Thermal Response of Core and Central-Cavity Components of a High-Temperature Gas-Cooled Reactor in the Absence of Forced Convection Coolant Flow

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MASTER

OAK RIDGE NATIONAL LABORATORY

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R. L. Whaley J. P. Sanders

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FOREWORD

The computational method incorporated in the computer program presented in this report was developed by R. L. Whaley as a graduate student from the University of Tennessee working with the Reactor Division at ORNL under a general consulting contract.

The work was performed as part of the studies of the performance of high-temperature gas-cooled reactors during abnormal transients, which are being made for the Office of Nuclear Reactor Regulation of the U.S. Nuclear Regulatory Commission. The work was done under the guidance of J. P. Sanders, Project Manager for these studies, and R. L. Reid, faculty member from the University of Tennessee in charge of the consulting contract.

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R. L. Whaley* J. P. Sanders

ABSTRACT

A means of determining the thermal responses of the core and the components of a high-temperature gas-cooled reactor after loss of forced coolant flow is discussed. A computer program, using a finite-difference technique, is presented together with a solution of the confined natural convection.

The results obtained are reasonable and demonstrate that the computer program adequately represents the confined natural convection.

Key words: cover plates, convection, gas coolant, reactors, computer program, thermal insulation, PCRV

INTRODUCTION

The high-temperature gas-cooled reactor (HTGR) was presented for licensing review as a commercial nuclear steam-supply system. There were several differences in the HTGR design that made it difficult to apply the safety standards that were originally developed for light-water reactors. The lack of operating experience with large HTGR plants and concern for public safety necessitated a careful study of design and operational parameters to predict system response under a variety of circumstances. To support their design, the major vendor of the HTGR, General Atomic Company (GAC), submitted a topical report¹ on the thermal response of the primary loop to the Nuclear Regulatory Commission.

The current area of interest is the thermal analysis of the core and central-cavity components after loss of forced convection coolant flow (LOFC) and the analysis of primary loop component temperatures after forced convection coolant flow is resumed. Creep in structural components at high temperatures could cause damage, resulting in loss of ability to cool the core after flow is resumed. This could lead to failure

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of primary system closures and release of radioactive fission products to the containment building.

The problem under investigation involves a hypothetical situation in which forced convection coolant flow ceases and is not immediately restarted and a reactor trip occurs simultaneously. (Reactor trip is the procedure of reducing activity in the core as quickly as possible.) Specifically, the problem is to determine the temperature of the metal plates located above the core as a function of time, as shown in Fig. 1.

Fig. 1. Primary system configuration in the PCRV.

CONDUCTION

There are two major parts to this problem, which involve different methods of solution. One is heat conduction in the core, and the other is confined natural convection due to nonuniform power generation. The first problem lends itself to numerical solution, while the second involves the solution of simultaneous equations. However, the conduction and convection are not independent of each other, and the two methods must be combined to provide a means of solution.

The conduction in the core was represented using a finite-difference technique. This was done by developing a model of the area around one coolant hole. Figure 2 shows a plan view of the core. There are 55 regions in the drawing, and the decimal number printed in each region is the power density factor. This factor is defined in the following chapter. Also shown is a cross-sectional view of a fuel column indicating the arrangement of coolant holes and fuel rods. The information presented in this figure is from the Preliminary Safety Analysis Report² for Delmarva Power and Light Company.

Figure 3, which is a segment from Fig. 2, shows one coolant hole surrounded by six fuel rods imbedded in graphite. Due to the symmetry of the arrangement of coolant holes and fuel rods in the core, the sides of the hexagon in Fig. 3 can be considered an insulated segment. An isolated configuration of one coolant hole in the center of a hexagon with one-third of a fuel rod at each corner results. To apply finite-difference technique to this geometry would require a three-dimensional array of nodes. Even after simplification resulting from the symmetry of the configuration, the number of required nodes and resultant equations is quite large.

Figure 4 shows an approximation of the configuration in a form which requires only a two-dimensional array of nodes. Fewer nodal equations are needed for this configuration than for the configuration in Fig. 3. The dimensions of the approximation in Fig. 4 were chosen to retain the same cross-sectional area for each component as in Fig. 3. The outside surface is considered to be insulated. The contact area between graphite and fuel is about 11% greater than that of the actual configuration, but

Fig. 2. Plan view of the core of an HTGR showing relative power densities in the various regions.

ORNL-DWG 76-10797

Fig. 3. Symmetrical segment of the fuel for one coolant channel.

ORNL DWG 76 10798

Fig. 4. Cylindrical representation of the symmetrical segment.

this difference can be represented by introducing a correction factor for the surface area.

The vertical dimensions of the model are shown in Fig. 5, along with the location of nodes used in the finite-difference technique. These nodes were chosen to match those used in another computer program used at ORNL from which initial temperatures were obtained.

Two examples for the deviation of the nodal equations are given. The energy equation for the node (1,3) is written by summing all the heat entering the node or generated at the node and equating this sum to the change in energy for the node:

$$\begin{aligned}
 & k_G \pi (r_F^2 - r_{E_1}^2) \frac{t_{1,2}^V - t_{1,3}^V}{\Delta Z_A} + k_F \pi (r_F^2 - r_{E_1}^2) \frac{t_{1,4}^V - t_{1,3}^V}{\Delta Z} \\
 & + \frac{2\pi k_G (\Delta Z_A/2) (t_{2,3}^V - t_{1,3}^V)}{\ln(r_F/r_G)} + \frac{2\pi k_F (\Delta Z/2) (t_{2,3}^V - t_{1,3}^V)}{\ln(r_F/r_G)} \\
 & + \pi (r_F^2 - r_{E_1}^2) \frac{\Delta Z}{2} = \rho_G C_G \pi (r_F^2 - r_{E_1}^2) \Delta Z_A \frac{t_{1,3}^{V+1} - t_{1,3}^V}{\Delta \theta} \\
 & + \rho_F C_F \pi (r_F^2 - r_{E_1}^2) \Delta Z \frac{t_{1,3}^{V+1} - t_{1,3}^V}{\Delta \theta}, \quad (1)
 \end{aligned}$$

where

- k_G, k_F = thermal conductivity of graphite and fuel,
- $t_{x,y}$ = temperature at the node,
- ρ_F, ρ_G = density of graphite and fuel
- C_F, C_G = specific heat of graphite and fuel,
- $\Delta Z, \Delta Z_A$ = dimensions as shown in Fig. 5,
- r_F, r_G = outer radius of fuel and graphite,
- r_{E_1} = a radial dimension used to define the element around the node,
- $\Delta \theta$ = an increment of time,

Fig. 5. Elevation for single-channel model used in natural convection calculation.

v and $v + 1$ = values for before and after the passage of an increment of time,

q = heat-generation rate per unit volume in the fuel.

Terms are grouped and rearranged to give the nodal equation:

$$t_{1,3}^{v+1} = t_{1,3}^v + \frac{2\Delta\theta}{\rho_G C_G \Delta Z_A + \rho_F C_F \Delta Z} \left[k_G \frac{t_{1,2}^v - t_{1,3}^v}{\Delta Z_A} + k_F \frac{t_{1,4}^v - t_{1,3}^v}{\Delta Z} + \frac{(k_G \Delta Z_A + k_F \Delta Z)(t_{2,3}^v - t_{1,3}^v)}{(r_F^2 - r_{E1}^2) \ln(r_F/r_G)} + q \frac{\Delta Z}{2} \right] \quad (2)$$

For the purpose of writing the equations about nodes located in the coolant hole, a cylindrical control volume about each node is used. The energy equation for a node near the center of the coolant hole is

$$\begin{aligned} \dot{m} C_p t_{4,n+1}^v - \dot{m} C_p t_{4,n}^v + h(2\pi r_c \Delta Z)(t_{3,n}^v - t_{4,n}^v) \\ = \rho_{He} C_p (\pi r_c^2 \Delta Z) \frac{t_{4,n}^{v+1} - t_{4,n}^v}{\Delta\theta}, \end{aligned} \quad (3)$$

where

$\dot{m}$ = mass flow rate in the coolant hole,

C_p = specific heat of helium at constant pressure,

h = convective heat transfer coefficient,

r_c = radius of the coolant hole,

ρ_{He} = density of helium at the node (4,n) at the time.

All other symbols are as defined previously. Note that Eq. (3) is written to represent upward flow in the coolant hole. This direction of flow is chosen to be positive. However, if the flow is downward (negative), the

first two terms in the equation would be

$$\dot{m} C_p t_{4,n}^v - \dot{m} C_p t_{4,n-1}^v$$

Recall that $\dot{m}$ in this case is a negative quantity.

When using this and similar equations in a computer program, the possibility that the coolant flow may be positive or negative must be considered. The direction of flow is calculated within the program and cannot be determined in advance. Therefore, it is necessary to include branch points in the program to execute either of the two forms of Eq. (3) for each coolant channel. This is done on the basis of the sign of $\dot{m}$.

Rearranging Eq. (3) gives the nodal equation:

$$t_{4,n}^{v+1} = t_{4,n}^v + \frac{\Delta\theta}{\rho_{\text{He}} \pi r_c^2} \left[\frac{\dot{m}}{\Delta Z} (t_{4,n+1}^v - t_{4,n}^v) + 2\pi r_c \frac{h}{C_p} (t_{3,n}^v - t_{4,n}^v) \right] \quad (4)$$

It can be seen from Eq. (4) that the Euler method of solution of the finite-difference equations is employed. Crank-Nicolson and pure implicit methods both require solution of simultaneous equations. This would be quite difficult, considering the number and complexity of the nodal equations, and the amount of computation time would be large.

Employing the Euler method requires care in choosing a time step so that it will not be so large as to cause oscillations or instabilities in the calculations. The upper limit of the time step cannot be determined exactly because it is dependent on the mass flow in the coolant holes. These flows are calculated within the program and are continually changing. The best that can be done is to estimate a time step that might be expected to work and redefine it by trial and error.

The convective heat transfer coefficient in the coolant holes is calculated using the following relations:

$$\begin{aligned} \text{Nu} &= 0.0038 \text{ Re Pr} \text{ for } \text{Re} < 4000, \\ \text{Nu} &= 0.023 \text{ Re}^{0.8} \text{ Pr}^{0.4} \text{ for } \text{Re} \geq 4000, \\ \text{Nu} &\geq 3.65, \end{aligned} \quad (5)$$

where Nu is the Nusselt number, Pr is the Prandtl number, and Re is the Reynolds number. These Nusselt numbers are based on the diameter of the coolant channel.

The first relation above is derived from graphical information concerning transition between laminar and turbulent flow, as presented in McCabe and Smith.³ The second relation is the Dittus-Boelter equation for turbulent flow inside circular tubes, as given in McAdams,⁴ and the third is for the laminar flow inside circular tubes with constant wall temperature.⁵ In the computer program, the value of Nusselt number is never allowed to go below the value determined by laminar flow correlation.

The temperature of the gas above and below the core in the upper and lower plenums is calculated utilizing the energy equation. The modes of energy transfer to or from these areas are mass transfer to or from the coolant holes and convection to or from the upper and lower surfaces of the core.

The convective heat transfer coefficient for the top and bottom surfaces of the core were calculated using the equation

$$Nu = C(Gr Pr)^m, \quad (6)$$

where Gr is the Grashof number.

C and m are obtained from Tables 7-1, 7-2, and 7-3 in *Heat Transfer* by Holman.⁶ Holman states that the characteristic dimension of length to be used for this calculation should be $0.9d$, where d is the outside diameter of the model shown in Fig. 4. The volume coefficient of expansion is calculated as the reciprocal of the absolute temperature of the gas by assuming that the helium behaves as an ideal gas.

CONFINED NATURAL CONVECTION

Confined natural convection in the coolant holes is important in this problem because heat generation in the core is not uniform. Since no forced coolant flow exists in this problem, the helium will circulate within the core cavity between higher- and lower-powered regions.

The power density factor of a region is the ratio of the average heat-generation rate per unit volume for that region to the average heat-generation rate per unit volume for the core. This is the radial power density factor. The radial power density factors for each region are shown in Fig. 2.

The axial (vertical) power density factor is defined as the ratio of the heat-generation rate per unit length for one axial subdivision to the heat-generation rate per unit length for the entire length of the active core. There are eight axial subdivisions. The power density factors for each subdivision are shown in Table 1. The information concerning power density factors is from the Delmarva Preliminary Safety Analysis Report.²

Returning to Fig. 2, it can be seen that regions 3 and 6 are the highest-powered regions at a power density factor of 1.6, and the lowest power density factor is 0.6705 in regions 40 and 49. Natural convection

Table 1. Axial power density factors

Fuel element block level j (j = 1 at top of core)	P_j , axial power density factor ^a
1	1.216
2	1.335
3	1.456
4	1.173
5	0.903
6	0.815
7	0.587
8	0.515

^aAn equation for axial power density factor P_j is $P_j = 0.563547 - 4.79909 \times 10^{-2} (Z) + 0.01574Z^2 - 5.92159 \times 10^{-4} (Z^3)$, where Z is the distance from the bottom of the active core in feet. (Divide Z by 304.8 to obtain mm.)

coolant flow would tend to be upward in the highest-powered regions and downward in the lowest-powered regions, but the direction of helium flow in any of the regions at intermediate power levels cannot be intuitively determined. There might also be cases in which coolant flow could reverse itself in some regions as temperatures in the core continue to increase. An attempt to calculate the natural convection flow in each hole in the core would be quite involved. A simplified model of this situation that represents all the coolant holes as two holes, one in a higher-powered region and one in a lower-powered region, can be solved more easily. This approximation, however, seems to be inadequate because it presupposes the direction of the buoyancy forces in each hole.

A model consisting of three coolant holes was chosen. This is the simplest model that functions in a manner similar to the actual arrangement. It seems logical to assume that if a means of solving the three-channel model is established and is combined with the finite-difference technique to give satisfactory results, then a model with a greater number of channels could be obtained by extending the system of solution. It should be noted that a model with more than three holes can be used, but the complexity of such solutions increases greatly as the number of holes increases.

The radial power density factors chosen for the regions surrounding the three holes were 0.7, 1.0, and 1.6. The factor 0.7 represents 141 fuel element columns with power density factors between 0.6705 and 0.85; 1.0 represents 123 columns with factors between 0.85 and 1.3; and 1.6 represents 79 columns with factors between 1.3 and 1.6. The high-powered region is represented by the factor 1.6 rather than some factor between 1.3 and 1.6, because the primary interest is in the thermal response of the highest-powered regions. The structural components located above the highest-powered regions should reach their damage limit before components located above other regions, because the gas impinging on them should be at a higher temperature than that from the other regions.

When all the power density factors for each fuel element column in Fig. 2 are summed and the equivalent calculations for the model are performed, it is seen that a 1.7% error exists in the heat-generation rate

derived from the model. This error is conservative, however, because the model has the higher heat-generation rate.

The heat-generation rate at any point in the fuel is determined by the radial and axial power density factors and the time elapsed since reactor trip. The equation for the decay of the heat-generation rate after reactor trip is

$$q_{t=\tau} = 0.128(\tau + 0.0003796)^{-0.261} q_{t=0}, \quad (7)$$

where q is the heat-generation rate and τ is time in seconds. From this equation, the average heat-generation rate per unit volume at any time can be calculated. The heat-generation rate at a fuel node is calculated using the equation

$$q_{i,j} = q_{av} P_i P_j, \quad (8)$$

where

- $q_{i,j}$ = heat-generation rate at node (i,j) ,
- q_{av} = average heat-generation rate per unit volume,
- P_i = radial power density factor,
- P_j = axial power density factor.

Equations (7) and (8) are from the Delmarva Preliminary Safety Analysis Report.²

Bernoulli's augmented equation between points at the top and bottom of one coolant hole is

$$Z_B + \frac{P_B}{\gamma} + \frac{V_B^2}{2g} = Z_T + \frac{P_T}{\gamma} + \frac{V_T^2}{2g} + H_L; \quad \gamma = \rho \frac{g}{g_c}, \quad (9)$$

where

- Z_B, Z_T = height above some reference plane,
- P_T, P_B = pressure at top and bottom of the hole,
- V_T, V_B = velocity of the gas at the top and bottom,
- ρ = average density of gas in the hole,

g = acceleration of gravity,
 g_c = gravitational constant,
 H_L = head loss between bottom and top.

The head loss is written

$$H_L = 4f \left(\frac{L}{D} \right) \left(\frac{V^2}{2g} \right), \quad (10)$$

where

f = friction factor,
 L = length of the coolant hole,
 D = diameter of the coolant hole,
 V = velocity of the fluid.

Since the density term in Bernoulli's equation as written here is an average density, an assumption of incompressible flow is being made. This assumption and the principle of continuity require that the velocity at each end of the coolant hole be the same because there is no variance in hole diameter.

Substituting the head loss term into Bernoulli's equation and rearranging gives

$$\rho(Z_T - Z_B) + 4\rho f \left(\frac{L}{D} \right) \left(\frac{V^2}{2g} \right) = (P_B - P_T) \left(\frac{g_c}{g} \right). \quad (11)$$

Note that $(Z_T - Z_B)$ is merely the length of the coolant hole (L). Also, the term on the right side of Eq. (11) is independent of the coolant hole that is being considered, because the holes open into a common space at each end. Therefore, for an instant in time, the term on the right side of Eq. (11) is constant for all holes. Using the mass flow $\dot{m} = \rho AV$, where $A = \pi(D^2/4)$, one obtains

$$\rho_i L + 64f_i \left(\frac{L}{D^5} \right) \left(\frac{\dot{m}_i^2}{2g \rho_i \pi^2} \right) = \text{const}, \quad (12)$$

where i indicates coolant hole number i . In the program, Eq. (12) is

arranged in this manner:

$$\rho_i \left(\frac{g D^5 \pi^2}{32} \right) + f_i \left(\frac{\dot{m}_i^2}{\rho_i} \right) = \text{const} . \quad (13)$$

These equations have been written for the case in which $\dot{m}_i$ is positive. If $\dot{m}_i$ is negative (downward), the sign of the second term on the left side of Eq. (13) is negative. The sign of this term can be automatically specified in the program by writing $\dot{m}^2$ as $\dot{m}|\dot{m}|$.

Assuming that there is no appreciable change in the mass of gas occupying the upper and lower plenums, a continuity equation is written for the coolant channels:

$$\sum \dot{m}_i = 0 . \quad (14)$$

The Bernoulli equations in the form of Eq. (13) for each channel and the continuity equation [Eq. (14)] are a system of simultaneous equations which can be solved for $\dot{m}_i$ and the constant. In the three-channel model, this means that there are four simultaneous equations to be solved to obtain the mass flow. This method of solution can be applied to a system with any number of holes; however, the number of simultaneous equations to solve will always be one greater than the number of channels. Also, a set of nodal equations must be solved for each hole in the system. These are the reasons why complexity increases greatly as the number of channels increases.

Weighting factors are used in the continuity equation to reflect the fact that there are 141 low-power fuel columns, 123 intermediate-power fuel columns, and 79 high-power fuel columns in the model.

The four simultaneous equations were reduced to two simultaneous equations by eliminating one mass-flow term and the constant from the equations. The two equations thus derived are solved in the program by the Newton-Raphson iterative technique. The equations are written in the form

$$f(x,y) = 0 ; \quad g(x,y) = 0 . \quad (15)$$

The new values of x and y for each iteration are calculated by

$$\begin{aligned} x_{n+1} &= x_n \frac{f(\partial g / \partial y) - g(\partial f / \partial y)}{(\partial f / \partial x)(\partial g / \partial y) - (\partial f / \partial y)(\partial g / \partial x)} , \\ y_{n+1} &= y_n + \frac{f(\partial g / \partial x) - g(\partial f / \partial x)}{(\partial f / \partial x)(\partial g / \partial y) - (\partial f / \partial y)(\partial g / \partial x)} . \end{aligned} \quad (16)$$

The friction factor is dependent on the mass flow. The value used in the four simultaneous equations is calculated using the initial guess for mass flow in the iterative process. The friction factor is treated as a constant throughout the iterations. When a new value of mass flow is determined, it is used to recalculate the friction factor. The process is repeated until a value for friction factor is found.

An attempt to recalculate the friction factor concurrently with mass flow in the iteration produced oscillations and was subsequently abandoned.

The friction factor in the laminar flow range is calculated as

$$f = \frac{16}{Re} . \quad (17)$$

According to McCabe and Smith,³ the friction factor in the turbulent range is given by

$$f = 0.0014 + \frac{0.125}{Re^{0.32}} . \quad (18)$$

A Reynolds number of 4000 was chosen as the upper limit of the transition region between laminar and turbulent flows, and a value of 2000 was chosen as the lower limit. A third equation is used to represent the friction factor in the transition region when the Reynolds numbers are between 2000 and 4000:

$$f = 5.6 \times 10^{-4} (Re)^{0.35} . \quad (19)$$

This equation represents a straight line on full logarithmic paper between the points $Re = 2000$ on the laminar line and $Re = 4000$ on the turbulent line.

STEADY-STATE SOLUTION FOR THERMAL BARRIER

A steady-state solution is used to determine the temperature of the thermal barrier* on the upper surface of the upper plenum. There is a lag in the thermal response of the barrier, so it will not actually be in equilibrium with its surroundings. Using a steady-state solution for the thermal barrier temperature in this particular problem where most component temperatures are generally increasing is conservative because the calculated value of the barrier temperature will be higher than the actual value. This, in turn, gives a conservative value for the time interval between loss of forced cooling and attainment of temperatures capable of damaging the thermal barrier.

Figure 6 shows the schematic used to evaluate the barrier temperature. The liner cooling system is assumed to be at a constant temperature of 340 K (150°F). Writing the energy equation for the barrier gives

$$k_w \frac{T_L - T_{barr}}{\Delta x} + h_B (T_{hot\ gas} - T_{barr}) + \epsilon \sigma (T_{surr}^4 - T_{barr}^4) = 0, \quad (20)$$

where

T_L = absolute temperature of the liner, 340 K (610°R),

k_w = thermal conductivity of Kaowool, 23.0 MW m⁻¹ K⁻¹ (0.0133 Btu hr⁻¹ ft⁻¹ °R⁻¹),

Δx = thickness of the Kaowool,

h_B = convective heat transfer coefficient for the barrier,

$T_{hot\ gas}$ = the absolute temperature of the gas impinging on the barrier,

ϵ = emissivity of the barrier (0.3),

σ = Boltzmann constant,

T_{barr} = absolute temperature of the barrier,

T_{surr} = absolute temperature of the gas in the upper plenum.

The convective heat transfer coefficient in this equation must be calculated. The hot gas impinging on the thermal barrier constitutes

* The term thermal barrier as used here actually refers to the thermal barrier cover plate as shown in Fig. 6.

Fig. 6. Model used for the determination of the temperature of thermal barrier.

axisymmetric stagnation flow. Kays⁷ has tabulated values of $Nu_x Re_x^{-1/2}$ for various Prandtl numbers in two-dimensional wedge flows. For two-dimensional stagnation flow and a Prandtl number of approximately 0.7 for helium, the value of $Nu_x Re_x^{-1/2}$ is 0.496. A way to alter this number for the axisymmetric case is desired. For a Prandtl number of 1.0, $Nu_x Re_x^{-1/2}$ is 0.57. Kays⁷ states that a good approximation when the Prandtl number is close to 1.0 is

$$Nu_x = 0.57 Re_x^{1/2} Pr^{0.4} . \quad (21)$$

The coefficient corresponds to the value tabulated by Kays.⁷ Kays also states that the same relation for the axisymmetric case is

$$Nu_x = 0.76 Re_x^{1/2} Pr^{0.4} . \quad (22)$$

If the tabulated value for a Prandtl number of 0.7 is altered so that the ratio of the old to the new value is the same as the ratio of the coefficient in Eq. (21) to that of Eq. (22), a relation that can serve for the axisymmetric stagnation flow for a Prandtl number of 0.7 is obtained:

$$Nu_x Re_x^{-1/2} = 0.6613 . \quad (23)$$

This equation should give a better value than that for two-dimensional flow.

The energy equation for the thermal barrier cannot be solved for the temperature of the barrier explicitly. The equation is rewritten in the following form:

$$T_{barr} = \frac{k_w T_L + h_B \Delta x T_{hot\ gas} + \epsilon \sigma \Delta x (T_{surr}^4 - T_{barr}^4)}{k_w + \Delta x h_B} . \quad (24)$$

Equation (24) is solved in the program by using Wegstein's iteration scheme. For an equation of the form $x = f(x)$, the first step in the

scheme is

$$x_1 = y_0 = f(x_0) ; \quad y_1 = f(x_1) . \quad (25)$$

Then all the following steps are

$$\left. \begin{aligned} x_{i+1} &= x_i + \frac{x_i - x_{i-1}}{[(x_{i-1} - y_{i-1})/(x_i - y_i)] - 1} \\ y_{i+1} &= f(x_{i+1}) \end{aligned} \right\} (i = 1, 2, \dots) . \quad (26)$$

This iteration continues until the difference between successive values of T_{barr} is within allowable limits.

OUTLINE OF COMPUTER PROGRAM

A very general description of how the computer progresses through the program is given below:

1. Read input and initial guess for the mass flow.
2. Calculate friction factor.
3. Perform iteration to new mass flow.
4. Calculate new friction factor from the new mass flow.
5. Determine if new friction factor is within tolerance of the old one. If yes, continue. If no, return to step 3.
6. Calculate new temperatures.
7. Perform iteration to the barrier temperature.
8. Return to step 3.

RESULTS AND CONCLUSIONS

The results of this work cannot be confirmed because there are no experimental measurements available for comparison, but some observations can be made. Figure 7 shows the thermal barrier temperature predicted by the program as a function of elapsed time after reactor trip. The unusual behavior of the curve in the first 2 min of elapsed time is due

Fig. 7. Thermal barrier temperature as a function of elapsed time.

to the values used for the initial core and coolant temperatures. Initial helium temperatures in the coolant holes were higher in low-powered regions than those in high-powered regions, so some time elapses while this situation changes. Figure 8 shows the results of a General Atomic Company calculation¹ for a similar situation. Apparently, the initial temperatures used for this computation are not the same as those used in the program developed in this work. The only conclusion that can be drawn is that the two curves are similar and there are no drastic variations in the slope of the curves.

The program developed here can be used to evaluate thermal response of other components with very little alteration. Most of the calculations involve determining the thermal response of the core and of the helium. These computations would have to be performed to determine the response of any other components.

Another aspect to this work was the development of a method for representing the confined natural convection that occurs due to nonuniform power distribution. Figure 9, which shows the mass flow in each region

Fig. 8. Thermal barrier temperature as a function of elapsed time, as given by General Atomic Company.⁷

Fig. 9. Mass flow as a function of elapsed time.

vs elapsed time, is presented to show that the program represents situations where the direction of flow may change. The behavior of the curves in the first 2 min of elapsed time is due to the initial temperatures, as explained previously.

With regard to improvements that can be made to the program, a more sophisticated program with more than three regions having different radial power density factors can be written, but at the cost of increased complexity and computing time. Also, some properties of the components were treated as constant when actually they vary with temperature. This can be corrected easily in the finite-difference solution, but it will require increased computing time.

Computing time is a limiting factor in any attempt to increase complexity, and methods should be investigated to reduce it. One way of doing this may be to reduce the number of nodes, but care should be exercised to prevent the representation from becoming too gross. Other methods of reducing the computational time without affecting the solution should be investigated.

SUMMARY

A computer program to predict the thermal response of the core and components of a high-temperature gas-cooled reactor after loss of forced convective coolant flow and reactor trip was developed and is presented in Appendices I, II, and III. The program employs a finite-difference technique to solve conduction in the core and a comparison of buoyancy forces in the coolant holes to solve the confined natural convection that results from nonuniform power distribution.

Experimental data are not available for the evaluation of the results, but the predicted values appear to be realistic. The computer program itself involves a large number of calculations; this factor complicates any attempts to increase the sophistication of the solution.

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Appendix I

LISTING OF THE COMPUTER PROGRAM

A copy of the computer program written for this work is presented here. The variables and their definitions are listed below.

A — constant defined in program
B — constant defined in program
C — heat capacity of helium (Btu/lb °F)
F — friction factor
H — convective heat transfer coefficient in channels (Btu/hr ft² °F)
I — subscript denoting region
J — subscript denoting radial position of node
K — subscript denoting axial (vertical) position of node
N — used to preclude wasteful calculations if instability is encountered
P — pressure (lb/ft²)
Q — heat-generation rate (Btu/ft³)
R — helium gas constant (ft-lb_m/lb_f °R)
T — nodal temperature
V — velocity of helium exiting channel 3 (ft/hr)
X — number of coolant holes per fuel column
CA — calculated in program, the constant in the potential flow solution for stagnation flow
CF — heat capacity of fuel elements (Btu/lb °F)
CG — heat capacity of graphite (Btu/lb °F)
DM — mass flow per channel (lb/hr)
DT — time step (hr)
DZ — vertical spacing between nodes for nodes 3 through 19 (ft)
EM — emissivity of thermal barrier
FK — thermal conductivity of fuel elements
F2 — new value of friction factor
GK — thermal conductivity of graphite (Btu/hr ft °F)
HB — convective heat transfer coefficient at thermal barrier
HK — thermal conductivity of helium (Btu/hr ft °F)

HT — distance between thermal barrier and top of core (ft)
 PF — defined in program
 PI — π
 PR — Prandtl number in channels
 QA — defined in program for purpose of applying power density factors
 QB — defined in program for purpose of applying power density factors
 QF — defined in program
 QM — power generation rate of core at maximum (Btu/hr)
 RC — radius of coolant hole (ft)
 RE — Reynolds number
 RF — outside radius of fuel ring (ft)
 RG — outside radius of graphite ring around coolant hole (ft)
 SB — defined in program
 TB — thermal barrier temperature ($^{\circ}\text{R}$)
 TE — defined in program
 TH — thickness of Kaowool above thermal barrier (ft)
 TL — liner temperature ($^{\circ}\text{R}$)
 TP — old values of nodal temperatures
 ZF — as defined in program
 ANU — Nusselt number in coolant holes
 DMM — old value of mass flow
 DZA — vertical spacing between nodes for nodes 1 through 3 (ft)
 DZB — vertical spacing between nodes for nodes 19 through 21 (ft)
 DZC — vertical spacing between nodes for nodes 21 through 23 (ft)
 FAV — average friction factor in coolant hole
 GMU — dynamic viscosity of helium in coolant holes (lb/hr ft)
 HLP — convective heat transfer coefficient on bottom surface of the core
 HUP — convective heat transfer coefficient on top surface of the core
 PML — mass of gas in lower plenum (lb)
 PMU — mass of gas in upper plenum (lb)
 RE1 — radial dimension used to define elements about the nodes
 RE2 — radial dimension used to define elements about the nodes
 RF1 — as defined in program
 RG2 — as defined in program

RHO — density in coolant holes (lb/ft^3)
R1G — defined in program
R12 — defined in program
R2C — defined in program
SB1 — defined in program
SB2 — defined in program
SUM — used in test for convergence
TB1 — defined in program
TB2 — defined in program
TLP — temperature of gas in the lower plenum ($^{\circ}\text{F}$)
TUP — temperature of gas in the upper plenum ($^{\circ}\text{F}$)
VLP — volume of the lower plenum (ft^3)
VUP — volume of the upper plenum (ft^3)
BOLT — Boltzmann constant ($\text{Btu/hr ft}^2 \text{ }^{\circ}\text{R}^4$)
DIFF — defined in program
DIF1 — defined in program
DIF2 — defined in program
DPD1 — defined in program
DPD2 — defined in program
DQD1 — defined in program
DQD2 — defined in program
FAV2 — new value of average friction factor
FDRC — defined in program
GDRC — defined in program
GRLP — Grashof number in lower plenum
GRUP — Grashof number in upper plenum
PRLP — Prandtl number in the lower plenum
PRUP — Prandtl number in the upper plenum
RFRG — defined in program
RGRC — defined in program
RHOG — density of graphite (lb/ft^3)
RHOU — density of fuel (lb/ft^3)
TEMP — temperature of the thermal barrier ($^{\circ}\text{F}$)
TIME — elapsed time (min)

ANULP — Nusselt number at lower surface of the core
ANUUP — Nusselt number at upper surface of the core
CONST — defined in program
DENOM — defined in program
ISKIP — used for counting purposes
PRDIF — defined in program
RHOAV — average density of helium in coolant hole
RHOLP — density of gas in the lower plenum
RHoup — density of gas in the upper plenum
TCKAO — thermal conductivity of Kaowool
ICOUNT — used to count calculations to avoid excessive computation
 time in case convergence does not occur
MINUTE — integer value of elapsed time (min)
NUMBER — used with MINUTE to specify when to print output
TIMLIM — value of elapsed time at which calculations will cease
TOLRNC — used to determine convergence of mass-flow values

Table A.1. Listing of Fortran program for NATCON

```

      DIMENSION TP(3,4,23), T(3,4,23), GMU(3,23), RE(3,23), EHO(3,23), FNTCN 1
1(3,23), FAV(3), DM(3), DMM(3), FHOAV(3), HK(3,23), PR(3,23), ANU(3NTCN 2
2,23), H(3,23), GRUP(3), GRIP(3), ANUUP(3), ANULF(3), HUP(3), HLP(3NTCN 3
3), Q(3,23), QA(3), QB(3), A(3), E(3), TE(3), FAV2(3), DIFF(3), F2(3NTCN 4
4,23) NTCN 5
      NAMELIST/VALUES/A,B,RHOAV,N,TIME,HB,TB,TE1,TB2,ICOUNT NTCN 6
      GMUF(S)=(6.7E-4)*(S+460.)**.68 NTCN 7
      RHOF(P,F,S)=P/(R*(S+460.)) NTCN 8
      HKF(S)=8.34957E-2+1.00842E-4*S-1.13598E-8*S*S NTCN 9
      REF(R,V,VIS,PI)=(2.*R*ABS(V))/(VIS*(R**2)*PI) NTCN 10
      P=0.6*725.*144. NTCN 11
      READ(5,801) TP NTCN 12
801 FORMAT(10F8.2) NTCN 13
      READ(5,802) DMM, RC, EG, RF, RE1, RE2, DZ, DZA, DZB, DZC, VLP, VUNTCN 14
1P, TUP, TLP, RHOG, RHOU, CG, CF, GK, FK, QM, DT NTCN 15
802 FORMAT(10E8.3) NTCN 16
      READ(5,803) HT, EM, TH, TIME, TOLRNC, C, TCKAO, PI, TL, X, TIMLIMNTCN 17
1, R, BOLT, NUMBER NTCN 18
803 FORMAT(6F6.4, F7.5, F11.9, 4F4.0, E8.3, I2) NTCN 19
      CONST=(32.2*((2.*RC)**5.)*(PI**2)*(3600.**2))/32. NTCN 20
      RF1=RF**2-RE1**2 NTCN 21
      R12=RE1**2-RE2**2 NTCN 22
      R1G=RE1**2-RG**2 NTCN 23
      RG2=RG**2-RE2**2 NTCN 24
      R2C=RE2**2-RC**2 NTCN 25
      RFRG=ALOG(RF/RG) NTCN 26
      RGRC=ALOG(RG/RC) NTCN 27
      GDRG=GK*DI/(RHOG*CG) NTCN 28
      FDRG=FK*DT/(RHOU*CF) NTCN 29
      DO 205 I=1,3 NTCN 30
205 DM(I)=DMM(I) NTCN 31
      DO 301 I=1,3 NTCN 32
      DO 301 J=1,23 NTCN 33
301 Q(I,J)=0.0 NTCN 34
      QA(1)=.7*QM NTCN 35
      QA(2)=1.0*QM NTCN 36
      QA(3)=1.6*QM NTCN 37
100 DO 101 I=1,3 NTCN 38
      DO 101 J=1,23 NTCN 39
      GMU(I,J)=GMUF(TP(I,4,J)) NTCN 40
      RHO(I,J)=RHOF(P,R,TP(I,4,J)) NTCN 41
101 RE(I,J)=REF(RC,DM(I),GMU(I,J),PI) NTCN 42
      CALL PFF(F,RE,3,23) NTCN 43
      CALL AVG(RHOAV,RHO,DZ,DZA,DZB,DZC) NTCN 44
      CALL AVG(FAV,F,DZ,DZA,DZB,DZC) NTCN 45
      N=0 NTCN 46
201 DO 102 I=1,3 NTCN 47
      A(I)=RHOAV(I)*CONST NTCN 48
102 B(I)=FAV(I)/RHOAV(I) NTCN 49
      PRDIP=10. NTCN 50
      ISKIP=0 NTCN 51
103 PF=B(1)*DMM(1)*ABS(DMM(1))-B(2)*DMM(2)*ABS(DMM(2))+A(1)-A(2) NTCN 52
      ZF=-(DMM(1)*141.+DMM(2)*123.)/79. NTCN 53
      QF=E(3)*ZF*ABS(ZF)-B(2)*DMM(2)*ABS(DMM(2))+A(3)-A(2) NTCN 54
      DPD1=2.*B(1)*ABS(DMM(1)) NTCN 55
      DPD2=-2.*B(2)*ABS(DMM(2)) NTCN 56
      DQD1=-2.*B(3)*ABS(ZF)*141./79. NTCN 57
      DQD2=DQD1*123./141.-2.*B(2)*ABS(DMM(2)) NTCN 58
      DENCM=DPD1*DQD2-DPD2*DQD1 NTCN 59
      DM(1)=DMM(1)-((PF*DQD2-QF*DPD2)/DENOM) NTCN 60
      DM(2)=DMM(2)+((PF*DQD1-QF*DPD1)/DENOM) NTCN 61
      DIP1=ABS(DM(1)-DMM(1)) NTCN 62
      DIP2=ABS(DM(2)-DMM(2)) NTCN 63
      SUM=(DIP1+DIP2)/(ABS(DM(1))+ABS(DM(2))) NTCN 64
      IF (PRDIP.LT.SUM) GO TO 996 NTCN 65
      GO TO 995 NTCN 66

```

Table A.1 (continued)

996	ISKIP=ISKIP+1	NTCN	67
	IF (ISKIP.GE.2) GO TO 999	NTCN	68
995	CONTINUE	NTCN	69
	IF (SUM.LT.TOLRNC) GO TO 104	NTCN	70
	PRDIF=SUM	NTCN	71
	DMM(1)=DM(1)	NTCN	72
	DMM(2)=DM(2)	NTCN	73
	GO TO 103	NTCN	74
104	DM(3)=- (DM(1)*141.+DM(2)*123.)/79.	NTCN	75
	DO 105 I=1,3	NTCN	76
	DO 105 J=1,23	NTCN	77
105	RE(I,J)=REF(RC,DM(I),GMU(I,J),FI)	NTCN	78
	CALL FFF(F2,RE,3,23)	NTCN	79
	CALL AVG(FAV2,F2,DZ,DZA,DZB,DZC)	NTCN	80
	DO 202 I=1,3	NTCN	81
	DIFP(I)=ABS(FAV(I)-FAV2(I))	NTCN	82
202	IF ((DIFP(I)/FAV2(I)).GT..010) GO TO 203	NTCN	83
	GO TO 106	NTCN	84
203	DO 204 I=1,3	NTCN	85
204	FAV(I)=FAV2(I)	NTCN	86
	GO TO 201	NTCN	87
106	DO 107 I=1,3	NTCN	88
	DO 107 J=1,23	NTCN	89
	HK(I,J)=ABS(HKF(TP(I,4,J)))	NTCN	90
107	PR(I,J)=GMU(I,J)*C/HK(I,J)	NTCN	91
	CALL NUS(ANU,RE,PR,3,23)	NTCN	92
	DO 108 I=1,3	NTCN	93
	DO 108 J=1,23	NTCN	94
108	H(I,J)=ANU(I,J)*HK(I,J)/(2.*RC)	NTCN	95
	RHOU=RHOF(P,R,TUP)	NTCN	96
	RHOLP=RHOF(P,R,TLP)	NTCN	97
	PMU=RHOU*VUP	NTCN	98
	PML=RHOLP*VLP	NTCN	99
	DO 109 I=1,3	NTCN	100
	GRUP(I)=(32.2)*(3600.**2)*(RHOU**2)*ABS(TP(I,2,1)-TUP)*((RC*2.*NTCN 101		
	1.9)**3)/((TOP+460.)*(GMUF(TUP)**2))	NTCN	102
109	GRLP(I)=(32.2)*(3600.**2)*(RHOLP**2)*ABS(TP(I,2,23)-TLP)*((RC*2.*NTCN 103		
	1*.9)**3)/((TLP+460.)*(GMUF(TLP)**2))	NTCN	104
	PRUP=GMUF(TUP)*C/ABS(HKF(TUP))	NTCN	105
	PRLP=GMUF(TLP)*C/ABS(HKF(TLP))	NTCN	106
	DO 110 I=1,3	NTCN	107
	ANUUP(I)=.54*(GRUP(I)*PRUP)**(.25)	NTCN	108
	IF ((GRUP(I)*PRUP).GE.(2.E7)) ANUUP(I)=.14*(GRUP(I)*PRUP)**(1./3.)	NTCN	109
	ANULP(I)=.27*(GRLP(I)*PRLP)**.25	NTCN	110
	HUP(I)=ANUUP(I)*HKF(TUP)/(RC*2.*.9)	NTCN	111
110	HLP(I)=ANULP(I)*HKF(TLP)/(RC*2.*.9)	NTCN	112
	DO 302 I=1,3	NTCN	113
302	QB(I)=QA(I)*.128*(TIME*60.+0003796)**(-.261)	NTCN	114
	DO 303 I=1,3	NTCN	115
	DO 303 J=3,19	NTCN	116
303	Q(I,J)=QB(I)*(.563547-4.79909E-2*FLOAT(19-I)*DZ+.01574*(FLOAT(19-INTCN 117		
	1)*DZ)**2-.5.92159E-4*(FLOAT(19-I)*DZ)*(FLOAT(19-I)*DZ)**2)	NTCN	118
	DO 111 I=1,3	NTCN	119
	T(I,1,1)=TP(I,1,1)+2.*GDRC*((TP(I,1,2)-TP(I,1,1))/(DZA**2)+(TP(I,2,NTCN 120		
	1,1)-TP(I,1,1))/(RF1*RFPG)+(HUP(I)/(GK*DZA))*(TUP-TP(I,1,1)))	NTCN	121
	T(I,1,2)=TP(I,1,2)+GDRC*((TP(I,1,1)+TP(I,1,3)-2.*TP(I,1,2))/(DZA**NTCN 122		
	12)+2.*(TP(I,2,2)-TP(I,1,2))/(RF1*RFPG))	NTCN	123
	T(I,1,3)=TP(I,1,3)+(2.*DT/(RHOG*CG*DZA+RHOU*CF*DZ))*(GK*(TP(I,1,2)NTCN 124		
	1-TP(I,1,3))/DZA+FK*(TP(I,1,4)-TP(I,1,3))/DZ+(GK*DZA+FK*DZ)*(TP(I,2,NTCN 125		
	2,3)-TP(I,1,3))/(RF1*RFPG)+Q(I,3)*DZ/2.)	NTCN	126
	T(I,1,19)=TP(I,1,19)+(2.*DT/(RHOG*CG*DZB+RHOU*CF*DZ))*(GK*(TP(I,1,NTCN 127		
	120)-TP(I,1,19))/DZB+FK*(TP(I,1,18)-TP(I,1,19))/DZ+(GK*DZB+FK*DZ)*(NTCN 128		
	2TP(I,2,19)-TP(I,1,19))/(RF1*RFPG)+Q(I,19)*DZ/2.)	NTCN	129
	T(I,1,20)=TP(I,1,20)+GDRC*((TP(I,1,19)+TP(I,1,21)-2.*TP(I,1,20))/(NTCN 130		
	1DZB**2)+2.*(TP(I,2,20)-TP(I,1,20))/(RF1*RFPG))	NTCN	131

Table A.1 (continued)

```

T(I,1,21)=TP(I,1,21)+2.*GDRC*((TP(I,1,22)/DZC+TP(I,1,20)/DZB)/(DZBNTCN 132
1+DZC)-TP(I,1,21)/(DZB*DZC)+(TP(I,2,21)-TP(I,1,21))/(RF1*RFRG)) NTCN 133
T(I,1,22)=TP(I,1,22)+GDRC*((TP(I,1,21)+TP(I,1,23)-2.*TP(I,1,22))/(NTCN 134
1DZC**2)+2.*(TP(I,2,22)-TP(I,1,22))/(RF1*RFRG)) NTCN 135
T(I,1,23)=TP(I,1,23)+2.*GDRC*((TP(I,1,22)-TP(I,1,23))/(DZC**2)+(TPNTCN 136
1(I,2,23)-TP(I,1,23))/(RF1*RFRG)+HLP(I)*(TLP-TP(I,1,23))/(GK*DZC)) NTCN 137
T(I,2,1)=TP(I,2,1)+GDRC*((TP(I,2,2)-TP(I,2,1))/(DZA**2)+(2./R12)*(NTCN 138
1(TP(I,1,1)-TP(I,2,1))/FFRG+(TP(I,3,1)-TP(I,2,1))/RGRC)+HUP(I)*(TUPNTCN 139
2-TP(I,2,1))/(GK*DZA)) NTCN 140
T(I,2,2)=TP(I,2,2)+GDRC*((TP(I,2,1)+TP(I,2,3)-2.*TP(I,2,2))/(DZA**NTCN 141
12)+(2./R12)*((TP(I,1,2)-TP(I,2,2))/RFRG+(TP(I,3,2)-TP(I,2,2))/RGRCNTCN 142
2)) NTCN 143
T(I,2,3)=TP(I,2,3)+(2.*DT/((RHO*CF*R1G+RHOG*CG*RG2)*DZ+RHOG*CG*R1NTCN 144
12*DZA))*(FK*R1G*(TP(I,2,4)-TP(I,2,3))/DZ+GK*(RG2*(TP(I,2,4)-TP(I,2NTCN 145
2,3))/DZ+R12*(TP(I,2,2)-TP(I,2,3))/DZA)+(FK*DZ+GK*DZA)*(TP(I,1,3)-TNTCN 146
3P(I,2,3))/RFRG+3K*(DZ+DZA)*(TP(I,3,3)-TP(I,2,3))/RGRC+Q(I,3)*R1G*DNNTCN 147
4Z/2.) NTCN 148
T(I,2,19)=TP(I,2,19)+(2.*DT/((RHO*CF*R1G+RHOG*CG*RG2)*DZ+RHOG*CG*NTCN 149
1R12*DZB))*(FK*R1G*(TP(I,2,18)-TP(I,2,19))/DZ+GK*(RG2*(TP(I,2,18)-TNTCN 150
2P(I,2,19))/DZ+R12*(TP(I,2,20)-TP(I,2,19))/DZB)+(FK*DZ+GK*DZB)*(TP(NTCN 151
3I,1,19)-TP(I,2,19))/RFRG+GK*(DZ+DZB)*(TP(I,3,19)-TP(I,2,19))/RGRC+NTCN 152
4Q(I,19)*R1G*DZ/2.) NTCN 153
T(I,2,20)=TP(I,2,20)+GDRC*((TP(I,2,19)+TP(I,2,21)-2.*TP(I,2,20))/(NTCN 154
1DZB**2)+(2./R12)*((TP(I,1,20)-TP(I,2,20))/RFRG+(TP(I,3,20)-TP(I,2,NTCN 155
220))/RGRC)) NTCN 156
T(I,2,21)=TP(I,2,21)+2.*GDRC*((TP(I,2,22)/DZC+TP(I,2,20)/DZB)/(DZBNTCN 157
1+DZC)-TP(I,2,21)/(DZC*DZB)+(TP(I,1,21)-TP(I,2,21))/RFRG+(TP(I,3,2NTCN 158
21)-TP(I,2,21))/RGRC)/R12) NTCN 159
T(I,2,22)=TP(I,2,22)+GDRC*((TP(I,2,21)+TP(I,2,23)-2.*TP(I,2,22))/(NTCN 160
1DZ**2)+(2./R12)*((TP(I,1,22)-TP(I,2,22))/RFRG+(TP(I,3,22)-TP(I,2,2NTCN 161
22))/RGRC)) NTCN 162
T(I,2,23)=TP(I,2,23)+GDRC*((TP(I,2,22)-TP(I,2,23))/(DZC**2)+(2./R1NTCN 163
12)*((TP(I,1,23)-TP(I,2,23))/RFRG+(TP(I,3,23)-TP(I,2,23))/RGRC)+HLPNTCN 164
2(I)*(TLP-TP(I,2,23))/(GK*DZC)) NTCN 165
T(I,3,1)=TP(I,3,1)+2.*GDRC*((TP(I,3,2)-TP(I,3,1))/(DZA**2)+((TP(I,NTCN 166
12,1)-TP(I,3,1))/RGRC+H(I,1)*RC*(TP(I,4,1)-TP(I,3,1))/GK)/R2C+HUP(INTCN 167
2)*(TUP-TP(I,3,1))/(GK*DZA)) NTCN 168
T(I,3,2)=TP(I,3,2)+GDRC*((TP(I,3,1)+TP(I,3,3)-2.*TP(I,3,2))/(DZA**NTCN 169
12)+(2./R2C)*((TP(I,2,2)-TP(I,3,2))/RGRC+H(I,2)*RC*(TP(I,4,2)-TP(I,NTCN 170
23,2))/GK)) NTCN 171
T(I,3,3)=TP(I,3,3)+2.*GDRC*((TP(I,3,2)/DZA+TP(I,3,4)/DZ)/(DZ+DZA)-NTCN 172
1P(I,3,3)/(DZ*DZA)+(TP(I,2,3)-TP(I,3,3))/RGRC+H(I,3)*RC*(TP(I,4,3NTCN 173
2)-TP(I,3,3))/GK)/R2C) NTCN 174
T(I,3,19)=TP(I,3,19)+2.*GDRC*((TP(I,3,18)/DZ+TP(I,3,20)/DZB)/(DZ+DNNTCN 175
1ZB)-TP(I,3,19)/(DZ*DZB)+(TP(I,2,19)-TP(I,3,19))/RGRC+H(I,19)*RC*(NTCN 176
2TP(I,4,19)-TP(I,3,19))/GK)/R2C) NTCN 177
T(I,3,20)=TP(I,3,20)+GDRC*((TP(I,3,19)+TP(I,3,21)-2.*TP(I,3,20))/(NTCN 178
1DZB**2)+(2./R2C)*((TP(I,2,20)-TP(I,3,20))/RGRC+H(I,20)*RC*(TP(I,4,NTCN 179
220)-TP(I,3,20))/GK)) NTCN 180
T(I,3,21)=TP(I,3,21)+2.*GDRC*((TP(I,3,20)/DZB+TP(I,3,22)/DZC)/(DZBNTCN 181
1+DZC)-TP(I,3,21)/(DZB*DZC)+(TP(I,2,21)-TP(I,3,21))/RGRC+H(I,21)*RNTCN 182
2C*(TP(I,4,21)-TP(I,3,21))/GK)/R2C) NTCN 183
T(I,3,22)=TP(I,3,22)+GDRC*((TP(I,3,21)+TP(I,3,23)-2.*TP(I,3,22))/(NTCN 184
1DZC**2)+(2./R2C)*((TP(I,2,22)-TP(I,3,22))/RGRC+H(I,22)*RC*(TP(I,4,NTCN 185
222)-TP(I,3,22))/GK)) NTCN 186
T(I,3,23)=TP(I,3,23)+2.*GDRC*((TP(I,3,22)-TP(I,3,23))/(DZC**2)+((TNTCN 187
1P(I,2,23)-TP(I,3,23))/RGRC+H(I,23)*RC*(TP(I,4,23)-TP(I,3,23))/GK)/NTCN 188
2R2C+HLP(I)*(TLP-TP(I,3,23))/(GK*DZC)) NTCN 189
IF (DM(I).GE.0.) GO TO 112 NTCN 190
T(I,4,1)=TP(I,4,1)+(DT/(RHO(I,1)*PI*FC**2))*(2.*DM(I)*(TP(I,4,1)-NTCN 191
1TUP)/DZA+2.*PI*RC*H(I,1)*(TP(I,3,1)-TP(I,4,1))/C) NTCN 192
T(I,4,2)=TP(I,4,2)+(DT/(RHO(I,2)*PI*FC**2))*(DM(I)*(TP(I,4,2)-TP(NTCN 193
1I,4,1))/DZA+2.*PI*RC*H(I,2)*(TP(I,3,2)-TP(I,4,2))/C) NTCN 194
T(I,4,3)=TP(I,4,3)+(DT/(RHO(I,3)*PI*FC**2))*(2.*DM(I)*(TP(I,4,3)-NTCN 195
1TP(I,4,2))/DZ+DZA)+2.*PI*RC*H(I,3)*(TP(I,3,3)-TP(I,4,3))/C) NTCN 196
T(I,4,19)=TP(I,4,19)+(DT/(RHO(I,19)*PI*RC**2))*(2.*DM(I)*(TP(I,4,NTCN 197

```

Table A.1 (continued)

```

119) -TP(I,4,18))/(DZ+DZB)+2.*PI*RC*H(I,19)*(TP(I,3,19)-TP(I,4,19))/NTCN 198
2C) NTCN 199
T(I,4,20)=TP(I,4,20)+(DT/(RHO(I,20)*PI*RC**2))*(DM(I)*(TP(I,4,20)-NTCN 200
1-TP(I,4,19))/DZB+2.*PI*RC*H(I,20)*(TP(I,3,20)-TP(I,4,20))/C) NTCN 201
T(I,4,21)=TP(I,4,21)+(DT/(RHO(I,21)*PI*RC**2))*(2.*DM(I)*(TP(I,4,NTCN 202
121)-TP(I,4,20))/(DZB+DZC)+2.*PI*RC*H(I,21)*(TP(I,3,21)-TP(I,4,21)) NTCN 203
2/C) NTCN 204
T(I,4,22)=TP(I,4,22)+(DT/(RHO(I,22)*PI*RC**2))*(DM(I)*(TP(I,4,22) NTCN 205
1-TP(I,4,21))/DZC+2.*PI*RC*H(I,22)*(TP(I,3,22)-TP(I,4,22))/C) NTCN 206
T(I,4,23)=TP(I,4,23)+(DT/(RHO(I,23)*PI*RC**2))*(2.*DM(I)*(TP(I,4,NTCN 207
123)-TP(I,4,22))/DZC+2.*PI*RC*H(I,23)*(TP(I,3,23)-TP(I,4,23))/C) NTCN 208
GO TO 113 NTCN 209
112 T(I,4,1)=TP(I,4,1)+(DT/(RHO(I,1)*PI*RC**2))*(2.*DM(I)*(TP(I,4,2)-NTCN 210
1TP(I,4,1))/DZA+2.*PI*RC*H(I,1)*(TP(I,3,1)-TP(I,4,1))/C) NTCN 211
T(I,4,2)=TP(I,4,2)+(DT/(RHO(I,2)*PI*RC**2))*(DM(I)*(TP(I,4,3)-TP(I,4,3)-NTCN 212
1I,4,2))/DZA+2.*PI*RC*H(I,2)*(TP(I,3,2)-TP(I,4,2))/C) NTCN 213
T(I,4,3)=TP(I,4,3)+(DT/(RHO(I,3)*PI*RC**2))*(2.*DM(I)*(TP(I,4,4)-NTCN 214
1TP(I,4,3))/DZ+DZA)+2.*PI*RC*H(I,3)*(TP(I,3,3)-TP(I,4,3))/C) NTCN 215
T(I,4,19)=TP(I,4,19)+(DT/(RHO(I,19)*PI*RC**2))*(2.*DM(I)*(TP(I,4,NTCN 216
120)-TP(I,4,19))/(DZ+DZB)+2.*PI*RC*H(I,19)*(TP(I,3,19)-TP(I,4,19))/NTCN 217
2C) NTCN 218
T(I,4,20)=TP(I,4,20)+(DT/(RHO(I,20)*PI*RC**2))*(DM(I)*(TP(I,4,21) NTCN 219
1-TP(I,4,20))/DZB+2.*PI*RC*H(I,20)*(TP(I,3,20)-TP(I,4,20))/C) NTCN 220
T(I,4,21)=TP(I,4,21)+(DT/(RHO(I,21)*PI*RC**2))*(2.*DM(I)*(TP(I,4,NTCN 221
122)-TP(I,4,21))/(DZB+DZC)+2.*PI*RC*H(I,21)*(TP(I,3,21)-TP(I,4,21)) NTCN 222
2/C) NTCN 223
T(I,4,22)=TP(I,4,22)+(DT/(RHO(I,22)*PI*RC**2))*(DM(I)*(TP(I,4,23) NTCN 224
1-TP(I,4,22))/DZC+2.*PI*RC*H(I,22)*(TP(I,3,22)-TP(I,4,22))/C) NTCN 225
T(I,4,23)=TP(I,4,23)+(DT/(RHO(I,23)*PI*RC**2))*(2.*DM(I)*(TLP-TP(NTCN 226
1I,4,23))/DZC+2.*PI*RC*H(I,23)*(TP(I,3,23)-TP(I,4,23))/C) NTCN 227
113 DO 111 J=4,18 NTCN 228
T(I,1,J)=TP(I,1,J)+FDEC*((TP(I,1,J+1)+TP(I,1,J-1)-2.*TP(I,1,J))/(DNTCN 229
1Z**2)+2.*(TP(I,2,J)-TP(I,1,J))/(RF1*RFRG)+Q(I,J)/FK) NTCN 230
T(I,2,J)=TP(I,2,J)+(DT/(RHO*CF*RI*RG+RHO*CG*FG2))*((FK*F1G+GK*RG2) NTCN 231
1*(TP(I,2,J-1)+TP(I,2,J+1)-2.*TP(I,2,J))/(NZ**2)+?.*FK*(TP(I,1,J)-TNTCN 232
2P(I,2,J))/RFRG+2.*GK*(TP(I,3,J)-TP(I,2,J))/FGRC+Q(I,J)*F1G) NTCN 233
T(I,3,J)=TP(I,3,J)+GDR*((TP(I,3,J-1)+TP(I,3,J+1)-2.*TP(I,3,J))/(DNTCN 234
1Z**2)+(2./R2C)*((TP(I,2,J)-TP(I,3,J))/RGRG+H(I,J)*RC*(TP(I,4,J)-TPNTCN 235
2(I,3,J))/GK)) NTCN 236
IF (DM(I).GE.0.0) GO TO 126 NTCN 237
T(I,4,J)=TP(I,4,J)+(DT/(RHO(I,J)*PI*RC**2))*(DM(I)*(TP(I,4,J) -TNTCN 238
1P(I,4,J-1))/DZ+2.*PI*RC*H(I,J)*(TP(I,3,J)-TP(I,4,J))/C) NTCN 239
GO TO 111 NTCN 240
126 T(I,4,J)=TP(I,4,J)+(DT/(RHO(I,J)*PI*RC**2))*(DM(I)*(TP(I,4,J+1)-TNTCN 241
1P(I,4,J))/DZ+2.*PI*RC*H(I,J)*(TP(I,3,J)-TP(I,4,J))/C) NTCN 242
111 CONTINUE NTCN 243
DO 500 I=1,3 NTCN 244
DO 500 J=1,4 NTCN 245
DO 500 K=1,23 NTCN 246
500 IF (T(I,J,K).LT.0.) GO TO 998 NTCN 247
DO 114 I=1,3 NTCN 248
TE(I)=TP(I,4,1) NTCN 249
114 IF (DM(I).LT.0.0) TE(I)=TUP NTCN 250
TUP=TUP+(DT*X/(PMU*C))*(C*(141.*DM(1)*TE(1)+123.*DM(2)*TE(2)+79.*DNTCN 251
1M(3)*TE(3))+PI*((RF**2-RE1**2)*(141.*HUP(1)*TP(1,1,1)+123.*HUP(2)NTCN 252
2)*TP(2,1,1)+79.*HUP(3)*TP(3,1,1)-(141.*HUP(1)+123.*HUP(2)+79.*HUP(NTCN 253
33))*TUP)+(RE1**2-RE2**2)*(141.*HUP(1)*TP(1,2,1)+123.*HUP(2)*TP(2)NTCN 254
4,2,1)+79.*HUP(3)*TP(3,2,1)-(141.*HUP(1)+123.*HUP(2)+79.*HUP(3))*TUNTCN 255
5P)+(RE2**2-RC**2)*(141.*HUP(1)*TP(1,3,1)+123.*HUP(2)*TP(2,3,1)+7NTCN 256
69.*HUP(3)*TP(3,3,1)-(141.*HUP(1)+123.*HUP(2)+79.*HUP(3))*TUP)) NTCN 257
DO 115 I=1,3 NTCN 258
TE(I)=TP(I,4,23) NTCN 259
115 IF (DM(I).GE.0.0) TE(I)=TLP NTCN 260
TLP=TLP+(DT*X/(PML*C))*(PI*((PF**2-FE1**2)*(141.*HLP(1)*TP(1,1,2)NTCN 261
13)+123.*HLP(2)*TP(2,1,23)+79.*HLP(3)*TP(3,1,23)-(141.*HLP(1)+123.*NTCN 262

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Table A.1 (continued)

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2HLP(2)+79.*HLP(3))*TLP)+(RE1**2.-RE2**2.)*(141.*HLP(1)*TP(1,2,23)+NTCN 263
3123.*HLP(2)*TP(2,2,23)+79.*HLP(3)*TP(3,2,23)-(141.*HLP(1)+123.*HLPNTCN 264
4(2)+79.*HLP(3))*TLP)+(RE2**2.-RC**2.)*(141.*HLP(1)*TP(1,3,23)+123.NTCN 265
5*HLP(2)*TP(2,3,23)+79.*HLP(3)*TP(3,3,23)-(141.*HLP(1)+123.*HLP(2)+NTCN 266
679.*HLP(3))*TLP))-C*(141.*DM(1)*TE(1)+123.*DM(2)*TE(2)+79.*DM(3)*TNTCN 267
7E(3))) NTCN 268
TIME=TIME+DI*60. NTCN 269
MINUTE=IFIX(TIME) NTCN 270
IF (MINUTE.GT.NUMBER) GO TO 124 NTCN 271
GO TO 123 NTCN 272
124 NUMBER=MINUTE NTCN 273
TB=TUP+460. NTCN 274
HB=0. NTCN 275
ICOUNT=0 NTCN 276
IF (DM(3).LE.0.0) GO TO 127 NTCN 277
V=DM(3)/(RHO(3,1)*PI*RC**2) NTCN 278
CA=V/HT NTCN 279
HB=.6613*SQRT(CA*RHO(3,1)/GMU(3,1))*HK(3,1) NTCN 280
127 TB1=(TCKAO*TL+HB*TH*(T(3,4,1)+460.))+BOLT*EM*TH*((TUP+460.))**4-TB*NTCN 281
14)))/(TCKAO+TH*HB) NTCN 282
SB=TB1 NTCN 283
SB1=(TCKAO*TL+HB*TH*(T(3,4,1)+460.))+BOLT*EM*TH*((TUP+460.))**4-TB1*NTCN 284
1*4)))/(TCKAO+TH*HB) NTCN 285
128 TB2=TB1+(TB1-TB)/((TB-SB)/(TB1-SB1)-1.) NTCN 286
SB2=(TCKAO*TL+HB*TH*(T(3,4,1)+460.))+BOLT*EM*TH*((TUP+460.))**4-TB2*NTCN 287
1*4)))/(TCKAO+TH*HB) NTCN 288
IF (ABS(TB2-TB1).LE.0.1) GO TO 129 NTCN 289
ICOUNT=ICOUNT+1 NTCN 290
IF (ICOUNT.GE.200) GO TO 997 NTCN 291
TB=TB1 NTCN 292
SB=SB1 NTCN 293
TB1=TB2 NTCN 294
SB1=SB2 NTCN 295
GO TO 128 NTCN 296
129 TB=TB2 NTCN 297
TEMP=TB-460. NTCN 298
WRITE(6,116) TIME NTCN 299
116 FORMAT(1H0,4X,'TIME=',F10.6) NTCN 300
DO 403 I=1,3 NTCN 301
WRITE(6,117) I NTCN 302
117 FORMAT(1H,4X,'TEMPERATURES IN NUMBER',I3,2X,'SECTION') NTCN 303
WRITE(6,118) NTCN 304
118 FORMAT(1H,4X,'1',10X,'2',10X,'3',10X,'4') NTCN 305
DO 403 K=1,23 NTCN 306
WRITE(6,404) (T(I,J,K),J=1,4) NTCN 307
404 FORMAT(1H,4F10.4) NTCN 308
403 CONTINUE NTCN 309
WRITE(6,125) TUP,TLP NTCN 310
125 FORMAT(1H,10X,'TUP=',F10.4,5X,'TLP=',F10.4) NTCN 311
WRITE(6,130) TEMP NTCN 312
130 FORMAT(1H,10X,'BARRIER TEMPERATURE=',F10.4) NTCN 313
WRITE(6,119) NTCN 314
119 FORMAT(1H,4X,'MASS FLOW IN CHANNELS:') NTCN 315
WRITE(6,120) NTCN 316
120 FORMAT(1H,22X,'1',29X,'2',29X,'3') NTCN 317
WRITE(6,121) DM(1),DM(2),DM(3) NTCN 318
121 FORMAT(1H,3F30.10) NTCN 319
IF (TIME.GE.TIMLIM) GO TO 401 NTCN 320
123 DO 402 I=1,3 NTCN 321
DO 402 J=1,4 NTCN 322
DO 402 K=1,23 NTCN 323
402 TP(I,J,K)=T(I,J,K) NTCN 324
GO TO 100 NTCN 325
998 N=N+1 NTCN 326
999 N=N+1 NTCN 327

```

Table A.1 (continued)

997	CONTINUE	NTCN 328
	WRITE (6,VALUES)	NTCN 329
401	CONTINUE	NTCN 330
	STOP	NTCN 331
	END	NTCN 332
	SUBROUTINE FFP(X,Y,M,N)	NTCN 333
	DIMENSION X(M,N), Y(M,N)	NTCN 334
	DO 10 I=1,M	NTCN 335
	DO 10 J=1,N	NTCN 336
	IF (Y(I,J).LT.10.) Y(I,J)=10.	NTCN 337
	X(I,J)=.0014+ (.125/((Y(I,J))**.32))	NTCN 338
	IF (Y(I,J).LE.4000.) X(I,J)=5.601205424E-4* (Y(I,J)**.3498327759)	NTCN 339
10	IF (Y(I,J).LE.2000.) X(I,J)=16./Y(I,J)	NTCN 340
	RETURN	NTCN 341
	END	NTCN 342
	SUBROUTINE AVG(X,Y,Z,A,B,C)	NTCN 343
	DIMENSION X(3), Y(3,23)	NTCN 344
	DO 10 I=1,3	NTCN 345
	X(I)=0.	NTCN 346
	DO 11 J=4,18	NTCN 347
11	X(I)=X(I)+Y(I,J)*Z	NTCN 348
10	X(I)=(X(I)+Y(I,1)*(A/2.)+Y(I,2)*A+Y(I,3)*((A+Z)/2.)+Y(I,19)*((B+Z)	NTCN 349
	1/2.)+Y(I,20)*B+Y(I,21)*((B+C)/2.)+Y(I,22)*C+Y(I,23)*(C/2.))/31.2	NTCN 350
	RETURN	NTCN 351
	END	NTCN 352
	SUBROUTINE NUS(X,Y,Z,M,N)	NTCN 353
	DIMENSION X(M,N), Y(M,N), Z(M,N)	NTCN 354
	DO 10 I=1,M	NTCN 355
	DO 10 J=1,N	NTCN 356
	X(I,J)=.023*(Y(I,J)**.8)*(Z(I,J)**.4)	NTCN 357
	IF(Y(I,J).LT.4000.) X(I,J)=.0038*Y(I,J)*Z(I,J)	NTCN 358
10	IF (X(I,J).LT.3.65) X(I,J)=3.65	NTCN 359
	RETURN	NTCN 360
	END	NTCN 361

Appendix II

SAMPLE INPUT FOR THE NATCON PROGRAM

Sample input for the program is shown on the next page. Initial temperatures for the nodes are given in the first 28 lines. If the temperatures are expressed in the form T(I,J,K), the computer reads the input so that the subscript I changes most rapidly and K changes least rapidly.

Each value presented in the next three lines uses eight digit spaces. These values are:

```
DMM(1) DMM(2) DMM(3) RC RG RF RE1 RE2 DZ DZA  
DZB DZC VLP VUP TUP TLP RHOG RHOU CG CF GK  
FK QM DT
```

The symbols for each value in the last line are given below. The number in parentheses is the number of digit spaces allotted to each value.

```
HT(6) EM(6) TH(6) TIME(6) TOLRNC(6) C(6)  
TCKAO(7) PI(11) TL(4) X(4) TIMLIM(4) R(4)  
BOLT(8) NUMBER(2)
```

Table A.2. Sample input for the NATCON program

[illegible]

Appendix III

SAMPLE OUTPUT FOR THE NATCON PROGRAM

Sample output from the program is given in the following pages. Elapsed time is stated in minutes. The temperatures are expressed in degrees Fahrenheit. Section 1 is the lowest-powered region, and section 3 is the highest-powered region. The temperatures correspond to the nodes as numbered in Fig. 5. The values TUP and TLP are upper and lower plenum gas temperatures, respectively.

TIME= 1.001711

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
328.56	328.72	330.43	358.83
343.16	343.32	345.14	375.69
382.77	381.95	379.67	412.68
432.84	431.37	422.20	444.96
450.54	449.06	439.80	461.30
468.07	466.58	457.20	476.97
485.58	484.08	474.51	491.58
503.00	501.49	491.63	504.39
514.30	512.79	502.85	514.13
524.16	522.64	512.65	522.85
532.87	531.35	521.33	530.80
540.39	538.88	528.86	538.25
549.48	547.95	537.83	545.69
558.10	556.57	546.31	552.03
564.19	562.66	552.32	556.75
569.38	567.84	557.44	560.51
576.02	574.47	563.85	563.24
582.31	580.74	569.79	563.11
564.16	563.21	558.91	558.18
556.67	556.67	556.68	557.55
564.44	564.40	564.00	558.89
569.08	569.00	568.01	553.41
573.62	573.47	571.64	541.67

TUP= 317.2141 TLP= 529.5413

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
322.06	322.04	321.82	319.28
332.41	332.38	332.13	327.44
379.84	378.02	369.25	351.55
445.70	442.74	421.30	386.21
462.57	459.63	438.55	412.35
479.38	476.44	455.52	433.97
496.25	493.32	472.46	453.31
513.18	510.25	489.41	471.52
523.23	520.31	499.69	485.69
531.80	528.88	508.41	497.07
539.19	536.28	515.92	506.44
545.31	542.41	522.15	514.19
553.32	550.42	530.15	522.09
560.85	557.95	537.70	529.82
565.54	562.64	542.49	536.02
569.24	566.34	546.27	540.95
574.63	571.73	551.65	546.13
579.67	576.77	556.71	551.25
544.77	543.01	535.22	541.06
523.50	523.51	523.67	529.26
528.05	528.04	528.01	528.42
530.90	530.89	530.81	529.68
533.78	533.77	533.63	531.13

BARRIER TEMPERATURE= 308.3154

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
316.81	316.79	316.64	316.88
323.44	323.41	323.12	320.62
388.77	385.36	369.00	347.03
484.38	478.83	438.50	389.88
500.86	495.32	455.28	419.94
517.36	511.82	471.95	443.63
534.04	528.50	488.72	464.17
550.85	545.32	505.58	483.13
559.67	554.16	514.81	497.40
566.95	561.46	522.45	508.51
573.04	567.57	528.85	517.39
577.81	572.35	533.91	524.45
584.97	579.51	541.16	531.71
591.66	586.21	547.95	538.80
595.09	589.65	551.60	544.18
597.48	592.05	554.20	548.19
601.98	596.55	558.75	552.53
606.10	600.68	562.95	556.82
542.25	538.96	524.40	536.77
499.11	499.15	499.73	512.63
501.18	501.20	501.43	506.13
502.53	502.54	502.62	504.44
504.01	504.00	504.01	504.36

8

MASS FLOW IN CHANNELS:

1
1.9890203475

2
-1.3765764236

3
-1.4067430496

TIME= 2.003179

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
329.52	329.59	330.23	331.37
344.24	344.31	345.05	346.51
389.69	388.97	386.29	388.03
448.10	446.85	438.50	438.87
465.78	464.52	456.14	456.49
483.26	482.00	473.59	473.91
500.69	499.42	490.95	491.22
517.97	516.70	508.08	508.10
529.23	527.96	519.30	519.26
539.06	537.78	529.10	529.01
547.75	546.48	537.77	537.65
555.28	554.01	545.32	545.24
564.32	563.04	554.31	554.21
572.87	571.59	562.80	562.61
578.93	577.65	568.82	568.60
584.08	582.80	573.95	573.76
590.60	589.31	580.33	580.06
596.66	595.35	586.06	584.95
569.90	569.11	565.45	565.08
556.67	556.68	556.74	556.89
564.21	564.20	564.12	564.20
568.45	568.42	568.07	567.97
572.21	572.11	571.00	568.41

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
321.91	321.91	321.82	321.19
332.18	332.15	331.91	327.72
389.93	388.37	380.45	356.87
471.60	469.07	449.70	400.99
488.79	486.29	467.58	432.82
505.74	503.26	484.93	457.82
522.69	520.22	502.10	479.16
539.65	537.18	519.17	498.53
549.85	547.40	529.67	513.59
558.51	556.07	538.55	525.63
565.98	563.54	546.16	535.50
572.16	569.73	552.48	543.62
580.17	577.74	560.49	551.71
587.71	585.28	568.04	559.56
592.46	590.04	572.90	565.92
596.20	593.78	576.74	571.01
601.59	599.17	582.11	576.25
606.61	604.20	587.15	581.41
555.81	554.38	548.38	561.54
523.76	523.81	524.47	537.39
528.06	528.07	528.23	531.94
530.83	530.83	530.84	531.36
533.63	533.62	533.52	532.11

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
316.87	316.95	318.15	363.48
323.54	323.67	325.51	388.86
408.65	406.01	395.49	460.36
534.09	529.60	498.65	520.02
550.79	546.30	515.43	535.41
567.37	562.69	532.00	549.95
584.07	579.59	548.62	563.19
600.88	596.38	565.20	574.20
609.62	605.33	574.14	581.43
617.20	612.71	581.53	587.48
623.38	618.89	587.71	592.59
628.23	623.75	592.61	596.93
635.40	630.91	599.69	600.82
642.10	637.60	606.22	602.42
645.59	641.08	609.57	600.51
648.01	643.50	611.76	594.83
652.45	647.91	615.61	583.60
656.40	651.81	618.43	562.00
562.50	559.71	546.47	524.12
499.39	499.41	499.62	503.55
501.28	501.30	501.54	508.37
502.59	502.62	503.06	514.96
504.17	504.23	505.01	523.30

TUP= 320.7815 TLP= 529.6755

BARRIER TEMPERATURE= 350.0388

MASS FLOW IN CHANNELS:

1
0.0213130191

2
-1.5016508102

3
2.2999734879

TIME= 3.001447

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
329.68	329.68	329.67	329.93
344.40	344.39	344.23	336.71
394.87	394.12	390.17	367.57
460.72	459.49	449.97	407.33
478.54	477.34	468.35	437.15
496.06	494.87	486.13	461.29
513.48	512.30	503.67	482.30
530.73	529.55	520.96	501.57
542.02	540.85	532.41	516.99
551.86	550.69	542.36	529.70
560.56	559.40	551.14	540.44
568.11	566.94	558.74	549.61
577.13	575.96	567.75	558.71
585.67	584.50	576.29	567.54
591.73	590.57	582.41	575.01
596.88	595.72	587.61	581.33
603.36	602.20	594.07	587.72
609.33	608.17	600.01	593.89
575.08	574.40	571.64	580.50
556.73	556.76	557.07	565.09
564.14	564.13	564.10	564.44
568.27	568.26	568.13	566.35
571.65	571.63	571.35	568.11

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
321.88	321.88	321.96	324.96
332.00	331.98	331.84	330.23
398.61	397.22	390.23	373.81
493.87	491.61	474.48	440.67
511.55	509.33	493.14	475.40
528.74	526.55	510.77	498.76
545.82	543.63	528.04	518.12
562.83	560.65	545.15	536.05
573.19	571.02	555.73	549.01
581.36	579.79	564.64	559.23
589.49	587.33	572.27	567.70
595.74	593.59	578.59	574.72
603.75	601.59	586.59	582.43
611.29	609.14	594.14	590.06
616.10	613.95	599.03	595.79
619.88	617.74	602.88	600.23
625.26	623.11	608.23	605.32
630.27	628.12	613.25	610.37
565.87	564.62	559.61	571.60
524.28	524.34	525.03	534.43
528.14	528.15	528.31	529.84
530.82	530.82	530.81	530.53
533.55	533.54	533.44	532.09

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
318.73	319.08	323.24	413.43
326.12	326.58	332.01	444.36
428.57	426.89	421.40	522.97
579.34	575.44	549.97	581.19
596.07	592.16	566.55	594.77
612.59	608.67	582.86	607.17
629.18	625.25	599.13	618.00
645.78	641.83	615.25	626.55
654.68	650.72	623.96	631.88
662.02	658.05	631.12	635.76
668.15	664.17	637.06	638.21
672.58	668.99	641.71	639.13
680.02	676.01	648.32	638.41
686.52	682.48	654.24	634.49
689.60	685.74	656.89	626.32
691.94	687.83	658.18	613.51
695.84	691.68	660.74	594.76
698.92	694.67	661.97	567.24
579.44	576.87	563.98	528.31
499.58	499.62	500.02	508.18
501.56	501.61	502.23	514.16
503.06	503.14	504.05	521.08
504.96	505.07	506.33	528.35

TUF= 330.4126 TLP= 533.0642

BARRIER TEMPERATURE= 392.3755

MASS FLOW IN CHANNELS:
1
-1.5106964111

2
-0.6911212802

3
3.7723522186

TIME= 4.002914

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
329.76	329.79	330.18	342.18
344.21	344.19	344.03	342.95
398.82	398.07	393.69	365.50
471.17	469.96	459.56	400.21
489.35	488.17	478.36	429.46
507.06	505.90	496.49	454.83
524.59	523.44	514.28	477.55
541.90	540.75	531.75	498.44
553.32	552.19	543.51	515.92
563.26	562.14	553.70	530.65
572.04	570.93	562.68	543.18
579.64	578.54	570.44	553.87
588.66	587.57	579.51	563.95
597.21	596.12	588.10	573.47
603.32	602.23	594.33	581.70
608.52	607.43	599.64	588.78
615.00	613.91	606.12	595.64
620.95	619.86	612.10	602.16
580.20	579.60	577.46	590.08
557.09	557.16	557.92	572.44
564.14	564.15	564.32	568.44
568.17	568.16	568.12	568.28
571.36	571.35	571.15	569.01

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
322.00	322.02	322.23	326.41
331.91	331.90	331.84	331.36
406.82	405.57	399.56	392.00
514.78	512.73	497.93	482.98
533.01	531.01	517.00	511.82
550.40	548.41	534.60	531.00
567.54	565.56	551.81	548.52
584.59	582.60	568.88	565.70
595.04	593.05	579.43	577.12
603.86	601.88	588.31	586.34
611.43	609.46	595.91	594.17
617.71	615.73	602.22	600.68
625.71	623.73	610.20	608.48
633.26	631.28	617.75	616.08
638.09	636.12	622.63	621.30
641.91	639.93	626.47	625.32
647.27	645.30	631.82	630.51
652.25	650.28	636.81	635.53
575.22	574.06	569.26	575.24
524.66	524.69	525.07	528.92
528.17	528.18	528.23	528.31
530.74	530.74	530.73	530.43
533.47	533.46	533.41	532.75

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
322.63	323.18	329.53	449.55
331.05	331.74	339.65	484.18
449.54	448.20	445.69	569.54
621.92	618.36	595.75	629.60
638.59	635.01	612.16	641.96
654.96	651.37	628.21	652.96
671.34	667.73	644.13	662.21
687.64	684.00	659.80	669.08
696.40	692.75	668.25	672.79
703.61	699.94	675.13	674.76
709.60	705.91	680.76	674.94
714.28	710.57	685.05	673.12
721.01	717.28	691.10	669.06
727.11	723.34	696.32	661.33
729.97	726.14	698.21	648.95
731.55	727.67	698.60	631.52
734.63	730.67	700.00	607.93
736.57	732.52	699.83	575.93
594.47	592.03	579.32	533.65
499.95	500.00	500.63	512.29
502.09	502.17	503.07	519.33
503.84	503.95	505.19	527.11
506.06	506.19	507.77	534.85

TUP= 348.6165 TLP= 539.6533

BARRIER TEMPERATURE= 424.7500

MASS FLOW IN CHANNELS:

1
-2.3676357269

2
-0.2227743864

3
4.5726270676

TIME= 5.001183

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
330.34	330.43	331.63	359.63
344.17	344.19	344.42	352.35
402.21	401.48	397.20	370.43
480.25	479.07	468.46	402.87
498.78	497.62	487.55	431.28
516.72	515.58	505.90	456.63
534.40	533.28	523.88	479.71
551.81	550.69	541.50	501.12
563.43	562.34	553.52	519.41
573.53	572.45	563.95	535.04
582.44	581.37	573.12	548.47
590.15	589.09	581.06	560.01
599.21	598.15	590.20	570.74
607.79	606.73	598.86	580.76
613.97	612.93	605.21	589.49
619.24	618.20	610.61	597.05
625.73	624.69	617.14	604.25
631.68	630.64	623.14	611.03
585.21	584.67	582.94	598.45
557.77	557.87	558.99	578.45
564.31	564.35	564.74	572.30
568.15	568.16	568.25	570.77
571.17	571.16	571.08	570.83

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
322.24	322.24	322.42	324.48
331.86	331.86	331.84	331.68
414.81	413.66	408.38	406.10
534.90	533.02	519.96	515.58
553.52	551.66	538.98	537.61
570.98	569.13	556.49	555.29
588.15	586.29	573.67	572.51
605.20	603.34	590.72	589.59
615.68	613.83	601.24	600.33
624.53	622.67	610.10	609.26
632.11	630.26	617.69	616.90
638.40	636.55	623.99	623.25
646.39	644.53	631.97	631.18
653.94	652.08	639.52	638.75
658.79	656.94	644.39	643.71
662.61	660.76	648.22	647.58
667.97	666.12	653.57	652.89
672.92	671.07	658.53	657.86
583.81	582.69	577.90	579.47
524.81	524.83	524.97	525.97
528.17	528.17	528.17	528.12
530.68	530.68	530.67	530.59
533.44	533.44	533.41	533.24

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
328.06	328.76	336.80	479.51
337.65	338.52	348.33	517.35
471.10	469.59	469.20	609.23
662.10	658.77	637.93	671.88
678.67	675.32	654.16	683.30
694.64	691.48	669.92	693.20
710.95	707.56	685.47	701.21
726.88	723.45	700.67	706.73
735.45	732.00	708.82	709.02
742.44	738.98	715.37	709.34
748.20	744.71	720.63	707.58
752.63	749.11	724.49	703.46
758.94	755.38	729.92	696.67
764.50	760.89	734.39	685.84
766.77	763.11	735.47	670.01
767.65	763.91	734.91	648.79
769.75	765.92	735.10	621.14
770.44	766.51	733.51	585.09
608.03	605.69	593.02	539.11
500.48	500.55	501.39	516.27
502.84	502.94	504.10	524.38
504.85	504.99	506.54	533.15
507.41	507.58	509.49	541.64

TUP= 372.1960 TLP= 546.8005

BARRIER TEMPERATURE= 452.7058

MASS FLOW IN CHANNELS:
1
-2.7978639603

2
-0.0489586443

3
5.0698795319

TIME= 6.002650

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
331.68	331.85	334.03	379.59
344.45	344.56	345.34	363.99
405.43	404.75	400.78	378.19
488.55	487.40	476.88	409.33
507.39	506.26	496.22	437.14
525.55	524.44	514.77	462.28
543.40	542.30	532.91	485.40
560.92	559.84	550.65	506.97
572.77	571.70	562.91	525.61
583.06	582.01	573.55	541.69
592.11	591.08	582.91	555.58
599.96	598.93	591.02	567.57
609.07	608.05	600.25	578.68
617.70	616.69	608.98	589.01
623.98	622.97	615.43	598.04
629.33	628.33	620.94	605.89
635.84	634.85	627.51	613.31
641.80	640.81	633.53	620.26
590.18	589.68	588.28	606.50
558.70	558.83	560.24	583.89
564.65	564.71	565.31	575.90
568.25	568.26	568.51	573.26
571.08	571.09	571.13	572.79

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
322.51	322.51	322.62	323.46
331.86	331.86	331.84	331.79
422.64	421.56	416.71	415.84
554.46	552.69	540.66	538.99
573.26	571.50	559.59	558.85
590.74	588.98	577.07	576.37
607.91	606.15	594.24	593.56
624.95	623.19	611.29	610.63
635.46	633.70	621.80	621.20
644.30	642.54	630.65	630.07
651.89	650.13	638.24	637.68
658.18	656.42	644.54	643.99
666.17	664.41	652.52	651.96
673.72	671.96	660.07	659.52
678.58	676.82	664.93	664.41
682.40	680.64	668.76	668.25
687.76	686.00	674.11	673.60
692.67	690.91	679.04	678.53
591.84	590.76	586.07	586.40
524.84	524.85	524.90	525.19
528.17	528.17	528.17	528.15
530.68	530.68	530.67	530.65
533.44	533.44	533.42	533.37

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
334.76	335.58	345.03	506.13
345.62	346.62	358.02	546.94
492.50	491.18	492.46	645.21
700.57	697.41	677.79	710.75
717.01	713.83	693.83	721.37
732.54	729.74	709.28	730.33
748.73	745.49	724.43	737.27
764.23	760.96	739.13	741.60
772.55	769.25	746.94	742.62
779.28	775.96	753.11	741.47
784.73	781.38	757.95	737.96
788.81	785.43	761.32	731.78
794.60	791.17	766.07	722.58
799.52	796.03	769.71	708.99
801.05	797.53	769.91	690.09
801.14	797.50	768.33	665.45
802.15	798.41	767.25	634.07
801.49	797.64	764.17	594.16
620.52	618.24	605.54	544.39
501.16	501.25	502.28	519.95
503.77	503.90	505.29	529.00
506.10	506.26	508.08	538.64
509.03	509.22	511.44	547.82

TUP= 398.6890 TLP= 553.3188

BARRIER TEMPERATURE= 478.3042

MASS FLOW IN CHANNELS:
1
-3.0126314163

2
-0.0128610395

3
5.3969564981

TIME= 7.000918

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
333.88	334.14	337.37	400.36
345.25	345.37	346.78	376.48
408.62	407.99	404.39	387.00
496.28	495.16	484.84	417.17
515.41	514.31	504.41	444.44
533.78	532.70	523.14	469.34
551.78	550.71	541.42	492.40
569.42	568.36	559.28	514.00
581.49	580.46	571.77	532.81
591.98	590.96	582.61	549.13
601.20	600.20	592.15	563.31
609.19	608.20	600.42	575.59
618.38	617.39	609.73	586.94
627.06	626.08	618.53	597.48
633.44	632.47	625.10	606.72
638.88	637.92	630.71	614.76
645.42	644.47	637.32	622.34
651.40	650.44	643.37	629.42
595.09	594.63	593.52	614.29
559.85	559.99	561.67	589.06
565.14	565.21	566.01	579.37
568.44	568.47	568.86	575.72
571.11	571.12	571.29	574.78

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
322.85	322.84	322.96	324.07
331.86	331.86	331.84	331.80
430.19	429.15	424.55	423.65
573.28	571.59	560.15	558.43
592.18	590.49	579.10	578.40
609.65	607.96	596.58	595.92
626.82	625.13	613.75	613.11
643.87	642.18	630.80	630.17
654.38	652.69	641.31	640.75
663.22	661.53	650.16	649.62
670.81	669.12	657.75	657.22
677.11	675.42	664.04	663.53
685.09	683.40	672.03	671.51
692.64	690.95	679.58	679.06
697.50	695.81	684.44	683.95
701.33	699.64	688.27	687.79
705.53	704.99	693.62	693.14
711.56	709.87	698.50	698.03
599.45	598.42	593.89	594.31
524.84	524.85	524.88	525.21
528.17	528.17	528.17	528.15
530.68	530.68	530.67	530.65
533.44	533.44	533.43	533.38

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
342.52	343.44	354.10	530.26
354.68	355.81	368.56	574.02
513.99	512.82	515.49	678.52
737.39	734.36	715.65	747.06
753.68	750.62	731.47	756.98
769.33	766.25	746.58	765.12
784.76	781.65	761.32	771.11
799.80	796.65	775.50	774.38
807.82	804.64	782.92	774.24
814.23	811.02	788.69	771.72
819.32	816.07	793.05	766.60
822.98	819.70	795.88	758.54
828.17	824.83	799.89	747.13
832.35	828.95	802.65	731.01
833.14	829.66	801.90	709.26
832.25	828.69	799.23	681.42
832.09	828.42	796.82	646.52
830.00	826.21	792.18	602.86
632.04	629.81	617.02	549.26
501.57	502.08	503.27	523.13
504.87	505.01	506.60	533.00
507.53	507.71	509.76	543.36
510.67	511.08	513.53	553.08

TUP= 426.0317 TLP= 558.8433

CARRIER TEMPERATURE= 502.0334

MASS FLOW IN CHANNELS:
1
-3.1325521469

2
-0.0139167644

3
5.6126747131

TIME= 8.002386

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
336.98	337.33	341.61	421.04
346.50	346.67	348.71	389.11
411.88	411.29	408.08	396.16
503.65	502.57	492.46	425.52
523.04	521.98	512.25	452.33
541.60	540.55	531.15	476.98
559.75	558.72	545.56	499.93
577.51	576.48	567.53	521.51
589.81	588.80	580.24	540.42
600.49	599.50	591.28	556.90
609.89	608.91	601.00	571.27
618.03	617.07	609.43	583.76
627.29	626.34	618.83	595.29
636.04	635.09	627.70	605.99
642.52	641.58	634.37	615.38
648.06	647.13	640.09	623.58
654.64	653.71	646.74	631.28
660.63	659.71	652.81	638.45
599.99	599.56	598.72	621.89
561.18	561.35	563.27	594.06
565.78	565.86	566.82	582.75
568.75	568.79	569.31	578.15
571.23	571.25	571.55	576.78

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
323.33	323.32	323.52	326.27
331.86	331.86	331.84	331.78
437.51	436.51	432.03	430.48
591.49	589.85	578.77	575.81
610.48	608.85	597.88	597.03
627.95	626.32	615.36	614.59
645.13	643.50	632.53	631.78
662.17	660.54	649.57	648.85
672.68	671.05	660.09	659.48
681.53	679.90	668.94	668.36
689.12	687.49	676.53	675.98
695.41	693.79	682.83	682.30
703.40	701.77	690.81	690.26
710.94	709.32	698.36	697.82
715.81	714.18	703.23	702.73
719.64	718.01	707.06	706.58
724.99	723.36	712.41	711.91
729.82	723.19	717.25	716.76
606.82	605.83	601.50	602.64
524.84	524.85	524.88	525.61
528.17	528.17	528.17	528.14
530.68	530.68	530.67	530.63
533.44	533.44	533.44	533.35

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
351.27	352.29	364.10	552.71
364.76	366.00	379.95	599.53
535.70	534.66	538.52	710.12
773.02	770.10	752.08	781.69
789.13	786.19	767.69	790.97
804.48	801.50	782.44	798.35
819.51	816.50	796.73	803.47
834.07	831.02	810.36	805.75
841.75	838.66	817.37	804.50
847.78	844.66	822.68	800.69
852.45	849.25	826.52	794.06
855.63	852.43	828.76	784.22
860.14	856.88	831.97	770.72
863.52	860.18	833.79	752.21
863.42	860.01	832.02	727.74
861.53	858.02	828.19	696.84
860.10	856.48	824.38	658.56
856.51	852.76	818.13	611.24
642.78	640.59	627.65	553.84
502.91	503.03	504.35	525.60
506.12	506.27	508.03	536.15
509.13	509.32	511.56	547.18
512.88	513.11	515.76	557.44

TUP= 453.1091 TLP= 563.4455

BARRIER TEMPERATURE= 524.4314

MASS FLOW IN CHANNELS:

-3.2025585175

-0.0267764479

5.757645607C

TIME= 9.000654

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
340.95	341.38	346.65	441.09
348.21	348.44	351.08	401.52
415.22	414.67	411.85	405.28
510.70	509.64	495.76	433.93
530.33	529.29	515.75	460.30
549.07	548.05	538.80	484.71
567.36	566.35	557.34	507.53
585.23	584.22	575.41	529.07
597.75	596.76	588.33	548.03
608.63	607.66	599.57	564.63
618.20	617.25	609.46	579.15
626.50	625.56	618.04	591.81
635.83	634.90	627.53	603.48
644.65	643.73	636.47	614.31
651.24	650.32	643.26	623.84
656.88	655.97	649.08	632.17
663.50	662.59	655.78	639.98
669.51	668.61	661.87	647.23
604.88	604.48	603.88	629.27
562.69	562.87	565.01	598.96
566.54	566.63	567.76	586.10
569.16	569.21	569.86	580.59
571.44	571.48	571.89	578.81

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
324.00	323.99	324.31	328.93
331.36	331.86	331.84	331.79
444.55	443.58	439.21	437.01
609.01	607.43	596.61	592.47
628.14	626.56	615.93	614.94
645.62	644.04	633.42	632.56
662.79	661.21	650.59	649.76
679.83	678.25	667.63	666.82
690.35	688.77	678.16	677.50
699.20	697.62	687.02	686.40
706.79	705.21	694.61	694.03
713.05	711.51	700.91	700.36
721.07	719.49	708.89	708.31
728.62	727.04	716.44	715.87
733.46	731.91	721.31	720.80
737.31	735.74	725.14	724.65
742.67	741.09	730.49	729.98
747.45	745.87	735.28	734.73
613.98	613.02	608.88	610.74
524.84	524.85	524.91	526.06
528.17	528.17	528.17	528.13
530.68	530.68	530.67	530.61
533.44	533.44	533.44	533.31

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
360.89	361.95	374.81	574.30
375.68	377.01	392.04	623.81
557.49	556.56	561.46	740.27
807.42	804.59	787.12	814.81
823.33	820.47	802.48	823.49
838.34	835.46	816.86	830.15
852.96	850.04	830.69	834.44
867.00	864.02	843.74	835.78
874.30	871.29	850.32	833.48
879.92	876.87	855.14	828.44
884.11	881.03	858.41	820.36
886.76	883.62	860.02	808.82
890.53	887.33	862.38	793.32
893.63	889.75	863.21	772.52
891.99	888.62	860.36	745.47
889.01	885.54	855.32	711.65
886.25	882.66	850.05	670.11
881.10	877.38	842.13	619.27
652.74	650.58	637.43	558.17
503.94	504.07	505.50	527.83
507.46	507.63	509.52	538.92
510.84	511.05	513.44	550.44
515.63	515.27	518.07	561.09

TUP= 479.1567

TLP= 567.2859

BARRIER TEMPERATURE= 546.0078

MASS FLOW IN CHANNELS:

1
-3.2482900620

2
-0.0376444422

3
5.8561687741

TIME= 10.002122

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
345.75	346.26	352.47	460.45
350.38	350.66	353.89	413.64
418.68	418.15	415.72	414.30
517.53	516.50	506.83	442.31
537.38	536.36	527.00	468.28
556.28	555.28	546.20	492.45
574.71	573.72	564.85	515.15
592.68	591.69	583.02	536.63
605.42	604.45	596.15	555.62
616.50	615.55	607.58	572.32
626.24	625.31	617.64	586.97
634.70	633.78	626.38	599.76
644.11	643.20	635.95	611.57
653.00	652.10	644.97	622.51
659.70	658.80	651.86	632.15
665.44	664.55	657.79	640.59
672.10	671.22	664.53	648.50
678.13	677.25	670.65	655.83
609.77	609.39	609.01	636.49
564.36	564.56	566.91	603.76
567.41	567.52	568.80	589.42
569.66	569.72	570.49	583.03
571.76	571.80	572.32	580.85

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
324.86	324.86	325.32	332.18
331.86	331.86	331.84	331.85
451.40	450.45	446.16	443.26
626.05	624.50	613.90	608.44
645.35	643.82	633.48	632.33
662.84	661.31	650.98	650.03
680.01	678.48	668.15	667.24
697.05	695.52	685.20	684.30
707.58	706.05	695.73	695.03
716.43	714.90	704.59	703.94
724.02	722.49	712.18	711.58
730.32	728.79	718.49	717.92
738.30	736.77	726.46	725.85
745.85	744.31	734.01	733.42
750.72	749.18	738.89	738.37
754.55	753.02	742.72	742.24
759.90	758.37	748.07	747.55
764.63	763.10	752.80	752.31
621.00	620.07	616.10	618.77
524.87	524.88	524.97	526.53
528.17	528.17	528.17	528.13
530.68	530.68	530.67	530.60
533.49	533.48	533.49	533.32

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
371.31	372.50	386.18	595.41
387.42	388.84	404.86	647.32
579.50	578.66	584.51	769.45
840.93	838.17	821.15	846.86
856.63	853.84	836.25	854.96
871.28	868.47	850.24	860.92
885.46	882.60	863.58	864.41
898.94	896.04	876.04	864.83
905.83	902.89	882.15	861.51
911.00	908.01	886.44	855.26
914.67	911.64	889.12	845.77
916.72	913.64	890.03	832.57
919.70	916.54	891.50	815.14
921.25	918.02	891.28	792.12
919.20	915.87	887.30	762.55
915.06	911.62	880.97	725.89
910.90	907.34	874.21	681.20
904.12	900.43	864.57	626.93
662.06	659.92	646.56	562.21
505.05	505.18	506.70	529.92
508.90	509.08	511.06	541.44
512.66	512.88	515.38	553.35
517.29	517.54	520.44	564.27

TUP= 504.1367 TLP= 570.5774

BARRIER TEMPERATURE= 567.0300

MASS FLOW IN CHANNELS:

1
-3.2764816284

2
-0.0488284491

3
5.9239206314

TIME= 11.000390

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
351.30	351.88	358.95	478.97
352.98	353.31	357.07	425.34
422.24	421.75	419.66	423.09
524.13	523.12	513.66	450.53
544.18	543.19	534.00	476.14
563.24	562.26	553.33	500.09
581.79	580.82	572.10	522.67
599.86	598.90	590.35	544.10
612.81	611.86	603.68	563.12
624.06	623.15	615.30	579.89
634.00	633.09	625.53	594.64
642.61	641.71	634.43	607.56
652.11	651.22	644.08	619.48
661.07	660.19	653.17	630.52
667.88	667.00	660.18	640.27
673.72	672.85	666.21	648.81
680.42	679.56	673.00	656.80
686.47	685.62	679.14	664.20
614.70	614.34	614.16	643.54
566.18	566.40	568.93	608.49
568.40	568.53	569.96	592.71
570.25	570.32	571.21	585.47
572.15	572.21	572.82	582.91

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
325.93	325.94	326.55	335.94
331.86	331.86	331.84	331.94
458.03	457.09	452.86	449.20
642.53	641.02	630.58	623.73
662.07	660.57	650.49	649.15
679.57	678.07	668.00	666.96
696.74	695.24	685.18	684.17
713.78	712.28	702.22	701.23
724.32	722.82	712.77	712.01
733.17	731.67	721.63	720.94
740.76	739.27	729.22	728.59
747.06	745.57	735.53	734.94
755.04	753.55	743.50	742.86
762.59	761.09	751.05	750.43
767.46	765.97	755.93	755.40
771.30	769.80	759.77	759.28
776.64	775.15	765.11	764.58
781.32	779.82	769.79	769.29
627.86	626.96	623.15	626.69
524.95	524.96	525.07	527.20
528.17	528.17	528.17	528.14
530.68	530.68	530.67	530.58
533.56	533.56	533.57	533.36

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
382.38	383.63	398.05	616.01
399.64	401.34	418.26	670.07
601.57	600.83	607.51	797.65
873.44	870.75	854.09	877.82
888.91	886.18	868.93	885.35
903.19	900.43	882.50	890.64
916.90	914.10	895.34	893.34
929.81	926.97	907.19	892.87
936.26	933.38	912.80	888.55
940.93	938.00	916.53	881.12
944.04	941.06	918.57	870.25
945.46	942.42	918.76	855.44
947.59	944.47	919.29	836.13
948.15	944.94	917.97	810.96
945.02	941.72	912.82	778.95
939.66	936.25	905.17	739.55
934.06	930.52	896.85	691.80
925.60	921.93	885.46	634.22
670.75	668.62	655.07	565.99
506.19	506.33	507.92	531.89
510.41	510.59	512.66	543.78
514.56	514.78	517.36	555.97
519.60	519.65	522.82	567.08

TUP= 527.8850

TLP= 573.4487

BARRIER TEMPERATURE= 587.4397

MASS FLOW IN CHANNELS:

1
-3.2919845581

2
-0.0596639775

3
5.9684591293

TIME= 12.001853

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
357.58	358.22	366.09	496.83
355.99	356.36	360.64	436.74
425.93	425.47	423.72	431.71
530.58	529.60	520.32	458.63
550.82	549.84	540.82	483.91
570.02	569.06	560.28	507.66
588.69	587.73	579.14	530.12
606.85	605.91	597.48	551.49
620.01	619.08	611.01	570.52
631.47	630.56	622.81	587.36
641.56	640.66	633.21	602.21
650.33	649.45	642.26	615.24
659.91	659.04	652.00	627.26
668.95	668.08	661.17	638.39
675.86	675.00	668.29	648.24
681.81	680.96	674.42	656.88
688.56	687.71	681.26	664.95
694.63	693.79	687.43	672.41
619.65	619.31	619.31	650.47
568.14	568.38	571.10	613.17
569.51	569.64	571.21	595.99
570.92	571.01	572.01	587.92
572.63	572.69	573.40	584.99

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
327.23	327.24	328.01	339.90
331.86	331.86	331.84	332.06
464.49	463.57	459.39	455.03
658.62	657.13	646.83	638.68
678.45	676.98	667.12	665.60
695.96	694.50	684.65	633.53
713.13	711.67	701.83	700.75
730.17	728.71	718.87	717.81
740.72	739.25	729.43	728.64
749.57	748.11	738.30	737.58
757.17	755.71	745.90	745.24
763.47	762.01	752.21	751.60
771.45	769.98	760.17	759.52
778.99	777.53	767.72	767.08
783.87	782.41	772.61	772.07
787.71	786.25	776.45	775.96
793.05	791.59	781.79	781.25
797.67	796.21	786.41	785.90
634.64	633.76	630.10	634.47
525.02	525.03	525.19	527.83
528.17	528.17	528.17	528.15
530.66	530.66	530.65	530.55
533.64	533.63	533.64	533.40

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
394.06	395.36	410.44	636.31
412.97	414.54	432.28	692.33
623.84	623.18	630.60	825.17
905.26	902.62	886.27	908.00
920.47	917.80	900.82	914.99
934.35	931.65	913.96	919.60
947.58	944.83	926.28	921.54
959.90	957.10	937.50	920.19
965.88	963.04	942.58	914.87
970.02	967.13	945.72	906.29
972.53	969.59	947.09	894.06
973.25	970.25	946.51	877.67
974.48	971.40	946.05	856.52
973.99	970.82	943.60	829.25
969.73	966.46	937.21	794.86
963.10	959.71	928.19	752.77
955.99	952.46	918.27	702.05
945.81	942.15	905.08	641.24
678.93	676.81	663.09	569.59
507.41	507.55	509.20	533.79
511.97	512.16	514.27	545.98
516.90	516.73	519.34	558.41
521.97	522.22	525.22	569.64

TUP= 550.6338 TLP= 576.0327

BARRIER TEMPERATURE= 607.4241

MASS FLOW IN CHANNELS:

1
-3.2989969254

2
-0.0688627362

3
5.9952955246

TIME= 13.000126

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
364.47	365.18	373.77	513.98
359.36	359.78	364.53	447.77
429.73	429.30	427.86	440.12
536.86	535.90	526.81	466.55
557.28	556.32	547.46	491.53
576.61	575.67	567.02	515.09
595.38	594.44	585.98	537.44
613.64	612.71	604.40	558.75
626.99	626.08	618.11	577.80
638.64	637.75	630.10	594.70
648.90	648.02	640.67	609.63
657.82	656.96	649.87	622.77
667.49	666.64	659.70	634.88
676.60	675.75	668.94	646.10
683.62	682.78	676.16	656.03
689.67	688.84	682.40	664.77
696.47	695.64	689.29	672.91
702.56	701.74	695.48	680.43
624.56	624.26	624.44	657.24
570.24	570.49	573.37	617.77
570.70	570.85	572.56	599.24
571.68	571.78	572.89	590.36
573.17	573.24	574.06	587.07

TUP= 572.3333 TLP= 578.4021

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
328.73	328.75	329.68	344.09
331.86	331.86	331.85	332.22
473.76	469.86	465.72	460.67
674.25	672.79	662.60	653.19
694.42	692.98	683.31	681.62
711.94	710.51	700.87	699.68
729.12	727.69	718.05	716.91
746.16	744.72	735.09	733.97
756.72	755.28	745.67	744.84
765.58	764.14	754.53	753.80
773.17	771.74	762.14	761.46
779.48	778.05	768.45	767.84
787.45	786.02	776.41	775.74
795.00	793.57	783.96	783.31
799.88	798.45	788.86	788.31
803.72	802.29	792.70	792.21
809.06	807.63	798.04	797.49
813.62	812.19	802.60	802.08
641.29	640.43	636.92	642.11
525.13	525.15	525.33	528.49
528.17	528.17	528.17	528.18
530.61	530.61	530.61	530.50
533.71	533.71	533.72	533.43

BARRIER TEMPERATURE= 626.7126

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
406.22	407.57	423.23	655.96
426.66	428.30	446.79	714.04
646.15	645.56	653.67	851.95
936.23	933.65	917.55	937.33
951.18	948.56	931.80	943.77
964.66	962.00	944.50	947.73
977.38	974.68	956.28	948.90
989.09	986.33	966.85	946.69
994.56	991.77	971.39	940.40
998.15	995.30	973.91	930.68
1000.02	997.11	974.57	917.12
1000.01	997.04	973.19	899.18
1000.30	997.25	971.71	876.22
998.72	995.57	968.09	846.90
993.28	990.03	960.43	810.19
985.32	981.95	949.99	765.51
976.66	973.15	938.45	711.89
964.73	961.08	923.45	647.95
686.59	684.49	670.61	573.01
508.66	508.81	510.49	535.63
513.57	513.76	515.92	548.09
518.48	518.71	521.35	560.70
524.33	524.58	527.59	572.01

MASS FLOW IN CHANNELS:
1
-3.2988691330

2
-0.0771704316

3
6.0080032349

TIME= 14.001554

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
371.98	372.75	381.99	530.58
363.10	363.55	368.75	458.54
433.65	433.24	432.11	448.37
543.04	542.09	533.18	474.36
563.61	562.67	553.96	499.04
583.06	582.13	573.62	522.42
601.94	601.01	592.67	544.66
620.28	619.37	611.18	565.92
633.83	632.94	625.07	584.97
645.66	644.78	637.23	601.92
656.09	655.22	647.96	616.94
665.16	664.31	657.31	630.18
674.92	674.07	667.23	642.38
684.10	683.26	676.55	653.68
691.24	690.41	683.88	663.70
697.38	696.56	690.22	672.52
704.23	703.42	697.16	680.74
710.35	709.54	703.38	688.31
629.54	629.23	629.57	663.92
572.46	572.73	575.77	622.35
572.01	572.17	573.99	602.49
572.53	572.63	573.84	592.83
573.80	573.88	574.78	589.17

TUP= 593.1604 TLP= 580.6426

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
330.44	330.46	331.55	348.10
331.86	331.86	331.86	332.40
476.90	476.02	471.91	466.32
689.56	688.12	678.03	667.63
710.12	708.71	699.21	697.39
727.66	726.26	716.80	715.57
744.84	743.44	733.99	732.81
761.88	760.47	751.02	749.87
772.45	771.05	761.62	760.77
781.31	779.91	770.49	769.74
788.91	787.51	778.09	777.41
795.23	793.83	784.41	783.79
803.19	801.79	792.37	791.69
810.74	809.34	799.92	799.25
815.63	814.23	804.82	804.27
819.47	818.07	808.67	808.18
824.81	823.41	814.00	813.45
829.30	827.90	818.50	817.98
647.88	647.05	643.67	649.52
525.28	525.30	525.50	529.08
528.17	528.17	528.17	528.20
530.54	530.54	530.53	530.42
533.79	533.79	533.79	533.48

BARRIER TEMPERATURE= 645.4963

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
418.90	420.31	436.58	675.19
440.95	442.65	461.85	735.40
668.65	668.12	676.83	878.23
966.64	964.10	948.21	966.07
981.30	978.73	962.15	971.96
994.35	991.74	974.39	975.27
1006.55	1003.89	985.62	975.70
1017.62	1014.91	995.53	972.63
1022.58	1019.82	999.49	965.37
1025.57	1022.76	1001.37	954.52
1026.76	1023.85	1001.29	939.65
1025.98	1023.04	999.06	920.19
1025.29	1022.26	996.53	895.46
1022.57	1019.44	991.68	864.12
1015.90	1012.66	982.72	825.15
1006.56	1003.20	970.82	777.91
996.31	992.81	957.61	721.47
982.58	978.93	940.76	654.47
693.84	691.75	677.73	576.29
509.96	510.11	511.82	537.44
515.17	515.37	517.57	550.14
520.47	520.70	523.36	562.90
526.70	526.95	529.96	574.27

MASS FLOW IN CHANNELS:

1
-3.2945365906

2
-0.0826828480

3
6.0088539124

TIME= 15.003061

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
380.03	380.84	390.68	546.64
367.16	367.66	373.26	469.04
437.67	437.30	436.44	456.46
549.10	548.17	539.42	482.03
569.82	568.90	560.32	505.44
589.38	588.46	580.08	529.64
608.35	607.44	599.21	551.78
626.77	625.88	617.79	572.98
640.51	639.63	631.86	592.04
652.53	651.66	644.20	609.04
663.11	662.26	655.08	624.14
672.34	671.50	664.59	637.47
682.19	681.35	674.59	649.75
691.44	690.62	683.99	661.13
698.69	697.87	691.43	671.24
704.94	704.13	697.87	680.14
711.84	711.04	704.86	688.43
717.97	717.18	711.10	696.05
634.52	634.23	634.73	670.49
574.80	575.08	578.26	626.87
573.42	573.59	575.53	605.73
573.44	573.56	574.86	595.29
574.49	574.58	575.57	591.28

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
332.34	332.37	333.60	352.36
331.86	331.86	331.88	332.60
482.90	482.03	477.96	471.81
704.53	703.11	693.11	681.68
725.52	724.14	714.80	712.84
743.09	741.71	732.43	731.15
760.27	758.90	749.61	748.40
777.31	775.93	766.64	765.46
787.90	786.52	777.26	776.39
796.76	795.38	786.13	785.37
804.37	802.99	793.74	793.05
810.68	809.31	800.07	799.44
818.65	817.27	808.02	807.33
826.19	824.81	815.57	814.90
831.09	829.71	820.48	819.93
834.93	833.56	824.33	823.84
840.27	838.89	829.65	829.10
844.69	843.31	834.08	833.57
654.39	653.58	650.32	656.86
525.43	525.45	525.69	529.73
528.17	528.17	528.17	528.23
530.46	530.46	530.46	530.34
533.87	533.86	533.87	533.52

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
432.06	433.52	450.35	694.15
455.76	457.52	477.36	756.42
691.24	690.77	700.05	904.00
996.41	993.92	978.21	994.18
1010.79	1008.25	991.82	999.54
1023.39	1020.81	1003.59	1002.20
1035.05	1032.43	1014.25	1001.88
1045.48	1042.80	1023.48	997.96
1049.87	1047.15	1026.84	989.74
1052.25	1049.46	1028.05	977.78
1052.73	1049.88	1027.20	961.62
1051.14	1048.23	1024.10	940.64
1049.43	1046.42	1020.48	914.18
1045.53	1042.42	1014.39	880.87
1037.58	1034.36	1004.07	839.66
1026.83	1023.48	990.68	789.94
1014.94	1011.45	975.77	730.75
999.39	995.75	957.06	660.77
700.69	698.62	684.47	579.45
511.26	511.41	513.16	539.22
516.84	517.03	519.24	552.15
522.46	522.69	525.35	565.03
529.06	529.32	532.33	576.45

TUP= 613.1882 TLP= 582.7913

BARRIER TEMPERATURE= 663.8892

MASS FLOW IN CHANNELS: 1
-3.2853603363

2
-0.0892467031

3
6.0011367798

TIME= 16.001328

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
388.53	389.39	399.78	562.22
371.52	372.05	378.04	479.30
441.80	441.45	440.85	464.40
555.05	554.13	545.54	489.56
575.89	574.98	566.54	513.70
595.55	594.66	586.38	536.74
614.61	613.72	605.60	558.78
633.12	632.23	624.25	579.93
647.04	646.17	638.49	599.00
659.22	658.37	651.00	616.04
669.97	669.14	662.04	631.21
679.35	678.53	671.69	644.62
689.29	688.47	681.79	656.99
698.62	697.81	691.26	668.44
705.97	705.17	698.80	678.62
712.32	711.53	705.34	687.61
719.27	718.48	712.39	695.96
725.43	724.65	718.66	703.63
639.53	639.26	639.90	676.95
577.23	577.53	580.85	631.35
574.90	575.08	577.14	608.95
574.43	574.56	575.95	597.75
575.25	575.35	576.43	593.40

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
334.41	334.45	335.82	356.66
331.86	331.86	331.89	332.81
488.76	487.90	483.86	477.19
719.14	717.74	707.82	695.44
740.61	739.25	730.06	727.97
758.21	756.85	747.72	746.41
775.39	774.04	764.91	763.67
792.42	791.07	781.94	780.73
803.03	801.67	792.57	791.69
811.90	810.55	801.45	800.68
819.51	818.15	809.07	808.37
825.83	824.48	815.39	814.77
833.79	832.43	823.34	822.64
841.33	839.98	830.89	830.21
846.24	844.88	835.81	835.26
850.09	848.73	839.66	839.17
855.42	854.06	844.99	844.43
859.76	858.41	849.34	848.84
660.82	660.01	656.87	664.06
525.59	525.61	525.89	530.36
528.17	528.17	528.17	528.25
530.39	530.39	530.38	530.26
533.94	533.94	533.95	533.56

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
445.62	447.12	464.47	712.79
470.59	472.81	493.24	777.05
713.84	713.43	723.20	929.21
1025.52	1023.06	1007.50	1021.64
1039.59	1037.09	1020.78	1026.46
1051.73	1049.19	1032.07	1028.48
1062.63	1060.24	1042.14	1027.42
1072.60	1069.95	1050.68	1022.66
1076.43	1073.73	1053.43	1013.50
1078.15	1075.40	1053.95	1000.44
1077.50	1075.08	1052.30	983.00
1075.47	1072.57	1048.29	960.55
1072.70	1069.71	1043.56	932.39
1067.59	1064.45	1036.19	897.14
1058.33	1055.12	1024.50	853.76
1046.12	1042.78	1009.58	801.61
1032.58	1029.09	992.96	739.74
1015.18	1011.54	972.37	666.86
707.17	705.10	690.85	582.49
512.56	512.71	514.50	540.98
518.51	518.71	520.92	554.11
524.44	524.67	527.33	567.11
531.43	531.68	534.67	578.55

TUP= 632.4907 TLP= 584.8534

BARRIER TEMPERATURE= 681.8638

MASS FLOW IN CHANNELS:
1
-3.2725954056

2
-0.0928884745

3
5.9855794907

TIME= 17.002701

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
397.53	398.43	409.33	577.53
376.20	376.76	383.11	489.43
446.05	445.72	445.38	472.27
560.94	560.04	551.60	497.04
581.90	581.00	572.70	520.93
601.65	600.77	592.62	543.80
620.80	619.92	611.91	565.75
639.38	638.51	630.63	586.84
653.48	652.62	645.04	605.91
665.84	665.00	557.71	622.99
676.75	675.92	568.91	638.23
686.28	685.46	578.70	651.72
696.29	695.49	688.88	664.17
705.71	704.91	698.43	675.69
713.16	712.37	706.08	685.95
719.62	718.84	712.73	695.01
726.62	725.84	719.82	703.43
732.81	732.04	726.12	711.14
644.58	644.32	645.09	683.36
579.80	580.10	583.56	635.81
576.48	576.67	578.83	612.17
575.50	575.63	577.11	600.22
576.09	576.19	577.35	595.53

TJP= 651.3633

TLP= 566.9097

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
336.58	336.73	338.24	361.17
331.86	331.86	331.91	333.04
494.53	493.68	489.66	482.46
733.55	732.17	722.31	708.97
755.54	754.20	745.14	742.91
773.18	771.84	762.85	761.50
790.36	789.03	780.04	778.78
807.39	806.05	797.07	795.84
818.01	816.68	807.72	806.83
826.89	825.56	816.61	815.83
834.50	833.17	824.22	823.52
840.83	839.49	830.56	829.92
848.78	847.45	838.50	837.80
856.33	854.99	846.05	845.37
861.24	859.90	850.97	850.42
865.09	863.76	854.83	854.34
870.42	869.08	860.15	859.60
874.69	873.36	864.44	863.93
667.21	666.43	663.38	671.25
525.31	525.83	526.12	531.04
528.17	528.17	528.17	528.29
530.31	530.31	530.30	530.19
534.02	534.02	534.02	533.61

BARRIER TEMPERATURE= 699.6443

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
459.67	461.21	479.05	731.33
486.77	488.63	509.61	797.54
736.65	736.28	746.51	954.15
1054.27	1051.84	1036.41	1048.76
1068.01	1065.54	1049.34	1053.04
1079.68	1077.17	1060.13	1054.42
1090.21	1087.65	1069.60	1052.62
1099.30	1096.68	1077.44	1047.02
1102.53	1099.85	1079.55	1036.91
1103.58	1100.84	1079.34	1022.75
1102.55	1099.75	1076.88	1004.04
1099.24	1096.36	1071.93	980.13
1095.38	1092.40	1066.04	950.27
1089.01	1085.93	1057.36	913.11
1078.40	1075.20	1044.25	867.59
1064.70	1061.36	1027.78	813.05
1045.45	1045.97	1009.41	748.55
1030.17	1026.54	986.90	672.82
713.36	711.30	696.96	585.46
513.94	514.09	515.88	542.75
520.20	520.40	522.61	556.07
526.43	526.66	529.33	569.17
533.78	534.04	536.99	580.63

MASS FLOW IN CHANNELS:
1
-3.2563047409

2
-0.0975546837

3
5.9637708664

TIME= 18.000885

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
406.91	407.85	419.20	592.49
381.13	381.72	388.41	499.38
450.39	450.08	449.98	480.01
566.74	565.85	557.56	504.41
587.30	586.92	578.74	528.05
607.64	606.77	598.73	550.77
626.86	626.00	618.09	572.61
645.51	644.65	636.87	593.64
659.79	658.94	651.45	612.71
672.31	671.48	664.28	625.83
683.38	682.56	675.62	645.13
693.05	692.25	685.56	658.70
703.16	702.36	695.83	671.22
712.65	711.86	705.46	682.81
720.21	719.43	713.22	693.14
726.77	726.00	719.95	702.27
733.83	733.06	727.11	710.76
740.03	739.27	733.43	718.52
649.61	649.37	650.27	689.65
582.45	582.76	586.35	640.22
578.13	578.33	580.59	615.37
576.63	576.77	578.33	602.69
576.99	577.09	578.33	597.67

TUP= 669.7190 TLP= 588.8965

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
339.12	339.18	340.82	365.82
331.86	331.86	331.94	333.31
500.18	499.34	495.34	487.62
747.64	746.27	736.48	722.19
770.19	768.87	759.94	757.56
787.87	786.55	777.69	776.31
805.06	803.74	794.89	793.60
822.09	820.77	811.92	810.66
832.72	831.41	822.58	821.68
841.61	840.29	831.48	830.69
849.22	847.91	839.10	838.39
855.55	854.24	845.43	844.80
863.50	862.19	853.37	852.66
871.05	869.73	860.92	860.23
875.96	874.65	865.85	865.30
879.82	878.51	869.71	869.23
885.14	883.83	875.03	874.47
889.34	888.03	879.24	878.74
673.54	672.78	669.82	678.34
526.04	526.06	526.38	531.75
528.17	528.17	528.17	528.32
530.25	530.25	530.25	530.13
534.10	534.09	534.10	533.65

BARRIER TEMPERATURE= 717.0933

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
474.04	475.62	493.90	749.61
502.90	504.81	526.28	817.70
759.45	759.13	769.76	978.62
1082.41	1080.02	1064.70	1075.30
1095.83	1093.39	1077.26	1079.05
1107.01	1104.53	1087.54	1079.79
1116.96	1114.43	1096.41	1077.26
1125.35	1122.76	1103.53	1070.83
1127.96	1125.31	1104.98	1059.78
1128.31	1125.60	1104.04	1044.54
1126.49	1123.71	1100.73	1024.58
1122.27	1119.41	1094.82	999.22
1117.29	1114.33	1087.76	967.71
1109.64	1106.57	1077.74	928.67
1097.65	1094.46	1063.19	881.05
1082.42	1079.09	1045.14	824.17
1065.45	1061.98	1025.00	757.10
1044.28	1040.65	1000.57	678.61
719.23	717.18	702.77	588.33
515.31	515.47	517.26	544.49
521.88	522.08	524.30	557.99
528.42	528.65	531.31	571.19
536.07	536.33	539.27	582.66

MASS FLOW IN CHANNELS:
1
-3.2373027802

2
-0.1018195152

3
5.9364948273

TIME= 19.032258

TEMPERATURES IN NUMBER 1 SECTION

1	2	3	4
416.69	417.67	429.44	607.25
386.32	386.95	393.96	509.24
454.84	454.55	454.68	487.71
572.48	571.61	563.46	511.73
593.63	592.77	584.72	535.13
613.55	612.69	604.77	557.67
632.85	632.00	624.19	579.41
651.57	650.73	643.03	600.39
666.01	665.18	657.77	619.46
678.70	677.88	670.75	636.61
689.92	689.12	682.25	651.97
699.74	698.95	692.33	665.61
709.93	709.15	702.68	678.20
719.50	718.72	712.39	689.86
727.17	726.40	720.25	700.26
733.83	733.07	727.08	709.46
740.94	740.18	734.29	718.00
747.17	746.42	740.64	725.81
654.69	654.46	655.47	695.83
585.19	585.52	589.22	644.60
579.87	580.08	582.43	618.57
577.83	577.97	579.62	605.16
577.95	578.06	579.38	599.61

TJP= 687.7456

TLP= 590.8896

TEMPERATURES IN NUMBER 2 SECTION

1	2	3	4
341.74	341.80	343.58	370.63
331.91	331.92	332.00	333.62
505.73	504.90	500.91	492.69
761.51	760.17	750.41	735.19
784.67	783.37	774.55	772.03
802.39	801.09	792.36	790.93
819.59	818.29	809.56	808.25
836.61	835.32	826.58	825.30
847.27	845.97	837.27	836.35
856.16	854.86	846.17	845.38
863.77	862.48	853.79	853.08
870.11	868.81	860.14	859.50
878.05	876.76	868.07	867.36
885.60	884.30	875.62	874.93
890.52	889.23	880.56	880.01
894.38	893.09	884.42	883.94
899.70	898.41	889.73	889.18
903.82	902.52	893.86	893.37
679.83	679.08	676.23	685.41
526.27	526.29	526.65	532.48
528.17	528.17	528.17	528.36
530.22	530.21	530.21	530.09
534.18	534.17	534.18	533.70

BARRIER TEMPERATURE= 734.3521

TEMPERATURES IN NUMBER 3 SECTION

1	2	3	4
488.61	490.42	509.12	767.77
519.45	521.40	543.34	837.70
782.35	782.07	793.08	1002.80
1110.17	1107.60	1092.57	1101.48
1123.24	1120.82	1104.77	1104.70
1133.92	1131.46	1114.52	1104.80
1143.27	1140.76	1122.77	1101.54
1150.96	1148.35	1129.16	1094.27
1152.93	1150.30	1129.94	1082.30
1152.56	1149.87	1128.23	1065.98
1149.90	1147.14	1124.05	1044.77
1144.75	1141.90	1117.15	1017.98
1138.61	1135.67	1108.89	984.82
1129.65	1126.59	1097.50	943.94
1116.25	1113.06	1081.49	894.25
1099.46	1096.13	1061.83	835.08
1080.74	1077.26	1039.90	765.48
1057.66	1054.03	1013.54	684.27
724.85	722.81	708.33	591.14
516.65	516.65	518.66	546.24
523.57	523.76	525.99	559.92
530.41	530.64	533.31	573.21
538.37	538.63	541.53	584.68

MASS FLOW IN CHANNELS:

1
-3.2158241272

2
-0.1059306264

3
5.9045619965

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