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SAFE: A COMPUTER CODE FOR THE STEADY-STATE AND
TRANSIENT THERMAL ANALYSIS OF LMR FUEL ELEMENTS

by

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ABSTRACT

SAFE is a computer code developed for both the steady-state and transient thermal analysis of single LMR fuel elements. The code employs a two-dimensional control-volume based finite difference methodology with fully implicit time marching to calculate the temperatures throughout a fuel element and its associated coolant channel for both the steady-state and transient events.

The code makes no structural calculations or predictions whatsoever. It does, however, accept as input structural parameters within the fuel such as the distributions of porosity and fuel composition, as well as heat generation, to allow a thermal analysis to be performed on a user-specified fuel structure.

The code was developed with ease of use in mind. An interactive input file generator and material property correlations internal to the code are available to expedite analyses using SAFE.

This report serves as a complete design description of the code as well as a user's manual. A sample calculation made with SAFE is included to highlight some of the code's features. Complete input and output files for the sample problem are provided.

I. INTRODUCTION

Sophisticated fuel performance codes use fuel design and manufacturing information and in-reactor power histories to predict the coupled thermal and mechanical response of a fuel element, which includes both the fuel and its cladding. Such codes are generally applicable to a specific fuel system. For analyzing and predicting the behavior of metallic fuel elements, Argonne National Laboratory has developed LIFE-METAL[1] for steady-state analyses and FPIN2[2] for transient analyses.

Situations arise, however, in which only the thermal analysis of a fuel element is needed, and the use of a currently existing fuel performance code is unnecessarily sophisticated and/or time consuming. First, fuel designers who wish to investigate new fuel systems that differ significantly from current designs can make use of a less sophisticated code for performing the initial scoping calculations of thermal behavior. This is possible since designers look first to the expected thermal performance of a candidate fuel element design as the limiting issue, addressing mechanical phenomena such as restructuring, creep, swelling, fuel-clad mechanical interaction, etc., only if the design's thermal behavior appears acceptable. Second, fuel experimenters are required to demonstrate the safety of fueled experiments during steady-state irradiation and certain anticipated transients prior to approval of the experiment and its acceptance for insertion into the reactor (i.e., show by calculation that none of the fuel element components reach temperature limits during the transient event). Such safety calculations generally require only a thermal analysis of the fuel elements.

The SAFE (Scoping Analysis of Fuel Elements) fuel element heat transfer code was developed for use in these situations. It is a simple and easily used code capable of performing a two-dimensional steady-state or transient temperature calculation for a single fuel element. SAFE is not a fuel performance code; it makes no attempt to calculate the mechanical behavior of the fuel element; e.g., no estimation of

creep, swelling, porosity redistribution, or fuel component migration is made. However, SAFE can accept as input a user-defined microstructure to allow thermal calculations to be made for postulated fuel structures as part of a design study. SAFE can also perform transient temperature calculations from a given steady-state condition. Coolant flowrate, coolant inlet temperature and pin power can be defined as functions of time, providing the ability to simulate loss-of-flow, loss-of-heat-sink and transient overpower events. User-supplied fuel structural data remain constant during the transient, however, making SAFE inappropriate for transients during which significant restructuring occurs. Material properties (thermal conductivity, specific heat and density) of the system (coolant, cladding, bond and fuel) can be user-defined or implemented via empirical correlations internal to the code, providing flexibility. Although SAFE was designed with a particular interest in the analysis of metallic fuel elements employed as driver fuel and blanket elements in EBR-II and the conceptual Integral Fast Reactor (IFR), other fuel systems, cladding and coolant options may be analyzed with the code and are discussed in detail in the next section.

II. CODE FEATURES

SAFE is a single-pin, steady-state and transient thermal analysis code for use in scoping or design analyses of liquid metal reactor fuel elements. The internal material options, modeling options and transient capabilities of the code are summarized in this section.

A. Internal Material Properties

The material properties required by SAFE for a transient calculation are the thermal conductivity, specific heat and density of the system components, i.e., fuel, bond, cladding and coolant. For a steady-state calculation, only the thermal conductivity of the fuel element components is needed, but all three properties are still required for the coolant. To provide flexibility, SAFE can read as input interpolation tables for all of these properties as functions of temperature for each fuel element component as well as the coolant. To

reduce input requirement demands, however, the material property correlations needed to analyze a variety of liquid metal fast reactor fuel element types are included within the code and can simply be selected for use; the available materials are presented in the following subsections, and summarized in Table I.

TABLE I. Summary of Internal Material Property Correlations

Coolant	Cladding	Bond	Fuel
Li	SS-316	Li	U-Pu-Zr
Na	D9	Na	(U,Pu)O ₂
K	HT9	K	(U,Pu)N
NaK-78	Nb-1Zr	NaK-78	(U,Pu)C
		He	
		Ar	
		Kr	
		Xe	

1. Coolant

Material property correlations are internal to SAFE for four liquid metal coolants: lithium, sodium, potassium and NaK-78 (eutectic, 77.8 w/o potassium).

2. Cladding

Material property correlations are internal to SAFE for four cladding materials: SS-316, D9, HT9 and Nb-1Zr.

3. Bond

The bond materials for which material property correlations are available within SAFE include both liquid metal and gas bonds: lithium, sodium, potassium, NaK-78, helium, argon, krypton and xenon.

4. Fuel

Material property correlations are internal to SAFE for four general fuel systems: U-Pu-Zr, which includes U-Zr as well as pure U

and pure Zr as a subset; (U,Pu)O₂; (U,Pu)N and (U,Pu)C. No dependence of the fuel material properties is currently available as a function of Pu fraction for the (U,Pu)O₂, (U,Pu)N or (U,Pu)C systems; however, the Pu fraction is important for these systems for certain power distribution options.

B. Fuel-clad Gap Model Options

Two options for the treatment of the fuel-clad gap exist in SAFE. Most appropriate for liquid-metal bonds is the option to explicitly solve the energy equation within the bond (IGMODEL = 1). This option is also most appropriate for transient calculations in order to account for the thermal inertia of the bond material. This option can be used for gas bonds as well. Currently, however, no radiative heat transfer model is included within the gap, which may be important for gas bonds.

An additional option exists within SAFE to simply treat the gap as a thermal resistance (IGMODEL = 0). In this case, the user supplies a gap conductance to be used. Although this option gives the bond no thermal inertia during a transient, it may be useful in instances where gas conduction alone in the gap is not adequate, or as a way to implement a contact resistance when the fuel and cladding are in contact.

C. Fuel Modeling Capabilities

A number of features provide significant flexibility in analysis capability within the fuel. While SAFE does not attempt to predict any structural effects that occur in nuclear fuels, it allows a user to define a fuel structure and evaluates the thermal behavior of the fuel element based on that input structure. The features that make this possible are discussed in the following subsections.

1. Zones and Rings

Zones and rings allow the fuel structure to be defined by the user. The fuel is first subdivided into axial zones; within each axial zone, the fuel can be divided into radial rings. Figure 1 illustrates the way in which the fuel can be subdivided.

The user supplies the number of axial zones to be used in the fuel model, NAX. In Fig. 1, the fuel model has six axial zones ($NAX = 6$). The axial zones 2 through $NAX-1$ are of equal axial length Δz ; the top and bottom axial zones are $0, \Delta z$. The reason for these choices will become apparent in Sect. III. Indexing begins with $j = 1$ for the axial zone at the coolant inlet and runs to $j = NAX$ at the top of the fuel column. The user also supplies the number of radial rings to be used in the fuel model, NRINGS. In the example in Fig. 1, $NRINGS = 3$. Note that the specification of NRINGS applies to all axial zones. However, the ring boundaries can be specified independently within each axial zone. The indexing for the radial rings begins with $i = 1$ for the ring (actually solid cylinder) that includes the fuel center, and runs to $i = NRINGS$ for the outermost ring that includes the fuel surface. Within each ring, a number of parameters can be specified independently.

2. Assignable Fuel Structure Parameters

The purpose of setting up the axial zones and radial rings is to allow different fuel structure parameters to be assigned within each of these regions. Below is a list of the parameters that must be specified for each axial zone and within each radial ring, and the impact each specification has on the calculations.

- Fuel composition. This includes plutonium fraction, zirconium fraction (for the U-Pu-Zr fuel system), and U-235 enrichment (if $NRINGS > 1$). This information is used both for material property evaluation and for certain power distribution options discussed in a subsequent subsection.

Fig. 1. Example of Zones and Rings Within the Fuel

- Porosity. This is used both for material property adjustment and for certain power distribution options discussed in a subsequent subsection.
- Sodium logging fraction. This is used to adjust the fuel material properties for the effect of sodium-logged porosity.
- Porosity correction factor model. This option can be used to adjust the fuel thermal conductivity in a variety of ways for the effect of porosity and logged sodium.
- Power shape factor. This is used to modify an input average pin power.

3. Porosity Correction Factor Options

Several porosity correction factor options are available to adjust the fuel thermal conductivity for the effects of porosity within SAFE. The two generic porosity correction factor options are the Maxwell-Eucken[1] empirical relation (IPCF = 1) and that of Cunningham and Peddicord (IPCF = 4).[3] The Maxwell-Eucken relation performs well for lower porosities; for porosities above 20% and up to ~50%, the correction of Cunningham and Peddicord is recommended. An analytically-based porosity correction factor option that includes the effects of sodium logging is also provided (IPCF = 3).[4] Finally, the porosity correction factor of 0.7 that has been recommended for use with high burnup metallic fuel[1] can be requested (IPCF = 2), or no correction whatsoever may be applied (IPCF = 0).

4. Power Generation and Its Distribution

The user must supply an average pin power and the fraction of that power generated within the cladding; an axial power factor for each of the axial zones must also be supplied. Within each axial zone, power may be further distributed within the radial rings through the use of radial power factors. Three options exist for the radial distribution of power.

One of these options assumes that power is simply generated uniformly at a given fuel cross-section; in this case all of the radial power factors for a given fuel cross-section are set to 1 (IRPF = 1). Another option allows these radial power factors to be supplied as input by the user (IRPF = 2). Finally, the code can be requested to assign radial power factors to the rings in proportion to the area-weighted relative fissile isotope density (IRPF = 0). U-235 and Pu-239 are the two fissile isotopes considered. Using this option, the effects of relative fuel density (including porosity) within the radial ring structure on power production are included. The two fissile isotopes,

however, are considered to be neutronically equal with respect to both fission cross sections and energy liberation.

It is important to note that in order to assure that the effective pin power used in the calculation is the same as the average pin power supplied by the user as input, two conditions must hold. First, the average of the axial power factors must be unity. Second, for each axial zone, the area-weighted average of the radial power factors must be unity; this condition is guaranteed internal to the code for $IRPF = 0$.

D. Transient Capabilities

SAFE provides the capability to perform transient calculations with three time-dependent degrees of freedom: coolant flow rate, coolant inlet temperature and pin power. Independent control of these three time-dependent parameters enable the user to analyze the major classes of reactor accidents, including loss-of-flow, loss-of-heat-sink and transient over-power events.

III. NUMERICAL FORMULATION

SAFE employs a control-volume based energy balance to develop a discretized energy equation for the fuel element in both the radial and axial dimensions. Solution is achieved using Gauss-Seidel iteration. When performing a transient calculation, the fully-implicit methodology is employed for time marching. In this section, the governing discretization equations are derived, and their implementation and solution within SAFE is described.

A. Discretization of the Fuel Element

The fundamental system modeled by SAFE is a single cylindrical fuel element and its associated coolant channel. The coolant channel is an idealized or effective channel since, in general, no physical channel boundaries exist within subassemblies. A recommended approach to

determining the effective single coolant channel input parameters is given in Subsect. IV.C.3.

The fuel element and coolant channel is discretized as shown in Fig. 2 (a solid fuel column is shown in this figure, although annular fuel can be requested as well), where the solid squares represent nodes. The noding in the axial dimension is identical in all four radial regions of the system (fuel, gap, clad and coolant) and is indexed from bottom (or coolant inlet) to top beginning with $j = 1$ and running to $j = NAX$. Only one radial node is used in the coolant; the number of radial nodes used in the fuel (NNFUEL), gap (NNGAP) and clad (NNCLAD) can be specified independent of one another. For this reason, the noding in these three regions is maintained independently and runs from $n = 1$ on the far left (as shown in Fig. 2) boundary of each radial region up to the specified number of nodes on the far right boundary of each region.

B. DEVELOPMENT OF THE ENERGY EQUATIONS

The discretized form of the general energy equation employed within the fuel element is developed with the aid of Fig. 3. In this figure, the shaded rectangular region represents the control volume about node P for which an energy balance will be performed, along with its four adjacent control volumes. The adjacent nodes are labeled N, S, E and W; the control volume boundaries are labeled n, s, e and w. In the following discussion, use of the uppercase labels refer to nodal values, while lowercase labels refer to control volume boundary (interface) parameters. The development provided in the subsections below follows the methodology of Patankar.[5]

1. General Energy Balance

For application to heat transfer within a fuel element, the governing energy equation reduces to the heat conduction equation. The differential form of the heat conduction equation is:

Fig. 2. Discretization of the Fuel Element and Coolant Channel

$$\rho c \frac{\partial T}{\partial t} = \frac{1}{r} \frac{\partial}{\partial r} \left(r k \frac{\partial T}{\partial r} \right) + \frac{\partial}{\partial z} \left(k \frac{\partial T}{\partial z} \right) + Q, \quad (1)$$

where ρ is density, c is specific heat, k is thermal conductivity, Q is volumetric heat generation rate, t is time, and r and z are the radial and axial coordinates, respectively. Integration of Eq. (1) over a time interval Δt and the control volume shown in Fig. 3 yields a form of the energy equation more amenable to discretization:

Fig. 3. Control Volume for the General Energy Balance

$$\int_{sw}^{ne} \int_t^{t+\Delta t} \rho c (\partial T) r dr dz = \int_t^{t+\Delta t} \int_{sw}^{ne} \partial \left(r k \frac{\partial T}{\partial r} \right) dz dt + \int_t^{t+\Delta t} \int_{ws}^{en} \partial \left(k \frac{\partial T}{\partial z} \right) r dr dt + \int_t^{t+\Delta t} \int_{sw}^{ne} Q r dr dz dt \quad (2)$$

Evaluating the four integrals in Eq.(2) individually yields:

$$\int_{sw}^{ne} \int_t^{t+\Delta t} \rho c (\partial T) r dr dz = \rho p c_p \left(\frac{r_e^2 - r_w^2}{2} \right) \Delta z (T_p - T_p^0) \quad (3)$$

$$\int_t^{t+\Delta t} \int_{sw}^{ne} \partial \left(r k \frac{\partial T}{\partial r} \right) dz dt = \Delta z \Delta t \left[r_e k_e \frac{T_E - T_p}{\Delta r} - r_w k_w \frac{T_p - T_w}{\Delta r} \right] \quad (4)$$

$$\int_t^{t+\Delta t} \int_w^e \frac{\partial}{\partial z} \left(k \frac{\partial T}{\partial z} \right) r dr dt = \Delta t \left(\frac{r_e^2 - r_w^2}{2} \right) \left[k_n \frac{T_N - T_P}{\Delta z} - k_s \frac{T_P - T_S}{\Delta z} \right] , \quad (5)$$

$$\int_t^{t+\Delta t} \int_s^e Q r dr dz dt = \Delta z \Delta t \left(\frac{r_e^2 - r_w^2}{2} \right) Q_p . \quad (6)$$

The variables with a superscript 0 denote values from time t , while unsuperscripted variables denote values at time $t + \Delta t$. Properties and parameters with uppercase subscripts denote average control volume values; such properties are evaluated using nodal temperatures. Properties, namely thermal conductivity, with lowercase subscripts denote interface values. Harmonic means of nodal conductivities are employed for interface conductivities. As an example, the interface conductivity between control volumes E and P would be:

$$k_e = \frac{2k_E k_P}{k_E + k_P} . \quad (7)$$

When Eqs. (3) through (6) are substituted into Eq. (2) and arranged appropriately, the resulting energy equation has the form:

$$a_P T_P = a_E T_E + a_W T_W + a_N T_N + a_S T_S + b , \quad (8)$$

with the six coefficients defined as:

$$a_E = \frac{k_e r_e}{\Delta r} \Delta z , \quad (9)$$

$$a_W = \frac{k_w r_w}{\Delta r} \Delta z , \quad (10)$$

$$a_N = \left(\frac{r_e^2 - r_w^2}{2} \right) \frac{k_n}{\Delta z} . \quad (11)$$

$$a_s = \left(\frac{r_e^2 - r_w^2}{2} \right) \frac{k_s}{\Delta z} , \quad (12)$$

$$a_p^0 = \rho_p c_p \left(\frac{r_e^2 - r_w^2}{2} \right) \frac{\Delta z}{\Delta t} , \quad (13)$$

$$b = Q_p \left(\frac{r_e^2 - r_w^2}{2} \right) \Delta z + a_p^0 T_p^0 , \text{ and} \quad (14)$$

$$a_p = a_E + a_W + a_N + a_S + a_p^0 . \quad (15)$$

Equations (8) through (15) represent the general discretized energy equation applied to internal control volumes throughout the fuel, bond and cladding. For control volumes on region edges, such as the interface between the fuel and bond, a different energy balance is used. This energy balance is described in the next subsection.

2. Energy Balance at Material Interfaces

A different energy balance is used at material interfaces. Figure 4 shows "zero-width" and "half-width" control volumes employed at the fuel-bond boundary. Node P is a common node for the fuel and bond regions and lies on the interface of these two materials.

The energy equation is set up in each of the three material regions of the fuel element (fuel, bond and clad) and solved separately. Heat flux boundary conditions link the regions together. The heat flux within the bond at the bond-clad interface is used as a boundary condition for the energy equation within the cladding. The heat flux within the fuel at the fuel-bond interface is used as a boundary condition for the energy equation within the bond. A condition of symmetry is used at the fuel centerline.

Fig. 4. Control Volume for Energy Balances at Material Interfaces

Based on currently known fuel temperatures (i.e., temperatures from previous iteration), the heat flux within the fuel at the fuel-bond interface is:

$$q_p'' = k_w \frac{T_W - T_P}{\Delta r_1} . \quad (16)$$

This assumed known heat flux is used as a boundary condition for the energy equation within the bond:

$$q_p'' = k_e \frac{T_P - T_E}{\Delta r_2} . \quad (17)$$

which yields the discretization equation needed for control volume P in the bond. Using the form of Eq. (8), the coefficients for a control volume at a material interface are defined as:

$$a_W = \frac{k_W}{\Delta r_1} \text{ and } a_E = \frac{k_E}{\Delta r_2} \quad (18)$$

$$a_N = a_S = a_P^0 = 0 , \quad (19)$$

$$b = 0 , \quad (20)$$

and the definition of a_P remains the same as that given in Eq. (15). This discretization is applied within the bond for the control volume at the fuel-bond interface and within the cladding for the control volume at the bond-clad interface. Within the fuel, the fuel surface temperature is known from the solution for temperatures within the bond of the previous iteration cycle. Likewise the bond-clad interface temperature is assumed known from the solution for temperatures within the clad of the previous iteration cycle.

The cladding outer surface temperature is obtained from an energy balance involving the coolant. The conduction heat flux within the cladding at the cladding coolant interface is computed based upon current estimates of the nodal temperatures as:

$$q_p'' = k_W \frac{T_W - T_P}{\Delta r_{clad}} . \quad (21)$$

This conduction heat flux is equal to the convection heat flux between the cladding and coolant, given as:

$$q_p'' = h(T_P - T_\infty) . \quad (22)$$

where h is the film convective heat transfer coefficient and the subscript ∞ denotes the coolant. Equating Eqs. (21) and (22) and arranging into the form of Eq. (8) yields a boundary condition at the cladding outer surface for the discretized energy equation within the cladding, with the coefficients defined as:

$$a_E = a_N = a_S = a_P^0 = 0 . \quad (23)$$

$$a_W = \frac{k_w}{\Delta r_{clad}} . \quad (24)$$

$$b = hT_\infty , \text{ and} \quad (25)$$

$$a_P = h + \frac{k_w}{\Delta r_{clad}} . \quad (26)$$

The convective heat transfer coefficient can be defined as input by the user or calculated by the code using the Lyon-Martinelli correlation [6].

3. Energy Balance in the Coolant

The cladding outer surface temperature is obtained from a radial energy balance with the coolant, as described in the previous subsection. An energy balance within the coolant is required to compute the coolant bulk temperature axially up the channel. Figure 5 shows a typical coolant control volume for performing the required energy balance.

In Fig. 5, control volume S is shown as a "half-width" control volume. Node S corresponds to the coolant inlet. Thus, its temperature is known. The energy balance on control volume P is:

$$q''_{clad} \cdot \pi D \Delta z = \dot{m} c (T_P - T_S) . \quad (27)$$

where the left-hand side of Eq. (27) is the total heat out of a cladding axial zone, and the right-hand side is the total heat transported by the coolant; D is the clad outer diameter and $\dot{m}$ is the coolant mass flow rate. With T_P known, T_N can be computed in an identical manner, thus marching up the coolant channel. Of course, the heat flux from the

cladding is known only approximately, requiring iteration to achieve the solution.

Fig. 5. Coolant Control Volume

As indicated by Eq. (27), only an energy balance is performed on the coolant. Momentum effects within the coolant are not addressed. Such a simple energy balance provides an adequate analysis for a wide variety of situations. Some error must be expected, however, in situations where momentum effects are significant, such as wire-wrapped fuel elements on the periphery of a subassembly where the component of flow moving in a transverse direction (swirl flow) can be considerable.

C. Solution Procedure

The previous subsections developed the discretized energy equations for all of the unique portions of the fuel element and its

coolant channel. The values of many of the parameters assumed known are not truly known. Estimates of these parameters, however, can be made; overall convergence of the solution can be obtained by iteratively re-evaluating all of the unknown quantities. The method SAFE uses to go about this process is outlined in this section. Figure 6 symbolically illustrates the solution procedure described in the following paragraphs.

When the solution procedure begins, the coolant inlet temperature, coolant flow rate, and power throughout the fuel are known. Physically reasonable temperatures are guessed throughout the fuel element and coolant to allow sensible evaluations of material properties. With the coolant inlet temperature known, the energy equations can be constructed for the bottom axial zone, $j = 1$. This begins by setting up and solving the energy equation at a constant axial elevation first in the cladding, then the bond, and finally the fuel. The Thomas algorithm, an optimized Gaussian elimination procedure, is used to obtain the radial temperature profile within the fuel element for this axial elevation. Axial conduction components from the adjacent control volumes above at $j = 2$, which are dependent upon unknown but estimated nodal temperatures at $j = 2$, are nevertheless assumed known and lumped in with the source term.

With this new estimate for the nodal temperatures at $j = 1$, the heat flux into the coolant is re-evaluated and used to estimate the coolant temperature at the next higher axial elevation, $j = 2$. With the coolant temperature "known" at this elevation, the radial temperature profile is obtained as before. Again the axial conduction terms are estimated and lumped into the source term. Note, however, that the axial conduction estimates from below, $j = 1$, are "better" than those from above, $j = 3$. This basic procedure is repeated until the top of the fuel element is reached.

When the top of the fuel element is reached, all of the nodal temperatures within the fuel and cladding are improved estimates relative to the initial guessed temperatures, but they probably do not represent the true solution. Each of the nodal temperatures are

Fig. 6. Solution Flow Diagram for SAFE

Fig. 6. (Contd.)

Fig. 6. (Contd.)

compared with the temperatures from the previous iteration cycle (in this first case, with the guessed temperatures). If the maximum nodal temperature difference is greater than a user-supplied error criterion (something like $\epsilon = 10^{-4}$), the solution is considered unconverged. New temperature estimates are obtained using the above procedure all over again. This process is repeated until the new estimates for nodal temperatures cease to change by more than ϵ per iteration. At this point, the temperature solution for time t is assumed converged.

If the calculation is for a user-supplied transient, the time is incremented to $t + \Delta t$. The coolant inlet temperature and flow rate, and the pin power are changed to their appropriate values for the new time, and iteration for the new nodal temperatures at time $t + \Delta t$ is begun as before. This time-marching procedure is repeated until the entire transient calculation is completed.

IV. INPUT REQUIREMENTS

This section describes all of the input data and files, including the file formats, required to make a calculation using SAFE.

A. Required Files

A minimum of two, and a maximum of three, input files are required for SAFE calculations. First is the control file, named SAFE.CONTROL. This file contains the information needed to define the node structure for the calculation, solution relaxation parameters, and the solution convergence criterion. This file is required for all calculations. Since this information changes infrequently or not at all, however, the same control file can be used for most calculations. It is provided primarily to allow convergence studies to be performed, or so that relaxation factors may be altered for transient calculations that exhibit convergence difficulties.

Second, a general input file named INPUT is required for all calculations. This file contains all of the remaining information

needed for a steady-state calculation. Third, an input file containing the transient forcing functions is required for transient calculations. The formats required for these files are explained in the following subsections.

B. File Formats

Since the amount of data contained within the required input files is generally small, all three files employ unformatted READ statements except for a few instances where text is involved. Numerical variables are typed implicitly. The metric system of units is used for all of the required input data.

1. Control File

The control file must be named SAFE.CONTROL, and is structured as follows:

INPUT 1: NNCLAD, NNGAP, NNFUEL

- NNCLAD - Number of radial nodes to be used in the clad.
- NNGAP - Number of radial nodes to be used in the fuel-clad gap/bond.
- NNFUEL - Number of radial nodes to be used in the fuel.

INPUT 2: TDENSC, TDENSB, TDENSE

- TDENSC - Temperature at which clad density is evaluated (K).
- TDENSE - Temperature at which fuel density is evaluated (K).

INPUT 3: ERROR

- ERROR - Error criterion for convergence of nodal temperatures.

INPUT 4: WCOOL, WC, WG, WF

- WCOOL - Relaxation factor for temperature estimation in coolant.
- WC - Relaxation factor for temperature estimation in cladding.
- WG - Relaxation factor for temperature estimation in fuel-clad gap (bond).
- WF - Relaxation factor for temperature estimation in fuel.

2. General Input File

The general input file must be named INPUT. The input file is logically partitioned into six groups: 1) control information, 2) calculation description, 3) coolant information, 4) cladding information, 5) gap/bond information, and 6) fuel information. The file format is as follows:

INPUT 1: ICALC, IPLOT

- ICALC - Calculation selection option,
 - 0 Steady-state calculation,
 - 1 Transient calculation.
- IPLOT - Plot file construction option,
 - 0 Do not generate plot files,
 - 1 Generate plot files.

INPUT 2.1: TRANS (FORMAT A20)

* * Optional Input if ICALC=1 * *

- TRANS - Name of transient input file.

INPUT 2.2: TITLE(I): I=1,5 (FORMAT A75)

- TITLE(I) - Alphanumeric text string descriptive of the problem to be run.

INPUT 3.1: ICOOL, TINLET(1), FLOWRATE, AREA, IHTC

- ICOOL - Coolant properties option,
 - 10 Use internal correlations for lithium properties,
 - 11 Use internal correlations for sodium properties,
 - 12 Use internal correlations for potassium properties,
 - 13 Use internal correlations for NaK (78 w/o K) properties,
 - 19 User will supply coolant properties.
- TINLET(1) - Coolant inlet temperature (K).
- FLOWRATE - Coolant volumetric flow rate (cm³/sec).
- AREA - Cross-sectional area of coolant flow channel (cm²).
- IHTC - Coolant film heat transfer coefficient option,
 - 0 Use internal correlation (Lyon-Martinelli),
 - 1 User will supply value of heat transfer coefficient.

INPUT 3.2: HTC
 * * Optional Input if IHTC=1 * *
 HTC - Coolant film heat transfer coefficient ($\text{W}/\text{cm}^2\text{-K}$).
INPUT 3.3: NSK
 * * Optional Input if IC00L=19 * *
 NSK - Number of entries in the coolant thermal conductivity
 interpolation table.
INPUT 3.4: TSK(I), SK(I); I=1.NSK
 * * Optional Input if IC00L=19 * *
 TSK(I) - Temperature for entry I in coolant thermal
 conductivity interpolation table (K).
 SK(I) - Thermal conductivity for entry I in coolant thermal
 conductivity interpolation table ($\text{W}/\text{cm-K}$).
INPUT 3.5: NSD
 * * Optional Input if IC00L=19 * *
 NSD - Number of entries in the coolant density interpolation
 table.
INPUT 3.6: TSD(I), SD(I); I=1.NSD
 * * Optional Input if IC00L=19 * *
 TSD(I) - Temperature for entry I in coolant density
 interpolation table (K).
 SD(I) - Density for entry I in coolant density interpolation
 table (g/cm^3).
INPUT 3.7: NSC
 * * Optional Input if IC00L=19 * *
 NSC - Number of entries in the coolant specific heat
 interpolation table.
INPUT 3.8: TSC(I), SC(I); I=1.NSC
 * * Optional Input if IC00L=19 * *
 TSC(I) - Temperature for entry I in coolant specific heat
 interpolation table (K).
 SC(I) - Specific heat for entry I in coolant specific heat
 interpolation table (g/cm^3).
INPUT 4.1: ICLAD, CLADRO, CLADT
 ICLAD - Cladding properties option,
 = 1 Use internal correlations for SS-316 properties,

- 2 Use internal correlations for D9 properties,
- 3 Use internal correlations for HT9 properties,
- 4 Use internal correlations for Nb-1w/oZr properties,
- 9 User will supply cladding properties.

CLADRO = Cladding outer radius (cm).

CLADT = Cladding thickness (cm).

INPUT 4.2: FPC

FPC = Fraction of total pin power generated in cladding.

INPUT 4.3: NCK

* * Optional Input if ICLAD=9 * *

NCK = Number of entries in the cladding thermal conductivity interpolation table.

INPUT 4.4: TCK(I), CK(I); I=1,NCK

* * Optional Input if ICLAD=9 * *

TCK(I) = Temperature for entry I in cladding thermal conductivity interpolation table (K).

CK(I) = Thermal conductivity for entry I in cladding thermal conductivity interpolation table (W/cm-K).

INPUT 4.5: NCD

* * Optional Input if ICLAD=9 * *

NCD = Number of entries in the cladding density interpolation table.

INPUT 4.6: TCD(I), CD(I); I=1,NCD

* * Optional Input if ICLAD=9 * *

TCD(I) = Temperature for entry I in cladding density interpolation table (K).

CD(I) = Density for entry I in cladding density interpolation table (g/cm³).

INPUT 4.7: NCC

* * Optional Input if ICLAD=9 * *

NCC = Number of entries in the cladding specific heat interpolation table.

INPUT 4.8: TCC(I), CC(I); I=1,NCC

* * Optional Input if ICLAD=9 * *

TCC(I) = Temperature for entry I in cladding specific heat interpolation table (K).

CC(I) - Specific heat for entry I in cladding specific heat interpolation table (g/cm^3).

INPUT 5.1: IGMODEL

IGMODEL - Fuel-clad gap (bond) modeling option,
- 0 User will supply a value for the gap conductance,
- 1 Explicitly solve energy equation in gap.

INPUT 5.2: HGAP

* * Optional Input if IGMODEL=0 * *

HGAP - Fuel-clad gap thermal conductance ($\text{W/cm}^2\text{-K}$).

INPUT 5.3: IGAP

* * Optional Input if IGMODEL=1 * *

IGAP - Fuel-clad gap (bond) properties option,
- 10 Use internal correlations for lithium properties,
- 11 Use internal correlations for sodium properties,
- 12 Use internal correlations for potassium properties,
- 13 Use internal correlations for NaK (78 w/o K) properties,
- 30 Use internal correlations for helium properties,
- 31 Use internal correlations for argon properties,
- 32 Use internal correlations for krypton properties,
- 33 Use internal correlations for xenon properties,
- 39 User will supply bond properties.

INPUT 5.4: PRESS

* * Optional Input if $30 \leq \text{IGAP} < 39$ * *

PRESS - Pressure of bond gas in gap (Pa).

INPUT 5.5: NBK

* * Optional Input if IGAP=39 * *

NBK - Number of entries in the bond thermal conductivity interpolation table.

INPUT 5.6: TBK(I), BK(I); I=1,NBK

* * Optional Input if IGAP=39 * *

TBK(I) - Temperature for entry I in bond thermal conductivity interpolation table (K).

BK(I) - Thermal conductivity for entry I in bond thermal conductivity interpolation table (W/cm-K).

INPUT 5.7: NBD
 * * Optional Input if IGAP=39 * *
 NBD - Number of entries in the bond density interpolation
 table.

INPUT 5.8: TBD(I), BD(I); I=1,NBD
 * * Optional Input if IGAP=39 * *
 TBD(I) - Temperature for entry I in bond density interpolation
 table (K).
 BD(I) - Density for entry I in bond density interpolation
 table (g/cm³).

INPUT 5.9: NBC
 * * Optional Input if IGAP=39 * *
 NBC - Number of entries in the bond specific heat
 interpolation table.

INPUT 5.10: TBC(I), BC(I); I=1,NBC
 * * Optional Input if IGAP=39 * *
 TBC(I) - Temperature for entry I in bond specific heat
 interpolation table (K).
 BC(I) - Specific heat for entry I in bond specific heat
 interpolation table (g/cm³).

INPUT 6.1: IFUEL, FRADIUS, FLEN, IANN, IZBC
 IFUEL - Fuel properties option,
 - 20 Use internal correlations for the U-Pu-Zr metallic
 fuel system,
 - 21 Use internal correlations for the (U,Pu)O₂ fuel
 system,
 - 22 Use internal correlations for the (U,Pu)N fuel system,
 - 23 Use internal correlations for the (U,Pu)C fuel system,
 - 29 User will supply fuel properties.
 FRADIUS - Fuel outer radius (cm).
 FLEN - Fuel column length (cm).
 IANN - Fuel type option,
 - 0 Solid fuel slug/pellet,
 - 1 Annular fuel slug/pellet.
 IZBC - Axial boundary condition option,
 - 0 No axial heat transfer at z=0,FLEN,

- 1 Temperature will be specified at $z=0, FLEN$.

INPUT 6.2: FIR
 * * Optional Input if $IANN=1$ * *

 FIR - Fuel inner radius for annular fuel (cm).

INPUT 6.3: IZBOT, TZTOP
 * * Optional Input if $IZBC=1$ * *

 TZBOT - Specified temperature at fuel bottom, $z=0$ (K).

 TZTOP - Specified temperature at fuel top, $z=FLEN$ (K).

INPUT 6.4: NFK
 * * Optional Input if $IFUEL=29$ * *

 NFK - Number of entries in the fuel thermal conductivity
 interpolation table.

INPUT 6.5: TFK(I), FK(I); I=1,NFK
 * * Optional Input if $IFUEL=29$ * *

 TFK(I) - Temperature for entry I in fuel thermal conductivity
 interpolation table (K).

 FK(I) - Thermal conductivity for entry I in fuel thermal
 conductivity interpolation table (W/cm-K).

INPUT 6.6: NFD
 * * Optional Input if $IFUEL=29$ * *

 NFD - Number of entries in the fuel density interpolation
 table.

INPUT 6.7: TFD(I), FD(I); I=1,NFD
 * * Optional Input if $IFUEL=29$ * *

 TFD(I) - Temperature for entry I in fuel density interpolation
 table (K).

 FD(I) - Density for entry I in fuel density interpolation
 table (g/cm^3).

INPUT 6.8: NFC
 * * Optional Input if $IFUEL=29$ * *

 NFC - Number of entries in the fuel specific heat
 interpolation table.

INPUT 6.9: TFC(I), FC(I); I=1,NFC
 * * Optional Input if $IFUEL=29$ * *

 TFC(I) - Temperature for entry I in fuel specific heat
 interpolation table (K).

FC(I) - Specific heat for entry I in fuel specific heat interpolation table (g/cm³).

INPUT 6.10: QL

QL - Fuel element average linear heat rate (W/cm).

INPUT 6.11: NAX, NRINGS, IRPF

NAX - Number of fuel axial zones.

NRINGS - Number of fuel radial rings.

IRPF - Radial power factor option.

- 0 Radial power factors calculated to be proportional to relative fissile isotope density.
- 1 Uniform power production across fuel cross-section.
- 2 User will supply radial power factors.

INPUT 6.12: J, AXP(J) [CR]
 I, RR(J,I), P(J,I), BETA(J,I), PCF(J,I), ENRICH(J,I),
 WZR(J,I), WPU(J,I); J=1,NAX; I=1,NRINGS

* * Optional Input if IFUEL=20 and 0≤IRPF≤1 * *

J - Axial fuel zone number.

AXPF(J) - Axial power factor for zone J.

I - Radial fuel ring number.

RR(J,I) - Relative radius (fraction of fuel radius) of outer boundary of ring I in axial zone J.

P(J,I) - Volume fraction porosity of ring I in axial zone J.

BETA(J,I) - Fraction of porosity logged with sodium for ring I in axial zone J.

PCF(J,I) - Porosity correction factor model option used for ring I in axial zone J,

- 0 Do not apply a correction for porosity,
- 1 Maxwell-Eucken correction formula used with $\beta=1.7$,
- 2 Correction factor of 0.7 used, recommended for high-burnup metallic fuel,
- 3 Bauer Na-logged fuel correction formula used,
- 4 Cunningham and Peddicord correction formula used.

ENRICH(J,I) - Enrichment fraction for U-235 in uranium.

WZR(J,I) - Zirconium weight fraction in fuel for ring I in axial zone J.

WPU(J,I) - Plutonium weight fraction in fuel for ring I in axial zone J.

INPUT 6.13: J, AXP(J) [CR]
I, RR(J,I), P(J,I), BETA(J,I), PCF(J,I), ENRICH(J,I),
WZR(J,I), WPU(J,I), RPF(J,I); J=1,NAX; I=1,NRINGS
 * * Optional Input if IFUEL=20 and IRPF=2 * *

RPF(J,I) - Radial power factor for ring I in zone J.
 (Other variables as defined in INPUT 6.12)

INPUT 6.14: J, AXP(J) [CR]
I, RR(J,I), P(J,I), PCF(J,I), WPU(J,I); J=1,NAX;
I=1,NRINGS
 * * Optional Input if 20<IFUEL≤29 and 0≤IRPF≤1 * *

WPU(J,I) - Plutonium mol fraction in fuel for ring I in axial zone J.
 (Other variables as defined in INPUT 6.12)

INPUT 6.15: J, AXP(J) [CR]
I, RR(J,I), P(J,I), PCF(J,I), WPU(J,I) RPF(J,I);
J=1,NAX; I=1,NRINGS
 * * Optional Input if 20<IFUEL≤29 and IRPF=2 * *

WPU(J,I) - Plutonium mol fraction in fuel for ring I in axial zone J.

RPF(J,I) - Radial power factor for ring I in zone J.
 (Other variables as defined in INPUT 6.12)

3. Transient Input File

The transient input file can have any name, and is structured as follows:

INPUT 1: NTS, NTSS

NTS - Total number of time steps in the calculation.

NTSS - Number of time sub-steps into which each time step should be subdivided.

INPUT 2.1: 1, 0.0, 1.0, 1.0, TINLET(1)

TINLET(1) - Initial, steady-state coolant inlet temperature (K).

INPUT 2.2: N, TIME(N), FLOW(N), POWER(N), TINLET(N); N=2,NTS+1

 N - Time step number.

 TIME(N) - Time of time step N (sec).

 FLOW(N) - Ratio of coolant flow rate at TIME(N) to flow rate at
 t = 0.

 POWER(N) - Ratio of pin power at TIME(N) to pin power at t = 0.

 TINLET(N) - Coolant inlet temperature at TIME(N) (K).

C. Suggestions and Recommendations

Most of the input data and model options required as input for SAFE calculations are straightforward. A few, however, warrant some suggestions, recommendations and/or cautions for effective use of the code as an analysis tool. These are discussed in the following subsections.

1. Noding Advice

The axial noding of the fuel element and coolant channel is accomplished via specification of the number of axial fuel zones, NAX. There are the same number of axial nodes as there are fuel zones. Thus, even if the same fuel specifications are desired axially throughout the fuel, enough axial zones to describe the axial power shape and allow for adequate resolution of axial heat conduction are needed. This axial mesh can be fairly coarse in many cases, since axial heat conduction in a fuel element is typically small. An axial node every 1 to 1.5 cm is recommended as a minimum. A maximum of 200 axial zones (and nodes) are allowed.

The radial noding of the cladding, gap, and fuel is controlled by specification of NNCLAD, NNGAP and NNFUEL within the control file SAFE.CONTROL. At least three nodes must be requested in each of these material regions; many more are generally needed. Since the heat transfer coupling between the coolant, clad, bond, and fuel is accomplished via heat flux calculations at each material interface, a radial mesh in each material that can adequately resolve these heat

fluxes is required. Obviously, more nodes are needed in the fuel than in the cladding or bond; since the fuel-clad gap is generally small, the bond usually needs the fewest nodes. A maximum of 500 radial nodes are allowed in each material region.

A final consideration is needed when determining the number of nodes needed in the fuel. The fuel nodes are equally spaced within the fuel with no regard to the ring structure defined by the user. If very narrow rings are defined, and few nodes specified in the fuel, it is possible that no nodes (or very few nodes) would lie within such a ring. This must be avoided! The internodal spacing in the fuel should be significantly less than the width of the narrowest fuel ring.

2. Fuel-clad Gap

As mentioned in a previous section, two gap modeling options exist within SAFE. A user-supplied gap conductance may be used to treat the gap as a simple thermal resistance (IGMODEL = 0). This option is recommended for gas bonds. Although this option gives the bond no thermal inertia during a transient, it may be useful in instances where gas conduction alone in the gap is not adequate, or as a way to implement a contact resistance when the fuel and cladding are in contact.

More appropriate for liquid-metal bonds is the option to explicitly solve the energy equation within the bond (IGMODEL = 1). This option is also more appropriate for transient calculations to account for the thermal inertia of the bond material, although such inertia is typically small. This option can be used for gas bonds as well. Currently, however, no radiative heat transfer model is included within the gap, which may be important for gas bonds.

3. Single-pin Effective Flow Area and Flow Rate

A SAFE calculation is performed for a single fuel element and its effective coolant channel. In reality, a fuel element exists in

a reactor as part of a subassembly containing many fuel elements. The subassembly flow area and coolant flow rate are generally known. For a SAFE calculation the user must determine the single-pin effective flow area and flow rate based on these values for the subassembly as a whole. The procedure recommended for estimating the effective single-pin values is described in this subsection.

The primary consideration when defining single-pin coolant channels is that no overlap occurs, especially if one is to make calculations for more than one element in a subassembly. Figure 7 shows the single-pin coolant channels defined for wire-wrapped elements in a triangular array. Three variations exist for internal pins, pins on one of the hex duct flats (edge), and pins in a corner of the hex duct. In each case, the flow area is the area of the coolant channel indicated by the dashed line less the cross-sectional area of the fuel element and wire(s) included within the dashed coolant channel. The effective coolant flow rate is calculated as the subassembly flow rate multiplied by the ratio of the single-pin flow area to the subassembly flow area.

This way of computing the single-pin effective flow area and flow rate for input to SAFE has been applied with reasonable success. Excellent results are generally obtained for internal pins. Results for edge and corner pins are typically less accurate; this decreased accuracy for pins on the periphery of the subassembly, however, is due at least in part to coolant momentum effects from swirl flow.

4. Time-step Size

Marching through a transient calculation is controlled by two parameters: the time-step size and the number of time-substeps. The time steps are defined by the user in the transient input file. Enough time steps are required to adequately describe the variation of power, flow and inlet temperature during the transient. If the time steps are too large for the variation of conditions during the time step, the calculation may diverge. Alternatively, although the implicit formulation used for time marching in SAFE does not have a minimum time

Fig. 7. Recommended Single-pin Flow Areas for (a) Internal Pin, (b) Edge Pin, and (c) Corner Pin

step size criterion for convergence, the time steps may not be fine enough to make an accurate calculation, even if the solution converges.

No general rule for the time-step sizes can be prescribed. The change in the solution with time-step refinement should always be analyzed for transient calculations. Rather than manually entering more time steps, one should increase the value of NTSS, the number of timesubsteps, within the transient input file. Each time step for a transient calculation is further subdivided linearly into NTSS "time substeps" internally within SAFE. No information regarding the solution at these time substeps is provided in the output file.

D. Interactive Input File Generator

To expedite the process of creating the general input file, INPUT, needed for any calculation using SAFE, the interactive input file generator CREATE has been developed. CREATE constructs the general input file based upon answers to questions supplied by the user during an interactive session. For most queries, CREATE shows a popular default value that can be selected with no required entry to further reduce session time. Not every option available within SAFE is queried during a CREATE session; rarely changed values or options included in SAFE primarily for benchmarking purposes are automatically set to their most appropriate values. The user can always edit the INPUT file for small such changes, however, after CREATE has generated the INPUT file.

In addition to speeding up the process of creating the INPUT file and assuring its format is correct, CREATE has several features that aid in determining the values of certain input parameters as well. The three most important are for the effective coolant cross-sectional flow area (AREA), the effective coolant flow rate (FLOWRATE), and the axial power factors [AXPF(J)]. CREATE internally computes the flow area and flowrate based on input flow and geometry data for the entire subassembly (information readily available) using the methodology described in the previous subsection; it also contains internal correlations for axial power profiles for locations in specific

reactors, and can automatically compute the required axial power factors. While SAFE can stand alone, the input file generator CREATE is a powerful tool for expediting analyses using SAFE.

V. CODE OUTPUT

Either two or four files are created during a SAFE execution. Two output files, one in metric units and one in English units, are always created. If plot files were requested within the general input file (IPLLOT = 1), two plot files are created, one in metric units and one in English units. These files are described in this section.

A. Output Files

Two identical output files, one in metric units and one in English units, are created during a SAFE calculation. These files will be named OUTPUT.METRIC and OUTPUT.ENGLISH. An example of the output file in metric units for a sample problem can be found in APPENDIX D.

The output file is organized into three sections. First is a presentation of the input data for the calculation along with a few preliminary calculations such as node spacing, total pin power, coolant velocity, gap width, etc. The second section presents the results of the calculation for each time step. The temperatures are given for each axial zone defined as input, and the following radial positions: coolant bulk temperature (TCOOL), clad outer temperature (TCO), clad inner temperature (TCI), fuel surface temperature (TS), and finally the temperatures at the interfaces of radial rings. These interfacial temperatures are labeled as $T(I+1,I)$, denoting the interface between radial rings $I+1$ and I ; $T(1,0)$ is the fuel centerline temperature for solid fuel, or the temperature of the fuel inner radius for annular fuel. The third section summarizes the maximum temperatures for the coolant, cladding and fuel for each time step.

B. Plot Files

If requested (IPLOT = 1), two plot files are created during a SAFE calculation, one in metric units and one in English units. The files will be named PLOT.METRIC and PLOT.ENGLISH. For a steady-state calculation, the plot files contain the axial temperature profiles within the fuel element arranged in six columns: (1) elevation measured from coolant inlet, (2) coolant bulk temperature, (3) clad outer temperature, (4) clad inner temperature, (5) fuel surface temperature, and (6) fuel centerline (solid) or inner radius (annular) temperature. For a transient calculation, the plot files contain the maximum temperatures for each time step arranged in six columns: (1) time, (2) maximum coolant temperature, (3) maximum clad outer temperature, (4) maximum clad inner temperature, (5) maximum fuel surface temperature, and (6) maximum fuel centerline (solid) or inner radius (annular) temperature. For metric units, cm and °C are employed; for English units, inches and °F are used. Time is measured in seconds.

VI. SUMMARY AND CONCLUSIONS

The SAFE code was developed for the transient thermal analysis of LMR fuel elements. The code employs a two-dimensional control-volume based finite difference methodology with fully implicit time marching.

SAFE is capable of performing steady-state and transient calculations. Transients are user-defined, with coolant inlet temperature, flow rate, and pin power allowed to vary with time. This makes possible calculations for the major classes of transients: loss-of-heat-sink, loss-of-flow, and transient-overpower events. This transient capability also makes SAFE ideal for performing the safety analyses required of fueled experiments before being placed in-reactor.

Only a thermal analysis, i.e., the calculation of temperatures throughout the cladding, bond, fuel, and coolant channel of a single fuel element, is performed. No mechanical or structural calculations are made. However, structural parameters within the fuel such as the

distributions of fuel composition and porosity (including sodium logging), as well as heat generation is accepted as input for a SAFE calculation. This allows a thermal analysis to be performed on an observed or postulated fuel element structure.

SAFE was developed with both designers and experimenters in mind. To enhance its ease of use, it comes complete with an interactive input file generator so that one need never edit an input file in order to develop and run a SAFE calculation. In this same spirit, material property correlations for a variety of LMR fuel element systems (including the metallic, oxide, nitride and carbide fuels) are included internally within the code to be selected for use in a calculation. Such features make analyses using the code easier and less time consuming than using a sophisticated fuel performance code.

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APPENDIX A. SUBROUTINE DESCRIPTIONS

Function COND (TEMP,IMAT,ZR,PU,POR,IPCF,XNA)

COND is an internal function that either computes thermal conductivity from empirical correlations or interpolates a value from user-supplied thermal conductivity data. For porous fuel, the required porosity correction factor is also calculated within COND. The arguments are defined as:

- TEMP - temperature (K),
- IMAT - material specification identifier,
- ZR - weight fraction Zr,
- PU - weight or mol fraction Pu,
- POR - volume fraction porosity,
- IPCF - porosity correction factor model option identifier, and
- XNA - fraction of porosity logged with liquid metal bond.

ZR, PU, POR, IPCF and XNA are only meaningful if IMAT corresponds to a fuel system. COND is called from program SAFE and subroutine HTCoeff.

Function CP (TEMP,IMAT,ZR,PU,POR,XNA)

CP is an internal function that either computes specific heat from empirical correlations or interpolates a value from user-supplied specific heat data; theoretical values are used for the specific heats of gases. The arguments are defined as for function COND. ZR, PU, POR and XNA are only meaningful if IMAT corresponds to a fuel system. CP is called from program SAFE and subroutine HTCoeff.

Function DENS (TEMP,IMAT,ZR,PU,POR,XNA,PRESS)

DENS is an internal function that either computes density from empirical correlations or interpolates a value from user-supplied density data; gas densities are computed from the ideal gas equation of state. The common arguments are defined as for function COND, with PRESS being the bond pressure (Pa). ZR, PU, POR and XNA are only meaningful if IMAT corresponds to a fuel system; PRESS is meaningful

only if IMAT corresponds to a gas. DENS is called from program SAFE and subroutines HTCoeff and RADIALPF.

Subroutine HTCoeff (ICOOL,VEL,HDIAM,TEMP,HTC)

HTCOEFF computes the film convective heat transfer coefficient between the coolant and cladding from the Lyon-Martinelli correlation. The arguments are defined as:

ICOOL - coolant material identifier,
VEL - coolant velocity (cm/s),
HDIAM - coolant channel hydraulic diameter (cm²),
TEMP - coolant bulk temperature (K), and
HTC - film convective heat transfer coefficient (W/cm²-K).

HTCOEFF is called from program SAFE.

Subroutine MATERIAL (ICOOL,ICLAD,IGAP,IFUEL,COOLANT,TYPE,BOND,FUEL)

MATERIAL assigns the names of the selected materials to the coolant and fuel element components. The arguments are defined as:

ICOOL - coolant material identifier,
ICLAD - cladding material identifier,
IGAP - gap/bond material identifier,
IFUEL - fuel material identifier,
COOLANT - text variable holding name of coolant,
TYPE - text variable holding name of cladding,
BOND - text variable holding name of bond, and
FUEL - text variable holding name of fuel.

MATERIAL is called from program SAFE.

Subroutine RADIALPF (NAX,NRINGS,IFUEL,IRPF,DELL,FRADIUS,FIR,RR,P,ENRICH,WPU,WZR,RPF)

RADIALPF assigns the radial power factors to all the fuel rings if IRPF = 0 or 1. If IRPF = 0, the radial power factors for each axial zone are computed to be proportional to the area-weighted concentration

of fissile material contained within each radial ring. The arguments are defined as:

- NAX - number of axial zones,
- NRINGS - number of radial fuel rings,
- IFUEL - fuel system identifier,
- IRPF - radial power factor calculation option,
- DELL - height of the axial zones (cm),
- FRADIUS - fuel outer radius (cm),
- FIR - fuel inner radius (cm),
- RR - relative radii of the radial rings,
- P - volume fraction porosity of the fuel radial rings,
- ENRICH - U-235 enrichment of the fuel radial rings,
- WPU - weight or mol fraction of Pu in fuel radial rings,
- WZR - weight fraction of Zr in fuel radial rings, and
- RPF - radial power factors for the fuel radial rings.

RADIALPF is called from program SAFE.

Program SAFE

The main SAFE program performs most of the effort. SAFE reads all of the input files and performs the preliminary calculations based on the input data. SAFE increments the time, sets up the energy equations in the coolant and fuel element components, calls TDMA for their solutions, checks for convergence of the solutions, reiterates if needed, and generates the output and plot files. A flow diagram for SAFE was given in Sect. III.C.

Subroutine TDMA (N,A,B)

TDMA employs the Thomas algorithm to solve the tridiagonal system $[A] X = B$, for N equations. The solution X is returned in the source vector B. TDMA is called from program SAFE.

APPENDIX B. VARIABLES USED IN THE CODE

To aid users interested in SAFE at the coding level, this appendix contains a list of the variables used in the code along with a short description of each. Arrays are shown with their dimension parameters. The parameters are set to the following values within the code:

MAXAX	-	200
MAXITER	-	1000
MAXR	-	9
MAXTS	-	9999
MI	-	20
MN	-	500

Currently, the ability to change these dimension settings without modification of the source code is not provided for the user. It is believed, however, that these settings are sufficiently high to allow the user considerable flexibility in performing calculations, while keeping the total memory required for execution of the code low.

<u>Variable</u>	<u>Definition</u>
A(MN,3)	Coefficient matrix for system of energy equations
ALPHA1	Low-temperature thermal expansion coefficient (1/K)
ALPHA2	High-temperature thermal expansion coefficient (1/K)
AREA	Coolant channel cross-sectional flow area (cm ²)
AXPF(MAXAX)	Axial power factor
B(MN)	Source vector for system of energy equations
BC(M)	Specific heat interpolation table for bond (J/g-K)
BD(M)	Density interpolation table for bond (g/cm ³)
BETA(MAXAX,MAXR)	Fraction of porosity in fuel ring logged with Na
BK(MI)	Thermal conductivity interpolation table for bond (W/cm-K)
BOND	Bond material (text)
CC(MI)	Specific heat interpolation table for clad (J/g-K)
CD(MI)	Density interpolation table for clad (g/cm ³)
CK(MI)	Thermal conductivity interpolation table for clad (W/cm-K)
CLADRI	Clad inner radius (cm)
CLADRO	Clad outer radius (cm)
CLADT	Clad thickness (cm)
CPNA	Local coolant specific heat (J/g-K)
CONDE	Thermal conductivity of control volume to the east (W/cm-K)
CONDEP	Interface thermal conductivity between CVs E and P (W/cm-K)
CONDN	Thermal conductivity of control volume to the north (W/cm-K)
CONDNA	Local coolant thermal conductivity (W/cm-K)

<u>Variable</u>	<u>Definition</u>
CONDNP	Interface thermal conductivity between CVs N and P (W/cm-K)
CONDO	Fully-dense thermal conductivity (W/cm-K)
CONDP	Thermal conductivity of control volume (W/cm-K)
CONDS	Thermal conductivity of control volume to the south (W/cm-K)
CONDSP	Interface thermal conductivity between CVs S and P (W/cm-K)
CONDW	Thermal conductivity of control volume to the west (W/cm-K)
CONDWP	Interface thermal conductivity between CVs W and P (W/cm-K)
DELL	Axial internodal spacing (cm)
DELRC	Radial internodal spacing in the clad (cm)
DELRF	Radial internodal spacing in the fuel (cm)
DELRG	Radial internodal spacing in the fuel-clad gap (cm)
DELST	Length of time substep (s)
DELT	Length of time step (s)
DELTC	Clad nodal temperature difference between iteration cycles (K)
DELTCOOL	Coolant nodal temperature difference between iteration cycles (K)
DELTF	Fuel nodal temperature difference between iteration cycles (K)
DELTG	Gap nodal temperature difference between iteration cycles (K)
DENSNA	Local coolant density (g/cm ³)
DENSO	Theoretical density (g/cm ³)
DIFF	Nodal temperature difference between iterations (K)
DIFFMAX	Maximum nodal temperature difference between iterations (K)
E	Local U-235 enrichment of the U component of the fuel ring

<u>Variable</u>	<u>Definition</u>
ENRICH(MAXAX,MAXR)	U-235 enrichment of the U component of the fuel ring
ERROR	Error criterion for convergence of temperature profile
F	Local fuel porosity correction factor
FC(MI)	Specific heat interpolation table for fuel (J/g-K)
FD(MI)	Density interpolation table for fuel (g/cm ³)
FK(MI)	Thermal conductivity interpolation table for fuel (W/cm-K)
FIR	Fuel inner radius for annular fuel (cm)
FLEN	Fuel column length (cm)
FLOW(MAXTS)	Relative coolant volumetric flow rate (fraction of flow at t=0)
FLOWM	Coolant mass flow rate (g/s)
FLOWR	Relaxed fractional flow during a time-substep
FLOWRATE	Coolant volumetric flow rate (cm ³ /s)
FM	Moles of fissile material in an axial fuel zone (mol)
FMPU(MAXR)	Moles of fissile Pu in a fuel radial ring (mol)
FMU(MAXR)	Moles of fissile U in a fuel radial ring (mol)
FPC	Fraction of total pin power deposited in cladding
FRADIUS	Fuel outer radius (cm)
FUEL	Fuel type (text)
GAPT	Fuel-clad gap thickness (cm)
H(MAXAX)	Heat transfer coefficient b/t coolant film and clad (W/cm ² -K)
HDIAM	Coolant channel hydraulic diameter (cm)
HFLUX	Local heat flux (W/cm ²)

<u>Variable</u>	<u>Definition</u>
HGAP	User input fuel-clad gap conductance (W/cm ² -K)
HTC	Convection heat transfer coefficient between coolant and clad (W/cm ² -K)
I	Radial node index
II	Fuel radial ring index
IANN	Annular fuel option specification flag
ICALC	Steady-state/transient calculation option specification flag
ICLAD	Clad material specification
ICOOL	Coolant material specification
IFUEL	Fuel material specification
IGAP	Fuel-clad gap (bond) material specification
IGMODEL	Fuel-clad gap model specification option flag
IHTC	User input heat transfer coefficient option specification option flag
IMAT	Generic material specification flag
IPCF	Porosity correction factor model option specification (for fuel)
IPLLOT	Plot file generation option flag
IRPF	Radial power factor option specification flag
ITER	Iteration index
IZBC	Axial boundary condition option specification flag
J	Axial node index
MAXAX	Maximum number of axial fuel regions allowed
MAXITER	Maximum number of iterations allowed
MAXR	Maximum number of fuel radial rings allowed

<u>Variable</u>	<u>Definition</u>
MAXTS	Maximum number of time steps allowed
MI	Maximum number of data pairs allowed in property interpolation tables
MN	Maximum number of nodes in each fuel element component allowed
NAX	Number of axial nodes
NBC	Number of interpolation pairs for bond specific heat
NBD	Number of interpolation pairs for bond density
NBK	Number of interpolation pairs for bond thermal conductivity
NCC	Number of interpolation pairs for clad specific heat
NCD	Number of interpolation pairs for clad density
NCK	Number of interpolation pairs for clad thermal conductivity
NFC	Number of interpolation pairs for fuel specific heat
NFD	Number of interpolation pairs for fuel density
NFK	Number of interpolation pairs for fuel thermal conductivity
NN	Total number of radial nodes
NNCLAD	Number of radial nodes in the clad
NNFUEL	Number of radial nodes in the fuel
NNGAP	Number of radial nodes in the fuel-clad gap
NRINGS	Number of fuel radial rings within each zone
NSC	Number of interpolation pairs for coolant specific heat
NSD	Number of interpolation pairs for coolant density
NSK	Number of interpolation pairs for coolant thermal conductivity
NTS	Number of time steps following steady-state calculation in the transient

<u>Variable</u>	<u>Definition</u>
NTSS	Number of time substeps within each time step
NU	Coolant Nusselt number
P(MAXAX,MAXR)	Volume fraction porosity of the fuel ring
PCF(MAXAX,MAXR)	Porosity correction factor model option for the fuel ring
PE	Coolant Peclet number
POR	Local volume fraction porosity
POWER(MAXTS)	Relative average pin power (fraction of power at t=0)
POWERR	Relaxed power during a time substep
PRESS	Pressure of bond gas in gap (Pa)
PU	Local weight fraction Pu
PU239M	Isotopic mass of Pu-239 (g/mol)
Q	Fuel average volumetric heat generation rate (W/cm ³)
QC	Clad average volumetric heat generation rate (W/cm ³)
QL	Average linear heat generation rate for the element (W/cm)
R	Radial position of current node (cm)
RAE	Radial position of adjacent node east of current node (cm)
RAW	Radial position of adjacent node west of current node (cm)
RE	Radial position of east face of current control volume (cm)
RELAX	Power and flow transient relaxation factor
RGAS	Ideal gas constant (J/mol-K)
RPF(MAXAX,MAXR)	Radial power factor for fuel ring
RR(MAXAX,MAXR)	Relative outer radius of fuel ring (fraction of fuel radius)

<u>Variable</u>	<u>Definition</u>
RW	Radial position of west face of current control volume (cm)
SC(MI)	Specific heat interpolation table for coolant (J/g-K)
SD(MI)	Density interpolation table for coolant (g/cm ³)
SK(MI)	Thermal conductivity interpolation table for coolant (W/cm-K)
TBC(MI)	Temperature interpolation table for bond specific heat (K)
TBD(MI)	Temperature interpolation table for bond density (K)
TBK(MI)	Temperature interpolation table for bond thermal conductivity (K)
TC(MAXAX,MN)	Clad temperature (K)
TCC(MI)	Temperature interpolation table for clad specific heat (K)
TCD(MI)	Temperature interpolation table for clad density (K)
TCI(MAXAX)	Clad inner surface temperature (K)
TCIMAX	Maximum clad inner temperature at current time step (K)
TCK(MI)	Temperature interpolation table for clad thermal conductivity (K)
TCMAX	Maximum fuel centerline temperature at current time step (K)
TCO(MAXAX)	Clad outer surface temperature at current time step (K)
TCOLD(MAXAX,MN)	Clad temperature from previous iteration (K)
TCOMAX	Maximum clad outer temperature at current time step (K)
TCOOL(MAXAX)	Coolant bulk temperature (K)
TCPS(MAXAX,MN)	Clad temperature at previous time step (K)
TDENSC	Temperature used to evaluate density of cladding (K)
TDENSF	Temperature used to evaluate density of fuel (K)
TEMP	Temperature (K)

<u>Variable</u>	<u>Definition</u>
TEMPI	Inlet temperature for coolant control volume (K)
TEMPO	Outlet temperature for coolant control volume (K).
TF(MAXAX,MN)	Fuel temperature (K)
TFC(MI)	Temperature interpolation table for fuel specific heat (K)
TFD(MI)	Temperature interpolation table for fuel density (K)
TFK(MI)	Temperature interpolation table for fuel thermal conductivity (K)
TFOLD(MAXAX,MN)	Fuel temperature from previous iteration (K)
TFPS(MAXAX,MN)	Fuel temperature at previous time step (K)
TG(MAXAX,MN)	Gap/bond temperature (K)
TGOLD(MAXAX,MN)	Gap/bond temperature from previous iteration (K)
TGPS(MAXAX,MN)	Gap/bond temperature at previous time step (K)
TIME(MAXTS)	Time into transient (s)
TINLET(MAXTS)	Inlet coolant bulk temperature (K)
TITLE#	Title cards for user input run decription
TMAX(MAXTS,5)	Maximum temperature array for each time step (K)
TOUTLET	Outlet coolant bulk temperature (K)
TS(MAXAX)	Fuel surface temperature (K)
TSC(MI)	Temperature interpolation table for coolant specific heat (K)
TSD(MI)	Temperature interpolation table for coolant density (K)
TSK(MI)	Temperature interpolation table for coolant thermal conductivity (K)
TSMAX	Maximum fuel surface temperature at current time step (K)
TTRANS	Thermal expansion transition temperature (K)

<u>Variable</u>	<u>Definition</u>
TZBOT	Specified temperature at bottom of fuel (K)
TZI(MAXAX,MAXR)	Fuel temperature at interface between fuel radial rings (K)
TYPE	Clad type (text)
TZTOP	Specified temperature at top of fuel (K)
U	Local weight fraction of U
U235M	Isotopic mass of U-235 (g/mol)
V(MAXR)	Volume of fuel ring (cm ³)
VOL	Volume of an axial fuel zone (cm ³)
VEL	Coolant velocity (cm/s)
WC	Relaxation factor for temperature solution in clad
WCOOL	Relaxation factor for temperature solution in coolant
WF	Relaxation factor for temperature solution in fuel
WG	Relaxation factor for temperature solution in gap
WPU(MAXAX,MAXR)	Weight or mol fraction of Pu present in fuel ring
WZR(MAXAX,MAXR)	Weight fraction of Zr present in fuel ring
XNA	Local fraction of porosity logged with sodium
ZR	Local weight fraction of Zr

APPENDIX C. BENCHMARK CALCULATIONS

This appendix gives the results of several benchmark calculations using SAFE. The results of the SAFE calculations are compared with analytical solutions.

A. Problem 1

An infinite solid cylinder of radius $R = 1$ cm has the following material properties: thermal conductivity of $k = 1$ W/cm-K, density of $\rho = 1$ g/cm³, and a specific heat of $c_p = 1$ J/g-K. At time $t = 0$, the temperature distribution within the cylinder is $T(r, t=0) = 100^\circ\text{C}$. For times $t > 0$, the surface of the cylinder is maintained at $T(r=R, t) = 0^\circ\text{C}$. The series solution of this problem is:

$$T(r, t) = 2 \frac{T_0}{R} \sum_{m=1}^{\infty} e^{-\alpha(\beta_m)^2 t} \frac{J_0(\beta_m r)}{\beta_m J_1(\beta_m R)} , \quad (\text{C.1})$$

where $T_0 = 100^\circ\text{C}$ and the thermal diffusivity $\alpha = 1$. The eigenvalues β_m in the solution are the roots of the transcendental equation:

$$J_0(\beta_m R) = 0 . \quad (\text{C.2})$$

The series converges rapidly. Shown in Table C1 is the series solution evaluated using 30 terms, along with the results obtained from the SAFE calculation of this problem. The agreement between the series solution and the SAFE calculation is excellent.

B. Problem 2

An infinite solid cylinder of radius $R = 1$ cm has the following material properties: $k = 1$ W/cm-K, $\rho = 1$ g/cm³, and $c_p = 1$ J/g-K. At time $t = 0$, the temperature distribution within the cylinder is $T(r, t=0) = 0^\circ\text{C}$. For times $t > 0$, the surface of the cylinder is maintained at $T(r=R, t) = 0^\circ\text{C}$, and an internal heat source of $q' = 500$ W/cm operates within the cylinder. The series solution of this problem is:

TABLE C1. Temperature Comparison of Series Solution and SAFE Calculation for Problem 1

time (s)	r/R=0.67		r/R=0.33		r/R=0.0	
	Series	SAFE	Series	SAFE	Series	SAFE
0.05	63.298	62.9	93.825	93.7	98.710	98.6
0.10	42.363	42.0	74.581	74.5	84.836	84.8
0.15	30.650	30.4	56.739	56.7	66.183	66.2
0.20	22.720	22.5	42.683	42.7	50.149	50.2
0.25	16.964	16.8	32.007	32.0	37.684	37.8
0.30	12.693	12.6	23.979	24.0	28.249	28.3
0.35	9.503	9.4	17.960	18.0	21.161	21.2
0.40	7.117	7.1	13.450	13.5	15.849	15.9
0.45	5.329	5.3	10.073	10.1	11.869	11.9
0.50	3.991	4.0	7.544	7.6	8.889	8.9
0.55	2.989	3.0	5.649	5.7	6.657	6.7
0.60	2.238	2.2	4.231	4.2	4.985	5.0
0.65	1.676	1.7	3.168	3.2	3.733	3.8
0.70	1.255	1.3	2.373	2.4	2.796	2.8
0.75	0.940	0.9	1.777	1.8	2.094	2.1
0.80	0.704	0.7	1.331	1.3	1.568	1.6
0.85	0.527	0.5	0.997	1.0	1.174	1.2
0.90	0.395	0.4	0.746	0.8	0.879	0.9
0.95	0.296	0.3	0.559	0.6	0.659	0.7
1.00	0.221	0.2	0.419	0.4	0.493	0.5

$$T(r,t) = \frac{q'(R^2 - r^2)}{4\pi R^2 k} - 2 \frac{q'}{\pi R^3 k} \sum_{m=1}^{\infty} e^{-\alpha(\beta_m)^2 t} \frac{J_0(\beta_m r)}{(\beta_m)^3 J_1(\beta_m R)}, \quad (C.3)$$

with the eigenvalues β_m given by Eq. (C.2). The series converges rapidly. Shown in Table C2 is the series solution evaluated using 30 terms, along with the results obtained from the SAFE calculation of this problem. Again, agreement between the series solution and the SAFE calculation is excellent.

C. Problem 3

A finite solid cylinder of radius $R = 15$ cm and height $L = 30$ cm has a thermal conductivity of $k = 0.5$ W/cm-K. The top, bottom and radial surfaces of the cylinder are maintained at 500°C , and an internal heat source of $q' = 500$ W/cm operates within the cylinder. The steady-state series solution of this problem:

TABLE C2. Temperature Comparison of Series Solution and SAFE Calculation for Problem 2

time (s)	r/R=0.67		r/R=0.33		r/R=0.0	
	Series	SAFE	Series	SAFE	Series	SAFE
0.05	6.616	6.6	7.842	7.8	7.942	7.9
0.10	10.720	10.6	14.559	14.5	15.326	15.3
0.15	13.591	13.5	19.760	19.7	21.329	21.3
0.20	15.696	15.6	23.691	23.6	25.934	25.9
0.25	17.264	17.1	26.643	26.6	29.406	29.4
0.30	18.435	18.3	28.856	28.8	32.012	32.0
0.35	19.312	19.2	30.513	30.5	33.965	33.9
0.40	19.969	19.8	31.754	31.7	35.427	35.4
0.45	20.461	20.3	32.684	32.6	36.522	36.5
0.50	20.829	20.7	33.380	33.3	37.342	37.3
0.55	21.105	20.9	33.901	33.9	37.957	37.9
0.60	21.312	21.1	34.291	34.2	38.417	38.4
0.65	21.466	21.3	34.584	34.5	38.761	38.8
0.70	21.582	21.4	34.803	34.8	39.019	39.0
0.75	21.669	21.5	34.967	34.9	39.212	39.2
0.80	21.734	21.6	35.090	35.0	39.357	39.4
0.85	21.782	21.6	35.181	35.1	39.466	39.5
0.90	21.819	21.6	35.250	35.2	39.547	39.5
0.95	21.846	21.7	35.302	35.3	39.607	39.6
1.00	21.867	21.7	35.341	35.3	39.653	39.7

$$T(r, z) = \frac{q'z(L - z)}{2\pi R^2 k} - 4 \frac{q' L^2}{\pi^4 R^2 k} \sum_{m=0}^{\infty} \frac{1}{(2m + 1)^3} \frac{I_0(\beta_m r) \sin(\beta_m z)}{I_0(\beta_m R)} \quad (C.4)$$

with the eigenvalues β_m calculated as:

$$\beta_m = (2m + 1) \frac{\pi}{L} \quad (C.5)$$

The series converges rapidly. Shown in Table C3 is the series solution evaluated using 30 terms, along with the results obtained from the SAFE calculation of this problem. The agreement between the series solution and the SAFE calculation is excellent.

D. Problem 4

An infinite hollow cylinder of outer radius $R = 1$ cm and inner radius $R_0 = 0.25$ cm has a thermal conductivity of $k = 0.2$ W/cm-K. Heat is generated within the cylinder at a rate of $q' = 700$ W/cm (a volumetric heat generation rate of $q''' = 237.7$ W/cm³). An adiabatic condition exists at the surface of the inner radius, while the surface

TABLE C3. Temperature Comparison of Series Solution and SAFE Calculation for Problem 3

z (cm)	r/R=0.67		r/R=0.33		r/R=0.0	
	Series	SAFE	Series	SAFE	Series	SAFE
0	500.000	500.0	500.000	500.0	500.000	500.0
1	506.992	507.0	509.683	509.7	510.433	510.4
2	512.783	512.8	518.085	518.0	519.570	519.6
3	517.573	517.6	525.336	525.2	527.527	527.5
4	521.534	521.5	531.561	531.4	534.417	534.4
5	524.809	524.8	536.875	536.7	540.346	540.3
6	527.515	527.5	541.383	541.2	545.412	545.4
7	529.745	529.7	545.179	545.0	549.706	549.7
8	531.573	531.5	548.345	548.2	553.308	553.3
9	533.058	533.0	550.954	550.8	556.289	556.3
10	534.246	534.2	553.064	552.9	558.711	558.7
11	535.174	535.1	554.726	554.5	560.624	560.6
12	535.869	535.8	555.979	555.8	562.069	562.0
13	536.351	536.3	556.852	556.6	563.079	563.0
14	536.635	536.6	557.368	557.1	563.676	563.6
15	536.729	536.7	557.539	557.3	563.873	563.8
16	536.635	536.6	557.368	557.1	563.676	563.6
17	536.351	536.3	556.852	556.6	563.079	563.0
18	535.869	535.8	555.979	555.8	562.069	562.0
19	535.174	535.1	554.726	554.5	560.624	560.6
20	534.246	534.2	553.064	552.9	558.711	558.7
21	533.058	533.0	550.954	550.8	556.289	556.3
22	531.573	531.5	548.345	548.2	553.308	553.3
23	529.745	529.7	545.179	545.0	549.706	549.7
24	527.515	527.5	541.383	541.2	545.412	545.4
25	524.809	524.8	536.875	536.7	540.346	540.3
26	521.534	521.5	531.561	531.4	534.417	534.4
27	517.573	517.6	525.336	525.2	527.527	527.5
28	512.783	512.8	518.085	518.0	519.570	519.6
29	506.992	507.0	509.683	509.7	510.433	510.4
30	500.000	500.0	500.000	500.0	500.000	500.0

at the outer radius of the cylinder transfers heat by convection to a medium at $T_{amb} = 600$ K with a heat transfer coefficient of $h = 5$ W/cm²-K. The analytical solution for the temperature within the cylinder is:

$$T(r) = T_{amb} + \frac{q'''}{2} \left\{ \frac{R^2 - r^2}{2k} + \frac{R_0^2}{k} \ln(r / R) + \frac{R^2 - R_0^2}{hR} \right\} . \quad (C.6)$$

The analytical solution gives temperatures for the outer and inner cylinder surfaces as 349.2847°C and 576.3212°C, respectively. A SAFE calculation obtained 349.2°C and 576.2°C.

E. Problem 5

A solid vertical cylinder of length $L = 30$ cm generates heat internally at the rate of $q' = 500$ W/cm. The rod transfers its heat to a coolant that flows upward along the rod at a rate of 100 g/s. The coolant has a specific heat of $c_p = 0.25$ J/g-K. The temperature of the coolant at the bottom of the rod is $T_{bot} = 100^\circ\text{C}$. The temperature of the coolant at the top of the rod is calculated analytically as:

$$T_{top} = T_{bot} + \frac{q' L}{\dot{m} c_p} . \quad (C.7)$$

or $T_{top} = 700.0^\circ\text{C}$. The SAFE calculation for this problem obtained the result $T_{top} = 700.3^\circ\text{C}$.

F. Problem 6

An infinitely long MK-VA fuel element has a fuel linear heat generation rate of $q' = 492$ W/cm and a clad outer temperature of $T_{co} = 550^\circ\text{C}$. The radii of the fuel, clad inner surface and clad outer surface are $R_f = 0.21971$ cm, $R_{ci} = 0.25400$ cm and $R_{co} = 0.29210$ cm, respectively. The thermal conductivities of the fuel, bond and clad are taken to be $k_f = 0.20$ W/cm-K, $k_b = 0.75$ W/cm-K and $k_c = 0.30$ W/cm-K, respectively. The analytical solution for the temperatures of the clad inner surface, fuel outer surface and fuel centerline are found in three steps. The temperature of the clad inner surface (T_{ci}) is:

$$T_{ci} = T_{co} - \frac{q'}{2\pi k_c} \ln\left(\frac{R_{ci}}{R_{co}}\right) . \quad (C.8)$$

Knowing the clad inner temperature, the fuel surface temperature (T_{fs}) is:

$$T_{fs} = T_{ci} - \frac{q'}{2\pi k_b} \ln\left(\frac{R_f}{R_{ci}}\right) . \quad (C.9)$$

Knowing the fuel surface temperature, the fuel centerline temperature (T_{fc}) is:

$$T_{fc} = T_{fs} + \frac{q'}{4\pi k_f} . \quad (C.10)$$

These expressions are evaluated and shown along with the results of the SAFE calculation for this problem in Table C4.

TABLE C4. Temperature Comparison of Analytical Solution and SAFE Calculation for Problem 6

Location	Temperature (°C)	
	Analytical Solution	SAFE
Clad Outer Surface	550.0000	550.0
Clad Inner Surface	586.4798	586.6
Fuel Surface	601.6213	601.7
Fuel Centerline	797.3819	797.5

The agreement between the analytical solution and the SAFE calculation is excellent.

APPENDIX D. SAMPLE PROBLEM

This appendix contains examples of the three input files necessary to make a transient calculation using SAFE, along with the output file created by SAFE during the calculation (only the output file in metric units is included). The sample problem is a transient calculation for a hypothetical transient overpower event in EBR-II. For the fuel element description needed as input to SAFE, manufacturing and postirradiation examination data for a metallic fuel element from experimental subassembly X447A in EBR-II that breached during RUN 155B was used. Subassembly X447 did not undergo such a transient event, and the transient forcing functions, fuel element nodding, and time steps employed in this calculation are coarse. This selection of input parameters were chosen simply to highlight some of the important features of the code without generating an excessively large output file.

File Listing of INPUT:

```
1 0
SAMPLE TRANSIENT
SAMPLE calculation for an Unlikely Reactivity Insertion event.
A binary U-Zr metallic fuel element at high burnup in position 4E2
of EBR-II.

11 644.3 71.71 0.13638 0
1 0.2921 0.03810
0.000
0
5.5700+01
20 0.25400 34.29 0 0
400.3
27 3 0
1 0.892
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
2 0.939
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
3 0.981
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
4 1.017
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
5 1.049
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
6 1.075
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
7 1.097
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
```

3 1.00 0.28 0.80 3 0.50 0.10 0.00
8 1.114
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
9 1.127
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
10 1.135
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
11 1.139
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
12 1.138
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
13 1.133
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
14 1.124
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
15 1.110
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
16 1.093
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
17 1.072
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
18 1.047
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
19 1.018
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
20 0.986
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
21 0.950
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
22 0.911
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
23 0.868
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
24 0.823
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
25 0.774
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
26 0.721
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00
27 0.666
1 0.46 0.35 0.00 4 0.50 0.26 0.00
2 0.74 0.15 0.01 3 0.50 0.05 0.00
3 1.00 0.28 0.80 3 0.50 0.10 0.00

File Listing of URI:

33 1
1 0.00 1.000 1.000 644.25
2 1.01 1.000 1.006 644.25
3 2.01 1.000 1.014 644.25
4 3.01 1.000 1.022 644.25
5 4.01 1.000 1.030 644.25
6 5.01 1.000 1.040 644.25
7 6.01 1.000 1.050 644.25
8 7.01 1.000 1.062 644.25
9 8.01 1.000 1.073 644.25
10 9.01 1.000 1.086 644.25
11 10.01 1.000 1.099 644.25
12 11.01 1.000 1.113 644.25
13 12.01 1.000 1.128 644.25
14 13.01 1.000 1.143 644.25
15 14.01 1.000 1.159 644.25
16 15.01 1.000 1.176 644.25
17 16.01 1.000 1.193 644.25
18 16.51 1.000 1.202 644.25
19 16.56 1.000 1.203 644.25
20 16.61 1.000 1.204 644.25
21 16.66 1.000 1.196 644.25
22 16.68 1.000 1.190 644.25
23 16.70 1.000 1.135 644.25
24 16.73 1.000 1.008 644.25
25 16.76 1.000 0.715 644.25
26 16.80 1.000 0.455 644.25
27 16.83 1.000 0.344 644.25
28 16.86 1.000 0.262 644.25
29 16.90 1.000 0.251 644.25
30 17.00 1.000 0.245 644.25
31 17.50 1.000 0.219 644.25
32 18.00 1.000 0.198 644.25
33 20.00 1.000 0.144 644.25
34 25.00 1.000 0.080 644.25

File Listing of SAFE.CONTROL:

7,5,30
300.0,300.0,300.0
1.0d-04
1.0,0.7,0.7,0.7

File Listing of OUTPUT.METRIC:

SAFE OUTPUT FILE
<S>oping <A>nalysis of <F>uel <E>lements
Version 1.0

***** CALCULATION DESCRIPTION *****
* SAMPLE calculation for an Unlikely Reactivity Insertion event. *
* A binary U-Zr metallic fuel element at high burnup in position 4E2 *
* of EBR-II. *
* *

***** REVIEW OF INPUT DATA *****

SOLUTION CONTROL PARAMETERS

Relaxation Factor in Coolant: 1.00
Relaxation Factor in Clad: 0.70
Relaxation Factor in Gap: 0.70
Relaxation Factor in Fuel: 0.70
Temperature Convergence Criterion: 0.1000000D-03

FUEL ELEMENT DISCRETIZATION

Number of Time Steps: 33
Number of Time Sub-Steps: 1

Number of Axial Nodes: 27; (0.13188460+01 cm inter-node spacing)
 No. of Radial Nodes in Clad: 7; (0.63500000-02 cm inter-node spacing)
 No. of Radial Nodes in Gap: 0; (0.00000000+00 cm inter-node spacing)
 No. of Radial Nodes in Fuel: 30; (0.89122810-02 cm inter-node spacing)

COOLANT INPUT

 Coolant: Na
 Inlet Temperature: 371.3 C
 Element Avg LHGR: 400.30 W/cm
 Power to Coolant: 13.73 kW
 Channel Flow Area: 0.13638 cm²
 Hydraul. Diameter: 0.29723 cm
 Volume Flowrate: 71.71 cm³/s
 Mass Flowrate: 61.890 g/s
 Velocity: 525.810 cm/s

CLADDING INPUT

 Clad Material: SS316
 Clad Inner Radius: 2.5400 mm
 Clad Outer Radius: 2.9210 mm
 Clad Thickness: 0.3810 mm
 Density Eval. at: 300.0 K
 Power from Clad: 0.00 %

GAP INPUT

 Gap Width: 0.00000 mm
 Gap Conductance: 5.5700+01 W/cm²-K

FUEL INPUT

 Fuel System: U-Pu-Zr
 Fuel Outer Radius: 0.25400 cm
 Fuel Inner Radius: 0.00000 cm
 Fuel Length: 34.290 cm
 Density Eval. at: 300.0 K
 Power from Fuel: 100.00 %
 Avg Linear Heat Rate: 400.30 W/cm
 Avg Volume Heat Rate: 1975.0 W/cm³

Fuel Zone and Ring Structure:

ZONE	AXLPF	RING	RADPF*	RELATIVE		POROSITY	XNA	PCF		ENRICH		WPU	WZR
				RADIUS				MODEL		U-235			
1	0.892	1	0.587	0.46	0.35	0.00	0.00	4		0.50	0.00	0.26	
		2	1.306	0.74	0.15	0.01	0.01	3		0.50	0.00	0.05	
		3	0.966	1.00	0.28	0.80	0.80	3		0.50	0.00	0.10	
2	0.939	1	0.587	0.46	0.35	0.00	0.00	4		0.50	0.00	0.26	
		2	1.306	0.74	0.15	0.01	0.01	3		0.50	0.00	0.05	
		3	0.966	1.00	0.28	0.80	0.80	3		0.50	0.00	0.10	
3	0.981	1	0.587	0.46	0.35	0.00	0.00	4		0.50	0.00	0.26	
		2	1.306	0.74	0.15	0.01	0.01	3		0.50	0.00	0.05	
		3	0.966	1.00	0.28	0.80	0.80	3		0.50	0.00	0.10	
4	1.017	1	0.587	0.46	0.35	0.00	0.00	4		0.50	0.00	0.26	
		2	1.306	0.74	0.15	0.01	0.01	3		0.50	0.00	0.05	
		3	0.966	1.00	0.28	0.80	0.80	3		0.50	0.00	0.10	
5	1.049	1	0.587	0.46	0.35	0.00	0.00	4		0.50	0.00	0.26	
		2	1.306	0.74	0.15	0.01	0.01	3		0.50	0.00	0.05	
		3	0.966	1.00	0.28	0.80	0.80	3		0.50	0.00	0.10	
6	1.075	1	0.587	0.46	0.35	0.00	0.00	4		0.50	0.00	0.26	
		2	1.306	0.74	0.15	0.01	0.01	3		0.50	0.00	0.05	
		3	0.966	1.00	0.28	0.80	0.80	3		0.50	0.00	0.10	
7	1.097	1	0.587	0.46	0.35	0.00	0.00	4		0.50	0.00	0.26	
		2	1.306	0.74	0.15	0.01	0.01	3		0.50	0.00	0.05	
		3	0.966	1.00	0.28	0.80	0.80	3		0.50	0.00	0.10	
8	1.114	1	0.587	0.46	0.35	0.00	0.00	4		0.50	0.00	0.26	
		2	1.306	0.74	0.15	0.01	0.01	3		0.50	0.00	0.05	
		3	0.966	1.00	0.28	0.80	0.80	3		0.50	0.00	0.10	
9	1.127	1	0.587	0.46	0.35	0.00	0.00	4		0.50	0.00	0.26	
		2	1.306	0.74	0.15	0.01	0.01	3		0.50	0.00	0.05	

		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
10	1.135	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
11	1.139	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
12	1.138	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
13	1.133	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
14	1.124	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
15	1.110	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
16	1.093	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
17	1.072	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
18	1.047	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
19	1.018	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
20	0.986	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
21	0.950	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
22	0.911	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
23	0.868	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
24	0.823	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
25	0.774	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
26	0.721	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10
27	0.666	1	0.587	0.46	0.35	0.00	4	0.50	0.00	0.26
		2	1.306	0.74	0.15	0.01	3	0.50	0.00	0.05
		3	0.966	1.00	0.28	0.80	3	0.50	0.00	0.10

IRPF = 0

TRANSIENT FORCING FUNCTIONS

TIME STEP	TIME (sec)	RELATIVE FLOW	RELATIVE POWER	INLET TEMP (C)
--------------	---------------	------------------	-------------------	-------------------

1	0.00000000+00	1.0000	1.0000	371.3
2	0.10100000+01	1.0000	1.0060	371.2
3	0.20100000+01	1.0000	1.0140	371.2
4	0.30100000+01	1.0000	1.0220	371.2
5	0.40100000+01	1.0000	1.0300	371.2
6	0.50100000+01	1.0000	1.0400	371.2
7	0.60100000+01	1.0000	1.0500	371.2
8	0.70100000+01	1.0000	1.0620	371.2
9	0.80100000+01	1.0000	1.0730	371.2
10	0.90100000+01	1.0000	1.0860	371.2
11	0.10010000+02	1.0000	1.0990	371.2
12	0.11010000+02	1.0000	1.1130	371.2
13	0.12010000+02	1.0000	1.1280	371.2
14	0.13010000+02	1.0000	1.1430	371.2
15	0.14010000+02	1.0000	1.1590	371.2
16	0.15010000+02	1.0000	1.1760	371.2
17	0.16010000+02	1.0000	1.1930	371.2
18	0.16510000+02	1.0000	1.2020	371.2
19	0.16560000+02	1.0000	1.2030	371.2
20	0.16610000+02	1.0000	1.2040	371.2
21	0.16660000+02	1.0000	1.1960	371.2
22	0.16680000+02	1.0000	1.1900	371.2
23	0.16700000+02	1.0000	1.1350	371.2
24	0.16730000+02	1.0000	1.0080	371.2
25	0.16760000+02	1.0000	0.7150	371.2
26	0.16800000+02	1.0000	0.4550	371.2
27	0.16830000+02	1.0000	0.3440	371.2
28	0.16860000+02	1.0000	0.2620	371.2
29	0.16900000+02	1.0000	0.2510	371.2
30	0.17000000+02	1.0000	0.2450	371.2
31	0.17500000+02	1.0000	0.2190	371.2
32	0.18000000+02	1.0000	0.1980	371.2
33	0.20000000+02	1.0000	0.1440	371.2
34	0.25000000+02	1.0000	0.0800	371.2

 ***** CALCULATION RESULTS *****
 ***** Axial Temperature Profiles by Time-Steps *****

TIME = 0.000D+00 s (22 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	357.1	22.2	371.3	380.1	421.0	422.9	462.2	495.9	538.8
1.319	375.9	22.1	377.4	386.7	429.4	431.5	472.5	507.6	552.1
2.638	392.7	22.1	383.8	393.5	437.9	440.1	482.6	519.0	564.7
3.957	407.1	22.0	390.4	400.5	446.3	448.6	492.3	529.8	576.5
5.275	419.9	21.9	397.3	407.8	454.7	457.0	501.9	540.3	587.8
6.594	430.3	21.8	404.4	415.2	463.0	465.4	511.1	550.1	598.2
7.913	439.1	21.7	411.7	422.7	471.2	473.6	520.0	559.5	608.0
9.232	445.9	21.6	419.0	430.3	479.3	481.8	528.5	568.4	617.1
10.551	451.1	21.5	426.5	438.0	487.3	489.8	536.8	576.9	625.7
11.870	454.3	21.4	434.1	445.7	495.1	497.6	544.7	584.9	633.5
13.188	455.9	21.2	441.8	453.5	502.7	505.2	552.2	592.3	640.7
14.507	455.5	21.1	449.4	461.2	510.1	512.6	559.3	599.2	647.1
15.826	453.5	21.0	457.0	468.8	517.3	519.8	566.1	605.6	652.9
17.145	449.9	20.9	464.6	476.4	524.2	526.7	572.4	611.4	658.1
18.464	444.3	20.8	472.2	483.8	530.8	533.3	578.2	616.6	662.4
19.783	437.5	20.7	479.6	491.1	537.2	539.6	583.7	621.3	666.3
21.102	429.1	20.6	486.9	498.3	543.2	545.6	588.7	625.5	669.4
22.420	419.1	20.5	494.1	505.2	548.9	551.3	593.2	629.0	671.7
23.739	407.5	20.4	501.0	511.9	554.3	556.5	597.2	632.0	673.3
25.058	394.7	20.3	507.8	518.4	559.3	561.5	600.7	634.3	674.3
26.377	380.3	20.3	514.4	524.6	563.9	566.0	603.7	636.0	674.5
27.696	364.7	20.2	520.7	530.5	568.0	570.1	606.1	637.1	674.0
29.015	347.5	20.1	526.7	536.1	571.8	573.7	608.0	637.5	672.7
30.333	329.4	20.0	532.4	541.4	575.1	576.9	609.4	637.4	670.8
31.652	309.8	19.9	537.8	546.3	577.9	579.6	610.2	636.4	667.9
32.971	288.6	19.9	542.9	550.8	580.2	581.8	610.2	634.7	664.1
34.290	266.6	19.8	547.6	555.0	582.0	583.5	609.8	632.4	659.7

TIME = 1.010D+00 s (16 Iterations Required)

AXIAL	POWER	H	TCOOL	TCO	TCI	TS	T(3,2)	T(2,1)	T(1,0)
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POS. (cm)	(W/cm)	(W/cm2-C)	(C)	(C)	(C)	(C)	(C)	(C)	(C)
0.000	359.2	22.2	371.2	380.1	421.2	423.2	462.6	496.5	539.6
1.319	378.1	22.1	377.4	386.7	429.6	431.7	472.9	508.2	552.9
2.638	395.1	22.1	383.8	393.6	438.2	440.4	483.1	519.7	565.6
3.957	409.5	22.0	390.5	400.6	446.6	448.9	492.9	530.5	577.4
5.275	422.4	21.9	397.4	407.9	455.1	457.4	502.5	541.0	588.7
6.594	432.9	21.8	404.5	415.4	463.4	465.8	511.7	550.9	599.1
7.913	441.8	21.7	411.8	422.9	471.6	474.1	520.6	560.3	609.0
9.232	448.6	21.6	419.2	430.6	479.8	482.3	529.2	569.3	618.1
10.551	453.8	21.5	426.8	438.3	487.8	490.3	537.5	577.8	626.7
11.870	457.1	21.4	434.4	446.1	495.6	498.1	545.4	585.8	634.6
13.188	458.7	21.2	442.1	453.8	503.3	505.8	553.0	593.3	641.8
14.507	458.3	21.1	449.7	461.6	510.7	513.2	560.2	600.2	648.2
15.826	456.3	21.0	457.4	469.2	517.9	520.4	566.9	606.6	654.1
17.145	452.6	20.9	465.0	476.8	524.9	527.4	573.3	612.4	659.2
18.464	447.0	20.8	472.6	484.3	531.5	534.0	579.1	617.6	663.6
19.783	440.2	20.7	480.1	491.6	537.9	540.3	584.6	622.4	667.4
21.102	431.7	20.6	487.4	498.8	544.0	546.4	589.6	626.5	670.5
22.420	421.6	20.5	494.6	505.8	549.7	552.0	594.1	630.1	672.9
23.739	410.0	20.4	501.6	512.5	555.0	557.3	598.1	633.0	674.5
25.058	397.1	20.3	508.4	519.0	560.1	562.3	601.7	635.4	675.5
26.377	382.6	20.2	515.0	525.3	564.7	566.8	604.6	637.1	675.7
27.696	366.9	20.2	521.3	531.2	568.8	570.9	607.1	638.2	675.2
29.015	349.5	20.1	527.4	536.8	572.6	574.5	609.0	638.5	673.8
30.333	331.4	20.0	533.1	542.1	575.9	577.8	610.4	638.4	671.9
31.652	311.7	19.9	538.5	547.1	578.7	580.5	611.1	637.5	669.0
32.971	290.3	19.9	543.6	551.6	581.0	582.7	611.2	635.7	665.2
34.290	268.2	19.8	548.4	555.7	582.9	584.4	610.7	633.4	660.7

TIME = 2.010D+00 s (16 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm2-C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	362.1	22.2	371.2	380.1	421.5	423.5	463.3	497.4	540.7
1.319	381.1	22.1	377.4	386.8	430.1	432.2	473.7	509.2	554.1
2.638	398.2	22.1	383.9	393.7	438.7	440.9	483.9	520.7	566.9
3.957	412.8	22.0	390.6	400.9	447.2	449.5	493.8	531.6	578.8
5.275	425.8	21.9	397.6	408.2	455.7	458.0	503.4	542.2	590.1
6.594	436.3	21.8	404.8	415.7	464.0	466.5	512.7	552.1	600.6
7.913	445.3	21.7	412.1	423.3	472.4	474.8	521.7	561.6	610.6
9.232	452.2	21.6	419.6	431.0	480.5	483.1	530.3	570.7	619.8
10.551	457.5	21.5	427.2	438.8	488.6	491.2	538.7	579.2	628.4
11.870	460.7	21.3	434.9	446.6	496.5	499.1	546.7	587.2	636.3
13.188	462.3	21.2	442.6	454.4	504.2	506.8	554.3	594.8	643.5
14.507	461.9	21.1	450.3	462.2	511.7	514.2	561.5	601.7	650.0
15.826	459.9	21.0	458.0	470.0	518.9	521.5	568.3	608.2	655.9
17.145	456.2	20.9	465.7	477.6	525.9	528.5	574.7	614.1	661.1
18.464	450.6	20.8	473.3	485.1	532.6	535.1	580.5	619.3	665.5
19.783	443.7	20.7	480.9	492.5	539.1	541.5	586.0	624.1	669.3
21.102	435.1	20.6	488.2	499.7	545.2	547.6	591.1	628.2	672.4
22.420	425.0	20.5	495.5	506.8	550.9	553.3	595.6	631.8	674.8
23.739	413.2	20.4	502.5	513.5	556.3	558.6	599.6	634.7	676.4
25.058	400.2	20.3	509.4	520.1	561.4	563.6	603.2	637.1	677.4
26.377	385.6	20.2	516.0	526.4	566.0	568.1	606.2	638.8	677.6
27.696	369.8	20.1	522.4	532.4	570.2	572.3	608.7	639.9	677.1
29.015	352.3	20.1	528.5	538.0	574.0	575.9	610.5	640.3	675.7
30.333	334.1	20.0	534.3	543.3	577.3	579.2	612.0	640.1	673.7
31.652	314.2	19.9	539.7	548.3	580.2	581.9	612.7	639.2	670.9
32.971	292.7	19.8	544.8	552.8	582.5	584.1	612.7	637.4	667.0
34.290	270.3	19.8	549.6	557.0	584.3	585.8	612.3	635.1	662.5

TIME = 3.010D+00 s (16 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm2-C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	364.9	22.2	371.2	380.2	421.9	423.9	464.0	498.3	541.9
1.319	384.2	22.1	377.5	386.9	430.5	432.7	474.4	510.2	555.4
2.638	401.3	22.1	384.0	393.9	439.2	441.4	484.7	521.8	568.3
3.957	416.1	22.0	390.8	401.1	447.7	450.1	494.7	532.8	580.2
5.275	429.2	21.9	397.8	408.5	456.3	458.7	504.4	543.4	591.7
6.594	439.8	21.8	405.0	416.0	464.8	467.2	513.7	553.4	602.2
7.913	448.8	21.7	412.4	423.7	473.1	475.6	522.8	563.0	612.2
9.232	455.7	21.6	420.0	431.5	481.4	483.9	531.5	572.1	621.5
10.551	461.1	21.4	427.6	439.3	489.5	492.1	539.9	580.7	630.2
11.870	464.3	21.3	435.4	447.2	497.4	500.0	548.0	588.8	638.1
13.188	466.0	21.2	443.1	455.1	505.2	507.8	555.6	596.4	645.4

14.507	465.6	21.1	450.9	462.9	512.7	515.3	562.9	603.4	652.0
15.826	463.5	21.0	458.7	470.7	520.1	522.6	569.7	609.9	657.9
17.145	459.8	20.9	466.5	478.4	527.1	529.7	576.2	615.8	663.1
18.464	454.1	20.8	474.1	486.0	533.8	536.4	582.1	621.1	667.5
19.783	447.2	20.7	481.7	493.5	540.3	542.8	587.6	625.9	671.4
21.102	438.6	20.6	489.2	500.7	546.5	548.9	592.7	630.1	674.5
22.420	428.3	20.5	496.4	507.8	552.3	554.7	597.3	633.7	676.9
23.739	416.5	20.4	503.6	514.7	557.7	560.0	601.3	636.7	678.5
25.058	403.4	20.3	510.5	521.3	562.8	565.0	604.9	639.1	679.5
26.377	388.7	20.2	517.1	527.6	567.5	569.6	607.9	640.8	679.7
27.696	372.7	20.1	523.5	533.6	571.7	573.8	610.4	641.9	679.2
29.015	355.1	20.0	529.7	539.3	575.5	577.5	612.3	642.2	677.8
30.333	336.7	20.0	535.5	544.7	578.9	580.7	613.7	642.1	675.8
31.652	316.6	19.9	541.0	549.7	581.7	583.5	614.5	641.1	673.0
32.971	295.0	19.8	546.2	554.3	584.1	585.7	614.5	639.4	669.1
34.290	272.5	19.8	551.0	558.4	585.9	587.4	614.0	637.0	664.6

TIME = 4.010D+00 s (16 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	367.8	22.2	371.2	380.3	422.3	424.3	464.7	499.2	543.1
1.319	387.2	22.1	377.5	387.0	431.0	433.1	475.2	511.3	556.7
2.638	404.5	22.0	384.1	394.1	439.7	441.9	485.6	522.9	569.7
3.957	419.3	22.0	390.9	401.3	448.3	450.7	495.6	534.0	581.7
5.275	432.5	21.9	398.0	408.8	457.0	459.4	505.4	544.7	593.2
6.594	443.2	21.8	405.3	416.4	465.5	467.9	514.8	554.8	603.9
7.913	452.3	21.7	412.7	424.1	473.9	476.4	523.9	564.5	613.9
9.232	459.3	21.5	420.3	432.0	482.2	484.8	532.7	573.6	623.3
10.551	464.7	21.4	428.1	439.9	490.4	493.0	541.2	582.3	632.0
11.870	468.0	21.3	435.9	447.8	498.4	501.0	549.3	590.4	640.0
13.188	469.6	21.2	443.7	455.7	506.2	508.8	557.0	598.1	647.3
14.507	469.2	21.1	451.6	463.7	513.8	516.4	564.3	605.1	653.9
15.826	467.1	21.0	459.4	471.5	521.2	523.8	571.2	611.6	659.9
17.145	463.4	20.9	467.2	479.3	528.3	530.9	577.7	617.6	665.1
18.464	457.7	20.8	474.9	486.9	535.1	537.6	583.7	622.9	669.6
19.783	450.7	20.7	482.6	494.4	541.6	544.1	589.3	627.8	673.5
21.102	442.0	20.6	490.1	501.8	547.8	550.3	594.4	632.0	676.6
22.420	431.7	20.5	497.4	508.9	553.7	556.1	599.0	635.6	679.1
23.739	419.7	20.4	504.6	515.8	559.2	561.5	603.1	638.6	680.7
25.058	406.5	20.3	511.6	522.4	564.3	566.5	606.7	641.0	681.7
26.377	391.7	20.2	518.3	528.8	569.0	571.1	609.7	642.8	681.9
27.696	375.6	20.1	524.7	534.9	573.3	575.3	612.2	643.9	681.4
29.015	357.9	20.0	530.9	540.6	577.1	579.0	614.1	644.3	680.0
30.333	339.3	20.0	536.8	546.0	580.5	582.4	615.6	644.1	678.0
31.652	319.1	19.9	542.4	551.1	583.4	585.1	616.3	643.2	675.1
32.971	297.3	19.8	547.6	555.7	585.7	587.3	616.4	641.4	671.3
34.290	274.6	19.7	552.4	559.9	587.6	589.1	615.9	639.0	666.7

TIME = 5.010D+00 s (18 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	371.4	22.2	371.2	380.4	422.8	424.8	465.5	500.4	544.6
1.319	390.9	22.1	377.6	387.2	431.5	433.7	476.2	512.5	558.3
2.638	408.4	22.0	384.2	394.3	440.3	442.6	486.6	524.3	571.3
3.957	423.4	22.0	391.1	401.6	449.0	451.4	496.7	535.5	583.5
5.275	436.7	21.9	398.3	409.1	457.8	460.2	506.6	546.2	595.1
6.594	447.5	21.8	405.6	416.8	466.3	468.8	516.1	556.4	605.8
7.913	456.7	21.6	413.1	424.6	474.8	477.4	525.3	566.2	616.0
9.232	463.8	21.5	420.8	432.5	483.2	485.8	534.1	575.4	625.4
10.551	469.2	21.4	428.6	440.5	491.5	494.1	542.7	584.1	634.2
11.870	472.5	21.3	436.5	448.5	499.6	502.2	550.9	592.3	642.2
13.188	474.2	21.2	444.4	456.5	507.5	510.1	558.7	600.0	649.6
14.507	473.8	21.1	452.3	464.5	515.1	517.8	566.0	607.1	656.3
15.826	471.7	21.0	460.2	472.5	522.6	525.2	573.0	613.7	662.3
17.145	467.9	20.9	468.1	480.3	529.7	532.3	579.5	619.8	667.6
18.464	462.1	20.8	475.9	488.0	536.6	539.1	585.5	625.1	672.1
19.783	455.0	20.7	483.6	495.6	543.2	545.7	591.2	630.0	676.0
21.102	446.3	20.6	491.2	503.0	549.4	551.9	596.4	634.3	679.2
22.420	435.9	20.5	498.6	510.2	555.3	557.8	601.0	637.9	681.6
23.739	423.8	20.4	505.8	517.2	560.9	563.2	605.1	640.9	683.3
25.058	410.5	20.3	512.9	523.9	566.0	568.3	608.8	643.4	684.3
26.377	395.5	20.2	519.7	530.3	570.8	573.0	611.8	645.1	684.5
27.696	379.3	20.1	526.2	536.4	575.1	577.2	614.4	646.3	684.0
29.015	361.4	20.0	532.4	542.2	578.9	580.9	616.3	646.6	682.6
30.333	342.6	19.9	538.3	547.7	582.4	584.3	617.7	646.5	680.6

31.652	322.2	19.9	543.9	552.8	585.3	587.1	618.5	645.5	677.7
32.971	300.2	19.8	549.2	557.4	587.6	589.3	618.6	643.7	673.8
34.290	277.3	19.7	554.1	561.7	589.5	591.1	618.1	641.3	669.2

TIME - 6.010D+00 s (18 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	374.9	22.2	371.2	380.4	423.3	425.3	466.4	501.6	546.1
1.319	394.7	22.1	377.6	387.3	432.1	434.3	477.1	513.8	559.9
2.638	412.3	22.0	384.3	394.5	441.0	443.3	487.7	525.7	573.1
3.957	427.5	21.9	391.3	401.9	449.8	452.1	497.9	536.9	585.4
5.275	440.9	21.8	398.5	409.5	458.6	461.0	507.9	547.8	597.1
6.594	451.8	21.7	405.9	417.3	467.2	469.7	517.4	558.1	607.9
7.913	461.1	21.6	413.5	425.1	475.8	478.4	526.7	567.9	618.1
9.232	468.2	21.5	421.3	433.1	484.3	486.9	535.6	577.2	627.5
10.551	473.7	21.4	429.1	441.2	492.6	495.2	544.3	586.0	636.4
11.870	477.1	21.3	437.1	449.3	500.8	503.4	552.5	594.3	644.5
13.188	478.7	21.2	445.1	457.4	508.7	511.4	560.4	602.1	652.0
14.507	478.3	21.1	453.1	465.4	516.5	519.1	567.8	609.2	658.7
15.826	476.2	21.0	461.1	473.4	524.0	526.6	574.8	615.9	664.8
17.145	472.4	20.9	469.0	481.4	531.2	533.8	581.4	622.0	670.1
18.464	466.5	20.8	476.9	489.1	538.1	540.7	587.5	627.4	674.6
19.783	459.4	20.7	484.7	496.8	544.8	547.3	593.2	632.3	678.6
21.102	450.6	20.6	492.3	504.3	551.1	553.6	598.4	636.6	681.8
22.420	440.1	20.5	499.8	511.5	557.1	559.5	603.1	640.3	684.3
23.739	427.9	20.4	507.1	518.6	562.6	565.0	607.3	643.4	686.0
25.058	414.4	20.3	514.2	525.3	567.9	570.2	610.9	645.8	687.0
26.377	399.3	20.2	521.1	531.8	572.6	574.9	614.0	647.6	687.2
27.696	382.9	20.1	527.7	538.0	577.0	579.1	616.6	648.7	686.7
29.015	364.8	20.0	534.0	543.9	580.9	582.9	618.6	649.1	685.3
30.333	345.9	19.9	540.0	549.4	584.4	586.3	620.0	649.0	683.3
31.652	325.3	19.8	545.6	554.5	587.3	589.1	620.8	648.0	680.4
32.971	303.0	19.8	550.9	559.2	589.7	591.4	620.8	646.2	676.5
34.290	279.9	19.7	555.8	563.5	591.6	593.1	620.4	643.8	671.9

TIME - 7.010D+00 s (18 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	379.2	22.2	371.2	380.6	423.8	425.9	467.4	503.0	547.9
1.319	399.2	22.1	377.7	387.5	432.8	435.0	478.3	515.3	561.8
2.638	417.0	22.0	384.5	394.8	441.7	444.0	488.9	527.3	575.1
3.957	432.3	21.9	391.5	402.2	450.6	453.0	499.2	538.7	587.5
5.275	445.9	21.8	398.8	409.9	459.5	462.0	509.3	549.7	599.3
6.594	457.0	21.7	406.3	417.8	468.3	470.8	519.0	560.0	610.2
7.913	466.4	21.6	414.0	425.7	476.9	479.5	528.4	569.9	620.5
9.232	473.6	21.5	421.8	433.8	485.5	488.1	537.4	579.3	630.1
10.551	479.1	21.4	429.8	442.0	493.9	496.6	546.1	588.3	639.0
11.870	482.5	21.3	437.8	450.1	502.2	504.8	554.4	596.6	647.2
13.188	484.2	21.2	445.9	458.3	510.2	512.9	562.4	604.5	654.8
14.507	483.8	21.1	454.0	466.5	518.0	520.7	569.9	611.7	661.6
15.826	481.7	21.0	462.1	474.6	525.6	528.3	577.0	618.4	667.6
17.145	477.8	20.9	470.1	482.6	532.9	535.6	583.6	624.6	673.1
18.464	471.9	20.8	478.1	490.5	539.9	542.5	589.8	630.0	677.6
19.783	464.7	20.6	486.0	498.2	546.7	549.2	595.5	635.0	681.6
21.102	455.7	20.5	493.7	505.7	553.0	555.6	600.8	639.4	684.9
22.420	445.1	20.4	501.3	513.1	559.1	561.5	605.5	643.1	687.4
23.739	432.8	20.3	508.6	520.2	564.7	567.1	609.7	646.2	689.1
25.058	419.2	20.2	515.8	527.1	570.0	572.3	613.5	648.7	690.1
26.377	403.9	20.1	522.7	533.6	574.8	577.0	616.6	650.4	690.3
27.696	387.3	20.1	529.4	539.9	579.2	581.4	619.2	651.6	689.8
29.015	369.0	20.0	535.8	545.8	583.1	585.2	621.2	652.0	688.4
30.333	349.9	19.9	541.8	551.4	586.7	588.6	622.6	651.9	686.4
31.652	329.0	19.8	547.5	556.5	589.6	591.5	623.4	650.9	683.5
32.971	306.5	19.7	552.9	561.3	592.0	593.7	623.5	649.1	679.5
34.290	283.1	19.7	557.8	565.6	594.0	595.5	623.0	646.7	674.9

TIME - 8.010D+00 s (18 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	383.1	22.2	371.2	380.6	424.4	426.5	468.4	504.3	549.6
1.319	403.3	22.1	377.8	387.7	433.4	435.6	479.4	516.8	563.7
2.638	421.4	22.0	384.6	395.0	442.5	444.8	490.1	528.9	577.1

3.957	436.8	21.9	391.7	402.6	451.4	453.9	500.5	540.3	589.6
5.275	450.6	21.8	399.1	410.3	460.4	462.9	510.7	551.4	601.5
6.594	461.7	21.7	406.7	418.3	469.3	471.8	520.4	561.9	612.5
7.913	471.2	21.6	414.5	426.3	478.0	480.6	529.9	571.9	622.9
9.232	478.5	21.5	422.4	434.5	486.7	489.3	539.0	581.4	632.5
10.551	484.1	21.4	430.4	442.7	495.2	497.9	547.9	590.4	641.6
11.870	487.5	21.3	438.5	451.0	503.5	506.2	556.2	598.8	649.8
13.188	489.2	21.2	446.7	459.3	511.7	514.4	564.3	606.8	657.5
14.507	488.8	21.1	454.9	467.5	519.5	522.3	571.9	614.1	664.3
15.826	486.6	21.0	463.1	475.7	527.2	529.9	579.0	620.8	670.4
17.145	482.8	20.8	471.2	483.8	534.6	537.3	585.8	627.1	675.9
18.464	476.8	20.7	479.2	491.7	541.7	544.3	592.0	632.6	680.5
19.783	469.5	20.6	487.2	499.5	548.5	551.1	597.8	637.6	684.6
21.102	460.4	20.5	495.0	507.2	554.9	557.5	603.1	642.0	687.9
22.420	449.7	20.4	502.6	514.6	561.0	563.5	607.9	645.8	690.4
23.739	437.3	20.3	510.1	521.8	566.7	569.1	612.2	648.9	692.1
25.058	423.5	20.2	517.3	528.7	572.0	574.4	615.9	651.4	693.2
26.377	408.0	20.1	524.3	535.4	576.9	579.2	619.1	653.2	693.4
27.696	391.3	20.0	531.1	541.7	581.4	583.6	621.7	654.4	692.9
29.015	372.8	19.9	537.5	547.6	585.4	587.4	623.7	654.8	691.5
30.333	353.5	19.9	543.6	553.3	588.9	590.9	625.2	654.7	689.5
31.652	332.4	19.8	549.4	558.5	591.9	593.8	626.0	653.7	686.5
32.971	309.7	19.7	554.8	563.3	594.3	596.1	626.1	651.9	682.6
34.290	286.1	19.6	559.8	567.7	596.3	597.9	625.6	649.4	677.9

TIME = 9.010D+00 s (18 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	387.8	22.2	371.2	380.8	425.0	427.1	469.5	505.8	551.6
1.319	408.2	22.1	377.8	387.9	434.1	436.4	480.6	518.4	565.7
2.638	426.5	22.0	384.8	395.3	443.3	445.6	491.5	530.6	579.3
3.957	442.1	21.9	392.0	402.9	452.4	454.8	502.0	542.2	591.9
5.275	456.0	21.8	399.4	410.8	461.4	464.0	512.3	553.4	603.9
6.594	467.3	21.7	407.1	418.8	470.4	473.0	522.1	564.0	615.0
7.913	476.9	21.6	415.0	427.0	479.3	481.9	531.7	574.1	625.5
9.232	484.3	21.5	423.0	435.2	488.0	490.7	540.9	583.7	635.3
10.551	489.9	21.4	431.1	443.6	496.6	499.3	549.8	592.8	644.4
11.870	493.4	21.3	439.3	451.9	505.0	507.8	558.3	601.3	652.8
13.188	495.2	21.2	447.6	460.3	513.3	516.0	566.5	609.4	660.5
14.507	494.7	21.1	455.9	468.6	521.3	524.0	574.1	616.7	667.4
15.826	492.5	20.9	464.1	476.9	529.0	531.7	581.4	623.6	673.6
17.145	488.6	20.8	472.4	485.1	536.5	539.2	588.2	629.9	679.1
18.464	482.5	20.7	480.5	493.2	543.6	546.3	594.5	635.4	683.8
19.783	475.2	20.6	488.5	501.1	550.5	553.1	600.3	640.5	687.9
21.102	466.0	20.5	496.5	508.8	557.0	559.6	605.7	645.0	691.2
22.420	455.2	20.4	504.2	516.3	563.2	565.7	610.6	648.8	693.8
23.739	442.6	20.3	511.7	523.6	569.0	571.4	614.9	652.0	695.5
25.058	428.6	20.2	519.1	530.6	574.4	576.7	618.7	654.5	696.6
26.377	413.0	20.1	526.2	537.3	579.3	581.6	621.9	656.4	696.8
27.696	396.0	20.0	533.0	543.7	583.8	586.0	624.6	657.6	696.3
29.015	377.3	19.9	539.5	549.7	587.8	589.9	626.6	658.0	694.9
30.333	357.8	19.8	545.7	555.4	591.4	593.4	628.1	657.8	692.9
31.652	336.5	19.8	551.5	560.7	594.5	596.3	628.9	656.9	689.9
32.971	313.4	19.7	557.0	565.6	596.9	598.7	629.0	655.0	685.9
34.290	289.5	19.6	562.0	570.0	598.9	600.5	628.5	652.6	681.2

TIME = 1.001D+01 s (18 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	392.4	22.2	371.2	380.9	425.6	427.8	470.6	507.3	553.5
1.319	413.1	22.1	377.9	388.1	434.8	437.1	481.8	520.1	567.8
2.638	431.6	22.0	384.9	395.6	444.1	446.5	492.9	532.4	581.5
3.957	447.4	21.9	392.2	403.3	453.3	455.8	503.5	544.1	594.3
5.275	461.5	21.8	399.8	411.3	462.5	465.1	513.9	555.5	606.4
6.594	472.9	21.7	407.5	419.4	471.5	474.2	523.8	566.1	617.6
7.913	482.6	21.6	415.5	427.6	480.5	483.2	533.5	576.4	628.3
9.232	490.1	21.5	423.6	436.0	489.4	492.1	542.9	586.1	638.1
10.551	495.8	21.4	431.8	444.4	498.1	500.8	551.9	595.3	647.3
11.870	499.3	21.3	440.1	452.9	506.6	509.4	560.4	603.9	655.8
13.188	501.1	21.2	448.5	461.4	514.9	517.7	568.7	612.0	663.6
14.507	500.6	21.0	456.9	469.8	523.0	525.8	576.4	619.5	670.5
15.826	498.4	20.9	465.3	478.2	530.8	533.6	583.7	626.4	676.8
17.145	494.5	20.8	473.6	486.5	538.4	541.2	590.7	632.8	682.4
18.464	488.3	20.7	481.8	494.6	545.6	548.4	597.0	638.4	687.1
19.783	480.8	20.6	490.0	502.6	552.6	555.3	603.0	643.6	691.3

21.102	471.6	20.5	498.0	510.5	559.2	561.8	608.4	648.1	694.6
22.420	460.6	20.4	505.8	518.1	565.5	568.0	613.3	651.9	697.2
23.739	447.8	20.3	513.4	525.4	571.3	573.8	617.7	655.1	699.0
25.058	433.8	20.2	520.8	532.5	576.7	579.1	621.5	657.7	700.1
26.377	417.9	20.1	528.0	539.3	581.7	584.1	624.8	659.6	700.4
27.696	400.8	20.0	534.9	545.8	586.3	588.5	627.5	660.8	699.9
29.015	381.9	19.9	541.5	551.9	590.4	592.5	629.5	661.2	698.5
30.333	362.1	19.8	547.7	557.7	594.0	596.0	631.0	661.1	696.4
31.652	340.5	19.7	553.7	563.0	597.1	599.0	631.9	660.1	693.4
32.971	317.2	19.7	559.2	567.9	599.6	601.3	631.9	658.3	689.4
34.290	293.0	19.6	564.3	572.4	601.6	603.2	631.5	655.8	684.6

TIME = 1.101D+01 s (18 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm2-C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	397.4	22.2	371.2	381.0	426.3	428.5	471.9	508.9	555.6
1.319	418.4	22.1	378.0	388.3	435.6	438.0	483.2	521.8	570.1
2.638	437.1	22.0	385.1	395.9	445.0	447.4	494.3	534.3	583.9
3.957	453.1	21.9	392.5	403.7	454.3	456.8	505.1	546.2	596.8
5.275	467.4	21.8	400.1	411.8	463.6	466.2	515.6	557.7	609.1
6.594	478.9	21.7	408.0	420.0	472.8	475.4	525.7	568.4	620.4
7.913	488.8	21.6	416.1	428.4	481.9	484.6	535.5	578.8	631.2
9.232	496.3	21.5	424.3	436.8	490.8	493.6	544.9	588.6	641.1
10.551	502.1	21.4	432.6	445.4	499.6	502.4	554.0	597.9	650.4
11.870	505.7	21.3	441.0	453.9	508.3	511.1	562.7	606.6	659.0
13.188	507.5	21.1	449.5	462.5	516.7	519.5	571.0	614.8	666.8
14.507	507.0	21.0	458.0	471.1	524.9	527.7	578.9	622.4	673.9
15.826	504.8	20.9	466.4	479.6	532.8	535.6	586.3	629.4	680.2
17.145	500.8	20.8	474.9	488.0	540.5	543.2	593.3	635.8	685.9
18.464	494.5	20.7	483.2	496.2	547.8	550.5	599.7	641.5	690.7
19.783	487.0	20.6	491.5	504.3	554.8	557.5	605.7	646.8	694.9
21.102	477.5	20.5	499.6	512.2	561.5	564.2	611.2	651.3	698.3
22.420	466.5	20.4	507.5	519.9	567.8	570.4	616.2	655.3	700.9
23.739	453.6	20.2	515.2	527.4	573.8	576.3	620.6	658.5	702.7
25.058	439.3	20.1	522.7	534.6	579.3	581.7	624.5	661.1	703.9
26.377	423.3	20.0	530.0	541.4	584.3	586.7	627.8	663.0	704.1
27.696	405.9	20.0	537.0	548.0	589.0	591.2	630.6	664.2	703.6
29.015	386.7	19.9	543.6	554.2	593.1	595.2	632.6	664.7	702.2
30.333	366.7	19.8	550.0	560.0	596.8	598.8	634.2	664.5	700.2
31.652	344.8	19.7	556.0	565.4	599.9	601.8	635.0	663.6	697.1
32.971	321.2	19.6	561.6	570.4	602.4	604.2	635.1	661.7	693.1
34.290	296.7	19.5	566.8	575.0	604.4	606.1	634.6	659.2	688.3

TIME = 1.201D+01 s (18 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm2-C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	402.8	22.2	371.2	381.1	427.0	429.2	473.1	510.7	557.9
1.319	424.0	22.1	378.1	388.5	436.5	438.8	484.6	523.7	572.5
2.638	443.0	22.0	385.3	396.2	446.0	448.4	495.9	536.4	586.5
3.957	459.2	21.9	392.8	404.2	455.4	457.9	506.8	548.4	599.5
5.275	473.7	21.8	400.5	412.3	464.8	467.4	517.4	560.0	611.9
6.594	485.4	21.7	408.5	420.7	474.1	476.8	527.6	570.9	623.4
7.913	495.3	21.6	416.7	429.1	483.3	486.0	537.6	581.4	634.2
9.232	503.0	21.5	425.0	437.7	492.4	495.2	547.1	591.3	644.3
10.551	508.9	21.4	433.4	446.4	501.3	504.1	556.4	600.7	653.7
11.870	512.5	21.2	441.9	455.1	510.0	512.9	565.1	609.6	662.4
13.188	514.3	21.1	450.5	463.8	518.6	521.4	573.6	617.9	670.3
14.507	513.9	21.0	459.1	472.4	526.9	529.7	581.5	625.5	677.5
15.826	511.6	20.9	467.7	481.0	534.9	537.7	589.0	632.6	683.9
17.145	507.5	20.8	476.3	489.5	542.7	545.5	596.1	639.1	689.6
18.464	501.2	20.7	484.7	497.9	550.1	552.9	602.6	644.9	694.5
19.783	493.5	20.5	493.1	506.1	557.2	560.0	608.7	650.2	698.7
21.102	484.0	20.4	501.3	514.1	564.0	566.7	614.3	654.8	702.2
22.420	472.8	20.3	509.3	521.9	570.4	573.0	619.3	658.8	704.8
23.739	459.7	20.2	517.2	529.5	576.4	578.9	623.8	662.1	706.7
25.058	445.2	20.1	524.8	536.8	582.0	584.5	627.8	664.7	707.8
26.377	429.0	20.0	532.1	543.7	587.1	589.5	631.1	666.6	708.1
27.696	411.4	19.9	539.2	550.4	591.8	594.1	633.9	667.9	707.6
29.015	391.9	19.8	545.9	556.6	596.0	598.1	636.0	668.3	706.2
30.333	371.6	19.7	552.4	562.6	599.7	601.8	637.6	668.2	704.2
31.652	349.5	19.7	558.4	568.0	602.9	604.8	638.4	667.2	701.1
32.971	325.6	19.6	564.1	573.1	605.4	607.2	638.5	665.4	697.0
34.290	300.7	19.5	569.4	577.7	607.5	609.2	638.0	662.8	692.2

TIME = 1.301D+01 s (18 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	408.1	22.2	371.2	381.3	427.7	430.0	474.5	512.4	560.1
1.319	429.6	22.1	378.2	388.8	437.3	439.7	486.1	525.6	574.9
2.638	448.8	22.0	385.5	396.6	446.9	449.4	497.5	538.5	589.1
3.957	465.3	21.9	393.1	404.6	456.5	459.1	508.5	550.6	602.2
5.275	480.0	21.8	400.9	412.9	466.0	468.7	519.3	562.3	614.8
6.594	491.9	21.7	409.0	421.3	475.4	478.2	529.6	573.4	626.4
7.913	501.9	21.6	417.3	429.9	484.8	487.5	539.7	584.0	637.4
9.232	509.7	21.5	425.7	438.6	493.9	496.8	549.3	594.0	647.6
10.551	515.7	21.4	434.2	447.4	503.0	505.8	558.7	603.6	657.1
11.870	519.3	21.2	442.9	456.2	511.8	514.7	567.6	612.5	665.8
13.188	521.1	21.1	451.6	465.0	520.5	523.4	576.1	620.9	673.9
14.507	520.7	21.0	460.3	473.8	528.9	531.8	584.2	628.7	681.1
15.826	518.4	20.9	469.0	482.5	537.0	539.9	591.8	635.8	687.6
17.145	514.3	20.8	477.7	491.1	544.9	547.8	598.9	642.4	693.4
18.464	507.9	20.6	486.2	499.6	552.4	555.2	605.5	648.3	698.3
19.783	500.1	20.5	494.7	507.9	559.6	562.4	611.7	653.7	702.6
21.102	490.5	20.4	503.0	516.1	566.5	569.2	617.4	658.4	706.1
22.420	479.0	20.3	511.2	524.0	573.0	575.7	622.5	662.4	708.8
23.739	465.8	20.2	519.1	531.6	579.1	581.7	627.0	665.7	710.7
25.058	451.1	20.1	526.8	539.0	584.7	587.2	631.0	668.4	711.9
26.377	434.7	20.0	534.3	546.1	589.9	592.4	634.4	670.3	712.2
27.696	416.8	19.9	541.4	552.8	594.7	597.0	637.2	671.6	711.7
29.015	397.1	19.8	548.3	559.1	598.9	601.1	639.4	672.1	710.3
30.333	376.6	19.7	554.8	565.1	602.7	604.8	641.0	672.0	708.2
31.652	354.1	19.6	560.9	570.7	605.9	607.9	641.9	671.0	705.2
32.971	329.9	19.6	566.7	575.8	608.5	610.4	642.0	669.1	701.0
34.290	304.7	19.5	572.0	580.5	610.6	612.3	641.5	666.6	696.2

TIME = 1.401D+01 s (19 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	413.8	22.2	371.2	381.4	428.5	430.8	475.8	514.3	562.5
1.319	435.6	22.1	378.3	389.0	438.2	440.6	487.6	527.7	577.5
2.638	455.1	22.0	385.7	396.9	448.0	450.5	499.2	540.6	591.8
3.957	471.8	21.9	393.4	405.1	457.6	460.3	510.3	552.9	605.1
5.275	486.7	21.8	401.3	413.5	467.3	470.0	521.2	564.8	617.8
6.594	498.7	21.7	409.5	422.0	476.8	479.6	531.7	576.0	629.6
7.913	509.0	21.6	417.9	430.7	486.3	489.1	541.9	586.8	640.7
9.232	516.8	21.5	426.5	439.5	495.6	498.5	551.7	596.9	651.0
10.551	522.9	21.3	435.1	448.4	504.8	507.7	561.2	606.6	660.6
11.870	526.6	21.2	443.9	457.4	513.7	516.6	570.2	615.6	669.5
13.188	528.4	21.1	452.7	466.3	522.5	525.4	578.8	624.1	677.6
14.507	528.0	21.0	461.5	475.2	531.0	533.9	587.0	632.0	684.9
15.826	525.7	20.9	470.4	484.1	539.3	542.2	594.7	639.3	691.5
17.145	521.5	20.7	479.1	492.8	547.3	550.1	601.9	645.9	697.4
18.464	515.0	20.6	487.8	501.4	554.9	557.7	608.6	651.9	702.3
19.783	507.1	20.5	496.4	509.8	562.2	565.0	614.9	657.3	706.7
21.102	497.4	20.4	504.9	518.1	569.2	571.9	620.6	662.1	710.3
22.420	485.8	20.3	513.1	526.1	575.7	578.4	625.8	666.2	713.0
23.739	472.3	20.2	521.2	533.9	581.9	584.5	630.4	669.5	714.9
25.058	457.5	20.1	529.0	541.4	587.7	590.2	634.5	672.3	716.1
26.377	440.0	20.0	536.5	548.5	592.9	595.4	637.9	674.2	716.5
27.696	422.7	19.9	543.8	555.3	597.8	600.1	640.8	675.6	716.0
29.015	402.7	19.8	550.7	561.8	602.0	604.3	643.0	676.0	714.6
30.333	381.8	19.7	557.3	567.8	605.9	608.0	644.6	675.9	712.5
31.652	359.1	19.6	563.6	573.5	609.1	611.1	645.5	675.0	709.4
32.971	334.5	19.5	569.4	578.7	611.8	613.6	645.6	673.0	705.2
34.290	309.0	19.4	574.8	583.4	613.9	615.6	645.1	670.5	700.3

TIME = 1.501D+01 s (19 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	419.9	22.2	371.2	381.5	429.3	431.7	477.3	516.3	565.1
1.319	442.0	22.1	378.4	389.3	439.2	441.6	489.2	529.8	580.2
2.638	461.8	22.0	385.9	397.3	449.1	451.6	500.9	543.0	594.7
3.957	478.8	21.9	393.7	405.6	458.9	461.5	512.3	555.4	608.2
5.275	493.8	21.8	401.8	414.1	468.7	471.4	523.3	567.5	621.0
6.594	506.1	21.7	410.1	422.8	478.3	481.1	533.9	578.8	632.9
7.913	516.4	21.6	418.6	431.6	487.9	490.8	544.3	589.7	644.1
9.232	524.4	21.5	427.3	440.5	497.3	500.3	554.2	600.0	654.6

10.551	530.5	21.3	436.1	449.6	506.7	509.6	563.8	609.8	664.4
11.870	534.3	21.2	444.9	458.6	515.7	518.7	572.9	618.9	673.3
13.188	536.2	21.1	453.9	467.7	524.6	527.6	581.7	627.6	681.6
14.507	535.7	21.0	462.9	476.8	533.3	536.2	589.9	635.5	689.0
15.826	533.4	20.8	471.8	485.7	541.7	544.6	597.8	642.9	695.6
17.145	529.1	20.7	480.7	494.6	549.7	552.7	605.1	649.7	701.6
18.464	522.5	20.6	489.5	503.3	557.5	560.4	611.9	655.7	706.6
19.783	514.5	20.5	498.2	511.9	564.9	567.8	618.3	661.2	711.0
21.102	504.6	20.4	506.8	520.3	572.0	574.8	624.1	666.0	714.7
22.420	492.9	20.2	515.2	528.4	578.7	581.4	629.4	670.2	717.5
23.739	479.2	20.1	523.4	536.3	584.9	587.5	634.0	673.6	719.4
25.058	464.2	20.0	531.3	543.9	590.7	593.3	638.2	676.4	720.7
26.377	447.2	19.9	539.0	551.1	596.1	598.6	641.6	678.4	721.0
27.696	428.9	19.8	546.3	558.0	601.0	603.4	644.5	679.7	720.5
29.015	408.6	19.7	553.4	564.6	605.3	607.6	646.7	680.2	719.1
30.333	387.4	19.6	560.1	570.7	609.2	611.4	648.4	680.1	717.0
31.652	364.4	19.6	566.4	576.5	612.5	614.5	649.3	679.1	713.9
32.971	339.4	19.5	572.3	581.7	615.2	617.1	649.4	677.2	709.7
34.290	313.5	19.4	577.8	586.5	617.4	619.1	649.0	674.6	704.7

TIME = 1.601D+01 s (19 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	426.0	22.2	371.2	381.7	430.1	432.5	478.8	518.3	567.6
1.319	448.4	22.1	378.5	389.5	440.1	442.6	490.9	532.0	582.9
2.638	468.5	22.0	386.1	397.7	450.2	452.8	502.7	545.3	597.6
3.957	485.7	21.9	394.0	406.1	460.1	462.8	514.2	557.9	611.2
5.275	501.0	21.8	402.2	414.7	470.0	472.8	525.4	570.1	624.3
6.594	513.4	21.7	410.6	423.5	479.8	482.7	536.2	581.6	636.3
7.913	523.9	21.6	419.3	432.5	489.6	492.5	546.6	592.6	647.7
9.232	532.0	21.4	428.1	441.6	499.1	502.1	556.7	603.1	658.2
10.551	538.2	21.3	437.0	450.7	508.6	511.5	566.4	613.0	668.1
11.870	542.0	21.2	446.0	459.9	517.8	520.8	575.7	622.3	677.2
13.188	543.9	21.1	455.1	469.1	526.8	529.8	584.6	631.0	685.6
14.507	543.5	20.9	464.2	478.3	535.6	538.6	593.0	639.1	693.0
15.826	541.1	20.8	473.3	487.4	544.1	547.1	600.9	646.5	699.8
17.145	536.8	20.7	482.3	496.4	552.3	555.2	608.4	653.4	705.9
18.464	530.1	20.6	491.3	505.3	560.1	563.0	615.2	659.5	711.0
19.783	522.0	20.5	500.1	514.0	567.7	570.5	621.7	665.1	715.4
21.102	511.9	20.3	508.8	522.4	574.8	577.7	627.6	670.0	719.1
22.420	500.0	20.2	517.3	530.7	581.6	584.4	632.9	674.2	722.0
23.739	486.2	20.1	525.6	538.7	587.9	590.6	637.7	677.7	724.0
25.058	470.9	20.0	533.6	546.4	593.9	596.5	641.9	680.5	725.2
26.377	453.7	19.9	541.4	553.8	599.3	601.8	645.4	682.6	725.6
27.696	435.1	19.8	548.9	560.8	604.3	606.7	648.4	683.9	725.1
29.015	414.5	19.7	556.0	567.4	608.7	611.0	650.6	684.5	723.7
30.333	393.0	19.6	562.8	573.7	612.6	614.8	652.3	684.4	721.6
31.652	369.6	19.5	569.2	579.5	616.0	618.0	653.2	683.4	718.5
32.971	344.3	19.4	575.2	584.8	618.7	620.6	653.4	681.4	714.2
34.290	318.1	19.4	580.8	589.7	620.9	622.7	652.9	678.8	709.2

TIME = 1.651D+01 s (17 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	429.2	22.2	371.2	381.8	430.6	433.0	479.5	519.3	568.9
1.319	451.8	22.1	378.5	389.7	440.6	443.1	491.7	533.1	584.4
2.638	472.0	22.0	386.2	397.9	450.7	453.4	503.7	546.5	599.1
3.957	489.3	21.9	394.2	406.3	460.7	463.5	515.2	559.2	612.8
5.275	504.7	21.8	402.4	415.0	470.8	473.6	526.5	571.5	625.9
6.594	517.2	21.7	410.9	423.9	480.6	483.5	537.3	583.1	638.0
7.913	527.8	21.6	419.6	432.9	490.4	493.3	547.9	594.2	649.5
9.232	536.0	21.4	428.5	442.1	500.0	503.0	558.0	604.7	660.1
10.551	542.3	21.3	437.5	451.3	509.6	512.6	567.8	614.7	670.1
11.870	546.1	21.2	446.6	460.6	518.8	521.9	577.1	624.0	679.2
13.188	548.0	21.1	455.7	469.9	527.9	531.0	586.1	632.8	687.6
14.507	547.6	20.9	464.9	479.1	536.8	539.8	594.5	640.9	695.2
15.826	545.2	20.8	474.0	488.3	545.3	548.3	602.5	648.4	702.0
17.145	540.8	20.7	483.1	497.3	553.6	556.6	610.0	655.4	708.1
18.464	534.1	20.6	492.2	506.3	561.5	564.4	616.9	661.5	713.2
19.783	525.9	20.4	501.1	515.0	569.1	572.0	623.5	667.1	717.7
21.102	515.8	20.3	509.8	523.6	576.3	579.2	629.4	672.1	721.4
22.420	503.8	20.2	518.4	531.9	583.1	585.9	634.8	676.3	724.3
23.739	489.8	20.1	526.7	539.9	589.5	592.2	639.5	679.8	726.3
25.058	474.4	20.0	534.8	547.7	595.5	598.1	643.8	682.7	727.6
26.377	457.1	19.9	542.7	555.1	600.9	603.5	647.4	684.7	727.9

27.696	438.3	19.8	550.2	562.2	606.0	608.4	650.3	686.1	727.5
29.015	417.6	19.7	557.4	568.9	610.4	612.7	652.6	686.6	726.1
30.333	396.0	19.6	564.2	575.2	614.4	616.6	654.3	686.6	724.0
31.652	372.4	19.5	570.7	581.0	617.8	619.8	655.3	685.6	720.8
32.971	346.9	19.4	576.7	586.4	620.5	622.4	655.4	683.6	716.6
34.290	320.5	19.3	582.3	591.3	622.7	624.5	654.9	681.0	711.5

TIME = 1.656D+01 s (25 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	429.6	22.2	371.2	381.8	430.6	433.0	479.6	519.4	569.1
1.319	452.2	22.1	378.6	389.7	440.7	443.2	491.8	533.2	584.5
2.638	472.4	22.0	386.2	397.9	450.8	453.4	503.8	546.6	599.3
3.957	489.7	21.9	394.2	406.4	460.8	463.5	515.3	559.4	613.0
5.275	505.2	21.8	402.5	415.1	470.8	473.6	526.6	571.6	626.1
6.594	517.7	21.7	411.0	423.9	480.7	483.6	537.5	583.2	638.2
7.913	528.3	21.6	419.7	433.0	490.5	493.4	548.0	594.3	649.7
9.232	536.5	21.4	428.5	442.1	500.1	503.1	558.1	604.8	660.3
10.551	542.7	21.3	437.5	451.4	509.7	512.7	567.9	614.8	670.3
11.870	546.6	21.2	446.6	460.7	518.9	522.0	577.3	624.2	679.4
13.188	548.5	21.1	455.8	469.9	528.1	531.1	586.2	633.0	687.8
14.507	548.0	20.9	465.0	479.2	536.9	539.9	594.7	641.1	695.4
15.826	545.6	20.8	474.1	488.4	545.4	548.5	602.7	648.6	702.2
17.145	541.3	20.7	483.2	497.4	553.7	556.7	610.2	655.6	708.3
18.464	534.5	20.6	492.3	506.4	561.6	564.6	617.1	661.7	713.4
19.783	526.3	20.4	501.2	515.1	569.2	572.1	623.6	667.3	717.9
21.102	516.2	20.3	509.9	523.7	576.5	579.3	629.6	672.3	721.7
22.420	504.2	20.2	518.5	532.0	583.3	586.1	635.0	676.5	724.5
23.739	490.2	20.1	526.8	540.1	589.7	592.4	639.7	680.0	726.5
25.058	474.8	20.0	535.0	547.8	595.6	598.3	644.0	682.9	727.8
26.377	457.5	19.9	542.8	555.3	601.1	603.6	647.5	685.0	728.2
27.696	438.7	19.8	550.3	562.3	606.1	608.6	650.5	686.3	727.7
29.015	418.0	19.7	557.5	569.0	610.6	612.9	652.8	686.9	726.3
30.333	396.3	19.6	564.4	575.3	614.6	616.8	654.5	686.8	724.2
31.652	372.7	19.5	570.8	581.2	618.0	620.0	655.5	685.8	721.1
32.971	347.2	19.4	576.9	586.5	620.7	622.6	655.6	683.9	716.8
34.290	320.7	19.3	582.5	591.4	622.9	624.7	655.1	681.2	711.8

TIME = 1.661D+01 s (26 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	429.9	22.2	371.2	381.8	430.7	433.1	479.7	519.5	569.2
1.319	452.6	22.1	378.6	389.7	440.7	443.2	491.9	533.4	584.7
2.638	472.8	22.0	386.2	397.9	450.9	453.5	503.9	546.8	599.4
3.957	490.2	21.9	394.2	406.4	460.9	463.6	515.4	559.5	613.2
5.275	505.6	21.8	402.5	415.1	470.9	473.7	526.7	571.8	626.3
6.594	518.1	21.7	411.0	424.0	480.8	483.7	537.6	583.4	638.4
7.913	528.7	21.6	419.7	433.0	490.6	493.5	548.1	594.5	649.9
9.232	536.9	21.4	428.6	442.2	500.2	503.2	558.3	605.0	660.5
10.551	543.2	21.3	437.6	451.4	509.8	512.8	568.1	615.0	670.5
11.870	547.0	21.2	446.7	460.7	519.1	522.1	577.4	624.4	679.6
13.188	549.0	21.1	455.9	470.0	528.2	531.2	586.4	633.2	688.0
14.507	548.5	20.9	465.0	479.3	537.0	540.0	594.8	641.3	695.6
15.826	546.1	20.8	474.2	488.5	545.6	548.6	602.8	648.8	702.4
17.145	541.7	20.7	483.3	497.5	553.9	556.9	610.4	655.8	708.5
18.464	535.0	20.6	492.3	506.5	561.8	564.7	617.3	661.9	713.7
19.783	526.8	20.4	501.3	515.2	569.4	572.3	623.8	667.6	718.2
21.102	516.7	20.3	510.0	523.8	576.6	579.5	629.8	672.5	721.9
22.420	504.6	20.2	518.6	532.1	583.4	586.2	635.2	676.7	724.8
23.739	490.6	20.1	527.0	540.2	589.8	592.5	639.9	680.2	726.8
25.058	475.2	20.0	535.1	548.0	595.8	598.4	644.2	683.1	728.1
26.377	457.9	19.9	542.9	555.4	601.3	603.8	647.7	685.2	728.4
27.696	439.1	19.8	550.5	562.5	606.3	608.7	650.7	686.6	728.0
29.015	418.3	19.7	557.7	569.2	610.8	613.1	653.0	687.1	726.6
30.333	396.7	19.6	564.5	575.5	614.8	616.9	654.7	687.0	724.5
31.652	373.0	19.5	571.0	581.3	618.1	620.2	655.7	686.0	721.3
32.971	347.5	19.4	577.0	586.7	620.9	622.8	655.8	684.1	717.0
34.290	321.0	19.3	582.7	591.6	623.1	624.9	655.3	681.4	712.0

TIME = 1.666D+01 s (26 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
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0.000	427.1	22.2	371.2	381.8	430.6	433.0	479.6	519.4	569.1
1.319	449.6	22.1	378.6	389.7	440.7	443.2	491.8	533.2	584.6
2.638	469.7	22.0	386.2	397.9	450.8	453.4	503.8	546.6	599.4
3.957	486.9	21.9	394.2	406.4	460.8	463.5	515.3	559.4	613.1
5.275	502.2	21.8	402.5	415.1	470.8	473.6	526.6	571.7	626.2
6.594	514.7	21.7	411.0	424.0	480.7	483.6	537.5	583.2	638.3
7.913	525.2	21.6	419.7	433.0	490.5	493.5	548.0	594.4	649.8
9.232	533.3	21.4	428.6	442.2	500.2	503.2	558.2	604.9	660.5
10.551	539.6	21.3	437.6	451.4	509.7	512.7	568.0	614.9	670.4
11.870	543.4	21.2	446.7	460.7	519.0	522.0	577.3	624.3	679.6
13.188	545.3	21.1	455.8	470.0	528.1	531.2	586.3	633.1	688.0
14.507	544.8	20.9	465.0	479.2	537.0	540.0	594.8	641.2	695.6
15.826	542.4	20.8	474.2	488.4	545.5	548.6	602.8	648.8	702.4
17.145	538.1	20.7	483.3	497.5	553.8	556.8	610.3	655.7	708.5
18.464	531.4	20.6	492.3	506.5	561.7	564.7	617.2	661.9	713.6
19.783	523.3	20.4	501.2	515.2	569.4	572.3	623.8	667.5	718.2
21.102	513.2	20.3	510.0	523.8	576.6	579.5	629.7	672.5	721.9
22.420	501.3	20.2	518.6	532.1	583.4	586.2	635.1	676.7	724.8
23.739	487.4	20.1	527.0	540.2	589.8	592.5	639.9	680.2	726.8
25.058	472.1	20.0	535.1	548.0	595.8	598.4	644.2	683.1	728.1
26.377	454.8	19.9	542.9	555.4	601.3	603.8	647.7	685.2	728.5
27.696	436.1	19.8	550.5	562.5	606.3	608.8	650.7	686.6	728.0
29.015	415.6	19.7	557.7	569.2	610.8	613.1	653.0	687.1	726.6
30.333	394.0	19.6	564.5	575.5	614.8	617.0	654.7	687.0	724.5
31.652	370.6	19.5	571.0	581.4	618.2	620.3	655.7	686.1	721.4
32.971	345.2	19.4	577.1	586.8	621.0	622.9	655.8	684.1	717.1
34.290	318.9	19.3	582.7	591.7	623.2	624.9	655.4	681.5	712.1

TIME = 1.668D+01 s (32 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	424.9	22.2	371.2	381.8	430.5	432.9	479.5	519.3	569.0
1.319	447.3	22.1	378.5	389.7	440.6	443.1	491.7	533.1	584.5
2.638	467.3	22.0	386.2	397.9	450.7	453.3	503.7	546.5	599.3
3.957	484.5	21.9	394.2	406.3	460.8	463.5	515.2	559.2	613.0
5.275	499.7	21.8	402.4	415.0	470.8	473.6	526.5	571.6	626.1
6.594	512.1	21.7	410.9	423.9	480.7	483.5	537.4	583.1	638.2
7.913	522.6	21.6	419.7	433.0	490.5	493.4	547.9	594.3	649.7
9.232	530.7	21.4	428.5	442.1	500.1	503.1	558.1	604.8	660.4
10.551	536.9	21.3	437.5	451.4	509.6	512.6	567.9	614.8	670.3
11.870	540.7	21.2	446.6	460.7	518.9	522.0	577.2	624.1	679.5
13.188	542.6	21.1	455.8	470.0	528.1	531.1	586.2	633.0	687.9
14.507	542.1	20.9	465.0	479.2	536.9	539.9	594.7	641.1	695.5
15.826	539.7	20.8	474.1	488.4	545.5	548.5	602.7	648.7	702.3
17.145	535.4	20.7	483.3	497.5	553.8	556.8	610.2	655.6	708.4
18.464	528.8	20.6	492.3	506.4	561.7	564.6	617.2	661.8	713.6
19.783	520.7	20.4	501.2	515.2	569.3	572.2	623.7	667.4	718.1
21.102	510.7	20.3	510.0	523.8	576.5	579.4	629.7	672.4	721.9
22.420	498.7	20.2	518.6	532.1	583.4	586.2	635.1	676.6	724.7
23.739	484.9	20.1	526.9	540.2	589.8	592.5	639.8	680.2	726.8
25.058	469.7	20.0	535.1	548.0	595.8	598.4	644.1	683.0	728.0
26.377	452.5	19.9	542.9	555.4	601.3	603.8	647.7	685.1	728.4
27.696	434.0	19.8	550.5	562.5	606.3	608.7	650.7	686.5	728.0
29.015	413.5	19.7	557.7	569.2	610.8	613.1	653.0	687.1	726.6
30.333	392.0	19.6	564.5	575.5	614.8	617.0	654.7	687.0	724.5
31.652	368.7	19.5	571.0	581.4	618.2	620.2	655.7	686.0	721.4
32.971	343.5	19.4	577.1	586.8	620.9	622.9	655.8	684.1	717.1
34.290	317.3	19.3	582.7	591.7	623.2	624.9	655.3	681.5	712.1

TIME = 1.670D+01 s (36 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	405.3	22.2	371.2	381.7	430.2	432.5	478.8	518.5	568.4
1.319	426.6	22.1	378.5	389.6	440.2	442.7	491.0	532.3	583.9
2.638	445.7	22.0	386.1	397.8	450.3	452.9	502.9	545.7	598.6
3.957	462.1	21.9	394.1	406.2	460.3	463.0	514.5	558.4	612.3
5.275	476.6	21.8	402.3	414.9	470.3	473.1	525.8	570.7	625.4
6.594	488.4	21.7	410.8	423.8	480.2	483.0	536.6	582.3	637.6
7.913	498.4	21.6	419.5	432.8	490.0	492.9	547.1	593.4	649.0
9.232	506.1	21.4	428.3	441.9	499.6	502.6	557.3	603.9	659.7
10.551	512.0	21.3	437.3	451.2	509.1	512.1	567.1	613.9	669.7
11.870	515.7	21.2	446.4	460.4	518.5	521.5	576.4	623.3	678.8
13.188	517.5	21.1	455.6	469.7	527.6	530.6	585.4	632.1	687.2
14.507	517.0	20.9	464.7	478.9	536.4	539.4	593.9	640.3	694.8
15.826	514.8	20.8	473.9	488.1	545.0	548.0	601.9	647.8	701.7

17.145	510.7	20.7	483.0	497.2	553.3	556.3	609.5	654.8	707.8
18.464	504.3	20.6	492.0	506.1	561.2	564.1	616.4	661.0	712.9
19.783	496.6	20.4	500.9	514.9	568.8	571.7	623.0	666.6	717.5
21.102	487.1	20.3	509.7	523.5	576.1	578.9	629.0	671.6	721.2
22.420	475.7	20.2	518.3	531.8	582.9	585.7	634.4	675.9	724.1
23.739	462.5	20.1	526.7	539.9	589.4	592.1	639.2	679.5	726.2
25.058	448.0	20.0	534.8	547.7	595.4	598.0	643.5	682.4	727.5
26.377	431.6	19.9	542.6	555.1	600.9	603.4	647.1	684.5	727.9
27.696	413.9	19.8	550.2	562.2	605.9	608.3	650.1	685.9	727.5
29.015	394.4	19.7	557.4	568.9	610.4	612.7	652.4	686.5	726.1
30.333	373.9	19.6	564.3	575.3	614.4	616.6	654.2	686.5	724.1
31.652	351.7	19.5	570.8	581.1	617.9	619.9	655.2	685.5	720.9
32.971	327.6	19.4	576.8	586.5	620.6	622.6	655.4	683.6	716.7
34.290	302.6	19.3	582.5	591.5	622.9	624.6	654.9	681.1	711.8

TIME = 1.6730+01 s (36 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	359.9	22.2	371.2	381.5	428.7	431.0	476.2	515.4	565.6
1.319	378.9	22.1	378.4	389.2	438.6	441.0	488.2	529.1	581.0
2.638	395.8	22.0	385.8	397.3	448.6	451.1	500.0	542.4	595.6
3.957	410.4	21.9	393.7	405.6	458.5	461.1	511.4	555.0	609.3
5.275	423.3	21.8	401.8	414.1	468.4	471.1	522.7	567.2	622.4
6.594	433.8	21.7	410.1	422.9	478.2	481.0	533.4	578.7	634.4
7.913	442.6	21.6	418.7	431.8	488.0	490.8	543.9	589.8	645.9
9.232	449.5	21.4	427.4	440.9	497.6	500.4	554.1	600.3	656.5
10.551	454.7	21.3	436.3	450.0	507.0	509.9	563.8	610.3	666.5
11.870	458.0	21.2	445.3	459.2	516.3	519.2	573.2	619.7	675.6
13.188	459.6	21.1	454.4	468.4	525.4	528.3	582.2	628.5	684.1
14.507	459.2	21.0	463.5	477.6	534.2	537.2	590.6	636.7	691.7
15.826	457.2	20.8	472.6	486.7	542.8	545.7	598.7	644.3	698.6
17.145	453.5	20.7	481.7	495.8	551.1	554.0	606.3	651.3	704.7
18.464	447.9	20.6	490.6	504.7	559.0	561.9	613.3	657.6	709.9
19.783	441.0	20.5	499.5	513.4	566.7	569.5	619.9	663.3	714.6
21.102	432.6	20.3	508.2	522.0	574.0	576.8	626.0	668.4	718.4
22.420	422.5	20.2	516.8	530.3	580.9	583.6	631.5	672.7	721.4
23.739	410.8	20.1	525.2	538.4	587.3	590.0	636.4	676.4	723.5
25.058	397.9	20.0	533.3	546.2	593.4	595.9	640.7	679.4	724.9
26.377	383.3	19.9	541.1	553.6	599.0	601.4	644.4	681.6	725.4
27.696	367.6	19.8	548.7	560.8	604.1	606.4	647.6	683.2	725.1
29.015	350.2	19.7	555.9	567.5	608.6	610.9	650.0	683.9	723.8
30.333	332.1	19.6	562.8	573.8	612.7	614.9	651.9	684.0	721.9
31.652	312.3	19.5	569.3	579.8	616.2	618.3	653.0	683.2	718.9
32.971	290.9	19.4	575.5	585.2	619.1	621.0	653.4	681.5	714.8
34.290	268.7	19.4	581.1	590.2	621.5	623.2	653.1	679.1	710.0

TIME = 1.6760+01 s (38 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	255.3	22.2	371.2	380.9	425.1	427.2	469.7	507.8	558.6
1.319	268.8	22.1	378.0	388.3	434.7	436.9	481.4	521.1	573.7
2.638	280.8	22.0	385.1	396.0	444.4	446.8	492.9	534.1	588.1
3.957	291.1	21.9	392.6	404.0	454.1	456.5	504.1	546.5	601.6
5.275	300.2	21.8	400.3	412.2	463.8	466.3	515.1	558.6	614.5
6.594	307.7	21.7	408.4	420.7	473.4	475.9	525.7	569.9	626.5
7.913	314.0	21.6	416.7	429.4	482.9	485.6	536.1	580.9	637.9
9.232	318.8	21.5	425.2	438.2	492.4	495.1	546.1	591.3	648.4
10.551	322.6	21.4	433.8	447.1	501.7	504.5	555.8	601.3	658.4
11.870	324.9	21.2	442.6	456.1	510.9	513.7	565.1	610.7	667.6
13.188	326.0	21.1	451.4	465.1	519.9	522.7	574.1	619.5	676.1
14.507	325.7	21.0	460.3	474.1	528.7	531.5	582.6	627.8	683.7
15.826	324.3	20.9	469.3	483.1	537.3	540.0	590.7	635.5	690.7
17.145	321.7	20.8	478.2	492.1	545.6	548.3	598.4	642.6	697.0
18.464	317.7	20.6	487.0	500.9	553.5	556.2	605.5	649.0	702.3
19.783	312.8	20.5	495.8	509.5	561.2	563.9	612.2	654.9	707.1
21.102	306.8	20.4	504.4	518.0	568.6	571.2	618.5	660.1	711.1
22.420	299.7	20.3	512.9	526.3	575.6	578.1	624.1	664.7	714.2
23.739	291.4	20.2	521.3	534.4	582.1	584.6	629.2	668.6	716.6
25.058	282.2	20.1	529.4	542.2	588.3	590.7	633.8	671.9	718.2
26.377	271.9	19.9	537.2	549.7	594.0	596.3	637.8	674.4	718.9
27.696	260.7	19.8	544.8	556.8	599.3	601.5	641.2	676.2	718.9
29.015	248.4	19.7	552.0	563.6	604.0	606.1	643.9	677.3	717.9
30.333	235.6	19.7	559.0	570.0	608.3	610.3	646.1	677.7	716.3
31.652	221.5	19.6	565.5	576.0	612.0	613.9	647.6	677.3	713.6
32.971	206.4	19.5	571.7	581.6	615.1	616.9	648.2	675.9	709.9

34.290 190.6 19.4 577.5 586.7 617.7 619.3 648.3 673.9 705.4

TIME = 1.680D+01 s (36 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm2-C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(1,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	162.5	22.2	371.2	379.8	418.8	420.6	458.3	493.7	544.4
1.319	171.0	22.1	377.3	386.5	427.7	429.7	469.3	506.3	558.9
2.638	178.7	22.1	383.7	393.5	436.8	438.8	480.3	518.8	572.9
3.957	185.2	22.0	390.4	400.8	445.9	448.0	490.9	530.7	586.0
5.275	191.1	21.9	397.5	408.4	455.1	457.3	501.5	542.3	598.6
6.594	195.8	21.8	404.9	416.2	464.2	466.5	511.7	553.3	610.3
7.913	199.8	21.7	412.6	424.3	473.3	475.7	521.7	564.1	621.5
9.232	202.9	21.5	420.5	432.6	482.4	484.8	531.5	574.3	632.0
10.551	205.3	21.4	428.5	440.9	491.4	493.9	541.0	584.1	641.9
11.870	206.7	21.3	436.8	449.5	500.3	502.8	550.2	593.5	651.1
13.188	207.5	21.2	445.1	458.0	509.1	511.6	559.1	602.4	659.6
14.507	207.3	21.1	453.6	466.7	517.7	520.2	567.5	610.7	667.4
15.826	206.4	21.0	462.1	475.3	526.2	528.7	575.7	618.5	674.5
17.145	204.7	20.9	470.6	483.9	534.4	536.9	583.4	625.8	681.0
18.464	202.2	20.7	479.1	492.4	542.3	544.8	590.7	632.4	686.6
19.783	199.1	20.6	487.6	500.9	550.0	552.5	597.6	638.6	691.7
21.102	195.3	20.5	496.0	509.2	557.4	559.8	604.1	644.2	696.0
22.420	190.7	20.4	504.3	517.3	564.5	566.8	610.0	649.1	699.5
23.739	185.4	20.3	512.5	525.3	571.2	573.5	615.5	653.4	702.3
25.058	179.6	20.2	520.4	533.0	577.5	579.8	620.4	657.2	704.4
26.377	173.0	20.1	528.2	540.5	583.4	585.6	624.8	660.2	705.6
27.696	165.9	20.0	535.7	547.7	588.9	591.0	628.7	662.6	706.1
29.015	158.1	19.9	543.0	554.5	594.0	596.0	631.9	664.3	705.7
30.333	149.9	19.8	549.9	561.0	598.6	600.5	634.6	665.3	704.7
31.652	141.0	19.7	556.6	567.2	602.6	604.5	636.6	665.6	702.7
32.971	131.3	19.6	562.9	572.9	606.1	607.8	637.9	665.0	699.7
34.290	121.3	19.5	568.8	578.2	609.1	610.7	638.6	663.7	695.9

TIME = 1.683D+01 s (38 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm2-C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	122.8	22.2	371.2	379.0		15.6	449.7	482.5	532.3
1.319	129.3	22.2	376.7	385.0		24.1	460.1	494.6	546.3
2.638	135.1	22.1	382.5	391.5		432.7	470.5	506.5	559.9
3.957	140.0	22.0	388.7	398.2	439.4	441.3	480.7	518.0	572.7
5.275	144.5	21.9	395.2	405.2	448.1	450.1	490.8	529.2	585.0
6.594	148.0	21.8	402.1	412.5	456.8	458.9	500.6	540.0	596.5
7.913	151.1	21.7	409.2	420.1	465.5	467.7	510.3	550.4	607.5
9.232	153.4	21.6	416.5	427.8	474.3	476.5	519.8	560.5	617.9
10.551	155.2	21.5	424.1	435.8	483.0	485.2	529.1	570.2	627.7
11.870	156.3	21.4	431.9	443.8	491.6	493.9	538.2	579.4	636.9
13.188	156.8	21.3	439.8	452.0	500.1	502.5	546.9	588.3	645.5
14.507	156.7	21.2	447.8	460.2	508.5	510.9	555.3	596.6	653.3
15.826	156.0	21.1	455.9	468.5	516.8	519.1	563.5	604.5	660.6
17.145	154.8	20.9	464.1	476.8	524.9	527.2	571.2	611.9	667.2
18.464	152.9	20.8	472.3	485.0	532.7	535.1	578.6	618.7	673.0
19.783	150.5	20.7	480.5	493.2	540.4	542.7	585.6	625.1	678.3
21.102	147.6	20.6	488.6	501.3	547.8	550.1	592.2	630.9	682.9
22.420	144.2	20.5	496.7	509.3	554.9	557.1	598.3	636.2	686.8
23.739	140.2	20.4	504.6	517.1	561.6	563.8	604.0	640.8	689.9
25.058	135.8	20.3	512.4	524.8	568.1	570.2	609.2	644.9	692.4
26.377	130.8	20.2	520.1	532.2	574.1	576.2	613.9	648.4	694.1
27.696	125.4	20.1	527.5	539.3	579.8	581.8	618.1	651.2	695.0
29.015	119.5	20.0	534.7	546.2	585.0	587.0	621.7	653.3	695.1
30.333	113.3	19.9	541.7	552.7	589.9	591.7	624.8	654.9	694.6
31.652	106.6	19.8	548.4	559.0	594.2	596.0	627.3	655.7	693.2
32.971	99.3	19.7	554.7	564.8	598.0	599.7	629.1	655.7	690.7
34.290	91.7	19.6	560.7	570.3	601.3	602.9	630.3	655.0	687.6

TIME = 1.686D+01 s (37 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm2-C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	93.6	22.2	371.2	378.1	409.3	410.8	441.4	471.5	519.5
1.319	98.5	22.2	376.1	383.6	417.1	418.6	451.1	482.9	533.0
2.638	102.9	22.1	381.4	389.4	425.0	426.6	460.9	494.2	546.0
3.957	106.7	22.0	387.0	395.6	433.0	434.7	470.5	505.2	558.4
5.275	110.0	21.9	392.9	402.0	441.2	443.0	480.1	516.0	570.4

6.594	112.7	21.8	399.2	408.8	449.4	451.2	489.6	526.4	581.7
7.913	115.1	21.7	405.7	415.8	457.6	459.6	498.9	536.5	592.5
9.232	116.8	21.7	412.5	423.0	465.9	467.9	508.1	546.3	602.7
10.551	118.2	21.6	419.6	430.4	474.3	476.3	517.1	555.8	612.5
11.870	119.0	21.5	426.8	437.9	482.5	484.6	525.9	564.9	621.6
13.188	119.5	21.4	434.2	445.6	490.8	492.9	534.5	573.7	630.2
14.507	119.4	21.3	441.8	453.4	498.9	501.1	542.8	582.0	638.1
15.826	118.8	21.1	449.4	461.3	507.0	509.1	550.8	589.9	645.5
17.145	117.9	21.0	457.2	469.2	514.9	517.0	558.6	597.4	652.3
18.464	116.4	20.9	465.0	477.1	522.6	524.7	565.9	604.4	658.3
19.783	114.6	20.8	472.8	485.0	530.1	532.3	573.0	610.9	663.9
21.102	112.4	20.7	480.6	492.8	537.4	539.6	579.7	617.0	668.8
22.420	109.8	20.6	488.4	500.6	544.5	546.6	586.0	622.5	673.0
23.739	106.8	20.5	496.1	508.2	551.3	553.4	591.8	627.4	676.4
25.058	103.4	20.4	503.7	515.7	557.8	559.8	597.3	631.9	679.3
26.377	99.6	20.3	511.2	523.0	563.9	565.9	602.3	635.7	681.4
27.696	95.5	20.2	518.5	530.1	569.7	571.7	606.8	639.0	682.9
29.015	91.0	20.1	525.6	536.9	575.1	577.0	610.7	641.6	683.5
30.333	86.3	20.0	532.5	543.5	580.2	582.0	614.2	643.7	683.5
31.652	81.2	19.9	539.2	549.7	584.8	586.5	617.1	645.0	682.7
32.971	75.6	19.8	545.6	555.7	588.8	590.5	619.3	645.6	680.9
34.290	69.8	19.8	551.6	561.3	592.5	594.0	621.1	645.6	678.4

TIME = 1.690D+01 s (34 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	89.6	22.2	371.2	377.2	404.4	405.6	432.4	459.1	503.7
1.319	94.3	22.2	375.5	382.0	411.3	412.7	441.3	469.7	516.4
2.638	98.6	22.1	380.1	387.1	418.5	419.9	450.3	480.2	528.7
3.957	102.2	22.0	385.0	392.6	425.8	427.3	459.2	490.5	540.6
5.275	105.4	22.0	390.3	398.3	433.2	434.8	468.1	500.6	552.0
6.594	108.0	21.9	395.8	404.4	440.8	442.4	476.9	510.5	562.9
7.913	110.2	21.8	401.7	410.7	448.4	450.2	485.7	520.1	573.4
9.232	111.9	21.7	407.8	417.2	456.1	457.9	494.4	529.5	583.4
10.551	113.2	21.6	414.1	423.9	463.9	465.7	503.0	538.7	592.9
11.870	114.0	21.5	420.7	430.8	471.6	473.5	511.4	547.6	602.0
13.188	114.4	21.4	427.4	437.9	479.4	481.3	519.6	556.1	610.5
14.507	114.3	21.4	434.4	445.0	487.1	489.1	527.7	564.3	618.5
15.826	113.8	21.3	441.4	452.3	494.8	496.8	535.5	572.2	626.0
17.145	112.9	21.2	448.6	459.7	502.3	504.3	543.1	579.6	632.9
18.464	111.5	21.1	455.9	467.1	509.8	511.8	550.4	586.7	639.2
19.783	109.8	21.0	463.2	474.5	517.1	519.1	557.4	593.3	645.0
21.102	107.7	20.9	470.5	481.9	524.2	526.2	564.1	599.6	650.2
22.420	105.2	20.8	477.9	489.3	531.1	533.1	570.5	605.3	654.8
23.739	102.3	20.7	485.2	496.6	537.8	539.8	576.5	610.6	658.7
25.058	99.1	20.6	492.4	503.8	544.3	546.2	582.1	615.4	662.1
26.377	95.5	20.5	499.6	510.8	550.4	552.3	587.3	619.6	664.8
27.696	91.5	20.4	506.7	517.7	556.3	558.2	592.1	623.3	666.8
29.015	87.2	20.3	513.6	524.4	561.9	563.7	596.4	626.4	668.1
30.333	82.7	20.2	520.3	530.9	567.1	568.8	600.3	629.1	668.8
31.652	77.8	20.1	526.8	537.2	571.9	573.5	603.6	631.0	668.7
32.971	72.4	20.0	533.2	543.1	576.2	577.8	606.4	632.3	667.7
34.290	66.9	19.9	539.2	548.8	580.2	581.7	608.6	633.0	666.1

TIME = 1.700D+01 s (29 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	87.5	22.2	371.2	375.8	396.7	397.7	418.4	439.0	474.6
1.319	92.1	22.2	374.5	379.5	402.2	403.2	425.6	447.7	485.4
2.638	96.2	22.1	378.0	383.4	407.9	409.0	432.9	456.5	496.1
3.957	99.7	22.1	381.8	387.7	413.7	414.9	440.3	465.1	506.4
5.275	102.9	22.0	385.9	392.2	419.8	421.1	447.7	473.7	515.5
6.594	105.4	22.0	390.2	396.9	425.9	427.3	455.1	482.1	526.2
7.913	107.6	21.9	394.8	401.9	432.2	433.6	462.5	490.5	535.6
9.232	109.3	21.8	399.7	407.1	438.6	440.0	469.9	498.7	544.7
10.551	110.5	21.8	404.7	412.5	445.1	446.6	477.3	506.9	553.5
11.870	111.3	21.7	410.0	418.1	451.6	453.2	484.6	514.8	562.0
13.188	111.7	21.6	415.4	423.8	458.2	459.8	491.8	522.5	570.1
14.507	111.6	21.5	421.1	429.7	464.8	466.4	499.0	530.0	577.7
15.826	111.1	21.5	426.8	435.7	471.4	473.0	506.0	537.3	585.0
17.145	110.2	21.4	432.7	441.9	478.0	479.7	512.9	544.3	591.9
18.464	108.9	21.3	438.8	448.1	484.5	486.2	519.5	551.0	598.3
19.783	107.2	21.2	444.9	454.3	491.0	492.7	526.1	557.5	604.3
21.102	105.1	21.1	451.1	460.7	497.4	499.1	532.4	563.6	609.9
22.420	102.7	21.0	457.3	467.0	503.6	505.4	538.5	569.4	615.0

23.739	99.8	20.9	463.6	473.3	509.8	511.5	544.3	574.8	619.5
25.058	96.7	20.9	469.9	479.7	515.8	517.5	549.8	579.9	623.6
26.377	93.2	20.8	476.2	485.9	521.6	523.3	555.1	584.5	627.0
27.696	89.3	20.7	482.4	492.1	527.2	528.9	560.0	588.8	630.0
29.015	85.1	20.6	488.5	498.2	532.6	534.2	564.6	592.5	632.4
30.333	80.7	20.5	494.6	504.1	537.7	539.3	568.8	595.9	634.3
31.652	75.9	20.4	500.6	509.9	542.6	544.1	572.6	598.7	635.4
32.971	70.7	20.4	506.4	515.5	547.1	548.6	576.0	600.9	635.9
34.290	65.3	20.3	512.1	521.0	551.3	552.8	579.0	602.7	635.8

TIME = 1.750D+01 s (19 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	78.2	22.2	371.2	373.9	386.0	386.6	398.6	410.0	428.4
1.319	82.3	22.2	373.1	375.9	389.0	389.6	402.6	414.8	434.5
2.638	86.0	22.2	375.1	378.1	392.1	392.8	406.6	419.7	440.6
3.957	89.2	22.1	377.2	380.4	395.3	396.0	410.7	424.5	446.6
5.275	92.0	22.1	379.4	382.9	398.6	399.4	414.7	429.3	452.5
6.594	94.2	22.1	381.8	385.5	402.0	402.7	418.8	434.0	458.2
7.913	96.2	22.0	384.3	388.2	405.4	406.2	423.0	438.7	463.8
9.232	97.7	22.0	387.0	391.0	408.9	409.7	427.1	443.4	469.3
10.551	98.8	22.0	389.7	393.9	412.5	413.3	431.2	448.1	474.8
11.870	99.5	21.9	392.6	396.9	416.1	416.9	435.3	452.7	480.0
13.188	99.9	21.9	395.5	400.1	419.7	420.6	439.5	457.2	485.1
14.507	99.8	21.8	398.6	403.2	423.4	424.3	443.5	461.7	490.0
15.826	99.3	21.8	401.7	406.5	427.1	428.0	447.6	466.0	494.8
17.145	98.5	21.8	405.0	409.9	430.8	431.8	451.6	470.3	499.3
18.464	97.3	21.7	408.3	413.3	434.5	435.5	455.5	474.4	503.7
19.783	95.8	21.7	411.6	416.7	438.2	439.2	459.4	478.4	507.9
21.102	94.0	21.6	415.0	420.2	441.9	442.9	463.2	482.3	511.8
22.420	91.8	21.6	418.5	423.8	445.5	446.6	467.0	486.1	515.5
23.739	89.2	21.5	422.0	427.3	449.2	450.2	470.6	489.7	519.0
25.058	86.4	21.5	425.5	430.9	452.7	453.8	474.1	493.1	522.3
26.377	83.3	21.4	429.1	434.5	456.3	457.3	477.5	496.4	525.2
27.696	79.9	21.4	432.6	438.0	459.7	460.7	480.7	499.5	527.9
29.015	76.1	21.3	436.2	441.6	463.1	464.1	483.8	502.3	530.3
30.333	72.1	21.3	439.7	445.1	466.4	467.4	486.8	505.0	532.5
31.652	67.9	21.2	443.2	448.6	469.5	470.5	489.6	507.4	534.2
32.971	63.2	21.2	446.7	452.0	472.6	473.5	492.1	509.5	535.6
34.290	58.4	21.1	450.1	455.4	475.5	476.4	494.5	511.4	536.7

TIME = 1.800D+01 s (19 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	70.7	22.2	371.2	373.2	382.4	382.9	392.0	400.3	412.7
1.319	74.4	22.2	372.6	374.7	384.5	385.0	394.7	403.5	416.7
2.638	77.8	22.2	374.1	376.3	386.7	387.2	397.5	406.8	420.7
3.957	80.6	22.2	375.6	378.0	388.9	389.4	400.2	409.9	424.6
5.275	83.1	22.1	377.2	379.7	391.1	391.7	402.9	413.1	428.4
6.594	85.2	22.1	378.9	381.5	393.3	393.9	405.5	416.1	432.0
7.913	86.9	22.1	380.7	383.4	395.6	396.2	408.2	419.2	435.6
9.232	88.3	22.1	382.5	385.3	397.9	398.5	410.8	422.1	439.0
10.551	89.3	22.0	384.4	387.2	400.2	400.8	413.5	425.0	442.4
11.870	90.0	22.0	386.3	389.3	402.5	403.1	416.1	427.9	445.6
13.188	90.3	22.0	388.3	391.3	404.8	405.5	418.6	430.6	448.8
14.507	90.2	22.0	390.4	393.4	407.1	407.8	421.1	433.3	451.8
15.826	89.8	21.9	392.4	395.5	409.4	410.1	423.6	436.0	454.6
17.145	89.1	21.9	394.5	397.7	411.7	412.4	426.0	438.5	457.4
18.464	88.0	21.9	396.7	399.9	414.0	414.7	428.4	440.9	459.9
19.783	86.6	21.8	398.8	402.0	416.3	417.0	430.7	443.3	462.4
21.102	85.0	21.8	401.0	404.2	418.5	419.2	432.9	445.6	464.7
22.420	83.0	21.8	403.2	406.5	420.7	421.4	435.1	447.7	466.9
23.739	80.7	21.8	405.4	408.7	422.9	423.6	437.2	449.8	468.9
25.058	78.1	21.7	407.6	410.9	425.0	425.7	439.2	451.7	470.8
26.377	75.3	21.7	409.7	413.0	427.1	427.8	441.1	453.5	472.5
27.696	72.2	21.7	411.9	415.2	429.1	429.8	443.0	455.2	474.0
29.015	68.8	21.6	414.1	417.4	431.1	431.8	444.7	456.8	475.3
30.333	65.2	21.6	416.3	419.5	433.0	433.7	446.4	458.3	476.5
31.652	61.3	21.6	418.4	421.6	434.9	435.5	448.0	459.6	477.4
32.971	57.1	21.5	420.5	423.6	436.6	437.2	449.4	460.7	478.1
34.290	52.8	21.5	422.5	425.6	438.3	438.9	450.6	461.6	478.7

TIME = 2.000D+01 s (15 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	51.4	22.2	371.2	372.6	378.8	379.1	385.3	390.8	398.6
1.319	54.1	22.2	372.2	373.6	380.1	380.5	387.0	392.8	401.0
2.638	56.5	22.2	373.1	374.6	381.5	381.8	388.6	394.7	403.4
3.957	58.6	22.2	374.1	375.7	382.8	383.2	390.3	396.6	405.6
5.275	60.5	22.2	375.2	376.8	384.2	384.5	391.9	398.4	407.7
6.594	62.0	22.2	376.3	377.9	385.5	385.9	393.4	400.1	409.7
7.913	63.2	22.1	377.4	379.1	386.9	387.2	394.9	401.8	411.6
9.232	64.2	22.1	378.5	380.2	388.2	388.6	396.4	403.4	413.4
10.551	65.0	22.1	379.7	381.4	389.5	389.9	397.9	405.0	415.1
11.870	65.4	22.1	380.9	382.6	390.8	391.2	399.2	406.4	416.7
13.188	65.7	22.1	382.0	383.8	392.1	392.5	400.6	407.8	418.2
14.507	65.6	22.1	383.3	385.0	393.3	393.7	401.9	409.1	419.5
15.826	65.3	22.0	384.5	386.3	394.5	394.9	403.1	410.3	420.8
17.145	64.8	22.0	385.7	387.5	395.7	396.1	404.2	411.5	421.9
18.464	64.0	22.0	386.9	388.7	396.9	397.3	405.3	412.5	422.9
19.783	63.0	22.0	388.1	389.9	398.0	398.4	406.4	413.5	423.8
21.102	61.8	22.0	389.3	391.0	399.1	399.5	407.3	414.4	424.6
22.420	60.4	22.0	390.4	392.2	400.1	400.5	408.2	415.2	425.2
23.739	58.7	21.9	391.6	393.3	401.1	401.5	409.1	415.9	425.8
25.058	56.8	21.9	392.7	394.4	402.0	402.4	409.8	416.5	426.2
26.377	54.8	21.9	393.8	395.5	402.9	403.3	410.5	417.0	426.5
27.696	52.5	21.9	394.9	396.5	403.7	404.1	411.1	417.4	426.6
29.015	50.0	21.9	396.0	397.5	404.5	404.8	411.6	417.7	426.7
30.333	47.4	21.9	397.0	398.5	405.2	405.6	412.1	418.0	426.6
31.652	44.6	21.9	398.0	399.4	405.9	406.2	412.4	418.1	426.4
32.971	41.6	21.8	398.9	400.3	406.5	406.7	412.7	418.0	426.0
34.290	38.4	21.8	399.8	401.2	407.0	407.2	412.8	417.9	425.5

TIME = 2.500D+01 s (12 Iterations Required)

AXIAL POS. (cm)	POWER (W/cm)	H (W/cm ² -C)	TCOOL (C)	TCO (C)	TCI (C)	TS (C)	T(3,2) (C)	T(2,1) (C)	T(1,0) (C)
0.000	28.6	22.2	371.2	372.0	375.4	375.6	379.0	382.0	386.3
1.319	30.1	22.2	371.8	372.5	376.1	376.3	379.9	383.0	387.6
2.638	31.4	22.2	372.3	373.1	376.9	377.0	380.8	384.1	388.8
3.957	32.6	22.2	372.8	373.7	377.6	377.8	381.6	385.1	390.0
5.275	33.6	22.2	373.4	374.3	378.3	378.5	382.5	386.1	391.1
6.594	34.4	22.2	374.0	374.9	379.0	379.2	383.3	387.0	392.2
7.913	35.1	22.2	374.6	375.5	379.7	379.9	384.1	387.9	393.2
9.232	35.7	22.2	375.2	376.1	380.4	380.6	384.9	388.7	394.1
10.551	36.1	22.2	375.8	376.7	381.1	381.3	385.7	389.5	395.0
11.870	36.3	22.2	376.4	377.4	381.8	382.0	386.4	390.2	395.7
13.188	36.5	22.1	377.1	378.0	382.5	382.7	387.1	390.9	396.5
14.507	36.4	22.1	377.7	378.7	383.1	383.3	387.7	391.6	397.1
15.826	36.3	22.1	378.4	379.3	383.7	383.9	388.3	392.2	397.7
17.145	36.0	22.1	379.0	379.9	384.3	384.5	388.9	392.7	398.2
18.464	35.5	22.1	379.6	380.6	384.9	385.1	389.4	393.2	398.7
19.783	35.0	22.1	380.2	381.2	385.5	385.7	389.9	393.7	399.0
21.102	34.3	22.1	380.9	381.8	386.0	386.2	390.4	394.1	399.3
22.420	33.5	22.1	381.5	382.4	386.5	386.7	390.8	394.4	399.6
23.739	32.6	22.1	382.1	382.9	387.0	387.2	391.1	394.7	399.7
25.058	31.6	22.1	382.6	383.5	387.4	387.6	391.5	394.9	399.8
26.377	30.4	22.1	383.2	384.0	387.8	388.0	391.7	395.0	399.8
27.696	29.2	22.1	383.7	384.5	388.2	388.4	391.9	395.1	399.7
29.015	27.8	22.0	384.3	385.0	388.5	388.7	392.1	395.2	399.6
30.333	26.4	22.0	384.8	385.5	388.8	389.0	392.2	395.2	399.4
31.652	24.8	22.0	385.2	385.9	389.1	389.2	392.3	395.1	399.1
32.971	23.1	22.0	385.7	386.3	389.3	389.4	392.3	394.9	398.7
34.290	21.3	22.0	386.1	386.7	389.5	389.6	392.3	394.7	398.2

 ***** CALCULATION RESULTS *****
 ***** Maximum Temperatures During Transient *****

TIME STEP	TIME (s)	COOLANT (C)	CLAD O.D. (C)	CLAD I.D. (C)	FUEL SURF. (C)	FUEL CENT. (C)
1	0.000000D+00	547.6	555.0	582.0	583.5	674.5
2	0.101000D+01	548.4	555.7	582.9	584.4	675.7
3	0.201000D+01	549.6	557.0	584.3	585.8	677.6

4	0.30100000+01	551.0	558.4	585.9	587.4	679.7
5	0.40100000+01	552.4	559.9	587.6	589.1	681.9
6	0.50100000+01	554.1	561.7	589.5	591.1	684.5
7	0.60100000+01	555.8	563.5	591.6	593.1	687.2
8	0.70100000+01	557.8	565.6	594.0	595.5	690.3
9	0.80100000+01	559.8	567.7	596.3	597.9	693.4
10	0.90100000+01	562.0	570.0	598.9	600.5	696.8
11	0.10010000+02	564.3	572.4	601.6	603.2	700.4
12	0.11010000+02	566.8	575.0	604.4	606.1	704.1
13	0.12010000+02	569.4	577.7	607.5	609.2	708.1
14	0.13010000+02	572.0	580.5	610.6	612.3	712.2
15	0.14010000+02	574.8	583.4	613.9	615.6	716.5
16	0.15010000+02	577.8	586.5	617.4	619.1	721.0
17	0.16010000+02	580.8	589.7	620.9	622.7	725.6
18	0.16510000+02	582.3	591.3	622.7	624.5	727.9
19	0.16560000+02	582.5	591.4	622.9	624.7	728.2
20	0.16610000+02	582.7	591.6	623.1	624.9	728.4
21	0.16660000+02	582.7	591.7	623.2	624.9	728.5
22	0.16680000+02	582.7	591.7	623.2	624.9	728.4
23	0.16700000+02	582.5	591.5	622.9	624.6	727.9
24	0.16730000+02	581.1	590.2	621.5	623.2	725.4
25	0.16760000+02	577.5	586.7	617.7	619.3	718.9
26	0.16800000+02	568.8	578.2	609.1	610.7	706.1
27	0.16830000+02	560.7	570.3	601.3	602.9	695.1
28	0.16860000+02	551.6	561.3	592.5	594.0	683.5
29	0.16900000+02	539.2	548.8	580.2	581.7	668.8
30	0.17000000+02	512.1	521.0	551.3	552.8	635.9
31	0.17500000+02	450.1	455.4	475.5	476.4	536.7
32	0.18000000+02	422.5	425.6	438.3	438.9	478.7
33	0.20000000+02	399.8	401.2	407.0	407.2	426.7
34	0.25000000+02	386.1	386.7	389.5	389.6	399.8

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