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ASSESSMENT OF THE NEED TO INCORPORATE THE
VARIABLE SWIRL MODEL IN THE ENERGY CODE

by

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Yi Bin Chen, Ka-Lam Ip, Neil E. Todreas, "Velocity Measurements in Edge Channels of Wire-Wrapped LMFBR Fuel Assemblies," American Nuclear Society Transactions, Vol. 19, 1974, pp. 323-324.

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M. Yeung, L. Wolf, "Effective Conduction Mixing Lengths for Subchannel Analysis of Finite Hexagonal LMFBR Bundles," ANS Meeting, New York, June 1977.

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ABSTRACT

At present the ENERGY model contains a correlated swirl flow that is circumferentially and axially constant. This report evaluates the need to include a variable swirl flow forcing function in this model. A suitable function for testing the variable swirl flow effects is obtained by reducing the existing world transverse flow experimental data, relying heavily on the MIT laser doppler anemometer data. A comparison of the existing constant swirl model with the variable swirl model using the resulting forcing function is made with the help of a few sample problems. These sample problems help to highlight the physical differences between the two swirl models. By evaluating these differences, the report concludes that in general, the variable swirl model implementation is not warranted. A discussion of when and how to use the variable swirl model if desired, is also included.

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1. INTRODUCTION

The ENERGY series of LMFBR thermal hydraulic codes all require two physically based empirical constants as inputs. For the ENERGY subchannel model (i.e., ENERGY Is, IIs, IIIs [1,5] and SUPERENERGY [2]), these constants are ϵ_1^* , a nondimensionalized enhanced eddy diffusivity, and C_1 , the ratio of the transverse velocity in the bundle periphery to the bundle average velocity. For the ENERGY porous-body model (i.e., ENERGY Ip, IIp, IIIP [1,5]), the corresponding constants, based on superficial flow velocities, are ϵ^* and C . The relationship between the two models is a function of bundle geometry and has been well documented by Khan [4,5]. Additional clarification and graphical conversion factors can be found in reference 6. Numerical values for these empirical constants, based on salt mixing and heated pin experiments, have been correlated by Khan [3,4,5]. Values for Clinch River radial blanket geometry, based on salt mixing experiments by Chiu [7], will soon be released.

The present system of codes assumes that the swirl or transverse velocity in the bundle periphery, represented by the nondimensionalized parameter C_1 , is a function only of fuel pin diameter, fuel pin pitch and wire wrap lead length. Variations in the transverse velocity, caused by wire wrap positioning, have been neglected. Thus, for a given bundle geometry, the transverse flow in the peripheral region is kept constant. This is clearly not the case, but is thought to give a good, simple, approximation of the temperature field when correlated values

of C_1 are used. Recent experimental studies, however, most notably the WARD [11] air flow experiments [8,9,10] and the MIT laser doppler anemometer water tests [11], have shown that these wire wrap induced variations of the transverse velocity can be quite large. Application of the data given by these studies to the ENERGY model, therefore, provides an excellent opportunity to check the significance of the constant transverse velocity assumption on temperature predictions.

The purpose of this report, then, is to examine the effects of a variable swirl flow model on the temperature field. This will be accomplished by reducing the available data to obtain a characteristic transverse velocity profile and comparing the results of a suitably modified SUPERENERGY temperature field output with the existing SUPERENERGY (constant swirl model) temperature field and with experimental data.

2. DATA REDUCTION

2.1 Assumptions

The desired result of the following data reduction is to provide a normalized characteristic velocity profile as a function of wire wrap angle which can be used as a shape forcing function for the swirl flow. The empirical constant C_1 , when used with the forcing function, would then represent a transverse velocity averaged over a wire wrap lead length, obtained, as before, by computer matchup of ENERGY with existing heated pin and salt mixing tests.

In order to make a comparison of the available transverse velocity data, it is necessary to graph the data using a common base. The convention applied here is that suggested by the WARD documents [8,9,10] and used by Sha [11]:

$$\frac{V_T}{V_B \cdot \tan \theta} \text{ versus } \alpha$$

where

V_T = transverse velocity in the bundle periphery

V_B = bundle average axial velocity

$\tan \theta$ = tangent of the angle of projection of the wire wrap centerline on the vertical axis of the rod

α = wire wrap position on the rod circumference. The zero position is when the wire is crossing the gap between the fuel rod and the duct wall.

This definition implies that when

$$\frac{V_T}{V_B \cdot \tan \theta} = 1,$$

then the flow is following the wire wrap tangentially. A more complete discussion of the implications of using this method of nondimensionalization is available in reference 8, but is not particularly applicable here since this graphing convention is used only as a means to compare magnitudes of different sets of data so that a normalized shape forcing function can be formed.

Some other assumptions about the transverse velocity profile are necessary until more data becomes available:

- (1) The transverse velocity in the edge subchannels is not a function of circumferential position, but only of wire wrap angle. This allows a data comparison between the transverse velocities of edge subchannels at different locations on a side (e.g., near the corner and near the center). This assumption is probably very good for subchannels not adjacent to the corner in bundles with a large number of pins.
- (2) The average transverse velocity in the bundle peripheral region, in the ENERGY code, has the same wire wrap angle dependent profile as the local transverse velocity in the subchannel gap given by data. This is not necessarily the case since data represents a pointwise velocity measurement while ENERGY uses an integral velocity. Also, the data as applied to the ENERGY model contains a transverse velocity superimposed on a smaller eddy velocity (modeled in ENERGY by the nondimensionalized enhanced eddy diffusivity of heat, ϵ^* , mentioned earlier) which is present in the absence of swirl flow.
- (3) There is no Reynolds number effect within the turbulent regime on the transverse velocity profile. This assumption allows data sets with different Reynolds numbers to be compared.

2.2 MIT - 61 Pin Bundle Data [11]

The MIT data was collected using laser doppler anemometer measurement techniques developed from those first applied to wire wrapped bundles by Wheeler, *et al.* [13]. Data was taken at several points radially (see Fig. 1) within a 61 pin water bundle at two flow rates (turbulent and laminar) and wire wrap lead lengths of six and twelve inches. For comparison, only the turbulent data was considered here since most cases of interest that satisfy the Gr_c^* criteria [4,5], enabling the use of forced convection ENERGY (i.e., ENERGY I and SUPERENERGY) will be in this flow regime. All MIT data is arbitrarily extrapolated to zero at $\alpha=0^\circ$, i.e., the point at which the wire wrap passes through the gap between the fuel pin and the duct wall. Thus, the range of reliable data extends from $45^\circ \leq \alpha \leq 315^\circ$.

Figures 2 and 3 show twelve inch wire wrap lead length data. In this case the transverse velocity plotted is the local transverse velocity, i.e., the velocity at a particular point within the subchannel. As mentioned before, some question exists regarding which data point is most applicable for use with the ENERGY model, since the model utilizes only sub-channel averaged velocities. The gap points A, B and C perhaps do the best job since they contain little of the internal sub-channel mixing effects (as compared to D and E) that are modeled by e_1^* . For ease in comparison, the data from these points is replotted on a normalized scale in Fig. 4. Also included are two averages, again normalized. The dashed line probably repre-

sents the best average since it uses data points that are far from the corner and the most developed hydrodynamically.

Figures 5, 6 and 7 are similar to Figures 2, 3 and 4, respectively, except they represent plots of the six inch lead length data. On the normalized plot is an average profile.

2.3 French - 19 Pin Bundle Data [14]

Lafay, et al., took some visual measurements of the transverse velocity in a six inch wire wrap lead length bundle which was designed primarily to investigate radial and axial pressure profiles in a wire wrap bundle. While the visual velocity profile may not be as precise as laser doppler anemometer or pilot tube measurements, it does serve to point out gross data errors that may go unnoticed with the more sophisticated data acquisition techniques. The data is shown on Figure 5 and again in normalized form on Figure 7.

2.4 WARD 11:1 Air Flow Tests [8,9,10]

The WARD 11:1 scale fuel bundle air-flow data was collected using pilot tubes. One of the more important results of the WARD tests was a detailed measurement of the cross flow profile in the subchannel gaps as a function of wire wrap angle and subchannel position. Of particular interest in the data reduction done here is the transverse velocity profile for the edge subchannels as reported in Reference 9. The average transverse velocity profile is reproduced in Figure 8. This profile will vary to a small degree (see Ref. 12) depending on the method

used to select the characteristic transverse velocity. Three possible choices are the gap averaged velocity, maximum velocity in the gap region, or the gap centerline velocity. The average velocity is used here since it appears to be the most reasonable choice physically. This choice, in reality, is not that important, since as can be seen the range of measurement is quite small, $-66.7^\circ \leq \alpha \leq 49^\circ$, and offers no hint as to the profile in the center region of Figure 8.

2.5 Selected Representative Profile

A selected representative profile of the transverse velocity behavior as a function of wire wrap angle, based on the MIT twelve inch wire wrap lead average profile in Figure 4 and the WARD data in Figure 8, is shown in Figure 9. Note the apparent disagreement between MIT and WARD data. For the purpose of this report, however, the assumed hybrid curve represents a close enough approximation to the transverse velocity shape. It can be expanded later to include six inch data and updated as new more reliable data becomes available. A similar profile is given by Sha, et al., in Reference 12.

In order to obtain the desired shape forcing function for C_1 from the profile in Figure 9, the curve needs to be renormalized based on the profile integrated average (i.e., the average is designated 1.00). This profile is shown in Figure 10. The empirical constant C_1 now specifies the transverse velocity magnitude and the profile in Figure 11 specifies the shape as a function of wire wrap angle.

3. VARIABLE SWIRL MODEL

3.1 Model Implementation

The implementation of the variable swirl model into the SUPERENERGY [2] code is accomplished quite readily by introducing the profile obtained in Section 2 as a data set and using a table lookup routine to find the function value with respect to the wire wrap angle of a given peripheral subchannel. The wire wrap position for an edge subchannel on bundle face 1 is given by:

$$\alpha_1 = \left(\frac{z}{h} - \text{INTEGER}\left(\frac{z}{h}\right)\right) * 360.0 - (i-1) * 60.0 + \alpha_{ST}$$

where

i = bundle face number $1 \leq i \leq 6$

α_1 = relative wire wrap position for an edge subchannel on bundle face 1

z = axial height

h = wire wrap lead length

α_{ST} = the wire wrap start angle on bundle face 1.

The forcing function obtained in Section 2 is also used for the corner subchannels, since experimental data is unavailable. In this case, however, the wire wrap angle is taken to be the average of the value for the two neighboring faces.

Appendix A shows a listing of the SUPERENERGY code main program with the variable swirl model included. It should be noted that the listing presented here also includes the inter-assembly conduction model discussed in Reference 15. The model

has nothing to do with the analysis done here.

3.2 Sample Problem

To show the effect of the variable swirl model clearly, an illustrative sample problem was devised using the input parameters listed in Table I. In order to provide the best possible skewed power profile, where one would postulate the variable swirl model would be most necessary, the energy is being added to the bundle by just two fuel pins. These pins are located along the duct wall on opposite sides of the bundle and are each adding an equivalent amount of energy. This skewed effect is enhanced by setting ϵ_1^* equal to zero, thus allowing no eddy diffusion of heat between subchannels. In addition, the conductivity has been arbitrarily set to zero to decouple the interior and peripheral regions of the bundle entirely. Heat transfer between subchannels, then, is by swirl flow only. Figures 11 through 15 show the results of the sample problem with this input for both constant and variable swirl cases.

Figures 11 through 14 are plots of a dimensionless temperature profile in the peripheral region versus its circumferential position for axial heights of 5, 10, 15, and 20 inches, respectively. The bundle is split into two halves, side A and side B, and plotted on the same coordinate system so that asymmetries due to variable swirl effects can be seen. As expected, the constant swirl profile, designated by the solid line, is perfectly symmetrical. The two half profiles which result from the variable swirl model fluctuate about this line

reflecting the advancement and retardation of the flow caused by the forcing function. This is most clearly evident in the subchannels between circumferential positions 3 and 1. Side B initially has the largest transverse flow rate due to the wire wrap location and carries the energy away quickly from the point of deposition to a point downstream of the constant swirl front (marked with an arrow on the small diagram accompanying each figure). By 10 inches (Fig. 12), this effect is reversed causing the relative magnitudes of A and B to switch positions downstream of the pin. At 20 inches (Fig. 14), the evidence of several changes in the relative magnitudes of A and B transverse flows can be seen as fluctuations about the constant swirl profile.

Since the above sample case contains a highly skewed power profile with no mixing other than swirl flow in the peripheral region, it represents an upper bound for the discrepancy between the constant and variable swirl models. This difference ranges from a high maximum of 40 percent of the average bundle temperature rise for Figure 11 to a low maximum of 20 percent for Figure 14. Problems containing non-zero eddy diffusion and conduction or more heated pins along the periphery will undoubtedly have smaller differences than this. This contention will be examined in subsection 3.4. Figure 15 is a plot of the average temperature rise in the sample bundle versus axial height for both the constant and variable swirl models. Notice that there is barely a discernable difference between the two

curves. The difference is a result of not requiring mass conservation in the variable swirl model. This assumption, though clearly wrong, was necessary to implement the variable swirl model quickly and with no loss of ENERGY model simplicity for comparison purposes only. The following subsection discusses the effects of having no mass balance using the current sample problem for illustration.

3.3 Conservation of Mass and Energy

An internal mass balance has not been necessary in the forced convection codes ENERGY I and SUPERENERGY, since the flowsplit method used [16] contains an axial flow mass balance as a constraint and the transverse flow is a nonvarying input parameter. With the introduction of a variable transverse flow, though, the mass in the peripheral region is no longer conserved at any axial level. This is because the set of discrete points taken from the normalized continuous forcing function (Figure 10) to adjust the transverse flow at various locations in the axial level, does not necessarily average to 1.00. The largest magnitude of the mass balance error will occur locally in an element composed of a corner subchannel and its two adjacent edge subchannels which is subject to two very different transverse flow rates entering and leaving the element (see Figure 16). This mass imbalance can be estimated by:

$$\frac{\Delta m}{m_{TOT}} = \frac{\rho A_T (V_{T_2} - V_{T_1})}{\rho A_T \bar{V}_T + \rho A_a \bar{V}_a} = \frac{\bar{V}_T (f(\alpha) - f(\alpha + 60^\circ))_{MAX}}{\bar{V}_T + \frac{A_a}{A_T} \bar{V}_a} \quad (3-1)$$

where

- m_{TOT} = total mass flowrate through the element = $\bar{m}_T + m_a$
- Δm = mass flowrate imbalance due to the variable swirl model
- $\bar{m}_T$ = average transverse mass flowrate
- m_a = element axial flowrate
- m_{T_1} = transverse mass flowrate into the element
- m_{T_2} = transverse mass flowrate out of the element
- $\bar{V}_B$ = bundle average axial velocity
- V_{T_1} = transverse velocity associated with m_{T_1}
- V_{T_2} = transverse velocity associated with m_{T_2}
- $\bar{V}_T$ = average transverse velocity
- V_a = axial velocity through element
- A_T = transverse flow area
- A_a = element axial flow area
- $f(\alpha)$ = forcing function value picked from Figure 11 at wire wrap angle α .

but $\bar{V}_T = C_1 \bar{V}_B$ and (3-1) becomes

$$\frac{\Delta m}{m_{TOT}} = \frac{C_1 (f(\alpha) - f(\alpha + 60^\circ))_{MAX}}{C_1 + \frac{A_a}{A_T} \frac{V_a}{V_B}} \quad (3-2)$$

Thus (3-2) represents the worst mass error that will occur in the element considered at a given axial level. Over the whole axial level, this error will be compensated for, in part, by the errors occurring at the other five corners. Therefore, it

seems reasonable to assume that the maximum average mass error for an entire axial level will have an upper bound of

$$\frac{\Delta m}{m_B} = \frac{m_{T_2} - m_{T_1}}{m_B} = \frac{C_1 (f(\alpha) - f(\alpha+60^\circ))_{MAX}}{A_B/A_T} \quad (3-3)$$

where

m_B = total bundle axial mass flowrate

A_B = total bundle axial flow area

For the bundle conditions stated in Table I and from examination of Figure 10, the following quantities result:

$$(f(\alpha) - f(\alpha+60^\circ))_{MAX} = f(300^\circ) - f(360^\circ) = 1.613$$

$$A_a = \left(\frac{D_R}{2} + D_w\right)\left(\frac{D_F}{2\sqrt{3}} + P\right) - \frac{7\pi}{24} (D_R^2 + D_w^2) = 6.34 \times 10^{-2} \text{ in}^2$$

$$A_B = \frac{\sqrt{3}}{2} D_F^2 - \frac{19\pi}{4} (D_R^2 + D_w^2) = 0.702 \text{ in}^2$$

$$A_T = D_w \frac{L}{N} = 2.24 \times 10^{-3} \text{ inches}$$

$$\frac{V_a}{V_B} = 1.00$$

Thus, the maximum local error, equation (3-2), is the following for the sample problem:

$$\frac{\Delta m}{m_{TOT}} = \frac{0.1(1.613)}{0.1 + \frac{6.34 \times 10^{-2}}{2.24 \times 10^{-3}}} \times 100 = 0.57\%$$

Similarly, the maximum average error at one axial layer can be calculated as:

$$\frac{m}{m_B} = \frac{0.1(3.613)}{\frac{0.702}{2.24 \times 10^{-3}}} \times 100 = 0.05\%$$

The variable swirl model local temperature error associated with the local mass error shown in equation (3-2) has been derived in Appendix B. By using the final equation (B-7) and inserting typical numbers for the sample problem operating conditions, the temperature error predicted here can be found to be on the order of one percent or less. Although, this tends to indicate the accumulated energy error is small compared to the energy already in the subchannel, the error is not zero, especially for small axial heights. This can be seen easily upon examination of Figure 11. The integral of the Side B is probably within 15 percent of, but not equal to, the integral of the constant swirl curve, indicating an energy difference between the two. At higher axial heights (see Figures 13 and 14), this effect tends to wash out due to compensating local errors. Bundle average energy errors are very small (Fig. 15), accurately reflecting the small average mass error calculated by equation (3-3).

This simplified analysis indicates, then, that the no-mass-balance assumption used in conjunction with the variable swirl model appears to be valid. This is particularly true for axial heights greater than one lead length where local errors are

small compared to the energy already within the bundle and have compensating effects. Also for real cases, non-zero conduction and eddy heat diffusion will mix the error with the large sink in the bundle interior region rather than having it confined artificially to the peripheral region as in the preceding example.

3.4 Additional Examples

Some more realistic examples using the variable swirl flow model are necessary to further show the differences between it and the simpler constant swirl model. The Oak Ridge FPM-2A test bundle cases [17] listed in Table II were chosen for this purpose. The bundle numbering scheme referred to by Table II is shown in Figure 17. Geometric parameters for the bundle are the same as those listed in Table I. Non-zero conduction and eddy heat diffusion effects have been included. The resultant circumferential temperature profiles at the bundle outlet for these examples are plotted in Figures 18 through 21.

Figures 18 and 19 show the circumferential profiles for the two tests having only three heated pins along the duct wall. As expected, these profiles are highly skewed reflecting the asymmetric power deposition into the bundle. The variable swirl model profile follows the constant swirl model profile, fluctuating a maximum of about 20 percent of the average bundle temperature rise about it. As predicted in subsection 3.2, this maximum discrepancy between the curves is bounded by the maximum difference seen in the artificial example used there.

Figures 20 and 21 are the circumferential temperature plots for an eleven heated pin test and a nineteen heated pin test, respectively. These examples are representative of the worst possible skewing that should realistically be expected to be modeled for any real bundles. Notice that the discrepancy between the variable swirl model and the constant swirl model profiles is about ten percent and five percent of the average axial temperature rise for each of the two figures, respectively. This is much smaller than the maximum projected difference using the sample problem of subsection 3.2.

From these examples, it can be seen that the variable swirl model profiles generated differ from the constant swirl profiles by about 10 percent for reasonable examples and by about 20 percent for less realistic ones. Reexamination of the figures shows that this difference is insignificant when compared with the large percentage by which the calculated profile misses the data points. While no attempt was made to match the data points exactly, the empirical parameters used were taken from Khan's correlations who evaluated this particular bundle as one of his many data sources. The implication of this is that the variable swirl model, though perhaps pointwise more accurate, is no better in general than the constant swirl model because it too is dependent on the accurate correlation of bundle specific tolerances which has not yet been accomplished. Indeed, these bundle tolerances have been shown [18] to have a sizeable effect on the temperature distribution.

4. SUMMARY AND CONCLUSIONS

This report investigated the effect of a wire wrap angle dependent swirl model on the temperature field predictions of the ENERGY model. This was accomplished by choosing a representative profile from the available transverse flow data and normalizing it based on the integrated average of the profile. This profile was used as a shape forcing function for the empirical input parameter C_1 . The mass imbalance caused by the variable transverse flow was shown to be small enough that, for the purpose of comparison, it along with the corresponding energy error could be neglected. Using this information the computer code SUPERENERGY was suitably modified and some example problems were examined.

A few conclusions can be drawn from the analysis presented in this report:

- (1) The variable swirl model will give temperature predictions close to the constant swirl model for axial heights above one wire wrap lead length and for power distributions that are not unrealistically skewed. At relatively large axial heights local fluctuations of opposite sign caused by the variable transverse velocity is less important in bundles that are not highly skewed.
- (2) The models will probably predict closer temperature profiles for bundles larger than those used here. In large bundles the interior region to peripheral

region area ratio increases, decreasing the peripheral region importance.

- (3) The mass imbalance effects are noticable. If a permanent implementation of the variable swirl flow model is attempted, a method of providing a mass balance will have to be included. This will have to be done carefully so as not to destroy the simplicity and physical nature of the ENERGY model.
- (4) The differences between the variable and constant swirl models are generally insignificant compared to bundle tolerance effects. It is recommended that variable swirl model not be used until it can be shown to be at least equal in variation magnitude to a model taking these effects into account.

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FIG.1: LOCATION OF MEASUREMENT POINTS - MIT DATA

FIGURE 13

FIGURE 15

FIG.16a : BUNDLE GEOMETRY AS MODELED BY SUPERENERGY

FIG.16b : SIMPLIFIED DIAGRAM OF CORNER SUBCHANNEL AND ADJACENT EDGE SUBCHANNELS

Figure 17 ORNL FFM-2A Bundle (looking upstream)

FIGURE 18

FIGURE 19

FIGURE 20

FIGURE 21

TABLE I

Sample Problem Input Parameters

Geometry Factors

Fuel Pin Diameter,	$D_R = 0.230$ inches
Fuel Pin Pitch,	$P = 0.286$ inches
Wire Wrap Diameter,	$D_W = 0.056$ inches
Wire Wrap Lead,	$h = 12.0$ inches
Wire Wrap Start Angle,	$\alpha_{ST} = 90^\circ$
Duct Flat to Flat Distance,	$D_F = 1.3328$ inches
Assembly Length,	$L = 24.00$ inches
Number of Pins,	$N = 19$

Operating Conditions

Axial Flux Distribution	-- Flat
Average Heat Flux,	$q'' = 7.5 \times 10^6$ Btu/hr-ft ²
Average Flow Rate,	$m_B = 25,000$ lbm/hr
Effective Eddy Diffu- sivity,	$\epsilon_1^* = 0.00$
Swirl Flow Ratio,	$C_1 = 0.100$
Number of Axial Steps	= 600

Table II
ORNL FFM-2A Pin Powers

Figure Number	ORNL Identification			Pin# Numbers	Combined Power (KW)
	Series	Test	Run		
19	2	2	101	1	- 0.03
				8,18,19	52.98
				12,13,14	- 0.10
				2,7,9,17	- 0.02
				4,5,11,15	- 0.19
				3,6,10,16	- 0.14
20	2	9	401	1	- 0.03
				8,18,19	0.00
				12,13,14	52.07
				2,7,9,17	- 0.04
				4,5,11,15	- 0.09
				3,6,10,16	- 0.13
21	2	9	201	1	- 0.03
				8,18,19	18.10
				12,13,14	- 0.09
				2,7,9,17	17.12
				4,5,11,15	- 0.09
				3,6,10,16	17.43
22	2	14	101	1	8.93
				8,18,19	39.33
				12,13,14	13.11
				2,7,9,17	44.25
				4,5,11,15	26.00
				3,6,10,16	34.78

*ORNL pin numbering scheme shown on Figure 1

APPENDIX A

INPUT INSTRUCTIONS FOR SUPERENERGY-INTERIM VERSION 2

CARD 1 Format (15)

JXQ = Number of cases to be run

CARD GROUP 1 - Multiassembly Data Pack

CARD 1 Format (2F10.1)

TIN = Coolant inlet temperature

TOUT = Approximate average coolant outlet temperature

CARD 2 Format (6I5)

NOASSM = Total number of assemblies for this case
Maximum number of 2 with enclosed listing
Maximum can be changed by enlarging all
02 dimensions in DIMENSION statements

NOPNT = Total number of axial printouts heights
to be specified.

NOINCP = 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

KOND = Interassembly gap conduction model option
= 1 for option

NTYPE = Number of different bundle types that will
be input in this case, e.g., if only fuel
assemblies, set equal to 1; if both fuel and
blanket, set equal to 2

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 Type Data Pack

Repeat this card group for each bundle type in the case
(i.e., L=1, NTYPE).

CARD 1 Format (3I5)

K = 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 couple assemblies of different
types (i.e., different number of pins)
only a 237 pin fuel assembly (ITYPE=1) and

a 91 pin blanket assembly (ITYPE=2) are properly couple.

JANG(K) = Choice of wire wrap forcing function for variable swirl flow model for this bundle type
= 0 constant swirl flow model selected
= 1 MIT-WARD turbulent data profile selected
= 2 French laminar visual data profile selected
= 3 user input profile selected
NROD(K) = number of pins in this bundle type

CARD 2 Format (5F10.5)

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
DFLAT(K) = Duct flat to flat distance in inches

CARD 3 Format (4F10.5)

LENGTH(K) = Assembly length in inches
S1(K) = Thickness of the duct wall in inches
S2(K) = Width of the interassembly gap in inches
ANG(K) = Wire wrap start angle, the edge subchannel boundary perpendicular to the duct wall in bundle face 1 (see COC-2245-20TR, Revision 1) is designated 0°.

CARD 4 Format (I.5)

(Optional) Used only if IANG(K) = 3

NOANG(3) = Number of points to specify wire wrap forcing function shape

CARD 5 to N Format (8F10.5)

(Optional) Used only if IANG(K) = 3

ANGL(I,3) = Wire wrap angle in degrees associated with forcing function point

FANGL(I,3) = Normalized forcing function point at previously specified wire wrap angle

Repeat input procedure in the above groups of two until NOANG(3) points have been read in.

CARD GROUP 3 - 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, must be type whose characteristics have been specified in CARD GROUP 2
= 1 fuel assembly
= 2 blanket assembly

CARD 2 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 3 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

Cl = Ratio of swirl flow velocity to bundle average
axial velocity

Khan's correlations (Ref. 2 and 4) 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 reference.

CARD 4 Format (2I5)

NOOFAX(L) = Number of points to specify the axial flux shape

NROD(K) = Number of rods in assembly

CARD 5 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 4 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. See manual for face number-
ing scheme.

Repeat card groups 2, 3, and 4 for each case.

```

C ***** SUPREENERGY INTERM VERSION 2 *****
C MAIN PROGRAM ONLY
C
C THIS PROGRAM IS MEANT ONLY TO SHOW HOW THE VARIABLE SWIRL MODEL WAS
C IMPLEMENTED -- THE CONDUCTION MODEL DISCUSSED IN CON-2245-31TR IS ALSO
C INCLUDED IN THIS LISTING BUT IS NOT USED. ONLY COMMENT CARDS PERTAINING
C TO THE INPUT AND VARIABLE SWIRL MODEL ARE INCLUDED HERE -- FOR A DES-
C cription on the use of the conduction model see document CON-2245-31TR
C
C | REAL LEAD,LENGTH                                00000020
C | INTEGER T                                         00000030
C | COMMON/PROP1/RHO,CP,COND,CONDM,ALPHA            00000040
C | COMMON/GEO /DR(3),DW(3),LEAD(3),P(3),DFLAT(3),PDD(3),CAP(3),A1(3),A0000050
C | 1A2(3),A3(3),A4(3),A5(3),A6(3),A7(3),ATOTAL(3),ATOTLG(3),DF1(3),A0000050
C | 2DE2(3),DE3(3),DE6(3),DF7(3),HP1(3),HP2(3),HP3(3),HPTOT(3),A0000070
C | 3ETA1(3),ETA2(3),ETA3(3),ETA4(3),ETA6(3),ETA8(3),X1(3),X2(3),X3(3),A0000090
C | 4S1(3),S2(3),LENGTH(3),V1R(3),V2R(3),V3R(3),V4R(3),V7R(3),A0000090
C | COMMON/NUM /NRND(3),NRND5(3),NCHANL(3),N1(3),N2(3),N3(3),N4(3),A0000090
C | 1N5(3),N6(3),N7(3),NA(3),LC(3,550,4),VR0D(3,440,3)
C | COMMON/TEMP/T(550)
C | COMMON FACTOR(3,3)                                00000130
C | DIMENSION FLOW(02),FLOWG2(02),R(02),SGAP(02),VAVG(02),VAVG0(02),A0000140
C | 1V1(02),V2(02),V3(02),V4(02),V7(02),VSWHAR(02)
C | DIMENSION TYPE(02),NOOFA1(02),AXIAL(50,02),FAX(50,02),MA(02,6),A0000160
C | DIMENSION FH1(02),FH2(02),EH3(02),EH4(02)
C | DIMENSION PE2(02),PE3(02),PE6(02),PE7(02),WU2(02),WU3(02),WU6(02),A0000180
C | 1NU7(02),REC2(02),RES3(02),RES4(02),RES7(02)
C | DIMENSION OTOTAL(02),DIFFH(02),DIFFH3(02),TS4(02),TS9(02),OSC(02),A0000200
C | DIMENSION TPRIM(550,02),OTD(550,02),SUMM1(40,02),POWFD(200),A0000210
C | DIMENSION T1(550,02),T2(550,02),T3(550,02),TAVG1(02),TAVG(02),A0000220
C | DIMENSION DONT(25),TANG1(3),NTANG(3),ANG(3),ANGL(50,3),FANGL(50,3)
C THE FOLLOWING DATA SETS CONTAIN THE NORMALIZED WIRE WRAP FORCING
C FUNCTION INFORMATION FOR THE MIT-WARD TURBULENT DATA PROFILE AND THE
C FRENCH LAMINAR VISUAL DATA PROFILE
C ***** VARIABLE SWIRL MODEL ADDITIONS *****
C DATA NOANG/2*25.0/
C DATA ANGL/0.0,15.0,30.0,45.0,60.0,75.0,90.0,105.0,120.0,135.0,150.0,165.0,180.0,195.0,210.0,225.0,240.0,255.0,270.0,285.0,300.0,315.0,330.0,345.0,360.0,375.0,390.0,405.0,420.0,435.0,450.0,465.0,480.0,495.0,510.0,525.0,540.0,555.0,570.0,585.0,600.0,615.0,630.0,645.0,660.0,675.0,690.0,705.0,720.0,735.0,750.0,765.0,780.0,795.0,810.0,825.0,840.0,855.0,870.0,885.0,900.0,915.0,930.0,945.0,960.0,975.0,990.0,1005.0,1020.0,1035.0,1050.0,1065.0,1080.0,1095.0,1110.0,1125.0,1140.0,1155.0,1170.0,1185.0,1200.0,1215.0,1230.0,1245.0,1260.0,1275.0,1290.0,1305.0,1320.0,1335.0,1350.0,1365.0,1380.0,1395.0,1410.0,1425.0,1440.0,1455.0,1470.0,1485.0,1500.0,1515.0,1530.0,1545.0,1560.0,1575.0,1590.0,1605.0,1620.0,1635.0,1650.0,1665.0,1680.0,1695.0,1710.0,1725.0,1740.0,1755.0,1770.0,1785.0,1800.0,1815.0,1830.0,1845.0,1860.0,1875.0,1890.0,1905.0,1920.0,1935.0,1950.0,1965.0,1980.0,1995.0,2010.0,2025.0,2040.0,2055.0,2070.0,2085.0,2100.0,2115.0,2130.0,2145.0,2160.0,2175.0,2190.0,2205.0,2220.0,2235.0,2250.0,2265.0,2280.0,2295.0,2310.0,2325.0,2340.0,2355.0,2370.0,2385.0,2400.0,2415.0,2430.0,2445.0,2460.0,2475.0,2490.0,2505.0,2520.0,2535.0,2550.0,2565.0,2580.0,2595.0,2610.0,2625.0,2640.0,2655.0,2670.0,2685.0,2700.0,2715.0,2730.0,2745.0,2760.0,2775.0,2790.0,2805.0,2820.0,2835.0,2850.0,2865.0,2880.0,2895.0,2910.0,2925.0,2940.0,2955.0,2970.0,2985.0,3000.0,3015.0,3030.0,3045.0,3060.0,3075.0,3090.0,3105.0,3120.0,3135.0,3150.0,3165.0,3180.0,3195.0,3210.0,3225.0,3240.0,3255.0,3270.0,3285.0,3300.0,3315.0,3330.0,3345.0,3360.0,3375.0,3390.0,3405.0,3420.0,3435.0,3450.0,3465.0,3480.0,3495.0,3510.0,3525.0,3540.0,3555.0,3570.0,3585.0,3600.0,3615.0,3630.0,3645.0,3660.0,3675.0,3690.0,3705.0,3720.0,3735.0,3750.0,3765.0,3780.0,3795.0,3810.0,3825.0,3840.0,3855.0,3870.0,3885.0,3900.0,3915.0,3930.0,3945.0,3960.0,3975.0,3990.0,4005.0,4020.0,4035.0,4050.0,4065.0,4080.0,4095.0,4110.0,4125.0,4140.0,4155.0,4170.0,4185.0,4200.0,4215.0,4230.0,4245.0,4260.0,4275.0,4290.0,4305.0,4320.0,4335.0,4350.0,4365.0,4380.0,4395.0,4410.0,4425.0,4440.0,4455.0,4470.0,4485.0,4500.0,4515.0,4530.0,4545.0,4560.0,4575.0,4590.0,4605.0,4620.0,4635.0,4650.0,4665.0,4680.0,4695.0,4710.0,4725.0,4740.0,4755.0,4770.0,4785.0,4800.0,4815.0,4830.0,4845.0,4860.0,4875.0,4890.0,4905.0,4920.0,4935.0,4950.0,4965.0,4980.0,4995.0,5010.0,5025.0,5040.0,5055.0,5070.0,5085.0,5100.0,5115.0,5130.0,5145.0,5160.0,5175.0,5190.0,5205.0,5220.0,5235.0,5250.0,5265.0,5280.0,5295.0,5310.0,5325.0,5340.0,5355.0,5370.0,5385.0,5400.0,5415.0,5430.0,5445.0,5460.0,5475.0,5490.0,5505.0,5520.0,5535.0,5550.0,5565.0,5580.0,5595.0,5610.0,5625.0,5640.0,5655.0,5670.0,5685.0,5700.0,5715.0,5730.0,5745.0,5760.0,5775.0,5790.0,5805.0,5820.0,5835.0,5850.0,5865.0,5880.0,5895.0,5910.0,5925.0,5940.0,5955.0,5970.0,5985.0,6000.0,6015.0,6030.0,6045.0,6060.0,6075.0,6090.0,6105.0,6120.0,6135.0,6150.0,6165.0,6180.0,6195.0,6210.0,6225.0,6240.0,6255.0,6270.0,6285.0,6300.0,6315.0,6330.0,6345.0,6360.0,6375.0,6390.0,6405.0,6420.0,6435.0,6450.0,6465.0,6480.0,6495.0,6510.0,6525.0,6540.0,6555.0,6570.0,6585.0,6600.0,6615.0,6630.0,6645.0,6660.0,6675.0,6690.0,6705.0,6720.0,6735.0,6750.0,6765.0,6780.0,6795.0,6810.0,6825.0,6840.0,6855.0,6870.0,6885.0,6900.0,6915.0,6930.0,6945.0,6960.0,6975.0,6990.0,7005.0,7020.0,7035.0,7050.0,7065.0,7080.0,7095.0,7110.0,7125.0,7140.0,7155.0,7170.0,7185.0,7200.0,7215.0,7230.0,7245.0,7260.0,7275.0,7290.0,7305.0,7320.0,7335.0,7350.0,7365.0,7380.0,7395.0,7410.0,7425.0,7440.0,7455.0,7470.0,7485.0,7500.0,7515.0,7530.0,7545.0,7560.0,7575.0,7590.0,7605.0,7620.0,7635.0,7650.0,7665.0,7680.0,7695.0,7710.0,7725.0,7740.0,7755.0,7770.0,7785.0,7800.0,7815.0,7830.0,7845.0,7860.0,7875.0,7890.0,7905.0,7920.0,7935.0,7950.0,7965.0,7980.0,7995.0,8010.0,8025.0,8040.0,8055.0,8070.0,8085.0,8100.0,8115.0,8130.0,8145.0,8160.0,8175.0,8190.0,8205.0,8220.0,8235.0,8250.0,8265.0,8280.0,8295.0,8310.0,8325.0,8340.0,8355.0,8370.0,8385.0,8400.0,8415.0,8430.0,8445.0,8460.0,8475.0,8490.0,8505.0,8520.0,8535.0,8550.0,8565.0,8580.0,8595.0,8610.0,8625.0,8640.0,8655.0,8670.0,8685.0,8700.0,8715.0,8730.0,8745.0,8760.0,8775.0,8790.0,8805.0,8820.0,8835.0,8850.0,8865.0,8880.0,8895.0,8910.0,8925.0,8940.0,8955.0,8970.0,8985.0,9000.0,9015.0,9030.0,9045.0,9060.0,9075.0,9090.0,9105.0,9120.0,9135.0,9150.0,9165.0,9180.0,9195.0,9210.0,9225.0,9240.0,9255.0,9270.0,9285.0,9300.0,9315.0,9330.0,9345.0,9360.0,9375.0,9390.0,9405.0,9420.0,9435.0,9450.0,9465.0,9480.0,9495.0,9510.0,9525.0,9540.0,9555.0,9570.0,9585.0,9600.0,9615.0,9630.0,9645.0,9660.0,9675.0,9690.0,9705.0,9720.0,9735.0,9750.0,9765.0,9780.0,9795.0,9810.0,9825.0,9840.0,9855.0,9870.0,9885.0,9900.0,9915.0,9930.0,9945.0,9960.0,9975.0,9990.0,10005.0,10020.0,10035.0,10050.0,10065.0,10080.0,10095.0,10110.0,10125.0,10140.0,10155.0,10170.0,10185.0,10200.0,10215.0,10230.0,10245.0,10260.0,10275.0,10290.0,10305.0,10320.0,10335.0,10350.0,10365.0,10380.0,10395.0,10410.0,10425.0,10440.0,10455.0,10470.0,10485.0,10500.0,10515.0,10530.0,10545.0,10560.0,10575.0,10590.0,10605.0,10620.0,10635.0,10650.0,10665.0,10680.0,10695.0,10710.0,10725.0,10740.0,10755.0,10770.0,10785.0,10800.0,10815.0,10830.0,10845.0,10860.0,10875.0,10890.0,10905.0,10920.0,10935.0,10950.0,10965.0,10980.0,10995.0,11010.0,11025.0,11040.0,11055.0,11070.0,11085.0,11100.0,11115.0,11130.0,11145.0,11160.0,11175.0,11190.0,11205.0,11220.0,11235.0,11250.0,11265.0,11280.0,11295.0,11310.0,11325.0,11340.0,11355.0,11370.0,11385.0,11400.0,11415.0,11430.0,11445.0,11460.0,11475.0,11490.0,11505.0,11520.0,11535.0,11550.0,11565.0,11580.0,11595.0,11610.0,11625.0,11640.0,11655.0,11670.0,11685.0,11700.0,11715.0,11730.0,11745.0,11760.0,11775.0,11790.0,11805.0,11820.0,11835.0,11850.0,11865.0,11880.0,11895.0,11910.0,11925.0,11940.0,11955.0,11970.0,11985.0,12000.0,12015.0,12030.0,12045.0,12060.0,12075.0,12090.0,12105.0,12120.0,12135.0,12150.0,12165.0,12180.0,12195.0,12210.0,12225.0,12240.0,12255.0,12270.0,12285.0,12300.0,12315.0,12330.0,12345.0,12360.0,12375.0,12390.0,12405.0,12420.0,12435.0,12450.0,12465.0,12480.0,12495.0,12510.0,12525.0,12540.0,12555.0,12570.0,12585.0,12600.0,12615.0,12630.0,12645.0,12660.0,12675.0,12690.0,12705.0,12720.0,12735.0,12750.0,12765.0,12780.0,12795.0,12810.0,12825.0,12840.0,12855.0,12870.0,12885.0,12900.0,12915.0,12930.0,12945.0,12960.0,12975.0,12990.0,13005.0,13020.0,13035.0,13050.0,13065.0,13080.0,13095.0,13110.0,13125.0,13140.0,13155.0,13170.0,13185.0,13200.0,13215.0,13230.0,13245.0,13260.0,13275.0,13290.0,13305.0,13320.0,13335.0,13350.0,13365.0,13380.0,13395.0,13410.0,13425.0,13440.0,13455.0,13470.0,13485.0,13500.0,13515.0,13530.0,13545.0,13560.0,13575.0,13590.0,13605.0,13620.0,13635.0,13650.0,13665.0,13680.0,13695.0,13710.0,13725.0,13740.0,13755.0,13770.0,13785.0,13800.0,13815.0,13830.0,13845.0,13860.0,13875.0,13890.0,13905.0,13920.0,13935.0,13950.0,13965.0,13980.0,13995.0,14010.0,14025.0,14040.0,14055.0,14070.0,14085.0,14100.0,14115.0,14130.0,14145.0,14160.0,14175.0,14190.0,14205.0,14220.0,14235.0,14250.0,14265.0,14280.0,14295.0,14310.0,14325.0,14340.0,14355.0,14370.0,14385.0,14400.0,14415.0,14430.0,14445.0,14460.0,14475.0,14490.0,14505.0,14520.0,14535.0,14550.0,14565.0,14580.0,14595.0,14610.0,14625.0,14640.0,14655.0,14670.0,14685.0,14700.0,14715.0,14730.0,14745.0,14760.0,14775.0,14790.0,14805.0,14820.0,14835.0,14850.0,14865.0,14880.0,14895.0,14910.0,14925.0,14940.0,14955.0,14970.0,14985.0,15000.0,15015.0,15030.0,15045.0,15060.0,15075.0,15090.0,15105.0,15120.0,15135.0,15150.0,15165.0,15180.0,15195.0,15210.0,15225.0,15240.0,15255.0,15270.0,15285.0,15300.0,15315.0,15330.0,15345.0,15360.0,15375.0,15390.0,15405.0,15420.0,15435.0,15450.0,15465.0,15480.0,15495.0,15510.0,15525.0,15540.0,15555.0,15570.0,15585.0,15600.0,15615.0,15630.0,15645.0,15660.0,15675.0,15690.0,15705.0,15720.0,15735.0,15750.0,15765.0,15780.0,15795.0,15810.0,15825.0,15840.0,15855.0,15870.0,15885.0,15900.0,15915.0,15930.0,15945.0,15960.0,15975.0,15990.0,16005.0,16020.0,16035.0,16050.0,16065.0,16080.0,16095.0,16110.0,16125.0,16140.0,16155.0,16170.0,16185.0,16200.0,16215.0,16230.0,16245.0,16260.0,16275.0,16290.0,16305.0,16320.0,16335.0,16350.0,16365.0,16380.0,16395.0,16410.0,16425.0,16440.0,16455.0,16470.0,16485.0,16500.0,16515.0,16530.0,16545.0,16560.0,16575.0,16590.0,16605.0,16620.0,16635.0,16650.0,16665.0,16680.0,16695.0,16710.0,16725.0,16740.0,16755.0,16770.0,16785.0,16800.0,16815.0,16830.0,16845.0,16860.0,16875.0,16890.0,16905.0,16920.0,16935.0,16950.0,16965.0,16980.0,16995.0,17010.0,17025.0,17040.0,17055.0,17070.0,17085.0,17100.0,17115.0,17130.0,17145.0,17160.0,17175.0,17190.0,17205.0,17220.0,17235.0,17250.0,17265.0,17280.0,17295.0,17310.0,17325.0,17340.0,17355.0,17370.0,17385.0,17400.0,17415.0,17430.0,17445.0,17460.0,17475.0,17490.0,17505.0,17520.0,17535.0,17550.0,17565.0,17580.0,17595.0,17610.0,17625.0,17640.0,17655.0,17670.0,17685.0,17700.0,17715.0,17730.0,17745.0,17760.0,17775.0,17790.0,17805.0,17820.0,17835.0,17850.0,17865.0,17880.0,17895.0,17910.0,17925.0,17940.0,17955.0,17970.0,17985.0,18000.0,18015.0,18030.0,18045.0,18060.0,18075.0,18090.0,18105.0,18120.0,18135.0,18150.0,18165.0,18180.0,18195.0,18210.0,18225.0,18240.0,18255.0,18270.0,18285.0,18300.0,18315.0,18330.0,18345.0,18360.0,18375.0,18390.0,18405.0,18420.0,18435.0,18450.0,18465.0,18480.0,18495.0,18510.0,18525.0,18540.0,18555.0,18570.0,18585.0,18600.0,18615.0,18630.0,18645.0,18660.0,18675.0,18690.0,18705.0,18720.0,18735.0,18750.0,18765.0,18780.0,18795.0,18810.0,18825.0,18840.0,18855.0,18870.0,18885.0,18900.0,18915.0,18930.0,18945.0,18960.0,18975.0,18990.0,19005.0,19020.0,19035.0,19050.0,19065.0,19080.0,19095.0,19110.0,19125.0,19140.0,19155.0,19170.0,19185.0,19200.0,19215.0,19230.0,19245.0,19260.0,19275.0,19290.0,19305.0,19320.0,19335.0,19350.0,19365.0,19380.0,19395.0,19410.0,19425.0,19440.0,19455.0,19470.0,19485.0,19500.0,19515.0,19530.0,19545.0,19560.0,19575.0,19590.0,19605.0,19620.0,19635.0,19650.0,19665.0,19680.0,19695.0,19710.0,19725.0,19740.0,19755.0,19770.0,19785.0,19800.0,19815.0,19830.0,19845.0,19860.0,19875.0,19890.0,19905.0,19920.0,19935.0,19950.0,19965.0,19980.0,19995.0,20010.0,20025.0,20040.0,20055.0,20070.0,20085.0,20100.0,20115.0,20130.0,20145.0,20160.0,20175.0,20190.0,20205.0,20220.0,20235.0,20250.0,20265.0,20280.0,20295.0,20310.0,20325.0,20340.0,20355.0,20370.0,20385.0,20400.0,20415.0,20430.0,20445.0,20460.0,20475.0,20490.0,20505.0,20520.0,20535.0,20550.0,20565.0,20580.0,20595.0,20610.0,20625.0,20640.0,20655.0,20670.0,20685.0,20700.0,20715.0,20730.0,20745.0,20760.0,20775.0,20790.0,20805.0,20820.0,20835.0,20850.0,20865.0,20880.0,20895.0,20910.0,20925.0,20940.0,20955.0,20970.0,20985.0,21000.0,21015.0,21030.0,21045.0,21060.0,21075.0,21090.0,21105.0,21120.0,21135.0,21150.0,21165.0,21180.0,21195.0,21210.0,21225.0,21240.0,21255.0,21270.0,21285.0,21300.0,21315.0,21330.0,21345.0,21360.0,21375.0,21390.0,21405.0,21420.0,21435.0,21450.0,21465.0,21480.0,21495.0,21510.0,21525.0,21540.0,21555.0,21570.0,21585.0,21600.0,21615.0,21630.0,21645.0,21660.0,21675.0,21690.0,21705.0,21720.0,21735.0,21750.0,21765.0,21780.0,21795.0,21810.0,21825.0,21840.0,21855.0,21870.0,21885.0,21900.0,21915.0,21930.0,21945.0,21960.0,21975.0,21990.0,22005.0,22020.0,22035.0,22050.0,22065.0,22080.0,22095.0,22110.0,22125.0,22140.0,22155.0,22170.0,22185.0,22200.0,22215.0,22230.0,22245.0,22260.0,22275.0,22290.0,22305.0,22320.
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CALL PROPITI
                                00000370
C  NOASSM=NO. OF ASSEMBLIES IN THIS CASE, NOPRNT=NO. OF AXIAL PRINTOUTS
C  DESIRED PER ASSEMBLY, NMINR=NO. OF TOTAL AXIAL STEPS TO BE USED WITH
C  THIS CASE, ISOLAT=BOUNDARY CONDITIONS-SEE SUPERENERGY MANUAL, KOND=1
C  FOR INTERASSEMBLY CONDUCTION MODEL OR 0 OTHERWISE, NTYPE=NO. OF DIFFERENT
C  BUNDLE TYPES IN THIS CASE
C  READ(5,10) NOASSM,NOPRNT,NMINR,ISOLAT,KOND,NTYPE
C  VARIABLE PRINTOUT ROUTINE ADDED- INPUT DESIRED PRINTOUT HEIGHTS IN
C  INCHES
      READ(5,50) (PRNT(I), I=1,NOPRNT)
      WRITE(6,51)
51  FORMAT(1X,'PRINTOUTS AT THE FOLLOWING AXIAL HEIGHTS:')
      WRITE(6,52) (PRNT(I), I=1,NOPRNT)
52  FORMAT(8F10.3)
      IF(KOND.EQ.1) WRITE(6,20)
20  FORMAT(1X,'CONDUCTION SOLUTION SELECTED')
      WRITE(6,11) NOASSM,NOPRNT,NMINR,ISOLAT,NTYPE
10  FORMAT(8I5)
11  FORMAT(1X,'NO. OF ASSEMBLIES=1,15,5X,'NO. OF PRINTS=1,15/1X,'NO. OF
      IF AXIAL INCREMENTS=1,15,5X,'TYPE OF BOUNDARY CONDITIONS=1,15/1X,'N
      20. OF ASSEMBLY TYPES=1,15)
                                00000400
C  DATA INPUT FOR EACH BUNDLE TYPE IN THE CASE
      DO 61 L=1,NTYPE
C  K=ASSEMBLY TYPE,K=1 FOR FUEL, K=2 FOR BLANKET
C  LANG(K)=VARIABLE SWIRL WIRE WRAP FORCING FUNCTION SELECTION, LANG(K)=0
C  FOR CONSTANT SWIRL, 1 FOR MIT-HAPP PROFILE, 2 FOR FRENCH PROFILE, 3 FOR
C  USER INPUT PROFILE
C  NROD(K)= NO. OF PINS IN BUNDLE TYPE
      READ(5,10) K, LANG(K), NROD(K)
      WRITE(6,62) K
62  FORMAT(1X,'GEOMETRY FOR ASSEMBLY TYPE',15)
C  INPUT IN ORDER, DIMENSIONS IN INCHES-- ROD DIAMETER, WIRE WRAP DIAMETER
C  WIRE WRAP LEAD, ROD PITCH, FLAT TO FLAT DISTANCE, ASSEMBLY LENGTH,
C  DUCT WALL THICKNESS, INTERASSEMBLY GAP THICKNESS
C  INPUT WIRE WRAP START ANGLE IN DEGREES
      READ(5,40) DR(K), DW(K), LEAD(K), P(K), DFLAT(K)
      READ(5,40) LENGTH(K), ST(K), S2(K), ANG(K)
16  FORMAT(1X,'ROD DIA. WIRE DIA. LEAD PITCH FLAT LENGTH
      1 DUCT TH. GAP TH. ST. ANGLE')
      WRITE(6,16)
      WRITE(6,41) DR(K), DW(K), LEAD(K), P(K), DFLAT(K), LENGTH(K), ST(K), S2(K),
      1), ANG(K)
41  FORMAT(9F10.5)
C  NUMB= AUTOMATIC NUMBERING SCHEME FOR CHANNELS AND RODS
      CALL NUMB(K)
                                00000810
C  GEOM= CALCULATES CHANNEL SIZES AND NOVENSTERN'S FLOW SPLIT - NEW
C  FLOWSPLIT INFORMATION WILL EVENTUALLY REPLACE THIS
      CALL GEOM(K)
                                00000820
      IF(LANG(K).NE.0) GO TO 43
C  IF USER INPUT PROFILE INDICATED, READ IN NO. OF POINTS TO SPECIFY PROFILE
      READ(5,10) NOANG(3)
      NOAN=NOANG(3)
      WRITE(6,42)
42  FORMAT(1X,'SWIRL VELOCITY RELATIVE SHAPE AS A FUNCTION OF WIRE WRAP
      1P ANGLE')
C  VARIABLE SWIRL FORCING FUNCTION AS A FUNCTION OF WIRE WRAP ANGLE
      READ(5,40) (ANGL(1,3),FWVOL(1,3), I=1,NOAN)
      WRITE(6,40) (ANGL(1,3),FWVOL(1,3), I=1,NOAN)
      GO TO 61
63  WRITE(6,43) LANG(K)
43  FORMAT(1X,'SWIRL VELOCITY DATA SET USED=1,15)

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61 CONTINUE
C DATA INPUT FOR EACH ASSEMBLY IN THE CASE
DO 30 L=1,N0ASSM
C L=ASSEMBLY NUMBER
WRITE(6,19) L
10 FORMAT(1X,22HDATA PACK FOR ASSEMBLY,15)
C ITYPE(L)=ASSEMBLY TYPE- SEE MANUAL
C ITYPE=1 FOR FULL ASSEMBLY, ITYPE=2 FOR BLANKET ASSEMBLY
C FOR INTERASSEMBLY CONDUCTION MODEL OR 0 OTHERWISE
READ(5,10) ITYPE(L)
WRITE(6,12) ITYPE(L)
12 FORMAT(1X,17HTYPE OF ASSEMBLY=,15)
K=ITYPE(L)
WRITE(6,17)
17 FORMAT(1X,42HAVE HEAT FLUX, FLOW RATES IN THE ASSEMBLY AND THE GAP)
C INPUT-- AVERAGE HEAT FLUX, FLOW RATES IN ASSEMBLY AND INTERASSEMBLY
C GAP-- SEE MANUAL FOR DIMENSIONS
READ(5,50) GAVG(L),FLOW(L),FLOWGP(L)
WRITE(6,50) GAVG(L),FLOW(L),FLOWGP(L)
50 FORMAT(9F10,1)
WRITE(6,18)
18 FORMAT(1X,60HFOR EFFECTIVE EDDY DIFFUSIVITIES AND SWIRL VELOCITY
1Y RATIO)
C READ 4 EFFECTIVE EDDY DIFFUSIVITIES AND SWIRL FLOW RATIO--LKHAN'S
C CORRELATION (C00-2249-14TR,C00-2249-17TR) CAN BE USED BUT MUST BE
C CORRECTED BY LATERAL AND AXIAL POROSITIES SINCE THIS CODE IS A SURCHAN-
C NEL CODE SEE APPENDICES OF SAME DOCUMENTS
READ(5,40) EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
WRITE(6,40) EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
C NOOFAX(L)= NO. OF AXIAL FLUX SHAPE POINTS, NPOD(K)=NO. OF RODS
READ(5,10) NOOFAX(L)
WRITE(6,13) NOOFAX(L),NPOD(K)
13 FORMAT(1X,12HNO. OF FLUX=,15,5X,12HNO. OF RODS=,15)
NOOFA=NPODAX(L)
WRITE(6,14)
14 FORMAT(1X,35HAXIAL DISTANCE VS FLUX DISTRIBUTION)
C AXIAL FLUX DISTRIBUTION AS A FUNCTION OF AXIAL HEIGHT
READ(5,40) (AXIAL(I,L)+FAX(I,L), I=1,NPOFA)
WRITE(6,40) (AXIAL(I,L)+FAX(I,L), I=1,NPOFA)
40 FORMAT(9F10,5)
NRO=NROD(K)
WRITE(6,15)
15 FORMAT(1X,38HAXIAL POWER DISTRIBUTION OF FUEL RODS)
C RADIAL RELATIVE POWER DISTRIBUTION AS A FUNCTION OF ROD NUMBER- SEE
C MANUAL
READ(5,40) (POWER(I),I=1,NRO)
WRITE(6,40) (POWER(I),I=1,NRO)
M2=M2(K)
M3=M3(K)
M4=M4(K)
M8=M8(K)
MK2=M2+1
MK3=M3+1
IOVER=NROD(K)+1
POWER(IOVER)=0
DO 60 I=1,M4
PROD=0
DO 70 J=1,J)
M=MRON(K,J,J)
PROD=PROD+POWER(M)
70 CONTINUE

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SUMM(I,L)=PROD                                00000970
60 CONTINUE                                    00000980
QTPAVG=(QAVG(L)+HPTOTL(K)/ATOTL(K))*12        00000990
DO 90 I=1,M2                                00001000
QTPRIN(I,L)=QTPAVG*(STATL(K)/A2(K))*(HP2(K)/HPTOTL(K))*SUMM(I,L) 00001010
I/3.0                                         00001020
90 CONTINUE                                    00001030
DO 90 I=M2,M3                                00001040
QTPRIN(I,L)=QTPAVG*(STATL(K)/A2(K))*(HP2(K)/HPTOTL(K))*SUMM(I,L) 00001050
I/2.0                                         00001060
90 CONTINUE                                    00001070
DO 100 I=M3,M4                                00001080
QTPRIN(I,L)=QTPAVG*(STATL(K)/A3(K))*(HP3(K)/HPTOTL(K))*SUMM(I,L) 00001090
100 CONTINUE                                  00001100
IF (FLOWG(L).LT.50.0) FL3VGP(L)=50.0       00001110
G(L)=IFLOW(L)/ATOTL(K)*144.0                00001120
GGAP(L)=(FLOWG(L)/ATOTL(K))*144.0           00001130
VAVG(L)=G(L)/RHO                             00001140
VAVGG(L)=GGAP(L)/RHO                         00001150
V1(L)=VAVG(L)*V1R(K)                         00001160
V2(L)=VAVG(L)*V2R(K)                         00001170
V3(L)=VAVG(L)*V3R(K)                         00001180
V5(L)=VAVGG(L)*V5R(K)                         00001190
V7(L)=VAVGG(L)*V7R(K)                         00001200
CONVER=VAVG(L)*DE1(K)/24.0                   00001210
EH1(L)=EHSTA1*CONVER                          00001220
EH2(L)=EHSTA2*CONVER                          00001230
EH3(L)=EHSTA3*CONVER                          00001240
EH4(L)=EHSTA4*CONVER                          00001250
C VSMBAR(L)= AVERAGE SWIRL FLOW VELOCITY FOR ASSEMBLY L
VSMBAR(L)=C)*VAVG(L)
PE2(L)=(DE2(K)*V2(L)/A2(K)*12.)              00001270
PE3(L)=(DE3(K)*V3(L)/A3(K)*12.)              00001280
PE4(L)=(DE4(K)*V4(L)/A4(K)*12.)              00001290
PE7(L)=(DE7(K)*V7(L)/A7(K)*12.)              00001300
NU2(L)=7.0*0.025*PE2(L)*0.45               00001310
NU3(L)=7.0*0.025*PE3(L)*0.45               00001320
NU6(L)=7.0*0.025*PE6(L)*0.45               00001330
NU7(L)=7.0*0.025*PE7(L)*0.45               00001340
RES2(L)=(1/NU2(L)+(5/4K)/DE2(K))*CONJ/CONOW/2)*DE2(K)/CONW/12 00001350
RES3(L)=(1/NU3(L)+(5/4K)/DE3(K))*CONJ/CONOW/1.732)*DE3(K)/CONW/12 00001360
RES6(L)=(1/NU6(L)+(5/4K)/DE6(K))*CONJ/CONOW/2)*DE6(K)/CONW/12 00001370
RES7(L)=(1/NU7(L)+(5/4K)/DE7(K))*CONJ/CONOW/1.732)*DE7(K)/CONW/12 00001380
30 CONTINUE                                    00001390
WRITE(6,31)                                    00001400
31 FORMAT(1X,74HNEIGHBORING ASSEMBLIES)        00001410
C READ IN NEIGHBORING ASSEMBLIES SEE MANUAL
DO 32 L=1,NOASM                                00001420
READ(5,10) (NA(L,I),I=1,5)                  00001430
WRITE(6,10) (NA(L,I),I=1,5)                  00001440
32 CONTINUE                                    00001450
I1=I*TYPE11)                                  00001470
IPRINT=1
PRINT=PRINT(JPRINT)
OZ=LENGTH(I1)/NOINCR
Z=OZ/2.
DO 115 L=1,NOASM                                00001510
QSA(L)=0                                       00001520
QSB(L)=0                                       00001530
QSC(L)=0                                       00001540
K=I*TYPE(L)                                    00001560

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      M8=N8(K)
      DO 110 I=1,M8
      T2(I,L)=TIN
110  CONTINUE
      IF(KOND.NE.1) GO TO 119
      MK2=N2(K)+1
      M4=N4(K)
      DO 111 I=M2,M4
      T1(I,L)=TIN
111  CONTINUE
119  CONTINUE
1000 CONTINUE
      ZOL=Z/LFNGTH(I)
      DO 120 L=1,N0A<SM
      CALL CURVE(FAXL,ZOL,FAX,AXIAL,N00FAX,L)
      K=ITYPE(L)
      M4=N4(K)
      DO 130 I=1,M4
      QTP(I,L)=QTPRIM(I,L)*FAXL
130  CONTINUE
120  CONTINUE
      DO 140 L=1,N0A<SM
      K=ITYPE(L)
      M1=N1(K)
      M2=N2(K)
      M3=N3(K)
      M4=N4(K)
      M5=N5(K)
      M6=N6(K)
      M7=N7(K)
      M8=N8(K)
      MK1=N1(K)+1
      MK2=N2(K)+1
      MK3=N3(K)+1
      MK4=N4(K)+1
      MK5=N5(K)+1
      MK6=N6(K)+1
      MK7=N7(K)+1
      DO 150 I=1,M1
      MM1=LC(K,I,1)
      MM2=LC(K,I,2)
      MM3=LC(K,I,3)
      T3(I,L)=T2(I,L)+QTP(I,L)*DZ/12/(V1(L)*RM0*CP)+(P(K)-DP(K))*QZ/
      1A1(K))*((ALPHA+EH1(L))/V1(L))*(T2(MM1,L)+T2(MM2,L)+T2(MM3,L)-
      23*T2(I,L))/ETA1(K))*J2
      QSA(L)=QSA(L)+QTP(I,L)
150  CONTINUE
      DO 160 I=M1,M2
      MM1=LC(K,I,1)
      MM2=LC(K,I,2)
      MM3=LC(K,I,3)
      Q=(I-1)/6.
      N=SQRT(D)+1.0001
      IQ=(1-6*(N-1)*(N-1)-1)/(2*N-1)+0.0001
      IR=(1-6*(N-1)*(N-1)-10*(2*N-1)+0.0001
      J=IR/2
      IF(IR.EQ.2*J) GO TO 1160
      EHA=EH1(L)
      EM9=EM2(L)
      ETAA=ETA1(K)
      ETAB=ETA2(K)

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      GO TO 2160
2160 CONTINUE
      EHA=EHI(L)
      EMR=EMJ(L)
      ETAA=ETA1(K)
      ETAB=ETA1(K)
2160 CONTINUE
      T3(I,L)=T2(I,L)+OTD(I,L)*DZ/12/1V1(L)*RHO*CP+(IP(K)-OR(K)*DZ)/
      1(Al(K)+V1(L))*1/(ALPHA*FHB)*((T2(MM),L)+T2(MM),L)+2*T2(I,L)/ETA1+
      2(ALPHA*FHB)*T2(MM),L*(T2(I,L))/ETA1)*12
      OSA(L)=OSA(L)+OTD(I,L)
160 CONTINUE
C ***** SWIRL MODEL ADDITIONS *****
      ILAST=0
C      ILAST=PAGE COUNTER
      IPO5=IFIX(7/LEAD(K))
C      IPO5= INTEGER LEAD LENGTH INDICATOR
      VSWRL=VSWRRL
C      FDFG SURCHANELS TEMPERATURE CALCULATION
      DO 170 I=MK2,M3
      IQ=(I-42-1)/NRING(K)+1.0001
      MM1=LC(K,I,1)
      MM2=LC(K,I,2)
      MM3=LC(K,I,3)
      IF(MM2.GT.43) GO TO 1170
      ETAA=ETA3(K)
      EHA=EHI(L)
      GO TO 2170
1170 CONTINUE
      ETAA=ETA4(K)
      EHA=EH4(L)
2170 CONTINUE
      IF(MM3.GT.43) GO TO 3170
      ETAB=ETA3(K)
      EMR=EMJ(L)
      GO TO 4170
4170 CONTINUE
      ETAB=ETA4(K)
      EMR=EH4(L)
4170 CONTINUE
      IF(KOND.EQ.1) GO TO 4175
      MM4=LC(K,I,4)
      RES1=RFS2(L)
      TTT=T2(MM4,L)
      GO TO 3175
4175 CONTINUE
      LP=HA(L,IQ)
      RES1=RES2(L)+RFS2(LP)+RFS6(L)+RES4(LP)
      TTT=T1(I,L)
4175 CONTINUE
C ***** SWIRL MODEL ADDITIONS *****
      IF(IANG(K).EQ.0) GO TO 4180
      IF(ILAST.EQ.101) GO TO 4180
      THETA=(7/LEAD(K)-IPO5)*350.0+ANG(K)-(IQ-1)*60.0
      MRL7=IFIX(THETA/360.0)
      THETA=THETA-360.0*MRL7
C      THETA= WIRE WRAP ANGLE AT THIS RADIAL AND AXIAL POSITION
      IF(THETA.LT.0.0) THETA=THETA+360.0
      IAN=IANG(K)
      CALL CURVE(FTHTA,THETA,2*ANGL,ANGL,NJANG,IAN)
C      FTHTA= FORCING FUNCTION VALUE AT THETA

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      VSWIRL=FTHETA*VSWRAD(I)
C   VSWIRL= SWIRL VELOCITY AT THIS AXIAL AND RADIAL POSITION
      ILAST=ILAST+1
1180 CONTINUE
C   FOGG SURCHANNEL GOVERNING EQUATION
      T3(I,L)=T2(I,L)+OTP(I,L)*DZ/12/(V2(L)*RHO*CP)+(GAP(K)*DZ/A2(K))* 00002450
      1(VSWIRL /V2(L))* (T2(MM2,L)-T2(I,L))+12*(P(K)-OR(K))*DT/A2(K)* 00002460
      2((ALPHA+EMPI(L))/V2(L))* (T2(MM1,L)-T2(I,L))/ETA2(K)+12*(GAP(K)*DT/ 00002470
      3(V2(L)*A2(K))* ((ALPHA+EMPI(L))* (T2(MM2,L)-T2(I,L))/ETA2*(ALPHA+EMPI(L)* 00002480
      4(T2(MM3,L)-T2(I,L))/ETA2*(P(K)*DZ/A2(K))* (T3-T2(I,L))/(V2(L)*RHO
      5*CP*REFI)
      QSB(L)=QSB(L)+OTP(I,L) 00002510
1190 CONTINUE 00002520
C   CALCULATION OF CORNER SURCHANNEL TEMPERATURES
      DO 180 I=MM3,MM4 00002530
      MM1=LC(K,I,1) 00002540
      MM2=LC(K,I,2) 00002550
      IF(KOND.EQ.1) GO TO 5300
      MM3=LC(K,I,3) 00002560
      TTI=T2(MM3,L)
      RES1=RES3(L)
      GO TO 5310
5300 CONTINUE
      RES1=RES3(L)+RES7(L)*X(I)/X2(K)
      TTI=T(I,L)
5310 CONTINUE
C   ***** SWIRL MODE: ADDITIONS *****
      IF(IANG(K).EQ.0) GO TO 5320
      THETA=(7/LEAD(K)-IPDS)*350.0+ANG(K)+30.0-(1-MM3)*40.0
      MULT=FIX(THETA/360.0)
      THETA=THETA-360.0*MULT
C   THETA= WIRE WRAP ANGLE AT THIS RADIAL AND AXIAL POSITION
      IF(THETA.LT.0.0) THETA=THETA+360.0
      CALL CHPVF(FTHETA,THETA,FANGL,ANGL,NDANG,IAN)
C   FTHETA= FORCING FUNCTION VALUE AT THETA
      VSWIRL=FTHETA*VSWRAD(I)
C   VSWIRL= SWIRL VELOCITY AT THIS AXIAL AND RADIAL POSITION
5320 CONTINUE
C   GOVERNING EQUATION FOR CORNER SURCHANNELS
      T3(I,L)=T2(I,L)+OTP(I,L)*DZ/12/(V3(L)*RHO*CP)+(GAP(K)*DZ/A3(K))* 00002570
      1(VSWIRL /V3(L))* (T2(MM1,L)-T2(I,L))+ (GAP(K)*DT/A3(K))*12* 00002580
      2((ALPHA+EMPI(L))/V3(L))* (T2(MM1,L)+T2(MM2,L)-2*T2(I,L))/ETA3(K)+ 00002590
      3(X(I)*DZ/A3(K))* (TTT-T2(I,L))/(V3(L)*RHO*CP*REFI)
      QSC(L)=QSC(L)+OTP(I,L) 00002610
180 CONTINUE 00002620
      IF(KOND.EQ.1) GO TO 140
      DO 210 I=MM5,MM6 00002630
      MM1=LC(K,I,1) 00002640
      MM2=LC(K,I,2) 00002650
      MM3=LC(K,I,3) 00002660
      IF(I.GT.MM7) GO TO 7210 00002670
      A=A6(K) 00002680
      V=V6(L) 00002690
      RES=RES6(L) 00002700
      X=P(K) 00002710
      TTI=T2(I,L) 00002720
      IQ=(I-MM5-1)/NFRING(K)+1.0001 00002730
      IP=(I-MM5-1)*NFRING(K)+0.0001 00002740
      J=IP/2 00002750
      JJ=IP-2*J 00002760
      LP=NAIL,IQ) 00002770

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I1=I1TYPE(L)	00002760
I2=I1TYPE(LP)	00002790
FAC=FACTOR(I1,I2)	00002800
IF (ISOLAT.EQ.1) GO TO 2217	00002810
IF (LP.EQ.L) GO TO 1215	00002820
IF (IQ.GT.3) GO TO 1216	00002830
MM4=N6(I2)+(IQ-2)*NRING(I2)+(NDING(K)-IR)*FAC+1	00002840
GO TO 2210	00002850
1210 CONTINUE	00002860
MM4=N6(I2)+(IQ-4)*NRING(I2)+(NDING(K)-IR)*FAC+1	00002870
GO TO 2210	00002880
1215 CONTINUE	00002890
TTT=T2(I,L)	00002900
GO TO 2217	00002910
2210 CONTINUE	00002920
IF (FAC.EQ.1) GO TO 2215	00002930
IF (FAC.GT.1) GO TO 2213	00002940
IF (IR.GE.(NRING(K)-1)) GO TO 2211	00002950
TTT=T2(MM4,LP)-(T2(MM4-1,LP)+T2(MM4-1,LP))/2.0+JJ*(T2(MM4-1,LP)-	00002960
T2(MM4-1,LP))/2.0	00002970
GO TO 2217	00002980
2211 TTT=T2(MM4,LP)-(T2(MM4-1,LP)+T2(MM4-1,LP))/4.0+JJ*(T2(MM4-1,LP)-	00002990
T2(MM4-1,LP))/2.0	00003000
GO TO 2217	00003010
2213 TTT=(T2(MM4,LP)+T2(MM4-1,LP))/2.0	00003020
GO TO 2217	00003030
2215 CONTINUE	00003040
TTT=T2(MM4,LP)	00003050
2217 CONTINUE	00003060
IF (MM2.GT.47) GO TO 2210	00003070
ETAA=ETAB(K)	00003080
GO TO 4210	00003090
4210 CONTINUE	00003100
ETAA=ETAB(K)	00003110
2210 CONTINUE	00003120
IF (MM3.GT.47) GO TO 5210	00003130
ETAB=ETAB(K)	00003140
GO TO 6210	00003150
5210 CONTINUE	00003160
ETAB=ETAB(K)	00003170
6210 CONTINUE	00003180
GO TO 220	00003190
7210 CONTINUE	00003200
TTT=T2(I,L)	00003210
A=A7(K)	00003220
V=V7(L)	00003230
RES=RES7(L)	00003240
X=X2(K)	00003250
ETAA=ETAB(K)	00003260
ETAB=ETAB(K)	00003270
220 CONTINUE	00003280
CONTINUE	00003290
T3(I,L)=T2(I,L)+X*07/(MM4*G+V*A)+((T2(MM1,I)-T2(I,L))/RES+TTT-	00003300
T2(I,L))*COND*24/52(K)+COND*07*52(K)/(2*040*CP*V*A)+((T2(MM7,I)-	00003310
2T2(I,L))/ETAA+(T2(MM4,I)-T2(I,L))/ETAB)*12	00003320
IJ=1-12*(NDING(K)+1)	00003330
IF (ISOLAT.EQ.2) T3(I,L)=T3(IJ,L)	00003340
2210 CONTINUE	00003350
DO 190 I=MM4,MM6	00003360
MM1=LC(K,I,1)	00003370
MM4=LC(K,I,4)	00003380

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      IF(I.GT.M5) GO TO 1190
      T3(I,L)=(RES5(L)*T3(M4,L)+RES7(L)*T3(M4,L))/(RES4(L)+RES2(L))
      GO TO 190
1190 CONTINUE
      T3(I,L)=(RES7(L)*X1(K)+T3(M4,L)+RES3(L)*X2(K)+T3(M4,L))/
      1(RES7(L)*X1(K)+RES3(L)+X2(K))
100 CONTINUE
140 CONTINUE
      DO 230 I=1,NDASSM
      K=TYPE(L)
      M3=M3(K)
      IF(KOND.NE.1) GO TO 270
      M3=M3(K)
      M4=M4(K)
      MK2=M2(K)+1
      MK3=M3+1
      DO 5400 I=MK2,M3
      IQ=(1-M2-1)/NRING(K)+1.0001
      IR=1-M2-(IQ-1)*NRING(K)+0.0001
      LP=NA(I,10)
      I2=TYPE(LP)
      FAC=FACTOR(K,I2)
      J=IQ/2
      JJ=IR-2*J
      MM5=LC(K,I,4)
      MM6=LC(K,MM5,4)
      IF(ISO,AT,AT,0) GO TO 4180
      IF(LP.NE.L) GO TO 4185
4180 CONTINUE
      T1(I,L)=T3(I,L)
      T3(MM5,L)=T3(I,L)
      T3(MM6,L)=T3(I,L)
      GO TO 5400
4195 CONTINUE
      IF(IQ.GT.3) GO TO 4190
      MM4=M2(I2)+(IQ+2)*NRING(I2)+(NRING(K)-IR)*FAC+1
      GO TO 4195
4190 CONTINUE
      MM4=M2(I2)+(IQ-4)*NRING(I2)+(NRING(K)-IR)*FAC+1
4195 CONTINUE
      IF(FAC.FO.1) GO TO 4010
      IF(FAC.GT.1) GO TO 4020
      IF(IR.GF.(NRING(K)-1)) GO TO 4030
      T1(I,L)=T3(MM4,LP)-(T3(MM4,LP)-T3(MM4-1,LP))/4.+J*(T3(MM4,LP)-
      T3(MM4-1,LP))/2.0
      GO TO 4200
4010 CONTINUE
      T1(I,L)=T3(MM4,LP)
      GO TO 4200
4020 CONTINUE
      T1(I,L)=(T3(MM4,LP)+T3(MM4+1,LP))/2.0
      GO TO 4200
4030 CONTINUE
      T1(I,L)=T3(MM4,LP)-(T3(MM4+1,LP)-T3(MM4,LP))/4.0+JJ*(T3(MM4+1,LP)-
      T3(MM4,LP))/2.0
4200 CONTINUE
      RL=RES2(L)+RES4(L)
      RLP=RES2(LP)+RES5(LP)
      T3(MM6,L)=(T3(I,L)*RL+T1(I,L)*RL)/(RL+RLP)
      T3(MM5,L)=(T3(I,L)*(RL+RES5(L))+T1(I,L)*RES2(L))/(RL+RLP)
4400 CONTINUE

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00001300

00003400

00003410

00003420

00003430

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00003480

00003490

00002770

00002780

00002750

00002760

```

00 5500 I=MK3,M4
I0=I+M3
IS=I0-1
IF(I0.E0.1) IS=8
LP=NA(L,I0)
LR=NA(L,IS)
I1=ITYPF(L0)
I2=ITYPF(L0)
MM3=LC(K,I,3)
MM6=LC(K,MM3,4)
IF(I50L8T.F0.0) GO TO 5401
T1(I,L)=T3(I,L)
T3(MM6,L)=T3(I,L)
T3(MM3,L)=T3(I,L)
GO TO 5500
5401 IF(I0,LT,3) GO TO 5405
MM5=N3(I1,I0-2)
GO TO 5410
5405 CONTINUE
MM5=N3(I1,I0+4)
5410 CONTINUE
IF(IS,LT,4) GO TO 5415
MM4=N3(I2,I5-3)
GO TO 5420
5415 CONTINUE
MM4=N3(I2,I5+3)
5420 CONTINUE
UX4=RES3(L0)/X1(I2)*RES7(L0)/X2(I2)
UX5=RES3(L0)/X1(I1)*RES7(L0)/X2(I1)
UX1=RES3(L)/X1(K)*RES7(L)/X2(K)
T1(I,L)=(T2(MM4,LR)*UX4+T2(MM5,LP)/UX5+T2(I,L)/UX1)/(1.0/UX4+1.0/
1UX5+1.0/UX1)
T3(MM6,L)=T1(I,L)
T3(MM3,L)=(RES7(L)*X1(K)*T3(I,L)+RES3(L)*X2(K)*T3(MM6,L))/
1*(RES7(L)*X2(K)+RES3(L)*X1(K))
5500 CONTINUE
270 CONTINUE
00 240 I=1,M8
T2(I,L)=T3(I,L)
240 CONTINUE
230 CONTINUE
Z=Z+02
DIFF=PRINT-7
IF(DIFF.GT,07) GO TO 1000
00 250 L=1,NDA54
K=ITYPE(L)
M2=M2(K)
M3=N3(K)
M4=N4(K)
M5=N5(K)
M6=N6(K)
M7=N7(K)
M8=N8(K)
MK2=M2+1
MK3=M3+1
MK6=M6+1
MK7=M7+1
00 260 I=1,M8
T(I)=T2(I,L)
260 CONTINUE
T11=0

```

0000350n
0000351n
0000352n
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0000375n


```

T22=0
T33=0
T66=0
T77=0
DO 500 J=1,M2
500 T11=T11+T2(J,L)
DO 501 J=M+2,M7
501 T22=T22+T2(J,L)
DO 502 J=M+3,M4
502 T33=T33+T2(J,L)
DO 504 J=M+6,M7
504 T66=T66+T2(J,L)
DO 505 J=M+7,M8
505 T77=T77+T2(J,L)
TAVG(L)=(T11*V1(L)*A1(K)+T22*V2(L)*A2(K)+T33*V3(L)*A3(K))/
I(M2*V1(L)*A1(K)+(M7-M2)*V2(L)*A2(K)+(M4-M3)*V3(L)*A3(K))
OTOTAL(L)=(OSAL(L)*A1(K)+OSB(L)*A2(K)+OSC(L)*A3(K))*07/12*3/3412
HIN=RM0*CP*FIN*(M2*A1(K)*V1(L)+(M3-M2)*A2(K)*V2(L)+(M4-M3)*A3(K)*
V3(L))/144/3412
HING=RM0*CP*FIN*(M7-M6)*A6(K)*V4(L)+(M8-M7)*A7(K)*V7(L)/144/3412
HTOTAL=RM0*CP*(T11*A1(K)*V1(L)+T22*A2(K)*V2(L)+T33*A3(K)*V3(L))/
144/3412
HTOTALG=RM0*CP*(TA6*A6(K)*V6(L)+T77*A7(K)*V7(L))/144/3412
DIFFH(L)=HTOTAL-HIN
DIFFHG(L)=HTOTALG-HING
WRITE(6,503) TAVG(L),OTOTAL(L),DIFFH(L),DIFFHG(L)
503 FORMAT(1H1,1X,5HTAVG=,1X,F7.1/,1X,11HTOTAL(KW)=,1X,F7.1/,1X,10H1DIFFH(KW)=,1X,F7.1/,1X,10H1DIFFHG(KW)=,1X,F7.1/)
WRITE(6,504) L
504 FORMAT(1X,17HTEMPERATURE DISTRIBUTION FOR ASSEMBLY,15)
WRITE(6,504) PRINT
504 FORMAT(1X,AXIAL HEIGHT=,F6.2, INCHES)
CALL PRIN(X)
250 CONTINUE
1PRINT=1PRINT+1
IF(1PRINT.GT.NOPRINT) GO TO 245
PRINT=PRINT(1PRINT)
GO TO 255
245 PRINT=(LENGTH(I1)+10.0
255 CONTINUE
IF(1PRINT.GT.LENGTH(I1)) GO TO 2000
GO TO 1000
2000 CONTINUE
1000 CONTINUE
7774 CONTINUE
STOP
END
SUBROUTINE PROP(TT)
COMMON/PROP1/RM0,CP,COND,CONGW,ALPHA
RM0=59.566-17.9504F-3)*TT-(0.2972F-6)*TT*TT+(0.06075E-9)*TT**3
CP=0.342071-17.07570F-4)*TT+(2.69171E-9)*TT*TT
COND=54.306-(1.878E-2)*TT+(2.89)4E-6)*TT*TT
ALPHA=COND/(RM0*CP)
CONGW=12.1
RETURN
END

```

APPENDIX B

DERIVATION OF LOCAL TEMPERATURE ERROR RELATION

From Figure 16, it can be seen that the energy balance in the absence of a mass balance for a corner subchannel and its two adjacent edge subchannels is given in explicit difference form by

$$\text{ENERGY IN} = \text{ENERGY OUT}$$

or

$$\begin{aligned} m_{T_1} C_p (T_1^J - T_R) + m_a C_p (T_0^J - T_R) + q''' A_a \Delta z \\ = m_{T_2} C_p (T_0^J - T_R) + m_a C_p (T_0^{J+1} - T_R) \end{aligned} \quad (B-1)$$

where

m_{T_1} = transverse flowrate into the subchannel group

m_{T_2} = transverse flowrate out of the subchannel group

m_a = subchannel axial mass flowrate

T_1^J = temperature of the upstream subchannel at axial level J

T_0^J = temperature of the subchannel group at axial level J

T_R = some reference temperature, taken here to be the bundle inlet temperature

q''' = volumetric heat generation rate

A_a = subchannel axial flow area

C_p = specific heat

Δz = axial mesh spacing

Rearranging (B-1) yields:

$$T_0^{J+1} - T_0^J = q'' \frac{A_a \Delta z}{C_p m_a} + \frac{m_{T1}}{m_a} (T_1^J - T_{R1}) - \frac{m_{T2}}{m_a} (T_0^J - T_R) \quad (B-2)$$

The axial temperature rise of the three adjoining subchannels from the inlet to the axial level J+1 is

$$\begin{aligned} (T_0^{J+1} - T_{IN}) \Big|_{\substack{\text{variable} \\ \text{swirl} \\ \text{model}}} &= T_0^J - T_{IN} + q'' \frac{A_a \Delta z}{C_p m_a} + \frac{m_{T1}}{m_a} (T_1^J - T_R) \\ &\quad - \frac{m_{T2}}{m_a} (T_0^J - T_R) \end{aligned} \quad (B-3)$$

If the constant swirl model is used

$$m_{T1} = m_{T2} = \bar{m}_T \quad (B-4)$$

and (B-3) becomes

$$(T_0^{J+1} - T_{IN}) \Big|_{\substack{\text{constant} \\ \text{swirl} \\ \text{model}}} = T_0^J - T_{IN} + q'' \frac{A_a \Delta z}{C_p m_a} + \frac{\bar{m}_T}{m_a} (T_1^J - T_0^J) \quad (B-5)$$

The local error in the temperature rise associated with the use of the variable swirl model without a mass balance is:

$$\Delta \epsilon = \frac{(T_0^{J+1} - T_{IN}) \Big|_{\text{var}} - (T_0^{J+1} - T_{IN}) \Big|_{\text{const.}}}{(T_0^{J+1} - T_{IN}) \Big|_{\text{const.}}} \quad (B-6)$$

or

$$\Delta \epsilon = \frac{\frac{T_1^J}{m_a} (m_{T1} - \bar{m}_T) - \frac{T_0^J}{m_a} (m_{T2} - \bar{m}_T) - \frac{T_R}{m_a} (m_{T1} - m_{T2})}{T_0^J - T_{IN} + q'' \frac{A_a \Delta z}{C_p m_a} + \frac{\bar{m}_T}{m_a} (T_1^J - T_0^J)} \quad (B-7)$$