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ANALYSIS OF THE THERMAL-HYDRAULIC BEHAVIOR IN
THE CRBR SECONDARY CONTROL ASSEMBLY,
INCLUDING INTERASSEMBLY HEAT TRANSFER EFFECTS

by

K.L. Basehore
N.E. Todreas

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ABSTRACT

This report represents a first effort at modeling the thermal hydraulic behavior of the CRBR secondary control assembly (SCA). For modeling purposes, the SCA is broken into two sections, the counterflow section and the poison control section, which contains the control bundle. The coolant temperature distribution in the counterflow section is evaluated by using a semianalytical solution technique. The distribution in the poison control section is found by using forward differenced numerical techniques. The wire wrap sweeping in the control bundle is represented by an empirical enhanced eddy diffusion of heat as in the ENERGY model. The SCA modeling scheme allows complete user specification of the bundle heat transfer boundary conditions, including also the capability for interassembly coupling to fuel bundles modeled by the SUPERENERGY code. A complete derivation of the governing equations is included. The computer program and associated sample problems are found in the Appendices.

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1. INTRODUCTION

The secondary control assembly (SCA) for the Clinch River Breeder Reactor (CRBR) is presently under development at General Electric. The current design, as illustrated in Figure 1, consists of a poison control section above a counterflow section into which the poison control bundle can be inserted during a scram. The assembly is positioned near the surrounding fuel sub-assemblies. Also, because of positioning, the assembly experiences moderate gamma heating effects.

The purpose of this report, then, is to develop a method of modeling the thermal-hydraulic behavior of the SCA. Any such model must include capabilities to handle the counter flow paths, volumetric heating effects due to gamma radiation and poison rod heat generation, and interassembly heat transfer effects. In this case, for multiassembly coupling, the SUPERENERGY [3] code will be used. These items will be discussed in more detail in the following sections.

2. SCA COUNTERFLOW SECTION - MODEL DEVELOPMENT

The counterflow section of the SCA is much like a counter-flow heat exchanger with internal heat generation due to gamma heating and a variable temperature boundary condition at the exterior wall due to the surrounding fuel bundles. Figure 2 shows the simplified counterflow section that will be modeled here, along with the appropriate subchannel labeling. A semi-analytical solution is possible in the downflow region,

designated subchannel type 2, but a numerical solution is required in subchannel types 1 and 3 because of the variable boundary conditions. These solutions are developed in the subsections which follow.

2.1 Downflow Region

Applying an energy balance to the downflow region in Figure 2 yields the following expression.

$$\dot{m}_2 C_p dT(x) = q_2'' dVol_{II} + q_{1 \rightarrow 2}'' dA_{II} \quad (2-1)$$

with the boundary condition

$$\bar{T}_1(x=0) = T_2(x=0) \quad (2-2)$$

where

$$dA_{II} = 2\pi R_1 dx \quad (2-3)$$

$$dVol_{II} = \pi R_1^2 dx \quad (2-4)$$

$$q_{1 \rightarrow 2}'' = (\bar{T}_1(x) - T_2(x)) / F_1 \quad (2-5)$$

The variable definitions are listed in the nomenclature section. $\bar{T}_1(x)$ is the average temperature of the circumferentially varying type 1 subchannels. It is the quantity that governs the type 2 subchannel heat transfer behavior. The volumetric heat generation rate is assumed to be represented by the sum of the two exponentials.

$$q_2'' = q_{2a}'' e^{-b_a x} + q_{2b}'' e^{-b_b x} \quad (2-6)$$

With the substitution of equations (2-3) to (2-6), equation (2-1) becomes.

$$\frac{dT_2(x)}{dx} = \beta(q_{2a}'' e^{-b_a x} + q_{2b}'' e^{-b_b x}) + \alpha(T_1(x) - T_2(x)) \quad (2-7)$$

where

$$\alpha = \frac{2\pi R_1}{m_2 C_p} \quad (2-7a)$$

$$\beta = \frac{\pi R^2}{m_2 C_p} \quad (2-7b)$$

Rearranging (2-7) and applying an integration factor yields

$$(T_2(x)e^{\alpha x})' = e^{\alpha x}[\beta q_{2a}'' e^{-b_a x} + \beta q_{2b}'' e^{-b_b x} + \alpha T_1(x)] \quad (2-8)$$

integrating (2-8) between 0 and x and introducing boundary condition (2-2) gives the following results

$$\begin{aligned} T_2(x) = e^{-\alpha x} T_1(0) + \frac{\beta q_{2a}''}{b_a - \alpha} \left(e^{-\alpha x} - e^{-b_a x} \right) + \frac{\beta q_{2b}''}{b_b - \alpha} \left(e^{-\alpha x} - e^{-b_b x} \right) \\ + e^{-\alpha x} \int_0^x e^{\alpha x} T_1(x) dx \end{aligned} \quad (2-9)$$

Equation 2-9 can be simplified using integration by parts on the last term. This is the crucial step in providing a quickly converging solution technique.

$$\int_0^x e^{\alpha x} T_1(x) dx = \frac{e^{\alpha x}}{\alpha} T_1(x) - \frac{T_1(0)}{\alpha} - \int_0^x \frac{e^{\alpha x}}{\alpha} T_1'(x) dx \quad (2-10)$$

Thus, the final expression for the temperature in the downflow region as a function of the average temperature in the type 1 subchannels is as follows:

$$T_2(x) = T_1(x) + \frac{\beta q''_a}{b_a - \alpha} \left[e^{-\alpha x} - e^{-b_a x} \right] + \frac{\beta q''_b}{b_b - \alpha} \left[e^{-\alpha x} - e^{-b_b x} \right] - e^{-\alpha x} \int_0^x e^{\alpha x} T_1(x) dx \quad (2-11)$$

Transformation to numerical form is necessary to use this expression with the pointwise values of the average type 1 subchannel temperature provided by the equations derived in the next subsection. The temperature of the downflow region at the axial level J from the bundle inlet is then

$$T_0^J = T_1^J + (C_2 + C_3) \exp[-C_1(L_C - Z_J)] - C_2 \exp[-b_a(L_C - Z_J)] - C_3 \exp[-b_b(L_C - Z_J)] - \exp[-C_1(L_C - Z_{J+1})] \prod_{I=J}^K \exp[C_1(L_C - (I+1)\Delta Z)] (T_1^I - T_1^{I+1}) \quad (2-12)$$

Where the subscript has been changed to 0 to be consistent with the conventions used in the difference equations of reference 4. The constants above are as follows:

$$C_1 = \alpha = \frac{2\pi R_1}{m_2 C_p P_1} \quad (2-13a)$$

$$C_2 = \frac{\beta q_{2a}'''}{b_a - \alpha} \quad (2-13b)$$

$$C_3 = \frac{\beta q_{2b}'''}{b_b - \alpha} \quad (2-13c)$$

The terms in equation (2-12) were all evaluated at the axial level $Z_J = J\Delta Z$ or at the J^{th} axial step in the numerical solution, with the exception of the integral term which was evaluated at $\Delta Z_{J+1/2} = (J+1/2)\Delta Z$ so that it could be expressed in terms of known temperatures T_1^I and T_1^{I+1} . The upper limit of the summation K represents the axial step number at $Z = L_C$, or $K = L_C/\Delta Z$. Notice that in order for the temperature T_0^J in equation (2-12) to be known, the average type 1 subchannel temperatures from $Z = Z_J$ to $Z = L_C$ must be known, implying an iterative solution is necessary. This will be discussed in more detail in subsection 2.3.

2.2 Upflow Region

As can be seen from Figure 2, the upflow region of the counterflow section of the SCA consists of the flow inside the duct walls passing through subchannels labeled type 1 and the flow in the interassembly gap through the type 3 subchannels. A forward differencing scheme was chosen to represent the energy balance in both types of subchannels because of the explicit nature of the resultant equations.

2.2.1 Type 1 Subchannels

Applying an energy balance to a representative type 1 sub-channel using the subchannel connection numbering scheme shown in Figure 3 yields

$$\begin{aligned} \dot{m}_1 c_p (T_0^{J+1} - T_0^J) = & \Delta Z A_1 q_1''^{J+1/2} + \frac{X_2 \Delta Z}{F_2} (T_3^J - T_0^J) \\ & \frac{(D_P - 2R_0) \Delta Z}{2\eta_1} k (T_1^J + T_2^J - 2T_0^J) + \frac{\pi R_1 \Delta Z}{3F_1} (T_4^J - T_0^J) \end{aligned} \quad (2-14)$$

where the variables are defined in the nomenclature section. Algebraic expressions for non-input parameters are given in Appendix A. Rearranging (2-14) and adding a user specified boundary condition at the duct wall yields the following equation for the temperature at the J+1 axial level.

$$\begin{aligned} T_0^{J+1} = & T_0^J + Q^J + D_2 q_1''^{J+1/2} + D_3 (T_1^J + T_2^J - 2T_0^J) \\ & + D_4 (T_4^J - T_0^J) \end{aligned} \quad (2-15)$$

where

$$Q^J = D_1 (T_3^J - T_0^J) \quad (2-16a)$$

for interassembly gap temperature boundary condition

$$Q^J = D_1 (T_{BC}^J - T_0^J) \quad (2-16b)$$

for duct wall temperature boundary condition

$$Q^J = \frac{X_2 \Delta Z}{\dot{m}_1 c_p} q_{BC}''^J \quad (2-16c)$$

for duct wall heat flux boundary condition

and

$$D_1 = \frac{X_2 \Delta Z}{\dot{m}_1 C_p F_2} \quad (2-17a)$$

$$D_2 = \frac{A_1 \Delta Z}{\dot{m}_1 C_p} \quad (2-17b)$$

$$D_3 = \frac{(D_P - 2R_0) \Delta Z k}{2 \dot{m}_1 C_p \eta_1} \quad (2-17c)$$

$$D_4 = \frac{\pi R_1 \Delta Z}{3 \dot{m}_1 C_p F_1} \quad (2-17d)$$

The volumetric heat generation rate, $\sigma_1^{''J+\frac{1}{2}}$, is assumed to be of the same form as the subchannel type 2 volumetric heat generation rate, evaluated at the $J+\frac{1}{2}$ axial level

$$q_1^{''J+\frac{1}{2}} = q_{2a}^{''} e^{+b_a \Delta Z/2} e^{-b_a(LC-Z_J)} + q_{2b}^{''} e^{+b_b \Delta Z/2} e^{-b_b(LC-Z_J)} \quad (2-18)$$

The coupling of equation (2-15) with (2-12) will be discussed in subsection 2.3.

2.2.2 Type 3 Subchannels

As indicated in equation (2-16a), the type 3 or interassembly gap subchannels associated with the SCA are required only when an interassembly gap boundary condition is specified. For this case, the resultant energy balance equation, as obtained by following the subchannel connection numbering scheme in

Figure 4, is as follows:

$$\dot{m}_3 C_p (T_0^{J+1} - T_0^J) = X_3 \Delta Z q_{IG}^n + \frac{X_2 \Delta Z}{P_2} (T_3^J - T_0^J) + \frac{g \Delta Z k}{2 P_3} (T_1^J + T_2^J - 2T_0^J) \quad (2-19)$$

Rearranging (2-19) gives the expression for the temperature of the type 3 subchannel at the J+1 axial level,

$$T_0^{J+1} = T_0^J + E_5 q_{IG}^n + E_1 (T_3^J - T_0^J) + E_2 (T_1^J + T_2^J - 2T_0^J) \quad (2-20)$$

where

$$E_5 = \frac{X_3 \Delta Z}{\dot{m}_3 C_p} \quad (2-21a)$$

$$E_1 = \frac{X_2 \Delta Z}{\dot{m}_3 C_p P_2} \quad (2-21b)$$

$$E_2 = \frac{g \Delta Z k}{2 \dot{m}_3 C_p P_3} \quad (2-21c)$$

and the heat flux, q_{IG}^n , represents the heat flow across the interassembly gap centerline due to the temperature difference between the type 3 subchannel and the imposed temperature at axial level J.

2.3 SCA Counterflow Section Solution Technique

The numerical expressions for the various subchannel temperatures derived in the preceding sections provide a basis for

the solution technique. The method is as follows:

- 1) Guess an initial distribution for the average temperature of type 1 subchannels. This guess is not particularly important since the derivative of the distribution will be used. Therefore, a constant distribution equal to the bundle inlet temperature is chosen.
- ii) Use this distribution to predict the temperature distribution of the downflow region for the next iteration using equation (2-12).
- iii) Find the new temperatures for subchannel types 1 and 3 by matching up the bundle using the expressions (2-15) and (2-20). Save only the type 1 average temperature distribution.
- iv) Compare the type 1 average temperature at $X=0$ (or $Z=L_C$) with the temperature predicted by equation (2-12) using the average temperature distribution from the last iteration (i.e., boundary condition (2-2)). If the error is greater than the specified tolerance go to (ii) and iterate.
- v) The error is less than the specified tolerance. Iterate one last time in order to print out the temperatures at the desired heights.
- vi) Proceed to the poison section of the bundle.

This solution method has been programmed using the geometric parameters derived in Appendix A. A listing of the program with the appropriate input description is given in Appendix B.

This program can handle user specified boundary conditions at either the interassembly gap or duct wall which may vary both radially and axially. The converged solution of the counterflow section of the program couples automatically with the poison section discussed in the next section.

The accuracy of the program solution method can be investigated by comparing a sample problem result with the exact analytical solution. The selected sample problem input parameters are listed in Table I. Using these parameters, the corresponding program input and output listings are shown in Appendix D.1. An exact analytical derivation is given in Appendix E. For purposes of comparison, the results of both are tabulated in Table II.

Examination of Table II shows that the counterflow solution scheme provides excellent agreement with the analytic solution for this sample problem, which is about at the limit of solvable analytic complexity. As expected, since the solution technique is semianalytic, the absolute temperature error in the downflow region does not increase above the value input from the upflow region at $Z=L_G$. The differences between the two sets of temperatures in the upflow region are probably the result of truncation error, roundoff and pointwise approximation of continuous functions (the exponentials in the volumetric heat flux term) within the numerical solution. These errors could probably be reduced by going to double precision coding and more elaborate iteration schemes, but from the small discrepancies observed in Table II this appears unnecessary.

3. SCA POISON CONTROL SECTION - MODEL DEVELOPMENT

The poison control section of the SCA is shown in Figure 5. The section consists of an interior 31 pin wire wrapped poison bundle surrounded by a bypass flow region and a stagnant flow area next to the duct wall. At the height, labeled as L_D in the figure, the stagnant region stops and is replaced by an expanded bypass region as shown in Figure 5b. The temperature field at any axial level in the poison control section can be found by using the set of explicit numerical equations to be derived for each subchannel type in the following subsections.

3.1 Poison Bundle Region

The poison bundle region has 31 wire wrapped pins that are arranged in a tight triangular pitch similar to that found in the CRBR blanket bundle. The major difference is that these pins are contained within a circular rather than hexagonal bundle tube. Six plugs attached to this bundle tube provide the necessary support to keep the pins properly aligned, and, as a consequence, eliminate the swirl flow effect seen in the periphery region of the CRBR bundles.

The region has been divided into a nodal mesh of five different configurations, labeled nodal types 4 through 8 on Figure 6. In the subchannel nodes (type= 4 through 7) the temperature expressions are obtained by a forward differenced nodal energy balance. The energy exchange process between subchannels, due to the wire wrap sweeping, is modeled by an enhanced eddy diffusivity of heat in the same manner as that

used by the ENERGY model [1,2,3]. The secondary control assembly model developed here does not contain the additional swirl flow effect also used by ENERGY. The plug node (type 8) temperature is obtained by a simple resistance averaging.

3.1.1 Type 4 Subchannels

Applying an energy balance to a representative type 4 subchannel using the nodal connection scheme shown in Figure 7 yields

$$\begin{aligned} \dot{m}_4 C_p (T_0^{J+1} - T_0^J) = & \bar{q}_0'' A_4 \Delta Z + \frac{(P-D)\Delta Z}{n_4} (k + \rho C_p \epsilon_{H_4}) * (T_1^J + T_2^J - 2T_0^J) \\ & + \frac{(P-D)\Delta Z}{n_A} (k + \rho C_p \epsilon_{H_A}) (T_3^J - T_0^J) \end{aligned} \quad (3-1)$$

where the subscript

A = 4 if connection 3 is a type 4 subchannel

A = 5 if connection 3 is a type 5 subchannel

A = 6 if connection 3 is a type 7 subchannel

Rearranging (3-1) gives the expression for the type 4 subchannel temperature at the J+1 axial level in terms of the temperature at the J level.

$$T_0^{J+1} = T_0^J + CC_1 r_r r_a + CC_2 (T_1^J + T_2^J - 2T_0^J) + CC_3 (T_3^J - T_0^J) \quad (3-2)$$

where

$$CC_1 = \frac{\bar{q}_0'' A_4 \Delta Z}{\dot{m}_4 C_p} \quad (3-3a)$$

$$CC_2 = \frac{(P-D)\Delta Z}{\dot{m}_4 C_p \eta_4} (k + \rho C_p \epsilon_{H_4}) \quad (3-3b)$$

$$CC_3 = \frac{(P-D)\Delta Z}{\dot{m}_4 C_p \eta_A} (k + \rho C_p \epsilon_{H_A}) \quad (3-3c)$$

and the constants f_r and f_a represent the radial and axial volumetric heat generation rate multipliers, respectively. Algebraic expressions for non-input parameters are given in Appendix A.

3.1.2 Type 5 Subchannels

Applying an energy balance to a representative type 5 sub-channel using the nodal connection scheme shown in Figure 8 yields

$$\begin{aligned} \dot{m}_5 C_p (T_0^{J+1} - T_0^J) &= q_0'' A_5 \Delta Z + \frac{(P-D)\Delta Z}{\eta_7} (k + \rho C_p \epsilon_{H_7}) (T_2^J - T_0^J) \\ &+ \frac{(P-D)\Delta Z}{\eta_8} (k + \rho C_p \epsilon_{H_8}) (T_3^J - T_0^J) \\ &+ \frac{(P-D)\Delta Z}{\eta_5} (k + \rho C_p \epsilon_{H_5}) (T_1^J - T_0^J) + \frac{X_5 \Delta Z}{P_5} (T_4^J - T_0^J) \end{aligned} \quad (3-4)$$

Rearranging (3-4) yields the expression for the type 5 sub-channel temperature at the J+1 axial level in terms of the temperatures at the J level.

$$T_0^{J+1} = T_0^J + DD_1 f_r f_a + DD_2 (T_2^J - T_0^J) + DD_3 (T_3^J - T_0^J) + DD_4 (T_1^J - T_0^J) + DD_5 (T_4^J - T_0^J) \quad (3-5)$$

where

$$DD_1 = \frac{\bar{q}'' A_5 \Delta Z}{\dot{m}_5 C_p} \quad (3-6a)$$

$$DD_2 = \frac{(P-D) \Delta Z}{\dot{m}_5 C_p \eta_7} (k + \rho C_p \epsilon_{H_7}) \quad (3-6b)$$

$$DD_3 = \frac{(P-D) \Delta Z}{\dot{m}_5 C_p \eta_8} (k + \rho C_p \epsilon_{H_8}) \quad (3-6c)$$

$$DD_4 = \frac{(P-D) \Delta Z}{\dot{m}_5 C_p \eta_5} (k + \rho C_p \epsilon_{H_5}) \quad (3-6d)$$

$$DD_5 = \frac{X_5 \Delta Z}{\dot{m}_5 C_p F_5} \quad (3-6e)$$

and as before the constants f_r and f_a represent the radial and axial volumetric heat generation rate multipliers, respectively. Algebraic expressions for non-input parameters are given in Appendix A.

3.1.3 Type 6 Subchannels

Applying an energy balance to a representative type 6 subchannel using the nodal connection scheme shown in Figure 9 yields

$$\begin{aligned}
 \dot{m}_6 C_p (T_0^{J+1} - T_0^J) = & \bar{q}_0'' A_6 \Delta Z + \frac{(P-D)\Delta Z}{\eta_8} (k + \rho C_p \epsilon_{H8}) (T_1^J - T_0^J) \\
 & + \frac{(P-D)\Delta Z}{\eta_9} (k + \rho C_p \epsilon_{H9}) (T_2^J - T_0^J) \\
 & + \frac{X_{6a} \Delta Z}{F_{6a}} (T_3^J - T_0^J) + \frac{X_{6b} \Delta Z}{F_{6b}} (T_4^J - T_0^J)
 \end{aligned} \quad (3-7)$$

Rearranging (3-7) gives the expression for the type 6 subchannel temperature at the J+1 axial level in terms of the temperatures at the J level.

$$\begin{aligned}
 T_0^{J+1} = & T_0^J + EE_1 f_r f_a + EE_2 (T_1^J - T_0^J) + EE_3 (T_2^J - T_0^J) \\
 & + EE_4 (T_3^J - T_0^J) + EE_5 (T_4^J - T_0^J)
 \end{aligned} \quad (3-8)$$

where

$$EE_1 = \frac{\bar{q}_0'' A_6 \Delta Z}{\dot{m}_6 C_p} \quad (3-9a)$$

$$EE_2 = \frac{(P-D)\Delta Z}{\dot{m}_6 C_p \eta_8} (k + \rho C_p \epsilon_{H8}) \quad (3-9b)$$

$$EE_3 = \frac{(P-D)\Delta Z}{\dot{m}_6 C_p \eta_9} (k + \rho C_p \epsilon_{H9}) \quad (3-9c)$$

$$EE_4 = \frac{X_{6a} \Delta Z}{\dot{m}_6 C_p F_{6a}} \quad (3-9d)$$

$$EE_5 = \frac{X_{6b} \Delta Z}{\dot{m}_6 C_p F_{6b}} \quad (3-9e)$$

Algebraic expressions for non-input parameters are given in Appendix A.

3.1.4 Type 7 Subchannels

Applying an energy balance to a representative type 7 subchannel using the nodal connection scheme shown in Figure 10 yields

$$\begin{aligned} \dot{m}_7 C_p (T_0^{J+1} - T_0^J) &= Q_D^{nr} A_7 \Delta Z + \frac{(P-D) \Delta Z}{\eta_9} (k + \rho C_p \epsilon_{H_9}) (T_2^J + T_3^J - 2T_0^J) \\ &+ \frac{(P-D) \Delta Z}{\eta_6} (k + \rho C_p \epsilon_{H_6}) (T_1^J - T_0^J) \\ &+ \frac{X_7 \Delta Z}{2F_7} (T_4^J + T_5^J - 2T_0^J) \end{aligned} \quad (3-10)$$

Rearranging (3-10) gives the expression for the type 7 subchannel temperature at the J+1 axial level in terms of the temperatures at the J level.

$$\begin{aligned} T_0^{J+1} &= T_0^J + GG_1 T_0^J + GG_2 (T_2^J + T_3^J - 2T_0^J) + GG_3 (T_1^J - T_0^J) \\ &+ GG_4 (T_4^J + T_5^J - 2T_0^J) \end{aligned} \quad (3-11)$$

where

$$GG_1 = \frac{\bar{q}'' A_7 \Delta Z}{\dot{m}_7 C_p} \quad (3-12a)$$

$$GG_2 = \frac{(P-D) \Delta Z}{\dot{m}_7 C_p n_9} (k + \rho C_p \epsilon_{H9}) \quad (3-12b)$$

$$GG_3 = \frac{(P-D) \Delta Z}{\dot{m}_7 C_p n_6} (k + \rho C_p \epsilon_{H6}) \quad (3-12c)$$

$$GG_4 = \frac{X_7 \Delta Z}{2 \dot{m}_7 C_p F_7} \quad (3-12d)$$

Algebraic expressions for non-input parameters are given in Appendix A.

3.1.5 Type 8 Nodes

The temperature for the J+1 axial level in the alignment plug node is obtained by simple resistance averaging using the J+1 level temperatures of the surrounding nodes. Using the connection scheme shown in Figure 12, the governing equation is

$$\begin{aligned} \frac{X_5 \Delta Z}{F_5} (T_1^{J+1} + T_2^{J+1} - 2T_0^{J+1}) + \frac{X_{6a} \Delta Z}{F_{6a}} (T_3^{J+1} + T_4^{J+1} - 2T_0^{J+1}) \\ + \frac{X_8 \Delta Z}{F_8} (T_5^{J+1} - T_0^{J+1}) = 0 \end{aligned} \quad (3-13)$$

Rearranging (3-13) gives the expression for the type 8 nodal temperature.

$$T_0^{J+1} = WW_1(T_3^{J+1} + T_4^{J+1}) + WW_2(T_1^{J+1} + T_2^{J+1}) + WW_3 T_5^{J+1} \quad (3-14)$$

where

$$WW_1 = \frac{X_{6a}}{F_{6a} R_{TOT}} \quad (3-15a)$$

$$WW_2 = \frac{X_5}{F_5 R_{TOT}} \quad (3-15b)$$

$$WW_3 = \frac{X_8}{F_8 R_{TOT}} \quad (3-15c)$$

and

$$R_{TOT} = \frac{2X_{6a}}{F_{6a}} + \frac{2X_5}{F_5} + \frac{X_8}{F_8} \quad (3-15d)$$

Algebraic expressions for non-input parameters are given in Appendix A.

3.2 Bypass Flow and Interassembly Gap Regions

The regions outside of the poison bundle in the poison control section of the SCA have been divided into the nodal arrangements shown in Figures 5 and 6. Temperature expressions for the nodal types 9, 11, and 12, are obtained using forward differencing techniques similar to those used in the last subsection. Only upflow solutions are considered here. The stagnant flow type 10 nodal temperature is found by simple resistance averaging.

3.2.1 Type 9 Subchannels

The type 9 subchannel exists for $Z \leq L_D$, at which point it becomes type 11. Applying an energy balance to a representative type 9 subchannel using the nodal connection scheme shown in Figure 13 yields

$$\begin{aligned} \dot{m}_9 C_p (T_0^{J+1} - T_0^J) = & q_0'' A_9 \Delta Z + \frac{X_{6b} \Delta Z}{F_{6b}} (T_2^J + T_3^J - 2T_0^J) \\ & + \frac{X_7 \Delta Z}{2F_7} (T_4^J + T_5^J - 2T_0^J) + \frac{X_8 \Delta Z}{F_8} (T_1^J - T_0^J) \\ & + \frac{k(R_1 - R_{DO}) \Delta Z}{\eta_{10}} (T_6^J + T_7^J - 2T_0^J) + \frac{X_9 \Delta Z}{F_9} (T_8^J - T_0^J) \end{aligned} \quad (3-16)$$

Rearranging (3-16) and adding a user specified boundary condition at the duct wall yields the following equation for the temperature at the J+1 axial level.

$$\begin{aligned} T_0^{J+1} = & T_0^J + XX_1 f_r f_a + XX_2 (T_2^J + T_3^J - 2T_0^J) + XX_3 (T_4^J + T_5^J - 2T_0^J) \\ & + XX_4 (T_1^J - T_0^J) + XX_6 (T_6^J + T_7^J - 2T_0^J) + Q^J \end{aligned} \quad (3-17)$$

where

$$Q^J = \frac{X_2 \Delta Z}{\dot{m}_9 C_p} q_{BC}'' \quad (3-18a)$$

for duct wall heat flux boundary condition

$$Q^J = XX_5 (T_8^J - T_0^J) \quad (3-18b)$$

for temperature boundary conditions

and

$$XX_1 = \frac{\bar{q}'' A_g \Delta Z}{\dot{m}_g C_p} \quad (3-19a)$$

$$XX_2 = \frac{X_{6b} \Delta Z}{\dot{m}_g C_p F_{6b}} \quad (3-19b)$$

$$XX_3 = \frac{X_7 \Delta Z}{2 \dot{m}_g C_p F_7} \quad (3-19c)$$

$$XX_4 = \frac{X_8 \Delta Z}{\dot{m}_g C_p F_8} \quad (3-19d)$$

$$XX_5 = \frac{X_9 \Delta Z}{\dot{m}_g C_p F_9} \quad (3-19e)$$

$$XX_6 = \frac{k(R_1 - R_{po}) \Delta Z}{\dot{m}_g C_p n_{10}} \quad (3-19f)$$

Algebraic expressions for non-input parameters are given in Appendix A.

3.2.2 Type 11 Subchannels

The type 11 subchannel exists for $z > L_D$. Applying an energy balance to a representative type 11 subchannel using the nodal connection scheme shown in Figure 15

$$\begin{aligned} \dot{m}_{11} C_p (T_0^{J+1} - T_0^J) = & q_0'' A_{11} \Delta Z + \frac{X_{6b} \Delta Z}{F_{6b}} (T_2^J + T_3^J - 2T_0^J) \\ & + \frac{X_7 \Delta Z}{2F_7} (T_4^J + T_5^J - 2T_0^J) + \frac{X_8 \Delta Z}{F_8} (T_1^J - T_0^J) \quad (3-20) \\ & + \frac{k(D_F - 2R_{po}) \Delta Z}{2\eta_{11}} (T_6^J + T_7^J - 2T_0^J) + \frac{X_{11} \Delta Z}{F_{11}} (T_8^J - T_0^J) \end{aligned}$$

Rearranging (3-20) and adding a user specified boundary condition at the duct wall yields the following equation for the temperature at the J+1 axial level.

$$\begin{aligned} T_0^{J+1} = & T_0^J + XX_1 f_r f_a + XX_2 (T_2^J + T_3^J - 2T_0^J) + XX_3 (T_4^J + T_5^J - 2T_0^J) \\ & + XX_4 (T_1^J - T_0^J) + XX_8 (T_6^J + T_7^J - 2T_0^J) + Q^J \quad (3-21) \end{aligned}$$

where in this case

$$Q^J = XX_7 (T_8^J - T_0^J) \quad (3-22a)$$

for interassembly gap temperature boundary conditions

$$Q^J = XX_7 (T_{BC}^J - T_0^J) \quad (3-22b)$$

for duct wall temperature boundary conditions

$$Q^J = \frac{X_2 \Delta Z}{\dot{m}_{11} C_p} q_{BC}'' \quad (3-22c)$$

for duct wall heat flux boundary conditions

and

$$XX_1 = \frac{\bar{q}'' A_{11} \Delta Z}{\dot{m}_{11} C_p} \quad (3-23a)$$

$$XX_2 = \frac{X_{6b} \Delta Z}{\dot{m}_{11} C_p F_{6b}} \quad (3-23b)$$

$$XX_3 = \frac{X_7 \Delta Z}{2\dot{m}_{11} C_p F_7} \quad (3-22c)$$

$$XX_4 = \frac{X_8 \Delta Z}{\dot{m}_{11} C_p F_8} \quad (3-23d)$$

$$XX_7 = \frac{X_{11} \Delta Z}{\dot{m}_{11} C_p F_{11}} \quad (3-23e)$$

$$XX_8 = \frac{k(D_F - 2R_{po}) \Delta Z}{2\dot{m}_{11} C_p \eta_{11}} \quad (3-23f)$$

Algebraic expressions for non-input parameters are given in Appendix A.

3.2.3 Type 12 Subchannels

The type 12 subchannels lie in the interfassembly gap. They are similar in characteristics to the type 3 subchannels evaluated in section 2.2.2 differing only by their resistance connections to the bundle interior. As in the type 3 subchannels, the type 12 subchannels are required only when an inter-assembly gap boundary condition is specified. For this case the energy balance equation for $Z \leq L_D$, obtained by following the subchannel connection numbering scheme in Figure 16 is

$$\begin{aligned} \dot{m}_3 C_p (T_0^{J+1} - T_0^J) = & X_3 \Delta Z q_{IG}^J + \frac{X_2 \Delta Z}{F_{10}} (T_1^J - T_0^J) \\ & + \frac{E \Delta Z k}{2\eta_3} (T_2^J + T_3^J - 2T_0^J) \end{aligned} \quad (3-24)$$

For $Z > L_D$, the second term on the right hand side of equation (3-24) becomes

$$\frac{X_{11} \Delta Z}{F_{11}} (T_1^J - T_0^J) \quad (3-25)$$

Rearranging (3-24) gives the following equation for the temperature in type 12 subchannel at the $J+1$ axial level.

$$T_0^{J+1} = T_0^J + E_5 q_{IG}^J + E_A (T_1^J - T_0^J) + E_2 (T_2^J + T_3^J - 2T_0^J) \quad (3-26)$$

where the subscript A on E_A is

$A = 3$ for axial height $Z \leq L_D$

$A = 4$ for axial height $Z > L_D$

and

$$E_2 = \frac{E \Delta Z k}{2\eta_3 \dot{m}_3 C_p} \quad (3-27a)$$

$$E_3 = \frac{X_2 \Delta Z}{\dot{m}_3 C_p F_{10}} \quad (3-27b)$$

$$E_4 = \frac{X_{11} \Delta Z}{\dot{m}_3 C_p F_{11}} \quad (3-27c)$$

$$E_5 = \frac{X_3 \Delta Z}{\dot{m}_3 C_p} \quad (3-27d)$$

where the heat flux, q_{IG}^J , represents the heat flow across the interassembly gap centerline due to the temperature difference between the type 12 subchannels and the imposed temperature at axial level J.

3.2.4 Type 10 Subchannels

The type 10 nodes represent stagnant flow regions that exist between the type 12 nodes and type 9 nodes at the axial levels $Z \leq L_D$. The temperature in these nodes is found by simple resistance averaging of adjacent type 9 node and type 12 node temperatures. Circumferential heat transfer between neighboring type 10 nodes is eliminated so that the solution of simultaneous equations can be avoided. This assumption appears justified because of the narrow transverse flow area between the nodes and the large conductivity of sodium in the adjacent type 9 and type 12 nodes. Using the nodal connection scheme in Figure 14, the temperature at the J+1 axial level as a function of boundary conditions is as follows:

For an imposed interassembly gap boundary condition

$$T_0^{J+1} = YY_1 T_1^{J+1} + YY_2 T_2^{J+1} \quad (3-28a)$$

For an imposed duct wall temperature boundary condition

$$T_0^{J+1} = YY_1 T_1^{J+1} + YY_2 T_{BC}^{J+1} \quad (3-28b)$$

For an imposed duct wall heat flux boundary condition

$$T_0^{J+1} = T_1^{J+1} \quad (3-28c)$$

where

$$YY_1 = \frac{X_9}{F_9 R_{TOT}} \quad (3-29a)$$

$$YY_2 = \frac{X_2}{F_{10} R_{TOT}} \quad (3-29b)$$

and

$$R_{TOT} = \frac{X_9}{F_9} + \frac{X_2}{F_{10}} \quad (3-29c)$$

Algebraic expressions for non-input parameters are given in Appendix A.

3.3 SCA Poison Section Solution Technique

The solution technique for temperature fields in the SCA poison section is straight forward using the equations just derived. The temperature in a flowing subchannel at a given axial level is found in terms of the subchannel properties at the previous axial level by using the derived explicit numerical temperature formulation. After solving for all the temperatures in the type 4, 5, 6, 7, 12 and 9 (or 11) subchannels at that axial level, the temperatures of the type 8 and 10 nodes are obtained by resistance averaging using the equations derived in 3.1.5 and 3.2.4, respectively. Appendix B contains a listing and associated input description of a computer program in which this solution method is applied.

The computer program contains a few additions which simplify user input and its applicability to a wider range of problems. These additions are as follows:

- 1) Geometric parameters derived in Appendix A are included in the program for input ease.
- ii) Automatic coupling between the counterflow section and the poison section is provided. The inlet temperatures for the poison section subchannels are taken directly from the counterflow section. Inlet mass flow rates are user specified by subchannel type through the use of flow split multipliers.
- iii) The heat source from the poison rods is modeled as a volumetric heat generation rate within the subchannels. Axial and radial power factors are user input. Radial power factors for subchannels neighboring bundle wall structure may be increased to include gamma heating effects.
- iv) The energy exchange between poison bundle subchannels due to wire wrap sweeping is modeled as an enhanced eddy diffusion of heat, enabling a major simplification in the solution technique. The eddy diffusivities may be obtained by experimental data matching or by using values taken from similar geometry [5].

A sample problem is provided in Appendix D.1. The counterflow section of this example was discussed previously

in subsection 2.3. The poison control section, which is of interest here, has a heat flux boundary condition on the duct wall and a nonzero volumetric source. For simplicity, both are taken to be constant radially and axially, but can just as easily be adjusted by user input arbitrarily varying multipliers with no time or storage penalty. The flow split in the poison bundle is determined on an area weighted basis. Details of the input are listed in Appendix D.1.

Programming methods used in the implementation of the SCA solution are compatible with those in SUPERENERGY [3] which can provide the bundle boundary conditions. This is the topic of the next section.

4. SCA - SUPERENERGY COUPLING

It is desirable to couple the secondary control assembly model discussed in the preceding sections with a multiassembly thermal-hydraulic LMFBR code. Coupling provides a way of assuring the correct fuel assembly induced variable temperature boundary condition at the SCA interassembly gap. Similarly, from the point of view of the fuel assembly, the SCA through its feedback effects, gives a good estimate of the fuel assembly boundary condition.

The SCA model was coded to couple easily with the SUPERENERGY [3] code. The SUPERENERGY code was chosen for a number of reasons. First, since it is written in explicit numerical

form, no iteration is necessary to find the temperature profile. This is helpful since the counterflow section of the SCA must iterate. Secondly, SUPERENERGY can function very efficiently with the large number of axial steps necessary to obtain an accurate solution in the SCA counterflow region, thus lending itself to easy one-to-one axial step coupling. Finally, the simplicity of the SUPERENERGY model makes interassembly coupling easy and any desirable future modifications straightforward.

The SCA modified SUPERENERGY code is listed in Appendix C along with the associated input description. Necessary modifications to the original SUPERENERGY are clearly marked in the listing. Some of these modifications are the addition of user specified variable printout heights, addition of an iteration loop governed by the SCA subroutine, and changes in the interassembly gap subchannel temperature expressions.

A sample problem using a coupled 217 pin fuel bundle to give the SCA a boundary condition on one side is illustrated in Appendix D.2. The other five sides are automatically provided with adiabatic boundary conditions. SCA subroutine input parameters are similar to those discussed previously and used with the last sample problem. A problem using six coupled 217 pin fuel assemblies to set up the SCA boundary conditions was attempted. The 600 axial steps necessary to comply with stability criteria (see reference 4) and the large feedback effects from the SCA produced slow convergence. The program

ran 30 cpu minutes on an IBM 360/65, and though it appeared to be converging, it was terminated due to our MIT budget limitations. The single coupled assembly only required under 3 cpu minutes on the same computer. However, it should be recognized that if such a six coupled assembly case is of design interest, it can be run if sufficient funds are allocated (we estimate on our IBM 360/65, 45 to 60 cpu minutes would be required).

Some future additions to the SCA-SUPERENERGY code should be considered to further reduce running time and increase user flexibility. These are the application of the porous body model [2,6] used in ENERGY I modifying the SUPERENERGY-SCA coupling so that different axial mesh size can be handled by the two models. The porous body model would allow user flexibility in radial node size selection. If the SUPERENERGY code is to be used only for boundary conditions, a fuel pin bounded subchannel mesh is clearly unnecessary. Similarly, variable axial step size would allow a fine meshed counterflow solution in the SCA subroutine to couple with coarsely meshed SUPERENERGY prescribed boundary conditions.

5. DESIGN APPLICATIONS

The purpose of this section is to provide the designer with a clear description of possible applications of the SCA model. In previous sections, the development and implementation of the modeling technique for the secondary control assembly was discussed along with possible future extensions

or improvements to the model. In the discussion below, however, the capabilities of the existing versions (Appendices B and C) will be dealt with.

The secondary control assembly treatment is common to both versions of the model. In it, the geometry is fixed to a simplification of the current design as described in previous sections. Changes in the magnitudes are subject only to certain user-input critical parameters clarified in the input description of Appendix B. The designer has complete control over the bundle flowrates including the poison bundle flowsplit. Volumetric heat generation rates are arbitrarily specified in the poison section and are a function of the sum of two exponentials in the counterflow section. The importance of wire wrap sweeping can be varied by changing the values of the enhanced eddy diffusivities of heat.

The secondary control model, as it exists, cannot handle downflow in any of the subchannels of the poison control section. Downflow does occur in the type 9 subchannels when the poison bundle is in the scrambled condition. In this instance, the bundle takes up a position within the counterflow region. An attempt at modeling this flow was thought to be unnecessary, since presumably most of the steady state analysis will occur in the operating configuration. Neither the SCA model presented here or the SUPERNEPGY code used in boundary condition coupling include the transient equations required for scrambled position analysis.

The main program associated with the Variable Boundary SCA Code (Appendix B) functions essentially to furnish boundary conditions for the SCA. These boundary conditions can be arbitrarily specified both radially and axially by user input multipliers. The three possible boundary condition types are duct wall specified heat flux or temperature and interassembly gap centerline specified temperature. Due to the ease and speed with which these boundary conditions can be applied (sample problem 1 in Appendix D.1 took 2.0 cpu seconds on an IBM 370/168) it is suggested that this version of the SCA model be used whenever possible.

The main program associated with the SUPERENERGY-SCA coupled version (Appendix C) allows the user to completely specify the character of the surrounding LMFBR fuel assemblies. This can get to be expensive if all six 217 pin fuel assemblies are included as discussed in the last section. Since the porous body model is not available in the version of SUPERENERGY applied here, it is suggested that fewer pin bundles be used to provide the coupling, thereby reducing the number of radial nodes and the running time. Since the SCA model interassembly gap nodes are large, this will give a good approximation of the 217 pin results, without going to the trouble of implementing the porous body model. Proper adjustment of the fuel pin, heat flux, pitch, rod diameter, and swirl flow gap width (specified through the duct flat-to-flat distance), should give the right temperature and velocities, both trans-

verse and axial, to allow for correct feedback to the SCA. These coupled fuel assemblies should all have the same number of pins since SUPERENERGY cannot properly couple unlike assemblies, other than 61 pin and 217 pin assemblies, to each other. They should also have an even number of rings of pins (e.g., 2 rings-19 pins, 4 rings-61 pins, etc.) to couple properly with the SCA interassembly gap subchannels.

6. SUMMARY AND CONCLUSIONS

In this report a computer model for analysis of the thermal-hydraulic behavior of the CRBR secondary control assembly was developed. The counterflow section of the SCA was modeled using a semi-analytic solution in the downflow region coupled with explicit numerical temperature expressions in the upflow and interassembly gap regions. The poison control section of the SCA is modeled entirely with explicit equations with the exception of stagnant nodes which use resistance averaging of neighboring subchannels. Within the control bundle itself, the energy exchange process between subchannels, due to wire wrap sweeping, is modeled by an enhanced eddy diffusivity of heat.

The listing of the coded version of the SCA model is given in Appendix B. A sample problem using the parameters given in Table I and Appendix D.1 was run to check the accuracy of the model. Comparison with the purely analytical results given in Appendix E, shows that the predicted axial temperature distributions are quite similar.

A summary listing of some of the important features of the model is as follows:

- i) The use of a semi-analytical solution technique in the downflow region decreases running time and increases speed of convergence.
- ii) The ability to specify arbitrarily varying boundary conditions (either temperature or heat flux) and volumetric heat generation rates in the poison bundle allows user flexibility.
- iii) Automatic coupling exists between the counterflow section and the poison section with user definable flowsplits.
- iv) The use of enhanced eddy diffusivities provides a simple, proven technique to model the energy exchange between poison bundle subchannels.
- v) Programming methods allow easy coupling to the slightly modified multiassembly LMFBR thermal-hydraulic code SUPERENERGY.

In an effort to develop a fast running generalized code a few items were left out of the model. These may limit some code uses and should be examined to see whether future efforts should be directed along these lines:

- 1) The present code does not take into account some of the fine structure of the assembly, particularly in the counterflow section (e.g., the piston and shielding plug).

- ii) The volumetric heat generation rate term in the counterflow region is not arbitrarily specified but can only be input as an axially varying sum of two exponentials. This is probably good enough for gamma heating but should be investigated.
- iii) Downflow in the type 9 subchannels of the SCA poison section, as is present when the control bundle is in the scrambled position, cannot be handled with the current explicit formulation. Depending on the intended use of this method, this can be a serious constraint and may require a complete overhaul of the solution scheme.
- iv) The node size in the interassembly gap and neighboring nodes is rather large. This appears to be a good assumption by virtue of the geometry (circle inside a hexagon). If a more detailed radial temperature profile is necessary and a finer mesh is used, circumferential conduction and mixing effects in the type 10 nodes will have to be included.
- v) As discussed in Section 4., addition of the porous body model and variable axial step sizing would decrease multiassembly running time.

This report represents a substantial first effort in modeling the LMFBR secondary control assembly. It should provide a basis for future models which will be modified to suit specific needs.

NOMENCLATURE

- A_1 = axial flow area of upflow subchannel in counterflow section - Equation (A-1)
- A_3 = axial flow area of interassembly gap subchannel - Equation (A-10)
- A_4 = axial flow area of type 4 subchannel in poison control section - Equation (A-17)
- A_5 = axial flow area of type 5 subchannel in poison control section - Equation (A-23)
- A_6 = axial flow area of type 6 subchannel in poison control section - Equation (A-31)
- A_7 = axial flow area of type 7 subchannel in poison control section - Equation (A-41)
- A_8 = cross sectional area of alignment plug in poison control section - Equation (A-50)
- A_9 = axial flow area of type 9 subchannel in poison control section - Equation (A-57)
- A_{11} = axial flow area of type 11 subchannel in poison control section - Equation (A-64)
- A_I = boundary area between upflow and downflow regions as viewed by upflow region in counterflow section - Equation (E-5)
- A_{II} = boundary area between upflow and downflow section regions as viewed by downflow region in counterflow section - Equations (2-3) and E-6)
- A_{III} = boundary area along hex duct wall - Equation (E-7)
- b_a = coefficient for the argument of the first exponential in the volumetric heat source term defined in (2-6) and (E-10)
- b_b = coefficient for the argument of the second exponential in the volumetric heat source term defined in (2-6) and (E-10)
- C_p = average specific heat of the sodium coolant
- D = diameter of the poison pins in the poison bundle

- D_D = hexagonal duct wall thickness
- D_{e1} = equivalent diameter of type 1 subchannel - Equation (A-3)
- D_{e3} = equivalent diameter of type 3 subchannel - Equation (A-12)
- D_{e4} = equivalent diameter of type 4 subchannel - Equation (A-19)
- D_{e5} = equivalent diameter of type 5 subchannel - Equation (A-25)
- D_{e6} = equivalent diameter of type 6 subchannel - Equation (A-34)
- D_{e7} = equivalent diameter of type 7 subchannel - Equation (A-43)
- D_{e9} = equivalent diameter of type 9 subchannel - Equation (A-59)
- D_{e11} = equivalent diameter of type 11 subchannel - Equation (A-66)
- D_F = hexagonal duct flat-to-flat distance
- D_W = wire wrap diameter in poison bundle
- f_a = axial heat generation rate multiplier for $\bar{q}'''$
- f_r = radial heat generation rate multiplier for $\bar{q}'''$
- F_1 = inverse equivalent heat transfer coefficient between sub-channel types 1 and 2 - Equation (A-9)
- F_2 = inverse equivalent heat transfer coefficient between sub-channel types 1 and 3 (or wall) - Equation (A-16)
- F_5 = inverse equivalent heat transfer coefficient between sub-channel type 5 and node type 8 - Equation (A-30)
- F_{6a} = inverse equivalent heat transfer coefficient between sub-channel type 6 and node type 8 - Equation (A-39)
- F_{6b} = inverse equivalent heat transfer coefficient between sub-channel types 6 and 9 (or 11) - Equation (A-40)
- F_7 = inverse equivalent heat transfer coefficient between sub-channel types 7 and 9 (or 11) - Equation (A-46)
- F_8 = inverse equivalent heat transfer coefficient between sub-channel types 9 (or 11) and node type 8 - Equation (A-52)
- F_9 = inverse equivalent heat transfer coefficient between sub-channel type 9 and node type 10 - Equation (A-63)
- F_{10} = inverse equivalent heat transfer coefficient between sub-channel type 12 (or wall) and node type 10 - Equation (A-73)

- F_{11} = inverse equivalent heat transfer coefficient between sub-channel types 11 and 12 (or wall)
- g = interassembly gap thickness
- h_1 = type 1 subchannel heat transfer coefficient - Equation (A-7)
- h_2 = type 2 subchannel heat transfer coefficient - Equation (A-8)
- h_3 = type 3 subchannel heat transfer coefficient - Equation (A-15)
- h_5 = type 5 subchannel heat transfer coefficient - Equation (A-29)
- h_6 = type 6 subchannel heat transfer coefficient - Equation (A-38)
- h_7 = type 7 subchannel heat transfer coefficient - Equation (A-45)
- h_9 = type 9 subchannel heat transfer coefficient - Equation (A-62)
- h_{11} = type 11 subchannel heat transfer coefficient - Equation (A-70)
- k = average conductivity of the sodium coolant
- k_w = conductivity of the duct walls
- l_1 = connection gap width between type 1 subchannels - Equation (A-4)
- l_5 = distance between type 8 nodal point and type 8 node boundary in direction of subchannel type 6 - Equation (A-53)
- l_6 = distance between type 8 nodal point and type 8 node boundary in direction of subchannel type 6 - Equation A-54)
- l_8 = distance between type 8 node and bundle tube wall - Equation (A-56)
- l_{10} = distance between type 10 nodal point and inside duct wall - Equation (A-72)
- L_C = axial length of counterflow section
- L_D = axial length to point in poison control section where node 10 disappears
- $\dot{m}_1$ = axial mass flow rate associated with type 1 subchannel
- $\dot{m}_2$ = axial mass flow rate associated with type 2 subchannel
- $\dot{m}_3$ = axial mass flow rate associated with type 3 subchannel
- $\dot{m}_4$ = axial mass flow rate associated with type 4 subchannel

$\dot{m}_5$ = axial mass flow rate associated with type 5 subchannel
 $\dot{m}_6$ = axial mass flow rate associated with type 6 subchannel
 $\dot{m}_7$ = axial mass flow rate associated with type 7 subchannel
 $\dot{m}_9$ = axial mass flow rate associated with type 9 subchannel
 $\dot{m}_{11}$ = axial mass flow rate associated with type 11 subchannel
 P = poison rod pitch

P_1 = wetted perimeter of type 1 subchannel - Equation (A-2)
 P_3 = wetted perimeter of type 3 subchannel - Equation (A-11)
 P_4 = wetted perimeter of type 4 subchannel - Equation (A-18)
 P_5 = wetted perimeter of type 5 subchannel - Equation (A-24)
 P_6 = wetted perimeter of type 6 subchannel - Equation (A-33)
 P_7 = wetted perimeter of type 7 subchannel - Equation (A-42)
 P_9 = wetted perimeter of type 9 subchannel - Equation (A-58)
 P_{11} = wetted perimeter of type 11 subchannel - Equation (A-65)

$q_{1 \rightarrow 2}''$ = heat flux from type 1 subchannel to type 2 subchannel
 at any axial height Z in the counterflow section

$q_{2 \rightarrow 1}''$ = heat flux from type 2 subchannel to type 1 subchannel
 at any axial height Z in the counterflow section

q_{BC}'' = specified heat flux boundary condition at the hexagonal duct wall

q_{IG}'' = heat flux at interassembly gap centerline due to the temperature difference between the type 3 subchannel and the imposed temperature boundary condition

$\bar{q}'''$ = average volumetric heat generation rate for poison bundle multiplied axially by f_a and radially by f_r

q_0''' = spatially varying volumetric heat generation rate associated with the subchannel of interest, called node 0.

q_1''' = axially varying volumetric heat generation rate in subchannel type 1 in counterflow section

q_2''' = axially varying volumetric heat generation rate in subchannel type 2 in counterflow section

q_{2a}''' = coefficient for first term of volumetric heat generation rate used in counterflow section - Equation (2-6) and (E-10)

q_{2b}''' = coefficient for second term of volumetric heat generation rate used in counterflow section - Equations (2-6) and (E-10)

R_1 = inside radius of cylindrical can in counterflow section

R_0 = outside radius of cylindrical can in counterflow section

R_{pi} = inside radius of cylindrical poison bundle can

R_{po} = outside radius of cylindrical poison bundle can

s = length of one face of hexagonal duct

S = source term for analytical model - Equation (E-15d)

t = thickness of type 8 node - Equation (A-47)

T_0 = temperature of the subchannel of interest; called node 0

T_1 = temperature of node 1, neighboring subchannel of interest

T_2 = temperature of node 2, neighboring subchannel of interest

T_3 = temperature of node 3, neighboring subchannel of interest

T_4 = temperature of node 4, neighboring subchannel of interest

T_5 = temperature of node 5, neighboring subchannel of interest

T_6 = temperature of node 6, neighboring subchannel of interest

T_7 = temperature of node 7, neighboring subchannel of interest

T_8 = temperature of node 8, neighboring subchannel of interest

$\bar{T}_1(X)$ = axially varying average temperature of type 1 subchannels

$T_2(X)$ = axially varying type 2 subchannel temperature

T_{1N} = counterflow section inlet temperature

Vol_I = total flow volume of the type 1 subchannels in the counterflow section - Equation (E-8)

Vol_{II} = flow volume of the type 2 subchannel in the counterflow section - Equations (2-4) and (E-9)

- W = width of the type 8 node - Equations (A-48a) and (A-48b)
 X = length coordinate, positive in the downflow direction
 X_2 = boundary length between subchannel types 1 and 3 - Equation (A-5)
 X_3 = subchannel type 3 distance along gap centerline - Equation (A-13)
 X_5 = boundary length between type 5 subchannel and type 8 node - Equation (A-28)
 X_{6a} = boundary length between type 6 subchannel and type 8 node - Equation (A-36)
 X_{6b} = boundary length between type 6 subchannel and bundle tube wall - Equation (A-37)
 X_7 = boundary length between type 7 subchannel and bundle tube wall - Equation (A-44)
 X_8 = boundary length between type 8 node and bundle tube wall - equation (A-51)
 X_9 = boundary length between type 9 subchannel and outer tube wall - Equation (A-60)
 X_{11} = boundary length between type 11 subchannel
 ΔZ = incremental axial height
 Z = length coordinate positive in the upflow direction
 Z_J = axial height at step indicator J

Greek letters

- α = quantity defined by equation (2-7a)
 β = quantity defined by equation (2-7b)
 γ = quantity defined by equation (E-15b)
 δ_1 = angle defined by equation (A-32a) and figure 11
 δ_2 = angle defined by equation (A-32b) and figure 11
 δ_3 = angle defined by equation (A-49) and figure 11

- δ_4 = angle defined by equation (A-55)
- ρ = average sodium coolant density
- ε = quantity defined by equation (E-15c)
- ε_{H4} = enhanced effective eddy diffusivity of heat between sub-channel types 4 and 4
- ε_{H5} = enhanced effective eddy diffusivity of heat between sub-channel types 4 and 5
- ε_{H6} = enhanced effective eddy diffusivity of heat between sub-channel types 4 and 7
- ε_{H7} = enhanced effective eddy diffusivity of heat between sub-channel types 5 and 5
- ε_{H8} = enhanced effective eddy diffusivity of heat between sub-channel types 5 and 6
- ε_{H9} = enhanced effective eddy diffusivity of heat between sub-channel types 6 and 7
- η_1 = nodal distances between type 1 and 1 nodes-Equation (A-6)
- η_3 = nodal distances between type 3 and 3 nodes-Equation (A-14).
- η_4 = nodal distances between type 4 and 4 nodes-Equation (A-20)
- η_5 = nodal distances between type 4 and 5 nodes-Equation (A-21)
- η_6 = nodal distances between type 4 and 7 nodes-Equation (A-22)
- η_7 = nodal distances between type 5 and 5 nodes-Equation (A-26)
- η_8 = nodal distances between type 5 and 6 nodes-Equation (A-27)
- η_9 = nodal distances between type 6 and 7 nodes-Equation (A-35)
- η_{10} = nodal distances between type 9 and 9 nodes-Equation (A-60)
- η_{11} = nodal distances between type 11 and 11 nodes-Equation (A-68)

Superscripts

- J = axial level
- J+1 = next highest axial level
- J + 1/2 = value taken between axial level J and J + 1

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FIG. 1: DETAILS OF ASSEMBLY

FIG. 2a: COUNTERFLOW SECTION

FIG. 2b: SUBCHANNEL TYPES

FIG. 2c: SUBCHANNEL NUMBERS

FIG. 3: TYPE 1 CONNECTION SCHEME

FIG. 4: TYPE 3 CONNECTION SCHEME

FIG. 6 : POISON BUNDLE SUBCHANNEL POSITIONING AND NODAL NUMBERING SCHEMES.

FIG. 7: TYPE 4 CONNECTION SCHEME

FIG. 8: TYPE 5 CONNECTION SCHEME

FIG. 9: TYPE 6 CONNECTION SCHEME

FIG.10: TYPE 7 CONNECTION SCHEME

FIG.11: DEFINITION OF ANGLES - APPENDIX A

FIG. 12: TYPE 8 CONNECTION SCHEME

FIG. 13: TYPE 9 CONNECTION SCHEME

FIG. 14: TYPE 10 CONNECTION SCHEME

FIG.15: TYPE 11 CONNECTION SCHEME

FIG.16: TYPE 12 CONNECTION SCHEME

TABLE I
COUNTERFLOW SECTION SAMPLE PROBLEM PARAMETERS

Bundle Geometry

Downflow section inside radius, $R_1 = 2.040"$

Downflow section outside radius, $R_o = 2.140"$

Bundle flat to flat distance, $D_F = 4.335"$

Bundle duct wall thickness, $D_D = 0.120"$

Counterflow section length, $L_C = 40.0"$

Operating Conditions

Inlet Temperature, $T_{1N} = 600^\circ\text{F}$

Total mass flow rate in upflow region, $\dot{m}_1 = 71000 \frac{\text{lbm}}{\text{hr}}$

Total mass flow rate in downflow region, $\dot{m}_2 = 54000 \frac{\text{lbm}}{\text{hr}}$

Constant heat flux applied to duct wall, $q''_{BC} = 5 \times 10^5 \frac{\text{BTU}}{\text{hr-ft}^2}$

Volumetric heat generation rate expression

$$q''_2 \left[\frac{\text{BTU}}{\text{hr-ft}^3} \right] = 3.5 \times 10^6 e^{-0.5x} + 1.5 \times 10^6$$

TABLE II
COUNTERFLOW SECTION SAMPLE PROBLEM RESULTS

	Axial Height, Z (inches)	Analytic Temperature of	Numerical Temperature of
UPFLOW SECTION	0.0	600.0	600.49
	10.0	629.80	631.15
$\bar{T}_1(x)$	20.0	658.58	660.35
	30.0	686.42	689.05
	39.8	712.80	715.91
DOWNFLOW SECTION	39.8	714.18	715.96
	30.0	732.63	734.46
$T_2(x)$	10.0	745.21	747.16
	20.0	753.19	754.99
	0.0	757.69	759.33

APPENDIX A
DERIVATION OF GEOMETRIC
PARAMETERS

APPENDIX A

A.1 Type 1 Geometry

Subchannel flow area

$$A_1 = \frac{\sqrt{3}}{12} D_F^2 - \frac{\pi}{6} R_O^2 \quad (A-1)$$

Wetted perimeter

$$P_1 = \frac{\pi}{3} R_O + \frac{D_F}{\sqrt{3}} \quad (A-2)$$

Equivalent diameter

$$D_{e1} = \frac{4A_1}{P_1} \quad (A-3)$$

Gap width between type 1 subchannels

$$L_1 = \frac{D_F}{2} - R_O \quad (A-4)$$

Boundary length between types 1 and 3 subchannels

$$X_2 = \frac{D_F}{\sqrt{3}} + \frac{D_D}{\sqrt{3}} \quad (A-5)$$

Distance between type 1 subchannel nodal points

$$\eta_1 = \frac{\pi}{3} (R_O + \frac{L_1}{2}) \quad (A-6)$$

Heat transfer coefficient

$$h_1 = \frac{k}{D_{e1}} \left[7.0 + 0.025 \left(\frac{D_{e1} C_{p1} \dot{m}_1}{A_1 k} \right)^{0.8} \right] \quad (A-7)$$

A.2 Type 2 Geometry

Heat transfer coefficient

$$h_2 = \frac{k}{2R_1} [7.0 + 0.025(\frac{C_p m_2}{\pi R_1 k})^{0.8}] \quad (A-8)$$

Inverse equivalent heat transfer coefficient between subchannel types 1 and 2

$$F_1 = \frac{1}{h_2} + \frac{R_1}{R_o h_1} + \frac{R_1}{k_w} \ln\left(\frac{R_o}{R_1}\right) \quad (A-9)$$

A.3 Type 3 Geometry

Subchannel flow area

$$A_3 = \frac{E}{2\sqrt{3}} (D_F + \frac{E}{2} + D_D g) \quad (A-10)$$

Wetted perimeter

$$P_3 = \frac{D_F}{\sqrt{3}} + \frac{2D_D}{\sqrt{3}} \quad (A-11)$$

Equivalent diameter

$$D_{e3} = \frac{4A_3}{P_3} \quad (A-12)$$

Distance along interassembly gap centerline

$$X_3 = \frac{D_F}{\sqrt{3}} + \frac{E}{\sqrt{3}} + \frac{2D_D}{\sqrt{3}} \quad (A-13)$$

Distance between type 3 subchannel nodal points

$$n_3 = \frac{D_F}{\sqrt{3}} + \frac{E}{2\sqrt{3}} + \frac{2D_D}{\sqrt{3}} \quad (A-14)$$

Heat Transfer Coefficient

$$h_3 = \frac{k}{D_{e3}} [7.0 + 0.025 \left(\frac{D_{e3} D_{p3}}{A_3 k} \right)^{0.8}] \quad (A-15)$$

Inverse equivalent heat transfer coefficient between subchannel types 1 and 3 (or wall)

$$F_2 = \frac{1}{h_3} + \frac{1}{h_1} + \frac{2D_D}{\sqrt{3} k_w} \quad (A-16)$$

Where the term $\frac{1}{h_3} = 0$ if the duct wall

temperature boundary condition is imposed.

A.4 Type 4 Geometry

Subchannel flow area

$$A_4 = \frac{\sqrt{3} P^2}{4} - \frac{\pi}{8} (D^2 + D_w^2) \quad (A-17)$$

Wetted perimeter

$$P_4 = \frac{\pi}{2} (D + D_w) \quad (A-18)$$

Equivalent diameter

$$D_{e4} = \frac{4A_4}{P_4} \quad (A-19)$$

Distance between type 4 subchannel nodal points

$$n_4 = \frac{P}{\sqrt{3}} \quad (A-20)$$

Distance between type 4 and type 5 subchannel nodal points

$$n_5 = \frac{P}{\sqrt{3}} \quad (A-21)$$

Distance between type 4 and type 7 subchannel nodal points

$$\eta_6 = \frac{P}{2\sqrt{3}} + \frac{P-D}{2} + \frac{D}{4} \quad (A-22)$$

A.5 Type 5 Geometry

Subchannel flow area

$$A_5 = \frac{\sqrt{3}}{4} P^2 - \frac{\pi}{12} (D^2 + D_w^2) - \frac{D^2}{4\sqrt{3}} \quad (A-23)$$

Wetted perimeter

$$P_5 = \frac{\pi}{3} (D + D_w) + \frac{D}{\sqrt{3}} \quad (A-24)$$

Equivalent diameter

$$D_{e5} = \frac{4A_5}{P_5} \quad (A-25)$$

Distance between type 5 subchannel nodal points

$$\eta_7 = \frac{P}{\sqrt{3}} \quad (A-26)$$

Distance between type 5 and type 6 subchannel nodal points

$$\eta_8 = \frac{P}{2\sqrt{3}} + \left[t - R_{p1}(1 - \cos \delta_3) - \frac{D}{4} \right] \frac{2}{\sqrt{3}} - \frac{P-D}{2} \quad (A-27)$$

Where δ_3 and t are evaluated in section A.8

Length of type 8 node bounded by type 5 subchannel

$$X_5 = \frac{D}{\sqrt{3}} \quad (A-28)$$

Heat transfer coefficient

$$h_5 = \frac{k}{D_{e5}} \left[7.0 + 0.025 \left(\frac{D_{e5} C_{p5} m_5}{A_5 k} \right)^{0.8} \right] \quad (A-29)$$

Inverse equivalent heat transfer coefficient between subchannel type 5 and node type 8

$$F_5 = \frac{1}{h_5} + \frac{k_5}{k_w} \quad (A-30)$$

Where k_5 is evaluated in section A.8

A.6 Type 6 Geometry

Subchannel area

$$A_6 = \frac{\delta_2}{360} \pi R_{p1}^2 - \frac{1}{2} A_8 - \frac{3\sqrt{3}}{4} P^2 - \frac{90-\delta_1}{360} \frac{\pi}{4} (D^2 + D_w^2) + \frac{D^2}{4\sqrt{3}} \quad (A-31)$$

Where from Figure 11

$$\delta_1 = \tan^{-1} \frac{1}{3\sqrt{3}} = 10.893^\circ \quad (A-32a)$$

and by symmetry

$$\delta_2 = 30^\circ - \delta_1 = 19.107^\circ \quad (A-32b)$$

Wetted perimeter

$$P_6 = \frac{90-\delta_1}{360} \pi (D + D_w) + (t - R_{p1}(1-\cos \delta_3)) \frac{2}{\sqrt{3}} - \frac{D}{2\sqrt{3}} + \frac{\delta_2 - \delta_3}{180} R_{p1} \quad (A-33)$$

where t and δ_3 are evaluated in section A.8

Equivalent diameter

$$D_{e6} = \frac{4A_6}{P_6} \quad (A-34)$$

Distance between type 6 and type 7 subchannel nodal points

$$n_9 = \frac{(30-\delta_3)}{180} \pi (R_{p1} - \frac{P-D}{2}) \quad (A-35)$$

Boundary length between type 8 node and type 6 subchannel

$$X_{6a} = [t - R_{p1}(1 - \cos \delta_3)] \frac{2}{\sqrt{3}} - \frac{D}{2\sqrt{3}} \quad (A-36)$$

Boundary length between type 6 subchannel and bundle tube wall

$$X_{6b} = \left(\frac{\delta_2 - \delta_3}{180} \right) \pi R_{p1} \quad (A-37)$$

Heat transfer coefficient

$$h_6 = \frac{k}{D_{e6}} \left[7.0 + 0.025 \left(\frac{D_{e6} G_p m_6}{A_6 k} \right)^{0.8} \right] \quad (A-38)$$

Inverse equivalent heat transfer coefficient between subchannel type 6 and node type 8

$$F_{6a} = \frac{1}{h_6} + \frac{l_6}{kw} \quad (A-39)$$

Where l_6 is evaluated in section A.8

Inverse equivalent heat transfer coefficient between subchannel types 6 and 9 (or 11)

$$F_{6b} = \frac{1}{h_6} + \frac{R_{p1}}{R_{po} h_A} + \frac{X_{6b}}{kw} \ln \frac{R_{po}}{R_{p1}} \quad (A-40)$$

Where the subscript A = 9 when $Z \leq L_D$
 A = 11 when $Z > L_D$

A.7 Type 7 Geometry

Subchannel Area

$$A_7 = \frac{2\delta_1}{360} \pi R_{p1}^2 - \frac{3\sqrt{3}}{4} P^2 - \frac{90+\delta_1}{360} \frac{\pi}{2} (D^2 + D_w^2) \quad (A-41)$$

Wetted Perimeter

$$P_7 = \frac{2\delta_1}{180} \pi R_{p1} + \frac{90+\delta_1}{180} \pi (D + D_w) \quad (A-42)$$

Equivalent Diameter

$$D_{e7} = \frac{4A_7}{P_7} \quad (A-43)$$

Boundary length between type 7 subchannel and bundle tube wall

$$X_7 = \frac{2\delta_1}{180} \pi R_{p1} \quad (A-44)$$

Heat transfer coefficient

$$h_7 = \frac{k}{D_{e7}} \left[7.0 + 0.025 \left(\frac{D_{e7} C_{p7} m_7}{A_7 k} \right)^{0.8} \right] \quad (A-45)$$

Inverse equivalent heat transfer coefficient between subchannel types 7 and 9 (or 11)

$$F_7 = \frac{1}{h_7} + \frac{R_{p1}}{R_{po} h_A} + \frac{X_7}{kw} \ln \frac{R_{po}}{R_{p1}} \quad (A-46)$$

Where the subscript A = 9 when $Z \leq L_D$
 A = 11 when $Z > L_D$

A.8 Type 8 Geometry

Thickness of the node (see Figure 11)

$$t = R_{p1} - 3P + \frac{D}{2} \quad (A-47)$$

Width of the node at the base (requires solution of simultaneous non-linear equations)

$$W = \frac{D}{\sqrt{3}} + [t - R_{p1}(1 - \cos\delta_3)] \frac{2}{\sqrt{3}} \quad (A-48a)$$

$$W = 2 R_{p1} \sin\delta_3 \quad (A-48b)$$

Solution using $P = 0.582"$, $\frac{P}{D} = 1.05$, $R_{p1} = 1.8485"$ yields.

$$\delta_3 = 11.20^\circ \quad (A-49)$$

Nodal area

$$A_8 = \frac{1}{2} \left(\frac{D}{3} + W \right) (t - R_{p1}(1 - \cos\delta_3)) + \frac{\delta_3}{180} \pi R_{p1}^2 - \frac{W}{2} (R_{p1} \cos\delta_3) \quad (A-50)$$

Boundary length between type node and bundle tube wall

$$X_8 = \frac{2\delta_3}{180} \pi R_{p1} \quad (A-51)$$

Inverse equivalent heat transfer coefficient between node type 8 and node type 9 (or 11)

$$R_8 = \frac{R_{p1}}{R_{po} h_A} + \frac{X_8}{kW} \ln \frac{R_{po}}{R_{p1}} + \frac{t_8}{kW} \quad (A-52)$$

Where the subscript A=9 when $Z \leq L_D$

A=11 when $Z > L_D$

Distance between type 8 nodal point and type 8 node boundary in direction of subchannel type 5

$$L_5 = \frac{D}{\sqrt{3}} \quad (A-53)$$

Distance between type 8 nodal point and type 8 node boundary in direction of subchannel type 6.

$$t_6 = \frac{D}{2 \cos \delta_4} \quad (A-54)$$

$$\text{Where } \delta_4 = \tan^{-1} \left[\frac{2\eta_8 - \frac{P}{\sqrt{3}}}{P} \right] \quad (A-55)$$

Distance between type 8 nodal point and bundle tube wall

$$t_8 = t - \frac{D}{2} \quad (A-56)$$

A.9 Type 9 Geometry

Subchannel area

$$A_9 = \frac{\pi}{6} (R_1^2 - R_{po}^2) \quad (A-57)$$

Wetted perimeter

$$P_9 = \frac{\pi}{3} (R_1 + R_{po}) \quad (A-58)$$

Equivalent diameter

$$D_{e9} = \frac{4A_9}{P_9} \quad (A-59)$$

Boundary length between type 9 subchannel and outer tube wall

$$X_9 = \frac{\pi}{3} R_1 \quad (A-60)$$

Distance between type 9 subchannel nodal points

$$\eta_{10} = \frac{\pi}{6} (R_1 + R_{po}) \quad (A-61)$$

Heat transfer coefficient

$$h_9 = \frac{k}{D_e} \left[7.0 + 0.025 \left(\frac{D_{e9} C_p m}{A_9 k} \right)^{0.8} \right] \quad (A-62)$$

Inverse equivalent heat transfer coefficient between node type 9 and node type 10

$$F_9 = \frac{h}{h_9} + \frac{X_9}{k_w} \ln \frac{R_0}{R_1} + \frac{g}{2k} \quad (A-63)$$

A.10 Type 11 Geometry

Subchannel area

$$A_{11} = A_1 + \frac{\pi}{6} (R_0^2 - R_{po}^2) \quad (A-64)$$

Wetted Perimeter

$$P_{11} = \frac{D_F}{\sqrt{3}} + \frac{\pi}{3} R_{po} \quad (A-65)$$

Equivalent diameter

$$D_{e11} = \frac{4A_{11}}{P_{11}} \quad (A-66)$$

Boundary length between type 11 subchannel and inside hexagonal duct wall.

$$X_{11} = \frac{D_F}{\sqrt{3}} \quad (A-67)$$

Distance between type 11 subchannel nodal points

$$n_{11} = \frac{\pi}{6} (R_{po} + \frac{D_F}{2}) \quad (A-68)$$

Heat transfer coefficient

$$h_{11} = \frac{k}{D_{e11}} [7.0 + 0.025 (\frac{D_{e11} G_{p11}}{A_{11} k})^{0.8}] \quad (A-70)$$

Inverse equivalent heat transfer coefficient between subchannels type 11 and type 12 (or wall)

$$F_{11} = \frac{1}{h_{11}} + \frac{1}{h_3} + \frac{2D}{\sqrt{3}kw} \quad (A-71)$$

Where the term $\frac{1}{h_3} = 0$ if a wall temperature boundary condition is imposed.

A.11 Type 10 Geometry

Distance between type 10 nodal point and inside duct wall

$$l_{10} = \frac{D_F}{\sqrt{3}} - R_o - \frac{z_i}{2} \quad (A-72)$$

Inverse equivalent heat transfer coefficient between nodes type 10 and type 12 (or wall)

$$F_{10} = \frac{1}{h_3} + \frac{2D_D}{\sqrt{3}kw} + \frac{l_{10}}{k} \quad (A-73)$$

Where the term $\frac{1}{h_3} = 0$ if a wall temperature boundary condition is imposed.

APPENDIX B

VARIABLE BOUNDARY CONDITION
SCA CODE LISTING
AND INPUT INSTRUCTIONS

INPUT INSTRUCTIONS FOR VARIABLE BOUNDARY
CONDITION SCA CODE

Main Program

CARD 1 Format (I5)

NOCASE = Number of different cases to be computed

CARD 2 Format (4I5)

NINCR = Total number of axial increments to be
used with this case

NOPRNT = Number of axial printout locations to
be specified

IAX = Number of points to specify boundary
condition axial multiplier

IBC = Boundary condition selection for secondary
control assembly

= 0 interassembly gap centerline tempera-
ture specified

= 1 duct wall temperature specified

= 2 duct wall heat flux specified

CARD 3 Format (2F10.1)

TOTLEN = Total secondary control assembly length
in inches

either QBAVG = Average heat flux along the duct wall
in BTU/hr-ft², only if IBC = 2

or TBAVG = Average temperature boundary condition
in °F, only if IBC = 0 or IBC = 1

CARD 4-J Format (8F10.1)

PRINT(I) = Desired axial printout heights in inches
Repeat card until all NOPRNT printouts
are listed

CARD J+1 Format (6F10.1)

FRAD(I) = Six boundary condition multipliers
corresponding to gap subchannels shown
in Figure 2

CARD J+2-K Format (8F10.1)

ZAX(I) = Relative axial distance associated with
boundary condition multiplier

FAXL(I) = Axial boundary condition multiplier

Repeat the input procedure in the above groups of two
until IAX points have been read in. The first point
group must be at 0.0 and the last at 1.00 on the rela-
tive height scale.

Subroutine SCA

CARD1 Format(4F10.1)

TIN = Bundle inlet temperature in OF
TT = Average temperature to be used in
property calculation in OF
CLEN = Counterflow section axial height in inches
DLEN = Height at which type 10 stagnant node dis-
appears in inches

CARD2 Format(7F10.1)

RIN = Inside radius of the cylindrical can in
the counterflow section in inches
ROUT = Outside radius of the cylindrical can in
the counterflow section in inches
RPIN = Inside radius of the cylindrical poison
bundle can in inches
RPOUT = Outside radius of the cylindrical poison
bundle can in inches
DF = Hexagonal duct flat-to-flat distance in
inches
DTHK = Hexagonal duct wall thickness in inches
GAPTH = Interassembly gap thickness in inches

CARD3 Format(F10.1)

MTOT1 = Total mass flowrate into counterflow
section in lbm/hr
MFL2 = Mass flowrate in downflow region of
counterflow section in lbm/hr
MFLGP = Interassembly gap total flowrate associated
with the secondary control assembly in
lbm/hr
MTOT9 = Total mass flowrate diverted through type
9 subchannels in the poison control
section in lbm/hr

CARD4 Format(4F10.1)

Q2A = Coefficient for first term of volumetric
heat generation rate used in counterflow
section in BTU/hr-ft³
Q2B = Coefficient for second term in BTU/hr-ft³
BA = Coefficient for argument of the first
exponential in the volumetric heat source
term in ft⁻¹
BB = Coefficient for argument of the second
exponential in ft⁻¹
ERR = Acceptable error in temperature at CLEN
Iteration convergence parameter

CARD5 Format(4F10.1)

QAVG = Average volumetric heat generation rate
in poison bundle section in BTU/hr-ft³

P = Poison rod pitch in inches
 DR = Poison rod diameter
 DW = Wire wrap diameter in inches

CARD6 Format(4F10.1)

FS4 = Flowsplit multiplier for type 4 subchannels
 in poison bundle. If set equal to 1.00,
 area weighted flowsplit only
 FS5 = Flowsplit multiplier for type 5 subchannels
 FS6 = Flowsplit multiplier for type 6 subchannels
 FS7 = Flowsplit multiplier for type 7 subchannels

CARD7 Format(6F10.1)

ESTAR4 = Nondimensionalized enhanced eddy
 diffusivity of heat between subchannel
 types 4.
 ESTAR5 = Same between subchannel types 4 and 5
 ESTAR6 = Same between subchannel types 4 and 7
 ESTAR7 = Same between subchannel types 5 and 5
 ESTAR8 = Same between subchannel types 5 and 6
 ESTAR9 = Same between subchannel types 6 and 7

Definition: $\epsilon_{\alpha}^* = \frac{\epsilon_{H_{\alpha}}}{\bar{V} D e_4}$ where $\alpha = 4, 5, 6, 7, 8, 9$

$D e_4$ and $\epsilon_{H_{\alpha}}$ are defined in nomenclature section and $\bar{V}$
 is the average bundle velocity. Until better values
 can be found by data fitting, the same value for all
 six is recommended to be taken from reference 5 which
 has similar geometry.

CARD8 Format(I5)

NAX = Number of points to specify axial power
 profile in the poison control section

CARD9 = N Format(8F10.1)

REL(I) = Relative axial height above CLEN associated
 with specified axial power shape point
 PAX(I) = Axial power shape point to multiply
 QAVG

Repeat unput procedure until in the above groups of
 two until NAX points have been read in. The first

point group must be at 0.0, and the last as
1.00 on the relative height scale

Repeat cards 2-K in the Main Program and cards
1 - N in the Subroutine SCA for each case of
NOCASE, cases

```

0001      COMMON/BLK1/COND,GAPTH,TOTLEN,J,NX,IBC,2,D2,QSCA(6),TSCA(16)
0002      COMMON/BLK2/PRINT(25),IPRNT,ITNUM
0003      COMMON/BLK3/TSCA2(100),PERR,N,MFL4,MFL5,MFL6,MFL7
0004      DIMENSION PR(16),ZAX(50),FAXL(50)
0005      REAL MFL4,MFL5,MFL6,MFL7
0006      C INPUT NCCASE=THE NUMBER OF CASES TO BE COMPUTED
0007      READ(5,1) NCCASE
0008      ON 1000 ICASE=1,NCCASE
0009      C ICASE= NO. OF THIS CASE
0010      WRITE(6,4) ICASE
0011      WRITE(6,3)
0012      1 FORMAT(15)
0013      2 FORMAT(1F10.1)
0014      3 FORMAT(' ',15X,'MAIN PROGRAM INPUT PARAMETERS')
0015      4 FORMAT('1',15X,'**** CASE NUMBER',13,'****')
0016      5 FORMAT(' ',10X,'MINCR,NOPRNT,IAX,IBC/' ',10X,4(15,2X))
0017      C INPUT MINCR=TOTAL NUMBER OF AXIAL INCREMENTS FOR THIS CASE, NOPRNT=
0018      C NUMBER OF AXIAL PRINTOUT POSITIONS DESIRED, IAX=NUMBER OF POINTS TO
0019      C SPECIFY BOUNDARY CONDITION AXIAL SHAPE FACTOR, IBC=BOUNDARY
0020      C CONDITION 0 FOR INTERASSEMBLY GAP TEMPERATURE SPECIFICATION, 1 FOR
0021      C DUCT WALL TEMPERATURE SPECIFICATION, 2 FOR DUCT WALL HEAT FLUX SPEC-
0022      C IFICATION.
0023      READ(5,1) MINCR,NOPRNT,IAX,IBC
0024      WRITE(6,5) MINCR,NOPRNT,IAX,IBC
0025      IF(IBC-1)20,20,10
0026      C IF IBC=2
0027      C INPUT TOTLEN=TOTAL SECONDARY CONTROL ASSEMBLY LENGTH IN INCHES.
0028      C QAVG=AVERAGE HEAT FLUX ALONG THE DUCT WALL IN BTU/HR-FT2
0029      10 READ(5,2) TOTLEN,QAVG
0030      WRITE(6,6) TOTLEN,QAVG
0031      6 FORMAT(' ',10X,'TOTLEN,QAVG/' ',10X,F10.3,2X,F10.2)
0032      GO TO 30
0033      C IF IBC=0 OR IBC=1
0034      C INPUT TOTLEN=TOTAL SECONDARY CONTROL ASSEMBLY LENGTH IN INCHES,
0035      C TAVG=AVERAGE TEMPERATURE FOR BOUNDARY CONDITION IN DEGREES F.
0036      20 READ(5,2) TOTLEN,TAVG
0037      WRITE(6,7) TOTLEN,TAVG
0038      7 FORMAT(' ',10X,'TOTLEN,TAVG/' ',10X,F10.3,2X,F10.2)
0039      C INPUT PRINT(1)= THE AXIAL PRINTOUT LOCATIONS IN INCHES,TOTAL NUMBER
0040      C SHOULD BE EQUAL TO NOPRNT
0041      30 READ(5,2)(PRINT(I),I=1,NOPRNT)
0042      C INPUT FRAO(1)= SIX AXIAL BOUNDARY CONDITION MULTIPLIERS
0043      READ(5,2)(FRAO(I),I=1,6)
0044      C INPUT ZAX(1)= RELATIVE AXIAL HEIGHT, FAXL(1)= AXIAL BOUNDARY-CONDITION
0045      C MULTIPLIER ASSOCIATED WITH ZAX(1) - INPUT IN GROUPS OF TWO
0046      READ(5,2)(ZAX(I),FAXL(I),I=1,IAX)
0047      WRITE(6,8)
0048      WRITE(6,9)(PRINT(I),I=1,NOPRNT)
0049      WRITE(6,11)
0050      WRITE(6,9)(FRAO(I),I=1,6)
0051      WRITE(6,12)
0052      WRITE(6,9)(ZAX(I),FAXL(I),I=1,IAX)
0053      8 FORMAT(' ',10X,'PRINTOUT LOCATIONS - INCHES')

```

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0035      9 FORMAT(' ',10X,6F12.4)
0036      11 FORMAT(' ',10X,'RELATIVE RADIAL MULTIPLIERS')
0037      12 FORMAT(' ',10X,'AXIAL RELATIVE HEIGHT VS. RELATIVE AXIAL MULTIPLE
      13      14      15      16      17      18      19      20      21      22
      23      24      25      26      27      28      29      30      31      32
      33      34      35      36      37      38      39      40      41      42
      43      44      45      46      47      48      49      50      51      52
      53      54      55      56      57      58      59      60      61      62
      63      64      65      66      67      68      69      70      71      72
      73      74      75      76      77      78      79      80      81      82
      83      84      85      86      87      88      89      90      91      92
      93      94      95      96      97      98      99      100      101      102
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      967      968      969      970      971      972      973      974      975
      976      977      978      979      980      981      982      983      984
      985      986      987      988      989      990      991      992      993
      994      995      996      997      998      999      1000

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0070 STDP
0071 END


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0001      SUBROUTINE SCA
0002      COMMON/BLK1/COND,GAPTH,TOTLEN,J,NX,IBC,2,02,QSCA161,7SCA1161
0003      COMMON/BLK3/1SCA2(100),PCRR,N,MFL4,MFL5,MFL6,MFL7
0004      DIMENSION 7SCA1(100),10ARR(500),A1(13),N2(13),A2(13),L01(24),LA2(24)
11,L03(24),LA1(30),L02(30),L03(30),L04(30),LC1(24),LC2(24),LC3(24),
2LC4(24),LC5(24),L0(8,6),LE1(6),LE2(6),LE3(6),PRA(90),PAK(50),
3REL(50)
0005      REAL MTC1,MFLGP,MTC2P,MFL1,MFL2,MFL3,MFL4,MFL5,MFL6,MFL7,MFL8,
MFL9,MFL11,MTC9
      C MODAL CONNECTION NUMBERS FOR COUNTERFLOW SECTION
0006      DATA A1/0,1,4,5,6,7,2,9,10,11,12,13,8/
0007      DATA A2/0,7,2,3,4,5,6,13,8,9,10,11,12/
0008      DATA A3/7,8,9,10,11,12,13,2,3,4,5,6,7/
      C MODAL CONNECTION NUMBERS FOR SUBCHANNEL NUMBERS 1-24 IN POISON SECTION
0009      DATA LA1/1,2,3,4,1,8,1,8,9,2,11,12,3,14,15,4,17,18,5,20,21,6,7/
0010      DATA LA2/6,7,4,5,6,5,24,7,10,11,10,13,14,13,18,17,16,19,20,19,22,
123,22,23/
0011      DATA LA3/8,11,14,17,20,23,26,9,28,31,12,33,36,19,38,41,18,43,40,21
1,48,51,24,53/
      C MODAL CONNECTION NUMBERS FOR SUBCHANNEL NUMBERS 25-54 IN POISON SECTION
0012      DATA LA1/26,7,26,7,28,31,10,11,12,33,36,13,36,15,38,41,16,41,18,43
1,46,17,44,21,48,51,22,51,24,53/
0013      DATA LA2/54,27,28,27,30,27,32,33,32,35,34,37,38,37,40,39,42,43,42,
145,44,47,48,47,50,49,52,51,52,25/
0014      DATA LA3/56,25,57,25,58,60,30,61,44,62,64,35,65,39,66,68,40,69,44,
170,72,45,73,49,74,76,50,77,54,78/
0015      DATA LA4/55,0,0,0,59,59,0,0,0,63,63,0,0,0,67,67,0,0,0,71,71,0,0,0,
175,75,0,0,0,55/
      C MODAL CONNECTION NUMBERS FOR SUBCHANNEL NUMBERS 55-78 IN POISON SECTION
0016      DATA LC1/25,25,27,29,29,30,32,34,34,37,37,39,39,40,42,44,44,45,47,
149,49,50,52,54/
0017      DATA LC2/54,57,56,57,30,61,60,61,35,65,64,65,40,69,68,69,45,73,72,
173,50,77,76,77/
0018      DATA LC3/56,55,58,59,58,59,62,63,62,63,66,67,66,67,70,71,70,71,74,
175,74,75,78,55/
0019      DATA LC4/78,79,79,80,80,80,80,81,81,81,82,88,82,82,83,72,83,83,
184,76,84,84,79/
0020      DATA LC5/79,0,80,0,80,0,81,0,81,0,82,0,82,0,83,0,83,0,84,0,84,0,79
1,0/
      C MODAL CONNECTION NUMBERS FOR SUBCHANNEL NUMBERS 79-84 IN POISON SECTION
0021      DATA L0/55,56,78,57,77,84,80,85,59,58,60,57,61,79,81,88,63,62,64,6
11,65,80,82,87,67,66,68,69,81,83,88,71,70,72,69,73,82,84,89,75,7
24,76,73,77,83,79,90/
      C MODAL CONNECTION NUMBERS FOR SUBCHANNEL NUMBERS 91-96 IN POISON SECTION
0022      DATA LE1/85,86,97,88,89,90/
0023      DATA LE2/96,91,92,93,94,95/
0024      DATA LE3/92,93,94,95,96,91/
0025      IF(IN-GE,2)GO TO 500
0026      IF(J-GE,-1) GO TO 100
      C DATA INPUT AND COEFFICIENT INITIALIZATION SECTION
      C INPUT TIN=BUNDLE INLET TEMPERATURE (F), TI=AVERAGE TEMPERATURE TO
      C BE USED FOR PROPERTY CALCULATION (F), CLEN=COUNTERFLOW SECTION AXIAL
      C HEIGHT (IN.), CLEN=HEIGHT AT WHICH TYPE 10 NODE DISAPPEARS

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0027      READ(5,1) TIN,TT,CLEN,DLEN
      C INPUT RIN=INSIDE RADIUS OF THE DOWNFLOW CAN IN COUNTERFLOW SECTION
      C (IN.), ROUT=OUTSIDE RADIUS OF SAME (IN.), RPIN=INSIDE RADIUS OF
      C POISON BLOCK CAN (IN.), RPOUT=OUTSIDE RADIUS OF SAME (IN.), DF=HEX
      C INSIDE FLAT-TO-FLAT DISTANCE (IN.), DTHK=HEX DUCT WALL THICKNESS (IN.),
      C GAPTH=INTERASSEMBLY GAP WIDTH (IN.)
0028      READ(5,1) RIN,ROUT,RPIN,RPOUT,DF,DTHK,GAPTH
      C INPUT MTOT1=TOTAL MASS FLOW RATE INTO COUNTERFLOW SECTION (LBM/HR),
      C MEL2=DOWNFLOW REGION MASS FLOW RATE (LBM/HR), MELGP=INTERASSEMBLY GAP
      C TOTAL FLOW RATE ASSOCIATED WITH SCA (LBM/HR), MTOT9=TOTAL MASS FLOW
      C RATE DIVERTED THROUGH TYPE 9 SUBCHANNELS (LBM/HR),
0029      READ(5,1) MTOT1,MEL2,MELGP,MTOT9
      C INPUT Q2A,Q2P=COEFFICIENTS FOR 1ST AND 2ND EXPONENTIAL VOLUMETRIC HEAT
      C GENERATION RATE TERMS RESPECTIVELY (BTU/HR-FT3), BA,BB=MULTIPLICATION
      C FACTORS INSIDE 1ST AND 2ND EXPONENTIALS OF VOLUMETRIC HEAT GENERATION
      C RATE TERMS RESPECTIVELY (FT-1), ERN=ACCEPTABLE ERROR IN TEMPERATURE
      C AT CLM ITERATION CONVERGENCE PARAMETER
0030      READ(5,1) Q2A,Q2P,BA,BB,ERN
      C QAVG=AVERAGE VOLUMETRIC HEAT GENERATION RATE IN POISON RIBBLE SECTION
      C TO BE MULTIPLIED BY PRA AND PAX (BTU/HR-FT3), P=POISON ROD PITCH (IN.),
      C DR=POISON ROD DIAMETER (IN.), DL=WIRED WRAP DIAMETER (IN.)
0031      READ(5,1) QAVG,P,DR,DL
      C INPUT FS4,FS5,FS6,FS7=FLOW SPLIT MULTIPLIERS FOR TYPE 4,5,6,7 MODES
      C RESPECTIVELY. AREA WEIGHTED FLOW SPLIT IF SET EQUAL TO 1.00, REMEMBER
      C TO CONSERVE MASS
0032      READ(5,1) FS4,FS5,FS6,FS7
      C INPUT ESTAR4,ESTAR5,ESTAR6,ESTAR7,ESTAR8,ESTAR9=EFFECTIVE FODY DIFFU-
      C SIVITIES CORRESPONDING TO VARIOUS SUBCHANNEL CONNECTIONS (SEEMANUAL)
0033      READ(5,1) ESTAR4,ESTAR5,ESTAR6,ESTAR7,ESTAR8,ESTAR9
      C INPUT NAX=NUMBER OF POINTS TO SPECIFY AXIAL POWER PROFILE
0034      READ(5,2) NAX
      C INPUT REL(1)=RELATIVE HEIGHT ABOVE CLEM AT WHICH AXIAL POWER SHAPE IS
      C TO BE SPECIFIED, AT CLEM REL(1)=0.0, AT BUNDLE EXIT REL(1)=1.00, BOTH
      C MUST BE INCLUDED. PAX(1)=VALUE OF AXIAL POWER SHAPE AT REL(1) - INPUT
      C IN GROUPS OF TWO
0035      READ(5,1) IREL(1),PAX(1),I=1,NAX
      C INPUT PRA(1)=RADIAL POWER MULTIPLIERS FOR SUBCHANNELS 1-84
0036      READ(5,1) (PRA(I),I=1,84)
0037      WRITE(6,5)
0038      WRITE(6,6) TIN,TT,CLEN,DLEN
0039      WRITE(6,7) RIN,ROUT,RPIN,RPOUT,DF,DTHK,GAPTH
0040      WRITE(6,8) MTOT1,MEL2,MELGP,MTOT9
0041      WRITE(6,9) Q2A,Q2P,BA,BB,ERN
0042      WRITE(6,10) QAVG,P,DR,DL
0043      WRITE(6,11) FS4,FS5,FS6,FS7
0044      WRITE(6,12) ESTAR4,ESTAR5,ESTAR6,ESTAR7,ESTAR8,ESTAR9
0045      WRITE(6,13)
0046      WRITE(6,4) (IREL(I),PAX(I),I=1,NAX)
0047      WRITE(6,14)
0048      WRITE(6,4) (PRA(I),I=1,84)
0049      1 FORMAT(10F10.1)
0050      2 FORMAT(6F5)
0051      4 FORMAT(' ',10X,6(F10.4,2X))

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0052      5 FORMAT(//19X,'SUBROUTINE SCA, INPUT PARAMETERS')
0053      6 FORMAT(' ',10X,'ITIN,TT,CLCH,OLEN') ' ',10X,2(F10.2,2X),2(F10.4,2X))
0054      7 FORMAT(' ',10X,'RIN,ROUT,RPIN,ROUT,DF,DTHK,GAPTH') ' ',10X,7(F10.4
1,1X))
0055      8 FORMAT(' ',10X,'NTOT1,MFL2,MFLGP,NTOT9') ' ',10X,4(F10.1,2X))
0056      9 FORMAT(' ',10X,'Q2A,Q2B,RA,EB,ERR') ' ',10X,2(F10.1,2X),3(F10.4,2X)
1)
0057      10 FORMAT(' ',10X,'QAVG,PIDN,BM') ' ',10X,F10.1,2X,3(F10.4,2X))
0058      11 FORMAT(' ',10X,'F4,FS5,FS6,FS7') ' ',10X,4(F10.4,2X))
0059      12 FORMAT(' ',10X,'ESTAR4,ESTARS,ESTARS,ESTAR7,ESTARA,ESTAR9') ' ',10X
1,6(F10.5,2X))
0060      13 FORMAT(' ',10X,'AXIAL RELATIVE HEIGHT VS. RELATIVE FLLX SHAPE')
0061      14 FORMAT(' ',10X,'SURCHANNEL RELATIVE RADIAL POWER PROFILE')
- C CALCULATE PROPERTIES FOR USE IN SCA
C RHO=SOBIUM DENSITY, C=SCDIUM SPECIFIC HEAT, CONO=SCDIUM CONDUCTIVITY,
C CONM=CONDUCTIVITY OF THE DUCT WALLS
RHO=37.556-(7.9504E-03)*TT-10.2877E-06)*TT**2+(0.06035E-09)*TT**3
C=0.34402-(7.01530E-5)*TT+12.68131E-8)*TT**2
CONO=54.306-(1.878E-2)*TT+(2.0914E-6)*TT**2
CONM=12.1
PI=3.14159
C CALCULATE FLOW RATES FOR SUBCHANNEL TYPES 1 AND 3
MFL1=NTOT1/6.
MFL3=MFLGP/6.
C SUBCHANNEL TYPE AREAS
A1=(0.86673*(DF/12.))**2-PI*(ROUT/12.))**2)/6.
A2=PI*(RIN/12.))**2
A3=(GAPTH/2.)*DF/1.7321+(0.5774*(GAPTH/2.)*DTHK*(GAPTH))/144.0
C SUBCHANNEL TYPE WETTED PERIMETERS
P1=4.2*PI*(ROUT/12.)+3.4641*(DF/12.))/6.
P3=(DF/1.7321+1.1547*DTHK)/12.
C SURCHANNEL TYPE EQUIVALENT DIAMETERS
DE1=4.*A1/P1
DE3=4.*A3/P3
C DISTANCES OF ONE SURCHANNEL ALONG HEX DUCT CENTERLINE AND INTERASSEMBLY
C GAP CENTERLINE RESPECTIVELY
X2=(DF/1.7321+0.5774*DTHK)/12.
X3=(DF/1.7321+1.1547*(GAPTH/2.)*DTHK)/12.
C GAP WIDTH BETWEEN TYPE 1 SURCHANNELS
WIDTH=ICF-2.*ROUT/24.
C NODAL DISTANCES BETWEEN TYPE 1 NODES AND BETWEEN TYPE 3 NODES
ET41=(ROUT/12.)*WIDTH/2.)*PI/3.
ET43=(DF/1.7321+1.1547*(DTHK*(GAPTH/4.)))/12.
- C HEAT TRANSFER COEFFICIENTS FOR TYPE NODES 1,2 AND3
HONF=(CONO/DE1)*17.0+0.025*(DE1*CP*MFL1/141*CONO)**0.81
HTWO=(16.*CONO/RIN)*17.0+0.025*(RIN*CP*MFL2/16.*A2*CONO)**0.81
HTH3=(CONO/DE3)*17.0+0.025*(DE3*CP*MFL3/143*CONO)**0.81
F=ALOG(ROUT/RIN)
C INVERSE EQUIVALENT HEAT TRANSFER COEFFICIENTS: F1=NODE TYPE1 TO TYPE
- C 2, F2=NODE TYPE1 TO TYPE3 (OR WALL)
F1=1./HTWO+RIN/ROUT*HONF+RIN*F/(12.*CONO)
IF((BC.NE.1) GO TO 15
F2=1./HCNE+1.1547*DTHK/(12.*CONO)

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0088      GO TO 17
0089      15 F2=1./HTHR+1./HOCF+1.1547*DTWK/(12.*CONDW)
0090      17 CONTINUE
0091      SCA=P1*(RIN/12.)*Z/(MFL2*CP)
          C COEFFICIENTS FOR TYPE 2 TEMPERATURE EXPRESSION
0092      C1=2.*P1*(RIN/(12.*MFL2*CP*F))
0093      C2=DETA*Q2A/(BA-C1)
0094      C3=DETA*Q2B/(CA-C1)
          C COEFFICIENTS FOR TYPE 1 TEMPERATURE EXPRESSION
0095      D1=X2*Q2/(12.*MFL1*CP*F2)
0096      D2=D1*A1/(MFL1*CP*12.)
0097      D3=4*(Q1+D2*CO,0)/(12.*MFL1*CP*ETA1)
0098      D4=P1*(RIN/12.)*Z/(432.*MFL1*CP*F)
          C COEFFICIENTS FOR TYPE 3 TEMPERATURE EXPRESSION
0099      E1=D1*MFL1/MFL3
0100      E2=GAPIN*D2*COND/1288.*MFL3*CP*ETA3)
0101      E3=D2*X3/(12.*MFL3*CP)
          C INITIALIZE ARRAYS
          C TPAR(I) STORES THE AVERAGE VALUE OF THE TYPE 4 TEMPERATURES AT THE
          C AXIAL LEVEL I=1
0102      IF 20 I=1,500
0103      TPAR(I)=TIM
0104      20 CONTINUE
0105      DO 25 I=1,6
0106      TSCA(I)=0.0
          C FOR IPC=0, TSCA(1) CONTAINS THE TEMPERATURE OF THE SECONDARY CONTROL
          C ASSEMBLY INTERASSEMBLY GAP SUBCHANNEL AT THE PREVIOUS AXIAL LEVEL, FOR
          C IPC=2 IT CONTAINS THE TEMPERATURE BOUNDARY CONDITION AT THE DUCT
          C WALL IN THE CURRENT AXIAL LEVEL
0107      TSCA(1)=TIM
0108      25 CONTINUE
          C INITIALIZE ARRAYS TSCA(1), TSCA(2)=SUBCHANNEL TEMPERATURES AT OLD
          C AND NEW AXIAL HEIGHTS RESPECTIVELY
0109      DO 30 I=2,13
0110      TSCA(I)=TIM
0111      TSCA(2)=0.0
0112      30 CONTINUE
          C SUM2=TEMPERATURE DERIVATIVE SUMMATION TERM FOR SCPI-ANALYTICAL NODE
          C TYPE 2 SOLUTION BASED ON NODE TYPE 1 AVERAGE TEMPERATURES OF THE
          C CURRENT ITERATION, SUM1=SUM2 BASED ON LAST ITERATIONS TEMPERATURES
0113      SUM1=0.0
0114      SUM2=0.0
          C QV=VOLUMETRIC HEAT FLUX TERM FOR COUNTERFLOW SECTION, HERE AT HEIGHT
          C Z=Q2/2, DELT=TEMPERATURE DIFFERENCE BETWEEN TYPE 2 AND AVERAGE TYPE
          C 1 SUBCHANNELS, HERE AT Z=0.0
0115      QV=Q2*EXP(-BA*(CLEN-DZ/2.)/(12.*1+Q2B*EXP(-BA*(CLEN-DZ/2.)/(12.*1
0116      DELT=(C2+C3)*EXP(-C1*(CLEN/12.))-C2*EXP(-BA*(CLEN/12.))-C3*EXP(-BS*(CLEN/12.))-SUM1*EXP(-C1*(CLEN/12.))
          TSCA(1)=TIM+OFLT
0117      N=1
0118      WRITE(6,40) N
0119      WRITE(6,41)
0120      WRITE(6,42) A1,A2,A3

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0122      WRITE(6,42)
0123      WRITE(6,35) P1,P3,DE1,DE3
0124      WRITE(6,43)
0125      WRITE(6,35) K2,K3,WIDTH,ETA1,ETA3
0126      WRITE(6,44)
0127      WRITE(6,35) HONE,HTWO,HTHR
0128      WRITE(6,45)
0129      WRITE(6,35) META,C1,C2,C3,D1,D2,D3,D4,E1,E2,E3
0130      WRITE(6,46)
0131      WRITE(6,35) RHO,CP,COND,CONDK
0132      FORMAT(' ',10X,6E13,4)
0133      40 FORMAT(//,15X,'SUBROUTINE SCA CALCULATED PARAMETERS - REGION',I3)
0134      41 FORMAT(' ',10X,'SUBCHANNEL AREAS IN SQ.FT. - A1,A2,A3')
0135      42 FORMAT(' ',10X,'WETTED PERIMETERS AND EQUIV. DIAMETERS IN FT. - P1
      L,P3,DE1,DE3')
0136      43 FORMAT(' ',10X,'SOME CHARACTERISTIC LENGTHS IN FT. - X2,X3,WIDTH,E
      (TA1,ETA3)')
0137      44 FORMAT(' ',10X,'HEAT TRANSFER COEFFICIENTS IN BTU/HR-FT2-F - HONE,
      HTWO,HTHR')
0138      45 FORMAT(' ',10X,'COEFFICIENTS FOR TEMPERATURE EXPRESSIONS - META,C1
      C2,C3,D1,D2,D3,D4,E1,E2,E3')
0139      46 FORMAT(' ',10X,'PROPERTIES BASED ON AVERAGE TEMPERATURE - RHO,CP,C
      (COND,CONDK)')
      C J=AXIAL STEP COUNTER
      C K=AXIAL REGION INDICATOR, 0 COUNTERFLOW REGION HAS NOT CONVERGED,
      C 1 COUNTERFLOW REGION HAS CONVERGED AND IS ON PRINTOUT ITERATION, 2 IN
      C POISON SECTION WHERE NODE TYPE 10 IS PRESENT, 3 ABOVE THAT POINT
      C NK=NEW ITERATION INDICATOR, WHEN IT EQUALS 1 ITERATE TO Z=0.0
0140      J=0
0141      NK=0
0142      GO TO 1009
0143      100 CONTINUE
0144      J=J+1
0145      ZZ=(Z+DZ)/2.
0146      IF(NK.EG.1) NK=0
0147      IF(18C,AE,01 GO TO 109
      C TYPE 3 TEMPERATURE CALCULATION - ONLY IF 18E=0
0148      DO 110 I=8,13
0149      L=I-7
      C GOVERNING TEMPERATURE EXPRESSION FOR NODE TYPE 3
      TSCA2(I)=TSCA1(I) +E5*QSCAL(L) +E1*(TSCAL(N3(I))-TSCAL(I))+E2*
      L*(TSCALIN1(I)+TSCALIN2(I))-2.*TSCA1(I)
0151      TSCA1(I)=TSCA2(I)
0152      110 CONTINUE
0153      109 CONTINUE
0154      TAV=0.0
      C TYPE 1 TEMPERATURE CALCULATION
0155      DO 120 I=2,7
0156      L=I-1
      C DETERMINE BOUNDARY CONDITION EFFECTS
0157      IF(18C-1) 115,113,111
0158      111 Q3=QSCAL(I)*DZ*X2/112.*HFL1*CP)
0159      GO TO 117

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0160      113 Q3=Q1*(TSCA3(L1)-TSCA1(I))
0161      TSCA2(I+6)=TSCA3(L1)
0162      GO TO 117
0163      115 Q3=Q1*(TSCA1(N3(I))-TSCA1(I))
0164      117 CONTINUE
C      GOVERNING TEMPERATURE EXPRESSION FOR NODE TYPE 1
0165      TSCA2(I)=TSCA1(I)+Q3+Q3*(TSCA1(N2(I))+TSCA1(N1(I))-2.*TSCA1(I))+D2
      (*Q3+Q4*(TSCA1(I)-TSCA1(I)))
0166      IF ITRC.EQ.21 TSCA2(I+6)=TSCA2(I)
0167      TAV=TAV+TSCA2(I)
0168      120 CONTINUE
0169      JJ=J+1
0170      R=ICLEN-ZZ1/12.
0171      IF (R.LT.0.0) R=0.0
0172      FALPH=EXP(-C1*R)
0173      FPA=EXP(-A2*R)
0174      FPR=EXP(-P2*R)
0175      DELT=(C2+C3)*EALPH-C2*EB4-C3*EBN-CALPH*SUM1
0176      QV=Q2A*EXP(-BA*(R-DZ/25.))+C2B*EXP(-BB*(R-DZ/25.))
C      FIND SUM1 FOR NEXT AXIAL STEP BEFORE TBAR(JJ) TAKES ON A NEW VALUE
C      FOR THE CURRENT ITERATION
0177      SUM1=SUM1+EXP(C1*R)*(TPAR(JJ)-TPAR(JJ))
0178      TPAR(JJ)=TAV/6.
C      FIND TYPE 2 TEMPERATURE FOR THIS AXIAL STEP
0179      TSCA2(I)=DELT+TBAR(JJ)
0180      SUM2=SUM2+EXP(C1*(R+DZ/12.))*TBAR(JJ)-TPAR(JJ)
C      PREPARE TSCA1(I) ARRAY FOR NEXT AXIAL STEP
0181      125 DO 130 I=1,13
0182      TSCA1(I)=TSCA2(I)
0183      130 CONTINUE
0184      IF ICLEN.GT.ZZ1 GO TO 1000
0185      SUM1=SUM2
0186      SUM2=0.0
C      CALCULATE ERROR IN TEMPERATURE AT Z=CLEN, IF CONVERGED ENTER ITERATION
C      LOOP ONE LAST TIME FOR PARTICLE OTHERWISE CONTINUE TO ITERATE
0187      FPRR=(TPAR(JJ)-TPAR(500))/TPAR(JJ)
0188      IF (FPRR.LT.1) GO TO 250
0189      IF (DEH4.LE.FPR) N=1
0190      TPAR(500)=TPAR(JJ)
0191      N=2
C      SET UP QV,TSCA1(I), AND SUM1 FOR NEW ITERATION
0192      QV=Q2A*FPA(-BA*ICLEN-DZ/25.)/12.)+C2B*EXP(-BB*ICLEN-DZ/25.)/12.)
0193      DELT=(C2+C3)*EXP(-C1*ICLEN/12.)-C2*EXP(-BA*ICLEN/12.)-C3*EXP(-BB*ICLEN/12.)-SUM1*EXP(-C1*ICLEN/12.)
      TSCA1(I)=FPA*DELT
0194      SUM1=SUM1+EXP(C1*ICLEN/12.)*TBAR(2)-TPAR(1)
0195      IF ITRC.NE.01 GO TO 195
0196      DO 190 I=1,6
0197      190 TSCA1(I)=TIN
0198      195 CONTINUE
0199      DO 200 I=2,13
0200      TSCA1(I)=TIN
0201      200 CONTINUE
0202

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0203      GO TO 1000
0204      C BEGINNING OF POISON SECTION PART OF THE PROGRAM
0205      250 H=H+1
0206      C INITIALIZE TEMPERATURES BASED ON COUNTERFLOW TEMPERATURES
0207      DO 270 I=79,84
0208      LX=I-77
0209      TSCA2(1)=TSCA2(LX)
0210      270 CONTINUE
0211      DO 280 I=91,96
0212      LX=I-83
0213      TSCA2(1)=TSCA2(LX)
0214      280 CONTINUE
0215      DO 260 I=1,78
0216      TSCA2(1)=TSCA2(1)
0217      260 CONTINUE
0218      C SUBCHANNEL TYPE AREAS
0219      A4= 0.4330*(P/12.)*2-P*(DR/12.)*2*(OW/12.)*2/6.
0220      A5= 0.4330*(P/12.)*2-P*(DR/12.)*2*(OW/12.)*2/12.-(DR/12.)*2
0221      1/6.9282
0222      A7=0.1901*(RPIN/12.)*2-1.2990*(P/12.)*2-0.4402*(DR/12.)*2*(OW/
0223      112.)*2
0224      AR=(DR/1.4641+0.1942*RPIN)*(DR/2.-3.*P+0.9810*RPIN)/144.+4.952C-03
0225      1919*1/12.)*2
0226      A6=0.1667*(RP/17.)*2-1.2990*(P/12.)*2-A8/2.-0.1725*(DR/12.)*2
0227      12*(OW/12.)*2*(DR/12.)*2/6.9282
0228      A9=P*(DR/12.)*2-(RPCUT/12.)*2/6.
0229      A11=41+P*(RPCUT/12.)*2-(RPCUT/12.)*2/6.
0230      C TOTAL FLOW AREA
0231      AT77=42.*A4+12.*A5+12.*A6+6.*A7
0232      C SUBCHANNEL TYPE NETTED PERIMETERS
0233      P4=P*(DR+OW)/24.
0234      P5=P*(DR+OW)/36.+DR/121/1.7321
0235      P6=10.690*(LR+OW)+1.270*RPIN-3.4641*P+0.2887*DR/12.
0236      P7=10.3202*RPIN+1.7609*(DR+OW)/12.
0237      P9=P*(RP+RPCUT)/36.
0238      P11=(DR/1.7321+P*(RPCUT/12.))/12.
0239      C NODAL DISTANCES - SEE MANUAL FOR NUMBERING SCHEME
0240      ET04=P/17.3/1.7321
0241      ET05=P/12.1/1.7321
0242      ET06=P/12.1/1.7321+(P-DR)/24.+DR/48.
0243      ET07=P/17.3/1.7321
0244      ET08=(DR/2.+1.1328*RPIN-3.6754*P+0.2887*DR)/12.
0245      ET09=0.3281*(RPIN-(P-DR)/2.)/12.
0246      ET10=P*(RA+RPCUT)/72.
0247      ET11=P*(RPCUT+DR/2.)/72.
0248      C SUBCHANNEL TYPE EQUIVALENT DIAMETERS
0249      DE4=4.0*A4/P4
0250      DE5=4.0*A5/P5
0251      DE6=4.0*A6/P6
0252      DE7=4.0*A7/P7
0253      DE9=4.0*A9/P9
0254      DE11=4.0*A11/P11
0255      C TOTAL FLOW RATE ENTERING POISON BUNDLE

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0244      MTOTP=MTOT1-MFL2-MTGT9
      C FLOWRATES FOR SUBCHANNEL TYPES 4,5,6,7,9,11
0245      MFL4=84*F54*MTOTP/ATOT
0246      MFL5=85*F55*MTOTP/ATOT
0247      MFL6=86*F56*MTOTP/ATOT
0248      MFL7=87*F57*MTOTP/ATOT
0249      MFL9=MTGT9/6.
0250      MFL11=MFL9
      C BUNDLE AVERAGE VELOCITY
0251      VPAR=MTCTP/(RHO*ATOT)
      C HEAT TRANSFER COEFFICIENTS FOR 5,6,7,9,11
0252      HFE=ICCN0/DE11*(7.0+0.025*(DE5*CP*MFL5/(85*COND1))**0.8)
0253      HSI=ICCN0/DE6*(7.0+0.025*(DE6*CP*MFL6/(86*COND1))**0.8)
0254      HSN=ICCN0/DE7*(7.0+0.025*(DE7*CP*MFL7/(87*COND1))**0.8)
0255      HNC=ICCN0/DE9*(7.0+0.025*(DE9*CP*MFL9/(89*COND1))**0.8)
0256      HFN=ICCN0/DE11*(7.0+0.025*(DE11*CP*MFL11/(811*COND1))**0.8)
0257      FACTOR=ALOG(RPOUT/RPIN)
      C INVERSE FCJ (VALC AT HEAT TRANSFER COEFFICIENTS - FOLLOW MANUAL DEFINITION)
0258      F=1./HFE*OR/(120.7852*COND1)
0259      F6A=1./HSI*OR/(112.*COND1)
0260      F9=1./HNF*PI*RTN*F/(136.*COND1)+MIDTH/(2.*COND1)
0261      IF(IPC.NT.1) GO TO 350
0262      F10=IDE/(1.7321-ROUT-6.*MTOT1)/(12.*COND1)+1.1547*DTHK/(12.*COND1)
0263      F11=1./HFN*1.1547*DTHK/(12.*COND1)
0264      GO TO 360
0265      350 F10=1./HNR*(DE/(1.7321-ROUT-6.*MTOT1)/(12.*COND1)+1.1547*DTHK/(12.*COND1)
0266      F11=1./HNR*1./HFN*1.1547*DTHK/(12.*COND1)
0267      360 CONTINUE
      C COEFFICIENTS FOR TYPE 4 TEMPERATURE EXPRESSION
0268      CC1=QAVC*Q2*AA/(112.*CP*MFL4)
0269      CC2=(P-DR)*Q2*(COND+RHO*CP*ESTAR4*(VBAR*DE41)/(144.*MFL4*CP*ETA4))
0270      CC3=(P-DR)*Q2*(COND+RHO*CP*ESTAR5*(VBAR*DE41)/(144.*MFL4*CP*ETA5))
0271      CC4=(P-DR)*Q2*(COND+RHO*CP*ESTAR6*(VBAR*DE41)/(144.*MFL4*CP*ETA6))
      C COEFFICIENTS FOR TYPE 5 TEMPERATURE EXPRESSION
0272      DD1=QAVC*Q2*AS/(112.*CP*MFL5)
0273      DD2=(P-DR)*Q2*(COND+RHO*CP*ESTAR7*(VBAR*DE41)/(144.*MFL5*CP*ETA7))
0274      DD3=(P-DR)*Q2*(COND+RHO*CP*ESTAR8*(VBAR*DE41)/(144.*MFL5*CP*ETA8))
0275      DD4=(P-DR)*Q2*(COND+RHO*CP*ESTAR9*(VBAR*DE41)/(144.*MFL5*CP*ETA9))
0276      DD5=Q2*OR/(144.*F5*MFL5*CP*1.7321)
      C COEFFICIENTS FOR TYPE 6 TEMPERATURE EXPRESSION
0277      EE1=QAVC*Q2*AC/(112.*CP*MFL6)
0278      EE2=(P-DR)*Q2*(COND+RHO*CP*ESTAR8*(VBAR*DE41)/(144.*MFL6*CP*ETA8))
0279      EE3=(P-DR)*Q2*(COND+RHO*CP*ESTAR9*(VBAR*DE41)/(144.*MFL6*CP*ETA9))
0280      EE4=OR/(3.4641-3.4641*P+1.1328*RPIN)*Q2/(144.*F6*MFL6*CP)
      C COEFFICIENTS FOR TYPE 7 TEMPERATURE EXPRESSION
0281      GG1=QAVC*Q2*87/(112.*CP*MFL7)
0282      GG2=(P-DR)*Q2*(COND+RHO*CP*ESTAR7*(VBAR*DE41)/(144.*MFL7*CP*ETA7))
0283      GG3=(P-DR)*Q2*(COND+RHO*CP*ESTAR8*(VBAR*DE41)/(144.*MFL7*CP*ETA8))
      C COEFFICIENTS FOR TYPE 9 TEMPERATURE EXPRESSIONS
0284      KK5=PI*RTN*Q2/(132.*MFL9*CP*F9)
0285      KK6=Q2*COND*IN*IN-RPOUT/(144.*CP*MFL9*ETA10)
      C COEFFICIENTS FOR TYPE 11 TEMPERATURE EXPRESSIONS

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0286      XX7=10F/(1.73211)*DZ/(144.*MFL1)*CP*F111
0287      XX8=DZ*CONO*(CP-2.*RPOUT)/(1288.*CP*MFL1)*E1A111
      C COEFFICIENTS FOR TYPE 10 TEMPERATURE EXPRESSION
0288      DNMTN=XX5*CP*MFL9+XZ*DZ/(12.*F10)
0289      YY1=XX5*MFL9*CP/DNMTN
0290      YY2=XZ*DZ/(12.*F10*DNMTN)
      C COEFFICIENTS FOR TYPE 12 TEMPERATURE EXPRESSION
0291      E3=YY2*DNMTN/(MFL3*CP)
0292      E4=XX7*MFL11/MFL3
0293      AA=49
0294      MFL8=MFL9
0295      HXIX=HANE
0296      500 CONTINUE
      C THESE COEFFICIENTS CHANGE WHEN SUBCHANNEL TYPE9 BECOMES TYPE 11
0297      F6B=1./HSIX*RPIN/(RPOUT*HXIX)+0.1380*RPIN*FACTOR/(12.*CONOW)
0298      F7=1./HSVN*RPIN/(RPOUT*HXIX)+0.3802*RPIN*FACTOR/(12.*CONOW)
0299      F8=RPIN/(APDUT*HXIX)+0.3910*RPIN*FACTOR/(12.*CONOW)+1*RPIN-3*P1/(12
      1.*CONOW)
0300      EC5=0.1380*RPIN*DZ/(144.*CP*MFL6*F6B)
0301      G74=0.3802*RPIN*DZ/(1288.*MFL7*CP*F7)
      C COEFFICIENTS FOR TYPE 8 TEMPERATURE EXPRESSION
0302      DNMTN=2.*F74*MFL6*CP+2*DD5*MFL5*CP+0.3910*RPIN*DZ/(144.*F8)
0303      WM1=EL4*YTLE*CP/DNMTN
0304      WM7=DD5*MFL5*CP/GRAOM
0305      WM3=0.3910*DZ*RPIN/(144.*F8*DENCM)
      C COEFFICIENTS FOR TYPE 9 AND 11 TEMPERATURE EXPRESSIONS
0306      XX1=QAVG*DZ*AA/(12.*CP*MFLA)
0307      XX2=EC5*MFL6/MFLA
0308      XX3=GG44*H17/MFLA
0309      XX4=WM3*DENCM/ICP*MFLA1
0310      IF(9,3F,9) GO TO 500
0311      WRITE(6,40) N
0312      WRITE(6,300)
0313      WRITE(6,35) A4,A5,A6,A7,A8,A9,A11,ATGT
0314      WRITE(6,301)
0315      WRITE(6,35) P4,P5,P6,P7,P9,P11
0316      WRITE(6,302)
0317      WRITE(6,35) ET4,ET5,CT4,ET7,CT8,ET9,FT4,ET10,ET11
0318      WRITE(6,303)
0319      WRITE(6,35) DE4,DE5,DE6,DE7,DC9,DC11
0320      WRITE(6,304)
0321      WRITE(6,35) FTOTP,MFL4,MFL5,MFL6,MFL7,MFL9,MFL11
0322      WRITE(6,305)
0323      WRITE(6,35) MFEV,HSIX,HSVN,HANE,NEVN
0324      WRITE(6,306)
0325      WRITE(6,35) F5,F6A,F6B,F7,F8,F9,F10,F11
0326      WRITE(6,307)
0327      WRITE(6,35) CC1,CC2,CC3,CC4
0328      WRITE(6,308)
0329      WRITE(6,35) DD1,DD2,DD3,DD4,DD5
0330      WRITE(6,309)
0331      WRITE(6,35) EE1,EE2,EE3,EE4,EE5
0332      WRITE(6,310)

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0333      WRITE(6,351) GG1,GG2,GG3,GG4
0334      WRITE(6,311)
0335      WRITE(6,351) WW1,WW2,WW3
0336      WRITE(6,312)
0337      WRITE(6,351) XX1,XX2,XX3,XX4,XX5,XX6,XX7,XX8
0338      WRITE(6,313)
0339      WRITE(6,351) YY1,YY2
0340      WRITE(6,314)
0341      WRITE(6,351) E3,E4
0342      300 FORMAT(' 1.10X,'SURCHANNFL AREAS IN SQ. FT. = A4,A5,A6,A7,A8,A9,A1
      11,ATOT')
0343      301 FORMAT(' 1.10X,'WETTED PERIMETERS IN FT. = P4,P5,P6,P7,P9,P11')
0344      302 FORMAT(' 1.10X,'SOME CHARACTERISTIC LENGTHS IN FT. = ETA4,ETA5,ETA
      16,ETA7,ETA8,ETA9,ETA10,ETA11')
0345      303 FORMAT(' 1.10X,'EQUIV. DIAMETERS IN FT. = DE4,DE5,DE6,DE7,DE9,DE11')
0346      304 FORMAT(' 1.10X,'MASS FLOWRATES IN LBM/HR = MTOTF,MFL4,MFL5,MFL6,MF
      11,MFL7,MFL8,MFL9,MFL11')
0347      305 FORMAT(' 1.10X,'HEAT TRANSFER COEFFICIENTS IN BTU/HR-FT2-F = HVE,
      1H51,H52,H53,H54,H55,H56,H57')
0348      306 FORMAT(' 1.10X,'INVERSE EQUIV. HEAT TRANSFER COEFF. = F5,F6,F7,F8,F
      11,F9,F10,F11')
0349      307 FORMAT(' 1.10X,'COEFF. FOR CHANNEL TYPE 4 TEMPERATURE EXPRESSION =
      1 CC1,CC2,CC3,CC4')
0350      308 FORMAT(' 1.10X,'COEFF. FOR CHANNEL TYPE 5 TEMPERATURE EXPRESSION =
      1 DD1,DD2,DD3,DD4,DD5')
0351      309 FORMAT(' 1.10X,'COEFF. FOR CHANNEL TYPE 6 TEMPERATURE EXPRESSION =
      1 EE1,EE2,EE3,EE4,EE5')
0352      310 FORMAT(' 1.10X,'COEFF. FOR CHANNEL TYPE 7 TEMPERATURE EXPRESSION =
      1 GG1,GG2,GG3,GG4')
0353      311 FORMAT(' 1.10X,'COEFF. FOR CHANNEL TYPE 8 TEMPERATURE EXPRESSION =
      1 WW1,WW2,WW3')
0354      312 FORMAT(' 1.10X,'COEFF. FOR CHANNEL TYPE 9 TEMPERATURE EXPRESSION =
      1 XX1,XX2,XX3,XX4,XX5,XX6,XX7,XX8')
0355      313 FORMAT(' 1.10X,'COEFF. FOR CHANNEL TYPE 10 TEMPERATURE EXPRESSION
      1 = YY1,YY2')
0356      314 FORMAT(' 1.10X,'COEFF. FOR CHANNEL TYPE 3 TEMPERATURE EXPRESSION =
      1 F3,E4')
0357      GO TO 721
0358      500 CONTINUE
0359      IF(N.GE.31) GO TO 520
0360      IF(LEN.GT.2) GO TO 520
0361      N=3
0362      AA=11
0363      MFLA=MFL11
0364      HXXA=HFXN
0365      GO TO 400
0366      520 CONTINUE
0367      ZOL=(12-CLEN)/(TOTLEN-CLEN)
0368      C FIND RELATIVE HEIGHT FROM CLEN AND AXIAL POWER FACTOR TO GO WITH IT
      IF(ZOL.GT.1.0) ZOL=1.0
0369      CALL FIT1FAX,ZOL,PAX,REL,NAX)
0370      DO 600 I=1,24

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      C TYPE 4 SUBCHANNEL GOVERNING EQUATION
0371 TSCA2(I)=TSCA1(I)+CC1*PRA(I)*FAX+CC2*(TSCA1(LA2(I))+TSCA1(LA2(I))-
      ITSCA1(LA2(I))-3.0*TSCA1(I))
0372 600 CONTINUE
0373 DO 610 I=25,54
0374 L=I-24
0375 IF(LB4(I).GT.0160) GO TO 620
0376 IF(LB7(I).GT.56) GO TO 610
      C TYPE 4 SUBCHANNEL GOVERNING EQUATION
0377 TSCA2(I)=TSCA1(I)+CC1*PRA(I)*FAX+CC2*(TSCA1(LB1(I))+TSCA1(LB2(I))-
      12.0*TSCA1(I))+CC3*(TSCA1(LB3(I))-TSCA1(I))
0378 GO TO 630
      C TYPE 4 SUBCHANNEL GOVERNING EQUATION
0379 TSCA2(I)=TSCA1(I)+CC1*PRA(I)*FAX+CC2*(TSCA1(LB1(I))+TSCA1(LB2(I))-
      12.0*TSCA1(I))+CC4*(TSCA1(LB3(I))-TSCA1(I))
0380 GO TO 630
      C TYPE 5 SUBCHANNEL GOVERNING EQUATION
0381 TSCA2(I)=TSCA1(I)+DD1*PRA(I)*FAX+DD4*(TSCA1(LB1(I))-TSCA1(I))+DD2*
      2*(TSCA1(LB2(I))-TSCA1(I))+DD3*(TSCA1(LB3(I))-TSCA1(I))+DD5*(TSCA1(L
      2B4(I))-TSCA1(I))
0382 630 CONTINUE
0383 DO 640 I=55,79
0384 L=I-54
0385 IF(LC5(I).EQ.01) GO TO 650
0386 IF(LF4(I).LT.79) GO TO 660
      C TYPE 7 SUBCHANNEL GOVERNING EQUATION
0387 TSCA2(I)=TSCA1(I)+GG1*PRA(I)*FAX+GG2*(TSCA1(LC2(I))+TSCA1(LC3(I))
      1-2.0*TSCA1(I))+GG3*(TSCA1(LC1(I))-TSCA1(I))+GG4*(TSCA1(LC4(I))+TSC
      2A1(LC5(I))-2.0*TSCA1(I))
0388 GO TO 660
      C TYPE 6 SUBCHANNEL GOVERNING EQUATION
0389 TSCA2(I)=TSCA1(I)+FC1*PRA(I)*FAX+FE2*(TSCA1(LC1(I))+TSCA1(I))+EE3*
      1*(TSCA1(LC2(I))-TSCA1(I))+EE4*(TSCA1(LC3(I))-TSCA1(I))+EE5*(TSCA1(L
      2C4(I))-TSCA1(I))
0390 660 CONTINUE
0391 DO 680 I=79,84
0392 L=I-78
0393 IF(IN.GT.2) GO TO 670
0394 IF(IBC-11665.665.66)
      C DETERMINE BOUNDARY CONDITION EFFECTS
0395 663 O3=OSCA(L)*DZ*X2/(12.*CP*HFL9)
0396 GO TO 667
0397 665 O3=XX5*(TSCA1(LD16,L1)-TSCA1(I))
0398 667 CONTINUE
      C TYPE 9 SUBCHANNEL GOVERNING EQUATION
0399 TSCA2(I)=TSCA1(I)+XX1*FAX*PRA(I)+XX2*(TSCA1(LD2(L))+TSCA1(LD3(L))
      1)-2.0*TSCA1(I)+XX3*(TSCA1(LD14,L1)+TSCA1(LD15,L1))-2.0*TSCA1(I)+
      2XX4*(TSCA1(LD11,L1)-TSCA1(I))+XX6*(TSCA1(LD16,L1)+TSCA1(LD17,L1))-
      32.0*TSCA1(I)+O3
0400 GO TO 680
0401 670 IF(IBC-11675.675.67)
      C DETERMINE BOUNDARY CONDITION EFFECTS
0402 671 O3=OSCA(L)*DZ*X2/(12.*HFL11*CP)

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```
0403      GO TO 677
0404      - 673 Q3=XX7*(TSCA31L1)-TSCA1(11)
0405      GO TO 677
0406      675 M1=LD18+L1+6
0407      Q3=XX7*(TSCA11N11)-TSCA1(11)
0408      677 CONTINUE
C      TYPE11 SUBCHANNEL GOVERNING EQUATION
0409      - TSCA2(11)=TSCA1(11)+XX1*FAX*PRA(11)+XX2*(TSCA11LD12,L1)+TSCA1(1D13,L1)-
      11-2.0*TSCA1(11)+XX3*(TSCA11LD14,L1)+TSCA1(1D15,L1)+2.0*TSCA1(11)+
      2XX4*(TSCA11LD11,L1)-TSCA1(11)+XX8*(TSCA11LD16,L1)+TSCA1(1D17,L1)-
      32.0*TSCA1(11)+Q3
0410      680 CONTINUE
0411      DD 690 1=55,75,4
0412      L=1-54
C      TYPE 8 SUBCHANNEL GOVERNING EQUATION
0413      TSCA2(11)=MM1*(TSCA21LC3(L1)+TSCA21LC4(L1))+MM2*(TSCA21LC1(L1)+TSCA
      121LC21(L1))+MM3*(TSCA21LC5(L1))
0414      690 CONTINUE
0415      IF(19C1(1,0)) GO TO 721
0416      D1 720 1=91,96
0417      L=1-90
0418      IF(19,GT,2) GO TO 700
C      TYPE12 SUBCHANNEL GOVERNING EQUATION IF Z LE DLEN
0419      TSCA2(11)=TSCA1(11)+E5*(TSCA11) +E3*(TSCA11LE31(L1)-TSCA1(11))+E2-
      1*(TSCA11LE21(L1)+TSCA1(1LE31(L1))-2.0*TSCA2(11))
0420      GO TO 710
0421      700 M1=LC11(L1)-6
0422      TSCA2(11)=TSCA1(11)+E5*(TSCA11) +F4*(TSCA11(L1)-TSCA1(11))+E2*(T
      1CA11LE21(L1)+TSCA11LE31(L1))-2.0*TSCA2(11)
0423      710 TSCA31L7=TSCA2111
0424      - - - 720 CONTINUE
0425      721 CONTINUE
0426      IF(19,GT,2) GO TO 761
0427      D1 760 1=95,90
C      TYPE10 SUBCHANNEL GOVERNING EQUATION IF Z LE DLEN
0428      LX=1-6
0429      IT(19C-1) 750,740,730
0430      730 TSCA21(1)=TSCA21LK1
0431      TSCA21(1+6)=TSCA21LK2
0432      GO TO 750
0433      740 LY=1-84
0434      TSCA21(1)=YY1*TSCA21LK1+YY2*TSCA31LY)
0435      TSCA21(1+6)=TSCA31LY)
0436      GO TO 760
0437      750 LY=1+6
0438      TSCA21(1)=YY1*TSCA21LK1+YY2*TSCA21LY)
0439      760 CONTINUE
0440      GO TO 771
0441      761 IF(19C-FQ,0) GO TO 771
0442      DD 770 1=91,96
0443      IF(19C-1) 771,765,763
0444      763 LX=1-32
```

```
0445      TSCA2(I)=TSCA2(LK)
0446      GO TO 770
0447      765 LX=1-90
0448      TSCA2(I)=TSCA2(LK)
0449      770 CONTINUE
0450      771 CONTINUE
0451      C PREPARE FOR NEXT AXIAL STEP
0452      DO 780 I=1,84
0453      780 TSCA1(I)=TSCA2(I)
0454      IND=85
0455      IF(N.GT.2) IND=90
0456      DO 790 I=IND,96
0457      790 TSCA1(I)=TSCA2(I)
0458      1000 CONTINUE
0459      RETURN
0460      END
```

```
0001      SUBROUTINE FIT(FX,K,F,Y,N)
0002      --C-- INTERPOLATION ROUTINE FOR SCA
0003      DIMENSION F(501,Y(501)
0004      DO 20 K=1,N
0005      IF(X-Y(K))90,30,20
0006      20 CONTINUE
0007      GO TO 60
0008      30 IF(K,0,1) GO TO 60
0009      B=(K-Y(K-1))/(Y(K)-Y(K-1))
0010      FX=FX(K-1)+B*(F(K)-F(K-1))
0011      RETURN
0012      60 PRINT 61
0013      61 FORMAT(1X, '**** PROGRAM STOPPED IN SUBROUTINE FIT ****')
0014      STOP
0015      END
```

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0001      SUBROUTINE PNTOUT
0002      C   SCA PRINTOUT ROUTINE
0003      COMMON/BLK2/PRNT(25),ITNUM
0004      COMMON/BLK3/TSCA2(100),PERR,N,MFL4,MFL5,MFL6,MFL7
0005      REAL MFL4,MFL5,MFL6,MFL7
0006      WRITE(6,10) N
0007      WRITE(6,15) PRNT(1:PRNT)
0008      WRITE(6,20)
0009      10 FORMAT(///15X,'TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASS
0010      15 FORMAT(' ',10X,'AXIAL REGION',I3/)
0011      15 FORMAT(' ',10X,'AXIAL HEIGHT',F7.2)
0012      20 FORMAT(' ',10X,'SURCHANNEL TEMPERATURES IN DEGREES F')
0013      GO TO (50,100,150),N
0014      50 TAVG=0.0
0015      TAVG50=0.0
0016      DO 60 I=2,7
0017          TAVG=TAVG+TSCA2(I)/6.0
0018          TAVG50=TAVG50+TSCA2(I)/6.0
0019      DO 80 I=1,4
0020          IB=I+8
0021          IC=I+13
0022      70 FORMAT(' ',15X,4(I3,2X,F7.2,4X))
0023      WRITE(6,70) I,TSCA2(I),IA,TSCA2(IA),IB,TSCA2(IB),IC,TSCA2(IC)
0024      GO TO 80
0025      75 WRITE(6,70) I,TSCA2(I),IA,TSCA2(IA),IB,TSCA2(IB)
0026      80 CONTINUE
0027      85 FORMAT(' ',10X,'RADIAL AVG. TEMPERATURE IN UPFLOW REGION',F7.2,' F
0028      86 FORMAT(' ',10X,'RADIAL AVG. TEMPERATURE IN DOWNFLOW REGION',F7.2,
0029      87 FORMAT(' ',10X,'RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP',F7.2,
0030      88 FORMAT(' ',10X,'NUMBER OF ITERATIONS TO CONVERGENCE',I3)
0031      90 FORMAT(' ',10X,'LAST ITERATION CONVERGED WITH AN OUTLET ERROR OF',
0032      91 F6.2,' PERCENT')
0033      WRITE(6,85) TAVG
0034      WRITE(6,86) TSCA2(1)
0035      WRITE(6,87) TAVG50
0036      WRITE(6,88) ITNUM
0037      FRACR=PERR*100.0
0038      WRITE(6,90) ERROR
0039      GO TO 200
0040      100 TOTL=0.0
0041      TAVG50=0.0
0042      TAVG50=C.0
0043      C   CALCULATE AVERAGE TEMPERATURE AT THIS AXIAL LEVEL
0044      DO 105 I=1,24
0045      105 TOTL=TOTL+TSCA2(1)*MFL4
0046      DO 110 I=25,50,5
0047      TOTL=TOTL+(TSCA2(1)+TSCA2(1+4))*MFL5+(TSCA2(1+1)+TSCA2(1+2)+TSCA2(
0048      110 1+3))*MFL6

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```
0046      110 CONTINUE
0047      DO 115 I=5F,76.4
0048
0049      115 TOTL=101L+TSCA2(11)+TSCA2(11+2)*MFL6+TSCA2(11+1)*MFL7
0049      TAVG=TOTL/142.0*MFL4+12.0*MFL5+12.0*MFL6+6.0*MFL7
0050      DO 120 I=1,6
0051      TAVGGP=TAVGGP+TSCA2(11+90I)/6.0
0052      120 TAVGGP=TAVGGP+TSCA2(11+70I)/6.0
0053      IF (N.EQ.3) GO TO 135
0054      DO 130 I=1,24
0055      IA=I+24
0056      IB=I+48
0057      IC=I+72
0058      130 WRITE(6,70) I,TSCA2(11),IA,TSCA2(11A),IB,TSCA2(11B),IC,TSCA2(11C)
0059      GO TO 140
0060      135 DO 140 I=1,23
0061      IF (I+24) 1,2,3
0062      IF (I+48) 1,2,3
0063      IF (I+72) 1,2,3
0064      IF (I+96) 1,2,3
0065      IF (I+120) 1,2,3
0066      WRITE(6,70) I,TSCA2(11),IA,TSCA2(11A),IB,TSCA2(11B),IC,TSCA2(11C)
0067      GO TO 140
0068      137 WRITE(6,70) I,TSCA2(11),IA,TSCA2(11A),IB,TSCA2(11B)
0069      140 CONTINUE
0070      145 FORMAT(' 10X,'RADIAL AVG. TEMPERATURE IN BYPASS REGION',F7.2,' F
0071      11)
0071      150 FORMAT(' 10X,'RADIAL AVG. TEMPERATURE IN CONTROL PIN REGION',F7.
0072      12,' E')
0072      WRITE(6,150) TAVG
0073      WRITE(6,145) TAVGGP
0074      WRITE(6,147) TAVGGP
0075      200 CONTINUE
0076      RETURN
0077      END
```


APPENDIX C

SUPERENERGY - SCA COUPLED CODE
LISTING AND INPUT DESCRIPTION

INPUT INSTRUCTIONS FOR SUPERENERGY - SCA COUPLED CODE

SUPERENERGY

CARD1 Format(I5)

NOCASE = Number of different cases to be computed

CARD GROUP 1 - Multiassembly Data Pack

CARD 1 Format(2F10.1)

TIN = Coolant inlet temperature

TOUT = Approximate average coolant outlet temperature

CARD 2 Format(5I5)

NOASSM = Total number of assemblies for this case, not including SCA. Maximum number of 7 with enclosed listing. Maximum can be changed by enlarging all 07 dimensions in DIMENSION statements.

NOPRNT = Total number of axial printouts to be specified later

NOINCR = Total number of axial steps to be used with this case

ISOLAT = Boundary condition to be used with this case

= 0 coupled assemblies boundary condition

= 1 isolated assembly boundary condition - adiabatic at the interassembly gap center

= 2 isolated wall boundary condition - adiabatic at the duct wall

ISCA = Secondary control assembly coupling option

= 1 for option

CARD 3-J Format(8F10.1)

PRNT(I) = Desired axial printout heights in inches, Repeat card until all NOPRNT printouts are listed

CARD GROUP 2 Assembly Data Pack

Repeat this card group for each assembly in the case in numerical order (i.e., L=1, NOASSM)

CARD 1 Format(I5)

ITYPE(L) = Assembly type

= 1 fuel assembly

= 2 blanket assembly

As long as all the assemblies in the case

are of the same type either number may be used. For coupled assemblies of different types (i.e., different number of pins) only a 217 pin fuel assembly (ITYPE=1) and a 91 pin blanket assembly (ITYPE=2) are properly coupled.

CARD 2 Format (8F10.5)

DR(K) = Rod diameter in inches
DW(K) = Wire wrap diameter in inches
LEAD(K) = Wire wrap lead in inches
P(K) = Rod pitch in inches
DPLAT(K) = Duct flat to flat distance in inches
LENGTH(K) = Assembly length in inches
S1(K) = Thickness of the duct wall in inches
S2(K) = Width of the interassembly gap in inches

CARD 3 Format(3F10.1)

QAVG(L) = Average linear heat generation rate for
assembly L in BTU/hr-ft²
FLOW(L) = Total flowrate in assembly in lbm/hr
FLOWGP(L) = Interassembly gap flowrate in lbm/hr

CARD 4 Format(5F10.5)

EHSTA1 = Effective enhanced eddy diffusivity between
interior channels
EHSTA2 = Effective enhanced eddy diffusivity between
edge and interior channels
EHSTA3 = Effective enhanced eddy diffusivity between
edge channels
EHSTA4 = Effective enhanced eddy diffusivity between
edge channels
C1 = Ratio of swirl flow velocity to bundle a
average axial velocity

Khan's correlations (Ref. 2 and 6) can be used within their limits but must be corrected by lateral and axial porosities for this subchannel type code as suggested in appendices of same references.

CARD5 Format(2I5)

NOOFAX(L) = Number of points to specify the axial flux
shape
NROD(K) = Number of rods in assembly (only even
ringed assemblies can be properly coupled to
the SCA, e.t., 19 pins or 61 pins)

CARD 6 to X Format (8F10.5)

AXIAL(I,L) = Relative axial distance associated with
flux point

FAX(I,L) = Normalized axial flux point - the flux should be normalized to one over the entire assembly length.

Repeat the input procedure in the above groups of two until NOOFAX(L) points have been read in. The first point group must be at 0.0 and the last at 1.00 on the relative height scale.

CARD X+1 to Y Format(8F10.5)

POWER(I) = Relative radial power distribution for the assembly. Read in NROD(K) points. See code manual for numbering scheme.

CARD GROUP 3 Format(6I5)

NA(L,I) = Neighboring assembly numbers as a function of face. Read in I=6 faces on L cards where L=NOASSM. The assemblies are numbered in the order they were input in card group 2. Secondary control assembly assigned the number 0. See Figure 2 or Reference 3 for face numbering scheme.

SUBROUTINE SCA

Input as described in Appendix B.

Repeat card groups 1,2 and 3 of SUPERENERGY and subroutine SCA input for each case.

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C ***** SUPERENERGY WITH SCA ADDITIONS *****
C
C ADDITIONAL SUPERENERGY --- EASY TO RECOGNIZE BY IDENTIFICATION
C PARKINGS AT RIGHT
C
C COMMENT CARDS INCLUDE TO HELP IN FOLLOWING LOGIC
C
CC01      REAL PFL4,PFL5,PFL6,PFL7          **SCA**
CC02      REAL LEAC,LEAGTH                  CCCCCC2C
CC03      INTEGER I                          CCCCCC3C
CC04      COMMON/PROF1/RHC,CP,CEN1,CEN2,ALPHA CCCCCC4C
CC05      COMMON/SEC JDR13,JDR13,LEA1(3),PI31,CPLAT13,PCE131,CAP131,A1(3),CCCCC5C
          1A2(3),A3(3),A4(3),A5(3),A6(3),A7(3),A1CTAL(3),A1CTLG(3),GE1(3), CCCCCC6C
          2CE2(3),CE2(3),CE6(3),CE7(3),HF1(3),HF2(3),HF3(3),HPTCL(3), CCCCCC7C
          3ET1(3),ET2(3),ET3(3),ET4(3),ET5(3),ET6(3),X1(3),X2(3),X3(3),CCCCC8C
          4S1(3),S2(3),LEAGTH(3),VIR1(3),VER1(3),V3R1(3),V6R1(3),V7R1(3) CCCCCC9C
CC06      COMMON/ALP /BRCC(3),NRING(3),NCHABL(3),A1(3),A2(3),A3(3),A4(3),
          1A5(3),A6(3),A7(3),A8(3),LC12,SEC,4),MPCE12,44C,3)
CC07      COMMON/TEMP/145C)
CC08      COMMON FACTER(2,3)                CCCCC13C
C
C SECONDARY CONTROL ASSEMBLY COMMON ADDITIONS
CC09      COMMON/ELM1/CAFT,ICTLEH,Z,CZ,ASC1,CSCA161,SCA3(6),IBC,AX,JCCLAT,**SCA**
          1125,ICLD                          **SCA**
CC10      COMMON/ELM2/PRAT1(25),TORAT,ITALP **SCA**
CC11      COMMON/ELM3/1SCA2(100),PEPR,APCA,PFL4,PFL5,PFL6,PFL7 **SCA**
CC12      DIMENSION FLEM(CT),FLEN(CT),E1(CT),CGAFIC(CT),VAVG1(CT),VAVG2(CT), CCCCC14C
          IN1(CT),V2(CT),V3(CT),V6(CT),V7(CT),V5WIRL(CT) CCCCC15C
CC13      DIMENSION ITAPEN(CT),ACTFAX(CT),AXIAL(5C,CT),FAX15C,CT),NA107,61 CCCCC16C
CC14      DIMENSION EH1(CT),EH2(CT),EH3(CT),EH4(CT) CCCCC17C
CC15      DIMENSION PE2(CT),PE3(CT),PE6(CT),PE7(CT),AL2(CT),NL3(CT),NL6(CT),CCCC18C
          IAL1(CT),RES2(CT),RES3(CT),RES6(CT),RES7(CT) CCCCC19C
CC16      DIMENSION G1CTAL(CT),CTFAX1(CT),CTFAX2(CT),CSA(CT),CSB(CT),CSC(CT) CCCCC20C
CC17      DIMENSION C1TRIM155C,CT1,CTP155C,CT3,SUPH144C,CT1,PCWER122C1 CCCCC21C
CC18      DIMENSION T1(55C,CT1),T2(55C,CT1),T2(55C,CT1),CAYG(CT),TAYG(CT) CCCCC22C
CC19      FACTOR1(1,1)=1. CCCCC23C
CC20      FACTOR1(1,2)=0.5 CCCCC24C
CC21      FACTOR1(2,1)=2. CCCCC25C
CC22      FACTOR1(2,2)=1. CCCCC26C
CC23      IBC=C **SCA**
C
C NCASE=NUMBER OF DIFFERENT CASES TO BE CALCULATED
CC24      READ(5,10) NCASE **SCA**
CC25      DO 2000 I=1,NCASE **SCA**
CC26      WRITE(6,21) I=1,NCASE **SCA**
CC27      WRITE(6,4) **SCA**
CC28      3 FORMAT(11,'15X','***** CASE NUMBER',I3,' *****') **SCA**
CC29      4 FORMAT(11,'15X','MAIN PROGRAM INLET PARAMETERS') **SCA**
C
C INLET INLET TEMPERATURE AND APPROXIMATE AVERAGE OUTLET TEMPERATURE
C TO BE USED FOR PROPERTY EVALUATION ONLY -- UNITS IN F
CC30      READ(5,50) TIN,TCUT CCCCC32C
CC31      WRITE(6,11) TIN,TCUT CCCCC33C
CC32      1 FORMAT(11,'10X INLET TEMPERATURE',F10.1,1X,24F4.0, OUTLET TEMPERATURE CCCCC34C
          1PE=FIC,17) CCCCC35C
CC33      TT=C,5*4TIN,TCUT CCCCC36C
C
C CALCULATE PROPERTIES BASED ON AVERAGE TEMPERATURE TT
CC34      CALL PROP(TT) CCCCC37C
C
C INLET NCASE=NUMBER OF BUNDLES IN THIS CASE(NOT INCLUDING SCA),
C NCASE=TOTAL NUMBER OF PRINTOUT LOCATIONS AXIALLY TO BE SPECIFIED
C LATER, NCINCR=TOTAL NUMBER OF AXIAL INCREMENTS DESIRED, 15CLAT=

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C BOUNDARY CONDITION COUPLED ASSEMBLIES, 1=ISOLATED ASSEMBLY, 2=ISC-
C LATED CLCT WALL, 3=DESCRIPTION FOR SECONDARY CONTROL ASSEMBLY=1
CC35 READ(5,10)ACASSP,ACPRAT,NCIACR,ISCLAT,ISCA **SCA**
CC36 IF(1SCA.EQ.0) WRITE(6,5) **SCA**
CC37 WRITE(6,11) ACASSP,ACPRAT,NCIACR,ISCLAT CCCC039C
CC38 5 FORMAT(1X,'SECONDARY CONTROL ASSEMBLY COUPLING SELECTED') **SCA**
CC39 10 FORMAT(1X) CCCC040C
CC40 15 FORMAT(1X,'AC. CF ASSEMBLIES',15,5X,'AC. CF PRINTS',15,1X,'NO. GF **SCA**
CC41 AXIAL INCREMENTS',15,5X,'TYPE CF BOUNDARY CONDITION',15) **SCA**
C VARIABLE PRINTEL HEIGHT SELECTION IN INCHES
CC41 READ(5,50) (PRAT(I), I=1,ACPRAT) **SCA**
CC42 WRITE(6,51) **SCA**
CC43 WRITE(6,52) (PRAT(I), I=1,ACPRAT) **SCA**
CC44 51 FORMAT(1X,'PRINTELTS AT THE FOLLOWING AXIAL HEIGHTS') **SCA**
CC45 52 FORMAT(1X) **SCA**
C ASSEMBLY INLET -- REPEAT FOR EACH ASSEMBLY(EXCEPT SCA)
CC46 10 30 L=1,ACASSP CCCC044C
CC47 WRITE(6,14) L CCCC045C
CC48 15 FORMAT(1X,'22-PORTA PACK FOR ASSEMBLY',15) CCCC046C
C INLET BUNDLE TYPE =1 FOR FUEL ASSEMBLY, =2 FOR BLANKET ASSEMBLY
CC49 READ(5,10) (TYPE(I), CCCC047C
CC50 WRITE(6,12) (TYPE(I), CCCC048C
CC51 12 FORMAT(1X,17TYPE CF ASSEMBLY,=1CF CCCC049C
CC52 K=TYPE(I) CCCC050C
CC53 WRITE(6,14) CCCC051C
CC54 16 FORMAT(1X,BCWRLD DIA. WIRE DIA. LEAD PITCH FLATS LEAD CCCC052C
CC55 1036 CLCT TH. CAP TH. ) CCCC053C
C INLET IN EXTER RCI DIAMETER, WIRE WRAP DIAMETER, WIRE WRAP LEAD LENGTH
C RCI FITCH, CLCT INSIDE FLAT-TO-FLAT DISTANCE, ASSEMBLY LENGTH, CLCT
C THICKNESS, INTERASSEMBLY CAP THICKNESS --- ALL IN INCHES
CC55 READ(5,40) CR(K),CN(K),LEAD(K),PK(K),CFLAT(K),LEACTH(K),SI(K),S2(K) CCCC054C
CC56 WRITE(6,40) CR(K),CN(K),LEAD(K),PK(K),CFLAT(K),LEACTH(K),SI(K),S2(K) CCCC055C
CC57 WRITE(6,17) CCCC056C
CC58 17 FORMAT(1X,52AVERAGE HEAT FLUX, FLOW RATES IN THE ASSEMBLY AND THE CAP) CCCC057C
C INLET AVERAGE HEAT FLUX FROM FUEL FIN, BLACLE AVERAGE FLOW RATE,
C PLACLE INTERASSEMBLY CAP FLOW RATE IN BTU/HR-FT2 AND LBM/HR
CC59 READ(5,90) CAVELI, FLOWLI, FLECHPIL CCCC058C
CC60 WRITE(6,90) CAVELI, FLOWLI, FLECHPIL CCCC059C
CC61 50 FORMAT(1X,11 CCCC060C
CC62 WRITE(6,10) CCCC061C
CC63 18 FORMAT(1X,64E FOUR EFFECTIVE EECY DIFFUSIVITIES AND SWIRL VELOC CCCC062C
CC64 1Y RATIO CCCC063C
C INLET 4 EECY DIFFUSIVITIES AND SWIRL FLOW RATIO -- KHAN'S VALUES MAY BE
C USED BUT MUST BE MODIFIED BY LATERAL AND AXIAL POSITIONS
CC64 READ(5,40) E1STAL, E1STAL2, E1STAL3, E1STAL4, C1 CCCC064C
CC65 WRITE(6,40) E1STAL, E1STAL2, E1STAL3, E1STAL4, C1 CCCC065C
C INLET ALPHA OF AXIAL POINTS NECESSARY TO SPECIFY AXIAL FLUX SHAPE,
C ALPHA OF RECS IN BLACLE
CC66 READ(5,10) ACFA(1), ACPEL(K) CCCC066C
CC67 WRITE(6,12) ACFA(1), ACPEL(K) CCCC067C
CC68 32 FORMAT(1X,12FAC. CF FLUX=,15,5X,12FAC. CF RECS=,15) CCCC068C
CC69 ACFA-ACFA(1) CCCC069C
CC70 WRITE(6,14) CCCC070C
CC71 14 FORMAT(1X,35AXIAL DISTANCE VS FLUX (1ST(RBUP)CN) CCCC071C
C INLET AXIAL FLUX SHAPE VS. RELATIVE AXIAL DISTANCE
CC72 READ(5,40) (AXIAL(I), I=1, ACFA) CCCC072C
CC73 WRITE(6,40) (AXIAL(I), I=1, ACFA) CCCC073C
CC74 40 FORMAT(1X,5) CCCC074C

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0075      RPO=ARCC(1)
0076      WRITE(6,15)
0077      IS FOR PARTIAL 20-RADIAL POWER DISTRIBUTION OF FUEL ROCS)
0078      CONTINUE
0079      C   RCD POWER FACTOR INPUT
0080      READ(5,40) (PCWER(I),I=1,NRC)
0081      WRITE(6,40) (PCWER(I),I=1,NRC)
0082      C   ALPHE(K) ALTERNATE SUBCHANNEL AND RCD ALPHABETIC SCHEME
0083      CALL ALPHE(K)
0084      C   GEOP(K) ALTERNATE SUBCHANNEL GEOMETRIC CALCULATION ROUTINE
0085      CALL GEOP(K)
0086      P2=A2(K)
0087      P3=A3(K)
0088      P4=A4(K)
0089      PE=AE(K)
0090      PK2=PK2+1
0091      PK3=PK3+1
0092      PCWER=ARCC(K)+1
0093      PCWER(1:VER)=C
0094      C   CALCULATE AVERAGE POWER FACTOR FOR CHANNEL J BASED ON SURROUNDING
0095      C   RCD POWER FACTORS
0096      CC 60 I=1,P4
0097      PREC=C
0098      CC 70 J=1,3
0099      F=PREC(K,I,J)
0100      PREC=PREC+PCWER(K)
0101      TO CONTINUE
0102      SUMP(I,J)=PREC
0103      CC CONTINUE
0104      C   AVERAGE VOLUMETRIC HEAT GENERATION RATE CALCULATION
0105      CTRAVC=(CTPVC(L)+HPTCL(K)/ATCTAL(K))*12
0106      C   CALCULATION OF VOLUMETRIC HEAT GENERATION RATE FOR SUBCHANNEL J
0107      CC 80 I=1,P2
0108      CTRP(I,L)=CTRAVC+(CTCTAL(K)/A2(K))*HPTCL(K)/HPTCL(K)*SUMP(I,L)
0109      I/3,C
0110      CC CONTINUE
0111      CC 90 I=PK2,P3
0112      CTRP(I,L)=CTRAVC+(CTCTAL(K)/A2(K))*HPTCL(K)/HPTCL(K)*SUMP(I,L)
0113      I/2,C
0114      CC CONTINUE
0115      CC 100 I=PK3,P4
0116      CTRP(I,L)=CTRAVC+(CTCTAL(K)/A3(K))*HPTCL(K)/HPTCL(K)*SUMP(I,L)
0117      I/2,C
0118      CC CONTINUE
0119      IF (FLCNCPL).LE.50,C1 FLCHCPL(1)=50,C
0120      FL(1)=FLCNCPL/ATCTAL(K)*144.0
0121      CTRP(1,L)=FLCHCPL/ATCTAL(K)*144.0
0122      C   CALCULATION OF AVERAGE VELOCITY
0123      VAVC(L)=CCL1/RPC
0124      VAVC(L)=CTRIP(L)/RPC
0125      C   CALCULATION OF VELOCITY FOR EACH SUBCHANNEL TYPE
0126      V1(L)=VAVC(L)*V1R(K)
0127      V2(L)=VAVC(L)*V2R(K)
0128      V3(L)=VAVC(L)*V3R(K)
0129      V4(L)=VAVC(L)*V4R(K)
0130      V5(L)=VAVC(L)*V5R(K)
0131      V6(L)=VAVC(L)*V6R(K)
0132      V7(L)=VAVC(L)*V7R(K)
0133      CENVER=VAVC(L)*DE1(K)/12.0
0134      C   ESTABLISH ECU DIFFUSIVITIES
0135      E1(L)=E113+CENVER

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C166      CSAIL)=C      CCCC153C
C167      CSPIL)=C      CCCC154C
C168      CSCIL)=C      CCCC155C
C169      K=ITYPE(L)      CCCC156C
C170      P=NEIN)      CCCC157C
C      C INITIALIZE TEMPERATURES OF SUBCHANNELS
C171      CC 110 I=1,P8      CCCC158C
C172      T2(I,L)=TIN      CCCC159C
C173      110 CONTINUE      CCCC160C
C174      115 CONTINUE      CCCC161C
C      C MAIN LOOP STARTS HERE
C175      1000 CONTINUE      CCCC162C
C176      CC 125 J=2,N      **SCA**
C177      125 CSCA(I)=C,C      **SCA**
C178      ZCL=Z/LEAC(I+1)      CCCC163C
C179      IF(ZCL,GT,1,C) ZCL=1,C      **SCA**
C      C FIND AXIAL MULTIPLICATION FACTOR BASED ON RELATIVE HEIGHT ZCL
C180      CC 130 L=L,ACOSSP      CCCC164C
C181      CALL CUNVEIFAXL,ZCL,FA,AXIAL,ACCFAX,L)      CCCC165C
C182      K=ITYPE(L)      CCCC166C
C183      P=NA(IK)      CCCC167C
C      C AXIALLY CORRECTED VOLUMETRIC HEAT GENERATION RATE FOR CHANNEL 1
C184      CC 135 J=L,P4      CCCC168C
C185      C1P(I,L)=CTERM(I,L)*FAHL      CCCC169C
C186      130 CONTINUE      CCCC170C
C187      135 CONTINUE      CCCC171C
C      C BEGINNING OF INNER LOOP --- REPEATED FOR EACH ASSEMBLY AT THIS AXIAL
C      C HEIGHT
C188      CC 140 L=L,ACOSSP      CCCC172C
C189      K=ITYPE(L)      CCCC173C
C      C P1, P2, P3, ETC. NUMBER OF CERTAIN CHANNEL TYPE FROM SUBCLINE NMP(IK)
C190      P1=N1(IK)      CCCC174C
C191      P2=N2(IK)      CCCC175C
C192      P3=N3(IK)      CCCC176C
C193      P4=N4(IK)      CCCC177C
C194      P5=N5(IK)      CCCC178C
C195      P6=N6(IK)      CCCC179C
C196      P7=N7(IK)      CCCC180C
C197      P8=N8(IK)      CCCC181C
C198      P9=N9(IK)+1      CCCC182C
C199      P10=N10(IK)+1      CCCC183C
C200      P11=N11(IK)+1      CCCC184C
C201      P12=N12(IK)+1      CCCC185C
C202      P13=N13(IK)+1      CCCC186C
C203      P14=N14(IK)+1      CCCC187C
C204      P15=N15(IK)+1      CCCC188C
C      C INTERIOR SUBCHANNEL TEMPERATURE CALCULATION
C205      CC 150 I=L,P1      CCCC189C
C      C P1,P2,P3 NEIGHBORING SUBCHANNEL NUMBERS-
C206      P1=LC(I,N,1)      CCCC190C
C207      P2=LC(I,N,2)      CCCC191C
C208      P3=LC(I,N,3)      CCCC192C
C      C INTERIOR SUBCHANNEL GOVERNING EQUATION
C209      T3(I,L)=T2(I,L)+CTP(I,L)*CZ/12/(V1(I,L)*P1+O+C1+(L*IK)-DRINK)*DZ/
      T3(I,L)=T2(I,L)+C1P(I,L)*CZ/12/(V1(I,L)+T2(I,P1,L)+T2(I,P2,L)+
      T2(I,P3,L))/ETA3(I,N)*12      CCCC193C
C      C CSAIL)= TOTAL HEAT ACCUM TO THIS SUBCHANNEL TYPE FROM CTP(I,L) TC
C      C TO IS AXIAL HEIGHT -- CSPIL) AND CSCIL) SIMILAR      CCCC194C
      CCCC195C

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0010      CS(L)=CS(1L)+CTF(1,L)      00001960
0011      35C CONTINUE                00001970
C      LAST RING OF INTERIOR SUBCHANNELS TEMPERATURE CALCULATION
C      CC 16C 1=PP1,P2      00001980
C      PP1=LC(1P,1,1)      00001990
C      PP2=LC(1P,1,2)      00002000
C      PP3=LC(1P,1,3)      00002010
C      PP4=LC(1P,1,4)      00002020
C      R=(1-1)/R      00002030
C      R=SCR1(N)+1.0001      00002040
C      16+FACE NUMBER, 1R RELATIVE POSITION OF FACE
C      TC=(1-0*(N-1)+(N-1)-1)/(2*(N-1)+0.0001      00002050
C      BR=(1-0*(N-1)+(N-1)-1)/(2*(N-1)+0.0001      00002060
C      J=1R/2      00002070
C      IF(1R.EC.FP) GO TO 116C      00002080
C      EPA=EPI(L)      00002090
C      EPB=EP2(L)      00002100
C      ETA1,ETA2,ETA3,ETA4,ETC. NOCAL DISTANCES FOR DIFFERENT GEOMETRIES
C      E1A=E1A1(K)      00002110
C      E1B=E1A2(K)      00002120
C      CC 17C 216C      00002130
C      116C CONTINUE      00002140
C      EPA=EPA1(L)      00002150
C      EPB=EP1(L)      00002160
C      EPA=EPA1(K)      00002170
C      E1B=E1A1(K)      00002180
C      216C CONTINUE      00002190
C      LAST INTERIOR RING COVERING EQUATION
C      T2(1,L)=T2(1,L)+CTP(1,L)*CZ/12/(V2(L)*R*O*CP1+(GAF(K)*CZ/A2(K))*      00002200
C      E1A1(K)+V1(L))*E1A1(K)+E1A1(K)*T2(1P1,L)+T2(1P2,L)-2*T2(1,L))/E1A1      00002210
C      21A1(K)+E1A1(K)*T2(1P2,L)-T2(1,L))/E1A1(K)*12      00002220
C      LSA(L)=LEA(L)+CTP(1,L)      00002230
C      16C CONTINUE      00002240
C      16C SUBCHANNEL TEMPERATURE CALCULATION      00002250
C      CC 17C 2=PP2,P3      00002260
C      PP1=LC(1P,1,1)      00002270
C      PP2=LC(1P,1,2)      00002280
C      PP3=LC(1P,1,3)      00002290
C      PP4=LC(1P,1,4)      00002300
C      IF(PP2.GT.P3) GO TO 117C      00002310
C      E1A=E1A2(K)      00002320
C      EPB=EP3(L)      00002330
C      CC 1C 217C      00002340
C      117C CONTINUE      00002350
C      E1A=E1A1(K)      00002360
C      EPB=EP4(L)      00002370
C      217C CONTINUE      00002380
C      IF(PP2.GT.P3) GO TO 217C      00002390
C      E1A=E1A2(K)      00002400
C      EPB=EP4(L)      00002410
C      CC 1C 217C      00002420
C      217C CONTINUE      00002430
C      E1A=E1A1(K)      00002440
C      EPB=EP4(L)      00002450
C      417C CONTINUE      00002460
C      16C SUBCHANNEL COVERING EQUATION
C      T2(1,L)=T2(1,L)+CTP(1,L)*CZ/12/(V2(L)*R*O*CP1+(GAF(K)*CZ/A2(K))*      00002470
C      11A1(K)+V2(L))*E1A1(K)+E1A1(K)*T2(1P2,L)-T2(1,L))/E1A1(K)+12*(GAF(K)*CZ/      00002480
C      21A1(K)+E1A1(K)*T2(1P2,L)-T2(1,L))/E1A1(K)+12*(GAF(K)*CZ/      00002490

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      3CV2(L1)+Z2(K11)+C1ALP+A+E+1*(T2(PM2,L1)-T2(L,L1))/E1AA+IALF+A+E+1* CCCC248C
      4IT2(PM2,L1)-T2(L,L1)/E1AB+ (P1K)+C2/A2(K11)*(T2(PM4,L1)-T2(L,L1))/ CCCC249C
      5(V2(L1)+R+C+CP+RES2(L1) CCCC250C
      6(SPIL)+C2B(L1)+C1P(L1,L) CCCC251C
C252      LTC CONTINUE CCCC252C
C253      C CORNER SURFACE CHANNEL TEMPERATURE CALCULATION
      CC LBC I=PM2,P4 CCCC253C
C254      P1=LCIK,I,11 CCCC254C
C255      P2=LCIK,I,21 CCCC255C
C256      P3=LCIK,I,31 CCCC256C
C257      C CORNER SURFACE COVERING EQUATION
      T2(L,L1)=T2(L,L1)+C1P(L1,L1)*(C2/A2(K11)+R+C+CP)+(C4F(K1)+C2/A2(K11)+ CCCC257C
      1(C15H3AL(L1)+V3(L1)+C124P(L1,L1)-T2(L,L1)+ (C4P(K1)+C2/A2(K11)+12* CCCC258C
      2(C1ALF+A+E+1(L1)/V3(L1)+1T2(PM1,L1)+T2(PM2,L1)-2*T2(L,L1))/E1AA(K1)+ CCCC259C
      3 (1X11)+C2/A2(K11)*(T2(PM2,L1)-T2(L,L1))/V3(L1)+R+C+CP+RES3(L1) CCCC260C
C261      C5C(L1)=C5C(L1)+C1P(L1,L1) CCCC261C
C262      LTC CONTINUE CCCC262C
C263      AT THIS POINT ALL TEMPERATURES INSIDE THE DUCT WALL HAVE BEEN CALCULATED
C264      AND ARE IN ARRAY T2(L,L1) FOR ASSEMBLY L
C265      INTERASSEMBLY GAP EXCE SURFACE CHANNEL TEMPERATURE CALCULATION
      CC ZIC I=PM6,P8 CCCC263C
C266      P1=LCIK,I,11 CCCC264C
C267      P2=LCIK,I,21 CCCC265C
C268      P3=LCIK,I,31 CCCC266C
C269      I1(L,C1,P7) CC TC Z2IC CCCC267C
C270      F=PM(K) CCCC268C
C271      V=V(L1) CCCC269C
C272      RES=RES(L1) CCCC270C
C273      X=P(K) CCCC271C
C274      CADIS=524(K1)/2.0 **SCA** CCCC272C
C275      I1=T2(L1,L1) CCCC273C
C276      IF(I1<L1,EC,1) CC TC Z211 CCCC274C
C277      IC=FACE DESIGNATION NUMBER CCCC275C
      IC=(I1-PM-1)/ARIAC(I1)+1,CCCC1 CCCC276C
C278      IF RELATIVE LOCATION OF SURFACE CHANNEL ON FACE IC
      ID=1-PM-(IC-1)*ARIAC(I1)+0,CCCC1 CCCC277C
C279      J=IN/2 CCCC278C
C280      L=I2-2*J CCCC279C
C281      C LP=RELATIVE CHANNEL ASSEMBLY REFERENCE NUMBER
      LP=NA(L,IC) CCCC280C
C282      IF(LP,EC,C) CC TC Z30C **SCA** CCCC281C
C283      I1=TYPE(L1) CCCC282C
C284      I2=TYPE(L2) CCCC283C
C285      F2C=F2C(I1,I2) CCCC284C
C286      IF(LP,EC,L1) CC TC Z215 CCCC285C
C287      IF(I1,C1,31) CC TC Z21C CCCC286C
C288      C CCCC C287C THROUGH AVERAGING TECHNIQUE TO FIND EQUIVALENT TEMPERATURE
C289      IN ADJACENT CHANNEL OF DESIGNATING BLADE --- FOR LIKE ASSEMBLIES
C290      WITH THE SAME NUMBER OF HCES, THE CCCC SIMPLY FINDS THE ADJACENT CHANNEL
C291      NUMBER -- FOR UNLIKE ASSEMBLIES ONLY SO FIN BLANKET BLADES (DESIGNATED
C292      TYPE(L1)=2) AND 217 FUEL BUNDLES (TYPE(L1)=1) CAN BE HANDLED PROPERLY
C293      BY THE CCCC AT PRESENT
C294      ALL COMBINATIONS OF BOUNDARY CONDITIONS ARE ALSO CONSIDERED
C295      PPA IS THE NEIGHBORING ASSEMBLY CHANNEL NUMBER
C296      T1T IS THE EQUIVALENT TEMPERATURE FOR THE ADJACENT CHANNEL IN THE
C297      NEIGHBORING ASSEMBLY
      PPA=PM(I2)+IC+21*ARIAC(I2)+(ARIAC(I1)-I1)*PAC+ CCCC288C
      CC TC Z21C CCCC289C

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C292      1210 CONTINUE
C293      PPA=NA*(I2)+1EG-4)*ARRING(I2)+ARRING(K)-1R)*FAC+L
C294      GC TC 2210
C295      1215 CONTINUE
C296      TTT=I21(L)
C297      GC TC 2217
C298      2260 CONTINUE
C299      IF(IISCLAT.EC.2) GC TC 2217
C300      GPCIS=S2(K)/4.C+GAP1/4.C
C301      IT=IC+3
C302      IF(IC.GT.2) IT=IC-3
C      IF EQUATING ASSEMBLY IS SCAL INDICATED BY APECF FIND APPROPRIATE SCAL
C      SURCHANNFL AND TEMPERATURE. DETERMINE THE AMOUNT OF HEAT ADDED OR
C      REMOVED FROM THAT ASSEMBLY
C303      PPA=1+1-1R/ARRING(K)/2+L
C304      IF(PPA.GT.0) PPA=PPA-0
C305      TTT=TSCA3(PPA)
C306      GSCA1=PPA)*SCA1*(I21(L)-TTT)/TSCA1*SCA1(CSCA(PPA)
C307      GC TC 2217
C308      2210 CONTINUE
C309      PPAFAC.EC.1) GC TC 2215
C310      IF(PPA.GT.1) GC TC 2217
C311      IF(IIR.GE.ARRING(K)-1) GC TC 2217
C312      TTT=I2(PPA,LP)-I2(PPA,LP)-I2(PPA-L,LP)/4.+JJ*(I2(PPA,LP)-
C313      I2(PPA-L,LP))/2.C
C314      GC TC 2217
C315      TTT=I2(PPA,LP)-I2(PPA+1,LP)-I2(PPA,LP)/4.+JJ*(I2(PPA+1,LP)-
C316      I2(PPA,LP))/2.C
C317      GC TC 2217
C318      2212 TTT=I2(PPA,LP)+I2(PPA+1,LP)/2.C
C319      GC TC 2217
C320      2215 CONTINUE
C321      TTT=I2(PPA,LP)
C322      2217 CONTINUE
C323      IF(PPA.GT.MY) GO TO 321C
C324      ETAA=ETAB(K)
C325      GC TC 421C
C326      321C CONTINUE
C327      ETAA=ETAB(K)
C328      421C CONTINUE
C329      IF(PPA.GT.MY) GO TO 521C
C330      ETAB=ETAB(K)
C331      GC TC 421C
C332      521C CONTINUE
C333      ETAB=ETAB(K)
C334      GC TC 521C
C335      521C CONTINUE
C336      721C CONTINUE
C      INFERASSEMBLY GAP CORNER SURCHANNFL TEMPERATURE CALCULATION
C337      TTT=I2(1,L)
C338      A=AT(K)
C339      A=AT(L)
C340      RES=RES(T)
C341      P=X2(K)
C342      ETAA=ETAB(K)
C343      ETAB=ETAB(K)
C344      GPCIS=S2(K)/2.C
C345      22C CONTINUE

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CCCC286C
CCCC287C
CCCC288C
CCCC289C
CCCC290C
CCCC291C
**SCA**
**SCA**
**SCA**
**SCA**
**SCA**

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**SCA**
**SCA**
**SCA**
**SCA**
**SCA**
CCCC292C
CCCC293C
CCCC294C
CCCC295C
CCCC296C
CCCC297C
CCCC298C
CCCC299C
CCCC300C
CCCC301C
CCCC302C
CCCC303C
CCCC304C
CCCC305C
CCCC306C
CCCC307C
CCCC308C
CCCC309C
CCCC310C
CCCC311C
CCCC312C
CCCC313C
CCCC314C
CCCC315C
CCCC316C
CCCC317C
CCCC318C
CCCC319C
CCCC320C

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CCCC321C
CCCC322C
CCCC323C
CCCC324C
CCCC325C
CCCC326C
CCCC327C
**SCA**
CCCC328C

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C   GENERATING TEMPERATURE FOR EACH THE CORNER AND EDGE INTERASSEMBLY GAP
C344      T2(I,L)=T2(I,L)+X*GZ/IR+C*CP*V*A*(1/2*(P*1,L)-T2(I,L))/RES+(1/2*
      1T2(I,L)+CCAC*12/CP*IS)+CCN*(CZ+S2(K))/(2*ARC*CP*V*A)*(1/2*(P*2,L)-
      2T2(I,L))/ETAP+(1/2*(P*3,L)-T2(I,L))/ETAP*1/2
C345      LU=1-12*(ARC*(K)+1)
C346      IF(IISCLAT.EQ.2) T2(I,L)=T2(I,L)
C347      210 CONTINUE
C   CUCT WALL TEMPERATURE DETERMINED BY RESISTANCE AVERAGING
C348      FC 150 I=PP4,PE
C349      PPI=LCIK,I,1)
C350      PP4=CCIK,I,4)
C351      IF(I-CT.PSI) GO TO 1150
C   EDGE CUCT WALL SUBCHANNEL EQUATION
C352      T2(I,L)=(RES6(I)*T3(P*1,L)+RES2(I)*T3(P*4,L))/(RES6(I)+RES2(I))
C353      GO TO 150
C354      1150 CONTINUE
C   CORNER CUCT WALL SUBCHANNEL EQUATION
C355      T2(I,L)=(RES7(I)*T3(I*1)+T3(P*1,L)+RES3(I)*T3(I*2)+T3(P*4,L))/
      11RES7(I)+X1(I)+RES3(I)+X2(I)
C356      150 CONTINUE
C357      140 CONTINUE
C   END OF ASSEMBLY INNER LOOP--AT THIS POINT ALL OF THE TEMPERATURES FOR
C   HAVE BEEN CALCULATED AND ARE IN T2(I,L) FOR ASSEMBLY L -- REPEAT
C   FOR EACH ASSEMBLY
C358      CC 230 L=L+1,NCASSP
C359      K=ITYPE(L)
C360      PE=PE+1
C361      CC 240 I=1,PE
C   PREPARE TEMPERATURE ARRAY FOR NEXT AXIAL STEP
C362      T2(I,L)=T2(I,L)
C363      240 CONTINUE
C364      230 CONTINUE
C365      IF(IISCA.NE.1) GO TO 245
C366      CALL SCA
C   IF SCA ITERATION HAS NOT CONVERGED EITHER ITERATE OR GO TO NEXT STEP
C367      IF(IX.EC.1) GO TO 35
C368      IF(IPRC.NE.0) GO TO 245
C369      I=2+GZ
C370      CC TO 1000
C371      245 IF(I2.L.PRNT(IPRNT)) GO TO 255
C   FINITE ELEMENT PREPARATION PHASE
C372      CC 250 L=L+1,NCASSP
C373      K=ITYPE(L)
C374      P2=K2(K)
C375      P3=K3(K)
C376      P4=K4(K)
C377      P5=K5(K)
C378      P6=K6(K)
C379      P7=K7(K)
C380      P8=K8(K)
C381      P*2=P2+1
C382      P*3=P3+1
C383      P*4=P4+1
C384      P*7=P7+1
C385      CC 260 I=L,PE
C386      T(I)=T2(I,L)
C387      260 CONTINUE
C388      260 CONTINUE

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CC55      PRCD(L,3)=PRCD(L,1,2)+1      00006690
CC56      506 IF(IA.EQ.ACRINC)GC TC 906 00006700
CC57      LC(L,1,2)=ACTRC+IC*(2+NA+L1+IR+1 00006710
CC58      CC TC 6 00006720
CC59      506 LC(L,1,2)=ACTRC+IC*(NA+1)+R+1)/2 00006730
CC60      CC TC 6 00006740
CC61      903 LC(L,1,1)=ACTR+1 00006750
CC62      LC(L,1,2)=ACTRC-1 00006760
CC63      PRCD(L,1,1)=1+IV+ACTL2 00006770
CC64      PRCD(L,1,2)=2+ACTC1 00006780
CC65      PRCD(L,1,2)=1+3+NA*(R+1) 00006790
CC66      CC TC 906 00006800
CC67      502 LC(L,1,1)=ACTR+2 00006810
CC68      LC(L,1,2)=ACTRC 00006820
CC69      PRCD(L,1,1)=1+IV+ACTL2 00006830
CC70      PRCD(L,1,2)=2+ACTC1 00006840
CC71      PRCD(L,1,2)=PRCD(L,1,2)+1 00006850
CC72      CC TC 906 00006860
CC73      6 CONTINUE 00006870
CC74      7 CONTINUE 00006880
CC75      CC 5 1=ACTR+L1,LSSTC 00006890
CC76      PRCD(L,1,3)=NCRDC+1 00006900
CC77      IF(11.LE.LSTN) CC TC 901 00006910
CC78      IC=1-LSSTC+5 00006920
CC79      LC(L,1,2)=NCR+IC+L1+ACR+AC+1 00006930
CC80      LC(L,1,3)=LSSTC+G-5+IC 00006940
CC81      LC(L,1,4)=1 00006950
CC82      PRCD(L,1,1)=2+NGEC1+IC+ACRING 00006960
CC83      PRCD(L,1,2)=NCRCE+1 00006970
CC84      IF(IC.PL.01) CC TC 902 00006980
CC85      LC(L,1,1)=ACTRC+IC+ACR+AC 00006990
CC86      CC TC 8 00007000
CC87      802 LC(L,1,1)=1-1 00007010
CC88      CC TC 8 00007020
CC89      801 IZ=L.CC01/L.SICM-5-1+ 00007030
CC90      IC=13-ACTRC-11/ACRINC+C.CC01 00007040
CC91      IR=1-AC1RG-1C+ACRING+C.CC01 00007050
CC92      LC(L,1,1)=ACTC1+IC*(2+ACRINC-1)+2+IR-1 00007060
CC93      LC(L,1,4)=LSSTC+IC+ACRINC+IR 00007070
CC94      PRCD(L,1,1)=1+NGEC1+IC+ACRING+IR 00007080
CC95      PRCD(L,1,2)=PRCD(L,1,1)+1+6+IZ+ACRINC 00007090
CC96      IF(1R.EQ.1) CC TC 903 00007100
CC97      IF(1R.EQ.ACRINC) CC TC 904 00007110
CC98      LC(L,1,2)=1-1 00007120
CC99      LC(L,1,3)=1+1 00007130
C100      CC TC 8 00007140
C101      802 LC(L,1,2)=LSSTC+IC+1 00007150
C102      LC(L,1,3)=1+1 00007160
C103      CC TC 8 00007170
C104      804 LC(L,1,2)=1-1 00007180
C105      LC(L,1,3)=1-1,2)*L.SSTC+IC+2)+IZ+1)+1 00007190
C106      CC TC 8 00007200
C107      8 CONTINUE 00007210
C108      9 CONTINUE 00007220
C109      CC 13 0=1,NA+LLS 00007230
C110      CC 11 1=LSSTC+1,LSSTC 00007240
C111      IF(11.LE.LSTN) CC TC 901 00007250
C112      IC=1-LSSTC-1 00007260

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C113      LC(L,1,1)=LSTG+1+IC      CCCC721C
C114      LC(L,1,3)=LSTG+IC+ACRING+1 CCCC720C
C115      IF(IJ.EC.NNALS) CC TC 12 CCCC729C
C116      LC(L,1,4)=LSTG+ACINCR+IC+1 CCCC730C
C117      CC TC 14 CCCC731C
C118      12 CONTINUE CCCC732C
C119      LC(L,1,4)=1 CCCC733C
C120      14 CONTINUE CCCC734C
C121      IF(IG.FG.C) CC TC 7C2 CCCC735C
C122      LC(L,1,2)=LSTG+IC+ACRING CCCC736C
C123      CC TC 1C CCCC737C
C124      7C2 LC(L,1,2)=1-1 CCCC738C
C125      CC TC 1C CCCC739C
C126      7C1 IP=1,CCCC/(LSTG+1+1) CCCC740C
C127      IC=L1-LSTG-19/ACRING+C.CC01 CCCC741C
C128      IP=1-LSTG-IC+ACRING+C.CC01 CCCC742C
C129      LC(L,1,1)=ACTRC+IC+ACRING+IR CCCC743C
C130      IF(IJ.EC.NNALS) CC TC 18 CCCC744C
C131      LC(L,1,4)=LSTG+G+10+ACRING+IR CCCC745C
C132      CC TC 10 CCCC746C
C133      16 CONTINUE CCCC747C
C134      LC(L,1,4)=1 CCCC748C
C135      18 CONTINUE CCCC749C
C136      IF(IG.EG.11) CC TC 7C3 CCCC750C
C137      IF(IG.EG.ACRING) CC TC 7C4 CCCC751C
C138      LC(L,1,2)=1-1 CCCC752C
C139      LC(L,1,3)=1+1 CCCC753C
C140      CC TC 1C CCCC754C
C141      7C4 LC(L,1,2)=1-1 CCCC755C
C142      LC(L,1,3)=(1-1)*C(LSTG+1C+2)+1*(1+1) CCCC756C
C143      CC TC 1C CCCC757C
C144      7C3 LC(L,1,2)=LSTG+IC+1 CCCC758C
C145      LC(L,1,3)=1+1 CCCC759C
C146      CC TC 1C CCCC760C
C147      1C CONTINUE CCCC761C
C148      31 CONTINUE CCCC762C
C149      ACRG=ACRG+ACINCR CCCC763C
C150      LSTG=LSTG+ACINCR CCCC764C
C151      LSTG=LSTG+1+ACINCR CCCC765C
C152      LSTG=LSTG+ACINCR CCCC766C
C153      LSTG=LSTG+ACINCR CCCC767C
C154      LSTG=LSTG+G+ACINCR CCCC768C
C155      13 CONTINUE CCCC769C
C156      RETURN CCCC770C
C157      END CCCC771C

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0001      * SUBROUTINE CCCH(1)
0002      C SUBCHANNEL GEOMETRY CALCULATION ROUTINE
0003      C CCMPCN/GEZ /CR1(3),DN(2),LEAC(3),P1(3),CFLAT(3),PCO(3),CAP(3),A1(3),CCCC772C
0004      1A2(2),A3(3),A4(3),A5(2),A6(2),A7(2),A1CTAL(3),A1CTLG(3),CE1(3),
0005      2CE2(3),CE3(3),CE6(3),CE7(3),PF1(3),PF2(3),PF3(3),PF10(3),
0006      2E1A1(3),E1A2(2),E1A3(2),E1A4(3),E1A6(3),E1A7(2),X1(3),X2(3),X3(3),CCCC7740
0007      4S1(3),S2(2),LENGTH(3),V1R(2),V2R(2),V3R(3),V4R(3),V7R(3)
0008      C CCMPCN/ALA /ARCC(3),ARJAC(3),ACHAL(2),A1(3),A2(3),A3(3),A4(3),
0009      3A5(3),A6(3),A7(2),A8(2),LC(2),ESC,47,PRCC(2),4C,3)
0010      N1=N2(1)
0011      N2=N3(1)+A2(1)
0012      N3=N4(1)+A3(1)
0013      C DISTANCE BETWEEN PINS IN OUTER RING AND DUCT WALL
0014      CAP(1)=(CFLAT(1)- 1.732* ARJAC(1)+P1(1)-ER(1))/2
0015      CFACE=DPLAT(1)/1.732
0016      FI=2.141552
0017      C CCMPCN SUBCHANNELS-- DISTANCE ALONG INSIDE-DUCT WALL,OUTSIDE DUCT WALL,
0018      AND INTERASSEMBLY GAP CENTERLINE
0019      * P1(1)=(CR(1)+4*GEZ(1))/1.732
0020      * P2(1)=X1(1)+2*S1(1)/1.732
0021      * P3(1)=X2(1)+2*S2(1)/1.732
0022      C CCMPCN CONNECTION LENGTHS
0023      E1A2(1)=P1(1)/1.732
0024      E1A3(1)=(E1A2(1)+CAP(1)+CR(1))/2)/2
0025      E1A4(1)=P1(1)
0026      E1A6(1)=E1A2(1)/2+X1(1)/4
0027      E1A7(1)=E1A3(1)/2+(X1(1)+X2(1))/4
0028      E1A8(1)=E1A3(1)/2+X2(1)/4
0029      C SUBCHANNEL FLOW AREAS
0030      * A1(1)=1.732*P1(1)+2/4*(ER(1)+2*CH(1)+2)*PF1/2
0031      * A2(1)=P1(1)+ER(1)/2+CAP(1)-(ER(1)+2*CH(1)+2)*PF1/2
0032      * A3(1)=ER(1)/4+CAP(1)/2+(CFACE-P1(1)+NRING(1))-(CR(1)+2*DN(1)+2)
0033      1*PF1/2
0034      A4(1)=E1A2(1)*S1(1)
0035      A5(1)=X1(1)+X2(1)+S1(1)/2
0036      A6(1)=E1A3(1)*S2(1)/2
0037      A7(1)=X2(1)+X3(1)+S2(1)/4
0038      C TOTAL BLADE AND GAP FLOW AREAS
0039      A1ETAL(1)=A1(1)+A2(1)+A3(1)+A4(1)+A5(1)+A6(1)+A7(1)*2
0040      A1ETLG(1)=NRING(1)+A6(1)+A7(1)*2
0041      C SUBCHANNEL NETTED PERIMETERS
0042      * P1(1)=CR(1)+CH(1)+P1(1)/2
0043      * P2(1)=P1(1)+P1(1)
0044      * P3(1)=CH(1)+CH(1)+P1(1)+CFACE-P1(1)+NRING(1)
0045      * P4(1)=E1A2(1)
0046      * P5(1)=X2(1)
0047      C SUBCHANNEL EQUIVALENT DIAMETERS
0048      CE1(1)=4.C*P1(1)/A1(1)
0049      CE2(1)=4.C*P2(1)/A2(1)
0050      CE3(1)=4.C*P3(1)/A3(1)
0051      CE4(1)=4.C*P4(1)/A4(1)
0052      CE5(1)=4.C*P5(1)/A5(1)
0053      C SUBCHANNEL NETTED PERIMETERS
0054      * P1(1)=CR(1)+P1(1)/2
0055      * P2(1)=CR(1)+P1(1)/2
0056      * P3(1)=CH(1)+P1(1)/2
0057      * P4(1)=CH(1)+P1(1)+A2(1)+P2(1)
0058      * P5(1)=A1(1)+P1(1)+A2(1)+P2(1)
0059      C FLOW SPLIT RATIOS BASED ON NEWCOMB'S METHOD

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PERFORM IV C LEVEL ZI

CCCC

DATE = 77186

21/32/CS

PAGE CCGZ

CC42	VERIL1=ATCTALIL)/IAJ1*PIIL)*N22*AZIL)*IICE2(LI)/CE1IL)*C.714)+	CCCC819C
	IAJ2*AZIL)*IICE3(LI)/CE1IL)*C.714)+	CCCC820C
CC43	VERIL1=ATCTALIL)/IAJ1*PIIL)*IICE1(LI)/CE2IL)*C.714)+N22*AZIL)*	CCCC821C
	IAJ2*AZIL)*IICE3(LI)/CE2IL)*C.714)+	CCCC822C
CC44	VERIL1=ATCTALIL)/IAJ1*PIIL)*IICE1(LI)/CE3IL)*C.714)+N22*AZIL)*	CCCC823C
	IICE2IL)/CE3IL)*C.714)+IAJ2*AZIL)*	CCCC824C
CC45	VERIL1=ATCTALIL)/IAJ1*PIIL)*IICE1(LI)/CE4IL)*C.714)+N22*AZIL)*	CCCC825C
CC46	VERIL1=ATCTALIL)/IAJ1*PIIL)*IICE1(LI)/CE5IL)*C.714)+N22*AZIL)*	CCCC826C
CC47	VERIL1=ATCTALIL)/IAJ1*PIIL)*IICE1(LI)/CE6IL)*C.714)+N22*AZIL)*	CCCC827C
CC48	VERIL1=ATCTALIL)/IAJ1*PIIL)*IICE1(LI)/CE7IL)*C.714)+N22*AZIL)*	CCCC828C

CC01	SUBROUTINE SPIN(K)	CCCC4350
C	SUBROUTINE PRINTOUT ROUTINE-- GIVES BLACKIE SHAPE OUTPLT FOR 61 AND	
C	217 FOR ASSEMBLIES	
CC02	CCPCH/TEMP/71550	CCCC4400
CC03	CCPCH/ALP /PRCD(3),ARRAC(3),NCFAN(3),A1(3),A2(3),A3(3),A4(3),	CCCC4410
	IN5(3),A6(3),A7(3),A8(3),LC(3,550,4),PRCD(3,440,3)	CCCC4420
CC04	IF(ARRINGIN).EQ.4) GO TO 600	CCCC4430
CC05	IF(ARRINGIN).EQ.8) GO TO 700	CCCC4440
CC06	GO TO 600	CCCC4450
CC07	600 CONTINUE	CCCC4460
CC08	WRITE(6,614) T(103),T(164),T(163),T(162),T(161),T(162)	CCCC4470
CC09	WRITE(6,615) T(153),T(134),T(133),T(132),T(131),T(132)	CCCC4480
CC10	WRITE(6,616) T(123),T(164),T(162),T(162),T(161),T(122)	CCCC4490
CC11	WRITE(6,602) T(165),T(166),T(164),T(162)	CCCC4500
CC12	WRITE(6,603) T(165),T(125),T(165),T(165),T(163),T(163),T(163),	CCCC4510
	T(163),T(163),T(163)	CCCC4520
CC13	WRITE(6,604) T(173),T(134),T(132),T(130),T(160)	CCCC4530
CC14	WRITE(6,605) T(166),T(136),T(106),T(133),T(131),T(131),T(129),	CCCC4540
	T(135),T(135),T(129),T(135)	CCCC4550
CC15	WRITE(6,606) T(173),T(136),T(132),T(130),T(128),T(158)	CCCC4560
CC16	WRITE(6,607) T(167),T(137),T(137),T(137),T(137),T(131),T(131),T(131),	CCCC4570
	T(127),T(151),T(158),T(128),T(158)	CCCC4580
CC17	WRITE(6,608) T(174),T(138),T(134),T(132),T(131),T(126),T(156)	CCCC4590
CC18	WRITE(6,609) T(168),T(138),T(168),T(135),T(135),T(135),T(135),T(135),	CCCC4600
	T(137),T(135),T(135),T(137),T(127),T(157)	CCCC4610
CC19	WRITE(6,610) T(184),T(154),T(124),T(121),T(151),T(138)	CCCC4620
CC20	WRITE(6,611) T(169),T(139),T(139),T(139),T(136),T(140),T(140),T(140),	CCCC4630
	T(124),T(154),T(154),T(120),T(150),T(150),T(150)	CCCC4640
CC21	WRITE(6,609) T(171),T(141),T(137),T(151),T(123),T(153),T(155)	CCCC4650
CC22	WRITE(6,607) T(170),T(140),T(140),T(140),T(142),T(140),T(122),	CCCC4660
	T(152),T(154),T(155),T(145),T(145),T(145)	CCCC4670
CC23	WRITE(6,606) T(179),T(142),T(139),T(121),T(151),T(153)	CCCC4680
CC24	WRITE(6,605) T(171),T(141),T(141),T(140),T(141),T(141),T(150),	CCCC4690
	T(152),T(141),T(140),T(140)	CCCC4700
CC25	WRITE(6,604) T(181),T(145),T(147),T(145),T(151)	CCCC4710
CC26	WRITE(6,603) T(172),T(142),T(142),T(142),T(144),T(144),T(140),T(140),	CCCC4720
	T(141),T(147),T(147)	CCCC4730
CC27	WRITE(6,612) T(103),T(165),T(167),T(169)	CCCC4740
CC28	WRITE(6,601) T(121),T(133),T(134),T(135),T(136),T(136)	CCCC4750
CC29	WRITE(6,610) T(155),T(143),T(144),T(145),T(146),T(156)	CCCC4760
CC30	WRITE(6,614) T(165),T(133),T(174),T(131),T(136),T(166)	CCCC4770
CC31	601 FORMAT(2X,51IC,15)	CCCC4780
CC32	602 FORMAT(17X,41IC//1)	CCCC4790
CC33	603 FORMAT(117X,315,51IC,315//)	CCCC4800
CC34	604 FORMAT(42X,51IC//)	CCCC4810
CC35	605 FORMAT(112X,315,61IC,315//)	CCCC4820
CC36	606 FORMAT(121X,61IC//)	CCCC4830
CC37	607 FORMAT(17X,315,51IC,315//)	CCCC4840
CC38	608 FORMAT(22X,71IC//)	CCCC4850
CC39	609 FORMAT(2X,315,61IC,315//)	CCCC4860
CC40	610 FORMAT(1X,315,62X,315//)	CCCC4870
CC41	611 FORMAT(12X,315,61IC,315//)	CCCC4880
CC42	612 FORMAT(37X,41IC//)	CCCC4890
CC43	613 FORMAT(127X,51IC,15//)	CCCC4900
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CC45	615 FORMAT(22X,1IC,5X,41IC,310)	CCCC4920
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PERFORM IV G LEVEL	PRIN	DATE # 17JUL	21/32/05	PAGE 0003
CC02	WRITTE(6,712) T(345),T(261),T(185),T(125),T(81),T(45),T(47),T(49),		CCCC552C	
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	T(12),T(64),T(86),T(88),T(50),T(144),T(710),T(266),T(378),T(429),		CCCC556C	
	T(462),T(537)		CCCC557C	
CC05	WRITTE(6,710) T(342),T(262),T(151),T(131),T(83),T(85),T(67),T(65),		CCCC558C	
	T(152),T(125),T(267),T(377)		CCCC559C	
CC06	WRITTE(6,709) T(523),T(467),T(413),T(346),T(264),T(192),T(132),		CCCC560C	
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	T(462),T(526)		CCCC562C	
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CC83	FCRPA(178),1015/		CCCC750C	
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CC86	FCRPA(181),1015/		CCCC753C	
CC87	FCRPA(182),1015/		CCCC754C	
CC88	FCRPA(183),1015/		CCCC755C	
CC89	FCRPA(184),1015/		CCCC756C	
CC90	FCRPA(185),1015/		CCCC757C	
CC91	FCRPA(186),1015/		CCCC758C	
CC92	FCRPA(187),1015/		CCCC759C	
CC93	FCRPA(188),1015/		CCCC760C	
CC94	FCRPA(189),10			

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C114 249 CCAIACE
C115 RETURN
C116 END

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CCCC6130

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CLPVE

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0001 SUBROUTINE CLPVE(X,X,P,Y,N,J)
0002 C INTERPOLATION ROUTINE
0003 CIPCONSTN FISC,77,YISC,71,N17)
0004 P=N17)
0005 10 IC 20 PM=J,P
0006 IFIX=Y(FK,J)30,85,20
0007 15 IF(FK.EC,P) CC IC 40
0008 20 CONTINUE
0009 CC IC 60
0010 30 IF(FK.EC,1) CC IC 60
0011 40 B=(X-Y(FK-1,J))/Y(FK,J)-Y(FK-1,J))
0012 50 F=F(FK-1,J)+B*(F(FK,J)-F(FK-1,J))
0013 RETURN
0014 60 PRINT 61
0015 61 FORMAT(1X,'FACC=STOPPED IN CLPVE')
0016 RETURN
0017 END

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0004230
0004240
0004250
0004260
0004270
0004280
0004290
0004300
0004310
0004320
0004330
0004340
0004350
0004360
0004370
0004380

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PORTAL IV C LEVEL 21

PROP

DATE = 771E4

21/22/05

PAGE 0001

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0001      SUBROUTINE PROP(T1)                                00004140
0002      C  CALCULATE PROPERTIES BASED ON AVERAGE TEMPERATURE T1
0003      C  CPMCA/PRCP1/RPC,CP,CCNC,CEACH,ALPHA
0004      R=C*59.56F-(7.9504E-3)*T1-(0.2872E-6)*T1+T1*(C.C4035E-5)*T1**3
0005      CP=C.344021-(7.C3529E-5)*T1+12.68131E-8)*T1**2
0006      CCNC=54.70E-(3.878E-2)*T1+12.0514E-6)*T1**2
0007      ALPHA=CCNC/(R*CP)
0008      CEACH=12.1
0009      RETURN
0010      END

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00004150
00004160
00004170
00004180
00004190
00004200
00004210
00004220

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CCCC1 SUPPLINE SCA
C ONLY CHANGE NECESSARY IN ROUTINE SCA TO ACCOMPLISH CONNECTION WITH
C THE SUPERENERGY MAIN PROGRAM
CCCC2 CEMPCK/OLR3/CAPTH,TCLEN,2,02,X3,CSCA16),TSCA216),IBC,AX,J,TAY, **SCA**
ITCLC **SCA**
CCCC3 CEMPCK/OLR3/TSCA21LCC1,PERR,A,PFL4,PFL5,PFL6,PFL7
CCCC4 DIMENSION TSCA1(100),TPAR1(500),A1(131),A2(131),A3(131),LA1(241),LA2(24
1),LA3(241),LB1(301),LB2(301),LB3(301),LC4(301),LC1(241),LC2(241),LC3(241),
21C4(241),LC5(241),LC6(61),LE1(61),LE2(61),LE3(61),PAR1(50),PAR2(50),
3REL(50)
CCCC5 REAL PDET1,PFLGP,PJCTF,PFL1,PFL2,PFL3,PFL4,PFL5,PFL6,PFL7,PFL8,
IFLG,PFL11,NTCL5
C ALOCAL CONNECTION NUMBERS FOR COUNTERFLOW SECTION
CCCC6 DATA A1/C,3,4,5,6,7,2,5,10,11,12,13,8/
CCCC7 DATA A2/C,7,2,3,4,5,6,13,8,5,10,11,12/
CCCC8 DATA A3/C,6,5,10,11,12,13,2,3,4,5,6,7/
CCCC9 C ALOCAL CONNECTION NUMBERS FOR SUECHANNEL NUMBERS 1-24 IN PCISEN SECTION
CCCC10 DATA LA1/2,1,2,3,4,1,8,1,8,5,2,13,12,3,14,15,4,17,18,5,20,21,6,7/
CCCC11 DATA LA2/L,3,4,5,6,5,24,7,10,11,10,13,14,13,16,17,16,19,20,19,22,
12,12,23/
CCCC12 DATA LA3/L,11,14,17,20,23,20,5,28,31,12,33,36,15,38,41,18,43,40,21
1,44,51,24,52/
CCCC13 C ALOCAL CONNECTION NUMBERS FOR SUECHANNEL NUMBERS 25-54 IN PCISEN SECTION
CCCC14 DATA LB1/26,7,26,9,28,21,10,31,12,33,36,13,36,15,38,41,16,41,18,43
1,44,19,46,21,46,51,22,51,24,53/
CCCC15 DATA LB2/L,54,27,28,27,20,25,22,33,32,35,34,37,38,37,40,39,42,43,42,
145,44,47,48,47,50,49,52,52,52,25/
CCCC16 DATA LB3/L,56,25,57,29,58,60,30,61,34,62,64,35,65,39,66,61,40,67,44,
130,72,45,73,45,74,76,50,77,54,78/
CCCC17 DATA LB4/L,5,C,C,C,55,55,C,C,C,69,63,C,C,C,67,67,C,C,C,71,71,C,C,C,
175,75,C,C,C,55/
CCCC18 C ALOCAL CONNECTION NUMBERS FOR SUECHANNEL NUMBERS 55-78 IN PCISEN SECTION
CCCC19 DATA LC1/25,25,27,25,29,70,22,34,34,35,37,35,39,40,42,44,44,45,47,
145,49,50,52,54/
CCCC20 DATA LC2/L,54,57,56,57,70,61,60,61,35,65,64,65,40,69,68,69,45,73,72,
173,50,73,76,77/
CCCC21 DATA LC3/L,55,56,55,50,55,62,63,62,63,64,67,66,67,70,71,70,71,74,
175,74,75,76,55/
CCCC22 DATA LC4/L,75,75,80,60,60,60,61,64,61,61,82,66,82,82,83,72,83,83,
184,76,84,84,79/
CCCC23 DATA LC5/L,5,C,80,C,80,C,81,C,82,C,82,C,83,C,83,C,84,C,84,C,79
1,6/
CCCC24 C ALOCAL CONNECTION NUMBERS FOR SUECHANNEL NUMBERS 79-84 IN PCISEN SECTION
CCCC25 DATA LC6/L,55,56,78,57,77,84,80,85,55,58,60,57,61,75,81,86,63,62,64,6
11,65,80,62,87,67,66,65,65,81,83,88,71,70,72,64,73,82,84,89,75,7
24,76,77,77,82,75,50/
CCCC26 C ALOCAL CONNECTION NUMBERS FOR SUECHANNEL NUMBERS 85-96 IN PCISEN SECTION
CCCC27 DATA LFL/L,5,86,87,88,89,90/
CCCC28 DATA LB2/L,51,52,93,94,95/
CCCC29 DATA LB3/L,92,93,94,95,96,97/
CCCC30 IF(A,CE,2)CC TO SCC
CCCC31 3F(1,GT,-1) CC TO JCC
CCCC32 C DATA INPUT AND COEFFICIENT INITIALIZATION SECTION
CCCC33 C INPLT 1)A=BUCKET INLET TEMPERATURE (F), 17=AVERAGE TEMPERATURE TO
CCCC34 BE USED FOR PROPERTY CALCULATION (F), CLEN=COUNTERFLOW SECTION AXIAL
CCCC35 HEIGHT (IN.), CLEN=HEIGHT AT WHICH TYPE 10 NODE DISAPPEARS
CCCC36 READ(15,1) TIN,TT,CLEN,CLEN
CCCC37 C INPLT 2)A=INSIDE RADII OF THE CHANNELS CAN IN COUNTERFLOW SECTION

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C      IIA.), RCUT=CUTSIDE RADII OF SAME (IA.), RPIH=INSIDE RADII OF
C      PCISCA BLADE CAN (IA.), RPEC=CUTSIDE RADII OF SAME (IA.),DF=HEX
C      BASE FLAT-TO-FLAT DISTANCE (IA.),CTHF=HEX CLOT WALL THICKNESS (IA.),
C      GAPTH=INTERASSEMBLY GAP WIDTH (IA.)
CC2E      READ(15,1) RIN,RCUT,RPIA,RPLC,CF,CTHK,GAPTH
C      FAPLT PICT1=TOTAL MASS FLOW RATE SATC COUNTERFLOW SECTION (LBM/HR),
C      PFL2=DOWNFLOW RECIRC MASS FLOW RATE (LBM/HR),PFLCP=INTERASSEMBLY CAP
C      TOTAL FLOW RATE ASSOCIATED WITH SCA (LBM/HR), PICT9=TOTAL MASS FLOW
C      RATE DIVERGED THROUGH TYPE 9 SUBCHANNELS (LBM/HR),
CC2F      READ(15,1) PICT1,PFL2,PFLCP,PICT9
C      IAGL1,C2A,C2P=COEFFICIENTS FOR 1ST AND 2ND EXPONENTIAL VOLUMETRIC HEAT
C      GENERATION RATE TERMS RESPECTIVELY (BTU/HR-F12), BA,BB=MULTIPLICATION
C      FACTORS INSIDE 1ST AND 2ND EXPONENTIALS OF VOLUMETRIC HEAT GENERATION
C      RATE TERMS RESPECTIVELY (FT-2), ERR=ACCEPTABLE ERROR IN TEMPERATURE
C      AT CLEAN ITERATION CONVERGENCE PARAMETER
CC3C      READ(15,1) C2A,C2B,BA,BB,ERR
C      CAVC=AVERAGE VOLUMETRIC HEAT GENERATION RATE IN FOUSCH BLADE SECTION
C      TO BE MULTIPLIED BY PRA AND PAX (BTU/HR-F12), P=PCISCA RCC PITCH (IA.),
C      CR=PCISCA RCC DIAMETER (IA.), CW=WIRE WRAP DIAMETER (IA.)
CC3J      READ(15,1) CAVC,F,CR,CW
C      INPLT F54,F55,F56,F57=FLOW SPLIT MULTIPLIERS FOR TYPE 4,5,6,7 ADDS
C      RESPECTIVELY AREA WEIGHTED FLOW SPLIT IF SET EQUAL TO 1.00, REMEMBER
C      TO LENGTHEN PASS
CC3Z      READ(15,1) F54,F55,F56,F57
C      INPLT 1STAR4,ESTAR5,ESTAR6,ESTAR7,ESTAR8,ESTAR9=EFFECTIVE EDDY DIFFU-
C      SIVITIES CORRESPONDING TO VARIOUS SUBCHANNEL CONNECTIONS (CGEMANUAL)
CC3Z      READ(15,1) ESTAR4,ESTAR5,ESTAR6,ESTAR7,ESTAR8,ESTAR9
C      INPLT NAX=NUMBER OF POINTS TO SPECIFY AXIAL POWER PROFILE,
CC3A      READ(15,2) NAX
C      INPLT REL(1)=RELATIVE HEIGHT ABOVE CLEAN AT WHICH AXIAL POWER SHAPE IS
C      TO BE SPECIFIED, AT CLEAN REL(1)=0.0, AT BLADE EXIT REL(1)=1.00, 2CTH
C      MUST BE INCLUDED, FAK(1)=VALUE OF AXIAL POWER SHAPE AT REL(1) - INPUT
C      IN COLUMNS OF INC
CC3Z      READ(15,1) IREL(1),PAX(1),I=1,NAX)
C      INPLT FPA(1)=AXIAL POWER MULTIPLIERS FOR SUBCHANNELS 1-84
CC3Z      READ(15,1) FPA(1),I=1,84)
CC3Z      WRITE(16,5)
CC3Z      WRITE(16,6) IN,IT,CLEN,CLEN
CC3Z      WRITE(16,7) RIN,RCUT,RPIA,RPLC,CF,CTHK,GAPTH
CC4C      WRITE(16,8) PICT1,PFL2,PFLCP,PICT9
CC4I      WRITE(16,9) C2A,C2B,BA,BB,ERR
CC4Z      WRITE(16,10) CAVC,F,CR,CW
CC4Z      WRITE(16,11) F54,F55,F56,F57
CC4A      WRITE(16,12) 1STAR4,ESTAR5,ESTAR6,ESTAR7,ESTAR8,ESTAR9
CC4S      WRITE(16,13)
CC4B      WRITE(16,41) IREL(1),PAX(1),I=1,NAX)
CC4J      WRITE(16,14)
CC4I      WRITE(16,41) (PAX(1),I=1,84)
CC4Z      1 FCRPAT(0F10,1)
CC5C      2 FCRPAT(0F5)
CC5Z      4 FCRPAT(1,1,1CX,0F12,4)
CC5Z      5 FCRPAT(1,15X,1'SUBROUTINE SCA, INPLT PARAMETERS')
CC5Z      6 FCRPAT(1,1CX,1'IN,IT,CLEN,CLEN') 1,1CX,2(F10,2,2X),2(F10,4,2X)
CC5Z      7 FCRPAT(1,10X,1'RIN,RCUT,RPIA,RPLC,CF,CTHK,CAPTH') 1,10X,7(F10,4
CC5Z      1,1X)
CC5Z      8 FCRPAT(1,1CX,1'PICT1,PFL2,PFLCP,PICT9') 1,1CX,4(F10,1,2X)
CC5Z      9 FCRPAT(1,1CX,1'C2A,C2B,BA,BB,ERR') 1,1CX,2(F10,1,2X),3(F10,4,2X)
CC5Z      11

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0057 10 FORMAT( '1,1CX,1QAVG,P,IR,IN', '1,1CX,F1C,1,2K,3IF1C,4,2X1)
0058 11 FORMAT( '1,1CX,1FS4,FS5,FS6,FS7', '1,1CX,4IF1C,4,2X1)
0059 12 FORMAT( '1,1CX,1ESTAR4,ESTAR5,ESTAR6,ESTAR7,ESTAR8,ESTAR9', '1,1CX
1,6IF1C,5,2X1)
0060 13 FORMAT( '1,1CX,1AXIAL RELATIVE HEIGHT VS. RELATIVE FLLX SHAPE')
0061 14 FORMAT( '1,1CX,1SURCHANNEL RELATIVE RACIAL POWER PROFILE')
C CALCULATE PROPERTIES FOR USE IN SC4
C RAC=SCC10P DENSITY, CP=SCC10P SPECIFIC HEAT, CCNC=SCC10M CONDUCTIVITY,
C CCNCN=CONDUCTIVITY OF THE CLCT WALLS
0062 RAC=59.566-(3.55046-C3)*T1-(C.28726-C6)*T1**2+(C.760356-C5)*T1**3
0063 CP=C.244021-17.03329E-5)*T1+12.66131E-8)*T1**2
0064 CCNC=C4.206-(1.6786-2)*T1+12.0914E-6)*T1**2
0065 CCNCN=12.1
0066 E1=3.14159
C CALCULATE FLOW RATES FOR SURCHANNEL TYPES 1 AND 2
0067 FFL1=PI*IC11/4.
0068 FFL2=PI*IC22/4.
C SURCHANNEL TYPE AREAS
0069 A1=IC.760356*(CP/12.1)**2-P1*IRGLT/12.1**21/4.
0070 A2=PI*IR11/12.1**2
0071 A3=(IC*G*TH/2.1)*ICF/1.7221+C.5774*(IC*G*TH/2.1+DTHK*G*TH)/144.0
C SURCHANNEL TYPE WEIGHT PERIMETERS
0072 W1=12.1*PI*IRGLT/12.1+3.4641*(CP/12.1)**2
0073 W2=ICF/1.7221+1.1547*(DTHK)/12.
C SURCHANNEL TYPE EQUIVALENT DIAMETERS
0074 ED1=4.141/F1
0075 ED2=4.141/F2
C DISTANCES OF THE SURCHANNEL ALONG THE CLCT CENTERLINE AND INTERASSEMBLY
C GAP CENTERLINE RESPECTIVELY
0076 X2=(ICF/1.7221+C.5774*G*TH)/12.
0077 X3=(ICF/1.7221+1.1547*(DTHK)/2.1+DTHK)/12.
C GAP WIDTH BETWEEN TYPE 1 SURCHANNELS
0078 WID1=(ICF-2.1*PI*IC11)/24.
C ACCESS DISTANCES BETWEEN TYPE 1 ACCESS AND BETWEEN TYPE 3 NODES
0079 ETA1=(IRGLT/12.1+XICTH/2.1)*PI/2.
0080 ETA2=(ICF/1.7221+1.1547*(DTHK+G*TH)/4.1)/12.
C HEAT TRANSFER COEFFICIENTS FOR TYPE ACCESS 1, 2 AND 3
0081 HCR1=(CCNC/CE1)**0.7*(C4C.025*(CE1*CP*FFL1/12.1+CCNC1)**0.21
0082 HTR1=(16.0*CCNC/RTN)**0.7*(C4C.025*(RTN*CP*FFL2/16.1+A2*CCNC1)**0.21
0083 HTR2=(CCNC/CE2)**0.7*(C4C.025*(CE2*CP*FFL3/16.1+CCNC2)**0.21
0084 E=PI*CC1*(IRGLT/RTN)
C INVERSE EQUIVALENT HEAT TRANSFER COEFFICIENTS F1=HCR1 TYPE1 TO TYPE
C 2, F2=HCR2 TYPE1 TO TYPE2 FOR WALL1
0085 F1=1.77*HCR1*(IRGLT+XCR1)*RTN**2/(12.0*CCNCN)
0086 IF(100.0E-1) GO TO 15
0087 F2=1.77*HCR2*(1.1547*DTHK/12.0*CCNCN)
0088 GO TO 17
0089 15 F2=1.77*HCR1*(1.77*HCR1+1.1547*DTHK/12.0*CCNCN)
0090 17 CONTINUE
0091 ETA1=PI*(RTN/12.1)**2/(FFL2*CP)
C COEFFICIENTS FOR TYPE 2 TEMPERATURE EXPRESSION
0092 C1=2.1*PI*RTN/12.1*FFL2*CP*F1
0093 C2=PI*G*G22/(ICF-C1)
0094 C3=PI*G*G22/(ICF-C1)
C COEFFICIENTS FOR TYPE 1 TEMPERATURE EXPRESSION
0095 F1=X2*C2/(12.1*FFL1*CP*F2)
0096 C2=C2*0.1/(FFL1*CP*12.1)
0097 C3=WIDTH*12.1*(C4E/12.1*FFL1*CP*ETA1)
    
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C058      C4=P1*(1+X2/(132.4*PFL1*CP*F1)
C          C COEFFICIENTS FOR TYPE 3 TEMPERATURE EXPRESSION
C059      E1=P1*(PFL1/PFL3)
C060      E2=G*P*TH*CC*CD/12*E3*(PFL3*CP*ETA3)
C061      E3=C2*X3/12.4*PFL3*CP*F1
C          C INITIALIZE ARRAYS
C          C TPAR(1) STORES THE AVERAGE VALUE OF THE TYPE 1 TEMPERATURES AT THE
C          C AXIAL LEVEL 1-3
C062      DO 20 I=1,500
C063      TPAR(I)=T1A
C064      20 CONTINUE
C065      DO 25 I=1,6
C066      TSCAL(I)=C
C          C FOR TSC=C, TSCA(1) CONTAINS THE TEMPERATURE OF THE SECONDARY CONTROL
C          C ASSEMBLY INTERASSEMBLY CAP SUBCHANNEL AT THE PREVIOUS AXIAL LEVEL, FOR
C          C IBC=2 IT FLUCTUATES AS THE TEMPERATURE BOUNDARY CONDITION AT THE CLCT
C          C WALL IN THE CURRENT AXIAL LEVEL
C067      TSCA(1)=T1A
C068      25 CONTINUE
C          C INITIALIZE ARRAYS TSCA(1), TSCA(2)=SUBCHANNEL TEMPERATURES AT CLC
C          C AND NEW AXIAL HEIGHTS RESPECTIVELY
C069      DO 30 I=2,33
C070      TSCA(I)=T1A
C071      TSCA(2)=T1C
C072      30 CONTINUE
C          C SUB2-TEMPERATURE DERIVATIVE SUMMATION TERM FOR SEPI-ANALYTICAL NODE
C          C TYPE 2 SOLUTION BASED ON NODE TYPE 1 AVERAGE TEMPERATURES OF THE
C          C CURRENT ITERATION, SLM1=SAME BASED ON LAST ITERATIONS TEMPERATURES
C073      SLM1=C1C
C074      SLM2=C1C
C          C CUMULATIVE HEAT FLUX TERM FOR COUNTERFLOW SECTION, HERE AT HEIGHT
C          C 1/2, CEL1=TEMPERATURE DIFFERENCE BETWEEN TYPE 2 AND AVERAGE TYPE
C          C 1 SUBCHANNELS, HERE AT Z=C,C
C075      C1=C2*EXP(-E1*CLCEN-C2/2.1/12.1+C2*EXP(-E3*(CLCEN-C2/2.1/12.1
C076      CELT=(C2+C3)*EXP(-C1*CLCEN/12.1)-C2*EXP(-E1*CLCEN/12.1)-C3*EXP(-E3*CLC
C          C EN/12.1)-SLM1*EXP(-C1*CLCEN/12.1
C077      TSCA(1)=T1A+CELT
C078      A=1
C079      WRITE(6,40) A
C080      WRITE(6,41)
C081      WRITE(6,2*) A1,A2,A3
C082      WRITE(6,42)
C083      WRITE(6,35) P1,P3,CE1,CE3
C084      WRITE(6,43)
C085      WRITE(6,35) X2,X3,NSCT,ETA1,ETA3
C086      WRITE(6,44)
C087      WRITE(6,35) TPAR,PTWC,PTTR
C088      WRITE(6,45)
C089      WRITE(6,35) EETA,C1,C2,C3,C4,C2,C3,C4,E1,E2,E3
C090      WRITE(6,46)
C091      WRITE(6,35) RHC,CP,CCNC,CCACW
C092      35 FORMAT(' ',3X,6E13.4)
C093      40 FORMAT(' ',15X,'SUBROUTINE SCA CALCULATED PARAMETERS - REGION',I3)
C094      41 FORMAT(' ',1X,'SUBCHANNEL AREAS IN SQ.FT. - A1,A2,A3')
C095      42 FORMAT(' ',1X,'HEATED PERIMETERS AND ECLIV. DIAMETERS IN FT. - P1
C          C 1,P2,CE1,CE3')
C096      43 FORMAT(' ',1X,'SCHE CHARACTERISTIC LENGTHS IN FT. - X2,X3,WIDTH,E
C          C 1TA,ETA3')

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C137      44 FORMAT(1X,'HEAT TRANSFER COEFFICIENTS IN BTU/HR-F2-F - HCAE,
C138      45 FORMAT(1X,'COEFFICIENTS FOR TEMPERATURE CORRECTIONS - BE16,C1
C139      46 FORMAT(1X,'PROPERTIES BASED ON AVERAGE TEMPERATURE - RHC,CPC,C
C140      100C,CONDW)
C141      C J=AXIAL STEP COUNTER
C142      C K=AXIAL PEECH INDICATOR, C COUNTERFLOW REGION HAS NOT CONVERGED,
C143      C 1 COUNTERFLOW REGION HAS CONVERGED AND IS ON PRESENT ITERATION, 2 IN
C144      C PCISCA SECTION WHERE ACT TYPE 1C IS PRESENT, 3 ABOVE THAT POINT
C145      C K=AXIAL ITERATION INDICATOR, WHEN IT EQUALS 1 ITERATE TO Z=C,C
C146      J=C
C147      K=C
C148      GO TO 3000
C149      100 CONTINUE
C150      J=J+1
C151      Z=Z+0.25
C152      IF (Z.CC.1) K=C
C153      IF (IHC.RE.C) GO TO 105
C154      C TYPE 2 TEMPERATURE CALCULATION - ONLY IF IHC=C
C155      GO TO 1+K,12
C156      1+K=7
C157      C GOVERNING TEMPERATURE EXPRESSION FOR ACCE TYPE 3
C158      TSCA211=TSCA111+ES+CSCA111+EXP(TSCA211K5(T11)-TSCA11111)+0.26
C159      TSCA211=TSCA211
C160      110 CONTINUE
C161      105 CONTINUE
C162      TAV=C,C
C163      C TYPE 1 TEMPERATURE CALCULATION
C164      GO TO 120 F=2.7
C165      C=1+K
C166      C DETERMINE BOUNDARY CORRECTION EFFECTS
C167      IF (IHC=1) 115,113,111
C168      111 C=CSCA111+C1+K2/(12+FFET+C01
C169      GO TO 117
C170      113 C=C1+TSCA111-TSCA111
C171      TSCA211=C-TSCA111
C172      GO TO 117
C173      115 C=C1+TSCA111(111)-TSCA11111
C174      117 CONTINUE
C175      C GOVERNING TEMPERATURE EXPRESSION FOR ACCE TYPE 1
C176      TSCA211=TSCA111+0.3+C1+TSCA111(111)+TSCA111(111)+2+TSCA111(111)+D2
C177      TSCA211=TSCA211
C178      IF (IHC.CC.2) TSCA211=TSCA211
C179      TAV=TAV+TSCA211
C180      120 CONTINUE
C181      J=J+1
C182      R=(C-RA-22)/12
C183      IF (R.LT.C) RHC=C
C184      EALPH=EXP(1-C1+R)
C185      ED=EXP(1-C1+R)
C186      EEP=EXP(1-ED+R)
C187      C=C2+C3+EALPH+C2+EPA-C2+EEP-EALPH+SLP1
C188      C=C2+EXP(1-40*(R-C2/24.1)+C2+EXP(1-EP4R-C2/24.1)
C189      C FIND SLM1 FOR NEXT AXIAL STEP BEFORE T0ARIJJ1 TAKES ON A NEW VALUE
C190      C FOR THE CURRENT ITERATION
C191      SLP1=SLP1+F*(C1+R1)+(T0ARIJJ1)-T0ARIJJ1

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C178      TPAR(JJ)=TAVZ.
C179      C      FIND TYPE 2 TEMPERATURE FOR THIS AXIAL STEP
C180      TSCA2(1)=CEL1+TBAR(JJ)
C181      SLP2=SLP2-EXPIC1*(R+CL/12.)*ITEPR(JJ)-TBAR(JJ)
C182      C      PREPARE TSCA1(1) ARRAY FOR NEXT AXIAL STEP
C183      125 DO 130 I=1,13
C184      TSCA1(I)=TSCA2(1)
C185      130 CONTINUE
C186      IF(CLEN.C1.22) GO TO 1000
C187      SLP1=SLP2
C188      SLP2=C.C
C189      C      CALCULATE ERROR IN TEMPERATURE AT Z=CLEN. IF CONVERGED ENTER ITERATION
C190      C      LOOP ONE LAST TIME FOR PRINTOUT OTHERWISE CONTINUE TO ITERATE
C191      PERH=ITEPR(JJ)-TBAR15CC)/TBAR1JJ
C192      IF (A-60.1) GO TO 250
C193      IF (PERH.LE.60) N=1
C194      TSCA=TBAR15CC)
C195      TPAR(500)=TBAR(JJ)
C196      N=N+1
C197      C      SET UP CV,TSCA1(1), AND SLP1 FOR NEW ITERATION
C198      CV=0.74*EXP1-FA*(CLEN-C/2.)/12.)+C20*EXP1-80*(CLEN-C/2.)/12.)
C199      CEL1=(C2+C3)*EXP1-C1*(CLEN/12.)-C2*EXP(-BA*(CLEN/12.))-C3*EXP1-80*CL6
C200      TSCA1(1)=TIN+CEL1
C201      SLP1=SLP1+EXP(C1*(CLEN/12.))*ITEPR(2)-TBAR1JJ
C202      IF (100.NE.C) GO TO 195
C203      DO 150 I=1,6
C204      150 TSCA3(I)=TIN
C205      155 CONTINUE
C206      DO 200 J=2,13
C207      TSCA1(J)=TIN
C208      200 CONTINUE
C209      GO TO 1000
C210      C      BEGINNING OF PCISGN SECTION PART OF THE PROGRAM
C211      250 N=N+1
C212      C      INITIALIZE TEMPERATURES BASED ON CCLATERFLOW TEMPERATURES
C213      DO 270 I=79,64
C214      LXX=177
C215      TSCA2(1)=TSCA2(LX)
C216      270 CONTINUE
C217      DO 280 J=51,56
C218      LX=1-83
C219      TSCA2(1)=TSCA2(LX)
C220      280 CONTINUE
C221      DO 260 I=1,18
C222      TSCA2(1)=TSCA2(1)
C223      260 CONTINUE
C224      C      SELECT PANEL TYPE AREAS
C225      A4=C.433C*(P/12.)*2-F1*(CR/12.)*2+ICW/12.)*2)/8.
C226      A5=C.433C*(P/12.)*2-F1*(CR/12.)*2+ICW/12.)*2)/12.-(DR/12.)*2
C227      1/6.52E2
C228      A7=C.15C1*(P/12.)*2-1.2990*(F/12.)*2-0.44C2*(DR/12.)*2+(CW/
C229      1/12.)*2
C230      A8=(CR/2.4641)+C.1542*FF1*(CR/2.-3.16+0.581C*(P/12.)*2-0.44C2-
C231      1*(P/12.)*2
C232      A9=C.1667*(P/12.)*2-1.259C*(P/12.)*2-AE/2.-C.1726*(CR/12.)*2
C233      12*(CW/12.)*2+1*(CR/12.)*2/6.52E2
C234      A9=PI*(R/12.)*2-1*(FCL/12.)*2)/6.

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0223)      A11=PI*(PI*(RCLT/12.1**2)-(RCLT/12.1**2)**2)
C      TOTAL FLOW AREA
0224)      PCT=42.484+12.485*12.486+6.487
C      SUBCHANNEL TYPE NETTED PERIMETERS
0225)      P4=PI*(EP+CH)/24.
0226)      P1=PI*(CP+CA)/36.4(CR/12.1/1.7321)
0227)      P6=(C.65C3*(CR+CA)+1.27C8*P7A-3.4641*P+0.2687*OR)/12.
0228)      P3=(C.36C2*PPIA+1.74C9*(CR+CA))/12.
0229)      P5=PI*(RIA+RCLT)/36.
0230)      P11=ICF/1.7321+P14RCLT/3.1/12.
C      LOCAL DISTANCES - SEE MANUAL FOR NUMBERING SCHEME
0231)      E184=(P/12.1/1.7321)
0232)      E185=(P/12.1/1.7321)
0233)      E186=(P/12.1/1.7321)+(P-CR)/24.4*CP/48.
0234)      E187=(P/12.1/1.7321)
0235)      E188=(CR/2.4+1.1328*PPIA-3.6754*P+C.2687*CR)/12.
0236)      E189=C.36C1*(PPIA-(P-CR)/2.4)/12.
0237)      E181C=P1*(CR+CA)*PCL1/12.
0238)      E181=DPI*(RCLT+CF/2.4)/12.
C      SUBCHANNEL TYPE EQUIVALENT DIMETERS
0239)      CE4=C.65/4
0240)      CE5=C.65/4
0241)      CE6=C.65/4
0242)      CE7=C.65/4
0243)      CE8=C.65/4
0244)      CE11=C.65/4
C      TOTAL FLOW RATE ENTERING PCISEA BUNDLE
0245)      PIG1A=PIC11+PFL2+PFC15
C      FLOW RATES FOR SUBCHANNEL TYPES 4,5,6,7,8,11
0246)      PFL4=P4*P5*P1C1P/PIC1
0247)      PFL5=P5*P5*P1C1P/PIC1
0248)      PFL6=P6*P5*P1C1P/PIC1
0249)      PFL7=P7*P5*P1C1P/PIC1
0250)      PFL9=PIC14/6.
0251)      PFL11=PFL9
C      BLACK AVERAGE VELOCITY
0252)      VEA2=PIC1P/(RCLT*PCT)
C      HEAT TRANSFER COEFFICIENTS FOR 5,6,7,8,11
0253)      HVE=CCEAC/CE51*(7.0+C.025*(CE5+CP*PFL5)/(45+CCND1))*0.8)
0254)      HSI=CCEAC/CE61*(7.0+C.025*(CE6+CP*PFL6)/(45+CCND1))*0.8)
0255)      HSA=CCEAC/CE71*(7.0+C.025*(CE7+CP*PFL7)/(47+CCND1))*0.8)
0256)      HAE=CCEAC/CE91*(7.0+C.025*(CE9+CP*PFL9)/(45+CCND1))*0.8)
0257)      HEVA=CCEAC/CE111*(7.0+C.025*(CE11+CP*PFL11)/(41+CCND1))*0.8)
0258)      FACTCR=ALCGRCLT/PPIA
C      INVERSE EQUIVALENT HEAT TRANSFER COEFFICIENTS - FOLLOW MANUAL DEFINITION
0259)      FS=1./HVE+CR/(20.7852*CCACN)
0260)      F6A=1./HSI+C.6305*CR/(12.*CCACN)
0261)      FS=1./HAE+P1*RIA/P/(36.4*CCACN)+NIGTH/(12.*CCND1)
0262)      IF(100.AE.1) GO TO 250
0263)      FIC=(CF/1.7321-RCLT-6.*NIGTH)/(12.*CCNC1)+1.1547*CTHK/(12.*CCND1)
0264)      F11=1./HEVA+1.1547*CTHK/(12.*CCND1)
0265)      GO TO 260
0266)      350 FIC=L./PTHR+ICF/1.7321-RCLT-6.*NIGTH)/(12.*CCNC1)+1.1547*CTHK/(12.*
      CCNC1)
0267)      F11=1./PTHR+1./HEVA+1.1547*CTHK/(12.*CCACN)
0268)      360 CONTINUE
C      COEFFICIENTS FOR TYPE 4 TEMPERATURE EXPRESSION
0269)      CCT=CAVC+C7*P4/(12.*CP*PFL4)

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C270      CC2=(P-CP)*C2*(CCNC+R+C)*CP*ESTAR4*(VEAR*DE4)/1144.*PFL4*CP*ETA4)
C271      CC3=(P-CN)*C2*(CCNC+R+C)*CP*ESTAR5*(VEAR*DE4)/1144.*PFL4*CP*ETA5)
C272      CC4=(P-CN)*C2*(CCNC+R+C)*CP*ESTAR6*(VEAR*DE4)/1144.*PFL4*CP*ETA6)
C273      C CCEFFICIENTS FOR TYPE 5 TEMPERATURE EXPRESSION
C274      CC1=C*VC+C2*45/112.*CF*PFL5)
C275      CC2=(P-CN)*C2*(CCNC+R+C)*CP*ESTAR7*(VEAR*DE4)/1144.*PFL5*CP*ETA7)
C276      CC3=(P-CN)*C2*(CCNC+R+C)*CP*ESTAR8*(VEAR*DE4)/1144.*PFL5*CP*ETA8)
C277      CC4=(P-CN)*C2*(CCNC+R+C)*CP*ESTAR9*(VEAR*DE4)/1144.*PFL5*CP*ETA9)
C278      CC5=C2*ER/1144.*P5*PFL5*CP*1.7221)
C279      C CCEFFICIENTS FOR TYPE 6 TEMPERATURE EXPRESSION
C280      EE1=C*VC+C2*46/112.*CF*PFL1)
C281      EE2=(P-CN)*C2*(CCNC+R+C)*CP*ESTAR6*(VEAR*DE4)/1144.*PFL6*CP*ETA6)
C282      EE3=(P-CN)*C2*(CCNC+R+C)*CP*ESTAR9*(VEAR*DE4)/1144.*PFL6*CP*ETA9)
C283      EE4=(CR/2.4441-3.4641)*P*1.1328*PFL6*CF)
C284      C CCEFFICIENTS FOR TYPE 7 TEMPERATURE EXPRESSION
C285      CC1=C*VC+C2*47/112.*CF*PFL7)
C286      CC2=(P-CN)*C2*(CCNC+R+C)*CP*ESTAR9*(VEAR*DE4)/1144.*PFL7*CP*ETA9)
C287      CC3=(P-CN)*C2*(CCNC+R+C)*CP*ESTAR6*(VEAR*DE4)/1144.*PFL7*CP*ETA6)
C288      C CCEFFICIENTS FOR TYPE 8 TEMPERATURE EXPRESSION
C289      XX5=PI*RI*CC2/1432.*PFL5*CP*P9)
C290      XX6=C2*(CCNC+R+C)*CP*ESTAR7*(VEAR*DE4)/1144.*PFL5*CP*ETA7)
C291      C CCEFFICIENTS FOR TYPE 11 TEMPERATURE EXPRESSION
C292      XX1=(P/2.7221)*C2/1144.*PFL11*CP*P11)
C293      XX2=C2*(CCNC+R+C)*CP*ESTAR7*(VEAR*DE4)/1144.*PFL11*CP*ETA7)
C294      C CCEFFICIENTS FOR TYPE 10 TEMPERATURE EXPRESSION
C295      LA*P7=XX5*CF*PFL5*XX2*C2/112.*PFL1)
C296      YY1=XX5*PFL5*CP/ENR10)
C297      YY2=XX2*C2/112.*PFL1*CP*P10)
C298      C CCEFFICIENTS FOR TYPE 12 TEMPERATURE EXPRESSION
C299      E3=YY2*CN*P10/PFL3*CF)
C300      Z4=YY2*PFL11/PFL3)
C301      Z5=05
C302      PFLA*PFL5
C303      P333=P3A6
C304      ACC CONTINUE
C305      C THESE CCEFFICIENTS CHANGE WHEN SUBCHANNEL TYPES BECOMES TYPE 11
C306      P2B=1.7*SV*PFL1/(PFL1*XX1)+C.1380*PFL1*FACTCH/112.*CCNCW)
C307      P3=L.7*SV*PFL1/(PFL1*XX1)+C.26C2*PFL1*FACTCH/112.*CCNCW)
C308      TE=PFL1/(PFL1*XX1)+C.3510*PFL1*FACTCH/112.*CCNCW)*(PFL1-3*P)/112
C309      L.*CCNCW)
C310      EE5=C.1380*PFL1*C2/1144.*CP*PFL6*P6B)
C311      CC4=C.38C2*PFL1*C2/1266.*PFL1*CP*P7)
C312      C CCEFFICIENTS FOR TYPE 8 TEMPERATURE EXPRESSION
C313      CENCP=2.*EE4*PFL6*CP*2*EC5*PFL5*CP+C.3510*PFL1*C2/1144.*PFL1)
C314      XX1=EE4*PFL6*CF/CENCP)
C315      XX2=EC5*PFL5*CP/CENCP)
C316      XX3=C.3510*C2*PFL1/1144.*PFL1*CP*P10)
C317      C CCEFFICIENTS FOR TYPE 9 AND 11 TEMPERATURE EXPRESSIONS
C318      XX1=C*VC+C2*48/112.*CF*PFL9)
C319      XX2=EE5*PFL6/PFL9)
C320      XX3=CC4*PFL7/PFL9)
C321      XX4=XX3*CCNCW/(CP*PFL9)
C322      IF (N.EE.3) GO TO 300
C323      WRITE(6,4C) A
C324      WRITE(6,2C) I
C325      WRITE(6,23) A4,A5,A6,A7,A8,A9,A11,ATCT
C326      WRITE(6,2C) I
C327      WRITE(6,35) P4,P5,P6,P7,P8,P11

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C377      WRITE(6,302)
C378      WRITE(6,351) ET44,ET45,ET46,ET47,ET48,ET49,ET4A,ET4B,ET4C,ET4D
C379      WRITE(6,303)
C380      WRITE(6,353) CE4,CE5,CE6,CE7,CE8,CE9
C381      WRITE(6,304)
C382      WRITE(6,355) P1CTP,PFL4,PFL5,PFL6,PFL7,PFL8,PFL9
C383      WRITE(6,305)
C384      WRITE(6,357) FVE,F5IX,F5VX,FNAE,FEVH
C385      WRITE(6,306)
C386      WRITE(6,359) FS,F6A,F6P,F7,FE,F5,FIC,F11
C387      WRITE(6,307)
C388      WRITE(6,361) CC1,CC2,CC3,CC4
C389      WRITE(6,308)
C390      WRITE(6,363) CC1,CC2,CC3,CC4,CC5
C391      WRITE(6,309)
C392      WRITE(6,365) EE1,EE2,EE3,EE4,EE5
C393      WRITE(6,310)
C394      WRITE(6,367) GG1,GG2,GG3,GG4
C395      WRITE(6,311)
C396      WRITE(6,371) HW1,HW2,HW3
C397      WRITE(6,312)
C398      WRITE(6,373) XX1,XX2,XX3,XX4,XX5,XX6,XX7,XX8
C399      WRITE(6,313)
C400      WRITE(6,375) YY1,YY2
C401      WRITE(6,314)
C402      WRITE(6,377) E244
C403      FORMAT('1,1CX,'SUCCH-PAUED AREAS IN FT. - E4,ES,AE,AT,AE,AS,AL
C404      11,XX1')
C405      301 FORMAT('1,1CX,'NETTED PERIMETERS IN FT. - E4,ES,PE,PT,PS,P11')
C406      302 FORMAT('1,1CX,'SCHE CHARACTERISTIC LENGTHS IN FT. - ET44,ET45,ET4
C407      10,ET47,ET48,ET49,ET4A,ET4B,ET4C,ET4D')
C408      303 FORMAT('1,1CX,'ECLIV. DIAPETERS IN FT. - CE4,CE5,CE6,CE7,CE8,CE9,CE11'
C409      11)
C410      304 FORMAT('1,1CX,'PASS FLOWRATES IN LPM/HR - P101P,PFL4,PFL5,PFL6,P
C411      117,PFL8,PFL9')
C412      305 FORMAT('1,1CX,'HEAT TRANSFER COEFFICIENTS IN BTL/HR-F12-F - FVE,
C413      11F5IX,F5VX,FNAE,FEVH')
C414      306 FORMAT('1,1CX,'INVERSE ECLIV. HEAT TRANSFER COEFF. - FS,F6A,F6P,F
C415      17,FE,F5,FIC,F11')
C416      307 FORMAT('1,1CX,'CEFF. FOR CHANNEL TYPE 4 TEMPERATURE EXPRESSION -
C417      1 CC1,CC2,CC3,CC4')
C418      308 FORMAT('1,1CX,'CEFF. FOR CHANNEL TYPE 5 TEMPERATURE EXPRESSION -
C419      1 CC1,CC2,CC3,CC4,CC5')
C420      309 FORMAT('1,1CX,'CEFF. FOR CHANNEL TYPE 6 TEMPERATURE EXPRESSION -
C421      1 EE1,EE2,EE3,EE4,EE5')
C422      310 FORMAT('1,1CX,'CEFF. FOR CHANNEL TYPE 7 TEMPERATURE EXPRESSION -
C423      1 GG1,GG2,GG3,GG4')
C424      311 FORMAT('1,1CX,'CEFF. FOR CHANNEL TYPE 8 TEMPERATURE EXPRESSION -
C425      1 HW1,HW2,HW3')
C426      312 FORMAT('1,1CX,'CEFF. FOR CHANNEL TYPE 9 TEMPERATURE EXPRESSION -
C427      1 XX1,XX2,XX3,XX4,XX5,XX6,XX7,XX8')
C428      313 FORMAT('1,1CX,'CEFF. FOR CHANNEL TYPE 10 TEMPERATURE EXPRESSION
C429      1- YY1,YY2')
C430      314 FORMAT('1,1CX,'CEFF. FOR CHANNEL TYPE 2 TEMPERATURE EXPRESSION -
C431      1 E2,EA')
C432      315
C433      316
C434      317
C435      318
C436      319
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C961      844
C962      845
C963      846
C964      847
C965      848
C966      849
C967      850
C968      851
C969      852
C970      853
C971      854
C972      855
C973      856
C974      857
C975      858
C976      859
C977      860
C978      861
C979      862
C980      863
C981      864
C982      865
C983      866
C984      867
C985      868
C986      869
C987      870
C988      871
C989      872
C990      873
C991      874
C992      875
C993      876
C994      877
C995      878
C996      879
C997      880
C998      881
C999      882

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C361      IF (CLEA,CT,21) GO TO 52C
C362      N=2
C363      AFA=11
C364      APLA=PFLL1
C365      FAXX=FEVA
C366      CC TO ACC
C367      52C CONTINUE
C368      ZCL=(Z-CLEN)/41CTLEN-CLEN1
C      FIND RELATIVE HEIGHT FROM CLEN AND AXIAL POWER FACTOR TO CC WITH IT
C369      IF (ZCL.GT).1.C3 ZCL=1.C
C370      CALL F11(FAX,ZCL,FAX,REL,NXP)
C371      CC ACC 1=1.24
C      TYPE 4 SUBCHANNEL GOVERNING EQUATION
C372      TSCA2(1)=TSCA1(1)+CC1*PRA(1)+FAX*CC2*(TSCA1(LA2(1))+TSCA1(LA2(1)))
      TSCA1(LA2(1))-3.C*TSCA1(1)
C373      40C CONTINUE
C374      CC 610 1=25.54
C375      L=1-24
C376      IF (L.NE).C3.0) GO TO 62C
C377      IF (L.B3(1),C1,56) GO TO 610
C      TYPE 4 SUBCHANNEL GOVERNING EQUATION
C378      TSCA2(1)=TSCA1(1)+CC1*PRA(1)+FAX*CC2*(TSCA1(LB1(1))+TSCA1(LB2(1))-
      12.C*TSCA1(1))+CC3*TSCA1(LB3(1))-TSCA1(1))
C379      CC TO 63C
C      TYPE 4 SUBCHANNEL GOVERNING EQUATION
C380      TSCA2(1)=TSCA1(1)+CC1*PRA(1)+FAX*CC2*(TSCA1(LB1(1))+TSCA1(LB2(1))-
      12.C*TSCA1(1))+CC4*TSCA1(LB3(1))-TSCA1(1))
C381      CC TO 63C
C      TYPE 5 SUBCHANNEL GOVERNING EQUATION
C382      42C TSCA2(1)=TSCA1(1)+CC1*PRA(1)+FAX*CC4*(TSCA1(LB1(1))-TSCA1(1))+CC2*
      211TSCA1(LB2(1))-TSCA1(1))+CC3*(TSCA1(LB3(1))-TSCA1(1))+CC5*(TSCA1(L
      2B4(1))-TSCA1(1))
C383      43C CONTINUE
C384      CC 660 1=55.78
C385      L=1-54
C386      IF (L.C5(1),C6,0) GO TO 650
C387      IF (L.C4(1),L7,79) GO TO 660
C      TYPE 7 SUBCHANNEL GOVERNING EQUATION
C388      TSCA2(1)=TSCA1(1)+CC1*PRA(1)+FAX*CC2*(TSCA1(LC2(1))+TSCA1(LC3(1))
      1+2.C*TSCA1(1))+CC3*(TSCA1(LC2(1))-TSCA1(1))+CC4*(TSCA1(LC4(1))+TSC
      2B1(LC4(1))-2.C*TSCA1(1))
C389      CC TO 66C
C      TYPE 8 SUBCHANNEL GOVERNING EQUATION
C390      45C TSCA2(1)=TSCA1(1)+EE1*PRA(1)+FAX*EE2*(TSCA1(LC1(1))-TSCA1(1))+EE3*
      11(TSCA1(LC2(1))-TSCA1(1))+EE4*(TSCA1(LC3(1))-TSCA1(1))+EE5*(TSCA1(L
      2C4(1))-TSCA1(1))
C391      46C CONTINUE
C392      CC 680 1=75.84
C393      L=1-78
C394      IF (L.C7,2) GO TO 67C
C395      IF (L.C6-1) 683,685,687
C      DETERMINE POLYNOMIAL COEFFICIENT EFFECTS
C396      683 C2=CCSCL(1)+C2*X2/(12.4C*PFLL9)
C397      CC TO 687
C398      685 C3=XX3*(TSCA1(LC10,L1))-TSCA1(1)
C399      687 CONTINUE
C      TYPE 9 SUBCHANNEL GOVERNING EQUATION
C400      TSCA2(1)=TSCA1(1)+XX1*FAX*PRA(1)+XX2*(TSCA1(LC12,L1)+TSCA1(LC13,L1)

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10=2.C*TS(1111)+XX3*(TS(11LC(4,L))+TS(11LC(5,L))-2.C*TS(1111)+
20=4*(TS(11LC(1,L))-TS(1111))+4*(TS(11LC(16,L))+TS(11LC(17,L))-
32.C*TS(1111)+C3
C401 CC TC 66C
C402 47C IF(IRC-17475,473,471)
C DETERMINE EQUINARY CONDITION EFFECTS
C403 471 C2=CSCA(1)*C2*X2/117.*PFL11*CP1
C404 CC TC 671
C405 472 C2=XX3*(TS(1111)-TS(1111))
C406 CC TC 677
C407 475 A1=LC(8,L)+6
C408 C2=XX7*(TS(1111)-TS(1111))
C409 477 CCA3(CLE
C C TYPE11 SURCHANEL GOVERNING EQUATION
C410 TS(1111)=TS(1111)+X1*(FAN*PRA11)+X2*(TS(11LC(2,L))+TS(11LC(3,L))
11=2.C*TS(1111)+XX3*(TS(11LC(4,L))+TS(11LC(5,L))-2.C*TS(1111)+
20=4*(TS(11LC(1,L))-TS(1111))+4*(TS(11LC(16,L))+TS(11LC(17,L))-
32.C*TS(1111)+C3
C411 485 CONTINUE
C412 CC 66C 1=55,75,4
C413 1=1-54
C C TYPE 11 SURCHANEL GOVERNING EQUATION
C414 TS(1111)=X1*(TS(11LC(3,L))+TS(11LC(4,L))+X2*(TS(11LC(1,L))+TS(11LC(2,L))
+X3*(TS(11LC(16,L))+TS(11LC(17,L))
C415 490 CONTINUE
C416 IF(IRC-NE,C) CC TC 721
C417 CC 720 1=91,56
C418 1=1-56
C419 IF(1=GT,2) CC TC 70C
C C TYPE12 SURCHANEL GOVERNING EQUATION IF 2 LE CLEN
C420 TS(1111)=TS(1111)+E3*(TS(11LC(1,L))-TS(1111))+E2
11*(TS(11LC(2,L))+TS(11LC(3,L))-2.C*TS(1111))
C421 CC TC 71C
C422 70C 11=LE(1111)+6
TS(1111)=TS(1111)+E3*(TS(11LC(1,L))+E4*(TS(11LC(16,L))-TS(11LC(17,L))+E2*(TS
C C TYPE12 SURCHANEL GOVERNING EQUATION IF 2 GT CLEN
C423 11*(TS(11LC(2,L))+TS(11LC(3,L))-2.C*TS(1111))
71C TS(1111)=TS(1111)
C424 72C CONTINUE
C425 721 CONTINUE
C426 IF(1=GT,2) CC TC 761
C427 CC 760 1=95,5C
C428 1=1-56
C C TYPE13 SURCHANEL GOVERNING EQUATION IF 2 LE CLEN
C429 1=1-56
C430 IF(IRC-1175C,74C,73C
C431 73C TS(1111)=TS(1111)
C432 TS(1111)=TS(1111)
C433 CC TC 76C
C434 74C 11=1-56
C435 TS(1111)=YY1*(TS(11LC(1,L))+YY2*(TS(11LC(16,L))
C436 TS(1111)=TS(1111)
C437 CC TC 76C
C438 75C 11=1-56
C439 TS(1111)=YY1*(TS(11LC(1,L))+YY2*(TS(11LC(16,L))
C440 76C CONTINUE
C441 CC TC 771
C442 761 IF(IRC-9C,C) CC TC 771
C443 CC 77C 1=91,56

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FORTRAN IV G LEVEL 21

SCA

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C444      IF IEC-L1 771,765,763
C445      763  L7=1-J2
C446      TSCA2(13)=TSCA2(LX)
C447      GC 1C 77C
C448      765  L7=1-9C
C449      TSCA2(17)=TSCA2(1LX)
C450      77C CCNTIAGE
C451      771 CCNTIAGE
C          PREPARE FOR NEXT AXIAL STEP
C452      GC 7EC 1+8,84
C453      78C TSCA1(11)=TSCA2(11)
C454      BAC=ES
C455      IF (K-CT,2) IAC=9C
C456      GC 79C 1+ENC,56
C457      79C TSCA1(17)=TSCA2(17)
C458      1CCC CCNTIAGE
C459      RETLRA
C460      ENC

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CCCC1      SUBROUTINE PRNOUT
C          SCA START/CLT RCLTIME
CCCC2      COMMON/BLK2/PRAT(25),IFRNT,ITALLP
CCCC3      COMMON/BLK2/TS(421140),PERR,M,PFL4,PFL5,PFL6,PFL7
CCCC4      REAL PFL4,PFL5,PFL6,PFL7
CCCC5      WRITE(6,10) A
CCCC6      WRITE(6,10) PRAT(IPRAT)
CCCC7      WRITE(6,20)
CCCC8      10 FORMAT(11111X,'TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASS
          TEMELY - AXIAL REGION',131)
CCCC9      15 FORMAT(11,'10X,'AXIAL HEIGHT',F7.2)
CCCC10     20 FORMAT(11,'10X,'SLOTTED CHANNEL TEMPERATURES IN DEGREES F')
CCCC11     CC IC 101,100,1001,A
CCCC12     30 TAVC=C.C
CCCC13     TAVCCP=C.C
CCCC14     CC IC 1=2,3
CCCC15     TAVCCP=TAVCCP+TSCA2(1142)/6,C
CCCC16     40 TAVG=3TAVG+TSCA2(1176)/3,C
CCCC17     CC PC 1=1,5
CCCC18     1A=1,4
CCCC19     1C=1,8
CCCC20     J=11,C,1,1 CC TO 75
CCCC21     1C=1,3
CCCC22     70 FORMAT(11,'15X,4(12,2X,F7.2,4X)')
CCCC23     WRITE(6,10) 1,TSCA2(17,10),TSCA2(140,10),TSCA2(110,10),TSCA2(110)
CCCC24     CC 4C PC
CCCC25     1A WRITE(6,20) 1,TSCA2(11,14),TSCA2(114,10),TSCA2(110)
CCCC26     20 CONTINUE
CCCC27     85 FORMAT(11,'10X,'RADIAL AVG. TEMPERATURE IN CFFLOW REGION',F7.2,' F
          1,3)
CCCC28     90 FORMAT(11,'10X,'RADIAL AVG. TEMPERATURE IN DOWNFLOW REGION',F7.2,
          1,' F')
CCCC29     95 FORMAT(11,'10X,'RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP',F7.2,
          1,' F')
CCCC30     98 FORMAT(11,'10X,'NUMBER OF ITERATIONS TO CONVERGENCE',12)
CCCC31     99 FORMAT(11,'10X,'LAST ITERATION CONVERGED WITH AN ULTIMATE ERROR OF',
          1FF,2,' PERCENT')
CCCC32     WRITE(6,10) TAVC
CCCC33     WRITE(6,10) TSCA2(1)
CCCC34     WRITE(6,10) TAVCCP
CCCC35     WRITE(6,10) ITALLP
CCCC36     PERR=PERR+1,C.C
CCCC37     WRITE(6,10) PERR
CCCC38     CC TO 200
CCCC39     100 IC1L4=C
CCCC40     TAVCCP=C.C
CCCC41     TAVCCP=C.C
C          CALCULATE AVERAGE TEMPERATURE AT THIS AXIAL LEVEL
CCCC42     CC 105 1=1,24
CCCC43     105 IC1L=IC1L+TSCA2(11)*PFL4
CCCC44     CC 110 1=25,50,5
CCCC45     IC1L=IC1L+(TSCA2(11)+TSCA2(114)+TSCA2(1140)+TSCA2(11)+TSCA2(1142)+TSCA2(
          11+311)*PFL4
CCCC46     110 CONTINUE
CCCC47     CC 115 1=56,76,4
CCCC48     115 IC1L=IC1L+(TSCA2(11)+TSCA2(1142))*PFL4+TSCA2(1140)*PFL7
CCCC49     TAVC=IC1L/(42,C*PFL4+12,C*PFL5+12,C*PFL6+6,C*PFL7)
CCCC50     CC 120 1=1,6

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CC51      TAVCEP=TAVCEP+TSCA211+50)/6.C
CC52      120 TAVCEP=TAVCEP+TSCA211+78)/6.C
CC53      IF(A,EC,2)CC 1C 135
CC54      1C 13C 1=1,24
CC55      1A=1+24
CC56      1E=1+46
CC57      1C=1+72
CC58      13C WRITE(6,7C) 1,TSCA211),1A,TSCA211A),1E,TSCA211B),1C,TSCA211C)
CC59      CC 1C 140
CC60      135 1C 14C 1=1,23
CC61      1A=1+23
CC62      1E=1+46
CC63      IF(1,C1,21) CC 1C 133
CC64      1C=1+69
CC65      IF(1,C1,15) 1C=1+75
CC66      WRITE(6,7C) 1,TSCA211),1A,TSCA211A),1E,TSCA211B),1C,TSCA211C)
CC67      CC 1C 140
CC68      133 WRITE(6,7C) 1,TSCA211),1A,TSCA211A),1E,TSCA211B)
CC69      14C CENTER
CC70      145 FORMAT(' ',1C),*RACIAL AVG. TEMPERATURE IN BYPASS REGION',F7.2,' F
CC71      146
CC72      15C FORMAT(' ',1C),*RACIAL AVG. TEMPERATURE IN CONTROL PIN REGION',F7.
CC73      12,' F')
CC74      WRITE(6,15C) TAVC
CC75      WRITE(6,15C) TAVGE
CC76      WRITE(6,11) TAVCEP
CC77      20C CENTER
CC78      RETURN
CC79      END

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0001      SLEPCUTJAE F(1)F(2)F(3)F(4)F(5)F(6)F(7)F(8)F(9)F(10)
0002      C INTERPOLATION ROUTINE FOR SCAL
0003      C DIMENSION F(150),Y(150)
0004      DC 20 K=1,150
0005      IF(X-Y(K)1)30,20,20
0006      20 CONTINUE
0007      CC 10 40
0008      30 IF(X,20,1) CC 10 40
0009      E=(X-Y(K-1))/(Y(K)-Y(K-1))
0010      F=X*F(K-1)+E*(F(K)-F(K-1))
0011      RETLRA
0012      40 PRINT 61
0013      61 SCANDATE(1X,'*** PROGRAM STOPPED IN SLEPCUTJAE #17 00001)
0014      STOP
0015      END

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APPENDIX D

D.1 VARIABLE BOUNDARY CONDITION
SAMPLE PROBLEM

D.2 SUPERENERGY - SCA COUPLED
SAMPLE PROBLEM

APPENDIX D.1

SAMPLE PROBLEM 1

PROPERTIES BASED ON AVERAGE TEMPERATURE - $\text{H}_2\text{O}, \text{CO}_2, \text{O}_2, \text{N}_2$
 $0.5067\text{E}+02$ $0.3071\text{F}+60$ $0.4179\text{E}+02$ $0.1210\text{E}+02$

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 1

AXIAL HEIGHT 0.0

SUBCHANNEL TEMPERATURES IN DEGREES F

1	759.33	5	600.49	9	600.49	13	600.49
2	600.49	6	600.49	10	600.49		
3	600.49	7	600.49	11	600.49		
4	600.49	8	600.49	12	600.49		

RADIAL AVG. TEMPERATURE IN UPFLOW REGION 600.49 F

RADIAL AVG. TEMPERATURE IN DOWNFLOW REGION 759.33 F

RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 600.49 F

NUMBER OF ITERATIONS TO CONVERGENCE 3

LAST ITERATION CONVERGED WITH AN OUTLET ERROR OF 0.95 PERCENT

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 1

AXIAL HEIGHT 10.00

SUBCHANNEL TEMPERATURES IN DEGREES F

1	754.99	5	631.15	9	631.15	13	631.15
2	631.15	6	631.15	10	631.15		
3	631.15	7	631.15	11	631.15		
4	631.15	8	631.15	12	631.15		

RADIAL AVG. TEMPERATURE IN UPFLOW REGION 631.15 F

RADIAL AVG. TEMPERATURE IN DOWNFLOW REGION 754.99 F

RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 631.15 F

NUMBER OF ITERATIONS TO CONVERGENCE 3

LAST ITERATION CONVERGED WITH AN OUTLET ERROR OF 0.95 PERCENT

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 1

AXIAL HEIGHT 20.00

SUBCHANNEL TEMPERATURES IN DEGREES F

1	747.16	5	660.35	9	660.35	13	660.35
2	660.35	6	660.35	10	660.35		
3	660.35	7	660.35	11	660.35		
4	660.35	8	660.35	12	660.35		

RADIAL AVG. TEMPERATURE IN UPFLOW REGION 660.35 F

RADIAL AVG. TEMPERATURE IN DOWNFLOW REGION 747.16 F

RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 660.35 F

NUMBER OF ITERATIONS TO CONVERGENCE 3

LAST ITERATION CONVERGED WITH AN OUTLET ERROR OF 0.95 PERCENT

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 1

AXIAL HEIGHT 30.00

SUBCHANNEL TEMPERATURES IN DEGREES F

1	734.46	5	689.05	9	689.05	13	689.05
2	689.05	6	689.05	10	689.05		
3	689.05	7	689.05	11	689.05		
4	689.05	8	689.05	12	689.05		

RADIAL AVG. TEMPERATURE IN UPFLOW REGION 689.05 F
 RADIAL AVG. TEMPERATURE IN DOWNFLOW REGION 734.46 F
 RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 689.05 F
 NUMBER OF ITERATIONS TO CONVERGENCE 3
 LAST ITERATION CONVERGED WITH AN OUTLET ERROR OF 0.95 PERCENT

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION - 1

AXIAL HEIGHT 39.00
 SUBCHANNEL TEMPERATURES IN DEGREES F
 1 715.91 5 715.91 9 715.91 13 715.91
 2 715.91 6 715.91 10 715.91
 3 715.91 7 715.91 11 715.91
 4 715.91 8 715.91 12 715.91
 RADIAL AVG. TEMPERATURE IN UPFLOW REGION 715.91 F
 RADIAL AVG. TEMPERATURE IN DOWNFLOW REGION 715.91 F
 RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 715.91 F
 NUMBER OF ITERATIONS TO CONVERGENCE 3
 LAST ITERATION CONVERGED WITH AN OUTLET ERROR OF 0.95 PERCENT

SUBROUTINE SCA CALCULATED PARAMETERS - REGION 2
 SUBCHANNEL AREAS IN SQ. FT. - A1,A5,A6,A7,A8,A9,A10,A11
 0.1756E-03 0.1916E-03 0.1576E-03 0.5099E-03 0.1354E-02 0.2164E-02
 0.5848E-02 0.1491E-01
 WETTED PERIMETERS IN FT. - P4,P5,P6,P7,P8,P11
 0.7405E-01 0.7736E-01 0.7439E-01 0.1438E+00 0.3428E+00 0.7734E+00
 SOME CHARACTERISTIC LENGTHS IN FT. - F1A4,F1A5,F1A6,F1A7,F1A8,F1A9,F1A10,F1A11
 0.2830E-01 0.2830E-01 0.4071E-01 0.2800E-01 0.3256E-01 0.5013E-01
 0.1714E+00 0.1770E+00
 EQUIV. DIAMETERS IN FT. - DC4,DC5,DC6,DC7,DC8,DC11
 0.9444E-02 0.7838E-02 0.8473E-02 0.1410E-01 0.2525E-01 0.6287E-01
 MASS FLOWRATES IN LBM/HR - W101,W104,W105,W106,W107,W108,W109,W111
 0.1000E+05 0.1255E+03 0.1050E+03 0.1101E+03 0.3563E+03 0.1167E+04
 0.1147E+04
 HEAT TRANSFER COEFFICIENTS IN BTU/HQ-FT²-F - H101,H104,H105,H106,H107,H108,H109,H111
 0.3998E+05 0.3705E+05 0.2270E+05 0.1323E+05 0.5271E+04
 INVERSE EQUIV. HEAT TRANSFER COEFF. - F5,F6,F7,F8,F9,F10,F11
 0.2728E-02 0.2434E-02 0.1495E-03 0.2239E-03 0.2822E-03 0.8071E-03
 0.1709E-02 0.1203E-02
 COEFF. FOR CHANNEL TYPE 4 TEMPERATURE EXPRESSION - CC1,CC2,CC3,CC4
 0.1553E+00 0.1874E-01 0.1874E-01 0.1289E-01
 COEFF. FOR CHANNEL TYPE 5 TEMPERATURE EXPRESSION - CC1,CC2,CC3,CC4,CC5
 0.1553E+00 0.2219E-01 0.1909E-01 0.2219E-01 0.4904E-02
 COEFF. FOR CHANNEL TYPE 6 TEMPERATURE EXPRESSION - EE1,EE2,EE3,EE4,EE5
 0.1553E+00 0.1835E-01 0.1192E-01 0.3195E-02 0.6007E-01
 COEFF. FOR CHANNEL TYPE 7 TEMPERATURE EXPRESSION - GG1,GG2,GG3,GG4
 0.1553E+00 0.3685E-02 0.4538E-02 0.1593E-01
 COEFF. FOR CHANNEL TYPE 8 TEMPERATURE EXPRESSION - HH1,HH2,HH3
 0.7477E-01 0.1104E+00 0.4297E+00
 COEFF. FOR CHANNEL TYPE 9 TEMPERATURE EXPRESSION - XX1,XX2,XX3,XX4,XX5,XX6,XX7,XX8
 0.2014E+00 0.5473E-02 0.4970E-02 0.2541E-02 0.8209E-02 0.1145E-03
 0.6453E-02 0.2047E-03
 COEFF. FOR CHANNEL TYPE 10 TEMPERATURE EXPRESSION - YY1,YY2
 0.6375E+00 0.3625E+00
 COEFF. FOR CHANNEL TYPE 3 TEMPERATURE EXPRESSION - E3,E4
 0.9445E-01 -0.7529E-01

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 2

AXIAL HEIGHT 40.20

SUBCHANNEL TEMPERATURES IN DEGREES F

1	716.11	25	716.11	49	716.11	73	716.11
2	716.11	26	716.11	50	716.11	74	716.11
3	716.11	27	716.11	51	716.11	75	716.11
4	716.11	28	716.11	52	716.11	76	716.11
5	716.11	29	716.11	53	716.11	77	716.11
6	716.11	30	716.11	54	716.11	78	716.11
7	716.11	31	716.11	55	716.14	79	716.16
8	716.11	32	716.11	56	716.11	80	716.16
9	716.11	33	716.11	57	716.11	81	716.16
10	716.11	34	716.11	58	716.11	82	716.16
11	716.11	35	716.11	59	716.14	83	716.16
12	716.11	36	716.11	60	716.11	84	716.16
13	716.11	37	716.11	61	716.11	85	716.16
14	716.11	38	716.11	62	716.11	86	716.16
15	716.11	39	716.11	63	716.14	87	716.16
16	716.11	40	716.11	64	716.11	88	716.16
17	716.11	41	716.11	65	716.11	89	716.16
18	716.11	42	716.11	66	716.11	90	716.16
19	716.11	43	716.11	67	716.14	91	716.16
20	716.11	44	716.11	68	716.11	92	716.16
21	716.11	45	716.11	69	716.11	93	716.16
22	716.11	46	716.11	70	716.11	94	716.16
23	716.11	47	716.11	71	716.14	95	716.16
24	716.11	48	716.11	72	716.11	96	716.16

RADIAL AVG. TEMPERATURE IN CONTROL PIN REGION 716.11 F

RADIAL AVG. TEMPERATURE IN BYPASS REGION 716.16 F

RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 716.16 F

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 2

AXIAL HEIGHT 50.00

SUBCHANNEL TEMPERATURES IN DEGREES F

1	725.74	25	726.24	49	726.24	73	727.93
2	725.74	26	725.88	50	726.24	74	727.11
3	725.74	27	725.94	51	725.88	75	727.37
4	725.74	28	725.18	52	725.98	76	727.11
5	725.74	29	725.24	53	725.88	77	726.93
6	725.74	30	726.24	54	726.24	78	727.11
7	725.74	31	725.18	55	727.37	79	727.82
8	725.74	32	725.94	56	727.11	80	727.82
9	725.74	33	725.88	57	726.93	81	727.82
10	725.74	34	726.24	58	727.11	82	727.82
11	725.74	35	725.24	59	727.37	83	727.82
12	725.74	36	725.98	60	727.11	84	727.82
13	725.74	37	725.79	61	726.73	85	727.82
14	725.74	38	725.88	62	727.11	86	727.82
15	725.74	39	725.24	63	727.37	87	727.82
16	725.74	40	726.74	64	727.11	88	727.82
17	725.74	41	725.88	65	726.93	89	727.82
18	725.74	42	725.49	66	727.11	90	727.82
19	725.74	43	725.88	67	727.37	91	727.82
20	725.74	44	726.24	68	727.11	92	727.82
21	725.74	45	726.24	69	726.93	93	727.82
22	725.74	46	725.70	70	727.11	94	727.82
23	725.74	47	725.94	71	727.37	95	727.82
24	725.74	48	725.88	72	727.11	96	727.82

RADIAL AVG. TEMPERATURE IN CONTROL PIN REGION 726.28 F

RADIAL AVG. TEMPERATURE IN BYPASS REGION 727.82 F

RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 727.82 F

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 2

AXIAL HEIGHT 60.00

SUBCHANNEL TEMPERATURES IN DECKERS F-

1	735.40	25	736.84	49	738.84	73	739.09
2	735.40	26	736.93	50	736.84	74	738.24
3	735.40	27	736.30	51	736.05	75	738.46
4	735.41	28	736.05	52	736.30	76	738.24
5	735.42	29	736.84	53	736.05	77	738.07
6	735.40	30	736.84	54	736.84	78	738.74
7	735.81	31	736.05	55	738.46	79	739.08
8	735.46	32	736.30	56	738.74	80	739.08
9	735.61	33	736.05	57	738.07	81	739.04
10	735.61	34	736.84	58	738.24	82	739.08
11	735.49	35	736.84	59	738.46	83	739.08
12	735.61	36	735.75	60	738.74	84	739.08
13	735.61	37	736.30	61	738.09	85	739.08
14	735.44	38	736.05	62	738.24	86	739.08
15	735.62	39	737.84	63	738.46	87	739.08
16	735.62	40	737.84	64	738.24	88	739.08
17	735.51	41	737.06	65	738.09	89	739.08
18	735.70	42	737.31	66	738.74	90	739.08
19	735.84	43	737.08	67	738.46	91	739.04
20	735.56	44	737.85	68	738.74	92	739.08
21	735.64	45	736.84	69	738.07	93	739.08
22	735.62	46	737.13	70	738.24	94	739.08
23	739.48	47	736.33	71	738.46	95	739.08
24	735.62	48	737.06	72	738.74	96	739.08

RAJIAL AVG. TEMPERATURE IN COOLING PIN REGION 734.75 F

RAOIAL AVG. TEMPERATURE IN BYPASS REGION 739.08 F

RADIAL AVG. TEMPERATURE IN INTRAASSEMBLY GAP 719.00 C

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION - 2

AXIAL HEIGHT 70.00

SUBCHANNEL TEMPERATURES IN DEGREES F

1	745.36	25	747.72	49	747.73	73	749.36
2	745.35	26	746.61	50	747.72	74	749.47
3	745.36	27	747.00	51	746.62	75	749.66
4	745.39	28	746.61	52	747.01	76	749.65
5	745.41	29	747.72	53	746.62	77	749.35
6	745.37	30	747.72	54	747.72	78	749.46
7	745.86	31	746.61	55	747.64	79	750.39
8	745.57	32	747.00	56	747.66	80	750.39
9	745.85	33	746.61	57	747.39	81	750.39
10	745.85	34	747.72	58	749.46	82	750.39
11	745.57	35	747.72	59	747.66	83	750.39
12	745.85	36	746.61	60	749.46	84	750.39
13	745.86	37	747.00	61	749.39	85	750.39
14	745.57	38	746.62	62	749.46	86	750.39
15	745.86	39	747.72	63	749.66	87	750.39
16	745.80	40	747.72	64	749.66	88	750.39
17	745.63	41	746.61	65	749.35	89	750.39
18	746.02	42	747.03	66	749.46	90	750.39
19	746.29	43	746.69	67	749.66	91	750.39
20	745.79	44	747.75	68	749.46	92	750.39
21	745.92	45	747.78	69	749.35	93	750.39
22	745.88	46	746.78	70	749.47	94	750.39
23	745.54	47	747.07	71	749.67	95	750.39
24	745.86	48	746.65	72	749.48	96	750.39

940IAL AVG. TEMPRATURE IN CONTROL PIN REGION 747.48 F

RADIAL AVG. TEMPERATURE IN BYPASS REGION 750.39 F

RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 750.39 F

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 2

AXIAL HEIGHT 79.00

SUBCHANNEL TEMPERATURES IN DEGREES F

1	755.16	25	758.30	49	758.32	73	760.20
2	755.16	26	756.96	50	758.31	74	760.24
3	755.17	27	757.49	51	758.97	75	760.46
4	755.22	28	756.96	52	757.46	76	760.28
5	755.25	29	758.30	53	756.96	77	760.19
6	755.19	30	758.30	54	758.30	78	760.27
7	755.04	31	756.96	55	760.45	79	761.25
8	755.52	32	757.45	56	760.27	80	761.25
9	755.94	33	756.46	57	760.18	81	761.25
10	755.04	34	758.30	58	760.27	82	761.25
11	755.52	35	758.30	59	759.65	83	761.26
12	755.94	36	756.46	60	760.27	84	761.25
13	755.94	37	757.45	61	760.18	85	761.25
14	755.52	38	756.46	62	760.27	86	761.25
15	755.94	39	758.30	63	760.45	87	761.25
16	755.98	40	758.30	64	760.27	88	761.25
17	755.61	41	756.96	65	760.18	89	761.26
18	756.17	42	757.49	66	760.27	90	761.25
19	756.51	43	757.06	67	760.45	91	761.25
20	755.75	44	758.36	68	760.78	92	761.25
21	756.04	45	754.39	69	760.19	93	761.25
22	755.98	46	757.19	70	760.29	94	761.25
23	755.54	47	757.55	71	760.48	95	761.26
24	755.94	48	757.02	72	760.30	96	761.25

RADIAL AVG. TEMPERATURE IN CONTROL PIN REGION 757.93 F

RADIAL AVG. TEMPERATURE IN BYPASS REGION 761.25 F

RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 761.25 F

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 3

AXIAL HEIGHT 80.20

SUBCHANNEL TEMPERATURES IN DEGREES F

1	755.49	24	756.28	47	757.40	70	760.61
2	755.48	25	758.66	48	757.37	71	761.19
3	755.50	26	757.30	49	758.67	72	760.62
4	755.56	27	757.40	50	758.65	73	760.54
5	755.58	28	757.30	51	757.31	74	760.60
6	755.51	29	758.66	52	757.80	75	761.17
7	756.27	30	758.64	53	757.30	76	760.59
8	755.85	31	757.30	54	758.64	77	760.53
9	756.27	32	757.80	55	761.16	78	760.59
10	756.27	33	757.30	56	760.54	79	762.31
11	756.84	34	758.66	57	760.52	80	762.31
12	756.27	35	758.64	58	760.99	81	762.31
13	756.27	36	757.37	59	761.16	82	762.31
14	755.85	37	757.80	60	760.59	83	762.32
15	756.28	38	757.40	61	760.52	84	762.31
16	756.31	39	758.65	62	760.59	85	762.31
17	755.94	40	758.65	63	761.16	86	762.31
18	756.51	41	757.32	64	760.59	87	762.31
19	756.84	42	757.84	65	760.52	88	762.31
20	756.08	43	757.40	66	760.59	89	762.32
21	756.77	44	757.71	67	761.16	90	762.31

22 756.31 45 750.74 68 760.49
 23 755.87 46 757.54 69 760.53
 RADIAL AVG. TEMPERATURE IN CONTROL PIN REGION 758.26 F
 RADIAL AVG. TEMPERATURE IN BYPASS REGION 762.31 F
 RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 762.31 F

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 3

AXIAL HEIGHT 90.00							
SUBCHANNEL TEMPERATURES IN DEGREES F							
1	765.64	24	766.86	47	770.13	70	779.97
2	765.63	25	772.61	48	768.79	71	784.18
3	765.65	26	768.82	49	772.65	72	779.99
4	765.71	27	769.97	50	772.63	73	779.00
5	765.77	28	768.82	51	768.85	74	779.95
6	765.68	29	772.61	52	767.96	75	784.14
7	766.85	30	772.61	53	768.83	76	779.94
8	766.17	31	768.82	54	772.61	77	778.98
9	766.85	32	769.97	55	784.12	78	779.93
10	766.84	33	768.82	56	779.93	79	789.79
11	766.18	34	772.61	57	770.97	80	789.79
12	766.85	35	772.61	58	779.93	81	789.79
13	766.83	36	768.83	59	784.12	82	789.79
14	766.18	37	769.97	60	779.93	83	789.81
15	766.87	38	768.83	61	779.97	84	789.80
16	766.91	39	772.62	62	779.93	91	789.79
17	766.32	40	772.63	63	784.12	92	789.79
18	767.25	41	768.87	64	779.93	93	789.79
19	769.04	42	770.04	65	778.87	94	789.79
20	766.56	43	768.82	66	779.94	95	789.81
21	767.00	44	772.72	67	784.13	96	789.80
22	766.71	45	772.77	68	779.94		
23	766.20	46	769.22	69	778.99		
RADIAL AVG. TEMPERATURE IN CONTROL PIN REGION 772.34 F							
RADIAL AVG. TEMPERATURE IN BYPASS REGION 789.80 F							
RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 789.80 F							

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 3

AXIAL HEIGHT 100.00							
SUBCHANNEL TEMPERATURES IN DEGREES F							
1	776.21	24	778.46	47	785.85	70	801.78
2	776.19	25	790.22	48	783.38	71	806.26
3	776.23	26	783.18	49	790.39	72	801.81
4	776.36	27	795.51	50	790.26	73	801.13
5	776.50	28	797.18	51	783.23	74	801.74
6	776.24	29	790.22	52	785.53	75	806.18
7	778.84	30	790.22	53	783.19	76	801.72
8	777.32	31	783.17	54	790.22	77	801.09
9	778.84	32	785.50	55	806.15	78	801.70
10	778.83	33	783.18	56	801.70	79	813.63
11	777.32	34	790.22	57	801.07	80	819.63
12	778.84	35	790.22	58	801.70	81	813.63
13	778.84	36	783.18	59	806.15	82	813.64
14	777.34	37	785.51	60	801.70	83	813.68
15	778.88	38	783.19	61	801.07	84	813.65
16	778.74	39	790.24	62	801.70	91	813.63
17	777.65	40	790.25	63	806.15	92	813.63
18	779.74	41	783.26	64	801.70	93	813.63
19	781.39	42	785.64	65	801.07	94	813.64
20	778.21	43	795.52	66	801.71	95	813.68

20	778.21	43	787.52	66	801.71	95	813.68
21	779.17	44	790.43	67	806.14	96	813.65
22	778.76	45	792.56	68	801.71		
23	777.38	46	784.08	69	801.10		
RADIAL AVG. TEMPERATURE IN CONTROL PIN REGION 789.02 F							
RADIAL AVG. TEMPERATURE IN BYPASS REGION 813.64 F							
RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 813.64 F							

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION - 3

AXIAL HEIGHT 110.00							
SUBCHANNEL TEMPERATURES IN DEGREES F							
1	787.08	24	792.82	47	803.71	70	823.62
2	787.95	25	800.22	48	800.04	71	828.17
3	788.03	26	777.62	49	809.38	72	823.68
4	788.29	27	801.05	50	809.70	73	828.78
5	788.52	28	799.62	51	799.72	74	823.54
6	788.13	29	800.22	52	803.10	75	828.03
7	792.79	30	809.21	53	799.65	76	823.51
8	790.11	31	799.62	54	809.22	77	823.27
9	792.77	32	803.05	55	827.97	78	823.47
10	792.77	33	799.62	56	823.47	79	836.58
11	790.10	34	800.22	57	821.26	80	836.58
12	792.77	35	800.22	58	821.47	81	836.58
13	792.79	36	799.62	59	827.97	82	836.60
14	790.15	37	801.07	60	823.47	83	836.66
15	792.86	38	799.66	61	823.25	84	836.61
16	793.02	39	800.25	62	823.47	91	836.58
17	790.72	40	800.28	63	827.97	92	836.58
18	794.30	41	799.78	64	823.47	93	836.58
19	796.66	42	801.32	65	823.26	94	836.60
20	791.62	43	800.26	66	823.48	95	836.66
21	793.40	44	809.81	67	827.99	96	836.61
22	793.02	45	809.85	68	823.50		
23	790.23	46	801.16	69	823.32		
RADIAL AVG. TEMPERATURE IN CONTROL PIN REGION 806.88 F							
RADIAL AVG. TEMPERATURE IN BYPASS REGION 836.60 F							
RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 836.60 F							

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION - 3

AXIAL HEIGHT 120.00							
SUBCHANNEL TEMPERATURES IN DEGREES F							
1	800.89	24	807.95	47	822.13	70	844.78
2	800.85	25	828.34	48	817.49	71	849.36
3	800.98	26	814.84	49	828.81	72	844.87
4	801.37	27	821.14	50	828.49	73	844.82
5	801.49	28	816.83	51	817.01	74	844.65
6	801.13	29	828.13	52	821.22	75	849.14
7	807.89	30	821.33	53	816.88	76	844.59
8	806.11	31	816.82	54	828.35	77	844.65
9	807.88	32	821.14	55	849.04	78	844.53
10	807.85	33	816.81	56	844.52	79	858.42
11	804.09	34	821.13	57	844.61	80	858.41
12	807.47	35	824.73	58	844.52	81	858.41
13	807.87	36	816.84	59	847.03	82	858.45
14	804.18	37	821.17	60	844.51	83	858.44
15	808.03	38	816.80	61	844.61	84	858.48
16	808.27	39	828.39	62	844.52	91	858.42
17	805.82	40	828.44	63	849.03	92	858.41
18	810.00	41	817.11	64	844.52	93	858.41

19	810.00	41	817.11	64	844.92	93	858.41
19	812.83	42	821.58	65	844.61	94	858.45
20	806.14	43	817.81	66	844.55	95	858.56
21	808.82	44	828.99	67	844.08	96	858.48
22	808.27	45	829.29	68	844.58		
23	804.31	46	818.98	69	844.71		

RADIAL AVG. TEMPERATURE IN CONTRL PIN REGION 825.00 F
 RADIAL AVG. TEMPERATURE IN BYPASS REGION 858.45 F
 RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 858.45 F

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APPENDIX D.2
SAMPLE PROBLEM 2

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      **** CASE NUMBER 1 4444
      MAIN PROGRAM INPUT PARAMETERS
      INLET TEMPERATURE= 730.C          AVG. OUTLET TEMPERATURE= 1000.C

      SECONDARY CONTROL ASSEMBLY COUPLING SELECTED
      NO. OF ASSEMBLIES= 1          NO. OF PRINTS= 5
      NO. OF AXIAL INCREMENTS= 600    TYPE OF BOUNDARY CONDITION= G
      PRINTS AT THE FOLLOWING AXIAL POSITIONS
      20.000  35.500  40.000  50.000  112.000
      DATA PACK FOR ASSEMBLY 1
      TYPE OF ASSEMBLY= 1
      REC DIA. WIRE DIA. LEAD          PITCH          FLATS          LENGTH          GLET TH.  GAP TH.
      C.73000  C.05000  11.50000  1.20750  4.75500  112.00000  0.16000  0.11000
      AVG HEAT FLUX, FLUX RATES IN THE ASSEMBLY AND THE GAP
      270000.0  105150.0  600.0
      FUEL EFFECTIVE FUEL DIFFUSIVITIES AND SWIRL VELOCITY RATIO
      C.0200  C.0320  C.0320  C.0320  C.0640
      NO. OF FLY= 30          NO. OF RECS= 217
      AXIAL DISTANCE VS FUEL DISTRIBUTION
      C.0  C.15000  C.01700  C.16700  C.03570  C.20000  C.04400  C.22500
      C.06250  C.24750  C.09500  C.44500  C.10710  C.50750  C.12350  C.03250
      C.10070  1.24500  C.17000  1.50000  C.10750  1.62500  C.15510  1.75000
      C.21420  1.85200  C.22720  1.50000  C.24110  1.50000  C.25050  2.01750
      C.26750  2.02500  C.27000  2.03130  C.20570  2.03130  C.24400  2.02500
      C.26200  2.00750  C.21750  1.50000  C.22140  1.50000  C.27500  1.60500
      C.24020  1.01250  C.25710  1.75500  C.27500  1.60000  C.40100  1.10750
      C.42000  C.27000  C.44000  C.25000  C.46430  C.25500  C.40210  C.20250
      C.50000  C.20000  C.51790  1.12500  C.53570  C.07000  C.55300  C.03500
      C.50000  C.0  1.00000  F.C
      RADIAL POWER DISTRIBUTION OF FUEL RECS
      1.02500  1.00000  1.01000  1.02300  1.05300  1.04000  1.02200  0.50200
      0.50000  0.50000  1.01100  1.03400  1.05700  1.07700  1.07000  1.06000
      1.03000  1.01200  0.99500  0.99500  0.96300  0.96400  0.96100  0.95500
      1.00000  1.00200  1.05800  1.00100  1.01000  1.05400  1.00400  1.07100
      1.04700  1.02300  0.99500  0.90900  0.97500  0.92500  0.92500  0.94000
      0.97000  0.92300  0.95000  0.90000  1.00200  1.02700  1.04600  1.00200
      1.10500  1.12500  1.13000  1.10000  1.09500  1.07900  1.05500  1.03100
      1.00700  0.90300  0.97000  0.96500  0.95200  0.91200  0.91000  0.91700
      0.91500  0.91000  0.90100  0.92500  0.94000  0.97200  0.95500  1.01500
      1.05100  1.00000  1.10000  1.12400  1.14500  1.14200  1.13200  1.11500
      1.10200  1.03400  1.06000  1.03000  1.01200  0.90000  0.90400  0.96000
      0.95200  0.94200  0.92000  0.80500  0.89300  0.89400  0.85200  0.80700
      0.87000  0.84700  0.89000  0.91300  0.93700  0.96000  0.90400  2.00700
      1.04200  1.07400  1.10400  1.12000  1.15300  1.17200  1.16000  1.15600
      1.14200  1.12300  1.10000  1.08000  1.06200  1.07000  1.01400  0.99000
      0.96600  0.94200  0.94100  0.93000  0.92000  0.91000  0.90500  0.86000
      0.81000  0.87100  0.80000  0.80300  0.85500  0.84400  0.83000  0.85300
      0.87000  0.85500  0.82700  0.84000  0.87000  0.85300  1.03300  1.00000
      1.09000  1.12000  1.15400  1.17700  1.15000  1.15100  1.14100  1.14000
      1.15200  1.13200  1.11000  1.00500  1.00100  1.03700  1.01200  0.96000
      0.96500  0.94300  0.91700  0.91900  0.91700  0.91300  0.90500  0.89500
      0.80200  0.84300  0.84700  0.80800  0.80600  0.80100  0.83200  0.82100
      0.80700  0.70500  0.80200  0.83500  0.83000  0.80200  0.80500  0.82500
      0.85200  0.87000  1.01700  1.05500  1.05000  1.12200  1.15200  1.17000
      1.20300  1.22200  1.21500  1.20500  1.19700  1.17400  1.15700  1.13500
      1.11000  1.00000  1.05000  1.03000  1.00000  0.90400  0.90000  0.93000
      0.91300  0.80900  0.85200  0.85500  0.89400  0.80900  0.80200  0.87200
      0.85500
      RECHECKS FOR ASSEMBLIES
      1 1 1 0 1 1

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2142

ITERATION NUMBER	SLIPARY LEFFLO TEMP.	CONFLCH TEPP.	FRACTIONAL ERRCR
1	741.40	736.00	0.0154
2	742.12	741.40	0.0010

TANG= TEE.1
 CTCTAL(KK)= 024.0
 DIFFER(KK)= 024.1
 DIFFER(KK)= 1.3

TEMPERATURE DISTRIBUTION FOR ASSEMBLY 1
 AXIAL HEIGHT = 20.00 INCHES

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      752      755      756 755 754 754 753 753 752 751      740
      756 755 756 755 754 753 752 751 750 749 748
      747 746 745 744 743 742 741 740 739 738 737
      736 735 734 733 732 731 730 729 728 727 726
      725 724 723 722 721 720 719 718 717 716 715
      714 713 712 711 710 709 708 707 706 705 704
      703 702 701 700 699 698 697 696 695 694 693
      692 691 690 689 688 687 686 685 684 683 682
      681 680 679 678 677 676 675 674 673 672 671
      670 669 668 667 666 665 664 663 662 661 660
      659 658 657 656 655 654 653 652 651 650 649
      648 647 646 645 644 643 642 641 640 639 638
      637 636 635 634 633 632 631 630 629 628 627
      626 625 624 623 622 621 620 619 618 617 616
      615 614 613 612 611 610 609 608 607 606 605
      604 603 602 601 600 599 598 597 596 595 594
      593 592 591 590 589 588 587 586 585 584 583
      582 581 580 579 578 577 576 575 574 573 572
      571 570 569 568 567 566 565 564 563 562 561
      560 559 558 557 556 555 554 553 552 551 550
      549 548 547 546 545 544 543 542 541 540 539
      538 537 536 535 534 533 532 531 530 529 528
      527 526 525 524 523 522 521 520 519 518 517
      516 515 514 513 512 511 510 509 508 507 506
      505 504 503 502 501 500 499 498 497 496 495
      494 493 492 491 490 489 488 487 486 485 484
      483 482 481 480 479 478 477 476 475 474 473
      472 471 470 469 468 467 466 465 464 463 462
      461 460 459 458 457 456 455 454 453 452 451
      450 449 448 447 446 445 444 443 442 441 440
      439 438 437 436 435 434 433 432 431 430 429
      428 427 426 425 424 423 422 421 420 419 418
      417 416 415 414 413 412 411 410 409 408 407
      406 405 404 403 402 401 400 399 398 397 396
      395 394 393 392 391 390 389 388 387 386 385
      384 383 382 381 380 379 378 377 376 375 374
      373 372 371 370 369 368 367 366 365 364 363
      362 361 360 359 358 357 356 355 354 353 352
      351 350 349 348 347 346 345 344 343 342 341
      340 339 338 337 336 335 334 333 332 331 330
      329 328 327 326 325 324 323 322 321 320 319
      318 317 316 315 314 313 312 311 310 309 308
      307 306 305 304 303 302 301 300 299 298 297
      296 295 294 293 292 291 290 289 288 287 286
      285 284 283 282 281 280 279 278 277 276 275
      274 273 272 271 270 269 268 267 266 265 264
      263 262 261 260 259 258 257 256 255 254 253
      252 251 250 249 248 247 246 245 244 243 242
      241 240 239 238 237 236 235 234 233 232 231
      230 229 228 227 226 225 224 223 222 221 220
      219 218 217 216 215 214 213 212 211 210 209
      208 207 206 205 204 203 202 201 200 199 198
      197 196 195 194 193 192 191 190 189 188 187
      186 185 184 183 182 181 180 179 178 177 176
      175 174 173 172 171 170 169 168 167 166 165
      164 163 162 161 160 159 158 157 156 155 154
      153 152 151 150 149 148 147 146 145 144 143
      142 141 140 139 138 137 136 135 134 133 132
      131 130 129 128 127 126 125 124 123 122 121
      120 119 118 117 116 115 114 113 112 111 110
      109 108 107 106 105 104 103 102 101 100 99
      98 97 96 95 94 93 92 91 90 89 88 87 86 85
      84 83 82 81 80 79 78 77 76 75 74 73 72 71
      70 69 68 67 66 65 64 63 62 61 60 59 58 57
      56 55 54 53 52 51 50 49 48 47 46 45 44 43
      42 41 40 39 38 37 36 35 34 33 32 31 30 29
      28 27 26 25 24 23 22 21 20 19 18 17 16 15
      14 13 12 11 10 9 8 7 6 5 4 3 2 1
  
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      755 801 800 795 797 796 794 793 761 765 784
744 757 769 752 800 800 756 767 795 754 792 791 788 780 760 757 754
      757 800 759 797 756 754 793 791 789 784
744 756 768 791 790 750 754 755 752 752 750 788 780 760 757 754
      795 757 756 755 753 752 750 788 784
744 756 767 768 752 752 791 750 788 787 785 788 780 757 753
      788 788 787 785 784 783 781 775
      766 766 766 765 764 764 763 762 761 760
      757 762 762 762 761 760 760 759 758 754
752 758 758 758 757 757 756 755 754 751

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TEMPERATURE DISTRIBUTION FOR SECONDARY CONTACT ASSEMBLY - INITIAL REGION 13

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AXIAL HEIGHT 20.00'
SECHANNELED TEMPERATURES IN DEGREES F
      1 775.22  5 736.05  9 743.10  13 735.56
      2 775.00  6 736.05  10 785.56
      3 736.21  7 736.05  11 735.54
      4 736.05  8 742.11  12 735.56
RADIAL AVG. TEMPERATURE IN INITIAL REGION 736.10 F
RADIAL AVG. TEMPERATURE IN COMPLET REGION 735.62 F
RADIAL AVG. TEMPERATURE IN INTERASSEMBLY CAP 738.00 F
NUMBER OF ITERATIONS TO CONVERGENCE 3
LAST ITERATION COMMENCED WITH AN OUTLET TEMPERATURE ERROR OF 0.10 PERCENT

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TAVG= 564.1
 CTCTALIN= 3443.2
 CIPFH(KN)= 3440.6
 CIPFHG(KN)= 6.8

TEMPERATURE DISTRIBUTION FOR ASSEMBLY 1
 TOTAL HEIGHT = 35.90 INCHES

EEC		EE6	EE6	EE3	EE6	EE7	EE4	EE1	EE6		EE2
EEC		EE3	EE2	EE4	EE5	EE2	EE5	EE6	EE3	EE4	
	EE7	EE5	EE6	EE4	EE1	EE7	EE4	EE6	EE2	EE2	
		EE2	EE7	EE2	EE2	EE3	EE8	EE2	EE1		
EE4	EE5	EE1	EE5	EE6	EE4	EE9	EE4	EE3	EE5	EE2	EE2
		EE4	EE6	EE7	EE2	EE6	EE6	EE4	EE5	EE4	
EE5	EE1	EE7	EE1	EE4	EE3	EE2	EE6	EE7	EE5	EE2	EE4
		EE6	EE7	EE6	EE1	EE5	EE6	EE2	EE5	EE5	EE4
EE1	EE7	EE3	EE6	EE1	EE1	EE7	EE1	EE5	EE2	EE4	EE5
		EE4	EE2	EE2	EE2	EE6	EE6	EE3	EE7	EE7	EE2
EE7	EE3	EE9	EE7	EE6	EE1	EE7	EE1	EE5	EE2	EE6	EE2
		EE2	EE3	EE1	EE1	EE6	EE2	EE6	EE7	EE2	EE4
EE2	EE2	EE5	EE4	EE1	EE1	EE5	EE6	EE4	EE7	EE5	EE2
		EE5	EE2	EE1	EE1	EE6	EE6	EE7	EE2	EE2	EE2
EE6	EE3	EE1	EE6	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
		EE4	EE2	EE2	EE2	EE1	EE1	EE5	EE2	EE2	EE2
EE5	EE6	EE1	EE4	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
		EE4	EE2	EE1	EE2	EE1	EE1	EE5	EE2	EE2	EE2
EE6	EE6	EE5	EE7	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
EE1	EE2	EE2	EE7	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
EE1	EE6	EE2	EE7	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
		EE6	EE2	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
799	EE6	EE1	798	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
		EE5	EE5	EE1	EE2	EE2	EE1	EE5	EE2	EE2	EE6
799	EE7	EE5	EE7	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
		EE7	EE2	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
795	EE7	EE4	EE5	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
		EE4	EE2	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6
798	EE5	EE2	EE1	EE2	EE2	EE2	EE1	EE5	EE2	EE2	EE6

1000 1023 1024 1019 1012 1004 555 593 585 974 948
 757 854 511 577 1015 1020 1016 1010 1002 557 590 582 567 525 875 865 864
 555 1016 1016 1011 1004 558 592 584 573 546
 757 852 558 572 1006 1009 1004 558 551 585 578 564 528 875 865 862
 585 1002 1000 554 588 582 572 566 543
 758 851 502 553 575 578 573 568 562 556 547 520 874 868 862
 554 560 557 552 547 542 536 523
 555 555 859 556 556 553 550 556 556 550 576
 550 552 552 550 550 550 550 550 550 550
 561 561 562 565 565 563 560 571 573 560 557

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 1

AXIAL MESH 35,50
 SELECTED TEMPERATURES IN DEGREE F
 1 742.71 4 741.27 5 747.50 13 740.97
 2 743.52 6 741.27 10 740.58
 3 743.41 7 741.27 11 740.61
 4 741.27 8 740.40 12 740.61
 AXIAL AVG. TEMPERATURE IN DUCT REGION 742.02 F
 RADIAL AVG. TEMPERATURE IN DUCT REGION 742.71 F
 RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 756.21 F
 NUMBER OF ITERATIONS TO CONVERGENCE 3
 LAST ITERATION CONVERGED WITH AN OUTLET ERROR OF 0.10 PERCENT

SURFACIC SEA CALCULATED PARAMETERS - REGION 2
 SURFACE AREA IN SQ. FT. - 84.25, 82.87, 88.25, 211, 210
 C.1794E-C2 C.1516E-C3 C.1504E-C2 C.9055E-C3 C.1354E-C2 C.2164E-C2
 C.9848E-C2 C.1421E-C1
 WETTED PERIMETERS IN FT. - 84.25, 82.87, 88.25, 211
 C.7605E-C1 C.7736E-C1 C.7435E-C1 C.1438E-C0 C.2428E-C0 C.2734E-C0
 SCHE CHARACTERISTIC LENGTHS IN FT. - 8749, 8745, 8746, 8747, 8748, 8749, 87410, 87411
 C.2800E-C1 C.2800E-C1 C.4071E-C1 C.2800E-C1 C.2250E-C1 C.5013E-C1
 C.1714E-C0 C.1770E-C0
 EQUIV. DIAMETERS IN FT. - 8749, 8745, 8746, 8747, 8748, 8749
 C.5444E-C2 C.7834E-C2 C.8472E-C2 C.1415E-C1 C.2525E-C1 C.6287E-C1
 MASS FLOWRATES IN LBM/HR - 2107, 2107, 2107, 2107, 2107, 2107
 C.1000E-C3 C.1255E-C3 C.1055E-C3 C.1100E-C3 C.1356E-C3 C.1167E-C4
 C.1107E-C4
 HEAT TRANSFER COEFFICIENTS IN BTU/HR-FT²-F - 8749, 8745, 8746, 8747, 8748, 8749
 C.2911E-C5 C.3540E-C5 C.2190E-C5 C.1267E-C3 C.3044E-C4
 INVERSE EQUIV. HEAT TRANSFER COEFF. - 8749, 8745, 8746, 8747, 8748, 8749
 C.2225E-C2 C.2435E-C2 C.1440E-C3 C.2291E-C3 C.8851E-C3 C.1118E-C3
 C.1745E-C2 C.1214E-C2
 COEFF. FOR CHANNEL TYPE 4 TEMPERATURE EXPRESSION - C01, C02, C03, C04
 C.1833E-C0 C.2181E-C1 C.2181E-C1 C.1500E-C1
 COEFF. FOR CHANNEL TYPE 5 TEMPERATURE EXPRESSION - C01, C02, C03, C04, C05
 C.1833E-C0 C.2584E-C1 C.2225E-C1 C.2584E-C1 C.5785E-C2
 COEFF. FOR CHANNEL TYPE 6 TEMPERATURE EXPRESSION - E01, E02, E03, E04, E05

C.1P33E CC C.2137E-C1 C.1300E-C1 C.3764E-C2 C.6849E-C1
 CCEFF. FOR CHANNEL TYPE 7 TEMPERATURE EXPRESSION - C01,C02,C03,C04
 C.1E33E CC C.4285E-C2 C.5262E-C2 C.1E97E-C1
 CCEFF. FOR CHANNEL TYPE 8 TEMPERATURE EXPRESSION - X41,X42,X43
 C.7452E-C1 C.1164E CC C.4245E CC
 CCEFF. FOR CHANNEL TYPE 9 TEMPERATURE EXPRESSION - XX1,XX2,XX3,XX4,XX5,XX6,XX7,XX8
 C.2377E CC C.6482E-C2 D.9614E-C2 D.2587E-C2 C.5631E-C2 C.1289E-C3
 D.7545E-C2 C.2255E-C3
 CCEFF. FOR CHANNEL TYPE 10 TEMPERATURE EXPRESSION - YY1,YY2
 C.6410E CC C.355CE CC
 CCEFF. FOR CHANNEL TYPE 1 TEMPERATURE EXPRESSION - E3,E4
 C.6252E-C1 C.8EC3E-C1

TYPICAL DATA
 CIRCUMFERENCE = 3465.1
 DIFFERENCE = 3466.4
 DIFFERENCE = 6.9

TEMPERATURE DISTRIBUTION FOR ASSEMBLY 1
 AXIAL HEIGHT = 40.00 INCHES

862		869	868	866	862	855	856	853	850		844										
868		875	874	871	868	864	861	858	855	850											
	875	881	880	877	873	869	866	862	860	860											
		934	929	925	930	925	920	914	909												
872	873	883	937	938	937	932	947	944	933	927	904	864	858	853							
		966	963	961	975	966	962	956	946	927											
878	884	885	954	987	950	985	979	973	967	960	947	914	887	862	856						
			975	1000	1000	993	988	982	978	965	952	932									
884	890	896	983	1000	1005	1001	995	988	982	978	967	953	946	869	863	858					
			987	1010	1011	1008	1000	992	987	980	973	962	935								
890	896	902	970	1005	1015	1014	1005	998	992	986	979	971	956	920	869	864	859				
			995	1019	1020	1015	1008	1002	995	985	963	975	964	937							
895	901	907	977	1017	1023	1019	1012	1007	1000	994	987	981	973	958	921	869	864	859			
			1002	1028	1027	1022	1016	1010	1003	997	990	984	976	965	938						
899	906	913	983	1024	1030	1027	1021	1014	1008	1001	995	988	982	973	958	921	869	864	859		
			1007	1033	1034	1028	1023	1016	1010	1003	997	990	984	977	965	937					
902	909	917	987	1030	1037	1032	1027	1021	1014	1008	1001	995	988	982	973	958	921	869	864	859	
			1008	1037	1040	1035	1029	1022	1016	1009	1003	996	990	983	976	963	933				
899	906	916	980	1030	1044	1035	1033	1026	1020	1013	1007	1000	994	987	980	972	954	914	869	862	858
873	887	914																			
882	898	915	980	1036	1043	1040	1034	1028	1024	1014	1008	1002	995	989	982	975	959	913	871	865	860
			1005	1039	1044	1038	1033	1025	1018	1012	1005	999	992	986	978	965	936				
890	898	917	990	1034	1042	1038	1032	1025	1019	1012	1006	999	993	986	978	962	924	875	869	863	
			1012	1035	1040	1035	1029	1022	1016	1009	1003	996	990	982	970	942					
890	899	917	990	1032	1035	1035	1025	1022	1016	1009	1003	996	989	981	966	927	876	871	865		
			1010	1036	1037	1032	1026	1019	1012	1006	999	993	985	972	945						
890	899	917	990	1034	1035	1033	1025	1018	1012	1005	999	992	984	968	929	877	872	866			
			1007	1032	1033	1028	1021	1015	1008	1002	995	988	978	947							
899	897	916	985	1024	1030	1028	1020	1014	1007	1001	994	985	970	931	877	872	866				

1003 1027 1028 1022 1016 1009 1003 996 989 977 949
 758 858 914 980 1019 1024 1020 1013 1007 1000 994 985 970 931 877 872 866
 998 1020 1020 1014 1006 1002 995 988 976 949
 758 854 931 974 1006 1012 1007 1001 995 988 981 967 930 877 871 866
 988 1005 1002 998 992 985 975 969 945
 755 852 908 980 982 981 976 970 965 955 950 923 877 871 865
 957 953 960 955 950 945 938 925
 902 901 902 901 895 890 892 888 883 878
 876 893 895 894 892 889 888 882 876 866
 862 885 888 888 886 883 880 876 870 860

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 2

AXIAL HEIGHT 40.00

SELECTED TEMPERATURES IN DEGREES F

1	742.15	25	742.15	49	742.15	73	742.15
2	742.15	26	742.15	50	742.15	74	742.15
3	742.15	27	742.15	51	742.15	75	742.15
4	742.15	28	742.15	52	742.15	76	742.15
5	742.15	29	742.15	53	742.15	77	742.15
6	742.15	30	742.15	54	742.15	78	742.15
7	742.15	31	742.15	55	742.15	79	743.29
8	742.15	32	742.15	56	742.15	80	743.18
9	742.15	33	742.15	57	742.15	81	741.36
10	742.15	34	742.15	58	742.15	82	741.36
11	742.15	35	742.15	59	742.15	83	741.26
12	742.15	36	742.15	60	742.15	84	741.36
13	742.15	37	742.15	61	742.15	85	759.35
14	742.15	38	742.15	62	742.15	86	755.95
15	742.15	39	742.15	63	742.15	87	741.26
16	742.15	40	742.15	64	742.15	88	741.26
17	742.15	41	742.15	65	742.15	89	741.20
18	742.15	42	742.15	66	742.15	90	741.26
19	742.15	43	742.15	67	742.15	91	767.33
20	742.15	44	742.15	68	742.15	92	768.84
21	742.15	45	742.15	69	742.15	93	741.00
22	742.15	46	742.15	70	742.15	94	740.90
23	742.15	47	742.15	71	742.15	95	740.90
24	742.15	48	742.15	72	742.15	96	741.07

RADIAL AVG. TEMPERATURE IN CONTROL PIN REGION 742.15 F

RADIAL AVG. TEMPERATURE IN BYPASS REGION 742.15 F

RADIAL AVG. TEMPERATURE IN INTERASSEMBLY GAP 761.85 F

TAVC= 1034.0
 CTOTALIN= 4460.8
 DIFFERIN= 4460.8
 DIFFERIN= 12.6

TEMPERATURE DISTRIBUTION FOR ASSEMBLY 1
 AXIAL HEIGHT = 80.00 INCHES

561 561 560 551 554 551 548 947 947 548
 962 562 561 556 554 551 549 947 947 949
 562 563 561 556 555 552 549 548 948 950
 576 563 562 570 573 568 562 556
 564 564 564 580 552 555 553 568 582 570 567 557 552 551 551
 550 1015 1020 1017 1012 1005 556 564 565
 569 569 569 554 1015 1010 1011 1026 1015 1011 1000 584 566 555 554 553
 1013 1035 1030 1020 1044 1037 1028 1016 559 577
 576 576 576 1005 1017 1025 1035 1045 1048 1040 1030 1018 559 570 558 556 555
 1024 1035 1030 1020 1044 1037 1028 1016 1000 1027 1007 580
 583 564 584 1015 1030 1031 1037 1048 1041 1051 1040 1023 1000 572 557 556 555
 1034 1046 1043 1047 1041 1016 1048 1059 1048 1033 1010 582
 551 551 552 1023 1040 1043 1058 1045 1042 1035 1046 1057 1044 1027 1001 572 557 556 555
 1041 1035 1053 1058 1054 1047 1035 1037 1042 1050 1034 1011 581
 558 555 555 1025 1047 1052 1040 1055 1057 1045 1037 1048 1059 1046 1027 1001 572 557 556 555
 1045 1041 1101 1106 1043 1058 1045 1040 1072 1042 1054 1034 1005 579
 1003 1004 1005 1021 1070 1057 1108 1101 1102 1094 1086 1077 1065 1055 1045 1026 598 569 557 557 556
 1041 1035 1103 1112 1110 1104 1096 1088 1080 1077 1061 1045 1030 1004 574
 1007 1007 1007 1025 1044 1046 1107 1103 1100 1092 1083 1076 1067 1057 1047 1020 561 565 555 558 557
 561 554 1003
 524 566 1007 1025 1044 1057 1107 1105 1100 1103 1095 1086 1076 1065 1058 1043 1021 552 567 564 563 562
 1042 1041 1106 1115 1113 1107 1095 1091 1085 1074 1064 1052 1033 1007 578
 562 568 1008 1024 1035 1103 1114 1113 1108 1100 1092 1082 1074 1064 1051 1033 1004 577 568 567 566
 1050 1047 1108 1114 1111 1104 1096 1088 1075 1070 1058 1041 1018 587
 523 567 1010 1038 1078 1102 1111 1110 1104 1096 1087 1079 1065 1056 1037 1010 582 570 569 568
 1053 1047 1105 1110 1106 1095 1091 1083 1073 1062 1045 1021 592
 522 568 1017 1035 1076 1098 1106 1104 1097 1090 1081 1071 1058 1040 1014 585 572 571 570
 1052 1044 1100 1103 1095 1092 1084 1075 1063 1047 1024 595
 523 568 1012 1038 1071 1091 1097 1094 1088 1080 1070 1058 1041 1015 587 574 573 572

1048 1077 1091 1093 1082 1081 1072 1062 1047 1024 596
 923 948 1012 1034 1063 1079 1083 1079 1072 1064 1053 1037 1014 588 576 575 574
 1042 1065 1075 1075 1070 1062 1053 1040 1021 596
 923 966 1010 1027 1048 1058 1055 1055 1048 1039 1027 1009 588 578 577 577
 1031 1045 1050 1048 1043 1036 1026 1012 594
 924 965 1008 1016 1026 1030 1026 1025 1019 1011 1000 586 582 581 580
 1014 1015 1020 1018 1014 1005 1001 990
 1004 1003 1003 1004 1002 1002 555 555 585 587
 551 1001 1002 1003 1002 1001 558 554 585 584
 584 555 1001 1002 1002 1000 557 593 588 583

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY - AXIAL REGION 3

AXIAL HEIGHT 20.00
 SUBCHANNEL TEMPERATURES IN DEGREES F

1	783.55	24	788.25	47	784.57	70	785.68
2	783.40	25	804.73	48	784.44	71	786.12
3	782.52	26	756.16	49	787.33	72	785.97
4	782.25	27	759.50	50	788.28	73	781.70
5	782.54	28	754.23	51	787.72	74	785.64
6	782.40	29	804.39	52	752.46	75	751.01
7	785.30	30	803.39	53	783.25	76	751.02
8	784.70	31	753.51	54	802.23	77	802.03
9	785.34	32	752.55	55	817.31	78	814.52
10	784.32	33	783.76	56	816.44	79	823.22
11	784.93	34	788.25	57	816.35	80	823.46
12	784.86	35	787.20	58	816.65	81	752.44
13	782.86	36	784.44	59	817.53	82	788.94
14	782.88	37	784.54	60	814.25	83	788.93
15	782.88	38	783.52	61	803.20	84	752.35
16	782.51	39	784.32	62	752.12	51	510.12
17	782.28	40	784.19	63	751.05	52	910.26
18	782.81	41	783.36	64	785.50	83	787.45
19	781.56	42	783.50	65	787.73	94	781.46
20	782.60	43	783.20	66	785.96	95	781.65
21	783.69	44	784.22	67	786.12	96	787.41
22	784.86	45	784.37	68	785.67		
23	784.50	46	782.65	69	785.58		

RADIAL AVE. TEMPERATURE IN CONTROL DIA REGION 750.74 F
 RADIAL AVE. TEMPERATURE IN BYPASS REGION 800.09 F
 RADIAL AVE. TEMPERATURE IN INTERASSEMBLY GAP 826.43 F

TEMPERATURE DISTRIBUTION FOR ASSEMBLY 1
AXIAL HEIGHT = 112.00 INCHES

155

1043 1063 1075 1079 1077 1072 1062 1052 1036 1021 1005
 954 946 1018 1023 1052 1064 1065 1068 1063 1033 1044 1030 1015 1003 1000 959 959
 1036 1053 1062 1063 1060 1054 1045 1033 1019 1006
 954 985 1017 1026 1042 1049 1051 1045 1043 1035 1025 1013 1004 1002 1002 1002
 1033 1040 1044 1044 1040 1035 1026 1016 1006
 955 985 1015 1022 1025 1032 1032 1030 1029 1019 1011 1005 1006 1005 1004
 1021 1025 1027 1026 1024 1015 1014 1008
 1014 1013 1016 1017 1016 1016 1016 1014 1010 1009
 1005 1013 1015 1017 1017 1017 1016 1013 1010 1008 1008
 1000 1012 1015 1016 1017 1017 1015 1013 1010 1007

TEMPERATURE DISTRIBUTION FOR SECONDARY CONTROL ASSEMBLY ~ AXIAL REGION 3

AXIAL HEIGHT 112.00

SLEEPMANAL TEMPERATURES IN DEGREES F

1	875.06	24	837.06	47	835.00	70	851.94
2	862.28	25	832.81	48	833.59	71	856.67
3	820.90	26	845.72	49	845.56	72	852.90
4	815.60	27	863.37	50	848.20	73	856.13
5	820.85	28	855.72	51	840.25	74	860.12
6	823.41	29	837.56	52	850.18	75	866.63
7	838.47	30	871.26	53	850.16	76	865.17
8	832.71	31	850.16	54	871.40	77	860.45
9	825.47	32	850.28	55	804.76	78	855.16
10	837.05	33	840.22	56	855.31	79	919.62
11	828.28	34	848.15	57	800.28	80	815.35
12	855.71	35	845.49	58	855.18	81	875.35
13	838.55	36	832.20	59	804.56	82	864.85
14	862.07	37	835.10	60	855.02	83	864.68
15	823.35	38	830.15	61	860.40	84	875.56
16	822.77	39	836.76	62	865.18	85	847.88
17	820.74	40	828.28	63	866.63	86	946.75
18	827.66	41	828.52	64	860.13	87	870.82
19	826.55	42	832.19	65	858.08	88	860.13
20	823.25	43	829.32	66	852.76	89	860.16
21	827.02	44	838.54	67	856.54	90	870.79
22	825.67	45	835.25	68	851.66		
23	828.35	46	821.44	69	851.61		

AXIAL AVG. TEMPERATURE IN CONTROL PIN REGION 860.72 F

AXIAL AVG. TEMPERATURE IN BYPASS REGION 866.64 F

AXIAL AVG. TEMPERATURE IN INTERASSEMBLY CAP 852.15 F

APPENDIX E

ANALYTIC SOLUTION TO SAMPLE

PROBLEM D.1

APPENDIX E

Analytic Solution to Sample Problem

Applying an energy balance to both the upflow and downflow regions of Figure 2 yields the following expressions:

Z direction: (E-1)

$$\dot{m}_1 C_P d\bar{T}_1 = q_1'' dVol_I + q'' dA_{III} + q_{2 \rightarrow 1}'' dA_I$$

x direction:

$$\dot{m}_2 C_P dT_2 = q_2'' dVol_{II} + q_{1 \rightarrow 2}'' dA_{II} \quad (E-2)$$

with the boundary conditions

$$\bar{T}_1(z) \Big|_{z=0} = T_{1N} \quad (E-3)$$

$$T_1 - T_2 \Big|_{x=0} = 0 \quad (E-4)$$

Where

$$dA_I = 2\pi R_1 dz \quad (E-5)$$

$$dA_{II} = 2\pi R_1 dx \quad (E-6)$$

$$dA_{III} = 6s dz \quad (E-7)$$

$$dVol_I = 6A_1 dz \quad (E-8)$$

$$dVol_{II} = \pi R_1^2 dx \quad (E-9)$$

The volumetric heat fluxes are assumed to be represented by the sum of two exponentials.

$$q_1'' = q_2'' = q_{2a}'' e^{-bax} + q_{2b}'' e^{-bbx} \quad (E-10)$$

inserting (E-5) through (E-10) into (E-1) and (E-2) yields

$$\frac{dT_1}{dz} = \frac{A_1}{m_1 C_p} (q_{2a}'' e^{-bax} + q_{2b}'' e^{-bbx}) + \frac{sq_{BC}}{m_1 C_p} + \frac{\pi R_1}{3m_1 C_p} (T_2 - \bar{T}_1) \quad (E-11)$$

and

(E-12)

$$\frac{dT_2}{dx} = \frac{\pi R_1^2}{m_2 C_p} (q_{2a}'' e^{-bax} + q_{2b}'' e^{-bbx}) + \frac{2\pi R_1}{m_2 C_p} (\bar{T}_1 - T_2)$$

Changing coordinate systems in (E-11) yields:

$$\frac{dT_1}{dx} = \frac{-A_1}{m_1 C_p} (q_{2a}'' e^{-bax} + q_{2b}'' e^{-bbx}) + \frac{\pi R_1}{3m_1 C_p} (\bar{T}_1 - T_2) - \frac{sq_{BC}}{m_1 C_p} \quad (E-13)$$

Subtracting (E-13) from (E-12) and rearranging gives

$$\frac{d\Delta T}{dx} + \gamma \Delta T = (q_{2a}'' e^{-bax} + q_{2b}'' e^{-bbx}) + S \quad (E-14)$$

Where

$$\Delta T = T_2 - \bar{T}_1 \quad (E-15a)$$

$$\gamma = \frac{2\pi R_1}{F_1 C_p} \left(\frac{1}{m_2} - \frac{1}{6m_1} \right) \quad (E-15b)$$

$$\epsilon = \frac{R_1^2}{m_2 C_p} + \frac{A_1}{m_1 C_p} \quad (E-15c)$$

$$S = \frac{\epsilon q_{BC}''}{m_1 C_p} \quad (E-15d)$$

Integrating (E-14) using an integrating factor (E-16)

$$\Delta T = \frac{\epsilon q_{2a}''}{\gamma - b_a} e^{-b_a x} + \frac{\epsilon q_{2b}''}{\gamma - b_b} e^{-b_b x} + \frac{S}{\gamma} + C_1 e^{-\gamma x}$$

Using boundary condition (E-4) to evaluate the constant C_1 , and replacing the result in (E-16) gives the complete expression for the temperature difference between subchannel types 1 and 2.

$$\begin{aligned} \Delta T = & \frac{\epsilon q_{2a}''}{\gamma - b_a} (e^{-b_a x} - e^{-\gamma x}) + \frac{\epsilon q_{2b}''}{\gamma - b_b} (e^{-b_b x} - e^{-\gamma x}) \\ & + \frac{S}{\gamma} (1 - e^{-\gamma x}) \end{aligned} \quad (E-17)$$

Substituting this expression back into (E-12) and (E-13) decouples the temperatures. After substitution and integration (E-13) becomes:

$$\begin{aligned} \bar{T}_1(x) = & \frac{k_1}{b_a} e^{-b_a x} + \frac{k_2}{b_b} e^{-b_b x} + \frac{k_3}{\gamma} e^{-\gamma x} \\ & - k_4 x + C_2 \end{aligned} \quad (E-18)$$

Where

$$k_1 = \frac{\pi R_1 \epsilon q_{2a}''}{3m_1 C_p F_1 (\gamma - b_a)} + \frac{A_1 \epsilon q_{2a}''}{m_1 C_p} \quad (E-19a)$$

$$k_2 = \frac{\pi R_1 \epsilon q_{2b}'''}{3m_1 C_p F_1 (\gamma - b_b)} + \frac{A_1 q_{2a}'''}{m_1 C_p} \quad (E-19b)$$

$$k_3 = \frac{\pi R_1}{3m_1 C_p F_1} \left[\frac{\epsilon q_{2a}'''}{b_a - \gamma} + \frac{\epsilon q_{2b}'''}{b_b - \gamma} - \frac{S}{\gamma} \right] \quad (E-19c)$$

$$k_4 = \frac{\epsilon q_{3C}'''}{m_1 C_p} \left(1 + \frac{m_2}{m_1 + m_2} \right) \quad (E-19d)$$

Applying boundary condition (E-3) to evaluate the constant C_2 , and replacing the result into (E-18) gives the expression for the temperature in the type 1 subchannels as a function of x .

$$\begin{aligned} \bar{T}_1(x) = T_{iN} + \frac{k_1}{b_a} (e^{-b_a x} - e^{-b_a L_c}) + \frac{k_2}{b_b} (e^{-b_b x} - e^{-b_b L_c}) \\ + \frac{k_3}{\gamma} (e^{-\gamma x} - e^{-\gamma L_c}) + k_4 (L_c - x) \end{aligned} \quad (E-20)$$

Substituting (E-17) into (E-12) and integrating yields the following result

$$T_2(x) = \frac{n_1}{b_a} e^{-b_a x} + \frac{n_2}{b_b} e^{-b_b x} + \frac{n_3}{\gamma} e^{-\gamma x} - n_4 x + C_3 \quad (E-21)$$

Where

$$n_1 = \frac{2\pi R_1 \epsilon q_{2a}'''}{m_2 C_p F_1 (\gamma - b_a)} - \frac{\pi R_1^2 q_{2a}'''}{m_2 C_p} \quad (E-22a)$$

$$n_2 = \frac{2\pi R_1 \epsilon q_{2b}'''}{m_2 C_p F_1 (\gamma - b_b)} - \frac{\pi R_1^2 q_{2b}'''}{m_2 C_p} \quad (E-22b)$$

$$\eta_3 = \frac{2\pi R_1}{\dot{m}_2 C_p F_1} \left[\frac{\epsilon q_{2a}'''}{b_a - \gamma} + \frac{\epsilon q_{2b}'''}{b_b - \gamma} - \frac{S}{\gamma} \right] \quad (E-22c)$$

$$\eta_4 = \frac{2\pi R_1}{\dot{m}_2 C_p F_1} \frac{S}{\gamma} = \frac{6sq_{BC}''}{C_p (\dot{m}_1 - \dot{m}_2)} \quad (E-22d)$$

Applying boundary condition (E-4) and equation (E-20) to evaluate the constant C_3 and replacing the result in (E-21) yields the expression for the temperature in the type 2 subchannel as a function of x .

$$\begin{aligned} T_2(x) = & T_{in} + \frac{\eta_1}{b_a} (e^{-b_a x} - 1) + \frac{\eta_2}{b_b} (e^{-b_b x} - 1) \\ & + \frac{\eta_3}{\gamma} (e^{-\gamma x} - 1) + \frac{k_1}{b_a} (1 - e^{-b_a L_c}) \\ & + \frac{k_2}{b_b} (1 - e^{-b_b L_c}) + \frac{k_3}{\gamma} (1 - e^{-\gamma L_c}) \\ & + k_4 L_c - \eta_4 x \end{aligned} \quad (E-23)$$

When the constant b_b is set to zero as in the sample problem listed in Appendix B.1 the final temperature expressions change as follows:

Equation (E-17) becomes

$$\Delta T = \frac{\epsilon q_{2a}'''}{\gamma - b_a} (e^{-b_a x} - e^{-\gamma x}) + \frac{\epsilon q_{2b}''' + S}{\gamma} (1 - e^{-\gamma x}) \quad (E-24)$$

Equation (E-20) becomes

$$T_1(x) = T_{1N} + \frac{k_1}{b_a} (e^{-b_a x} - e^{-b_a L_c}) + \frac{k_3}{\gamma} (e^{-\gamma x} - e^{-\gamma L_c}) \\ + (k_2 + k_4)(L_c - x) \quad (E-25)$$

Equation (E-23) becomes

$$T_2(x) = T_{1N} + \frac{n_1}{b_a} (e^{-b_a x} - 1) + \frac{n_3}{\gamma} (e^{-\gamma x} - 1) \\ + \frac{k_1}{b_a} (1 - e^{-b_a L_c}) + \frac{k_3}{\gamma} (1 - e^{-\gamma L_c}) \quad (E-26) \\ + (k_2 + k_4)L_c + (n_2 + n_4)x$$

Applying the sample problem parameters shown in Table I and the variable definitions given previously to the above equations (E-25) and (E-26) yields the exact analytical solution to the sample problem

$$T_1(x) = 10,177.0 + 0.7396 e^{-0.5x} + 9464.4 e^{-1.251 \times 10^{-2} x} \\ - 149.8x \quad (E-27)$$

$$T_2(x) = 13,204.6 + 42.896 e^{-0.5x} + 12,448 e^{-1.251 \times 10^{-2} x} \\ - 149.8x \quad (E-28)$$