+02	6.3635D+02
9	8.1771D+02	8.0896D+02	7.9160D+02	7.6590D+02	7.3225D+02	6.9116D+02	6.4327D+02	5.8928D+02	6.0978D+02
8	7.4833D+02	7.4031D+02	7.2441D+02	7.0086D+02	6.7004D+02	6.3241D+02	5.8856D+02	5.3916D+02	5.5808D+02
7	6.4952D+02	6.4255D+02	6.2872D+02	6.0824D+02	5.8143D+02	5.4869D+02	5.1056D+02	4.6763D+02	4.8432D+02
6	5.2845D+02	5.2276D+02	5.1147D+02	4.9475D+02	4.7284D+02	4.4668D+02	4.1488D+02	3.7972D+02	3.9371D+02
5	5.2339D+01	5.1780D+01	5.0675D+01	4.9043D+01	4.6920D+01	4.4353D+01	4.1406D+01	3.8138D+01	3.4179D+01
4	3.5463D+01	3.5084D+01	3.4332D+01	3.3222D+01	3.1774D+01	3.0015D+01	2.7974D+01	2.5667D+01	2.2808D+01
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Z-AXIS	R-AXIS 10	R-AXIS 11	R-AXIS 12	R-AXIS 13	R-AXIS 14	R-AXIS 15	R-AXIS 16
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	1.9019D+01	1.4687D+01	1.0159D+01	6.6555D+00	0.0	0.0	0.0
16	2.8444D+01	2.1475D+01	1.3505D+01	8.3495D+00	0.0	0.0	0.0
15	3.3029D+02	2.6112D+02	1.8721D+01	1.0666D+01	0.0	0.0	0.0
14	4.0555D+02	3.1858D+02	2.3943D+01	1.3198D+01	0.0	0.0	0.0
13	4.6679D+02	3.6560D+02	2.7935D+01	1.5239D+01	0.0	0.0	0.0
12	5.0972D+02	3.9867D+02	3.0635D+01	1.6652D+01	0.0	0.0	0.0
11	5.3179D+02	4.1570D+02	3.1999D+01	1.7374D+01	0.0	0.0	0.0
10	5.3179D+02	4.1570D+02	3.1999D+01	1.7374D+01	0.0	0.0	0.0
9	5.0972D+02	3.9867D+02	3.0635D+01	1.6652D+01	0.0	0.0	0.0
8	4.6679D+02	3.6560D+02	2.7935D+01	1.5239D+01	0.0	0.0	0.0
7	4.0555D+02	3.1858D+02	2.3943D+01	1.3198D+01	0.0	0.0	0.0
6	3.3029D+02	2.6112D+02	1.8721D+01	1.0666D+01	0.0	0.0	0.0
5	2.8444D+01	2.1475D+01	1.3505D+01	8.3495D+00	0.0	0.0	0.0
4	1.9019D+01	1.4687D+01	1.0159D+01	6.6555D+00	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

*** FX2 TIME-DEPENDENT STORAGE ALLOCATION, FIXED MESH ***

CORE REQUIREMENTS SUMMARY FOR SMALL CORE CONTAINER

NUMBER OF WORDS IN CONTAINER	=	2000
NUMBER OF WORDS REQUIRED FOR PERMANENT IN-CORE ARRAYS	=	334
NUMBER OF WORDS REQUIRED FOR SCRATCH ARRAYS FOR THIS PROBLEM	=	1340
TOTAL NUMBER OF WORDS REQUIRED IN THIS CONTAINER	=	1674

CORE REQUIREMENTS SUMMARY FOR LARGE CORE CONTAINER

NUMBER OF WORDS IN CONTAINER	=	13000
NUMBER OF WORDS REQUIRED FOR PERMANENT IN-CORE ARRAYS	=	299
NUMBER OF WORDS REQUIRED FOR SCRATCH ARRAYS FOR THIS PROBLEM	=	5372
TOTAL NUMBER OF WORDS REQUIRED IN THIS CONTAINER	=	5671

NUMBER OF ADDITIONAL WORDS REQUIRED TO STORE SCATTERING BAND OF FLUXES = 320

LOCATION OF SCRATCH FILES IN LARGE CORE CONTAINER FOR THIS RUN-

NAME	LENGTH	LOCATION	TOTAL WORDS REQUIRED
XSPFIS	192	CORE	6023
XSPSCT	30	CORE	6041
XSPGRP	48	CORE	6077
FRIP1	1280	CORE	6969
VFRACH	1600	CORE	8569
PREC2M	1920	CORE	9917
PDCOEF	3840	CORE	12129

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*****
* BEGIN SHAPE STEP NO.      1 *
*****

*****
* BEGIN REACTIVITY STEP NO. 1 *
*****

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FIRST REACTIVITY STEP = 10000 INITIAL GENERATION TIMES

REACTIVITY STEP BEGINS AT 0.0 SEC, ENDS AT 0.409987D-02 SEC, LENGTH = 0.409987D-02 SEC

SHAPE STEP BEGINS AT 0.0 SEC, ENDS AT 0.409987D-02 SEC, LENGTH = 0.409987D-02 SEC

THE FOLLOWING DRIVING FUNCTIONS APPLY THIS REACTIVITY STEP

REGION	MATERIAL	START TIME	END TIME	COEF1 (DT)	COEF2 (DT**2)	NEW VOL. FRAC.
INCORE	SS	0.0	0.100000D+01	-0.100000D+00	0.0	0.249590D+00

AMPLITUDE CHANGE OVER SHAPE STEP TERMINATES THIS STEP

*** SUMMARY FOR REACTIVITY STEP NUMBER 1 ***

STEP BEGAN AT 0.0 SECONDS, ENDS AT 0.40998670D-02 SECONDS INTO TRANSIENT

END-OF-STEP REACTIVITY	=	0.36711922D-04	EFFECTIVE DELAYED NEUTRON FRACTION =	0.36874056D-02
GENERATION TIME (SECONDS)	=	0.40998670D-05	AMPLITUDE FUNCTION VALUE (N)	= 0.10097890D+01
AMPLITUDE FUNCTION DERIVATIVE (DN)	=	0.24809093D+01	TOTAL ENERGY RELEASE (WATT-SEC)	= 0.20596671D+07
MAXIMUM FUEL TEMP. CHANGE (DEG.K)	=	0.0	MAXIMUM FUEL TEMPERATURE (DEG.K)	= 0.0

TOTAL REACTOR POWER (WATTS) = 0.50489452D+09

COMPUTING TIME SUMMARY	CENTRAL PROCESSOR (SEC)	PERIPHERAL PROCESSOR (SEC)	
TOTAL FOR THIS STEP	0.53	2.39	
TOTAL ELAPSED COMPUTING TIME (SEC)	7.39	30.82	= 38.21

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FX2-TH TEST PROBLEM 1

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OUTER ITERATION SUMMARY REAL SOLUTION TIMDEP PROBLEM PROBLEM TIME = 0.409987D-02 SECONDS

OPTIMIZED INNER ITERATION STRATEGY FOR ROW RELAXATION											
GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS	GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS	GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS	GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS
1	0.12025D+01	5	2	0.14041D+01	7	3	0.13048D+01	6	4	0.12176D+01	5

OUTER IT. NO.	REL. POINT ERROR	REL. SUM ERROR	EIGENVALUE CHANGE	POLY. ORDER	SPEC. RAD. USED	SPEC. RAD. ESTIMATED	GAMMA FACTOR
1	2.413E9D-04	8.500047D-05	0.0	0	0.0	1.000000D+00	9.99999881D-01
2	5.263378D-05	8.104013D-05	0.0	0	0.0	9.534234D-01	9.99997671D-01
3	2.958119D-05	8.809553D-06	0.0	0	0.0	1.087103D-01	1.00000185D+00

OUTER ITERATIONS COMPLETED AT ITERATION 3, ITERATIONS HAVE CONVERGED

GAMMA FACTOR FOR SHAPE CALCULATION = 1.00000184896

*** AMPLITUDE FUNCTION UPDATE PASS 1 FOR SHAPE STEP NUMBER 1 ***

RHO STEP NO.	STEP LENGTH (SEC)	END TIME (SEC)	NO. TEMP. CORR. ITER.	BETA		UPDATED VALUE		AMPLITUDE
				GEN. TIME (SEC)	REACTIVITY	REACTIVITY (\$)	ALPHA (DN/N)	
1	0.40998670D-02	0.40998670D-02	0	0.36877324D-02	0.36727527D-04	0.23953741D+01	0.10095242D+01	
				0.40995217D-06	0.93593796D-02			

FX2-TH 07/77

FX2-TH TEST PROBLEM 1

2/01/78 19.49.31

*** SUMMARY FOR SHAPE STEP NUMBER 1 ***

STEP BEGAN AT 0.0 SECONDS, ENDS AT 0.40998670D-02 SECONDS INTO TRANSIENT

STEP REQUIRED 1 GAMMA FACTOR ITERATIONS AND 1 REACTIVITY STEPS.

REACTOR POWER LEVEL = 0.50486191E+09 WATTS

TOTAL ENERGY RELEASE = 0.20597336D+07 WATT-SEC

COMPUTING TIME SUMMARY	CENTRAL PROCESSOR (SEC)	PERIPHERAL PROCESSOR (SEC)	
THERMAL HYDRAULICS	0.0	0.0	
	0.0	0.0	
GENERATE CROSS SECTIONS	0.14	0.25	
COMPUTE AMPLITUDE FUNCTION EQUATION COEFFICIENTS	0.32	0.96	
SHAPE FUNCTION SOLUTION	0.80	3.37	
SOLVE FOR AMPLITUDE FUNCTION, MISC.	0.27	1.76	
TOTAL FOR THIS STEP	1.53	6.34	
TOTAL ELAPSED COMPUTING TIME (SEC)	8.39	34.77	= 43.16

 * BEGIN SHAPE STEP NO. 2 *

 * BEGIN REACTIVITY STEP NO. 2 *

REACTIVITY STEP SELECTION TEST SUMMARY

	TEMPERATURE CHANGE	AMPLITUDE CHANGE	MAX. STEP SIZE	DOJELE LAST STEP	DRIVING FUNCTION	SHAPE STEP END	PROBLEM END
TIME STEP (SEC)	0.0	0.492789D+00	0.200000D+00	0.819950D-02	0.0	0.0	0.495900D+00

REACTIVITY STEP BEGINS AT 0.409987D-02 SEC, ENDS AT 0.122994D-01 SEC, LENGTH = 0.819950D-02 SEC

SHAPE STEP SELECTION TEST SUMMARY

	FLUX SHAPE CHANGE	MAX. STEP SIZE	10 TIMES LAST STEP	DRIVING FUNCTION	PROBLEM END
TIME STEP (SEC)	0.401989D+00	0.500000D+00	0.409975D-01	0.0	0.495900D+00

SHAPE STEP BEGINS AT 0.409987D-02 SEC, ENDS AT 0.450973D-01 SEC, LENGTH = 0.409975D-01 SEC

THE FOLLOWING DRIVING FUNCTIONS APPLY THIS REACTIVITY STEP

REGION INCORE	MATERIAL	START TIME	END TIME	COEF1 (DT)	COEF2 (DT**2)	NEW VOL. FRAC.
	SS	0.0	0.100000D+01	-0.100000D+00	0.0	0.248770D+00

AMPLITUDE CHANGE OVER SHAPE STEP TERMINATES THIS STEP

*** THIS SHAPE STEP HAS BEEN REDUCED IN LENGTH - TERMINATES NOW ***

NEW LENGTH = 0.819950D-02 SEC, STEP END TIME = 0.122994D-01 SEC

FX2-TH 07/77

FX2-TH TEST PROBLEM 1

2/01/78 19.49.31

*** SUMMARY FOR REACTIVITY STEP NUMBER 2 ***

STEP BEGAN AT 0.40998670D-02 SECONDS, ENDS AT 0.12299363D-01 SECONDS INTO TRANSIENT

END-OF-STEP REACTIVITY	=	0.11015450D-03	EFFECTIVE DELAYED NEUTRON FRACTION	=	0.36883859D-02
GENERATION TIME (SECONDS)	=	0.40988315D-06	AMPLITUDE FUNCTION VALUE (N)	=	0.10300615D+01
AMPLITUDE FUNCTION DERIVATIVE (DN)	=	0.25498266D+01	TOTAL ENERGY RELEASE (WATT-SEC)	=	0.62417564D+07
MAXIMUM FUEL TEMP. CHANGE (DEG.K)	=	0.0	MAXIMUM FUEL TEMPERATURE (DEG.K)	=	0.0

TOTAL REACTOR POWER (WATTS) = 0.51518323D+09

COMPUTING TIME SUMMARY
TOTAL FOR THIS STEP
TOTAL ELAPSED COMPUTING TIME (SEC)

CENTRAL PROCESSOR (SEC)

0.37

8.76

PERIPHERAL PROCESSOR (SEC)

1.29

36.06

=

44.82

FX2-TH 07/77

FX2-TH TEST PROBLEM 1

2/01/78 19.49.31

OUTER ITERATION SUMMARY REAL SOLUTION TIMDEP PROBLEM PROBLEM TIME = 0.122994D-01 SECONDS

OPTIMIZED INNER ITERATION STRATEGY FOR ROW RELAXATION											
GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS	GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS	GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS	GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS
1	0.12025E+01	5	2	0.14041D+01	7	3	0.13349D+01	6	4	0.12176D+01	5

OUTER IT. NO.	REL. POINT ERROR	REL. SUM ERROR	EIGENVALUE CHANGE	POLY. ORDER	SPEC. RAD. USED	SPEC. RAD. ESTIMATED	GAMMA FACTOR
1	3.833249D-05	1.523363D-05	0.0	0	0.0	1.000000D+00	1.00000351D+00
2	1.959726D-05	1.069660D-05	0.0	0	0.0	7.021648D-01	1.00000089D+00
3	1.052936D-05	5.338671D-06	0.0	0	0.0	4.990969D-01	1.00000034D+00

OUTER ITERATIONS COMPLETED AT ITERATION 3, ITERATIONS HAVE CONVERGED

GAMMA FACTOR FOR SHAPE CALCULATION = 1.00000033803

*** AMPLITUDE FUNCTION UPDATE PASS 1 FOR SHAPE STEP NUMBER 2 ***

RHO STEP NO.	STEP LENGTH (SEC)	END TIME (SEC)	NO. TEMP. CORE. ITER.	BEIA GEN. TIME (SEC)	REACTIVITY REACTIVITY (\$)	UPDATED VALUE ALPHA (DN/N)	AMPLITUDE
1	0.81594960D-02	0.12299363D-01	0	0.36883843D-02 0.40988512D-06	0.11015818D-03 0.29866243D-01	0.24767090D+01	0.10300678D+01

FX2-TH 07/77

FX2-TH TEST PROBLEM 1

2/01/78 19.49.31

*** SUMMARY FOR SHAPE STEP NUMBER 2 ***

STEP BEGAN AT 0.40998670D-02 SECONDS, ENDS AT 0.12299363D-01 SECONDS INTO TRANSIENT

STEP REQUIRED 1 GAMMA FACTOR ITERATIONS AND 1 REACTIVITY STEPS.

REACTOR POWER LEVEL = 0.51518781D+09 WATTS

TOTAL ENERGY RELEASE = 0.62417773D+07 WATT-SEC

COMPUTING TIME SUMMARY	CENTRAL PROCESSOR (SEC)	PERIPHERAL PROCESSOR (SEC)
THERMAL HYDRAULICS	0.0	0.0
	0.0	0.0
GENERATE CROSS SECTIONS	0.13	0.32
COMPUTE AMPLITUDE FUNCTION EQUATION COEFFICIENTS	0.31	0.94
SHAPE FUNCTION SOLUTION	0.62	3.33
SOLVE FOR AMPLITUDE FUNCTION, MISC.	0.12	0.63
TOTAL FOR THIS STEP	1.18	5.22
TOTAL ELAPSED COMPUTING TIME (SEC)	9.57	39.99
		= 49.56

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*****
*          BEGIN SHAPE STEP NO.      3          *
*****

*****
*          BEGIN REACTIVITY STEP NO.  3          *
*****

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REACTIVITY STEP SELECTION TEST SUMMARY

	TEMPERATURE CHANGE	AMPLITUDE CHANGE	MAX. STEP SIZE	DOUBLE LAST STEP	DRIVING FUNCTION	SHAPE STEP END	PROBLEM END
TIME STEP (SEC)	0.0	0.457341D+00	0.200000D+00	0.163988D-01	0.0	0.0	0.487701D+00

REACTIVITY STEP BEGINS AT 0.122994D-01 SEC, ENDS AT 0.286982D-01 SEC, LENGTH = 0.163988D-01 SEC

SHAPE STEP SELECTION TEST SUMMARY

	FLUX SHAPE CHANGE	MAX. STEP SIZE	10 TIMES LAST STEP	DRIVING FUNCTION	PROBLEM END
TIME STEP (SEC)	0.420176D+00	0.500000D+00	0.409970D+00	0.0	0.437701D+00

SHAPE STEP BEGINS AT 0.122994D-01 SEC, ENDS AT 0.422269D+00 SEC, LENGTH = 0.409970D+00 SEC

THE FOLLOWING DRIVING FUNCTIONS APPLY THIS REACTIVITY STEP

REGION	MATERIAL	START TIME	END TIME	COEF1 (DT)	COEF2 (DT**2)	NEW VOL. FRAC.
INCORE	SS	0.0	0.100000D+01	-0.100000D+00	0.0	0.247130D+00

AMPLITUDE CHANGE OVER SHAPE STEP TERMINATES THIS STEP

*** THIS SHAPE STEP HAS BEEN REDUCED IN LENGTH - TERMINATES NOW ***

NEW LENGTH = 0.163988D-01 SEC, STEP END TIME = 0.286982D-01 SEC

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*** SUMMARY FOR REACTIVITY STEP NUMBER 3 ***

STEP BEGAN AT 0.12259363D-01 SECONDS, ENDS AT 0.28698154D-01 SECONDS INTO TRANSIENT

END-OF-STEP REACTIVITY	=	0.25592236D-03	EFFECTIVE DELAYED NEUTRON FRACTION	=	0.36896876D-02
GENERATION TIME (SECONDS)	=	0.40375107D-06	AMPLITUDE FUNCTION VALUE (N)	=	0.10738325D+01
AMPLITUDE FUNCTION DERIVATIVE (DN)	=	0.27334174D+01	TOTAL ENERGY RELEASE (WATT-SEC)	=	0.14870432D+08
MAXIMUM FUEL TEMP. CHANGE (DEG.K)	=	0.0	MAXIMUM FUEL TEMPERATURE (DEG.K)	=	0.0

TOTAL REACTOR POWER (WATTS) = 0.53729164D+C9

COMPUTING TIME SUMMARY
TOTAL FOR THIS STEP
TOTAL ELAPSED COMPUTING TIME (SEC)

CENTRAL PROCESSOR (SEC)	PERIPHERAL PROCESSOR (SEC)	
0.38	1.28	
9.95	41.27	= 51.22

OUTER ITERATION SUMMARY REAL SOLUTION TIMDEP PROBLEM PROBLEM TIME = 0.286982D-01 SECONDS

OPTIMIZED INNER ITERATION STRATEGY FOR ROW RELAXATION		
GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS
1	0.12025D+01	5
2	0.14041D+01	7
3	0.13049D+01	6
4	0.12176D+01	5

OUTER IT. NO.	REL. POINT ERROR	REL. SUM ERROR	EIGENVALUE CHANGE	POLY. ORDER	SPEC. RAD. USED	SPEC. RAD. ESTIMATED	GAMMA FACTOR
1	8.372254D-06	2.587473D-06	0.0	0	0.0	1.000000D+00	9.99998760D-01

OUTER ITERATIONS COMPLETED AT ITERATION 1, ITERATIONS HAVE CONVERGED

GAMMA FACTOR FOR SHAPE CALCULATION = 0.99999875988

*** AMPLITUDE FUNCTION UPDATE PASS 1 FOR SHAPE STEP NUMBER 3 ***

RHO STEP NO.	STEP LENGTH (SEC)	END TIME (SEC)	NO. TEMP. CORR. ITER.	UPDATED VALUE		AMPLITUDE
				BETA GEN. TIME (SEC)	REACTIVITY REACTIVITY (\$)	
1	0.16398791D-01	0.28698154D-01	0	0.36896910D-02 0.40975054D-06	0.25692149D-03 0.69632250D-01	0.26010885D+01 0.10738298D+01

*** SUMMARY FOR SHAPE STEP NUMBER 3 ***

STEP BEGAN AT 0.12299363D-01 SECONDS, ENDS AT 0.28698154D-01 SECONDS INTO TRANSIENT

STEP REQUIRED 1 GAMMA FACTOR ITERATIONS AND 1 REACTIVITY STEPS.

REACTOR POWER LEVEL = 0.53729067D+09 WATTS

TOTAL ENERGY RELEASE = 0.14870430D+08 WATT-SEC

COMPUTING TIME SUMMARY CENTRAL PROCESSOR (SEC) PERIPHERAL PROCESSOR (SEC)

THERMAL HYDRAULICS	0.0	0.0
GENERATE CROSS SECTIONS	0.0	0.0
COMPUTE AMPLITUDE FUNCTION EQUATION COEFFICIENTS	0.13	0.34
SHAPE FUNCTION SOLUTION	0.32	0.95
SOLVE FOR AMPLITUDE FUNCTION, MISC.	0.33	1.97
	0.13	0.65
TOTAL FOR THIS STEP	0.91	3.81
TOTAL ELAPSED COMPUTING TIME (SEC)	10.48	43.80
		54.28

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* BEGIN SHAPE STEP NO. 4 *

* BEGIN REACTIVITY STEP NO. 4 *

REACTIVITY STEP SELECTION TEST SUMMARY

	TEMPERATURE CHANGE	AMPLITUDE CHANGE	MAX. STEP SIZE	DOUBLE LAST STEP	DRIVING FUNCTION	SHAPE STEP END	PROBLEM END
TIME STEP (SEC)	0.0	0.442979D+00	0.200000D+00	0.327963D-01	0.0	0.0	0.471302D+00

REACTIVITY STEP BEGINS AT 0.286982D-01 SEC, ENDS AT 0.614944D-01 SEC, LENGTH = 0.327963D-01 SEC

SHAPE STEP SELECTION TEST SUMMARY

	FLUX SHAPE CHANGE	MAX. STEP SIZE	10 TIMES LAST STEP	DRIVING FUNCTION	PROBLEM END
TIME STEP (SEC)	0.421835D+00	0.500000D+00	0.409953D+01	0.0	0.471302D+00

SHAPE STEP BEGINS AT 0.286982D-01 SEC, ENDS AT 0.450533D+00 SEC, LENGTH = 0.421835D+00 SEC

THE FOLLOWING DRIVING FUNCTIONS APPLY THIS REACTIVITY STEP

REGION INCORE	MATERIAL SS	START TIME 0.0	END TIME 0.100000D+01	COEF1 (DT) -0.100000D+00	COEF2 (DT**2) 0.0	NEW VOL. FRAC. 0.243851D+00
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AMPLITUDE CHANGE OVER SHAPE STEP TERMINATES THIS STEP

*** THIS SHAPE STEP HAS BEEN REDUCED IN LENGTH - TERMINATES NOW ***

NEW LENGTH = 0.327963D-01 SEC, STEP END TIME = 0.614944D-01 SEC

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*** SUMMARY FOR REACTIVITY STEP NUMBER 4 ***

STEP BEGAN AT 0.28698154D-01 SECONDS, ENDS AT 0.61494415D-01 SECONDS INTO TRANSIENT

END-OF-STEP REACTIVITY	=	0.55004454D-03	EFFECTIVE DELAYED NEUTRON FRACTION	=	0.36923018D-02
GENERATION TIME (SECONDS)	=	0.40948167D-06	AMPLITUDE FUNCTION VALUE (N)	=	0.11747851D+01
AMPLITUDE FUNCTION DERIVATIVE (DN)	=	0.33913540D+01	TOTAL ENERGY RELEASE (WATT-SEC)	=	0.33307867D+08
MAXIMUM FUEL TEMP. CHANGE (DEG.K)	=	0.0	MAXIMUM FUEL TEMPERATURE (DEG.K)	=	0.0

TOTAL REACTOR POWER (WATTS) = 0.53827471D+09

COMPUTING TIME SUMMARY	CENTRAL PROCESSOR (SEC)	PERIPHERAL PROCESSOR (SEC)	
TOTAL FOR THIS STEP	0.38	1.28	
TOTAL ELAPSED COMPUTING TIME (SEC)	10.86	45.08	= 55.94

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OUTER ITERATION SUMMARY PEAL SOLUTION TIMDEP PROBLEM PROBLEM TIME = 0.614944D-01 SECONDS

GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS	GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS	GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS	GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS
1	0.12034D+01	5	2	0.14046D+01	7	3	0.13052D+01	6	4	0.12178D+01	5

OUTER IT. NO.	REL. POINT ERROR	REL. SUM ERROR	EIGENVALUE CHANGE	POLY. ORDER	SPEC. RAD. USED	SPEC. RAD. ESTIMATED	GAMMA FACTOR
1	2.206466D-05	5.868349D-06	0.0	0	0.0	1.000000D+00	9.99996764D-01

OUTER ITERATIONS COMPLETED AT ITERATION 1, ITERATIONS HAVE CONVERGED

GAMMA FACTOR FOR SHAPE CALCULATION = 0.99999676434

*** AMPLITUDE FUNCTION UPDATE PASS 1 FOR SHAPE STEP NUMBER 4 ***

RHO STEP NO.	STEP LENGTH (SEC)	END TIME (SEC)	NO. TEMP. CORR. ITER.	BETA GEN. TIME (SEC)	REACTIVITY REACTIVITY (\$)	UPDATED VALUE ALPHA (DN/M)	AMPLITUDE
1	0.32796261D-01	0.61494415D-01	0	0.36923154D-02 0.40948035D-06	0.55004627D-03 0.14897055D+00	0.28864115E+01	0.11747769D+01

*** SUMMARY FOR SHAPE STEP NUMBER 4 ***

STEP BEGAN AT 0.28698154D-01 SECONDS, ENDS AT 0.61494415D-01 SECONDS INTO TRANSIENT

STEP REQUIRED 1 GAMMA FACTOR ITERATIONS AND 1 REACTIVITY STEPS.

REACTOR POWER LEVEL = 0.58827150D+09 WATTS

TOTAL ENERGY RELEASE = 0.33307846D+08 WATT-SEC

COMPUTING TIME SUMMARY

CENTRAL PROCESSOR (SEC)

PERIPHERAL PROCESSOR (SEC)

THERMAL HYDRAULICS

0.0

0.0

GENERATE CROSS SECTIONS

0.0

0.0

COMPUTE AMPLITUDE FUNCTION EQUATION COEFFICIENTS

0.13

0.27

SHAPE FUNCTION SOLUTION

0.32

1.05

SOLVE FOR AMPLITUDE FUNCTION, MISC.

0.51

2.18

0.13

0.62

TOTAL FOR THIS STEP

1.09

4.12

TOTAL ELAPSED COMPUTING TIME (SEC)

11.57

+

47.92

=

59.49


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*****
*          BEGIN SHAPE STEP NO.      5          *
*****

*****
*          BEGIN REACTIVITY STEP NO.   5          *
*****

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REACTIVITY STEP SELECTION TEST SUMMARY

	TEMPERATURE CHANGE	AMPLITUDE CHANGE	MAX. STEP SIZE	DOUBLE LAST STEP	DRIVING FUNCTION	SHAPE STEP END	PROBLEM END
TIME STEP (SEC)	0.0	0.400411D+00	0.200000D+00	0.655787D-01	0.0	0.0	0.438506D+00

REACTIVITY STEP BEGINS AT 0.614944D-01 SEC, ENDS AT 0.127073D+00 SEC, LENGTH = 0.655787D-01 SEC

SHAPE STEP SELECTION TEST SUMMARY

	FLUX SHAPE CHANGE	MAX. STEP SIZE	10 TIMES LAST STEP	DRIVING FUNCTION	PROBLEM END
TIME STEP (SEC)	0.420763D+00	0.500000D+00	0.421745D+01	0.0	0.438506D+00

SHAPE STEP BEGINS AT 0.614944D-01 SEC, ENDS AT 0.482257D+00 SEC, LENGTH = 0.420763D+00 SEC

THE FOLLOWING DRIVING FUNCTIONS APPLY THIS REACTIVITY STEP

REGION INCRE	MATERIAL	START TIME	END TIME	COEF1 (DT)	COEF2 (DT**2)	NEW VGL. FRAC.
	SS	0.0	0.100000D+01	-0.100000D+00	0.0	0.237293D+00

AMPLITUDE CHANGE OVER SHAPE STEP TERMINATES THIS STEP

*** THIS SHAPE STEP HAS BEEN REDUCED IN LENGTH - TERMINATES NOW ***

NEW LENGTH = 0.655787D-01 SEC, STEP END TIME = 0.127073D+00 SEC

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*** SUMMARY FOR REACTIVITY STEP NUMBER 5 ***

STEP BEGAN AT 0.61494415D-01 SECONDS, ENDS AT 0.12707315D+00 SECONDS INTO TRANSIENT

END-OF-STEP REACTIVITY	=	C.11345512D-02	EFFECTIVE DELAYED NEUTRON FRACTION	=	0.36975528D-02
GENERATION TIME (SECONDS)	=	C.40894113D-06	AMPLITUDE FUNCTION VALUE (N)	=	0.14528374D+01
AMPLITUDE FUNCTION DERIVATIVE (DN)	=	C.52922774D+01	TOTAL ENERGY RELEASE (WATT-SEC)	=	0.76182015D+08
MAXIMUM FUEL TEMP. CHANGE (DEG.K)	=	0.0	MAXIMUM FUEL TEMPERATURE (DEG.K)	=	0.0

TOTAL REACTOR POWER (WATTS) = 0.72867793D+09

COMPUTING TIME SUMMARY	CENTRAL PROCESSOR (SEC)	PERIPHERAL PROCESSOR (SEC)	
TOTAL FOR THIS STEP	0.41	1.27	
TOTAL ELAPSED COMPUTING TIME (SEC)	11.98	49.19	= 61.17

OUTER ITERATION SUMMARY REAL SOLUTION TIMDEP PROBLEM PROBLEM TIME = 0.127073D+00 SECONDS

OPTIMIZED INNER ITERATION STRATEGY FOR POW RELAXATION		
GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS
1	0.12034D+01	5
2	0.14046D+01	7
3	0.13052D+01	6
4	0.12178D+01	5

OUTER IT. NO.	REL. POINT ERROR	REL. SUM ERROR	EIGENVALUE CHANGE	POLY. ORDER	SPEC. RAD. USED	SPEC. RAD. ESTIMATED	GAMMA FACTOR
1	5.103032D-05	9.284831D-06	0.0	0	0.0	1.000000D+00	9.99989674D-01

OUTER ITERATIONS COMPLETED AT ITERATION 1, ITERATIONS HAVE CONVERGED

GAMMA FACTOR FOR SHAPE CALCULATION = 0.9998967441

*** AMPLITUDE FUNCTION UPDATE PASS 1 FOR SHAPE STEP NUMBER 5 ***

RHO STEP NO.	STEP LENGTH (SEC)	END TIME (SEC)	NO. TEMP. CORR. ITER.	BETA GEN. TIME (SEC)	UPDATED VALUE REACTIVITY (\$)	ALPHA (DN/N)	AMPLITUDE
1	0.65578739D-01	0.12707315D+00	0	0.36976383D-02 0.40893701D-06	0.11346069D-02 0.30684886D+00	0.36427226D+01	0.14528235D+01

*** SUMMARY FOR SHAPE STEP NUMBER 5 ***

STEP BEGAN AT 0.61494415D-01 SECONDS, ENDS AT 0.12707315D+00 SECONDS INTO TRANSIENT

STEP REQUIRED 1 GAMMA FACTOR ITERATIONS AND 1 REACTIVITY STEPS.

REACTOR POWER LEVEL = 0.72867769D+09 WATTS

TOTAL ENERGY RELEASE = 0.76182253D+08 WATT-SEC

COMPUTING TIME SUMMARY CENTRAL PROCESSOR (SEC) PERIPHERAL PROCESSOR (SEC)

THERMAL HYDRAULICS	0.0	0.0
GENERATE CROSS SECTIONS	0.0	0.0
COMPUTE AMPLITUDE FUNCTION EQUATION COEFFICIENTS	0.13	0.24
SHAPE FUNCTION SOLUTION	0.32	1.00
SOLVE FOR AMPLITUDE FUNCTION, MISC.	0.33	1.83
	0.16	0.67
TOTAL FOR THIS STEP	0.94	3.74
TOTAL ELAPSED COMPUTING TIME (SEC)	12.51	51.66 = 64.17

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FX2-TH TEST PROBLEM 1

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* BEGIN SHAPE STEP NO. 6 *

* BEGIN REACTIVITY STEP NO. 6 *

REACTIVITY STEP SELECTION TEST SUMMARY

	TEMPERATURE CHANGE	AMPLITUDE CHANGE	MAX. STEP SIZE	DOUBLE LAST STEP	DRIVING FUNCTION	SHAPE STEP END	PROBLEM END
TIME STEP (SEC)	0.0	C.321420D+00	0.2000C0D+00	0.130851E+00	0.0	0.0	0.372927D+00
REACTIVITY STEP BEGINS AT 0.127073D+00 SEC, ENDS AT 0.257924D+00 SEC, LENGTH = 0.130851D+00 SEC							

SHAPE STEP SELECTION TEST SUMMARY

	FLUX SHAPE CHANGE	MAX. STEP SIZE	10 TIMES LAST STEP	DRIVING FUNCTION	PROBLEM END
TIME STEP (SEC)	0.417665D+00	0.500000D+00	0.419779D-01	0.0	0.372927D+00
SHAPE STEP BEGINS AT 0.127073D+00 SEC, ENDS AT 0.500000D+00 SEC, LENGTH = 0.372927D+00 SEC					

THE FOLLOWING DRIVING FUNCTIONS APPLY THIS REACTIVITY STEP

REGION INCORE	MATERIAL	START TIME	END TIME	COEF1 (DT)	COEF2 (DT**2)	NEW VOL. FRAC.
	SS	0.0	C.100000D+01	-C.100000D+00	0.0	0.224208D+00

AMPLITUDE CHANGE OVER SHAPE STEP TERMINATES THIS STEP

*** THIS SHAPE STEP HAS BEEN REDUCED IN LENGTH - TERMINATES NOW ***
NEW LENGTH = 0.130851D+00 SEC, STEP END TIME = 0.257924D+00 SEC

*** SUMMARY FOR REACTIVITY STEP NUMBER 6 ***

STEP BEGAN AT 0.12707315D+00 SECONDS, ENDS AT 0.25792416D+00 SECONDS INTO TRANSIENT

END-OF-STEP REACTIVITY	=	0.22942095D-02	EFFECTIVE DELAYED NEUTRON FRACTION	=	0.37081274D-02
GENERATION TIME (SECONDS)	=	0.40785719D-06	AMPLITUDE FUNCTION VALUE (N)	=	0.27857083D+01
AMPLITUDE FUNCTION DERIVATIVE (DN)	=	0.19354763D+02	TOTAL ENERGY RELEASE (WATT-SEC)	=	0.20636508D+09
MAXIMUM FUEL TEMP. CHANGE (DEG.K)	=	0.0	MAXIMUM FUEL TEMPERATURE (DEG.K)	=	0.0

TOTAL REACTOR POWER (WATTS) = 0.14016901D+10

COMPUTING TIME SUMMARY
TOTAL FOR THIS STEP
TOTAL ELAPSED COMPUTING TIME (SEC)

CENTRAL PROCFSSOR (SEC)		PERIPHERAL PROCESSOR (SEC)	
0.44		1.32	
12.95	+	52.98	= 65.93

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FX2-TH TEST PROBLEM 1

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OUTER ITERATION SUMMARY REAL SOLUTION TIMDEP PROBLEM PROBLEM TIME = 0.257924D+00 SECONDS

OPTIMIZED INNER ITERATION STRATEGY FOR ROW RELAXATION		
GROUP NO.	OPTIMUM OMEGA	NO. OF INNERS
1	0.12034D+01	5
2	0.14046D+01	7
3	0.13052D+01	6
4	0.12179D+01	5

OUTER IT. NO.	REL. POINT ERROR	REL. SUM ERROR	EIGENVALUE CHANGE	POLY. ORDER	SPEC. RAD. USED	SPEC. RAD. ESTIMATED	GAMMA FACTOR
1	1.986362D-04	4.940247D-05	0.0	0	0.0	1.000000D+00	9.99960901D-01
2	3.554935D-05	3.540226D-05	0.0	0	0.0	7.166110D-01	9.9999982D-01
3	1.571415D-05	4.912283D-06	0.0	0	0.0	1.387584D-01	1.00000178D+00

OUTER ITERATIONS COMPLETED AT ITERATION 3, ITERATIONS HAVE CONVERGED

GAMMA FACTOR FOR SHAPE CALCULATION = 1.00000177690

*** AMPLITUDE FUNCTION UPDATE PASS 1 FOR SHAPE STEP NUMBER 6 ***

RHO STEP NO.	STEP LENGTH (SEC)	END TIME (SEC)	NO. TEMP. CORR. ITER.	BETA GEN. TIME (SEC)	REACTIVITY REACTIVITY (\$)	UPDATED VALUE ALPHA (DN/N)	AMPLITUDE
1	0.13085100D+00	0.25792416D+00	0	0.37083536D-02 0.40784271D-06	0.22948368D-02 0.61882900D+00	0.69530252D+01	0.27864477D+01

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FX2-TH TEST PROBLEM 1

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*** SUMMARY FOR SHAPE STEP NUMBER 6 ***

STEP BEGAN AT 0.12707315D+00 SECONDS, ENDS AT 0.25792416D+00 SECONDS INTO TRANSIENT

STEP REQUIRED 1 GAMMA FACTOR ITERATIONS AND 1 REACTIVITY STEPS.

REACTOR POWER LEVEL = 0.14021263D+10 WATTS

TOTAL ENERGY RELEASE = 0.20638379D+09 WATT-SEC

COMPUTING TIME SUMMARY	CENTRAL PROCESSOR (SEC)	PERIPHERAL PROCESSOR (SEC)	
THERMAL HYDRAULICS	0.0	0.0	
	0.0	0.0	
GENERATE CROSS SECTIONS	0.14	0.27	
COMPUTE AMPLITUDE FUNCTION EQUATION COEFFICIENTS	0.31	0.96	
SHAPE FUNCTION SOLUTION	0.63	3.85	
SOLVE FOR AMPLITUDE FUNCTION, MISC.	0.22	0.65	
TOTAL FOR THIS STEP	1.30	5.73	
TOTAL ELAPSED COMPUTING TIME (SEC)	13.81	57.39	= 71.20

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*****
* BEGIN SHAPE STEP NO. 7 *
*****

*****
* BEGIN REACTIVITY STEP NO. 7 *
*****

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REACTIVITY STEP SELECTION TEST SUMMARY

	TEMPERATURE CHANGE	AMPLITUDE CHANGE	MAX. STEP SIZE	DOUBLE LAST STEP	DRIVING FUNCTION	SHAPE STEP END	PROBLEM END
TIME STEP (SEC)	0.0	0.177542E+00	0.200000D+00	0.248233D+00	0.0	0.0	0.242076D+00

REACTIVITY STEP BEGINS AT 0.257924D+00 SEC, ENDS AT 0.435466D+00 SEC, LENGTH = 0.177542D+00 SEC

SHAPE STEP SELECTION TEST SUMMARY

	FLUX SHAPE CHANGE	MAX. STEP SIZE	10 TIMES LAST STEP	DRIVING FUNCTION	PROBLEM END
TIME STEP (SEC)	0.393121D+00	0.500000D+00	0.396169D+01	0.0	0.242076D+00

SHAPE STEP BEGINS AT 0.257924D+00 SEC, ENDS AT 0.500000D+00 SEC, LENGTH = 0.242076D+00 SEC

THE FOLLOWING DRIVING FUNCTIONS APPLY THIS REACTIVITY STEP

REGION	MATERIAL	START TIME	END TIME	COEF1 (DT)	COEF2 (DT**2)	NEW VOL. FRAC.
INCORE	SS	0.0	0.100000D+01	-0.100000D+00	0.0	0.206453D+00

AMPLITUDE CHANGE OVER SHAPE STEP TERMINATES THIS STEP

*** AMPLITUDE = 0.453563D+04, GREATER THAN ALLOWED MAX. ***

*** THIS SHAPE STEP HAS BEEN REDUCED IN LENGTH - TERMINATES NOW ***

NEW LENGTH = 0.177542D+00 SEC, STEP END TIME = 0.435466D+00 SEC

*** CALCULATION WILL BE TERMINATED BEFORE REQUESTED TIME ***

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FX2-TH TEST PROBLEM 1

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*** SUMMARY FOR REACTIVITY STEP NUMBER 7 ***

STEP BEGAN AT 0.25792416D+00 SECONDS, ENDS AT 0.43546596D+00 SECONDS INTO TRANSIENT

END-OF-STEP REACTIVITY	=	0.38538220D-02	EFFECTIVE DELAYED NEUTRON FRACTION	=	0.37228415D-02
GENERATION TIME (SECONDS)	=	0.40636727D-06	AMPLITUDE FUNCTION VALUE (N)	=	0.45356290D+04
AMPLITUDE FUNCTION DERIVATIVE (DN)	=	0.15592132D+07	TOTAL ENERGY RELEASE (WATT-SEC)	=	0.92831915D+10
MAXIMUM FUEL TEM2. CHANGE (DEG.K)	=	0.0	MAXIMUM FUEL TEMPERATURE (DEG.K)	=	0.0

TOTAL REACTOR POWER (WATTS) = 0.22923686D+13

COMPUTING TIME SUMMARY
TOTAL FOR THIS STEP
TOTAL ELAPSED COMPUTING TIME (SEC)

CENTRAL PROCESSOR (SEC)		PERIPHERAL PROCESSOR (SEC)	
0.81		1.44	
14.62	+	58.83	= 73.45

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FX2-TH TEST PROBLEM 1

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OUTER ITERATION SUMMARY REAL SOLUTION TIMDEF PROBLEM PROBLEM TIME = 0.435466D+00 SECONDS

GROUP			OPTIMIZED INNER			ITERATION STRATEGY FOR ROW RELAXATION			GROUP		
NO.	OPTIMUM OMEGA	NO. OF INNERS	NO.	OPTIMUM OMEGA	NO. OF INNERS	NO.	OPTIMUM OMEGA	NO. OF INNERS	NO.	OPTIMUM OMEGA	NO. OF INNERS
1	0.12103D+01	5	2	0.14685D+01	8	3	0.13090D+01	6	4	0.12182D+01	5

OUTER IT. NO.	REL. POINT ERROR	REL. SUM ERROR	EIGENVALUE CHANGE	POLY. ORDER	SPEC. RAD. USED	SEEC. RAD. ESTIMATED	GAMMA FACTOR
1	4.163898D-04	1.238922D-04	0.0	0	0.0	1.000000D+00	9.99775034D-01
2	6.162838D-05	2.105172D-04	0.0	0	0.0	1.699307D+00	9.99993781D-01
3	4.612425D-05	1.115343D-05	0.0	0	0.0	5.298665D-02	1.00000546D+00
4	1.777081D-05	9.660331D-06	0.0	0	0.0	8.651285D-01	1.00000232D+00

OUTER ITERATIONS COMPLETED AT ITERATION 4, ITERATIONS HAVE CONVERGED

GAMMA FACTOR FOR SHAPE CALCULATION = 1.00000232213

*** AMPLITUDE FUNCTION UPDATE PASS 1 FOR SHAPE STEP NUMBER 7 ***

RHO STEP NO.	STEP LENGTH (SEC)	END TIME (SEC)	NC. TEMP. CORR. ITER.	BETA GEN. TIME (SEC)	REACTIVITY REACTIVITY (\$)	UPDATED VALUE ALPHA (DN/N)	AMPLITUDE
1	0.17754180D+00	0.43546556D+00	0	0.37234962D-02 0.40627733D-06	0.38553438D-02 0.10355439D+01	0.34684993D+03	0.47704425D+04

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FX2-TH TEST PROBLEM 1

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*** SUMMARY FOR SHAPE STEP NUMBER 7 ***

STEP BEGAN AT 0.25792416D+00 SECONDS, ENDS AT 0.43546596D+00 SECONDS INTO TRANSIENT

STEP REQUIRED 1 GAMMA FACTOR ITERATIONS AND 1 REACTIVITY STEPS.

REACTOR POWER LEVEL = 0.24116234D+13 WATTS

TOTAL ENERGY RELEASE = 0.96201683D+10 WATT-SEC

COMPUTING TIME SUMMARY	CENTRAL PROCESSOR (SEC)	PERIPHERAL PROCESSOR (SEC)
THERMAL HYDRAULICS	0.0	0.0
	0.0	0.0
GENERATE CROSS SECTIONS	0.13	0.28
COMPUTE AMPLITUDE FUNCTION EQUATION COEFFICIENTS	0.31	1.17
SHAPE FUNCTION SOLUTION	0.95	4.29
SOLVE FOR AMPLITUDE FUNCTION, MISC.	0.98	0.58
TOTAL FOR THIS STEP	2.37	6.32
TOTAL ELAPSED COMPUTING TIME (SEC)	16.18	63.71
	+	=
		79.89

* A RESTART FILE HAS BEEN WRITTEN ON LUN/DSRN 49 *
* SHAPE STEP NO. = 8 *
* REACTIVITY STEP NO. = 7 *
* PROBLEM TIME (SEC) = 0.4354660D+00 *

FX2-TH 07/77

FX2-TH TEST PROBLEM 1

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REAC. STEP	AMPL. ITER.	GAMMA ITER.	TIME (SEC)	REAC. STEP LENGTH (SEC)	REACTIVITY (DOLLARS)	MAX. FUEL TEMP. (K)	MAX. FUEL DELTA TEMP. (K)	TOTAL ENERGY (WATT-SEC)	AMPLITUDE	TOTAL POWER (WATTS)
* 1	1	1	4.09987D-03	4.09987D-03	9.95938D-03	0.0	0.0	2.05973D+06	1.00962D+00	5.04362D+08
* 2	1	1	1.22994D-02	8.19950D-03	2.93662D-02	0.0	0.0	6.24179D+06	1.03007D+00	5.15193D+08
* 3	1	1	2.96982D-02	1.63988D-02	6.95322D-02	0.0	0.0	1.48704D+07	1.07393D+00	5.37291D+08
* 4	1	1	6.14944D-02	3.27963D-02	1.48971D-01	0.0	0.0	3.33079D+07	1.17478D+00	5.98272D+08
* 5	1	1	1.27073D-01	6.55787D-02	3.06549D-01	0.0	0.0	7.61823D+07	1.45282D+00	7.29673D+08
* 6	1	1	2.57924D-01	1.30851D-01	6.18529D-01	0.0	0.0	2.06384D+08	2.78645D+00	1.40213D+09
* 7	1	1	4.35466D-01	1.77542D-01	1.03554D+00	0.0	0.0	9.62017D+09	4.77044D+03	2.41162D+12

* SUMMARY COMPLETED *

* PROBLEM COMPLETED *

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