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DEVELOPMENT REPORT

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FIPER-I, A FORTRAN IV PROGRAM FOR THE
RELEASE OF FISSION PRODUCTS FROM A HIGH TEMPERATURE
GAS-COOLED NUCLEAR POWER REACTOR

by

B. W. Roos and J. E. Welch

Prepared under
Contract AT(04-3)-167
Project Agreement No. 17
for the
San Francisco Operations Office
U. S. Atomic Energy Commission

May 2, 1968

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Gulf General Atomic Incorporated

P.O. Box 608, San Diego, California 92112

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I. INTRODUCTION.

The release of radioactive fission products, generated by nuclear fission processes inside the fuel particles, into the helium coolant gas is of considerable interest for the evaluation of the safety characteristics of an high temperature gas-cooled nuclear power reactor, (HTGR).

In this report we present a description of the FORTRAN IV computer code FIPER-I. This code, which is based on the theoretical formulation of Appel and Roos,⁽¹⁾ computes the temperature and concentration induced, transient and steady-state, diffusion of fission product isotopes in one-dimensional slab geometry. In particular it serves to compute the release rates of metallic fission products from the core of an HTGR.

(1) J. Appel and B. W. Roos, "A study of the release of radioactive metallic isotopes from high temperature gas-cooled reactors." Submitted for publication to the Journal of Nuclear Science and Engineering.

II. PROBLEM STATEMENT.

In slab geometry, the simultaneous diffusion of I radioactive fission product isotopes in a particular medium can be described by the continuity equations,

$$\frac{\partial C_i(x,t)}{\partial t} = S_i(x,t) - \lambda_i C_i(x,t) - \frac{\partial J_i(x,t)}{\partial x} \quad i=1,2,\dots,I .$$

where,

$C_i(x,t)$ denotes the average volume concentration of the i-th isotope.

$S_i(x,t)$ denotes the production rate of the i-th isotope.

λ_i denotes the decay constant of the i-th isotope.

$J_i(x,t)$ denotes the particle current of the i-th isotope.

In FIPER I, it has been assumed that the particle current $J_i(x,t)$ can be written as the sum of two terms,

$$J_i(x,t) = - F_i(x,t) \frac{\partial C_i(x,t)}{\partial x} - G_i(x,t) \frac{\partial T(x,t)}{\partial x}$$

where $F_i(x,t)$ and $G_i(x,t)$ are given functions of position and time and of the concentrations $C_i(x,t)$, $i=1,2,\dots,I$. $T(x,t)$ denotes the temperature in the slab and is assumed to be a known function of position and time.

For example, if the concentration gradient is the only driving force present and $F_i(x,t) = D_i(x,t)$, where $D_i(x,t)$ is the diffusion coefficient of the i -th isotope in the medium considered, then the expression for the particle current, given above, reduces to the customary formulation of Fick's law of diffusion. In this case, the diffusion equations, obtained by substitution of the expressions for the particle currents into the continuity equations, are uncoupled and linear. A more interesting case ensues when the driving force is generated by concentration and temperature gradients. For example, the particle current can have two contributions corresponding to a driving force caused by the gradient of the chemical potential and a driving force caused by the gradient of the temperature field. According to the theory of thermodynamics we now need to write,

$$J_i(x,t) = -L_{11,i} \frac{\partial}{\partial x} \left(\frac{\mu_i}{T} \right) + L_{12,i} \frac{\partial}{\partial x} \left(\frac{1}{T} \right)$$

where the chemical potential μ_i can be related to the concentrations and $L_{11,i}$ and $L_{12,i}$ are given transport coefficients. In this case, the resulting diffusion equations are coupled and highly non-linear. They can be solved by iterative numerical techniques only.

The boundary conditions, which are imposed on the solutions of the diffusion equations in FIPER I, are symmetry conditions at the origin,

$$\frac{\partial C_i(x=0,t)}{\partial x} = 0$$

and inhomogeneous mixed Dirichlet and Neumann conditions at the outside boundary,

$$\frac{\partial C_i(x=x_b,t)}{\partial x} + \psi_i(t)C(x=x_b,t) = \Xi_i(t)$$

where $\psi_i(t)$ and $\Xi_i(t)$ can be given functions of time and of the concentrations $C_i(x_b,t)$, $i=1,2,\dots,I$.

At an interface, indicating a change in the physical properties of the transport medium, we impose the equilibrium condition that the concentration $C^-(x_m,t)$ just to the left of the interface is a fraction of the concentration $C^+(x_m,t)$ just to the right of the interface,

$$C^-(x_m,t) = \phi(x_m)C^+(x_m,t)$$

We require furthermore that the particle currents are continuous over an interface,

$$J^-(x_m,t) = J^+(x_m,t)$$

To complete the specification of this boundary value problem we shall assume that the concentrations at time $t=0$ are known functions of position,

$$C_i(x, t=0) = C_{i0}(x)$$

Our boundary value problem may therefore be stated as follows.

To find the solution of the following system of diffusion equations,

$$\frac{\partial C_i(x, t)}{\partial t} = S_i(x, t) - \lambda_i C_i(x, t) - \frac{\partial J_i(x, t)}{\partial x} \quad i=1, 2, \dots, I.$$

where

$$J_i(x, t) = - F_i(x, t) \frac{\partial C_i(x, t)}{\partial x} - G_i(x, t) \frac{\partial T(x, t)}{\partial x}$$

subject to the interface conditions,

$$C_i^-(x_m, t) = \phi_i(m) C_i^+(x_m, t)$$

$$J_i^-(x_m, t) = J_i^+(x_m, t)$$

the boundary conditions,

$$\frac{\partial C_i(x=0,t)}{\partial x} = 0$$

$$\frac{\partial C_i(x=x_b,t)}{\partial x} + \psi(t)C_i(x=x_b,t) = \Xi_i(t)$$

and the initial condition,

$$C_i(x,t=0) = C_{oi}(x)$$

In the following section we shall present the derivation of the equivalent finite difference formulation of this boundary value problem.

III. THE FINITE DIFFERENCE EQUATIONS.

To obtain the equivalent finite difference formulation of the boundary value problem delineated in the preceding section, we superimpose a grid of mesh points $x_m, (m=1,2,\dots,M)$, over the interval $0 < x < x_b$, such that the interface points are points of this grid. At each mesh point we require that the current condition,

$$J_i^-(x_m, t) = J_i^+(x_m, t)$$

and the equilibrium condition,

$$C_i^-(x_m, t) = \phi_i(x_m) C_i^+(x_m, t)$$

are satisfied and we do not distinguish therefore between ordinary mesh points and interface mesh points.

We now integrate the continuity equation for the i -th isotope over the interval $x_{m-1/2} < x < x_{m+1/2}$.

$$\begin{aligned}
& \int_{x_{m-1/2}}^{x_m} \frac{\partial C_i(x,t)}{\partial t} dx + \int_{x_m}^{x_{m+1/2}} \frac{\partial C_i(x,t)}{\partial t} dx = \int_{x_{m-1/2}}^{x_{m+1/2}} [S_i(x,t) - \lambda C_i(x,t)] dx \\
& + [J_i(m-1/2,t) - J_i(m+1/2,t)]
\end{aligned}$$

where we made use of the current condition,

$$J_i^-(m,t) = J_i^+(m,t)$$

and introduced the notation,

$$J(x_m,t) = J(m,t)$$

The current at the point $x_{m+1/2}$ can be approximated by the expression,

$$\begin{aligned}
J_i(m+1/2,t) = & - F_i(m+1/2,t) \frac{C_i^-(m+1,t) - C_i^+(m,t)}{2\Delta_{m+1}} - \\
& - G_i(m+1/2,t) \frac{T(m+1,t) - T(m,t)}{2\Delta_{m+1}}
\end{aligned}$$

Hence, using the equilibrium condition,

$$C_i^-(m,t) = \phi_i(m) C_i^+(m,t)$$

the diffusion equation in finite difference form may be written as,

$$\Delta_m \frac{\partial C_i(m-1,t)}{\partial t} + 3 [\Delta_m \phi_i(m) + \Delta_{m+1}] \frac{\partial C_i(m,t)}{\partial t} + \Delta_{m+1} \phi_i(m+1) \frac{\partial C_i(m+1,t)}{\partial t} =$$

$$= K_i(m,t) - \lambda_i \Delta_m C_i(m-1,t) - 3\lambda_i [\Delta_m \phi_i(m) + \Delta_{m+1}] C_i(m,t) - \lambda_i \Delta_{m+1} C_i(m+1,t) +$$

$$+ 2F_i(m+1/2,t) \frac{\phi_i(m+1) C_i(m+1,t) - C_i(m,t)}{\Delta_{m+1}} - 2F_i(m-1/2,t) \frac{\phi_i(m) C_i(m,t) - C_i(m-1,t)}{\Delta_m}$$

where,

$$C_i(m,t) = C_1^+(m,t)$$

and,

$$K_i(m,t) = \Delta_{m+1} S_i(m+1,t) + 3(\Delta_m + \Delta_{m+1})S_i(m,t) + \Delta_m S_i(m-1,t) +$$

$$+ 2 G_i(m+1/2,t) \frac{T(m+1,t)-T(m,t)}{\Delta_{m+1}} - 2 G_i(m-1/2,t) \frac{T(m,t)-T(m-1,t)}{\Delta_m}$$

Replacing the time derivative, $\partial C / \partial t$, by a weighted average,

$$\frac{\partial C}{\partial t} = \omega \left(\frac{\partial C}{\partial t} \right)_{(n+1)} + (1-\omega) \left(\frac{\partial C}{\partial t} \right)_{(n)}$$

where n is the index of the n -th time step, the finite difference equations may be written as a system of simultaneous linear algebraic equations of the form,

$$-U_i(m)C_i(m+1,n+1) + V_i(m)C_i(m,n+1) - W_i(m)C_i(m+1,n+1) = X_i(m,n,n+1)$$

$$m=2, \dots, M-1$$

where the coefficients $U_i(m)$, $V_i(m)$, $W_i(m)$ and the inhomogeneous term

$X_i(m)$ are defined by the relations,

$$U_i(m) = [\omega \Delta t \left\{ \frac{2F_i(m+1/2, n+1)}{\Delta_{m+1}} - \lambda_i \Delta_{m+1} \right\} - \Delta_{m+1}] \phi_i(m+1)$$

$$V_i(m) = 2\omega \Delta t \left[\frac{F_i(m+1/2, n+1)}{\Delta_{m+1}} + \frac{F_i(m-1/2, n+1)}{\Delta_m} \phi_i(m) \right] + 3(\lambda_i \omega \Delta t + 1) [\phi_i(m) \Delta_m + \Delta_{m+1}]$$

$$W_i(m) = \omega \Delta t \left[\frac{2F_i(m-1/2, n+1)}{\Delta_m} - \lambda_i \Delta_m \right] - \Delta_m$$

$$X_i(m) = (1-\omega) \Delta t K_i(m, n) + \omega \Delta t K_i(m, n+1) +$$

$$+ [1-\lambda_i(1-\omega) \Delta t] [C_i(m-1, n) \Delta_m + 3 \{ \phi_i(m) \Delta_m + \Delta_{m+1} \} C_i(m, n) + \Delta_{m+1} \phi_i(m+1) C_i(m+1, n)]$$

$$+ 2(1-\omega) \Delta t [F_i(m+1/2, n) \frac{\phi_i(m+1) C_i(m+1, n) - C_i(m, n)}{\Delta_{m+1}} - F_i(m-1/2, n) \frac{\phi_i(m) C_i(m, n) - C_i(m-1, n)}{\Delta_m}]$$

This system of linear algebraic equations is completed by means of the finite difference equivalents of the boundary value conditions. The symmetry condition at the origin takes the finite difference form,

$$-C_i(2, n+1) + C_i(1, n+1) = 0$$

and thus,

$$U_i(1) = 1$$

$$V_i(1) = 1$$

and

$$X_i(1) = 0$$

On the outside boundary we obtain the condition,

$$[1 + \Delta_M \Psi_i(n+1)] C_i(M, n+1) - [1 - \Delta_M \Psi_i(n+1)] C_i(M-1, n+1) = 2\Delta_M \Xi_i(n+1)$$

$\vec{C}_i$ is a column vector with components,

$$C_i(1) , C_i(2), \dots, C_i(M)$$

and $\vec{X}_i$ is a column vector with components

$$X_i(1) , X_i(2), \dots, X_i(M)$$

If the diffusion and boundary equations are uncoupled and linear (for example in the case of Fickian diffusion when the diffusion coefficients are independent of the concentrations) the elements of the matrix A_i are independent of the concentrations. In this case the solutions of the systems of linear algebraic equations

$$A_i(n)\vec{C}_i(n+1) = \vec{X}_i(n,n+1)$$

can be obtained by matrix inversion,

$$\vec{C}_i(n+1) = A_i^{-1}(n)\vec{X}_i(n,n+1)$$

However, if the diffusion equations and/or the boundary equations are nonlinear and/or coupled, the solutions of the systems of equations

$$A_i(n,n+1)\vec{C}_i(n+1) = \vec{X}_i(n,n+1)$$

can be obtained by an iterative numerical technique only. In the following section we shall present an outline of the iterative procedure used in FIPER I.

IV. THE ITERATIVE SCHEME.

At the time step,

$$t_n = \sum_{k=1}^n \Delta t_k$$

we have to obtain the solution of I coupled systems of linear algebraic equations of the form,

$$A_i \vec{C}_i(n+1) = \vec{X}_i \quad i=1,2,\dots,I$$

where the elements of the tridiagonal matrices A_i and the components of the vectors $\vec{X}_i$ may depend on the components of the vectors $\vec{C}_i$.

Suppose that the systems are ordered,

$$A_1 \vec{C}_1(n+1) = \vec{X}_1$$

$$A_2 \vec{C}_2(n+1) = \vec{X}_2$$

.....

.....

.....

.....

$$A_I \vec{C}_I(n+1) = \vec{X}_I$$

The solution of this ordered set of coupled systems of algebraic equations can be obtained by successive cycles of inner and outer iterations.

For let $\vec{\alpha}$ denote an inner iteration index vector with I components and β an outer iteration index number. We set $\vec{\alpha}=0$ and $\beta=0$ and consider the solution of the system,

$$A_i \vec{C}_i(n+1) = \vec{X}_i$$

Setting $\vec{\alpha}=(1,0,\dots,0)$ we write,

$$A_1^{(0,0)} \vec{C}_1^{(0,1)} = \vec{X}_1^{(0,0)}$$

where,

$$A_1^{(0,0)} = A_1(\vec{C}_1^{(0,0)}, \vec{C}_2^{(0,0)}, \dots, \vec{C}_I^{(0,0)})$$

$$\vec{X}_1^{(0,0)} = \vec{X}_1(\vec{C}_1^{(0,0)}, \vec{C}_2^{(0,0)}, \dots, \vec{C}_I^{(0,0)})$$

and

$$\vec{C}_i^{(0,0)} = \vec{C}_i(n)$$

i.e. the elements of the matrix $A_i^{(0,0)}$ and the components of the vector $\vec{X}_i^{(0,0)}$ depend on the concentrations at the previous time step only.

In the next step in the inner iteration procedure for the first system of equations we set $\vec{\alpha}=(2,0,0,\dots,0)$ and solve the system of equations,

$$A_1^{(0,1)} \vec{C}_i^{(0,2)} = \vec{X}_1^{(0,1)}$$

where,

$$A_1^{(0,1)} = A_1(\vec{C}_1^{(0,1)}, \vec{C}_2^{(0,0)}, \dots, \vec{C}_I^{(0,0)})$$

$$\vec{X}_1^{(0,1)} = \vec{X}_1(\vec{C}_1^{(0,1)}, \vec{C}_1^{(0,0)}, \vec{C}_2^{(0,0)}, \dots, \vec{C}_I^{(0,0)})$$

In general, setting $\vec{\alpha}=(\alpha_1, \dots, 0)$ we solve, after α_1-1 steps in the inner iteration procedure of the first system of equations, the equation,

$$A_1^{(0, \alpha_1-1)} \vec{C}_1^{(0, \alpha_1)} = \vec{X}_1^{(0, \alpha_1-1)}$$

where

$$A_1^{(0, \alpha_1-1)} = A_1(\vec{C}_1^{(0, \alpha_1-1)}, \vec{C}_2^{(0,0)}, \dots, \vec{C}_I^{(0,0)})$$

and

$$\vec{X}_1^{(0, \alpha_1-1)} = \vec{X}_1(\vec{C}_1^{(0, \alpha_1-1)}, \vec{C}_1^{(0,0)}, \dots, \vec{C}_I^{(0,0)})$$

The inner iteration cycle for the system of equations for $\vec{C}_1$ in the first outer iteration, $\beta=0$, is completed when,

$$\left| \frac{C_{lm}^{(0,\alpha_1)} - C_{lm}^{(0,\alpha_1-1)}}{C_{lm}^{(0,\alpha_1)}} \right| \leq \epsilon \text{ (inner)} \quad m=1,2,\dots,M.$$

where $\epsilon \text{ (inner)}$ is a given small positive number.

The second step in the first outer iteration concerns the solution by a series of inner iterations of the system of equations,

$$A_2 \vec{C}_2^{(n+1)} = \vec{X}_2$$

Now we consider the solution of equations of the form,

$$A_2^{(0,\alpha_2-1)} \vec{C}_2^{(0,\alpha_2)} = \vec{X}_2^{(0,\alpha_2-1)} \quad \alpha_2=1,2,\dots$$

where

$$A_2^{(0,\alpha_2-1)} = A_2(\vec{C}_1^{(0,\alpha_1)}, \vec{C}_2^{(0,\alpha_2-1)}, \vec{C}_3^{(0,0)}, \dots, \vec{C}_I^{(0,0)})$$

and

$$\vec{X}_2^{(0,\alpha_2-1)} = \vec{X}_2(\vec{C}_1^{(0,\alpha_1)}, \vec{C}_2^{(0,\alpha_2-1)}, \vec{C}_1^{(0,0)}, \dots, \vec{C}_I^{(0,0)})$$

Again the inner iteration cycle for the second system of equations is terminated on the α_2 inner iteration when

$$\left| \frac{C_{2m}^{(\alpha_2)} - C_{2m}^{(\alpha_2-1)}}{C_{2m}^{(\alpha_2)}} \right| < \epsilon \text{ (inner)} \quad m=1,2,\dots,M.$$

We now turn to the third system of equations in the first outer iteration and continue this procedure until for $\beta=0$ the solutions are obtained of all systems,

$$A_1 \vec{C}_1^{(0,\alpha_1)} = \vec{X}_1 \quad i=1,\dots,I$$

This completes the first outer iteration $\beta=0$. At the start of the second outer iteration we set $\alpha=0$ and $\beta=1$. In this iteration we solve systems of equations of the form,

$$A_i \vec{C}_i^{(1,\alpha_i-1)} = \vec{X}_i^{(1,\alpha_i-1)}$$

where

$$A_i^{(1,\alpha_i-1)} = A_i^{(1,\alpha_i-1)} (\vec{C}_1^{(1,\alpha_1)}, \vec{C}_2^{(1,\alpha_2)}, \dots,$$

$$\dots, \vec{C}_i^{(1,\alpha_i-1)}, \vec{C}_{i+1}^{(0,\alpha_i+1)}, \dots, \vec{C}_I^{(0,\alpha_I)})$$

and $\vec{X}_i^{(1,\alpha_i-1)}$ satisfies a similar dependence relation.

As in the first outer iteration we work our way through the ordered set of I systems of equations terminating the series of inner iterations for a particular system if a convergence criterion of the form,

$$\left| \frac{C_{im}^{(1, \alpha_i)} - C_{im}^{(1, \alpha_i - 1)}}{C_{im}^{(1, \alpha_i)}} \right| < \epsilon \text{ (inner)} \quad m=1, 2, \dots, M$$

is satisfied.

This procedure is continued with the outer iterations $\beta=2, 3, \dots$, until the instance that the condition,

$$\left| \frac{C_{im}^{(\beta_i, \alpha_i)} - C_{im}^{(\beta_i - 1, \alpha_i)}}{C_{im}^{(\beta_i, \alpha_i)}} \right| < \epsilon \text{ (outer)} \quad m=1, 2, \dots, M$$

is satisfied, where $\epsilon \text{ (outer)}$ is some small positive number.

V. LINE INVERSION METHOD FOR THE SOLUTION OF A
TRIDIAGONAL SYSTEM OF ALGEBRAIC EQUATIONS.

A single equation of the system,

$$A \vec{C} = \vec{X}$$

is of the form

$$-U(m)C(m+1) + V(m)C(m) - W(m)C(m-1) = X(m) \quad \text{where } 2 \leq m \leq M-1$$

We assume that the boundary conditions can be represented by finite difference equations of the form:

$$\begin{aligned} -U(1)C(2) + V(1)C(1) &= X(1) \\ + V(M)C(M) - W(M)C(M-1) &= X(M) \end{aligned}$$

An efficient method to obtain the solution of such a system of algebraic equations is the line inversion method. In this method one starts out by defining coefficients

$$E(1) = \frac{U(1)}{V(1)}$$

$$F(1) = \frac{X(1)}{V(1)}$$

and

$$E(m) = \frac{U(m)}{V(m) - W(m)E(m-1)} \quad 2 \leq m \leq M-1$$

$$F(m) = \frac{X(m) + W(m)F(m-1)}{V(m) - W(m)E(m-1)} \quad 2 \leq m \leq M$$

Then,

$$C(M) = F(M)$$

and

$$C(m) = E(m)C(m+1) + F(m) \qquad 1 \leq m \leq M-1$$

VI. CONSERVATION CHECKS.

To obtain a running check on the numerical accuracy of the computation some conservation checks are built into the code.

Integrating the continuity equation at a particular instant in time over the interval $(0, x_b)$ we find,

$$\int_0^{x_b} \frac{\partial C_i}{\partial t} dx = \int_0^{x_b} [S_i(x,t) - \lambda_i C_i(x,t)] dx + J_i(0,t) - J_i(x_b,t)$$

Thus, printing the currents at the origin and at the boundary and the space integrals of the source, concentration and time derivative of the concentration, some check is obtained on the accuracy with which the continuity equations are satisfied at a particular instant in time.

Similarly, integrating the continuity equation at a particular point on the interval $(0, x_b)$ over time we obtain the equation,

$$C_i(x,t) - C_i(x,0) = \int_0^t [S_i(x,t) - \lambda C_i(x,t) - \frac{\partial J_i}{\partial x}] dt$$

which relates the concentration at a particular point to the time integrals of the source, concentration, and the current.

All relevant quantities and integrals are printed. It should be noted that in some instances the integrals over the source can be computed analytically.

VII. THE COMPUTER PROGRAM.

The Computational Mesh

The computational region is composed of a one-dimensional array of mesh points X_m , ($1 \leq m \leq \bar{M}$), where X_m is the Cartesian coordinate of the point, and m is the index number associated with the point. The mesh points are separated by a variable finite length where $\Delta_{m-\frac{1}{2}}$ refers to the distance between points $X_{m-\frac{1}{2}}$ and X_m , and $\Delta_{m+\frac{1}{2}}$ is the distance between X_m and $X_{m+\frac{1}{2}}$. The index $m+\frac{1}{2}$ refers to the midpoint between the points X_m and X_{m+1} . Likewise, $m-\frac{1}{2}$ refers to the midpoint between points X_{m-1} and X_m .

The left boundary is positioned at the midpoint between X_1 and X_2 . The right boundary is positioned at the midpoint between $X_{\bar{M}-1}$ and $X_{\bar{M}}$. If there is a graphite-fuel interface, it is defined at one of the mesh points m , (see Fig. 1).

In addition to the mesh index m , many of the variables are also dependent on the isotope index i ($1 \leq i \leq \bar{I}$).

Positioning of the Variables

The variables of the problem are positioned as shown in Fig. 2. When the value of a variable is needed at a point at which it is not defined, an average is used. For example, $T_{m+\frac{1}{2}} = \frac{T_{m+1} + T_m}{2}$.

If a variable Z_m is defined at the mesh points, then in FORTRAN notation:

$$Z(M) = Z_m ; \quad Z(M-1) = Z_{m-1} ; \quad Z(M+1) = Z_{m+1} .$$

○ = MIDPOINT
 △ = MESH POINT

FIGURE 1. The computational mesh for the case where there is a fuel region, graphite region, and coolant stream.

○ = MESH POINT
 △ = MIDPOINT

FIGURE 2. Mesh positions of the variables.

If the variable $Z_{m+\frac{1}{2}}$ is defined at the midpoints, then the FORTRAN notation would be:

$$Z(M) = Z_{m+\frac{1}{2}} ; \quad Z(M-1) = Z_{m-\frac{1}{2}} .$$

Equations

The equations used in the computer program have been slightly rearranged from those shown in the first part of the report in order to obtain a more highly efficient computer program. Although they look quite different, they are in all cases exactly the same equations discussed previously. $F_{m+\frac{1}{2},i}$ and $G_{m+\frac{1}{2},i}$ have been redefined to be $-F_{m+\frac{1}{2},i}$ and $-G_{m+\frac{1}{2},i}$.

We wish to solve the system of equations:

$$-U_m C_{m+1,i} + V_m C_{m,i} - W_m C_{m-1,i} = XX_m \quad 1 \leq m \leq \bar{M} \quad (1)$$

where:

$$U_m = - \left[\gamma_{m+\frac{1}{2}} + \omega \Delta t \left(\lambda_i \gamma_{m+\frac{1}{2}} + \frac{F_{m+\frac{1}{2},i}}{2 \Delta_{m+\frac{1}{2}}} \right) \right] \phi_{m+1} \quad (2)$$

$$W_m = - \left[\gamma_{m-\frac{1}{2}} + \omega \Delta t \left(\lambda_i \gamma_{m-\frac{1}{2}} + \frac{F_{m-\frac{1}{2},i}}{2 \Delta_{m-\frac{1}{2}}} \right) \right] \quad (3)$$

$$V_m = \left[3\gamma_{m-\frac{1}{2}} + \omega \Delta t \left(3\lambda_i \gamma_{m-\frac{1}{2}} - \frac{F_{m-\frac{1}{2},i}}{2 \Delta_{m-\frac{1}{2}}} \right) \right] \phi_{m,i} \quad (4)$$

$$+ \left[3\gamma_{m+\frac{1}{2}} + \omega \Delta t \left(3\lambda_i \gamma_{m+\frac{1}{2}} - \frac{F_{m+\frac{1}{2},i}}{2 \Delta_{m+\frac{1}{2}}} \right) \right]$$

$$X X_m = \omega \Delta t \text{ GTERM}_{m,i}^{n+1} + \text{XTERM}_{m,i}^n \quad (5)$$

where:

$$\text{GTERM}_{m,i}^{n+1} = G_{m-\frac{1}{2},i}^{n+1} \left(\frac{\partial T}{\partial X} \right)_{m-\frac{1}{2}}^{n+1} - G_{m+\frac{1}{2},i}^{n+1} \left(\frac{\partial T}{\partial X} \right)_{m+\frac{1}{2}}^{n+1} \quad (6)$$

$$\begin{aligned} \text{XTERM}_{m,i}^n &= \omega \Delta t \text{ STERM}_{m,i}^{n+1} + (1-\omega) \Delta t \text{ STERM}_{m,i}^n \\ &+ (1-\omega) \Delta t \text{ GTERM}_{m,i}^n + \text{CTERM}_{m,i}^n \end{aligned} \quad (7)$$

where:

$$\text{STERM}_{m,i}^n = \gamma_{m-\frac{1}{2}} S_{m-1,i}^n + 3(\gamma_{m-\frac{1}{2}} + \gamma_{m+\frac{1}{2}}) S_{m,i}^n + \gamma_{m+\frac{1}{2}} S_{m+1,i}^n \quad (8)$$

$$\begin{aligned} \text{CTERM}_{m,i}^n &= \gamma_{m-\frac{1}{2}} C_{m-1,i}^n + 3(\gamma_{m-\frac{1}{2}} \Phi_{m,i} + \gamma_{m+\frac{1}{2}}) C_{m,i}^n + \gamma_{m+\frac{1}{2}} \Phi_{m+1,i} C_{m+1,i}^n \\ &- (1-\omega) \Delta t (f C_{m-1,i}^n + g C_{m,i}^n + h C_{m+1,i}^n) \end{aligned} \quad (9)$$

$$f = \lambda_i \gamma_{m-\frac{1}{2}} + \frac{F_{m-\frac{1}{2},i}}{2\Delta_{m-\frac{1}{2}}} \quad (10)$$

$$g = \left(3\lambda_i \gamma_{m-\frac{1}{2}} - \frac{F_{m-\frac{1}{2},i}}{2\Delta_{m-\frac{1}{2}}} \right) \Phi_{m,i} + \left(3\lambda_i \gamma_{m+\frac{1}{2}} - \frac{F_{m+\frac{1}{2},i}}{2\Delta_{m+\frac{1}{2}}} \right) \quad (11)$$

$$h = \left(\lambda_i \gamma_{m+\frac{1}{2}} + \frac{F_{m+\frac{1}{2},i}}{2\Delta_{m+\frac{1}{2}}} \right) \Phi_{m+1,i} \quad (12)$$

To solve the system of equations (1) we first compute, from left to right, the quantities,

$$E_m = \frac{U}{V - W^*E_{m-1}} \quad (13)$$

$$FF_m = \frac{XX + W^*FF_{m-1}}{V - W^*E_{m-1}} \quad (14)$$

Then solving from right to left we get:

$$C_{m,i} = C_{m+1,i} E_m + FF_m \quad (15)$$

Boundary Conditions

a) Left boundary - The left boundary is a boundary of symmetry and results in the following conditions,

$$E_1 = 1.0 \quad (16)$$

$$FF_1 = 0.0 \quad (17)$$

$$T_1 = T_2 \quad (18)$$

$$C_1 = C_2 \quad (19)$$

$$S_1 = S_2 \quad (20)$$

b) Right boundary - On the right boundary the boundary conditions are applied by using the following equations:

$$V_{\overline{M}} = 1 + \Delta_{\overline{M}-\frac{1}{2}} \psi_i \quad (21)$$

$$W_{\overline{M}} = 1 - \Delta_{\overline{M}-\frac{1}{2}} \psi_i \quad (22)$$

$$XX_{\overline{M}} = 2 \Delta_{\overline{M}-\frac{1}{2}} x_i \quad (23)$$

$$C_{\overline{M},i} = \frac{XX + W^*FF_{\overline{M}-1}}{V - W^*E_{\overline{M}-1}} \quad (24)$$

When the Freundlich boundary condition is applied

$$(P_+)_i = P_{M-\frac{1}{2},i} \quad (25)$$

$$(J_+)_i = W_{bi} C_i^+ - \left(\frac{D_{He}}{\ell} C_0 \right)_i \quad (26)$$

$$(C_+)_i = P_i^+ / 10^{-6} R^* T_{M-\frac{1}{2},i} \quad (27)$$

It should be pointed out that there are many boundary conditions which could be applied using equations (21) through (24). The type of boundary condition depends on the values assigned to ψ and χ .

$$\frac{\partial C}{\partial X} + \psi C = \chi \quad (28)$$

In the special case where the Freundlich boundary condition is applied, ψ and χ are rather complicated functions. In many other cases of interest, they are quite simple. For example, to apply the condition $\frac{\partial C}{\partial X} = 0$, we merely set ψ and χ to zero. For the condition $C = 0.0$, we set χ to zero, and ψ to some large number like 10^{20} . Several such conditions are built into the code as options. Other conditions desired could be coded in as either temporary or permanent changes.

Functions

The functions $F_{m+\frac{1}{2},i}$; $G_{m+\frac{1}{2},i}$; $\Phi_{m,i}$; $D_{m+\frac{1}{2},i}$; ψ_i ; χ_i and $S_{m,i}$ may take several forms and are coded as subroutines to allow for easier change. The most commonly used forms of these functions are:

$$D_{m+\frac{1}{2},i} = e^{(\ln D_0 - \frac{E_i}{RT_{m+\frac{1}{2}}})} (1 - FX) + e^{(\ln D_b - \frac{EB_i}{RT_{m+\frac{1}{2}}})} FX \quad (29)$$

where:

$$FX = \frac{1}{e^{\left(\frac{x-a}{b}\right)} + 1}$$

$$F_{m+\frac{1}{2},i} = -D_{m+\frac{1}{2},i} \quad (30)$$

$$G_{m+\frac{1}{2},i} = \frac{-D_{m+\frac{1}{2},i} C_{m+\frac{1}{2},i} Q_i^*}{U_{m+\frac{1}{2},i} RT_{m+\frac{1}{2}}^2} \quad (31)$$

$$x_i = -\left(\frac{D_{He}}{\ell}\right)_i \frac{C_i}{F_{M-\frac{1}{2},i}} \quad (32)$$

$$\psi_1 = \frac{1}{F_{M-\frac{1}{2},i}} \left[\frac{G_{M-\frac{1}{2},i}}{C_{M-\frac{1}{2},i}} \left(\frac{\partial T}{\partial X} \right)_{M-\frac{1}{2}} - \frac{(w_b)_i e^v p_o^u \left(\sum_{i'=1}^I \frac{C_{M-\frac{1}{2},i'}}{CM_{i'}} \right)^{u_i-1}}{10^{-6} R^* T_{M-\frac{1}{2}} CM_i} \right] \quad (33)$$

where:

$$v_i = A_i + B_i \frac{10^3}{T} \quad (34)$$

$$A_i = a_i + c_i \ln CM_i \quad (35)$$

$$B_i = b_i + d_i \ln CM_i \quad (36)$$

$$u_i = c_i + d_i \frac{10^3}{T} \quad (37)$$

$$(W_b)_i = \left(\frac{D_{He}}{\ell} \right)_i \left[1 - 2K_i \frac{T_b - T_0}{T_b + T_0} - \xi_i \right] \quad (38)$$

$$S_{m,i} = \left[\frac{(S_1 - S_0)X_m}{a} + S_0 \right] FX \quad \text{if } X_m \leq a \quad (39)$$

where:

$$FX = \frac{1}{e^{\left(\frac{X-a}{b} \right)} + 1} \quad (40)$$

$$S_{m,i} = S_1 * FX \quad \text{if } X_m > a \quad (41)$$

where: S_0 = source at $X = 0.0 = N_0 * R_0$

S_1 = source at $X = a$ = fuel graphite interface = $N_0 * R_1$.

For most points,

$$\phi_{m,i} = 1.0 \quad (42)$$

At the graphite fuel interface, $\phi_{m,i}$ is sometimes specified and requires a change in the program.

Integrals for Print

Several conservation integrals are calculated for print purposes only. These are:

$$\int_{m-\frac{1}{2}}^{m+\frac{1}{2}} C(X,t) dX = A1 + A2 \quad (\text{see Fig. 3}) \quad (43)$$

where

$$A1 = \left(\frac{C_{m-\frac{1}{2}} + \phi_m C_m}{2} \right) \Delta_{m-\frac{1}{2}} = \frac{\left[\left(\frac{C_{m-1} + \phi_m C_m}{2} \right) + \phi_m C_m \right] \Delta_{m-\frac{1}{2}}}{2} \quad (44)$$

$$A2 = \left(\frac{C_m + C_{m+\frac{1}{2}}}{2} \right) \Delta_{m+\frac{1}{2}} = \frac{\left[\left(\frac{C_m + \phi_{m+1} C_{m+1}}{2} \right) + C_m \right] \Delta_{m+\frac{1}{2}}}{2} \quad (45)$$

$$\int_{m-\frac{1}{2}}^{m+\frac{1}{2}} C(X,t) dX = \gamma_{m-\frac{1}{2}} C_{m-1} + 3\gamma_{m-\frac{1}{2}} \phi_m C_m + 3\gamma_{m+\frac{1}{2}} C_m + \gamma_{m+\frac{1}{2}} \phi_{m+1} C_{m+1} \quad (46)$$

$$CINTG = \int_0^L C(X,t) dX = \sum_{m=2}^{\bar{M}-1} \left\{ \gamma_{m-\frac{1}{2}} (C_{m-1} + 3\phi_m C_m) + \gamma_{m+\frac{1}{2}} (3C_m + \phi_{m+1} C_{m+1}) \right\} \quad (47)$$

likewise,

$$SINTG_i = \int_0^L S(X,t) dX = \sum_{m=2}^{\bar{M}-1} \left\{ \gamma_{m-\frac{1}{2}} S_{m-1} + 3(\gamma_{m-\frac{1}{2}} + \gamma_{m+\frac{1}{2}}) S_m + \gamma_{m+\frac{1}{2}} S_{m+1} \right\} \quad (48)$$

$$DCINTG_i = CINTG_i^{n+1} - CINTG_i^n \quad (49)$$

$$CLINTG_i = \lambda CINTG_i \quad (50)$$

$$\begin{aligned} CSUM_i &= \int_0^L \frac{\partial C}{\partial t} dX \\ &= (1-\omega) \Delta t \left[SINTG_i - CLINTG_i + J(0) - J(L) \right]^n \\ &\quad + \omega \Delta t \left[SINTG_i - CLINTG_i + J(0) - J(L) \right]^{n+1} \end{aligned} \quad (51)$$

○ = MIDPOINT
 △ = MESH POINT

FIGURE 3. Conservation integrals are calculated as summations of the areas of trapezoids.

$$\text{SINTT}_{ji} = \int_0^t S(X_m, t) dt = \sum_{n+1=1}^N \left\{ (1-\omega) \Delta t^{n+1} S_{m,i}^n + \omega \Delta t^{n+1} S_{m,i}^{n+1} \right\} \quad (52)$$

$$\text{CINTT}_{ji} = \lambda \int_0^t C(X_m, t) dt = \sum_{n+1=1}^N \left\{ (1-\omega) \Delta t^{n+1} C_{m,i}^n + \omega \Delta t^{n+1} C_{m,i}^{n+1} \right\} \lambda_i \quad (53)$$

$$\text{XJINTT}_{ji} = \int_0^t \left\{ J(X_{m+\frac{1}{2}}, t) - J(X_{m-\frac{1}{2}}, i) \right\} dt = \sum_{n+1=1}^N \left\{ (1-\omega) \Delta t^{n+1} \Delta J_{m,i}^n + \omega \Delta t^{n+1} \Delta J_{m,i}^{n+1} \right\} \quad (54)$$

$$\text{CSUMT}_{ji} = (\Delta_{m-\frac{1}{2}} + \Delta_{m+\frac{1}{2}}) (C_{m,i}^{n+1} - \text{SINTT}_{ji} + \text{CINTT}_{ji}) \quad (55)$$

$$\text{REL}_i^{n+1} = e^{-\lambda \Delta t} \text{REL}_i^n + \frac{1}{2} \Delta t (J_+^n e^{-\lambda \Delta t} + J_+^{n+1}) \quad (56)$$

$$\text{TOR}_i = \text{TIAREA} * \text{REL}_i \quad (57)$$

Time Cycle

A complete run consists of following the time dependent behavior of the problem through a series of finite time cycles, each of length Δt^n .

A time cycle consists of the following series of steps.

- 1) Sources, temperatures, and other time-dependent parameters are determined.
- 2) Quantities dependent on the concentrations at the previous time steps are calculated.
- 3) Concentrations at the new time are calculated.
- 4) Conservation integrals are updated.

This process is repeated up to a previously specified final time unless the problem is terminated because of convergence failures.

VIII. INPUT CARDS.

Card #1 (12A6) = 72 column title card

Card #2 - 6 place integers (12 per card)

- 1) MMAX = number of mesh points including 2 extra boundary cells.
- 2) IMAX = number of isotopes.
- 3) JMAX = number of points for print integrals.
- 4) NMAX = number of different time steps to be loaded.
- 5) NPMAX = number of different print intervals.
- 6) NIM = max number inner iterations (use 100).
- 7) NOM = max number outer iterations (use 100).
- 8) KFC = flag for calculating or loading initial concentrations.
 - a) 0 = calculate
 - b) 1 = input
- 9) NTMP = number of temperatures loaded across mesh.
- 10) LBOP = left boundary option (use 1).
 - a) 1 = symmetry
 - b) 2 = (may be added later)
- 11) ISX = number of times for loading sources and temperatures.
- 12) MINT = m index for interface between fuel and graphite.

Card #3 6E12.4

- 1) ω = relaxation parameter.
- 2) ΔX = mesh interval (if 0.0, input table of X_m)(cm).
- 3) EPSI = ϵ_{inner} = convergence criterion for inner iterations.
- 4) EPSO = ϵ_{outer} = convergence criterion for outer iterations.
- 5) AFERM = a in the Fermi function
$$FX = \frac{1}{e^{\left(\frac{x-a}{b}\right)} + 1}$$

= X coordinate of graphite fuel interface.

6) BFERM = b in the Fermi function FX.

CARD #4 6E12.4 (time is in seconds)

- 1) DELT(1) = first time step to use.
- 2) TMAX(1) = maximum time for using DELT(1).
- 3) DELT(2) = second time step to use.
- 4) TMAX(2) = maximum time for using DELT(2).
- ⋮
- DELT(NMAX) = last time step to use.
- TMAX(NMAX) = maximum time for using DELT(NMAX).

Card #5 6E12.4 (time is in seconds)

- 1) DELTP(1) = print interval.
- 2) TPMAX(1) = max time for using DELTP(1).
- 3) DELTP(2) = second print interval.
- 4) TPMAX(2) = max time for using DELTP(2).
- ⋮
- DELTP(NPMAX) = last print interval.
- TPMAX(NPMAX) = max time for using DELTP(NPMAX).

Card #6 (6E12.4)

TMAXS(IS) $1 \leq IS \leq ISX$

= max times associated with temperatures and sources.

The following two cards are loaded for each isotope. Both cards are read for isotope 1, and then for each succeeding isotope.

Card #7 (6E12.4)

$R_0(I, IS) = \text{source at } X = 0.0 \quad 1 \leq IS \leq ISX$

for isotope i as a function of time.

Card #8 (6E12.4)

$R_1(I, IS) = \text{source at fuel graphite} \quad 1 \leq IS \leq ISX$

interface for isotope i as a function of time.

Card #9 (12I6)

$MTMP(N) = \text{mesh indices for temperature to be loaded.} \quad 1 \leq N \leq NTMP$

Note: $MTMP(1)$ should be 1.

$MTMP(2)$ should be about 6 (temperature distribution is parabolic between $MTMP(1)$ and $MTMP(2)$).

$MTMP(NTMP)$ should be at $m = MMAX$.

The following card is loaded for each $TMAX(IS)$. $1 \leq IS \leq ISX$.

Card #10 (6E12.4)

$TEMP(N, IS) \quad 1 \leq N \leq NTMP$

= temperatures associated with $MTMP(N)$ as a function of time ($^{\circ}K$)

Note: $TEMP(2, IS)$ is recalculated, so it does not matter what is loaded.

Card #11 (6E12.4)

$MPTS(J) \quad 1 \leq J \leq JMAX$

= mesh indices for points where output integrals are calculated.

Repeat the sequence of cards #12, 13, 14, 15 and 16 for each isotope.

Card #12 (6E12.4)

1) $XLAM(I) = \lambda_1 = \text{decay constant.}$

2) $D20(I) = \text{PRE-EXP of diffusion coefficient in coating.}$

(for print purposes only)

3) $E2(I) = \text{activation energy in coating. (for print purposes only)}$

4) $D1(I) = \text{diffusion coefficient in kernel. (for print purposes only)}$

Card #12 (Cont'd.)

- 5) $RA(I)$ = radius of kernel. (for print purposes only)
- 6) $RB(I)$ = radius of coating. (for print purposes only)

Card #13 (6E12.4)

- 1) $ZNZ(I) = N_1$ = number of fuel particles/cm³ = coefficient for multiplying R_0 and R_1 to get S_0 and S_1 .
- 2) $PP(I)$ = local power density.
- 3) $Y(I)$ = fission yield.
- 4) $LNDZ(I) = (\ln D_0)_i = \log_e$ of pre-exponential of diffusion coefficient in graphite.
- 5) $EI(I)$ = activation energy for diffusion in graphite.
- 6) $Q(I) = Q^*$ = coefficient of heat transport in graphite.

Card #14 (6E12.4)

- 1) $PZ(I) = P_i$ = normalization pressure.
- 2) $SA(I) = a_i$ = chemical potential constant.
- 3) $SB(I) = b_i$ = chemical potential constant.
- 4) $SC(I) = c_i$ = chemical potential constant.
- 5) $SD(I) = d_i$ = chemical potential constant.
- 6) $XK(I) = K_i$ = coefficient of heat transport in gas.

Card #15 (6E12.4)

- 1) $TZ(I) = T_i$ = temperature in coolant stream.
- 2) $ZETA(I) = \xi_i$ = ratio of concentration in turbulent gas to graphite-gas boundary.
- 3) $SI(I)$ = diameter of isotope atom.
- 4) $ZMI(I) = M_i$ = mass of isotope atom.

Card #15 (Cont'd.)

- 5) CZ(I) = concentration in coolant stream.
- 6) CM(I) = monolayer concentration.

Card #16 (6E12.4)

- 1) $DZB(I) = (\ln D_b)_i = \log_e$ of pre-exponential of diffusion coefficient in fuel coating.
- 2) EB(I) = activation energy for diffusion in fuel coating.

Card #17 (6E12.4)

- 1) $XNHE = N_{He}$ = number of helium atoms/cm³.
- 2) SHE = diameter of helium atom.
- 3) $XKB = K_b$ = Boltzmann constant.
- 4) $XMHE = M_{He}$ = mass of helium atom.
- 5) XLGR = length of graphite.
- 6) XLBO = length of boundary layer.

Card #18 (6E12.4)

- 1) XNFR = number of fuel regions
- 2) XNCH = number of coolant holes/region.
- 3) XNSY = number of segments/coolant hole.
- 4) HCO = height of core.
- 5) WSY = width of segment.
- 6) XLFU = length of fuel region.

Card #19 (6E12.4) (not needed if DELX $\neq$ 0.0)

X_m = mesh coordinates. $1 \leq m \leq MMAX.$

Card #20 (6E12.4) (not needed if KFC = 0)

$C_{m,i}$ = concentrations for each mesh point from $1 \leq m \leq \text{MMAX}$.

Repeat for each isotope i .

Card #21 (12I6)

- 1) IFF = time position for calculating F. 1 = initial time only
- 2) IG = time position for calculating G. 2 = previous time step
- 3) IFEE = time position for calculating Φ . 3 = previous outer iteration
- 4) IPSI = time position for calculating ψ_i . 4 = present outer iteration
- 5) ICHI = time position for calculating χ_i . 5 = present outer for j and present inner for i
- 6) IDD = time position for calculating D.
- 7) JFF = equation for calculating F.

$$1 = F_{m+\frac{1}{2},i} = -D_{m+\frac{1}{2},i}$$

$$2 = ? \text{ (may be added later)}$$

- 8) JG = equation for calculating G.

$$1 = G_{m+\frac{1}{2},i} = 0.0$$

$$2 = G_{m+\frac{1}{2},i} = \frac{-D_{m+\frac{1}{2},i} C_{m+\frac{1}{2},i} Q_i^*}{u_{m+\frac{1}{2},i} 1.986 T_{m+\frac{1}{2}}^2}$$

- 9) JFEE = equation for calculating Φ .

$$1 = \Phi_{m,i} = 1.0$$

$$2 = ? \text{ (may be added later)}$$

- 10) JPSI = equation for calculating ψ_i .

$$1 = \psi_i = \frac{1}{F_i} \frac{G_i}{C_i} \frac{\partial T}{\partial X} - \frac{W_b P_o^u e^v \left(\sum \frac{C_{i'}}{CM_{i'}} \right)^{u-1}}{10^{-6} R^* T CM_i}$$

$$2 = \psi_i = 10^{20}$$

$$3 = \psi_i = 0.0$$

Card #21 (Cont'd.)

11) JCHI = equation for calculating χ_i .

$$1 = \chi_i = -DC^0 / F_{m+\frac{1}{2},i} \ell$$

$$2 = \chi_i = 0.0$$

12) JDD = flag for calculating D.

$$1 = D_{m+\frac{1}{2},i} = e^{(\ln D_0 - EI)/RT}$$

$$2 = D_{m+\frac{1}{2},i} = e^{(\ln D_0 - EI)/RT} (1 - FX) + e^{(\ln D_b - EB)/RT} FX$$

where

$$FX = \frac{1}{e^{\left(\frac{x-a}{b}\right)} + 1}$$

NOTE: Several problems may be stacked and run together.

Whether several problems are run, or only one, the last card of the entire run must be a blank. This is the signal to the program to write an end of file on the plot tape and terminate the run.

Problem Output

The output from the program consists of printed listings of the quantities of interest at specified times, and SC-4020 graphs of the concentration as a function of X (see Fig. 4). At the end of the run, a graph is made of the integrated release into the coolant stream for each isotope as a function of time (see Fig. 5).

Word		
Column		
Format		
Card		
Symbol		

Word	1	2	3	4	5	6	7	8	9	10	11	12	12I6 Cards
Column	1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	61-66	67-72	
Format	I6	I6	I6	I6	I6	I6	I6	I6	I6	I6	I6	I6	
Card													
Symbol													

Word	1	2	3	4	5	6	6E12.4 Cards
Column	1-12	13-24	25-36	37-48	49-60	61-72	
Format	E12.4	E12.4	E12.4	E12.4	E12.4	E12.4	
Card							
Symbol							

Word		
Column		
Format		
Card		
Symbol		

CONCENTRATION MICROMOLES/CM

DISTANCE CM

FIGURE 4. Plot of concentration as a function of X at a given time.

TOTAL RELEASE MICRO-MOLES

TIME DAYS

FIGURE 5. Plot of total release as a function of time.

IX. FORTRAN VARIABLES.

a) Subscripted Variables

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
C(M,I)	$C_{m,i}^{n+1}$	Concentration of isotope i at mesh point m at new time.
CN(M,I)	$C_{m,i}^n$	Concentration at previous time.
XTERM(M,I)		Collection of terms used in calculation of XX.
G(M,I)	$G_{m+\frac{1}{2},i}$	Used to calculate current J.
F(M,I)	$F_{m+\frac{1}{2},i}$	Used to calculate current J.
FEE(M,I)	$\phi_{m,i}$	Ratio of concentration at left of point to concentration at right of point.
S(M,I)	$S_{m,i}^{n+1}$	Source term.
STERM(M,I)		Term involving sources used for calculation of XX.
E(M)	E_m	Coefficient used for inverting matrix.
FF(M)	FF_m	Coefficient used for inverting matrix.
DX(M)	$\Delta_{m+\frac{1}{2}}$	Distance between X_m and $X_{m+\frac{1}{2}}$.
GA(M)	$\gamma_{m+\frac{1}{2}}$	$\Delta_{m+\frac{1}{2}}/4$.
DTDX(M)	$\left(\frac{\partial T}{\partial X}\right)_{m+\frac{1}{2}}$	Derivative of temperature with respect to X.

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
T(M)	T_m	Temperature.
X(M)	X_m	Cartesian coordinate of mesh point.
XLAM(I)	λ_i	Decay constant for isotope i.
PP(I)		Local power density.
Y(I)		Fission yield.
SINTG(I) SSUM(I) CINTG(I) SELTD(I) CLINTG(I) DCINTG(I) CSUM(I) CSUMD(I)		{ Conservation integrals calculated for printout.
PSI(I)	ψ_i	Used in right boundary condition.
XKI(I)	x_i	Used in right boundary condition.
LNDZ(I)	$(\ln D_0)_i$	Log _e of pre-exponential of diffusion coefficient in graphite.
EI(I)	E_i	Activation energy for diffusion in graphite.
PZ(I)	P_i^0	Normalization pressure.
SA(I)	a_i	Chemical potential constant.
SB(I)	b_i	Chemical potential constant.
SC(I)	c_i	Chemical potential constant.
SD(I)	d_i	Chemical potential constant.

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
XK(I)	K_i	Coefficient of heat transport in coolant gas.
XLL(I)	ℓ_i	Thickness of boundary layer.
PSICØ(I)		Term used in calculation of ψ_i .
XJPL(I)	J_i^+	Current in boundary layer of coolant.
CPL(I)	C_i^+	Concentration in boundary layer of coolant.
PPL(I)	P_i^+	Pressure in boundary layer of coolant.
CPCØ(I)		Term used in calculation of C_i^+ .
WBB(I)	$(W_b)_i$	Term used in calculation of ψ_i .
REL(I)		Integrated release/cm ³ .
XJPØ(I)		Part of conservation integral.
CZ(I)		Concentration in turbulent gas.
DZB(I)	$(\ln D_b)_i$	Log _e of pre-exponential of diffusion coefficient in fuel.
EB(I)	$(E_b)_i$	Activation energy for diffusion in fuel.
D2O(I)		Pre-exponential of diffusion coefficient in coating.
E2(I)		Activation energy in coating.
RA(I)		Radius of kernel.
RB(I)		Radius of coating.

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
TZ(I)	T^o	Temperature in turbulent gas.
ZETA(I)	ξ_i	Ratio of concentration in turbulent gas to concentration at boundary.
Dl(I)		Diffusion coefficient in kernel.
ZNZ(I)	N_i^o	Number of fuel particles/cm ³ .
SI(I)	σ_i	Diameter of isotope atom.
CM(I)	CM_i	Monolayer concentration.
Rl(I,IS)	$Rl_{i,is}$	Release rate from a fuel particle at graphite-fuel interface.
RZ(I,IS)	$RO_{i,is}$	Release rate from a fuel particle at origin.
TMAXS(IS)		Maximum times associated with time dependent input.
ZMI(I)	M_i	Isotope mass.
Q(I)	Q_i^*	Coefficient of heat transport in graphite.
SINTT(J,I) SOLD(J,I) CINTT(J,I) COLD(J,I) XJINTT(J,I) DJOLD(J,I) CSUMT(J,I)		<div style="display: flex; align-items: center;"> <div style="font-size: 3em; margin-right: 10px;">{</div> <div> Time dependent conservation integrals at $X = X_m$ where $m = MPTS_j$. </div> </div>
MPTS(J)		Index values of m for calculating conservation integrals.
DELT(N)		Time steps to be used.
TMAX(N)		Maximum time for using DELT(N).

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
DELTP(NP)		Print intervals to be used.
TPMAX(NP)		Maximum time for using print interval DELTP(NP).
MTMP(N)		Index values m for points to load temperatures.
TEMP(NT,IS)		Temperatures loaded as a function of X and time.
D(M,I)	$D_{m,i}$	Diffusion coefficient.
DD(I)	D_{He}	Diffusion coefficient in helium.
RES(NP,I)		Total integrated release as a function of time = REL(I) multiplied by the total graphite-coolant interface area.
TT(NP)		Times associated with RES(NP,I).

b) Nonsubscripted Real Variables or Parameters

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
ADAMP	a	Parameter for Fermi function.
BDAMP	b	Parameter for Fermi function.
CMAG		Used to calculate initial concentration profile.
BLANKS		One word of alphanumeric blanks.
CØN		Relative convergence.
CØNMAX		Maximum convergence number in system.

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
CRIT		Critical level of summation for change-over from Freundlich to Langmuir behavior.
CSLØPE		Slope of line for calculating initial concentration profile.
DELTAX	ΔX	Input value for interval between mesh points.
DT	Δt^{n+1}	Time step used for cycle (n+1).
DTIMP		Δt expressed in days for printout.
DTP	Δt_p	Print interval being used.
EMLT	$e^{-\lambda \Delta t}$	Decay term.
EPSI	ϵ_{inner}	Convergence criterion for inner iteration loop.
EPSØ	ϵ_{outer}	Convergence criterion for outer iteration loop.
FX	FX_m	Fermi function
HCØ		Height of core.
HLAB		Horizontal label for plots.
VLAB		Vertical label for plots.
ØDT		$\omega \Delta t$.
ØMODT		$(1 - \omega) \Delta t$.
ØM	ω	Relaxation parameter.
P	$P_{m+\frac{1}{2},i}$	Pressure calculated for printout.

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
PHEE		$e^v p_0^u$.
RST	R^*	Gas constant = 82.0.
SF	f	Term used in calculation of concentration.
SG	g	Term used to calculate concentration.
SH	h	Term used to calculate concentration.
SHE	σ_{He}	Diameter of helium atom.
SU	u	Freundlich adsorption parameter.
SV	v	Freundlich adsorption parameter.
SUM	$\sum_{i=1}^I \frac{C_{m,i'}}{CM_1'}$	
SZ	S_0	Source at origin.
Sl	S_1	Source at graphite fuel interface.
TIAREA		Total interface area of coolant holes.
TIME	t^{n+1}	Time in seconds.
TIMP		Time in days for printout.
TPRNT		Next time to print.
U	U_m	Coefficients for calculating concentrations.
V	V_m	
W	W_m	
XX	XX_m	

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
WSY		Width of segment.
XNFR		Number of fuel regions.
XNSY		Number of segments/coolant hole.
XLFU		Length of fuel region.
XLBO		Length of boundary layer.
XNHE	N_{He}	Number of helium atoms/cm ³ .
XKB	K_b	Boltzmann constant.
XLGR		Length of graphite.
XMHE	M_{He}	Mass of helium.
XNCH		Number of coolant holes/region.

c) Nonsubscripted Integer Variables or Parameters

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
ICON		Isotope which has the hardest time converging.
MCON		Mesh point where convergence is hardest.
ICHI		Flag indicating when to calculate χ .
IDD		Flag indicating when to calculate D.
IFEE		Flag indicating when to calculate ϕ .
IFF		Flag indicating when to calculate F.
IG		Flag indicating when to calculate G.

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
IPSI		Flag indicating when to calculate ψ .
JCHI		Flag indicating which equation to use for calculating χ .
JDD		Flag indicating which equation to use for calculating D.
JFEE		Flag indicating which equation to use for calculating ϕ .
JFF		Flag indicating which equation to use for calculating F.
JG		Flag indicating which equation to use for calculating G.
JPSI		Flag indicating which equation to use for calculating ψ .
IMAX	$\bar{I}$	Number of isotopes.
IS		Index indicating which set of temperatures and sources are being used.
ISX		Number of times for loading temperatures and sources.
KFC		Flag indicating whether to load or calculate initial concentration profile.
KRET		Index for returning from region 600.
LBØP		Left boundary option.
MINT		Mesh index for position of graphite-fuel interface.
MMAX	$\bar{M}$	Total number of mesh points.

<u>Variable Name</u>	<u>Symbol</u>	<u>Description</u>
MMAXM	$\bar{M} - 1$	Number of mesh points minus one.
NDT		Index associated with time step being used.
NP		Index associated with print interval being used.
NIM		Max number of inner iterations allowed.
NT		Index for storing release as a function of time.
NMAX		Number of time steps loaded.
NØM		Maximum number of outer iterations allowed.
NØ		Number of outer iterations performed.
NI		Number of inner iterations performed.
NPMAX		Number of print intervals loaded.
NTMP		Number of temperatures loaded across mesh.

X. FLOW DIAGRAMS AND CODE LISTINGS

The following pages contain flow diagrams and code listings for the FIPER code, and for the subroutines called by it. Most of the flow diagramming conventions are standard with the following exceptions:

The rhombus is used to indicate a call to a subroutine.

The symbol is used as the decision box.

FIPER MASTER FLOW SHEET

BPRT(i)

FUNS (11, IOP)

FUNIN

PSIFUN (11)

FFUN(II)

GFUN (11)

CHIFUN (11)

FEFUN (11)

DFUN (11)

WELCH FIPER 050 \$ JOB 454 \$

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#1 FOR FIPER,FIPER
UNIVAC 1108 FORTRAN IV LEVEL 2201 0029 F40148
THIS COMPILATION WAS DONE ON 20 FEB 68 AT 16:23:03

MAIN PROGRAM ENTRY POINT 000000

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	004135
0000	*DATA	001106
0002	*BLANK	000000
0003	FIPCOM	023204
0004	COM1	000160
0005	COM2	007062
0006	BPCOM	000001

EXTERNAL REFERENCES (BLOCK, NAME)

0007	SETUP
0010	FUNIN
0011	SGMT
0012	ALUG
0013	ICRANG
0014	EXP
0015	WAKN
0016	RELPLT
0017	FINISH
0020	FUNS
0021	BPRT
0022	BCUCON
0023	PLUTV
0024	NRUC\$
0025	N101\$
0026	N102\$
0027	NPKT\$
0030	NEXP6\$
0031	NSTOP\$
0032	NWDUS

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	000174 10F	0001	000005 100L	0000	000300 1000F	0000	000304 1001F	0001	001406 1013G
0001	000416 102L	0001	000431 104L	0001	001464 1047G	0001	001500 1052G	0001	000474 107L
0000	000267 1087F	0001	000536 109L	0000	000177 11F	0000	000307 1100F	0000	000330 1101F
0000	000333 1102F	0000	000363 1103F	0000	000422 1104F	0000	000446 1105F	0000	000463 1106F
0000	000565 1107F	0000	000607 1108F	0000	000410 1109F	0000	000417 1110F	0000	000175 1111F
0001	002007 1160G	0001	002034 1165G	0001	002102 1176G	0000	000200 12F	0001	002255 1235G
0001	002336 1247G	0001	002466 1275G	0000	000202 13F	0001	002563 1330G	0001	002566 1333G
0001	000011 134G	0000	000227 14F	0001	002723 1406G	0001	002771 1414G	0001	003101 1435G

WELCH		FIPEK	050	\$ JOB 454 \$	20 FEB 68	PAGE	4	
0001	000025	1456	0001	003220	14536	0001	003352	1502G
0001	003372	15166	0001	003504	15346	0001	003677	1624G
0001	003762	16566	0001	003763	16616	0000	000257	17F
0000	000275	19F	0000	000612	20F	0001	001567	200L
0001	001652	203L	0001	001612	204L	0001	000143	205G
0001	001757	207L	0001	001760	210L	0001	001771	211L
0001	000167	223G	0001	000176	230G	0001	000201	234G
0001	000231	256G	0001	000234	262G	0001	000246	271G
0001	000411	361G	0001	000425	370G	0001	000446	375G
0001	002510	402L	0001	002611	404L	0001	000462	405G
0000	000640	41F	0001	002655	410L	0001	000465	411G
0001	002072	413L	0000	000656	42F	0001	000515	420G
0001	000533	431G	0001	000624	453G	0001	000626	456G
0001	000705	520G	0001	000716	526G	0001	001053	567G
0001	003323	600L	0001	003651	601L	0001	001073	605G
0000	000741	62F	0001	001112	622G	0000	000744	63F
0001	001135	642G	0000	000762	65F	0001	001150	652G
0000	001000	67F	0001	001235	706G	0001	001264	725G
0001	001353	772G	0005	R 004714	ADAMP	0012	R 000000	ALOG
0003	R 000000	C	0000	R 000152	CBO	0000	R 000155	CLP
0005	R 001046	CINTT	0003	R 002624	CLINTG	0005	R 000024	CM
0000	R 000171	CMIN	0000	R 000165	CMN	0003	R 002114	CM
0000	R 000145	CON	0000	R 000130	CONMAX	0003	023122	CPCO
0000	R 000035	CRITO	0000	R 000033	CSLUPE	0003	R 002650	CSUM
0000	R 000120	CTERM	0003	R 023172	CZ	0005	R 002532	U
0000	R 000160	DELU	0005	R 001445	DELT	0000	R 000050	DELTAX
0005	R 001274	JJULD	0003	R 004704	DT	0003	R 002030	JTDX
0003	R 021474	JX	0004	R 000002	JZB	0004	R 000052	U1
0004	R 000014	ED	0003	R 022732	E1	0000	R 000157	EMLT
0014	R 000000	LXP	0004	R 000040	E2	0003	R 010460	F
0000	R 000120	FX	0003	R 006344	G	0003	R 021652	GA
0000	R 000007	HCG	0000	R 000001	HLAB	0000	I 000037	I
0005	004705	ADD	0005	004701	IFEE	0005	004677	IFF
0000	I 000166	ILI	0005	I 004674	JMAX	0005	004703	JPSI
0000	I 000031	IS	0000	I 000055	J	0005	004712	JCHI
0005	004700	JFF	0005	004707	JG	0000	I 000040	JMAX
0000	I 000115	KRET	0005	I 004742	LBOP	0003	R 022720	LNDZ
0004	I 000000	MINT	0005	I 004675	MMAX	0005	I 004676	MMAXM
0005	I 001440	MPTS	0005	I 001515	MTMP	0000	I 000053	N
0000	I 000133	NI	0000	I 000043	NIM	0000	I 000161	NLP
0000	I 000132	NO	0000	I 000044	NUM	0000	I 000074	NP
0005	I 007061	NTMP	0000	R 000075	OUT	0000	R 000047	UM
0000	R 000113	PHEE	0003	R 022554	PP	0003	R 023110	PPL
0003	R 022744	PZ	0005	R 000012	Q	0004	R 000064	RA
0005	004743	RES	0000	R 000105	RDOT	0000	R 000000	RST
0003	R 014710	S	0003	R 022756	SA	0000	R 000106	SAP
0003	R 023002	SC	0003	R 023014	SU	0005	R 004716	SELTO
0000	R 000125	SH	0000	R 000057	SHE	0004	R 000146	SI
0005	R 000764	SOLD	0011	R 000000	SWRT	0005	R 004730	SSUM
0000	R 000112	SU	0000	R 000153	SUM	0000	R 000111	SV
0003	R 022206	T	0000	R 000151	TB	0000	R 000110	TEE
0005	R 007060	TIME	0000	R 000101	TIMP	0005	R 001457	TMAX
0000	R 000100	TPKNT	0005	R 006713	TT	0004	R 000122	TZ
0000	R 000140	V	0000	R 000015	VLAB	0000	R 000135	VPL
0000	000247	15F	0000	000253	16F	0001	004045	1700G
0001	001576	201L	0001	001662	205L	0001	001765	212L
0001	000210	242G	0001	000254	276G	0000	000620	40F
0001	002263	405L	0001	002635	411L	0001	000517	423G
0001	000645	476G	0001	001063	576G	0000	000721	61F
0001	001126	633G	0000	001003	66F	0001	001324	750G
0005	R 004715	BDAMP	0003	R 022612	CINTG	0000	R 000032	CMAG
0000	R 000144	CNEW	0003	023076	CPL	0003	R 022662	CSUMOD
0003	R 022636	DCINTG	0005	R 001471	DELTP	0000	R 000102	DTIMP
0004	R 000026	D20	0000	R 000051	EPSI	0003	R 012574	FEE
0000	R 000122	GT	0005	004702	ICHI	0005	004700	IG
0000	I 000054	IS	0005	004713	JDD	0005	004711	JPSI
0000	I 000072	M	0000	I 000143	MMM	0000	I 000073	NDT
0000	I 000041	NMAX	0000	I 000042	NPMAX	0000	R 000076	OMODT
0003	R 022674	PSI	0004	R 000076	RB	0005	R 000346	RZ
0003	R 022770	SB	0000	R 000123	SF	0003	R 017024	STERM
0000	R 000116	SZ	0005	R 001546	TEMP	0005	R 000656	TMAXS
0000	R 000137	U	0015	R 000000	WARN			

0003 R 023134 WBS	0000 R 000070 WSY	0003 R 022364 X	0000 R 000164 XJ	0000 R 000162 XJL
0005 R 001212 XJINIT	0000 R 000147 XJL	0003 023064 XJPL	0000 R 000156 XJPLS	0003 R 023160 XJPO
0000 R 000150 XJR	0000 R 000163 XJTH	0003 R 023026 XK	0000 R 000060 XKB	0003 R 022706 XKI
0005 I 004646 XLAB	0003 R 022542 XLAM	0000 R 000063 XLBO	0000 R 000103 XLEN	0000 R 000071 XLFU
0000 R 000062 XLGR	0003 R 023040 XLL	0000 R 000104 XLLI	0000 R 000061 XMLE	0000 R 000065 XNCH
0000 R 000064 XNFR	0000 R 000056 XNHE	0000 R 000066 XNSY	0003 R 004230 XTERM	0000 R 000142 XX
0003 R 022566 T	0004 R 000134 ZETA	0005 R 000000 ZMI	0004 R 000110 ZNZ	

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00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. REAL LNRZ,LNRZ
00103 2. PARAMETER IU=10, MD=110, JD=5, ND=10, NPU=10, NTD=25
00104 3. PARAMETER ISU=20
00105 4. COMMON/FIPCOM/ C(MD,IU), CN(MD,IU), XTERM(MD,IU),
00105 5. * G(MD,IU), F(MD,IU), FEE(MD,IU),
00105 6. * S(MD,IU), STERM(MD,IU),
00105 7. * E(MD), FF(MD), DX(MD),
00105 8. * GA(MD), DTUX(MD), T(MD),
00105 9. * X(MD),
00105 10. * XLAM(10), PP(10),
00105 11. * Y(10), SINTG(10),
00105 12. * CINTG(10), CLINTG(10), DCINTG(10),
00105 13. * CSUM(10), CSUMOD(10), PSI(10),
00105 14. * XKI(10), LNDZ(10), EI(10),
00105 15. * PZ(10), SA(10), SB(10),
00105 16. * SL(10), SD(10), XK(10),
00105 17. * XLL(10), PSICO(10),
00105 18. * XJPL(10), CPL(10), PPL(10),
00105 19. * CPLC(10), WBS(10), REL(10),
00105 20. * XJPO(10), CZ(10)
00106 21. COMMON/COM1/
00106 22. * MINT, CRIT,
00106 23. * U2B(10), ED(10),
00106 24. * U20(10), E2(10), U1(10),
00106 25. * RA(10), RD(10), ZNZ(10),
00106 26. * LZ(10), ZETA(10), SI(10),
00107 27. COMMON/COM2/
00107 28. * CM(10), R1(10,ISD), RZ(10,ISD),
00107 29. * TMAXS(1SD),
00107 30. * SINTT(JD,10), SOLD(JD,10), CINTT(JD,10),
00107 31. * COLU(JD,10), XJINTT(JD,10), DJULD(JD,10),
00107 32. * CSUMT(JD,10),
00107 33. * MPTS(JD), DELT(ND), TMAX(ND),
00107 34. * DELTP(NPD), TPMAX(NPD),
00107 35. * MTPM(NTD), TEMP(NTD,ISD),
00107 36. * U(MD,IU), XLAB(12), OD(10),
00107 37. * IMAX, MMAX, MMAXM,
00107 38. * IF, IG, IFEE,
00107 39. * ICH1, IPSI, DT,
00107 40. * IUD, JFF, JG,
00107 41. * JFEE, JPSI, JCH1,
00107 42. * JUD, ADAMP, BDAMP,

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00107 43. * SELTO(ID), SSUM(ID), LBOP,
00107 44. * RES(100,10), TT(100), NT,
00107 45. * TIME, NTMP
00110 46. DATA RST/82.0/
00112 47. COMMON/BPCOM/IIAHEA
00113 48. DIMENSION HLAB(12),VLAB(12)
00114 49. DATA HLAB/12H01STANCE CM,10*1H /
00116 50. DATA VLAB/30HCONCENTRATION MICROMOLES/CM ,7*1H /
00120 51. DATA CMAG,CSLOPE/1,E-10,-1,E-10/
00123 52. DATA DFUELO,CRITO/1,E-8,.033/
00126 53. INTEGER XLAB,BLANKS
00127 54. DATA BLANKS/6H /
00127 55. C*****
00127 56. C***** REGION 100 READS INPUT CARDS AND SETS INITIAL *****
00127 57. C***** CONDITIONS FOR PROBLEM. *****
00127 58. C*****
00127 59. C***** PREPARE PLOT TAPE. *****
00131 60. CALL SETUP(0,0,0,16)
00131 61. C***** READ FIRST CARD. *****
00132 62. 100 READ 10,(XLAB(I),I=1,12)
00140 63. 10 FORMAT(12A6)
00140 64. C***** IF FIRST WORK UP CARD IS BLANK, END PROBLEM. *****
00141 65. IF(XLAB(1).EQ.BLANKS)GO TO 212
00143 66. PRINT 111,(XLAB(I),I=1,12)
00151 67. 1111 FORMAT(1H1,12A6)
00151 68. C***** READ DATA CARDS. *****
00152 69. READ 11,MMAX,IMAX,JMAX,NMAX,NPMAX,NIM,NOM,KFC,NTMP,LBOP
00152 70. *,ISX,MINT
00170 71. 11 FORMAT(12I6)
00171 72. MMAX=MMAX-1
00172 73. READ 12,OM,DELTA,TAX,EPSI,EPSO,AVAMP,BDAMP
00202 74. 12 FORMAT(6E12.6)
00203 75. READ 12,(DELTA(N),TMAX(N),N=1,NMAX)
00212 76. READ 12,(DELTA(N),TPMAX(N),N=1,NPMAX)
00221 77. READ 12,(TMAXS(IS),IS=1,ISX)
00227 78. DO 131 I=1,IMAX
00232 79. READ 12,(RZ(I,IS),IS=1,ISX)
00240 80. 131 READ 12,(R1(I,IS),IS=1,ISX)
00247 81. READ 11,(NTMP(N),N=1,NTMP)
00255 82. DO 140 IS=1,ISX
00260 83. 140 READ 12,(TEMP(N,IS),N=1,NTMP)
00267 84. READ 11,(MPTS(J),J=1,JMAX)
00275 85. DO 101 I=1,IMAX
00300 86. 101 READ 12,XLAM(I),D20(I),E2(I),U1(I),RA(I),RB(I),ZNZ(I),
00300 87. *PP(I),Y(I),LNUZ(I),EI(I),Q(I),PZ(I),
00300 88. *SA(I),SB(I),SC(I),SU(I),XK(I),TZ(I),ZETA(I),SI(I),ZMI(I),CZ(I)
00300 89. *,CM(I),DZB(I),EB(I)
00335 90. READ 12,XNME,SHE,XKB,XME,XLGR,XLBO
00345 91. READ 12,XNFR,XNCH,XNSY,HCU,WST,XLFU
00345 92. C***** IF DX=0.0, READ X ARRAY. *****
00355 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00355 93. IF(DELTA.NE.0.0)GO TO 102
00357 94. READ 12,(X(M),M=1,MMAX)
00365 95. GO TO 104

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00365 96. C***** CALCULATE X ARRAY. *****
00366 97. 102 X(1)=-.5*DELTA
00367 98. DO 103 M=2,MMAX
00372 99. 103 X(M)=X(M-1)+DELTA
00372 100. C***** SET UP DX AND GA ARRAYS. *****
00374 101. 104 DO 105 M=1,MMAX
00377 102. DX(M)=.5*(X(M+1)-X(M))
00400 103. 105 GA(M)=.25*DX(M)
00400 104. C***** IF KFC=1, READ IN CONCENTRATION PROFILE. *****
00402 105. IF(KFC,EG,0) GO TO 107
00404 106. DO 106 I=1,IMAX
00407 107. 106 READ 12,(C(M,I),M=1,MMAX)
00416 108. GO TO 109
00416 109. C***** CALCULATE CONCENTRATION PROFILE. *****
00417 110. 107 DO 108 I=1,IMAX
00422 111. DO 108 M=1,MMAX
00425 112. 108 C(M,I)=CMAG+ABS(X(M))*CSLOPE
00430 113. DO 130 I=1,IMAX
00433 114. 130 C(MMAX,I)=C(MMAX,I)
00433 115. C***** INITIALIZE VARIABLES AND PARAMETERS. *****
00435 116. 109 CONTINUE
00436 117. TIME=0.0
00437 118. CRIT=CRITO
00440 119. NDT=1
00441 120. NT=1
00442 121. NP=1
00443 122. DT=DELTA(NDT)
00444 123. ODT=OM*DT
00445 124. OMOUT=(1.0-OM)*DT
00446 125. DTP=DELTA(NP)
00447 126. TPKNT=0.0
00450 127. TIMP=0.0
00451 128. DTIMP=0.0
00452 129. DO 115 I=1,IMAX
00455 130. DO 114 M=1,MMAX
00460 131. CN(M,I)=C(M,I)
00461 132. S(M,I)=0.0
00462 133. 114 CONTINUE
00464 134. REL(I)=0.0
00465 135. SSUM(I)=0.0
00466 136. SINTG(I)=0.0
00467 137. CLINTG(I)=0.0
00470 138. DCINTG(I)=0.0
00471 139. CSUM(I)=0.0
00472 140. SELTO(I)=0.0
00473 141. CINTG(I)=0.0
00474 142. CSUMOD(I)=0.0
00475 143. DO 116 J=1,JMAX
00500 144. M=MPPTS(J)
00501 145. CSUMT(J,I)=0.0
00502 146. COLD(J,I)=C(M,I)
00503 147. SINTT(J,I)=0.0
00504 148. SOLD(J,I)=0.0
00505 149. CINTT(J,I)=0.0

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00506 150.      XJINTT(J,I)=0.0
00507 151.      DJULD(J,I)=0.0
00510 152.      116 CONTINUE
00512 153.      115 CONTINUE
00514 154.      TIAREA=HCO*XNFR*XNCH*XNSY*WSY
00515 155.      XLLEN=XLFU+XLGR
00516 156.      XLLI=XLB0/XLEN
00517 157.      DO 120 I=1,IMAX
00522 158.      120 XLL(I)=XLLI
00522 159.      C***** READ INPUT PERTAINING TO FUNCTIONS. *****
00524 160.      CALL FUNIN
00525 161.      DO 121 I=1,IMAX
00530 162.      ROOT=SQRT((XK0*TZ(I))/(6.2832*ZMI(I)))*((ZMI(I)+XMHE)/XMHE)
00531 163.      DO(I)=1.5*ROOT/(XNHE*(SME+S1(I))*2)
00532 164.      SA(I)=SA(I)+SC(I)*ALOG(CM(I))
00533 165.      SB(I)=SB(I)+SD(I)*ALOG(CM(I))
00534 166.      121 CONTINUE
00534 167.      C***** SET VARIABLES WITH TIME DEPENDENT INPUT. *****
00536 168.      CALL TCHANG(I)
00536 169.      C***** DO INITIAL PRINT *****
00537 170.      PRINT 13,MMAX,IMAX,JMAX,NMAX,NPMAX,NIM,NOM,KFC,NTMP,LBOP
00538 171.      13 FORMAT(1H0,6H MMAX=,16,6H IMAX=,16,6H JMAX=,16,6H NMAX=,16,
00539 172.      *6H NPMAX=,16,6H NIM=,16,6H NOM=,16,6H KFC=,16,
00539 173.      *6H NTMP=,16,6H LBOP=,16)
00534 174.      PRINT 14,UM,DELTAX,EPSI,EP50,ADAMP,BDAMP
00534 175.      14 FORMAT(7H UM=,1PE12.4,6H DELTX=,E12.4,6H EPSI=,E12.4,6H EP50=,
00534 176.      *E12.4,6H AFERM,E12.4,6H BFERM,E12.4)
00535 177.      PRINT 15,(DELT(N),N=1,NMAX)
00535 178.      15 FORMAT(6HDELTA=,1P9E12.4)
00534 179.      PRINT 16,(TMAX(N),N=1,NMAX)
00534 180.      16 FORMAT(6H TMAX=,1P9E12.4)
00534 181.      PRINT 17,(DELT(N),N=1,NPMAX)
00534 182.      17 FORMAT(6H UTP=,1P9E12.4)
00534 183.      PRINT 18,(TPMAX(N),N=1,NPMAX)
00534 184.      18 FORMAT(6H TPMX=,1P9E12.4)
00534 185.      DO 141 IS=1,ISX
00534 186.      PRINT 1087,IS,TMAXS(IS)
00534 187.      1087 FORMAT(6H0 IS=,16,7H TMAXS=,1PE11.4)
00534 188.      PRINT 19,(MTMP(N),N=1,NTMP)
00534 189.      19 FORMAT(6H MTMP=,9I12)
00534 190.      141 PRINT 1000,(TEMP(N,IS),N=1,NTMP)
00534 191.      1000 FORMAT(6H TEMP=,1P9E12.4)
00534 192.      PRINT 1001,(MPTS(N),N=1,JMAX)
00534 193.      1001 FORMAT(6H MPTS=,9I12)
00534 194.      PRINT 1100
00534 195.      1100 FORMAT(1H0,29H CHEMICAL POTENTIAL CONSTANTS/6H 1,
00534 196.      * 7X,5HPZERO,11X,1HA,11X,1HB,11X,1HC,11X,1HD,10X,2HCM)
00534 197.      DO 117 I=1,IMAX
00534 198.      SAP=SA(I)-SC(I)*ALOG(CM(I))
00534 199.      SBP=SB(I)-SD(I)*ALOG(CM(I))
00534 200.      117 PRINT 1101,I,PZ(I),SAP,SBP,SC(I),SD(I),CM(I)
00534 201.      1101 FORMAT(1H ,15,1P9E12.4)
00534 202.      PRINT 1102
00534 203.      1102 FORMAT(35H0TRANSPORT COEFFICIENTS IN GRAPHITE,10X,

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00704 204. *32HTRANSPORT COEFFICIENTS IN BINDER/6M 1,
00704 205. *6X,6HLOG UZ,11X,1HE,11X,1HQ, 5X,7HLOG UZB,10X,2HEF)
00705 206. DO 118 I=1,1MAX
00710 207. 118 PRINT 1101,1,ENDZ(I),E1(I),Q(I),UZB(I),EB(I)
00721 208. PRINT 1103
00723 209. 1103 FORMAT(28H0SOURCE AND DECAY PARAMETERS/6M 1,
00723 210. *9X,3H020,10X,2HE2,10X,2H01,10X,2HRA,10X,2HRB,11X,1HN,
00723 211. *11X,1HY,11X,1HP,7X,5HLMUA)
00724 212. DO 119 I=1,1MAX
00727 213. 119 PRINT 1101,1,020(I),E2(I),D1(I),RA(I),RB(I),ZNZ(I),Y(I),PP(I),
00727 214. *XLAM(I)
00744 215. PRINT 1109
00746 216. 1109 FORMAT(6HU 1,10X,2HRZ,10X,2HR1,7X,5HTMAX5)
00747 217. DO 132 I=1,1MAX
00752 218. DO 132 IS=1,15X
00755 219. 132 PRINT 1110,1,RZ(I,IS),R1(I,IS),TMAX5(IS)
00765 220. 1110 FORMAT(1H ,15,1P9E12.4)
00766 221. PRINT 1104
00770 222. 1104 FORMAT(38H0TRANSPORT COEFFICIENTS IN COOLANT GAS/6M 1,
00770 223. *11X,1HK,8X,4HT(U),8X,4HEFA,11X,1HD,11X,1HL,10X,2HR*,7X,5HCZERO,
00770 224. *)
00771 225. DO 135 I=1,1MAX
00774 226. 135 PRINT 1101,1,XK(I),IZ(I),ZEFA(I),DU(I),XLL(I),RST,CZ(I)
01007 227. PRINT 1105
01011 228. 1105 FORMAT(6HU 1,7X,5HM(HE),5X,7H0IA(HE),6X,6H0IA(I),8X,4HK(B),
01011 229. *8X,4HM(I),7X,5HM(HE))
01012 230. DO 136 I=1,1MAX
01015 231. 136 PRINT 1101,(1,XNHE,SHE,SI(I),XKB,ZMI(I),XMHE)
01027 232. PRINT 1106,XNFR,XNCH,XNST,HCO,WST,XLFU,XLGR,XLBO,TIAREA
01042 233. 1106 FORMAT(1HU/17H REACTOR GEOMETRY /25H0NUMBER OF FUEL REGIONS = ,1P1
01042 234. 1E13.5 /37H NUMBER OF COOLANT HOLES PER REGION = , E13.5 /38H NUMBE
01042 235. 2R OF SEGMENTS PER COOLANT HOLE = ,E13.5 /17H HEIGHT OF CORE = ,E13
01042 236. 5.5 ,1X,2HCM /19H WIDTH OF SEGMENT = ,E13.5 ,1X,2HCM /17H LENGTH OF
01042 237. 4 FUEL = ,E13.5 ,1X,2HCM /21H LENGTH OF GRAPHITE = ,E13.5 ,1X,2HCM
01042 238. 5/27H LENGTH OF BOUNDARY LAYER = ,E13.5, 1X, 2HCM /23H TOTAL INTERF
01042 239. ACE AREA = ,E13.5 ,1X, 5HCM*CM )
01043 240. PRINT 1107
01045 241. 1107 FORMAT(6M1 I,5X,1HM,11X,1HX,4X,8HU(M+1/2),4X,8HV(M+1/2),
01045 242. *2X,10HE**Y*PZ**U,11X,1HI,4X,8HD(M+1/2),6X,6HPI(M))
01046 243. DO 125 I=1,1MAX
01051 244. DO 125 M=1,MMAX
01054 245. TEE=.5*(T(M)+T(M+1))
01055 246. SV=SA(I)+SB(I)/TEE*1000.0
01056 247. SU=SC(I)+1000.0*SU(I)/TEE
01057 248. PHEE=EXP(SV)*PZ(I)**SU
01060 249. PRINT 1108,1,M,X(M),SU,SV,PHEE,T(M),D(M,1),FEE(M,I)
01073 250. 1108 FORMAT(1H ,216,1P9E12.4)
01074 251. 125 CONTINUE
01077 252. IS=1
01100 253. GO TO 200
01100 254. C*****
01100 255. C*****
01100 256. C***** REGION 200 IS CONTROL REGION, AND HANDLES OUTPUT.*****
01100 257. C***** TIME IS ADVANCED AT END OF 200, AND NEW TIME *****

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01100 258. C***** CYCLE BEGINS. *****
01100 259. C*****
01100 260. C***** IF APPROACHING MAX TIME, GO TO 210. *****
01101 261. 200 IF (WARN(N,N).LT.0.01)GO TO 201
01103 262. GO TO 210
01103 263. C***** IF NOT TIME TO PRINT, GO TO 202 *****
01104 264. 201 IF (TIME.LT.TPRT+.01*DT)GO TO 202
01104 265. C***** PRINT AND THEN SEE IF TIME TO CHANGE PRINT STEPS.*****
01106 266. ASSIGN 204 TO KKEI
01107 267. GO TO 600
01110 268. 204 IF (TPRNT+UTP.GT.TPMAX(NP)+.01*DT)GO TO 203
01112 269. TPRNT=TIME+UTP
01113 270. 202 IF (TIME+DT.LT.TMAX(NDT)+.01*DT)GO TO 205
01115 271. ASSIGN 205 TO KKEI
01116 272. GO TO 600
01117 273. 203 NP=NP+1
01120 274. UTP=DELTP(NP)
01121 275. TPRNT=TIME+UTP
01121 276. C***** IF NOT TIME TO CHANGE TIME STEP, GO TO 200. *****
01122 277. 205 IF (TIME+DT.LT.TMAX(NDT)+.01*DT)GO TO 206
01122 278. C***** CHANGE TIME STEP. *****
01124 279. NDT=NDT+1
01125 280. IF (NDT.GT.NMAX)GO TO 211
01127 281. DT=DELDT(NDT)
01130 282. UDT=0.4*DT
01131 283. UMDT=(1.0-UM)*DT
01131 284. C***** ADVANCE TIME *****
01132 285. 200 TIME=TIME+DT
01133 286. TIMP=TIME/86400.0
01134 287. UTIMP=DT/86400.0
01135 288. PRINT 20,TIMP,UTIMP
01141 289. 20 FORMAT(6H TIME=,1PE12.4,4A,4H DT=,1PE12.4)
01141 290. C***** SEE IF TIME TO CHANGE VARIABLES DEPENDING ON *****
01141 291. C***** TIME DEPENDENT INPUT. *****
01142 292. IF (TIME.LT.TMAXS(1S)+.01*DT)GO TO 207
01144 293. 1S=1S+1
01145 294. CALL TCHANG(1S)
01146 295. 207 CONTINUE
01147 296. GO TO 300
01147 297. C***** DO PLOT OF RELEASE VS TIME. *****
01150 298. 210 NT=NT+1
01151 299. CALL RELPLT
01151 300. C***** PUT END OF FILE ON PLOT TAPE AND END PROBLEM. *****
01152 301. 212 CALL FINISH
01153 302. STOP
01153 303. C***** DO RELEASE PLOT AND GO TO NEXT PROBLEM. *****
01154 304. 211 NT=NT+1
01155 305. CALL RELPLT
01156 306. GO TO 100
01150 307. C*****
01150 308. C*****
01150 309. C***** REGION 300 CALCULATES TERMS NEEDED FOR *****
01150 310. C***** CALCULATION OF XA. *****
01150 311. C*****

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01156 312. C***** CALCULATE SOURCES. *****
01157 313. 300 DO 303 I=1,IMAX
01162 314. S1=RZ(I,IS)*ZNZ(I)
01163 315. S1=R1(I,IS)*ZNZ(I)
01164 316. DO 306 M=1,MMAX
01167 317. FX=1.0/(EXP((ABS(X(M))-ADAMP)/BDAMP)+1.0)
01170 318. S(M,I)=(S1-S2)*X(I)/ADAMP+S2)*FX
01171 319. IF(X(M).GT.ADAMP)S(M,I)=S1*FX
01173 320. 306 CONTINUE
01173 321. C***** CALCULATE STERN AND XTERM. *****
01175 322. DO 302 M=2,MMAXM
01200 323. STERNP=GA(M-1)*S(M-1,I)+3.0*(GA(M-1)+GA(M))*S(M,I)+GA(M)*S(M+1,I)
01201 324. GT=G(M-1,I)*UTDX(M-1)-G(M,I)*UTDX(M)
01202 325. SF=XLAM(I)*GA(M-1)+F(M-1,I)/(2.0*DX(M-1))
01203 326. SG=(3.0*XLAM(I)*GA(M-1)-F(M-1,I)/(2.0*DX(M-1)))*FEE(M,I)
01203 327. 1+3.0*XLAM(I)*GA(M)-F(M,I)/(2.0*DX(M))
01204 328. SH=(XLAM(I)*GA(M)+F(M,I)/(2.0*DX(M)))*FEE(M+1,I)
01205 329. CTERM=GA(M-1)*C(M-1,I)+3.0*(GA(M-1)*FEE(M,I)+GA(M))*C(M,I)
01205 330. 1+GA(M)*FEE(M+1,I)*C(M+1,I)
01206 331. CTERM=CTERM
01206 332. 2-UMOUT*(SF*C(M-1,I)+SG*C(M,I)+SH*C(M+1,I))
01207 333. XTERM(M,I)=OUT*STERNP+UMOUT*(STERN(M,I)+GT)+CTERM
01210 334. STERN(M,I)=STERNP
01211 335. 302 CONTINUE
01213 336. 303 CONTINUE
01213 337. C***** SET E AND FF FOR LEFT BOUNDARY. *****
01215 338. E(1)=1.0
01216 339. FF(1)=0.0
01217 340. GO TO 400
01217 341. C*****
01217 342. C*****
01217 343. C***** REGION 400 CALCULATES NEW CONCENTRATIONS. *****
01217 344. C*****
01220 345. 400 MCUN=0 400
01221 346. CONMAX=0.0 400
01222 347. ICON=0 400
01223 348. NO=0 400
01223 349. C***** 412 IS BEGINNING OF OUTER ITERATION LOOP. *****
01224 350. 412 PRINT 40,NO,CONMAX,ICON,MCUN 400
01232 351. 40 FORMAT(17H END OF OUTER NO ,I3,5X,13HRELATIVE CON=,1PE12.4, 400
01232 352. 15X,11HISOTOPE NO ,I2,5X,11HGRID PT NO ,I3) 400
01233 353. CALL FUNS(0,3)
01233 354. C***** DO INNER ITERATIONS FOR EACH ISOTOPE. *****
01234 355. DO 403 I=1,IMAX
01237 356. CALL FUNS(I,4)
01240 357. NI=0
01240 358. C***** 405 IS BEGINNING OF INNER ITERATION LOOP. *****
01241 359. 405 CONTINUE
01242 360. CALL FUNS(I,5)
01242 361. C***** CALCULATE E AND FF FOR ALL INTERIOR MESH POINTS. *****
01243 362. M=1
01244 363. UPL=-(GA(M)+OUT*(XLAM(I)*GA(M)+F(M,I)/(2.0*DX(M))))
01245 364. VPL=3.0*GA(M)+OUT*(3.0*XLAM(I)*GA(M)-F(M,I)/(2.0*DX(M)))
01246 365. DO 401 M=2,MMAXM

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01251 360.      W=UPL
01252 367.      UPL=(GA(M)+OUT*(XLAM(I)*GA(M)+F(M,I)/(2.0*DX(M))))
01253 368.      U=FCE(M+1,I)*UPL
01254 369.      V=FCE(M,I)*VPL
01255 370.      VPL=3.0*GA(M)+OUT*(3.0*XLAM(I)*GA(M)+F(M,I)/(2.0*DX(M)))
01256 371.      V=V+VPL
01257 372.      GTERM=G(M-1,I)*DTDX(M-1)-G(M,I)*DTDX(M)
01260 373.      XX=OUT*GTERM+XTERM(M,I)
01261 374.      E(M)=U/(V-W+E(M-1))
01262 375.      FF(M)=(XX+W*F(M-1))/(V-W+E(M-1))
01263 376.      4J1 CONTINUE
01263 377.      C***** CALCULATE C AT RIGHT BOUNDARY. *****
01265 378.      M=M*MAX
01266 379.      V=1.0+DX(M-1)*PSI(I)
01267 380.      W=1.0-DX(M-1)*PSI(I)
01270 381.      XX=2.0*DX(M-1)*XK1(I)
01271 382.      C(M,I)=(XX+W*F(M-1))/(V-W+E(M-1))
01272 383.      CONMAX=0.0
01272 384.      C***** CALCULATE C FOR ALL INTERIOR MESH POINTS. *****
01273 385.      M,M=M*MAX
01274 386.      DO 402 M=4MM,1,-1
01277 387.      CNE#=#(M)*C(M+1,I)+FF(M)
01300 388.      CON=ABS((C(M,I)-CNE#)/CNE#)
01301 389.      IF(CON,LT,CONMAX)GO TO 402
01303 390.      CONMAX=CON
01304 391.      MCUN=M
01305 392.      4J2 C(M,I)=CNE#
01307 393.      NI=NI+1
01307 394.      C***** IF CONCENTRATIONS HAVE CONVERGED, GO TO 409. *****
01310 395.      IF(CONMAX,LT,EP51)GO TO 409
01310 396.      C***** IF MAX NUMBER OF INNER ITERATIONS HAS NOT BEEN *****
01310 397.      C***** EXCEEDED, GO TO 405 FOR ANOTHER INNER ITERATION. *****
01312 398.      IF(NI,LT,NIM)GO TO 405
01314 399.      GO TO 410
01315 400.      4J9 PRINT 41,NI,I,CONMAX,MCUN
01323 401.      41 FORMAT(1H,10X,I3,14H INVERS FOR I=,I2,5X,13HRELATIVE CON=,
01323 402.      11P=12.4,5X,11HGR10 PT NO ,I3)
01324 403.      4J3 CONTINUE
01324 404.      C***** DETERMINE IF MORE OUTER ITERATIONS ARE NEEDED. *****
01326 405.      CONMAX=0.0
01327 406.      DO 404 I=1,IMAX
01332 407.      DO 404 M=1,M*MAX
01335 408.      CON=ABS((C(M,I)-CN(M,I))/C(M,I))
01336 409.      CN(M,I)=C(M,I)
01337 410.      IF(CON,LT,CONMAX)GO TO 404
01341 411.      CONMAX=CON
01342 412.      MCUN=M
01343 413.      ICUN=I
01344 414.      4J4 CONTINUE
01347 415.      NO=NO+1
01350 416.      IF(CONMAX,LT,EP50)GO TO 411
01352 417.      IF(NO,LT,NOM)GO TO 412
01354 418.      GO TO 413
01355 419.      4J1 PRINT 40,NO,CONMAX,ICUN,MCUN

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01363 420. CALL FUNS(0,0) 400
01364 421. GO TO 500 400
01365 422. 410 PRINT 42,NIM,1,CONMAX,MCN 400
01373 423. 42 FORMAT(1H,13,20H INNERX EXCEEDED I=,I2,5X, 400
01373 424. 114HRELATIVE CON=,1PE12.4,5X,11HGRID PT NO ,13) 400
01374 425. STOP 400
01375 426. 413 PRINT 43 NOM,1CON,CONMAX,MCN
01403 427. 43 FORMAT(1H,13,20H OUTERX EXCEEDED I=,I2,5X,
01403 428. 114HRELATIVE CON=,1PE12.4,5X,11HGRID PT NO ,13) 400
01404 429. STOP
01404 430. C*****
01404 431. C*****
01404 432. C***** REGION 500 CALCULATES INTEGRALS FOR PRINT. *****
01404 433. C*****
01405 434. 500 DO 503 I=1,IMAX
01410 435. CINTO=CINTG(I)
01411 436. SINTG(I)=0.0
01412 437. CINTG(I)=0.0
01413 438. DO 501 M=2,MMAXM
01416 439. SINTG(I)=SINTG(I)+STER4(M,I)
01417 440. CINTG(I)=CINTG(I)+C(M-1,I)+3.0*FEE(M,I)*C(M,I)
01417 441. 1+GA(M)*(3.0*C(M,I)+FEE(M+1,I)*C(M+1,I))
01417 442. 2+CINTG(I)
01420 443. 501 CONTINUE
01422 444. CLINTG(I)=XLAM(I)*CINTG(I)
01423 445. DCINTG(I)=CINTG(I)-CINTO
01424 446. CSUM(I)=CSUMOD(I)
01425 447. XJL=F(1,I)*(C(2,I)-C(1,I))/(2.0*UX(1))+G(1,I)*DTDX(1)
01426 448. XJR=F(MMAX,I)*(C(MMAX,I)-C(MMAX,I))/(2.0*UX(MMAX))
01426 449. 1+G(MMAX,I)*DTDX(MMAX)
01427 450. CSUMOD(I)=SINTG(I)-CLINTG(I)+XJL-XJR
01430 451. CSUM(I)=0.4OUT*CSUM(I)+OUT*CSUMOD(I)
01431 452. TB=.5*(T(MMAX)+T(MMAX))
01432 453. CB0=.5*(C(MMAX,I)+C(MMAX,I))
01433 454. SUM=0.0
01434 455. DO 504 II=1,IMAX
01437 456. 504 SUM=SUM+.5*(C(MMAX,II)+C(MMAX,II))/CM(II)
01441 457. IF(SUM,LT,CRIT)SUM=CRIT
01443 458. SV=SA(I)+1000.0*SB(I)/TB
01444 459. SU=SC(I)+1000.0*SD(I)/TB
01445 460. CCP=EXP(SV)*PZ(I)**SU*CB0*(ABS(SUM))**(SU-1.0)/(1.E-6*RT*TB)
01445 461. *CM(I)
01446 462. XJPLS=JDB(I)*CCP-DD(I)*CZ(I)/XLL(I)
01447 463. EMLT=EXP(-XLAM(I)*DT)
01450 464. REL(I)=REL(I)+EMLT+.5*DT*(XJPO(I)+EMLT+XJPLS)
01451 465. XJPO(I)=XJPLS
01452 466. DO 502 J=1,JMAX
01455 467. M=MPTS(J)
01456 468. SINTT(J,I)=SINTT(J,I)+OUT*S(M,I)+OMOUT*SOLD(J,I)
01457 469. SOLD(J,I)=S(M,I)
01460 470. CINTT(J,I)=CINTT(J,I)+XLAM(I)*(OUT*C(M,I)+OMOUT*COLD(J,I))
01461 471. COLD(J,I)=C(M,I)
01462 472. XJL=F(M-1,I)*(FEE(M,I)*C(M,I)-C(M-1,I))/(2.0*UX(M-1))
01462 473. 1+.5*(M-1,I)*JTDX(M-1)

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01463 474.      XJCF(M,I)*(FEE(M+1,I)*C(M+1,I)-C(M,I))/(2.0*UX(M))
01463 475.      1+G(M,I)*DIDX(M)
01464 476.      DELJ=XJR-XJL
01465 477.      XJINTT(J,I)=XJINTT(J,I)+ODT*DELJ+OMODT*DJOLD(J,I)
01466 478.      DJOLD(J,I)=DELJ
01467 479.      CSUMT(J,I)=-{UX(M-1)+UX(M)}*(C(M,I)-SINTT(J,I)+CINTT(J,I))
01470 480.      502 CONTINUE
01472 481.      503 CONTINUE
01474 482.      GO TO 200
01474 483.      C*****
01474 484.      C*****
01474 485.      C***** REGION 600 IS PRINT REGION *****
01474 486.      C*****
01475 487.      DOO DO 603 I=1,IMAX
01500 488.      PRINT 60,(XLAB(N),N=1,9),TIMP,DTIMP
01510 489.      OJ FORMAT(1H1, 9A5,6H TIME=,1PE12,4,5H UT=,1PE12,4)
01511 490.      PRINT 61
01513 491.      O1 FORMAT(1H ,5X,1H1,5X,1HM,11X,1HX,11X,1HC,11X,1HS,11X,1HU,10X,2HJC,
01513 492.      *9X,3HJTH,11X,1HF,11A,1HW,11A,1HP)
01514 493.      NLP=3
01514 494.      C***** PRINT ONE LINE FOR EACH MESH POINT. *****
01515 495.      DO 601 M=1,MMAX
01515 496.      C***** CALCULATE PRESSURE (P). *****
01520 497.      XJCF(M,I)/(2.0*UX(M))*(FEE(M+1,I)*C(M+1,I)-C(M,I))
01521 498.      XJTH=O(M,I)*DIDX(M)
01522 499.      XJ=XJC+XJTH
01523 500.      TEE=O*(T(M)+I(M+1))
01524 501.      SV=SA(I)+SD(1)/TEE*1000.0
01525 502.      SU=SC(I)+SD(1)/TEE*1000.0
01526 503.      CMM=C(I)
01527 504.      IF(M,LT,MINT)CMM=FEE(MINT,I)*CMM
01531 505.      PHEE=EXP(SV)*PZ(I)**SU/CMM
01532 506.      SJ=0.0
01533 507.      DO 604 I1=1,IMAX
01536 508.      CMM=C(I1)
01537 509.      IF(M,LT,MINT)CMM=FEE(MINT,I1)*CMM
01541 510.      604 SUM=SUM+ABS(.5*(C(M,I1)+FEE(M+1,I1)*C(M+1,I1)))/CMM
01543 511.      IF(SUM,LT,CRIT)SUM=CRIT
01545 512.      P=PHEE*SUM**{SU-1.0}*.5*(C(M,I)+FEE(M+1,I)*C(M+1,I))
01546 513.      IF(M,EG,MAXM)PPL(I)=P
01546 514.      C***** PRINT FOR MESH POINT M. *****
01550 515.      PRINT 62,1,M,X(M),C(M,I),S(M,I),XJ,XJC,XJTH,F(M,I),G(M,I)
01550 516.      *,P
01550 517.      O2 FORMAT(1H ,21O,1PE12,4)
01556 518.      NLP=NLP+1
01557 519.      IF(NLP,LE,54)GO TO 601
01571 520.      PRINT 60,(XLAB(N),N=1,9),TIMP,DTIMP
01601 521.      PRINT 61
01603 522.      NLP=3
01604 523.      601 CONTINUE
01604 524.      C***** PRINT CONSERVATION INTEGRALS. *****
01606 525.      PRINT 63
01610 526.      O3 FORMAT(1HJ,16HINTEGRALS OVER X/11X,1HS,5X,7HLMUA*C, 8X,4HDELL,
01610 527.      *6X,6HSHJ*UT)

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01611 528. PRINT 64,SINTG(1),CLINTG(1),DCINTG(1),CSUM(1)
01617 529. 04 FORMAT(1P4E12.4)
01620 530. PRINT 65
01622 531. 05 FORMAT(1H0,31HINTEGRALS OVER TIME FOR GIVEN X/ 5X,1HM,11X,1HX,
01622 532. *1X,1HS,
01622 533. * SX,7HLMADA*G,8X,4HDELJ,6X,6HSUM*DX)
01623 534. DO 602 J=1,JMAX
01626 535. M=MPTS(J)
01627 536. PRINT 66,M,X(M),SINTT(J,1), CINTT(J,1),XJINTT(J,1),
01627 537. *CSUMT(J,1)
01637 538. 06 FORMAT(1H,16,1P6E12.4)
01640 539. 602 CONTINUE
01640 540. C***** PRINT VALUES OUTSIDE RIGHT BOUNDARY. *****
01642 541. CALL BPRT(1)
01643 542. 603 CONTINUE
01643 543. C***** DO 4020 PLOT OF CONCENTRATIONS. *****
01645 544. MM2=MMAX-2
01646 545. CALL BCDCON(XLAB(10))
01647 546. WRITE(0,67),TIMP
01652 547. 07 FORMAT(6H TIME=,1PE12.4)
01653 548. CMIN=C(1,1)
01654 549. CMAX=C(1,1)
01655 550. DO 605 M=2,MMAXM
01660 551. DO 605 I=1,IMAX
01663 552. CMIN=AMIN1(CMIN,C(M,1))
01664 553. 605 CMAX=AMAX1(CMAX,C(M,1))
01667 554. IF(CMAX-CMIN.LT.1.E-10)CMAX=CMIN+1.0
01671 555. NGRID=3
01672 556. IF(CMIN.LT.1.E-20)NGRID=1
01674 557. IF(CMIN/CMAX.GT..1)NGRID=1
01676 558. J=1
01677 559. DO 606 I=1,IMAX
01702 560. CALL PLOTV(J,NGRID,48,3,MM2,X(2),C(2,1),X(1),X(MMAX),CMIN,CMAX,
01702 561. *HLAB,VLAB,XLAB)
01703 562. CALL PLOTV(2,NGRID,1,2,1,X(1),C(2,1),X(1),X(MMAX),CMIN,CMAX,
01703 563. *HLAB,VLAB,XLAB)
01704 564. J=2
01705 565. 606 CONTINUE
01707 566. T1(NT)=TIMP
01710 567. NT=NT+1
01711 568. GO TO KRET
01712 569. END

```

END OF LISTING. 2 *DIAGNOSTIC* MESSAGE(S).


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00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. SUBROUTINE FUNS(II,IOP)
00103 2. REAL LNRZ,LNUZ
00104 3. PARAMETER IU=10, MU=110, JU=5, NU=10, NPD=10, NTD=25
00105 4. PARAMETER ISD=20
00106 5. COMMON/FIPCOM/ C(MD,IU), CN(MD,IU), XTERM(MD,IU),
00106 6. * G(MD,IU), F(MD,IU), FEE(MD,IU),
00106 7. * S(MD,IU), STERM(MD,IU),
00106 8. * E(MD), FF(MD), DX(MD),
00106 9. * GA(MD), DTUX(MD), T(MD),
00106 10. * X(MD),
00106 11. * XLAM(IU), PP(IU),
00106 12. * Y(IU), SINTG(IU),
00106 13. * CLINTG(IU), CLINTG(IU), UCINTG(IU),
00106 14. * CSUM(IU), CSUMOD(IU), PSI(IU),
00106 15. * XKI(IU), LNUZ(IU), EI(IU),
00106 16. * PZ(IU), SA(IU), SB(IU),
00106 17. * SC(IU), SD(IU), XK(IU),
00106 18. * XLL(IU), PSICO(IU),
00106 19. * XJPL(IU), CPL(IU), PPL(IU),
00106 20. * CPCO(IU), WBS(IU), REL(IU),
00106 21. * XJPO(IU), CZ(IU)
00107 22. COMMON/CO,1/
00107 23. * MINT, CRIT,
00107 24. * UZB(IU), EB(IU),
00107 25. * UZD(IU), E2(IU), U1(IU),
00107 26. * RA(IU), RB(IU), ZNZ(IU),
00107 27. * TZ(IU), ZETA(IU), SI(IU)
00110 28. COMMON/CO,2/
00110 29. * CM(IU), ZM1(IU), Z(IU),
00110 30. * TMAXS(ISD), R1(IU,ISD), RZ(IU,ISD),
00110 31. * SINTT(JU,IU), SOLD(JU,IU), CINTT(JU,IU),
00110 32. * COLD(JU,IU), XJINTT(JU,IU), JUJLD(JU,IU),
00110 33. * CSUMT(JU,IU),
00110 34. * MPTS(JU), DELT(ND), TMAX(ND),
00110 35. * DELTP(NPD), TPMAX(NPD),
00110 36. * MTMP(NTD), TEMP(NTD,ISD),
00110 37. * D(MD,IU), XLAB(12), DD(IU),
00110 38. * IMAX, MMAX,
00110 39. * IFF, IG, IFEE,
00110 40. * ICH1, IPSI, DT,
00110 41. * IJU, JFF, JG,
00110 42. * JFEE, JPSI, JCH1,
00110 43. * JUJ, ADAMP, BDAMP,
00110 44. * SELTO(IU), SSUM(IU), LBOP,
00110 45. * RES(100,IU), TT(100), NT,
00110 46. * TIME, NTMP
00111 47. DATA RST/2.0/
00111 48. C*****
00111 49. C***** FUNS DETERMINES IF FUNCTIONS ARE TO BE CALCULATED*****
00111 50. C*****

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#ELCH FIPER 050 \$ JOB 454 \$

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00113 51. IF(10P,EQ,0,OK,10P,EQ,1FEE)CALL FEFUN(11)
00115 52. IF(10P,EQ,0,OK,10P,EQ,100)CALL DFUN(11)
00117 53. IF(10P,EQ,0,OK,10P,EQ,1G)CALL GFUN(11)
00121 54. IF(10P,EQ,0,OK,10P,EQ,1FF)CALL FFUN(11)
00123 55. IF(10P,EQ,0,OK,10P,EQ,1PS1)CALL PSIFUN(11)
00125 56. IF(10P,EQ,0,OK,10P,EQ,1CH1)CALL CHIFUN(11)
00127 57. RETURN
00130 58. END
```

END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).

#1 FOR DFUN,DFUN
UNIVAC 1108 FORTRAN IV LEVEL 2201 0029 F4014B
THIS COMPILATION WAS DONE ON 20 FEB 68 AT 16:23:13

SUBROUTINE DFUN ENTRY POINT 000214

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000226
0000	*DATA	000031
0002	*BLANK	000000
0003	FIPCOM	023204
0004	COM1	000160
0005	COM2	007062

EXTERNAL REFERENCES (BLOCK, NAME)

0006	EXP
0007	NEKR25

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	00004+ 10L	0001	000026 100L	0001	000032 101L	0001	000205 102L	0001	000050 126G
0001	000054 131G	0001	000110 140G	0001	000124 143G	0001	000104 20L	0001	000203 30L
0001	000204 40L	0005 R	004714 ADAMP	0005 R	004715 BDAMP	0003	000000 C	0003	022612 CINTG
0005	001040 CINTI	0003	022624 CLINTG	0005	000024 CM	0003	002114 CN	0005	001130 COLD
0003	023122 CPOU	0003	023076 CPL	0004	000001 CRIT	0003	022650 CSUM	0003	022662 CSUMOU
0005	001350 CSUMT	0003	023172 CZ	0005 R	002532 D	0003	022636 DCINTG	0005	004662 DO
0005	001440 DELT	0005	001471 DELIP	0000 R	000005 DFUEL	0005	001274 DJOLD	0005	004704 DT
0003	022030 DTDX	0003	021474 DX	0004 R	000002 DZB	0004	000052 D1	0004	000026 D20
0003	021140 E	0004 R	000014 EB	0003 R	022732 EI	0006 R	000000 EXP	0004	000040 E2
0003	010400 F	0003	012574 FEE	0003	021316 FF	0000 R	000006 FX	0003	006344 G
0003	021652 GA	0000 I	000003 I	0005	004702 ICHI	0005 I	004705 IUD	0005	004701 IFEE
0005	004677 IFF	0005	004700 IG	0005 I	004674 IMAX	0005	004703 IPSI	0000 I	000001 I1
0000 I	000002 J2	0005	004712 JCH1	0005 I	004713 JDD	0005	004710 JFEE	0005	004706 JFF
0005	004707 JG	0005	004711 JPS1	0005	004742 LBOP	0003 R	022720 LNOZ	0000 I	000004 M
0004	000000 MINT	0005	004675 MMAX	0005 I	004676 MMAXM	0005	001440 MPTS	0005	001515 MTMP
0005	007057 NT	0005	007061 NTMP	0003	022554 PP	0003	023110 PPL	0003	022674 PSI
0003	023032 PS1CO	0003	022744 PZ	0005	000012 Q	0004	000064 RA	0004	000076 RB
0003	023140 REL	0005	004743 RES	0000 R	000000 RST	0005	000346 RZ	0005	000036 R1
0003	014710 S	0003	022756 SA	0003	022770 SB	0003	023002 SC	0003	023014 SD
0005	004710 SELTD	0004	000146 SI	0003	022600 SINTG	0005	000702 SINTT	0005	000764 SOLD
0005	004730 SSUM	0003	017024 SIERM	0003 R	022206 T	0005	001546 TEMP	0005 R	007060 TIME
0005	001457 TMAX	0005	000556 TMAXS	0005	001503 TPMAX	0005	006713 TT	0004	000122 TZ
0003	023134 XBO	0003 R	022364 X	0005	001212 XJINTT	0003	023064 XJPL	0003	023160 XJPO
0003	023020 XK	0003	022706 XK1	0005	004646 XLAB	0003	022542 XLAM	0003	023040 XLL
0003	004230 XTERX	0003	022566 Y	0004	000134 ZETA	0005	000000 ZMI	0004	000110 ZNZ

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00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. SUBROUTINE DFUN(II)
00103 2. REAL LNRZ,LNUZ
00104 3. PARAMETER IU=10, MU=110, JU=5, NU=10, NPU=10, NTU=25
00105 4. PARAMETER ISD=20
00106 5. COMMON/FIPCOM/ C(MU,IU), CN(MU,IU), XTERM(MU,IU),
00106 6. * G(MU,IU), F(MU,IU), FEE(MU,IU),
00106 7. * S(MU,IU), STERM(MU,IU),
00106 8. * E(MU), FF(MU), DX(MU),
00106 9. * GA(MU), DTUX(MU), T(MU),
00106 10. * X(MU),
00106 11. * XLAM(IU), PP(IU),
00106 12. * Y(IU), SINTG(IU),
00106 13. * CINIG(IU), CLINTG(IU), UCINTG(IU),
00106 14. * CSUM(IU), CSUMU(IU), PSI(IU),
00106 15. * XKI(IU), LNJZ(IU), EI(IU),
00106 16. * PZ(IU), SA(IU), SB(IU),
00106 17. * SC(IU), SD(IU), XK(IU),
00106 18. * XLL(IU), PSICO(IU),
00106 19. * XJPL(IU), CPL(IU), PPL(IU),
00106 20. * CPCU(IU), WBB(IU), REL(IU),
00106 21. * XJPO(IU), CZ(IU)
00107 22. COMMON/CO41/
00107 23. * MINT, CRIT,
00107 24. * JZB(IU), EB(IU),
00107 25. * U20(IU), E2(IU),
00107 26. * RA(IU), RB(IU),
00107 27. * TZ(IU), ZETA(IU),
00110 28. COMMON/CO42/
00110 29. * CM(IU), RI(IU,ISD),
00110 30. * TMAXS(ISD),
00110 31. * SINTT(JU,IU), SOLT(JU,IU),
00110 32. * COLD(JU,IU), XJINTT(JU,IU),
00110 33. * CSUMT(JU,IU),
00110 34. * MPTS(JU), DELT(NU),
00110 35. * DELTP(NPU), TPMAX(NPU),
00110 36. * MTMP(NTU), TEMP(NTU,ISD),
00110 37. * U(MU,IU), XLAB(12),
00110 38. * IMAX, MMAX,
00110 39. * IFF, Ig,
00110 40. * ICH1, IPSI,
00110 41. * IUD, JFF,
00110 42. * JFEE, JPSI,
00110 43. * JUD, ADAMP,
00110 44. * SELTU(IU), SSUM(IU),
00110 45. * RES(100,IU), TT(100),
00110 46. * TIME, NTMP
00111 47. DATA RST/82.0/
00111 48. C*****
00111 49. C***** DFUN CALCULATES DIFFUSION COEFFICIENT D(M+1/2,I).*****
00111 50. C*****
00113 51. IF(IUD,E3.1,AND,T1-E.010.0)GO TO 102

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#ELCH FIPER 050 \$ JOB 454 \$

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00115 52.      IF(11,EQ,0)GO TO 100
00117 53.      11=11
00120 54.      12=11
00121 55.      GO TO 101
00122 56.      100 11=1
00123 57.      12=1MAX
00124 58.      101 GO TO (10,20,30,40),JDD
00125 59.      10 00 11 I=11,12
00130 60.      DO 11 M=1,MAXM
00133 61.      11 D(M,I)=EXP(LNDZ(I)-EI(I)/(1.986*(T(M)+T(M+1))*5))
00136 62.      GO TO 102
00137 63.      20 00 21 I=11,12
00142 64.      DO 21 M=1,MAXM
00145 65.      D(M,I)=EXP(LNDZ(I)-EI(I)/(1.986*(T(M)+T(M+1))*5))
00146 66.      DFUEL=EXP(DZB(I)-EB(I)/(1.986*(T(M)+T(M+1))*5))
00147 67.      FX=1.0/(EXP(((X(M)+X(M+1))/2.0-AJAMP)/BDAMP)+1.0)
00150 68.      21 D(4,I)=D(4,I)*(1.0-FX)+FX*DFUEL
00153 69.      GO TO 102
00154 70.      30 GO TO 102
00155 71.      40 GO TO 102
00156 72.      102 RETURN
00157 73.      END

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END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).


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00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. SUBROUTINE GFUN(11)
00103 2. REAL LNRZ,LNUZ
00104 3. PARAMETER ID=10, MU=110, JD=5, ND=10, NPU=10, NTD=25
00105 4. PARAMETER ISD=20
00106 5. COMMON/FIPCOM/ C(MD,1D), CN(MD,1D), XTERM(MD,1D),
00106 6. * G(MD,1D), F(MD,1D), FEE(MD,1D),
00106 7. * S(MD,1D), STERM(MD,1D),
00106 8. * E(MD), FF(MD), DX(MD),
00106 9. * GA(MD), DTUX(MD), T(MD),
00106 10. * X(MD),
00106 11. * XLAM(1D), PP(1D),
00106 12. * Y(1D), SINTG(1D),
00106 13. * CINTG(1D), CLINTG(1D), DCINTG(1D),
00106 14. * CSUM(1D), CSUMOW(1D), PSI(1D),
00106 15. * XKI(1D), LNUZ(1D), EI(1D),
00106 16. * PZ(1D), SA(1D), SB(1D),
00106 17. * SC(1D), SD(1D), XK(1D),
00106 18. * XLL(1D), PSICO(1D),
00106 19. * XJPL(1D), CPL(1D), PPL(1D),
00106 20. * LPCO(1D), WBB(1D), REL(1D),
00106 21. * XJPO(1D), CZ(1D)
00107 22. COMMON/CO41/
00107 23. * MINT, CRIT,
00107 24. * DZB(1D), EB(1D),
00107 25. * U20(1D), E2(1D), O1(1D),
00107 26. * RA(1D), RB(1D), ZNZ(1D),
00107 27. * TZ(1D), ZETA(1D), SI(1D),
00110 28. COMMON/CO12/ ZM1(1D), Q(1D),
00110 29. * CM(1D), R1(1D,1SD), RZ(1D,1SD),
00110 30. * TMAXS(1SD),
00110 31. * SINTT(JD,1D), SOLD(JD,1D), CINTT(JD,1D),
00110 32. * COLD(JD,1D), XJINTT(JD,1D), UJOLD(JD,1D),
00110 33. * CSUMT(JD,1D),
00110 34. * MPTS(JD), DELT(ND), TMAX(ND),
00110 35. * DELTP(NPD), TPMAX(NPD),
00110 36. * MTPM(NTD), TEMP(NTD,1SD),
00110 37. * U(MD,1D), XLAB(12), DD(1D),
00110 38. * IMAX, MMAX, MMAXM,
00110 39. * IFF, IG, IFE,
00110 40. * ICH1, IPSI, DT,
00110 41. * IUD, JFF, JG,
00110 42. * JFE, JPSI, JCH1,
00110 43. * JUD, ADAMP, BDAMP,
00110 44. * SELTO(1D), SSUM(1D), LBOP,
00110 45. * RES(100,1D), TT(100), NT,
00110 46. * TIME, NTMP
00111 47. DATA RST/02.0/
00111 48. C*****
00111 49. C***** GFUN CALCULATES G(M+1/2,1). *****
00111 50. C*****
00113 51. IF(IG.EQ.1.AND.TIME.GT.0.0)GO TO 102
00113 52. IF(11.EQ.0)GO TO 100

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GFUN

		WELCH	FIPER	050	\$ JOB 454 \$	20 FEB 68	PAGE	24
00117	53.	I1=I1						
00120	54.	I2=I1						GFUN
00121	55.	GO TO 101						GFUN
00122	56.	100 I1=1						GFUN
00123	57.	I2=IMAX						GFUN
00124	58.	101 GO TO (10,20,30,40),JG						
00125	59.	10 DO 11 I=I1,I2						
00130	60.	DO 11 M=1,MMAX						
00133	61.	11 G(M,I)=0.0						
00136	62.	GO TO 102						
00137	63.	20 DO 21 I=I1,I2						
00142	64.	DO 21 M=1,MMAX						
00145	65.	G(M,I)=-D(M,I)*(C(M,I)+FEE(M+1,I)*C(M+1,I))*S*Q(I)/						
00145	66.	*(1.986+.25*(T(M)+T(M+1))**2)						
00146	67.	21 G(M,I)=G(M,I)/(SC(I)+SD(I)*1000.0/(.5*(T(M)+T(M+1))))						
00151	68.	GO TO 102						
00152	69.	30 GO TO 102						
00153	70.	40 GO TO 102						
00154	71.	102 CONTINUE						GFUN
00155	72.	RETURN						
00156	73.	END						

END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).

#1 FOR FFUN,FFUN
 UNIVAC 1103 FORTRAN IV LEVEL 2201 0029 F40148
 THIS COMPILATION WAS DONE ON 20 FEB 68 AT 16:23:16

SUBROUTINE FFUN ENTRY POINT 000043

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000052
0000	*DATA	000015
0002	*BLANK	000000
0003	F1PCOM	023204
0004	COM1	000160
0005	COM2	007062

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000015	100L	0001	000021	101L	0001	000031	123G	0001	000032	126G	0005	004714	ADAMP
0005	004715	ADAMP	0003	000000	L	0003	022612	CINTG	0005	001046	CINTT	0003	022624	CLINTG
0005	000024	CM	0003	002114	CM	0005	001130	COLD	0003	023122	CPCO	0003	023076	CPL
0004	000001	CRIT	0003	022650	CSUM	0003	022662	CSUMOD	0005	001356	CSUMT	0003	023172	CZ
0005	R 002532	U	0003	022636	UCINTG	0005	004662	JD	0005	001445	DELT	0005	001471	DELTP
0005	001274	UJOLD	0005	004704	JT	0003	022030	UTDX	0003	021474	DX	0004	000002	DZB
0004	000052	U1	0004	000026	U20	0003	021140	E	0004	000014	EB	0003	022732	E1
0004	000040	L2	0003	R 010400	F	0003	012574	FEE	0003	021316	FF	0003	006344	G
0003	021052	GA	0000	I 000003	I	0005	004702	ICH1	0005	004705	IDD	0005	004701	IFEE
0005	004677	IFF	0005	004700	IG	0005	I 004674	IVAX	0005	004703	IPSI	0000	I 000001	I1
0000	I 000002	I2	0005	004712	JCH1	0005	004713	JDD	0005	004710	JFEE	0005	004706	JFF
0005	004707	UG	0005	004711	JPS1	0005	004742	LBOP	0003	R 022720	LNDZ	0000	I 000004	M
0004	000000	MINI	0005	004675	IMAX	0005	I 004676	MMAXM	0005	001440	MPTS	0005	001515	MTMP
0005	007057	NT	0005	007061	NTMP	0003	022554	PP	0003	023110	PPL	0003	022674	PS1
0003	023052	PS1CO	0003	022744	PZ	0005	000012	W	0004	000064	RA	0004	000076	RB
0003	023140	REL	0005	004743	RES	0000	R 000000	RST	0005	000346	RZ	0005	000036	R1
0003	014710	S	0003	022756	SA	0003	022770	SH	0003	023002	SC	0003	023014	SD
0005	004710	SELTU	0004	000146	SI	0003	022600	SINTG	0005	000702	SINTT	0005	000764	SOLO
0005	004750	SSUM	0003	017024	STERM	0003	022206	T	0005	001546	TEMP	0005	007060	TIME
0005	001457	IMAX	0005	000650	TMAXS	0005	001503	TPMAX	0005	006713	TT	0004	000122	TZ
0003	023134	WBB	0003	022364	X	0005	001212	XJINTT	0003	023064	XJPL	0003	023160	XJPO
0005	023020	AK	0003	022706	XKI	0005	004646	XLAB	0003	022542	XLAM	0003	023040	XLL
0003	004230	XTERM	0003	022506	Y	0004	000134	ZETA	0005	000000	ZMI	0004	000110	ZNZ

00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
 00101 1. SUBROUTINE FFUN(11)
 00103 2. REAL LNRZ,LNUZ
 00104 3. PARAMETER IU=10, MU=110, JU=5, NU=10, NPU=10, NTD=25
 00105 4. PARAMETER ISD=20
 00106 5. COMMON/F1PCOM/ C(MU,IU), CN(MU,IU), XTERR(MU,IU),
 00106 6. * S(MU,IU), F(MU,IU), FEE(MU,IU),

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00100 7. * S(MD,1D), STERN(MD,1D),
00100 8. * E(MD), FF(MD), DX(MD),
00100 9. * GA(MD), DTUX(MD), T(MD),
00100 10. * X(MD),
00100 11. * XLAM(1D), PP(1D),
00100 12. * Y(1D), SINTG(1D),
00100 13. * CINTG(1D), CLINTG(1D), UCINTG(1D),
00100 14. * CSUM(1D), CSUMOD(1D), PSI(1D),
00100 15. * XK1(1D), LN2Z(1D), EI(1D),
00100 16. * PZ(1D), SA(1D), SB(1D),
00100 17. * SC(1D), SD(1D), XK(1D),
00100 18. * XLL(1D), PSIC(1D),
00100 19. * XJPL(1D), CPL(1D), PPL(1D),
00100 20. * CPCO(1D), XJB(1D), REL(1D),
00100 21. * XJPO(1D), CZ(1D),
00107 22. COMMON/CO.41/
00107 23. * MINT, CRIT,
00107 24. * UZB(1D), E3(1D),
00107 25. * UZ0(1D), E2(1D), D1(1D),
00107 26. * KA(1D), RB(1D), ZN2(1D),
00107 27. * TZ(1D), ZETA(1D), SI(1D),
00110 28. COMMON/CO.42/ Q(1D),
00110 29. * CM(1D), ZM1(1D), RZ(1D,1SD),
00110 30. * TMAXS(1SD), R1(1D,1SD),
00110 31. * SINTT(JD,1D), SOLD(JD,1D), CINIT(JD,1D),
00110 32. * COLD(JD,1D), XJINTT(JD,1D), DUCOLD(JD,1D),
00110 33. * CSUMT(JD,1D),
00110 34. * MPTS(JD), DELT(ND), TMAX(ND),
00110 35. * JELTP(NPD), TPMAX(NPD),
00110 36. * MTP(N1D), TEMP(NTD,1SD),
00110 37. * J(MD,1D), XLAB(12), JD(1D),
00110 38. * IMAX, MMAX, MMAXM,
00110 39. * IFF, IG, IFEE,
00110 40. * ICH1, IPSI, DT,
00110 41. * IUD, JFF, JG,
00110 42. * JFEE, JPSI, JCH1,
00110 43. * JUD, ADAMP, BDAMP,
00110 44. * SELT(1D), SSUM(1D), LBOP,
00110 45. * RES(100,1D), TT(100), NT,
00110 46. * TIME, NIMP
00111 47. DATA RST/82.0/
00111 48. C*****
00111 49. C***** FFUN CALCULATES F(M+1/2,1). *****
00111 50. C*****
00113 51. IF(11.E9.0)GO TO 100
00115 52. I1=11 FFUN
00115 53. I2=11 FFUN
00117 54. GO TO 101 FFUN
00120 55. 100 I1=1 FFUN
00121 56. I2=IMAX FFUN
00122 57. 101 DO 102 I=1,12 FFUN
00123 58. DO 102 M=1,MMAXM FFUN
00130 59. F(I,1)=J(M,1) FFUN
00131 60. 102 CONTINUE FFUN

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WELCH FIPER 050 \$ JOB 454 \$
U0134 61. RETURN
U0135 62. END

20 FEB 68 PAGE 27

END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).

WI FOR FEFUN,FEFUN
 UNIVAC 1105 FORTRAN IV LEVEL 2201 0029 F40148
 THIS COMPILATION WAS DONE ON 20 FEB 68 AT 16:23:18

SUBROUTINE FEFUN ENTRY POINT 000100

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000110
0000	*DATA	000026
0002	*BLANK	000000
0003	FIPCOM	023204
0004	COM1	000160
0005	COM2	007062

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000015	10UL	0001	000021	10IL	0001	000073	103L	0001	000032	123G	0001	000033	126G
0001	000063	141G	0005	004714	ADAMP	0005	004715	BDAMP	0003	000000	C	0005	022612	CINTG
0005	001046	CINTT	0003	022624	CLINTG	0005	000024	CM	0003	002114	CN	0005	001130	COLD
0003	023122	CPL0	0003	023076	CPL	0004	000001	CRIT	0003	022650	CSUM	0003	022662	CSUM70
0005	001355	CSUMT	0003	023172	CZ	0005	002532	U	0003	022636	DCINTG	0005	004662	DD
0005	001443	DELT	0005	001471	JELTP	0005	001274	UJOLD	0005	004704	DT	0003	022030	DTUX
0003	021474	JX	0004	000002	JZB	0004	000052	U1	0004	000026	D20	0003	021140	E
0004	000014	ED	0003	022732	E1	0004	000040	E2	0003	010460	F	0003	012574	FEE
0003	021310	FF	0003	006344	G	0003	021652	GA	0000	I 000003	I	0005	004702	ICHI
0005	004705	IG	0005	004701	IFEE	0005	004677	IFF	0005	004700	IG	0005	004674	IVAX
0005	004703	IPS1	0000	I 000001	11	0000	I 000002	12	0005	004712	JCHI	0005	004713	JDU
0005	I 004710	JFEE	0005	004706	JFF	0005	004707	JG	0005	004711	JH31	0005	004742	LYOP
0003	R 022720	LN0Z	0000	I 000004	4	0004	I 000000	MINT	0005	I 004675	MMAX	0005	004676	MMAXM
0005	001440	MP15	0005	001515	MIMP	0005	007057	NT	0005	007061	NIMP	0005	022554	PP
0003	023110	PPL	0003	022674	PS1	0003	023052	PSICO	0003	022744	PZ	0005	000012	Q
0004	000064	KA	0004	000076	KB	0003	023146	REL	0005	004743	RES	0000	000000	RS1
0005	000346	KZ	0005	000036	R1	0003	014710	S	0003	022756	SA	0003	022770	SB
0003	R 023002	SC	0003	R 023014	SU	0005	004716	SELTO	0004	000146	SI	0005	022600	SINTG
0005	000702	SINTT	0005	000764	SOLD	0005	004730	SSUM	0003	017024	STERM	0000	000006	SU
0003	R 022206	I	0005	001546	TEMP	0005	007060	TIME	0000	R 000005	TINT	0005	001457	TMAX
0005	000656	IMAXS	0005	001503	TPMAX	0005	006713	TT	0004	000122	TZ	0003	023134	WHB
0003	022304	X	0005	001212	XJINTT	0003	023064	XJPL	0003	023160	XJPU	0003	023026	XK
0003	022700	AK1	0005	004646	XLAB	0003	022542	XLAM	0003	023040	XLL	0003	004230	XTERM
0003	022566	I	0004	000134	ZETA	0005	000000	ZMI	0004	000110	ZNZ			

00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
 00101 1. SUBROUTINE FEFUN(II)
 00103 2. REAL LNRZ, LNUZ
 00104 3. PARAMETER IU=10, MD=110, JD=5, ND=10, NPU=10, NTD=25
 00105 4. PARAMETER ISU=20
 00106 5. COMMON/FIPCOM/ C(MD,IU), CN(MD,IU), XTERM(MD,IO),

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00106 6. * G(MD,1D), F(MD,1D), FEE(MD,1D),
00106 7. * S(MD,1D), STER(MD,1D),
00106 8. * E(MD), FF(MD), DX(MD),
00106 9. * GA(MD), DTDX(MD), T(MD),
00106 10. * X(MD),
00106 11. * XLAM(1D), PP(1D),
00106 12. * Y(1D), SINTG(1D),
00106 13. * CINTG(1D), CLINTG(1D), DCINTG(1D),
00106 14. * CSUM(1D), CSUMOD(1D), PSI(1D),
00106 15. * XK1(1D), LNUZ(1D), EI(1D),
00106 16. * PZ(1D), SA(1D), SB(1D),
00106 17. * SC(1D), SD(1D), XK(1D),
00106 18. * XLL(1D), PSICO(1D),
00106 19. * XJPL(1D), CPL(1D), PPL(1D),
00106 20. * CPCO(1D), WBB(1D), REL(1D),
00106 21. * XJPO(1D), CZ(1D),
00107 22. * COMMON/COM1/
00107 23. * MINT, CRIT,
00107 24. * DZB(1D), EB(1D),
00107 25. * DZ0(1D), E2(1D), D1(1D),
00107 26. * RA(1D), RB(1D), ZNZ(1D),
00107 27. * TZ(1D), ZETA(1D), SI(1D),
00110 28. * COMMON/COM2/
00110 29. * CM(1D), ZMI(1D), Q(1D),
00110 30. * TMAXS(1SD), R1(1D,1SD), RZ(1D,1SD),
00110 31. * SINTT(JD,1D), SOLD(JD,1D), CINTT(JD,1D),
00110 32. * COLD(JD,1D), XJINTT(JD,1D), DJOLD(JD,1D),
00110 33. * CSUM1(JD,1D),
00110 34. * MPTS(JD), DELT(ND), TMAX(ND),
00110 35. * DELTP(NPD), TPMA(NPD),
00110 36. * MTMP(NTD), TEMP(NTD,1SD),
00110 37. * U(MD,1D), XLAB(12), UD(1D),
00110 38. * IMAX, MMAX,
00110 39. * IFF, IG, IFEE,
00110 40. * ICHI, IPSI, DT,
00110 41. * IUD, JFT, JG,
00110 42. * JFEE, JPSI, JCHI,
00110 43. * JUD, ADAMP, BDAMP,
00110 44. * SELT0(1D), SSUM(1D), LBOP,
00110 45. * RES(100,1D), TT(10D), NT,
00110 46. * TIME, NTMP
00111 47. DATA RST/82.0/
00111 48. C*****
00111 49. C***** FEFUN CALCULATES FEE(M,I). *****
00111 50. C*****
00113 51. IF(11.EQ.0)GO TO 100 FEFUN
00115 52. I1=11 FEFUN
00116 53. I2=11 FEFUN
00117 54. GO TO 101 FEFUN
00120 55. 100 I1=1 FEFUN
00121 56. I2=IMAX FEFUN
00122 57. 101 DO 102 I=11,I2 FEFUN
00125 58. DO 102 M=1,MMAX FEFUN
00130 59. FEE(M,I)=1.0 FEFUN

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WELCH FIPER 050 \$ JOB 454 \$

20 FEB 68 PAGE 30

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00131 60. 102 CONTINUE
00134 61. IF(JFEE.EQ.1)GO TO 103
00136 62. M=MINI
00137 63. TINT=.5*(T(M)+T(M-1))
00140 64. DO 104 I=11,12
00143 65. SU=SC(I)+1000.0*SD(I)/TINT
00144 66. FEE(M,I)=100.
00145 67. 104 CONTINUE
00147 68. 103 RETURN
00150 69. END
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FEFUN

FEFUN

END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).

W1 FOR PSIFUN,PSIFUN
UNIVAC 1108 FORTRAN IV LEVEL 2201 0029 F40145
THIS COMPILATION WAS DONE ON 20 FEB 68 AT 10:23:19

SUBROUTINE PSIFUN ENTRY POINT 000214

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000235
0000 *DATA 000046
0002 *BLANK 000000
0003 FIPCOM 023204
0004 COM1 000160
0005 COM2 007062

EXTERNAL REFERENCES (BLOCK, NAME)

0006 NEKR25
0007 NEAP65

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000057 10L	0001 000041 100L	0001 000045 101L	0001 000176 104L	0001 000071 1276
0001 000112 130G	0001 000107 150G	0001 000162 20L	0001 000173 30L	0001 000175 40L
0005 004714 ADAMP	0005 004715 BUA4P	0003 R 000000 C	0003 022612 CINTG	0005 001046 CINTT
0003 022024 CLINTG	0005 R 000024 CM	0003 002114 CN	0005 001130 COLU	0003 023122 CPLE
0003 023070 CPL	0004 R 000001 CR11	0003 022650 CSUM	0003 022662 CSUMU	0005 001356 CSUMT
0003 023172 CZ	0005 002532 J	0003 022630 UCINTG	0005 004662 DD	0005 001445 DELT
0005 001471 DELTP	0005 001274 DULU	0005 004704 JT	0003 R 022030 DTUX	0003 021474 DY
0004 000002 DZD	0004 000052 J1	0004 000020 D20	0003 021140 E	0004 000014 EH
0003 022732 EI	0004 000040 E2	0003 R 010460 F	0003 012574 FEE	0003 021316 FF
0003 R 006344 G	0003 021052 GA	0000 I 000004 I	0005 004702 ICH1	0005 004705 IDU
0005 004701 IFEE	0005 004677 IFF	0005 004700 IG	0005 I 004674 IMAX	0005 I 004703 IPSI
0000 I 000001 II	0000 I 000002 I2	0005 004712 JCH1	0005 004713 JDD	0005 004710 JFEE
0005 004706 JFF	0005 004707 JG	0005 I 004711 JPSI	0005 004742 LBUP	0003 R 022720 LNUZ
0000 I 000000 M	0004 000000 YINT	0005 I 004675 MMAX	0005 I 004676 MMAXV	0005 001440 MPIS
0005 001515 MTMP	0005 007057 NI	0005 007061 NTMP	0003 022554 PP	0003 023110 PPL
0003 R 022674 PSI	0003 R 023052 PS1CO	0003 022744 PZ	0005 000012 Q	0004 000054 RA
0004 000075 RB	0003 023146 REL	0005 004743 RES	0000 R 000000 RST	0005 000346 RZ
0005 000030 R1	0003 014710 S	0003 022756 SA	0003 022770 SB	0003 R 023002 SC
0003 R 023014 SJ	0005 004716 SELTU	0004 000146 SI	0003 022600 SINTG	0005 000702 SINTT
0005 000764 SOLU	0005 004730 SSUM	0003 017024 STERM	0000 R 000005 SU	0000 R 000003 SUM
0003 R 022200 I	0005 001546 TEMP	0005 R 007060 TIME	0005 001457 TMAX	0005 000656 TMAXS
0000 R 000007 TMP1	0005 001503 TPMAX	0005 006713 TT	0004 000122 TZ	0003 023134 YBH
0003 022304 A	0005 001212 XJINTT	0003 023064 XJPL	0003 023160 XJPO	0003 023026 XK
0003 022706 AK1	0005 004646 XLAS	0003 022542 XLAM	0003 023040 XLL	0003 004230 XTERRM
0003 022350 I	0004 000134 ZETA	0005 000000 ZMI	0004 000110 ZNZ	

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00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. SUBROUTINE PSIFUN(11)
00103 2. REAL LNRZ,LNUZ
00104 3. PARAMETER ID=10, MD=110, JD=5, ND=10, NPD=10, NTD=25
00105 4. PARAMETER ISD=20
00106 5. COMMON/FIPCOM/ C(MD,1D), CN(MD,1D), XTERM(MD,1D),
00106 6. * S(MD,1D), F(MD,1D), FEE(MD,1D),
00106 7. * S(MD,1D), STERM(MD,1D),
00106 8. * E(MD), FF(MD), DX(MD),
00106 9. * GA(MD), DTUX(MD), T(MD),
00106 10. * X(MD),
00106 11. * XLAM(1D), PP(1D),
00106 12. * Y(1D), SINTG(1D),
00106 13. * CINTG(1D), CLINTG(1D), DCINTG(1D),
00106 14. * CSUM(1D), CSUMOD(1D), PSI(1D),
00106 15. * XK1(1D), LNUZ(1D), EI(1D),
00106 16. * PZ(1D), SA(1D), SB(1D),
00106 17. * SC(1D), SD(1D), XK(1D),
00106 18. * XLL(1D), PSICO(1D),
00106 19. * XJPL(1D), CPL(1D), PPL(1D),
00106 20. * CPCO(1D), WBS(1D), REL(1D),
00106 21. * XJPO(1D), CZ(1D)
00107 22. COMMON/CO41/
00107 23. * MIN1, CRIT,
00107 24. * QZB(1D), E3(1D),
00107 25. * J20(1D), E2(1D), J1(1D),
00107 26. * KA(1D), RB(1D), ZNZ(1D),
00107 27. * TZ(1D), ZETA(1D), S1(1D)
00110 28. COMMON/CO42/
00110 29. * CM(1D), R1(1D,ISD), RZ(1D,ISD),
00110 30. * FMAXS(1SD),
00110 31. * SINTT(JD,1D), SOLD(JD,1D), CINTT(JD,1D),
00110 32. * COLD(JD,1D), XJINTT(JD,1D), UJOLD(JD,1D),
00110 33. * CSUMT(JD,1D),
00110 34. * MPTS(JD), DELT(ND), TMAX(ND),
00110 35. * DELTP(NPD), TPMAX(NPD),
00110 36. * MTPM(NTD), TEMP(NTD,ISD),
00110 37. * U(MD,1D), XLAB(12), UD(1D),
00110 38. * IMAX, MMAX, MMAXX,
00110 39. * IFF, IG, IFEE,
00110 40. * ICHI, IPSI, UT,
00110 41. * IDU, JFF, JG,
00110 42. * JFEE, JPSI, JCHI,
00110 43. * JDU, ADAMP, BDAMP,
00110 44. * SELTO(1D), SSUM(1D), LBOP,
00110 45. * RES(100,1D), TT(100), NT,
00110 46. * TIME, NTMP
00111 47. DATA RST/32.0/
00111 48. C*****
00111 49. C***** PSIFUN CALCULATES PSI(I). *****
00111 50. C*****
00113 51. IF (IPSI.EQ.1.AND.TIME.GT.0.0) GO TO 104

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00115 52.      IF(I1.EQ.0)GO TO 100      PSIFUN
00117 53.      I1=I1                      PSIFUN
00120 54.      I2=I1                      PSIFUN
00121 55.      GO TO 101                  PSIFUN
00122 56.      100 I1=1                   PSIFUN
00123 57.      I2=IMAX                    PSIFUN
00124 58.      101 GO TO(10,20,30,40),JPSI
00125 59.      10 SUM=0.0
00126 60.      DO 103 I=1,IMAX
00131 61.      103 SUM=SUM+(C(MMAX,I)+C(MMAXM,I))/(2.0*CM(I))      PSIFUN
00133 62.      IF(SUM.LT.CRIT)SUM=CRIT      PSIFUN
00135 63.      DO 102 I=1,I2              PSIFUN
00140 64.      SU=SC(I)+SD(I)*1000.0/(.5*(I(MMAX)+I(MMAXM)))      PSIFUN
00141 65.      M=MMAXM
00142 66.      TMP1=G(M,I)/(C(M,I)+C(M+1,I))*2.0*DTUX(M)
00143 67.      PSI(I)=(TMP1-PSICO(I)/CM(I)*ABS(SUM) ** (SU-1.0))/F(M,I)      PSIFUN
00144 68.      102 CONTINUE                PSIFUN
00146 69.      GO TO 104
00147 70.      20 DO 21 I=1,I2
00152 71.      21 PSI(I)=1.E+20
00154 72.      GO TO 104
00155 73.      30 PSI(I)=0.0
00156 74.      40 GO TO 104
00157 75.      104 CONTINUE
00160 76.      RETURN
00161 77.      END

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END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).

W1 FOR CHIFUN,CHIFUN
UNIVAC 1108 FORTRAN IV LEVEL 2201 0029 F40148
THIS COMPILATION WAS DONE ON 20 FEB 68 AT 16:23:21

SUBROUTINE CHIFUN ENTRY POINT 000103

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000113
0000	*DATA	000016
0002	*BLANK	000000
0003	FIPCOM	023204
0004	COM1	000160
0005	COM2	007062

EXTERNAL REFERENCES (BLOCK, NAME)

0006 NERR2\$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000044	10L	0001	000026	100L	0001	000032	101L	0001	000076	102L	0001	000001	126G
0001	000000	134G	0001	000054	20L	0001	000076	30L	0001	000076	40L	0005	004714	ADAMP
0005	004715	ADAMP	0003	000000	C	0003	022612	CINTG	0005	001046	CINTT	0003	022624	CLINTG
0005	000024	CM	0003	002114	CM	0005	001130	COLD	0003	023122	CPLO	0003	023076	CPL
0004	000001	CRIT	0003	022650	CSUM	0003	022662	CSUMOD	0005	001356	CSUMT	0003	023172	CZ
0005	002532	D	0003	022636	DCINTG	0005	R 004662	DD	0005	001445	DELIT	0005	001471	DELTP
0005	001274	DDULD	0005	004704	DI	0003	022030	DTDX	0003	021474	DX	0004	000002	DZB
0004	000052	DI	0004	000026	D20	0003	021140	E	0004	000014	EB	0003	022732	EI
0004	000040	EE	0003	R 010460	F	0003	012574	FEF	0003	021316	FF	0003	006344	G
0003	021652	GA	0000	I 000003	I	0005	I 004702	ICHI	0005	004705	IDU	0005	004701	IFEE
0005	004677	IFF	0005	004700	IG	0005	I 004674	IMAX	0005	004703	IPSI	0000	I 000001	I1
0000	I 000002	I2	0005	I 004712	JCHI	0005	004713	JDD	0005	004710	JFEE	0005	004706	JFF
0005	004707	JG	0005	004711	JPSI	0005	004742	LBOP	0003	R 022720	LN0Z	0004	000000	MINT
0005	004675	MMAX	0005	I 004676	MMAXM	0005	001440	MPTS	0005	001515	MTMP	0005	007057	NT
0005	007061	NTMP	0003	022554	PP	0003	023110	PPL	0003	022674	PSI	0003	023052	PSICO
0003	022744	PZ	0005	000012	Q	0004	000064	KA	0004	000076	RB	0003	023146	REL
0005	004743	RES	0000	R 000000	RST	0005	000340	RZ	0005	000036	R1	0003	014710	S
0003	022756	SA	0003	022770	Sd	0003	023002	SC	0003	023014	SD	0005	004716	SELTO
0004	000140	SI	0003	022600	SINTG	0005	000702	SINTT	0005	000764	SOLD	0005	004730	SSUM
0003	017024	STERM	0003	022206	T	0005	001546	TEMP	0005	R 007060	TIME	0005	001457	TMAX
0005	000650	TPMAX	0005	001503	TPMAX	0005	006713	TT	0004	000122	TZ	0003	023134	WHB
0003	022364	X	0005	001212	XJINTT	0003	023064	XJPL	0003	023160	XJPO	0003	023026	YK
0003	R 022706	XK1	0005	004646	XLAD	0003	022542	XLAM	0003	R 023040	XLL	0003	004230	XTERM
0003	022566	Y	0004	000134	ZETA	0005	000000	ZMI	0004	000110	ZNZ			

```

00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. SUBROUTINE CHIFUN(II)
00103 2. REAL LNRZ,LNRZ
00104 3. PARAMETER IU=10, MD=110, JD=5, ND=10, NPU=10, NTU=25
00105 4. PARAMETER ISD=20
00106 5. COMMON/FIPCOM/ C(MD,IU), CN(MD,IU), XTERM(MD,IU),
00106 6. * S(MD,IU), F(MD,IU), FEE(MD,IU),
00106 7. * S(MD,IU), STERM(MD,IU),
00106 8. * E(MD), FF(MD), UX(MD),
00106 9. * GA(MD), DTUX(MD), T(MD),
00106 10. * X(MD),
00106 11. * XLAM(IU), PP(IU),
00106 12. * Y(IU), SINTG(IU),
00106 13. * CLINTG(IU), CLINTG(IU), DCINTG(IU),
00106 14. * CSUM(IU), CSUMOD(IU), PSI(IU),
00106 15. * XKI(IU), LNRZ(IU), EI(IU),
00106 16. * PZ(IU), SA(IU), SB(IU),
00106 17. * SC(IU), SD(IU), XK(IU),
00106 18. * XLL(IU), PSICO(IU),
00106 19. * XJPL(IU), CPL(IU), PPL(IU),
00106 20. * CFCU(IU), WDB(IU), REL(IU),
00106 21. * XJPO(IU), CZ(IU)
00107 22. COMMON/COM1/
00107 23. * MIN1, CRIT,
00107 24. * UZB(IU), EB(IU),
00107 25. * UZO(IU), EZ(IU), U1(IU),
00107 26. * RA(IU), RB(IU), ZNZ(IU),
00107 27. * FZ(IU), ZCFA(IU), SI(IU)
00110 28. COMMON/COM2/
00110 29. * CM(IU), RM(IU,ISD), RZ(IU,ISD),
00110 30. * TMAXS(ISD),
00110 31. * SINTT(JD,IU), SOLD(JD,IU), CINTT(JD,IU),
00110 32. * COLD(JD,IU), XJINTT(JD,IU), DJULD(JD,IU),
00110 33. * CSUMT(JD,IU),
00110 34. * MPTS(JD), DELT(ND), TMAX(ND),
00110 35. * DELTP(NPD), TPMAX(NPD),
00110 36. * MTMP(NTU), TEMP(NTU,ISD),
00110 37. * J(MD,IU), XLAB(12), DD(IU),
00110 38. * IMAX, VMAX, MMAX,
00110 39. * IFF, IG, IFEE,
00110 40. * ICHI, IPSI, DT,
00110 41. * IUD, JFF, JG,
00110 42. * JFEE, JPSI, JCHI,
00110 43. * JUD, ADAMP, BDAMP,
00110 44. * SELTD(IU), SSUM(IU), LBOP,
00110 45. * RES(100,IU), TT(100), NT,
00110 46. * TIME, NTMP
00111 47. DATA RST/82.0/
00111 48. C*****
00111 49. C***** CHIFUN CALCULATES X<I(I). *****
00111 50. C*****
00113 51. IF(ICH1.EQ.1.AND.TIME.GT.0.0100 TO 102
00115 52. IF(II.EQ.0)GO TO 100 CHIFUN
00117 53. I1=II CHIFUN

```

#ELCH FIPER 050 \$ JOB 454 \$

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```
00120 54.      12=11
00121 55.      60 TO 101
00122 56.    100 11=1
00123 57.      12=1MAX
00124 58.    101 60 TO(20,10,30,40),JCHI
00125 59.      10 DO 11 I=11,12
00130 60.      11 XK1(I)=0.0
00132 61.      60 TO 102
00133 62.      20 DO 21 I=11,12
00136 63.      21 XK1(I)=-DD(I)*CZ(I)/(P(MMAXM,1)*XLL(I))
00140 64.      60 TO 102
00141 65.      30 CONTINUE
00142 66.      40 CONTINUE
00143 67.    102 RETURN
00144 68.      END
```

CHIFUN
CHIFUN
CHIFUN
CHIFUN
CHIFUN

END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).

WI FOR FUNIN,FUNIN
 UNIVAC 1108 FORTRAN IV LEVEL 2201 0029 F40148
 THIS COMPILATION WAS DONE ON 20 FEB 68 AT 16:23:22

SUBROUTINE FUNIN ENTRY POINT 000073

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000075
0000	*DATA	000036
0002	*BLANK	000000
0003	FIPCOM	023204
0004	COM1	000160
0005	COM2	007062

EXTERNAL REFERENCES (BLOCK, NAME)

0006	NRUCS
0007	NIU1S
0010	NIU2S
0011	NPRTS

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	000001	00F	0000	000002	81F	0000	000017	82F	0005	004714	ADAMP	0005	004715	ADAMP
0003	000000	C	0003	022612	CLINTG	0005	001046	CLINTT	0003	022624	CLINTG	0005	000024	CM
0003	002114	CM	0005	001130	COLD	0003	023122	CPCO	0003	023076	CPL	0004	000001	CRIT
0003	022650	CSUM	0003	022662	CSUMOD	0005	001356	CSUMT	0003	023172	CZ	0005	002532	D
0003	022636	DCINTG	0005	004662	DU	0005	001445	DELT	0005	001471	DELTP	0005	001274	DJOLJ
0005	004704	DT	0003	022030	DTDX	0003	021474	DX	0004	000002	DZB	0004	000052	D1
0004	000026	DUO	0003	021140	E	0004	000014	EB	0003	022732	EI	0004	000040	E2
0003	010460	F	0003	012574	FEE	0003	021316	FF	0003	006344	G	0003	021652	GA
0005	I 004702	ICHI	0005	I 004705	IUD	0005	I 004701	IFEE	0005	I 004677	IFF	0005	I 004700	IG
0005	004674	IMAX	0005	I 004703	IPSI	0005	I 004712	JCHI	0005	I 004713	JUD	0005	I 004710	JFEE
0005	I 004706	JFF	0005	I 004707	JG	0005	I 004711	JPSI	0005	004742	LBOP	0003	R 022720	LNUZ
0004	000000	MINT	0005	004675	MMAH	0005	004676	MMAH	0005	001440	MPTS	0005	001515	MTMP
0005	007057	NT	0005	007061	NIMP	0003	022554	PP	0003	023110	PPL	0003	022674	PSI
0003	023052	PSICO	0003	022744	PZ	0005	000012	Q	0004	000064	RA	0004	000076	RB
0003	023146	REL	0005	004743	RES	0000	R 000000	RST	0005	000346	RZ	0005	000036	R1
0003	014710	S	0003	022756	SA	0003	022770	SB	0003	023002	SC	0003	023014	SD
0005	004716	SELTO	0004	000146	SI	0003	022600	SINTG	0005	000702	SINTT	0005	000764	SOLD
0005	004730	SSUM	0003	017024	STERM	0003	022206	T	0005	001546	TEMP	0005	007060	TIME
0005	001457	IMAX	0005	000656	IMAXS	0005	001503	TPMAX	0005	006713	TT	0004	000122	TZ
0003	023134	WBB	0003	022364	X	0005	001212	XJINTT	0003	023064	XJPL	0003	023160	XJPO
0003	023026	XK	0003	022706	XK1	0005	004646	XLAB	0003	022542	XLAM	0003	023040	XLL
0003	004230	ATERM	0003	022566	Y	0004	000134	ZETA	0005	000000	ZMI	0004	000110	ZNZ

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00000 *DIAGNOSTIC* THE NAME LNKZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. SUBROUTINE FUNIN
00103 2. REAL LNRZ,LNUZ
00104 3. PARAMETER IU=10, MD=110, JU=5, ND=10, NPU=10, NTD=25
00105 4. PARAMETER ISD=20
00106 5. COMMON/FIPCOM/ C(MD,IU), CN(MD,IU), XTERM(MD,IU),
00106 6. * G(MD,IU), F(MD,IU), FEE(MD,IU),
00106 7. * S(MD,IU), STERM(MD,IU),
00106 8. * E(MD), FF(MD), DX(MD),
00106 9. * GA(MD), DTUX(MD), T(MD),
00106 10. * X(MD),
00106 11. * XLAM(IU), PP(IU),
00106 12. * Y(IU), SINTG(IU),
00106 13. * CINTG(IU), CLINTG(IU), DCINTG(IU),
00106 14. * CSUM(IU), CSUMOU(IU), PSI(IU),
00106 15. * XKI(IU), LNUZ(IU), EI(IU),
00106 16. * PZ(IU), SA(IU), SB(IU),
00106 17. * SC(IU), SD(IU), XK(IU),
00106 18. * XLL(IU), PSICO(IU),
00106 19. * XJPL(IU), CPL(IU), PPL(IU),
00106 20. * CPCO(IU), WBB(IU), REL(IU),
00106 21. * XJPO(IU), CZ(IU)
00107 22. COMMON/COM1/
00107 23. * MINT, CRIT,
00107 24. * DZB(IU), EB(IU),
00107 25. * UZ0(IU), E2(IU), D1(IU),
00107 26. * RA(IU), RB(IU), ZNZ(IU),
00107 27. * TZ(IU), ZETA(IU), SI(IU),
00110 28. COMMON/COM2/
00110 29. * CM(IU), ZM1(IU), Q(IU),
00110 30. * IMAXS(ISD), RI(IU,ISD), RZ(IU,ISD),
00110 31. * SINTT(JU,IU), SOLD(JU,IU), CINTT(JU,IU),
00110 32. * COLD(JU,IU), XJINTT(JU,IU), DJOLD(JU,IU),
00110 33. * CSUMT(JU,IU),
00110 34. * MPTS(JU), DELT(NU), TMAX(NU),
00110 35. * DELTP(NPU), TPMAX(NPU),
00110 36. * MTMP(NTD), TEMP(NTD,ISD),
00110 37. * U(MD,IU), XLAB(12), DD(IU),
00110 38. * IMAX, VMAX, MMAX,
00110 39. * IFF, IG, IFEE,
00110 40. * ICHI, IPSI, DT,
00110 41. * IJU, JFF, JG,
00110 42. * JFEE, JPSI, JCHI,
00110 43. * JDU, ADAMP, BDAMP,
00110 44. * SELTO(IU), SSUM(IU), LBOP,
00110 45. * RES(100,IU), TT(100), NT,
00110 46. * TIME, NTMP
00111 47. DATA RST/82.0/
00111 48. C*****
00111 49. C***** FUNIN HANDLES INPUT PERTAINING TO FUNCTIONS. *****
00111 50. C*****
00113 51. READ 80,IFF,IG,IFEE,IPSI,ICHI,IJU,JFF,JG,JFEE,JPSI,JCHI,JDU
00131 52. BU FUMAT(1216) FUNIN

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00132 33. PRINT R1,IFF,IG,IFEE,IPSI,ICHI,IUD
00142 54. 01 FORMAT(6H IFF=,10,6H IG=,16,6H IFEE=,16,6H IPSI=,16,6H ICHI=, FUNIN
00142 55. *10,6H IUD=,16)
00143 56. PRINT R2,JFF,JG,JFEE,JPSI,JCHI,JUD
00153 57. 02 FORMAT(6H JFF=,10,6H JG=,16,6H JFEE=,16,6H JPSI=,16,
00153 58. *6H JCHI=,16,6H JUD=,16)
00154 59. RETURN
00155 60. END
```

END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).


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00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. SUBROUTINE BPRT(11)
00103 2. REAL LNRZ,LNUZ
00104 3. PARAMETER ID=10, MD=110, JU=5, ND=10, NPU=10, NT0=25
00105 4. PARAMETER ISD=20
00106 5. COMMON/FIPCOM/ C(MD,10), CN(MD,10), XTERM(MD,10),
00106 6. * G(MD,10), F(MD,10), FEE(MD,10),
00106 7. * S(MD,10), STERM(MD,10),
00106 8. * E(MD), FF(MD), UX(MD),
00106 9. * GA(MD), DTUX(MD), T(MD),
00106 10. * X(MD),
00106 11. * XLAM(10), PP(10),
00106 12. * Y(10), SINTG(10),
00106 13. * CINTG(10), CLINTG(10), DCINTG(10),
00106 14. * CSUM(10), CSUM0(10), PSI(10),
00106 15. * XKI(10), LNUZ(10), EI(10),
00106 16. * PZ(10), SA(10), SB(10),
00106 17. * SC(10), SD(10), XK(10),
00106 18. * XLL(10), PSICO(10),
00106 19. * XJPL(10), CPL(10), PPL(10),
00106 20. * CPCO(10), #BB(10), REL(10),
00106 21. * XJPO(10), CZ(10)
00107 22. COMMON/COM1/
00107 23. * MIN1, CR1,
00107 24. * DZB(10), EB(10),
00107 25. * DZ0(10), E2(10), D1(10),
00107 26. * RA(10), RB(10), ZNZ(10),
00107 27. * IZ(10), ZETA(10), SI(10),
00110 28. COMMON/COM2/
00110 29. * CM(10), R1(10,ISD), RZ(10,ISD),
00110 30. * TMAXS(1SD),
00110 31. * SINTT(JU,10), SOLD(JU,10), CINTT(JU,10),
00110 32. * COLD(JU,10), XJINTT(JU,10), DJOLD(JU,10),
00110 33. * CSUMT(JU,10),
00110 34. * MPTS(JU), DELT(ND), TMAX(ND),
00110 35. * DELTP(NPD), TPMAX(NPD),
00110 36. * MTPM(NT0), TEMP(NT0,ISD),
00110 37. * U(MD,10), XLAB(12), DD(10),
00110 38. * IMAX, VMAX, MMAX,
00110 39. * IFF, IG, IFE,
00110 40. * ICHI, IPSI, DT,
00110 41. * IUD, JFF, JG,
00110 42. * JFE, JPSI, JCHI,
00110 43. * JU0, ADAMP, BDAMP,
00110 44. * SELTO(10), SSUM(10), LBOP,
00110 45. * RES(100,10), TT(100), NT,
00110 46. * TIME, NTMP
00111 47. COMMON/BPLOC/PIAREA
00112 48. DATA RST/02.0/
00112 49. C*****
00112 50. C***** BPRT PRINTS QUANTITIES FOR RIGHT BOUNDARY. *****
00112 51. C*****

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WELCH FIPER 050 \$ JOB 454 \$

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00114 52.      CPL(II)=PPL(II)/CPCU(II)
00115 53.      XJPL(II)=WBB(II)*CPL(II)-UU(II)*CZ(II)/XLL(II)      BPRT
00116 54.      TOR=TIAREA*REL(II)      BPRT
00117 55.      RES(NT,II)=TOR      BPRT
00120 56.      PRINT 10
00122 57.      PRINT 11,11,PSI(II),XKI(II),XJPL(II),CPL(II),PPL(II),REL(II)
00122 58.      *,TOR      BPRT
00134 59.      10 FORMAT(6HJ      1,9X,3HPS1,9X,3HXK1,7X,5HJPLUS,7X,5HCPLUS,
00134 60.      *7X,5HJPLUS,3X,9HREL/LM**2,5X,7HRELEASE)      BPRT
00135 61.      11 FORMAT(1H ,15,1P9E12.4)
00136 62.      PRINT 12
00140 63.      12 FORMAT(1HJ)
00141 64.      RETURN
00142 65.      END

```

END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).

#1 FOR RELPLT,RELPLT
 UNIVAC 1108 FORTRAN IV LEVEL 2201 0029 F40148
 THIS COMPILATION WAS DONE ON 20 FEB 68 AT 16:23:25

SUBROUTINE RELPLT ENTRY POINT 000170

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000201
0000	*DATA	000100
0002	*BLANK	000000
0003	FIPCOM	023204
0004	COM1	000160
0005	COM2	007062
0006	DPCOM	000001

EXTERNAL REFERENCES (BLOCK, NAME)

0007	BCDCON
0010	PLUTV
0011	IN#005
0012	IN#025

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000020	1166	0001	000021	1216	0001	000072	1466	0001	000105	1516	0000	000040	2116
0001	000155	2116	0001	000117	2146	0000	000043	2216	0000	000052	2316	0005	004714	ADAMP
0005	004715	ADAMP	0003	000000	C	0003	022612	CINT6	0005	001046	CINTT	0003	022624	CLINTC
0005	000024	CM	0003	002114	CM	0005	001130	COLD	0003	023122	CPCO	0003	023076	CPL
0004	000001	CRIT	0003	022650	CSUM	0003	022662	CSUMOD	0005	001356	CSUMI	0003	023172	CZ
0005	002532	C	0003	022636	DCINT6	0005	004662	DO	0005	001445	DELT	0005	001471	DELTP
0005	001274	DOULJ	0005	004704	DI	0003	022030	DTUX	0003	021474	DX	0004	000002	DZB
0004	000052	DI	0004	000026	DUO	0003	021140	E	0004	000014	EB	0003	022732	EI
0004	000040	E2	0003	010460	F	0003	012574	FEE	0003	021316	FF	0003	006344	G
0003	021652	GA	0000	R 000000	GLAB	0000	I 000033	I	0005	004702	ICHI	0005	004705	IDU
0005	004701	IFEE	0005	004677	IFP	0005	004700	IG	0005	I 004674	IMAX	0005	004703	IPSI
0000	I 000030	J	0005	004712	JCHI	0005	004713	JDD	0005	004710	JFEE	0005	004706	JFF
0005	004707	JG	0005	004711	JPSI	0005	004742	LBOP	0003	R 022720	LNDZ	0004	000000	MINT
0005	004675	MMAX	0005	004676	MMAXM	0005	001440	MPTS	0005	001515	MTMP	0000	I 000032	N
0000	I 000037	NP	0005	I 007057	NI	0005	007061	NTMP	0003	022554	PP	0003	023110	PPL
0003	022674	PSI	0003	023052	PSICO	0003	022744	PZ	0005	000012	Q	0004	000064	RA
0004	000076	RB	0003	023146	REL	0005	R 004743	RES	0000	R 000034	RN	0000	R 000030	RX
0005	000340	RZ	0005	000036	RI	0003	014710	S	0003	022756	SA	0003	022770	SB
0003	023002	SC	0003	023014	SD	0005	004716	SELTO	0004	000146	SI	0003	022600	SINTG
0005	000702	SINTT	0005	000764	SOLU	0005	004730	SSUV	0003	017024	STERM	0003	022206	T
0005	001540	TEMP	0006	000000	TIAKKA	0005	007060	TIME	0005	001457	TMAX	0005	000656	TMAXS
0000	R 000035	IN	0005	001503	TPMAX	0005	R 006713	TT	0000	R 000031	TX	0004	000122	TZ
0003	023134	WDB	0003	022364	X	0005	001212	XJINTT	0003	023064	XJPL	0003	023160	XJPO
0003	023020	XK	0003	022706	XKI	0005	R 004646	XLAB	0003	022542	XLAM	0003	023040	XLL

WELCH

FIPER

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0003 004230 XTERN

0003 022506 Y

0000 R 000014 YLAB

0004 000134 ZETA

0005 000000 ZMI

0004 000110 ZMZ

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00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. SUBROUTINE RELPLT
00103 2. REAL LNRZ,LNUZ
00104 3. PARAMETER IU=10, MU=110, JU=5, NU=10, NPU=10, NTU=25
00105 4. PARAMETER ISU=20
00106 5. COMMON/FIPCOM/ C(MU,IU), CN(MU,IU), XTERM(MU,IU),
00106 6. * G(MU,IU), F(MU,IU), FEE(MU,IU),
00106 7. * S(MU,IU), STEPM(MU,IU),
00106 8. * E(MU), FF(MU), DX(MU),
00106 9. * GA(MU), DTUX(MU), T(MU),
00106 10. * X(MU),
00106 11. * XLAM(IU), PP(IU),
00106 12. * Y(IU), SINTG(IU),
00106 13. * CINTG(IU), CLINTG(IU), UCINTG(IU),
00106 14. * CSUM(IU), CSUMMU(IU), PSI(IU),
00106 15. * XK1(IU), LNUZ(IU), EI(IU),
00106 16. * PZ(IU), SA(IU), SB(IU),
00106 17. * SL(IU), SD(IU), XK(IU),
00106 18. * XLL(IU), PSICO(IU),
00106 19. * XJPL(IU), CPL(IU), PPL(IU),
00106 20. * CPLO(IU), XBS(IU), REL(IU),
00106 21. * XJPO(IU), CZ(IU)
00107 22. COMMON/CO-1/
00107 23. * MINT, CRIT,
00107 24. * DZB(IU), EB(IU),
00107 25. * JZ0(IU), E2(IU), D1(IU),
00107 26. * RA(IU), RB(IU), ZNZ(IU),
00107 27. * TZ(IU), ZETA(IU), SI(IU),
00110 28. COMMON/CO-2/
00110 29. * CA(IU), ZMI(IU), Q(IU),
00110 30. * TMAXS(ISU), R1(IU,ISU), RZ(IU,ISU),
00110 31. * SINTT(JU,IU), SOLD(JU,IU), CINTT(JU,IU),
00110 32. * COLU(JU,IU), XJINTT(JU,IU), UJOLU(JU,IU),
00110 33. * CSUMT(JU,IU),
00110 34. * MPTS(JU), DELT(NU), TMAX(NU),
00110 35. * DELTP(NPU), TPMAX(NPU),
00110 36. * MTPM(NTU), TEMP(NTU,ISU),
00110 37. * U(MU,IU), XLAB(12), DD(IU),
00110 38. * LMAX, MMAX,
00110 39. * IFF, IG, IFEE,
00110 40. * ICHI, IPSI, DT,
00110 41. * IJU, JFF, JG,
00110 42. * JFEC, JPSI, JCHI,
00110 43. * JUU, ADAMP, BDAMP,
00110 44. * SELTO(IU), SSUM(IU), LBOP,
00110 45. * RES(100,IU), TT(100), NT,
00110 46. * TIME, NTMP
00111 47. COMMON/SPCOM/PIAREA

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00112 48.      DIMENSION GLAB(12),      YLAB(12)
00112 49.      C*****
00112 50.      C***** RELPLT GIVES 4020 PLOT OF RELEASE VS TIME. *****
00112 51.      C*****
00113 52.      RX=RES(1,1)
00114 53.      TX=TT(NT)
00115 54.      DO 212 N=1,NT
00120 55.      DO 212 I=1,IMAX
00123 56.      212 RX=AMAX1(RX,RES(N,I))
00126 57.      RN=1.E-7*RX
00127 58.      TN=0.0
00130 59.      CALL BCDCON(XLAB(10))
00131 60.      WRITE(0,21)
00133 61.      21 FORMAT(12H          )
00134 62.      CALL BCDCON(YLAB)
00135 63.      WRITE(0,22)
00137 64.      22 FORMAT(28H TOTAL RELEASE    MICRO-MOLEES,44X)
00140 65.      CALL BCDCON(GLAB)
00141 66.      WRITE(0,23)
00143 67.      23 FORMAT(10H TIME DAYS,62X)
00144 68.      J=1
00145 69.      DO 211 I=1,IMAX
00150 70.      DO 213 N=1,NT
00153 71.      213 IF(RES(N,I).GT.RN)GO TO 214
00156 72.      GO TO 211
00157 73.      214 NP=NT-N+1
00160 74.      CALL PLOTV(J,3,1,3,NP,TT(N),RES(N,1),TN,TX,RN,RX,GLAB,YLAB,XLAB) RELPLT
00161 75.      J=2
00162 76.      211 CONTINUE
00164 77.      RETURN
00165 78.      END

```

END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).

#1 FOR TCHANG,TCHANG
 UNIVAC 1108 FORTKIN 1V LEVEL 2201 0029 F40148
 THIS COMPILATION WAS DONE ON 20 FEB 68 AT 16:23:27

SUBROUTINE TCHANG ENTRY POINT 000233

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000256
0000	*DATA	000055
0002	*BLANK	000000
0003	FIPCOM	023204
0004	COM1	000160
0005	COM2	007062

EXTERNAL REFERENCES (BLOCK, NAME)

0006	EXP
0007	FUNS
0010	NEAP65

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000041	1206	0001	000057	1266	0001	000077	1346	0001	000112	1436	0001	000123	1506
0005	004714	ADAMP	0005	004715	BDAMP	0003	000000	C	0003	022612	CINTG	0005	001046	CINTT
0003	022624	CLINTG	0005	000924	CM	0003	002114	CM	0005	001130	COLU	0003 R	023122	CPCO
0003	023070	CPL	0004	000901	CKIT	0003	022650	CSUM	0003	022662	CSUMOD	0005	001356	CSUMT
0003	023172	CZ	0005	002552	D	0003	022630	DCINTG	0005 R	004662	DD	0005	001445	DELT
0005	001471	DELTP	0005	001274	DDJULU	0005	004704	DT	0003 R	022030	DTDX	0003	021474	DX
0004	000002	DZB	0004	000052	D1	0004	000026	D20	0003	021140	E	0004	000014	EB
0003	022732	E1	0006 R	000000	EXP	0004	000040	E2	0003	010460	F	0003	012574	FEE
0003	021316	FF	0003	000344	G	0003	021652	GA	0000 I	000010	I	0005	004702	ICHI
0005	004705	IGU	0005	004701	IFEE	0005	004677	IFF	0005	004700	IG	0005 I	004674	IMAX
0005	004703	IPSI	0005	004712	JCHI	0005	004713	JDD	0005	004710	JFEE	0005	004706	JFF
0005	004707	JG	0005	004711	JPSI	0000 I	000006	K	0005	004742	LBOP	0003 R	022720	LNDZ
0000 I	000004	M	0004	000000	MINI	0005 I	004675	MMAX	0005 I	004676	MMAXM	0005	001440	MPTS
0005 I	001515	MTMP	0000 I	000007	M1	0000 I	000001	M2	0000 I	000002	M3	0005	007057	NT
0005 I	007061	NTMP	0000 I	000005	NTMPM	0003	022554	PP	0003	023110	PPL	0003	022674	PS1
0003 R	023052	PS1CU	0003 R	022744	PZ	0005	000012	Q	0004	000064	RA	0004	000076	RB
0003	023146	REL	0005	004743	RES	0000 R	000000	RST	0005	000345	RZ	0005	000036	R1
0003	014710	S	0003 R	022756	SA	0003 R	022770	SB	0003 R	023002	SC	0003 R	023014	SD
0005	004716	SELTO	0004	000146	SI	0003	022600	SINTG	0005	000702	SINTT	0000 R	000003	SLOPE
0005	000764	SOLD	0005	004730	SSUM	0003	017024	STERM	0000 R	000014	SU	0000 R	000013	SV
0003 R	022206	I	0000 R	000011	TD	0005 R	001546	TEMP	0005	007060	TIME	0005	001457	TMAX
0005	000650	IMAXS	0005	001503	TPMAX	0005	006713	TT	0004 R	000122	TZ	0000 R	000012	WB
0003 R	023134	*BB	0003 R	022364	X	0005	001212	XJINTT	0003	023064	XJPL	0003	023160	XJPO
0003 R	023026	XK	0003	022706	XKI	0005	004646	XLAB	0003	022542	XLAM	0003 R	023040	XLL
0003	004230	ATERM	0003	022566	Y	0004 R	000134	ZETA	0005	000000	ZMI	0004	000110	ZNZ

```

00000 *DIAGNOSTIC* THE NAME LNRZ APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101 1. SUBROUTINE TCHANG(IS)
00103 2. REAL LNRZ,LNUZ
00104 3. PARAMETER ID=10, MD=110, JD=5, ND=10, NPD=10, NTU=25
00105 4. PARAMETER ISD=20
00106 5. COMMON/FIPCOM/ C(MD,10), CN(MD,10), XTERM(MD,10),
00106 6. * G(MD,10), F(MD,10), FEE(MD,10),
00106 7. * S(MD,10), STERM(MD,10),
00106 8. * E(MD), FF(MD), DX(MD),
00106 9. * GA(MD), DTUX(MD), T(MD),
00106 10. * X(MD),
00106 11. * XLAM(10), PP(10),
00106 12. * Y(10), SINTG(10),
00106 13. * CINTG(10), CLINTG(10), DCINTG(10),
00106 14. * CSUM(10), CSJMU(10), PSI(10),
00106 15. * XK1(10), LNUZ(10), EI(10),
00106 16. * PZ(10), SA(10), SB(10),
00106 17. * SC(10), SJ(10), XK(10),
00106 18. * XLL(10), PSICO(10),
00106 19. * XJPL(10), CPL(10), PPL(10),
00106 20. * CPCU(10), WBS(10), REL(10),
00106 21. * XJPO(10), CZ(10)
00107 22. COMMON/CO41/
00107 23. * MINT, CRIT,
00107 24. * DZB(10), EB(10),
00107 25. * DZ0(10), E2(10), D1(10),
00107 26. * RA(10), RB(10), ZNZ(10),
00107 27. * TZ(10), ZETA(10), SI(10)
00110 28. COMMON/CO42/
00110 29. * CM(10), R1(10,ISD), RZ(10,ISD),
00110 30. * TMAXS(ISD),
00110 31. * SINIF(JD,10), SOLD(JD,10), CINTT(JD,10),
00110 32. * COLU(JD,10), XJINTT(JD,10), DJOLO(JD,10),
00110 33. * CSUMT(JD,10),
00110 34. * MPTS(JD), DELT(ND), TMAX(ND),
00110 35. * DELTP(NPD), TPMAX(NPD),
00110 36. * MTMP(NTU), TEMP(NTU,ISD),
00110 37. * D(MD,10), XLAB(12), DD(10),
00110 38. * IMAX, VMAX, MMAX,
00110 39. * IFF, IG, IFEE,
00110 40. * ICH1, IPSI, DT,
00110 41. * IDD, JFF, JG,
00110 42. * JFEE, JPSI, JCH1,
00110 43. * JUD, ADAMP, BDAMP,
00110 44. * SELTO(10), SSUM(10), LBOP,
00110 45. * RES(100,10), TT(100), NT,
00110 46. * TIME, NTMP
00111 47. DATA RST/02.0/
00111 48. C****
00111 49. C***** TCHANG CALCULATES PARAMETERS DEPENDING ON TIME *****
00111 50. C***** DEPENDENT INPUT. *****

```

```

00111 51. C*****
00112 52.      109 M2=TEMP(2)
00114 53.      M3=TEMP(3)
00115 54.      SLOPE=(TEMP(3,15)-TEMP(1,15))/(2.0*X(M3)-X(M2))
00116 55.      TEMP(2,15)=TEMP(1,15)+SLOPE*X(M2)
00117 56.      DO 110 M=1,M2
00122 57.      110 T(M)=TEMP(1,15)+SLOPE*(X(M)**2)/X(M2)
00124 58.      NTEMP=NTEMP-1
00125 59.      DO 111 K=2,NTEMP
00130 60.      M1=TEMP(K)
00131 61.      M2=TEMP(K+1)
00132 62.      SLOPE=(TEMP(K+1,15)-TEMP(K,15))/(X(M2)-X(M1))
00133 63.      DO 111 M=1,M2
00136 64.      T(M)=TEMP(K,15)+SLOPE*(X(M)-X(M1))
00137 65.      111 CONTINUE
00142 66.      DO 112 M=1,MMAX
00145 67.      112 TUX(M)=(T(M+1)-T(1))/(X(M+1)-X(M))
00147 68.      DO 121 I=1,IMAX
00152 69.      TB=(T(MMAX)+T(MMAX))/2.0
00153 70.      AB=UD(I)/ALL(1)*(1.0-2.0*XK(I)*((TB-TZ(I))/(TB+TZ(I)))
00153 71.      *-ZETA(I))
00154 72.      SV=SA(I)+1000.0*SB(1)/TB
00155 73.      SU=SC(I)+1000.0*SU(1)/TB
00156 74.      PSLC(I)=AB*EXP(SV)*PZ(1)**SU/(
00157 75.      WDB(I)=WB
00160 76.      PCU(1)=1.0-6*RS*T*TB
00161 77.      121 CONTINUE
00163 78.      CALL FUN5(0,0)
00164 79.      RETURN
00165 80.      END

```

END OF LISTING. 1 *DIAGNOSTIC* MESSAGE(S).

WELCH FIPER 050 \$ JOB 454 \$

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* XGT CUR

1. OUT A

2. TEF A

3. TRI A

END CUR LCC 1102-0035 L6

WELCH FIPER 050 \$ JOB 454 \$

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W XQT FIPER

STARTING ADDRESS 014000

CORE LIMITS 014000 037500 100000 141373 163372 163377

FIPER /CODE

0 100000-101105
1 014000-020134

NPAUS\$/GA

0 101100-101110
1 020135-020160

NEXP6\$/CODE

1 020167-020170
2 101111-101111

NEHR\$/GA

1 020177-020320
2 101112-101145

NXPAP\$/CODE

1 020327-020414
2 101146-101151

NXPAX\$/CODE

1 020415-020437
2 101152-101152

NOUT\$/GA

0 101153-101154
1 020440-021035
2 101155-101277

NFTV\$/CODE

1 021634-021657

NFMT\$/GA

0 101300-101300
1 021660-022065
2 101301-101561

..ELUM

PIPER

750

\$ 003 454 5

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VIER3 /GA

1 022004-023030
2 101502-101017

V14P13/GA

1 023034-024012
2 101020-101034

PLU1V /C00E

0 101030-101040
1 024010-024127

PLU1P /C00E

0 101044-101000
1 024130-024442

UVR /A1

0 101000-101720
1 024440-025000

SL4E /A1

0 101721-101724
1 025001-025020

PUR0E /A1

0 101725-101732
1 025025-025037

V14V /GA

1 025037-025070
2 101733-102050

IL43L3/C00E

0 102050-102000

IS4R43/C00E

0 102000-102140

THRU3 /C00E

0 102141-102250

IS4AP3/C00E

0 102254-102304

TI4TL3/C00E

0 102305-102450

U04P1 /A1

0 102454-102470
1 020570-020020

P00MP3/GA

0 102474-103111

WELCH

PIPEX

000

\$ JOB 454 \$

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1 020624-027735

YUNIT /CODE

0 103112-103117

1 027736-027770

XUNIT /CODE

0 103120-103125

1 027777-030030

OR /CODE

1 030037-030045

PLUTC /A1

0 103120-103130

1 030044-030077

PLOT /A1

0 103131-103155

1 030100-030275

ALOG10/CODE

1 030276-030315

2 103154-103160

LAD /CODE

0 103161-103170

1 030314-030365

RIFE /CODE

0 103177-103200

1 030365-030605

RATEL /CODE

0 103207-103235

1 030604-031124

NEXP15/CODE

1 031125-031160

2 103236-103230

VCHAR1/CODE

0 103237-103267

1 031161-031050

AND /CODE

1 031651-031055

CSIZE /CODE

0 103270-103274

1 031650-031717

GRIDV /CODE

0 103275-103301

WELCH

FIPER

050

\$ JOB 454 \$

20 FEB 68 PAGE 53

1 031720-032030

ULJGV /CODE

0 103302-103340

1 032037-032263

LABELG/CODE

0 103347-103370

1 032264-032372

NELPSS/CODE

1 032373-032424

2 103371-103373

TSP /A1

0 103374-103450

1 032425-033000

FUCON /A1

0 103450-103500

1 033004-033140

ULINV /CODE

0 103601-103640

1 033146-033432

GXA1 /A1

0 103644-103664

1 033433-033554

COMPL /CODE

1 033655-033657

LADELN/CODE

0 103665-103722

1 033660-034030

GYA1 /A1

0 103723-103740

1 034030-034250

FRAME /A1

0 103744-103757

1 034254-034332

AUF /A1

0 103760-103762

1 034333-034340

CUTMRK/A1

0 103763-104000

1 034347-034372

BLUCOV/GA

WELCH

FIPER

050

\$ JOB 454 \$

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U 104004-104000

BPRX /CODE

U 104007-104040

1 034375-034457

FUNS /CODE

U 104041-104047

1 034460-034055

CHIFUN/CODE

U 104050-104065

1 034650-034770

PSIFUN/CODE

U 104000-104135

1 034771-035225

FFUN /CODE

U 104134-104150

1 035220-035277

GFUN /CODE

U 104151-104205

1 035300-035470

JFUN /CODE

U 104206-104230

1 035477-035724

FEFUN /CODE

U 104237-104264

1 035725-036034

FINISH/A1

U 104205-104271

1 036035-036000

SL4020/CODE

U 104272-104277

1 036061-036100

RELPLT/CODE

U 104300-104377

1 036101-036301

WARN /GA

U 104400-104427

EXP /CODE

1 036302-036344

2 104430-104447

TCHANG/CODE

U 104450-104524
1 036345-036022

ALCO /CJCE
1 030020-030052
2 104525-104552

SWRT /CJCE
1 030650-036710
2 104555-104560

FOUNIN /CJCE
U 104501-104010
1 036710-037012

3-IUP /A1
U 104017-104000
1 037010-037100

INMNUB/GA
1 037101-037110

IUP /A1
U 104001-104737
1 037174-037450

3A10 /R+R14
1 037454-037402

751 /A1
U 104730-104737
1 037402-037500

PLPUB/*****
U 104740-100140

UVA /*****
U 100144-100020

UPE /*****
U 100324-107400

3PUB /*****
U 107400-107400

ULIP /*****
U 107401-140000

UVC /*****
U 140000-140740

UVC /*****
140741-141202

WELCH FIPER 050 3 J08 454 3

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PPKGC1/*****
U 141263-141375

END OF ALLOCATION 4103 0033