APT Blanket Safety Analysis: Preliminary Analyses of Downflow Through a Lateral Row 1 Blanket Model Under Near RHR Conditions

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THROUGH A LATERAL ROW 1 BLANKET
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1 Summary

To address a concern about a potential maldistribution of coolant flow through an APT blanket module under low flow near RHR conditions, a scoping study of downflow mixed convection in parallel channels was conducted. Buoyancy will adversely effect the flow distribution in module bins with downflow and non-uniform power distributions. This study consists of two parts: a simple analytical model of flow in a two channel network, and a lumped eleven channel FLOWTRAN-TF [Ref. 1] model of a front lateral Row-1 blanket module bin. Results from both models indicate that the concern about coolant flow in a vertical module being diverted away from high power regions by buoyancy is warranted. The FLOWTRAN-TF model predicted upflow (i.e., a flow reversal) through several of the high power channels, under some low flow conditions. The transition from the regime with downflow in all channels to a regime with upflow in some channels was abrupt.

Regardless of the direction of net mass flow through a module bin (i.e., net downflow or upflow), a non-uniform horizontal power distribution will result in non-uniform mass fluxes, for sufficiently low net mass flowrates. Under net downflow conditions a noticeable overall increase in hydraulic losses is observed. Consequently, it is recommended that the modules with vertical flow be designed with upflow through the higher power bins. This will minimize the adverse impact of buoyancy.

2 Background

For cooling purposes, adjacent blanket module bins are grouped together in pairs with coolant flowing sequentially through the two bins, down through the first and up through the second. Each bin has numerous discrete flow channels that are connected to common inlet and outlet plenums. Under normal operating conditions, the coolant can potentially be more efficiently utilized if it first flows through the higher power bin in the module. This could allow an increase in the lead to water ratio in the higher power modules, and therefore an increase in tritium production efficiency due to lower temperature water flowing through the high power bin. However, the downside to this design modification is, for the lateral blanket modules, the flow direction is opposite to that which would occur due to buoyancy. During normal operation this should not be a problem because the forced convection overwhelms the influence of buoyancy, but at low flow conditions buoyancy can significantly influence the flow distribution within a bin. Flow is partially diverted from the high to the low power region. A second effect is the partial diversion of flow from high power vertical modules to horizontal modules above and below the target and lower power vertical modules. These two adverse effects are complementary. The higher power vertical blanket modules will have proportionally more flow diverted away, and reducing the downflow through a vertical module aggravates the buoyancy induced maldistribution of flow within a bin with downflow. The buoyancy induced diversion of flow within the front lateral Row-1 module bin is considered in this study. There is a sevenfold increase in deposited power in the beamwise direction within this bin.

This study consists of two analyses, described in the next two sections of this document, that were completed sequentially. The first is a simple analytical model of mixed convection downflow through a two parallel channel network. The second is an eleven

channel numerical model of downflow through a front lateral Row-1 bin. The overall conclusions/results are based on the numerical model and are presented in Sections 5 and 6 below. The reader may skip the following discussion on the analytic model contained within Section 3 (and its development in Appendix A) without a loss of continuity with regard to the results and conclusions.

3 Two Channel Analytical Model

As an initial step towards quantifying the effect of non-uniform heating on the distribution of downflow through a vertical blanket module, a simple system with two parallel channels was considered. Figure 1 is a schematic of a mixed convection network with downflow through the parallel heated channels. The two channels are geometrically similar, but they are heated differentially, each with uniform heating along its length. Incompressible steady flow with a Boussinesq fluid and well mixed top and bottom plenums are assumed. Flow regimes with downflow through both channels and upflow through the high power channel are considered. The net mass flowrate through the network is specified, and the analytical model predicts the flow split. Equation 1 is the non-dimensional momentum equation for the network with downflow through both channels. This equation is derived in Appendix A.

$$2(\dot{m}^*)^3 - 3(\dot{m}^*)^2 + \left(1 + \frac{Gr}{f Re^2}\right) \dot{m}^* - \frac{Gr}{f Re^2} \dot{Q}^* = 0 \quad (1)$$

where

$$\dot{m}^* = \frac{\dot{m}_1}{\dot{m}} \quad \& \quad \dot{Q}^* = \frac{\dot{Q}_1}{\dot{Q}}$$

and

$$Gr = \frac{g\beta D^3 \Delta T}{\nu^2} \quad Re = \frac{\rho V D}{\mu}$$

The value of the Archimedes number, the non-dimensional grouping with the Grashoff number in the numerator and the product of the friction factor and square of the Reynolds number in the denominator, is a measure of the relative importance of buoyancy and forced convection to the flow. The relative importance of buoyancy is directly proportional to the value of this parameter. Channel 1 is assumed to have the higher deposited power of the two channels, and it has the lower flowrate of the two. If the power split between the two channels is equal then the flow split is equal, irrespective of the value of the Archimedes number. Figure 2 is a plot of the flow splits as functions of the power split and the Archimedes number. Results for six different values of the Archimedes number are presented. The dotted line in Fig. 2 is the limit below which steady-state solutions with downflow through both channels do not exist. For values of the Archimedes number greater than 0.1, there is a maximum value of the power split ratio above which steady-state flows in this flow regime do not exist. The limiting power split ratio decreases as the value of the Archimedes number increases.

Equation 2 is the momentum equation for the case in which steady-state upflow through the higher power channel is assumed. This equation is also derived in Appendix A, and solutions are presented in Fig. 2.

$$2(\dot{m}^*)^4 + 4(\dot{m}^*)^3 + 3(\dot{m}^*)^2 + \left(1 - \frac{Gr}{f Re^2}\right)\dot{m}^* - \frac{Gr}{f Re^2}\dot{Q}^* = 0 \quad (2)$$

Since upflow in channel one was assumed in the derivation of eq. 2, the mass flowrate ratio is positive. In Fig. 2 these ratios are plotted as negative to distinguish them from solutions to eq. 1, (i.e., downflow through both channels). Cases with the same Archimedes number are shown in Fig. 2 with the same symbols, irrespective of the flow direction in channel one. For a specified Archimedes number, the flow regime transitions abruptly from downflow through both channels to that with upflow through channel one once the limiting value of the power split, shown by the dotted line in the figure, is exceeded.

During normal operation, the flow through a lateral Row-1 bin has a Reynolds number of approximately 18,000 [Ref. 2]. At four percent flow, the capacity of a single RHR system, the Reynolds number would be 720, and at one percent flow it becomes 180. With the following assumed values for the parameters in the Grashoff and Reynolds numbers, and using the laminar pipe flow expression for the Darcy friction factor, the two values for the Archimedes number are 0.055 and 0.22 for four and one percent of normal operation flow respectively:

$$D_h \approx 0.005m$$

$$\Delta T \approx 5^\circ C$$

$$\beta = 0.00018 \frac{1}{K}$$

$$\nu = 6.58 \times 10^{-7} \frac{m^2}{s}$$

While the predicted buoyancy induced flow diversion is small at the designed RHR flowrate of four percent, this flowrate is uncomfortably close to the region where the flow diversion becomes significant and reverse flow in the high power channels is possible. The concern about downflow through the high power blanket bins is warranted. The numerous simplifying assumptions in this scoping model limit the quantitative value of the results, but they do have qualitative value and suggest that further study is necessary. To this end, the FLOWTRAN-TF model of a front lateral Row-1 module bin, described in the next section, was developed.

4 Eleven Channel FLOWTRAN-TF Model

A front lateral Row-1 module bin has 44 plates and 308 discrete parallel flow passages. These channels were lumped into eleven geometrically similar rectangular channels in the FLOWTRAN-TF model of an entire bin. Figure 3 is a drawing of a horizontal cross-section of the model, showing the eleven channels and the finite-element grid of the solid heat structure. The solid region and channels are discretized into ten axial cells. Each of the eleven lumped channels has a flow area of 19.48 cm^2 and a hydraulic diameter 0.47 cm. Values for these channel parameters were estimated from a

schematic of a lateral Row-1 plate in Ref. 1. Each of the rectangular channels shown in Fig. 3 has a cross-sectional area of 44.12 cm^2 . This represents the cross-sectional area of the 28 flow channels associated with four plates and also the associated helium tubes. The solid region in the model represents the volume of lead and aluminum associated with the 44 plates in the bin. The channel flow areas and hydraulic diameters are specified in the input file, and they do not have to be geometrically consistent with the discretization of the solid region. Table 1 lists thermal properties for the solid region. Since the solid region represents a homogenization of discrete lead plates that are clad with aluminum, it is anisotropic and different values are used for the vertical and horizontal thermal conductivities.

Figures 4 through 6 show the axial, lateral, and beamwise profiles for the relative deposited lead power in the solid region of the model [Ref. 2], respectively. The power varies by approximately a factor of seven in the beamwise direction. This power distribution influences the flow distribution among the eleven channels. All of the results shown have a total deposited power of 33.96 kW, one percent of nominal power.

The specified flow boundary conditions are the inlet volume flowrate and the bottom plenum pressure. These are time independent, and a false transient was run until convergence to steady-state was achieved. Cases were run with flowrates between 0.5 and 8.0% of full flow ($0.09036 \text{ m}^3/\text{s}$).

5 Discussion and Results

Figure 7 shows the channel mass flow fractions in channels 1 and 11 for net downflow through the bin with flowrates between 0.75% and 6.0% of normal flow. Channel 1 is the front channel of the bin in the beamwise direction and the channel through the lowest power region. Channel 11 is the back channel and the one through the highest power region. The total deposited power is 1% of normal power in all cases. The flow fractions for all of the channels are listed in Table 2. The flow distribution is uniform above 4% flow, and flow is partially diverted through the lower power channels below this value. At approximately 1.25% flow, the flow regime abruptly transitions to one in which there is upflow through the high power channels. Figure 8 shows the inlet plenum pressures with net downflow through the bin and flowrates between 0.75% and 4.0% of normal flow. The outlet plenum pressure is held constant at 584 kPa. Also shown are results where the power distribution in the beamwise direction is uniform. This figure shows the influence of the beamwise power distribution on the overall bin frictional pressure drop. This influence is discernible at flows below 2%, and it abruptly becomes very significant when upflow occurs in the high power channels. This is a phenomena that would not be predicted in a system model where a module is represented by a single 1-D channel. Table 3 lists the inlet and outlet plenum pressures. Figure 9 shows a 3-D perspective view of the temperature distribution in the solid region of the bin for the case with 4% flow.

Figure 10 shows the channel mass flow fractions in channels 1 and 11 for net upflow through the bin with flowrates between 0.75% and 8.0% of normal flow. The deposited power is 1% of normal power in all cases. The flow fractions for all of the channels are listed in Table 4. The flow distribution is non-uniform and flow is partially diverted through the high power channels below 8% of normal flow. Figure 11 shows the top or outlet plenum pressures with net upflow through the module and flowrates between 0.5% and 4.0% of normal flow. The bottom plenum pressure is held constant at 584

kPa. Also shown are results where the power distribution in the beamwise direction is uniform. The influence of the power distribution is discernible at flows below 0.75 %. Table 5 lists the inlet and outlet plenum pressures.

6 Conclusions

From a safety analysis standpoint, configuring the coolant flowpaths through the blanket modules such that there is downflow through the highest power bins is not a good practice. While the coolant maldistribution in a front lateral Row-1 bin at the design RHR flowrate of 4% of normal flow is not severe, the point where reverse flow can occur in the highest power channels is uncomfortably close. The buoyancy induced diversion of flow between modules will reduce the RHR flow through the high power modules below design levels and can aggravate the flow maldistributions within the bins.

In addition to the potential adverse physical impact of downflow on the thermal-hydraulic performance of the RHR system, the safety analysis is further complicated. A 1-D TRAC system model, which lumps all of the channels in a bin into a single equivalent channel, will not capture the non-uniform flow distribution phenomena and increased hydraulic losses. Therefore, it would not produce appropriate boundary conditions for a detailed FLOWTRAN-TF model of a "hot" plate within a bin and its associated flow channels. Either the TRAC system model or the FLOWTRAN-TF model would have to be considerably more complicated, or an intermediate model that captures the flow distribution would be required.

Long term cooling under unmitigated event sequences uses natural circulation to transfer deposited power outside of the cavity vessel. Configuring the higher power bins in downflow adversely impacts natural circulation, at least during the early phase of an accident before a global flow reversal occurs.

7 References

1. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket Detailed Bin Model Based on Initial Plate-Type Design - 3-D FLOWTRAN-TF Model," Westinghouse Savannah River Company, WSRC-TR-98-0055 (July 1998).
2. R. Kapernick, "APT Blanket Design," Los Alamos National Laboratory APT Safety Meeting, slide presentation (March, 31, 1988).

Table 1 FLOWTRAN-TF solid material thermal properties used for modeling front lateral Row-1 bin.

Material type	Density (kg/m ³)	Specific heat (J/kg-K)	Thermal conductivity (W/m-K)
pure aluminum	2713.0	925.0	171.0
pure lead	11340.0	132.3	32.5
Row-1 mixture average	10123.0 (volume)	162.2 (volume)	48.0 (horizontal) 52.0 (vertical)
11 channel effective values	10123.0	162.2	79.1

Table 2 FLOWTRAN-TF channel mass flow fractions for front lateral Row-1 bin at 1% power and near RHR flow conditions for the net downflow case (a negative number implies an upflow condition).

[illegible]

Table 3 FLOWTRAN-TF inlet/outlet plenum pressures for front lateral Row-1 bin at 1% power and near RHR flow conditions for the net downflow case.

% flow	multi-channel		1-D model	
	inlet	outlet	inlet	outlet
0.75	543.5153	584.0	543.3979	584.0
1.0	543.4854	584.0	543.4113	584.0
1.25	543.4441	584.0	543.4386	584.0
1.5	543.4743	584.0	543.4719	584.0
2.0	543.5494	584.0	543.5486	584.0
3.0	543.7194	584.0	543.7192	584.0
4.0	543.8983	584.0	543.8982	584.0
6.0	544.2646	584.0	544.2649	584.0

Table 4 FLOWTRAN-TF channel mass flow fractions for front lateral Row-1 bin at 1% power and near RHR flow conditions for the net upflow case (a positive number implies an upflow condition).

[illegible]

Table 5 FLOWTRAN-TF top/bottom plenum pressures for front lateral Row-1 bin at 1% power and near RHR flow conditions for the net upflow case.

% flow	multi-channel		1-D model	
	top	bottom	top	bottom
0.5	543.2555	584.0	543.2098	584.0
0.75	543.1427	584.0	543.1371	584.0
1.0	543.0670	584.0	543.0679	584.0
2.0	542.8368	584.0	542.8376	584.0
3.0	542.6349	584.0	542.6352	584.0
4.0	542.4401	584.0	542.4402	584.0
6.0	542.0581	584.0	542.0582	584.0
8.0	541.4704	584.0	541.4704	584.0

Figure 1 Schematic of the mixed convection two-channel network with differentially heated channels.

Figure 2 Flow splits in the heated two-channel network.

Figure 3 Plan view of FLOWTRAN-TF 11 channel model of front lateral Row-1 bin.

Figure 4 Axial power shape for front lateral Row-1 bin.

Figure 5 Lateral power shape for front lateral Row-1 bin.

Figure 6 Power shape parallel with beam for front lateral Row-1 bin.

Figure 7 FLOWTRAN-TF channel 1 and 11 mass flow fractions for front lateral Row-1 bin at 1% power and near RHR flow conditions for the net downflow case.

Figure 8 FLOWTRAN-TF inlet plenum pressure for front lateral Row-1 bin at 1% power and near RHR flow conditions for the net downflow case.

Figure 9 3-D perspective of FLOWTRAN-TF 11 channel model of front lateral Row-1 bin (temperature profile under RHR conditions for the net downflow case included).

Figure 10 FLOWTRAN-TF channel 1 and 11 mass flow fractions for front lateral Row-1 bin at 1% power and near RHR flow conditions for the net upflow case.

Figure 11 FLOWTRAN-TF top plenum pressure for front lateral Row-1 bin at 1% power and near RHR flow conditions for the net upflow case.

Appendix A: Derivation of the Governing Equations for Mixed Convection Downflow through the Lumped Two-Channel APT Blanket Module

Figure 1 is a schematic of a mixed convection flow network with downflow through two parallel heated passages. This is a simple lumped model of a front lateral row 1 blanket bin. The deposited powers in the flows through the two channels differ, modeling the power tilt in the beamwise direction. The deposited powers in each of the two channels are assumed to be distributed uniformly over the lengths of the channels. The channels are assumed to be geometrically similar. The flow is assumed to be steady-state, with a Boussinesq fluid (Eq. A-1).

$$\rho = \rho_o [1 - \beta(T - T_o)] \quad (A-1)$$

The net mass flowrate through the network is specified. Two flow regimes are considered: downflow through both channels, and upflow through the higher power channel.

A.1 Downflow through Both Channels

Figure A-1 is a schematic of a differential length of one of the channels in Fig. 1. The integral form of the linear momentum equation (eq. A-2) is applied to this control volume. For steady-state flow through a constant area duct, the left side of this equation is equal to zero. Summing the pressure, body, and wall shear forces results in an equation for the channel pressure gradient (eq. A-3). Integrating this expression over the lengths of both channels results in two expressions for the channel pressure drops. Equating the two channel pressure drops yields the momentum equation for the flow network (eq. A-4).

$$\frac{d}{dt} \int_{vol} \rho \bar{V} d(Vol) + \oint_A \rho \bar{V} (\bar{V}_r \cdot \hat{n}) dA = \sum \bar{F} \quad (A-2)$$

$$\frac{dP}{ds} = \rho_o g [1 - \beta(T - T_o)] - \frac{f \dot{m}^2}{2 \rho A^2 D} \quad (A-3)$$

$$\rho_o g \beta \int_0^L (T_1 - T_o) ds + \frac{f_1 \dot{m}_1^2 L}{2 \rho A_1^2 D_1} = \rho_o g \beta \int_0^L (T_2 - T_o) ds + \frac{f_2 \dot{m}_2^2 L}{2 \rho A_2^2 D_2} \quad (A-4)$$

Figure A-1 A differential section of a channel with downflow, showing the applied surface and body forces.

The reference temperature (eq. A-5) is the integrated mean temperature in both channels. Substituting the expressions for the temperature distributions (eq. A-6) into eq. A-5 and integrating, results in the final expression for the reference temperature (eq. A-7).

$$T_o = \frac{1}{(A_1 + A_2)L} \left[\int_0^L A_1 T_1 ds + \int_0^L A_2 T_2 ds \right] \quad (A-5)$$

$$T_i = T_{in} + \frac{\dot{Q}_i}{\dot{m}_i C_p} \left(\frac{s}{L} \right) \quad (A-6)$$

$$T_o = T_{in} + \frac{1}{2C_p(A_1 + A_2)} \left(\frac{\dot{Q}_1 A_1}{\dot{m}_1} + \frac{\dot{Q}_2 A_2}{\dot{m}_2} \right) \quad (A-7)$$

The expressions for the reference temperature and the channel temperature distributions are substituted into the momentum equation (eq. A-4), and the appropriate integrations are carried out. This yields an expression for the two channel mass flowrates (eq. A-8). The channel mass flowrates and the channel powers are normalized with the network total values for these parameters. Equation A-9 is the normalized momentum equation. The channel diameters, cross-sectional areas, and friction factors are assumed to be equal in this derivation.

$$\frac{\rho_o g \beta \dot{Q}_1 L}{\dot{m}_1 C_p} + \frac{f_1 \dot{m}_1^2 L}{\rho A_1^2 D_1} = \frac{\rho_o g \beta \dot{Q}_2 L}{\dot{m}_2 C_p} + \frac{f_2 \dot{m}_2^2 L}{\rho A_2^2 D_2} \quad (\text{A-8})$$

$$\dot{m}^* = \frac{\dot{m}_1}{\dot{m}} \quad \& \quad \dot{Q}^* = \frac{\dot{Q}_1}{\dot{Q}}$$

$$2(\dot{m}^*)^3 - 3(\dot{m}^*)^2 + \left(1 + \frac{\dot{Q} \rho^2 A^2 D g \beta}{f C_p \dot{m}^3}\right) \dot{m}^* - \frac{\dot{Q} \rho^2 A^2 D g \beta}{f C_p \dot{m}^3} \dot{Q}^* = 0 \quad (\text{A-9})$$

The non-dimensional grouping in eq. A-9 that contains the total deposited power and flowrate can be expressed in terms of the Reynolds and Grashoff numbers. The final form of the momentum equation is eqn. A-10 (eq. 1 in the main body of this document). The non-dimensional grouping with the Grashoff and Reynolds numbers is termed the Archimedes number.

$$2(\dot{m}^*)^3 - 3(\dot{m}^*)^2 + \left(1 + \frac{Gr}{f Re^2}\right) \dot{m}^* - \frac{Gr}{f Re^2} \dot{Q}^* = 0 \quad (\text{A-10})$$

where

$$\dot{Q} = \dot{m} C_p \Delta T, \quad Re = \frac{\rho V D}{\mu}, \quad \& \quad Gr = \frac{g \beta D^3 \Delta T}{\nu^2}$$

A.2 Upflow through the High Power Channel

There is the possibility for upflow through the higher power channel. The momentum equation for this flow situation was derived in the same manner as the case with downflow through both channels. Channel one is assumed to be the higher power channel, and upflow is assumed through this channel. Figure A-2 is a schematic of a differential length of the upflow channel, showing the applied forces on the control volume. With upflow, the direction of the wall shear force is down. Application of the linear momentum equation to this control volume and integrating, results in an expression for the pressure drop along the upflow channel. Equating this pressure drop with the pressure drop in the downflow channel, results in a momentum equation analogous to eq. A-4 for the case with downflow through both channels. Equations A-11 and A-12 are the temperature distributions in channels one and two respectively. The top and bottom plenums are assumed to be well mixed and isothermal. Equation A-13 is the expression for the reference temperature. Substituting these temperature expressions into the momentum equation and integrating, results in an expression for the two channel mass flowrates (eq A-14). This equation is normalized in the same fashion as for the case with downflow through both channels. Equation A-15 is the expression for the normalized upflow as a function of the channel power split and system flowrate. This is eq. 2 in the main body of this document. The flow directions were assumed in this derivation, therefore an upward mass flowrate ratio in the high power leg is positive.

Figure A-2 A differential section of the higher power channel with upflow, showing the applied surface and body forces.

$$T_1 = T_{out} + \frac{\dot{Q}_1}{\dot{m}_1 C_p} \left(1 - \frac{s}{L}\right) \quad (A-11)$$

$$T_2 = T_{out} - \frac{\dot{Q}_2}{\dot{m}_2 C_p} \left(1 - \frac{s}{L}\right) \quad (A-12)$$

$$T_o = T_{out} + \frac{1}{4C_p} \left(\frac{\dot{Q}_1}{\dot{m}_1} - \frac{\dot{Q}_2}{\dot{m}_2} \right) \quad (A-13)$$

$$\frac{fC_p}{\rho^2 A^2 g \beta D} (\dot{m}_1^2 + \dot{m}_2^2) - \frac{\dot{Q}_1}{\dot{m}_1} - \frac{\dot{Q}_2}{\dot{m}_2} = 0 \quad (A-14)$$

$$2(\dot{m}^*)^4 + 4(\dot{m}^*)^3 + 3(\dot{m}^*)^2 + \left(1 - \frac{Gr}{f Re^2}\right) \dot{m}^* - \frac{Gr}{f Re^2} \dot{Q}^* = 0 \quad (A-15)$$

Appendix B: FLOWTRAN-TF Input File for Front Lateral Row-1 Bin (downflow and upflow under near RHR conditions)

Below is a listing of the FLOWTRAN-TF input deck for the 11 channel model of a front lateral Row-1 bin. The finite element input of the solid geometric parameters is based on the most recently available information concerning a front lateral Row-1 bin taken from a slide presentation presented by Rick Kapernick at a LANL information meeting held March 31, 1998 [Ref. 2].

Input file chn11.in:

```
/** 11-channel APT input deck for flowtran-apt code **/  
!    lumped representation of entire front lateral row-1 bin  
!  
! Input Deck Description:  
!  
!    Input deck to test coupled flowtran-tf + heatel code  
!  
! General Comments:  
!    *The solid input units are: [T] = C  
!    *The fluid input units are determined by iunits as described below  
!    *The working units in the fluid modules are: s, m, kg, K, Pa, J, W, ...  
!    *The working units in the solid modules are: s, m, kg, C, Pa, J, W, ...  
/RUN TIME, TIME STEP LIMITS, AND PRINT TIMES/  
! total      minimum      maximum      minimum      maximum  
! runtime fluid time step fluid time step solid time step solid time step  
!-----  
! runsec,      dtmin,      dtmax,      dtsmin,      dtsmax  
! 100.0        1.0e-6      0.10       0.10       0.5         !>  
!  
!    printing intervals in seconds  
! fluid      solid      power      plot      criteria  
! dtpfld,    dtplsld,    dtppwr,    dtpplt,    dtpcrt  
! 100.0      100.0      100.0     100.0     100.0         !>  
!-----  
!  
/BOUNDARY CONDITION, UNITS, RESTART, AND PRINT FLAGS/  
! ibond: 1 = P      (fluid and gas momentum balances at plenum)  
!        2 = Qf      (prescribed Qf replaces fluid mom. bal. at plenum)  
!        3 = Qg      (prescribed Qg replaces gas mom. bal. at plenum)  
!        4 = Qf,Qg    (prescribed Qf, Qg replace both mom. bal. at plenum)  
!       -2 = Qf      (prescribed Qf replaces fluid mom. bal. at tank bottom)  
!       -3 = Qg      (prescribed Qg replaces gas mom. bal. at tank bottom)  
!       -4 = Qf,Qg    (prescribed Qf, Qg replace both mom. bal. at tank bottom)  
! iunits applies to the fluid input only  
! iunits: 1 = SI (m , m^2 , m^3 , Pa , m^3/s, C)  
!        2 = SRS (in, in^2, in^3, psia, gpm , C)  
! istart: 0 = new  
!        1 = restart (time = runsec)  
!        2 = restart (time = zero)  
!        3 = restart (time = tcrit0)  
! isave: 0 = no restart file saved  
!        1 = restart file saved and tsec set to runsec  
!        2 = restart file saved and tsec set to zero  
!        3 = restart file saved and tsec set to tcrit0  
! iprint: 1 = short print  
!        2 = long print
```


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```

! icrit: 0 = no printing of criteria messages
!         1 = print criteria messages
! iscrn: 0 = no screen print
!         1 = long screen print
!         2 = short screen print
! istdy: -1 = grid generation only
!         0 = transient from tsec to runsec
!         1 = steady state from tsec
!         2 = steady state at tsec
!         3 = steady state at tsec followed by a transient to runsec
! igpsk: 0 = no node renumbering
!         1 = optimum node renumbering (profile) using Gibbs-Poole-Stockmeyer-King
!         2 = optimum node renumbering (bandwidth) using Gibbs-Poole-Stockmeyer-Cuthill-
Mckee
! inorm: 0 = use unnormalized axial power shapes
!         1 = normalize the axial power shape
! -----
! ibond, iunits, istart, isave, iprint
! 2      1      0      2      2
! icrit, iscrn, istdy, ippu, ibpu
! 0      2      0      0      0
! igpsk inorm
! 1      0
! -----
!
/REFERENCE PRESSURE, COMPRESSIBILITY FACTOR, .../
! ilq: liquid identification, 1=H2O, 2=D2O
! pref: reference pressure used in subroutine inner to compute
!       relative changes in the dp's
! factor: multiplier to drho,fluid/dP to increase fluid compressibility
! vminz: minimum absolute velocity for full donoring in z direction
! tol: accchk parameter
! tolss: steady state tolerance on dhmix/dt, (J/m^3-s)
! tolts: relative tolerance on solid temperature
! ttol: relative tolerance on solid time step change
! dtsup: wall superheat reduction, C
! htdamp: solid-fluid heat transfer damping factor
! cidamp: interfacial drag damping factor
! xa0: source/sink air mass fraction
! dtf: perturbation to liquid temperature for derivative estimation
! dtg: perturbation to gas temperature for derivative estimation
! nstdy: maximum iterations for steady-state (istdy > 0)
! nmat: maximum number of solid materials
! delox: surface oxide layer thickness (m)
! tkox: oxide thermal conductivity (W/m-K)
! -----
! ilq, pref, factor, vminz
! 1      5.0e+5      1.0      0.05
!
! tol, tolss, tolts, ttol
! 1.0      10.0      0.1      0.1
!
! dtsup, htdamp, cidamp, xa0
! 0.0      1.0      0.1      0.0
!
! dtf, dtg, nstdy, nmat
! 1.0      1.0      9000      10
!
! delox, tkox
! 5.08e-5      2.16
! -----
!

```

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/BOILING CURVE AND INTERPHASE TRANSPORT OPTIONS/

```

! iboil: 0 = use specified heat transfer coefficient
!         1 = forced convection (SRL)
!         2 = forced convection (Dittus-Boelter)
!         3 = forced convection (Sieder-Tate)
!         4 = Mikic-Rohsenow interpolation
!         5 = Chen correlation
!  ichf: 1 = SRS correlation
!         2 = Biasi
! matgas: 1 = helium dissolved in water
!         2 = air dissolved in water
! persat: percent of saturation (0-100)
! igami: 0 = bulk interfacial mass transport off
!         1 = bulk interfacial mass transport on
! igamw: 0 = wall interfacial mass transport off
!         1 = wall interfacial mass transport on

```

```

-----
! iboil,   ichf,   matgas,   persat,   igami,   igamw
!    2      2      2        0.0      0        0
!>
-----
!

```

/SOLID PARAMETERS/

```

! isolid: 0 = no solid calculations
!         1 = solid calculations with matrix decomposition every time step
!         2 = solid calculations with matrix decomposition first time step
! tsolid: initial solid temperature
! beta: implicitness parameter in solid calculations
! iheat: 0 = no wall heat transfer calculation
!         1 = wall heat transfer calculations
! qsurf: specified surface heat flux (used when iheat = 0)
! hfix: specified heat transfer coefficient (used when iboil = 0)
! iaxcon: 0 = no axial conduction
!         1 = explicit axial conduction calculation

```

```

-----
! isolid,   tsolid,   beta,   iheat,   qsurf,   hfix,   iaxcon
!    2       53.0    1.0    1        0.0    1.0e4    1
!>
-----
!

```

/INNER ITERATION OPTIONS & NEWTON ITERATION PARAMETERS/

```

! irebal: 0 = no coarse mesh rebalance
!         1 = coarse mesh rebalance on first pass
!         2 = coarse mesh rebalance on each pass
! ncmr: number of coarse mesh rebalances when irebal = 1 or 2
! epsin: inner iteration convergence criterion for relative dp error
! initmx: max. number of inner iterations allowed
! epsp: newton iteration convergence criterion for absolute p error in Pa
! epsalp: newton iteration convergence criterion for absolute alp error
! epstg: newton iteration convergence criterion for absolute tg error in K
! epstf: newton iteration convergence criterion for absolute tf error in K
! epsxa: newton iteration convergence criterion for absolute xa error
! nitmax: |nitmax| = max. number of newton iterations allowed
!         If nitmax is positive and |nitmax| iterations are reached, then
!         then computations continue using the mth iterate values from the
!         |nitmax| iteration.
!         If nitmax is negative and |nitmax| iterations are reached, then
!         a new time step with a time step reduction is requested.

```

```

-----
! irebal, ncmr,   epsin,   initmx
!    1      1    1.0e-5    200
!>
!         epsy,   epsf,   nitysi
!         1.0e-5  0.01    50
!>
!         epsp,   epsalp,   epstg,   epstf,   epsxa,   nitmax

```

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```
50.0 0.0005 0.05 0.05 0.005 -100 !>
!-----
!
! /NUMBER OF SPLINE PROFILES AND DATA POINTS/
! ndata: number of data groups
! itime: number of time snapshots for axial power profiles
!-----
! ndata, itime
! 4 2 !>
!-----
! npdat: number of data points per data set
! nset: number of data sets in data group
!-----
! npdat nset
! 3 1 !>
! 4 1 !>
! 29 1 !>
! 3 1 !>
!-----
!
! /GEOMETRIC DIMENSIONS:/
! nchn: number of flow channels
! nzt: number of top section axial cells (>=2)
! nz: number of middle section axial cell layers (>=3)
! nzb: number of bottom section axial cells (>=2)
!-----
! nchn, nzt, nz, nzb
! 11 2 10 2 !>
!-----
!
! /POWER ITERATION INPUT/
! power: initial power in kW
! maxpi: maximum number of power iterations
! tolpow: tolerance on power limit
! ncrit: number of criteria used to check for power limit
!-----
! power, maxpi, tolpow, ncrit
! 33.960 1 0.005 8 ! 1 % nominal operating power >
!-----
!
! SENSITIVITY VARIABLES INPUT SECTION
!
! /SENSITIVITY PARAMETERS/
! cizfac: axial interfacial drag multiplying factor
!-----
! xcofh, xreh, xcofl, xrel, xkmet, xcvmet
! 1.0 1.0 1.0 1.0 1.0 1.0 !>
!
! xhfi, xhgi, xkgi, xphi
! 1.0 1.0 1.0 1.0 !>
!
! cizfac xfric, plnht, cipln, formhs, alphas
! 1.0 1.0 8.75 1.0 5.382 0.05 !>
!
! alb2, als2, ala2, expbs, expsa
! 0.25 0.52 0.75 4.0 4.0 !>
!-----
!
! INPUT FOR SOLID FINITE ELEMENT CALCULATIONS
! Simple Heated Block Test Case
!
! inrg - number of finite element regions
```

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! inbp - number of boundary points
! iflag - output flag (1 = echo input, 0 = no input echo)

/ inrg inbp iflag /
58 260 1

! node (x,y) coordinates within grid

/ jnod xp(jnod) yp(jnod) i=1,inbp (cm) /

1	0.00000	0.00000
2	0.01270	0.00000
3	0.02540	0.00000
4	0.08636	0.00000
5	0.14732	0.00000
6	0.17272	0.00000
7	0.19812	0.00000
8	0.25908	0.00000
9	0.32004	0.00000
10	0.34544	0.00000
11	0.37084	0.00000
12	0.43180	0.00000
13	0.49276	0.00000
14	0.51816	0.00000
15	0.54356	0.00000
16	0.60452	0.00000
17	0.66548	0.00000
18	0.69088	0.00000
19	0.71628	0.00000
20	0.77724	0.00000
21	0.83820	0.00000
22	0.86360	0.00000
23	0.88900	0.00000
24	0.94996	0.00000
25	1.01092	0.00000
26	1.03632	0.00000
27	1.06172	0.00000
28	1.12268	0.00000
29	1.18364	0.00000
30	1.20904	0.00000
31	1.23444	0.00000
32	1.29540	0.00000
33	1.35636	0.00000
34	1.38176	0.00000
35	1.40716	0.00000
36	1.46812	0.00000
37	1.52908	0.00000
38	1.55448	0.00000
39	1.57988	0.00000
40	1.64084	0.00000
41	1.70180	0.00000
42	1.72720	0.00000
43	1.75260	0.00000
44	1.81356	0.00000
45	1.87452	0.00000
46	1.88722	0.00000
47	1.89992	0.00000
48	0.00000	0.01557
49	0.02540	0.01557
50	0.14732	0.01557
51	0.19812	0.01557
52	0.32004	0.01557
53	0.37084	0.01557

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54	0.49276	0.01557
55	0.54356	0.01557
56	0.66548	0.01557
57	0.71628	0.01557
58	0.83820	0.01557
59	0.88900	0.01557
60	1.01092	0.01557
61	1.06172	0.01557
62	1.18364	0.01557
63	1.23444	0.01557
64	1.35636	0.01557
65	1.40716	0.01557
66	1.52908	0.01557
67	1.57988	0.01557
68	1.70180	0.01557
69	1.75260	0.01557
70	1.87452	0.01557
71	1.89992	0.01557
72	0.00000	0.03113
73	0.01270	0.03113
74	0.02540	0.03113
75	0.08636	0.03113
76	0.14732	0.03113
77	0.17272	0.03113
78	0.19812	0.03113
79	0.25908	0.03113
80	0.32004	0.03113
81	0.34544	0.03113
82	0.37084	0.03113
83	0.43180	0.03113
84	0.49276	0.03113
85	0.51816	0.03113
86	0.54356	0.03113
87	0.60452	0.03113
88	0.66548	0.03113
89	0.69088	0.03113
90	0.71628	0.03113
91	0.77724	0.03113
92	0.83820	0.03113
93	0.86360	0.03113
94	0.88900	0.03113
95	0.94996	0.03113
96	1.01092	0.03113
97	1.03632	0.03113
98	1.06172	0.03113
99	1.12268	0.03113
100	1.18364	0.03113
101	1.20904	0.03113
102	1.23444	0.03113
103	1.29540	0.03113
104	1.35636	0.03113
105	1.38176	0.03113
106	1.40716	0.03113
107	1.46812	0.03113
108	1.52908	0.03113
109	1.55448	0.03113
110	1.57988	0.03113
111	1.64084	0.03113
112	1.70180	0.03113
113	1.72720	0.03113
114	1.75260	0.03113
115	1.81356	0.03113

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116	1.87452	0.03113
117	1.88722	0.03113
118	1.89992	0.03113
119	0.00000	0.04923
120	0.02540	0.04923
121	0.14732	0.04923
122	0.19812	0.04923
123	0.32004	0.04923
124	0.37084	0.04923
125	0.49276	0.04923
126	0.54356	0.04923
127	0.66548	0.04923
128	0.71628	0.04923
129	0.83820	0.04923
130	0.88900	0.04923
131	1.01092	0.04923
132	1.06172	0.04923
133	1.18364	0.04923
134	1.23444	0.04923
135	1.35636	0.04923
136	1.40716	0.04923
137	1.52908	0.04923
138	1.57988	0.04923
139	1.70180	0.04923
140	1.75260	0.04923
141	1.87452	0.04923
142	1.89992	0.04923
143	0.00000	0.06732
144	0.01270	0.06732
145	0.02540	0.06732
146	0.08636	0.06732
147	0.14732	0.06732
148	0.17272	0.06732
149	0.19812	0.06732
150	0.25908	0.06732
151	0.32004	0.06732
152	0.34544	0.06732
153	0.37084	0.06732
154	0.43180	0.06732
155	0.49276	0.06732
156	0.51816	0.06732
157	0.54356	0.06732
158	0.60452	0.06732
159	0.66548	0.06732
160	0.69088	0.06732
161	0.71628	0.06732
162	0.77724	0.06732
163	0.83820	0.06732
164	0.86360	0.06732
165	0.88900	0.06732
166	0.94996	0.06732
167	1.01092	0.06732
168	1.03632	0.06732
169	1.06172	0.06732
170	1.12268	0.06732
171	1.18364	0.06732
172	1.20904	0.06732
173	1.23444	0.06732
174	1.29540	0.06732
175	1.35636	0.06732
176	1.38176	0.06732
177	1.40716	0.06732

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178	1.46812	0.06732
179	1.52908	0.06732
180	1.55448	0.06732
181	1.57988	0.06732
182	1.64084	0.06732
183	1.70180	0.06732
184	1.72720	0.06732
185	1.75260	0.06732
186	1.81356	0.06732
187	1.87452	0.06732
188	1.88722	0.06732
189	1.89992	0.06732
190	0.00000	0.08288
191	0.02540	0.08288
192	0.14732	0.08288
193	0.19812	0.08288
194	0.32004	0.08288
195	0.37084	0.08288
196	0.49276	0.08288
197	0.54356	0.08288
198	0.66548	0.08288
199	0.71628	0.08288
200	0.83820	0.08288
201	0.88900	0.08288
202	1.01092	0.08288
203	1.06172	0.08288
204	1.18364	0.08288
205	1.23444	0.08288
206	1.35636	0.08288
207	1.40716	0.08288
208	1.52908	0.08288
209	1.57988	0.08288
210	1.70180	0.08288
211	1.75260	0.08288
212	1.87452	0.08288
213	1.89992	0.08288
214	0.00000	0.09845
215	0.01270	0.09845
216	0.02540	0.09845
217	0.08636	0.09845
218	0.14732	0.09845
219	0.17272	0.09845
220	0.19812	0.09845
221	0.25908	0.09845
222	0.32004	0.09845
223	0.34544	0.09845
224	0.37084	0.09845
225	0.43180	0.09845
226	0.49276	0.09845
227	0.51816	0.09845
228	0.54356	0.09845
229	0.60452	0.09845
230	0.66548	0.09845
231	0.69088	0.09845
232	0.71628	0.09845
233	0.77724	0.09845
234	0.83820	0.09845
235	0.86360	0.09845
236	0.88900	0.09845
237	0.94996	0.09845
238	1.01092	0.09845
239	1.03632	0.09845

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240	1.06172	0.09845
241	1.12268	0.09845
242	1.18364	0.09845
243	1.20904	0.09845
244	1.23444	0.09845
245	1.29540	0.09845
246	1.35636	0.09845
247	1.38176	0.09845
248	1.40716	0.09845
249	1.46812	0.09845
250	1.52908	0.09845
251	1.55448	0.09845
252	1.57988	0.09845
253	1.64084	0.09845
254	1.70180	0.09845
255	1.72720	0.09845
256	1.75260	0.09845
257	1.81356	0.09845
258	1.87452	0.09845
259	1.88722	0.09845
260	1.89992	0.09845

!
! region side boundary condition specifications

!-----
/nrg (jt(nrg,j),j=1,4) /

1	24	2	0	0
2	-2	3	0	1
3	25	4	0	2
4	-2	5	0	3
5	26	6	0	4
6	-2	7	0	5
7	27	8	0	6
8	-2	9	0	7
9	28	10	0	8
10	-2	11	0	9
11	29	12	0	10
12	-2	13	0	11
13	30	14	0	12
14	-2	15	0	13
15	31	16	0	14
16	-2	17	0	15
17	32	18	0	16
18	-2	19	0	17
19	33	20	0	18
20	-2	21	0	19
21	34	22	0	20
22	-2	23	0	21
23	35	0	0	22
24	36	-2	1	0
25	37	-2	3	-2
26	39	-2	5	-2
27	41	-2	7	-2
28	43	-2	9	-2
29	45	-2	11	-2
30	47	-2	13	-2
31	49	-2	15	-2
32	51	-2	17	-2
33	53	-2	19	-2
34	55	-2	21	-2
35	57	0	23	-2
36	0	38	24	0
37	0	40	25	38

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[illegible]

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25	10	4	5	76	77	78	122	149	148	147	121
25	2	2									
25	4	1									
26	10	4	5	80	81	82	124	153	152	151	123
26	2	3									
26	4	2									
27	10	4	5	84	85	86	126	157	156	155	125
27	2	4									
27	4	3									
28	10	4	5	88	89	90	128	161	160	159	127
28	2	5									
28	4	4									
29	10	4	5	92	93	94	130	165	164	163	129
29	2	6									
29	4	5									
30	10	4	5	96	97	98	132	169	168	167	131
30	2	7									
30	4	6									
31	10	4	5	100	101	102	134	173	172	171	133
31	2	8									
31	4	7									
32	10	4	5	104	105	106	136	177	176	175	135
32	2	9									
32	4	8									
33	10	4	5	108	109	110	138	181	180	179	137
33	2	10									
33	4	9									
34	10	4	5	112	113	114	140	185	184	183	139
34	2	11									
34	4	10									
35	10	4	3	116	117	118	142	189	188	187	141
35	4	11									
36	10	3	3	143	144	145	191	216	215	214	190
37	10	3	5	147	148	149	193	220	219	218	192
38	10	3	5	145	146	147	192	218	217	216	191
38	3	1									
39	10	3	5	151	152	153	195	224	223	222	194
40	10	3	5	149	150	151	194	222	221	220	193
40	3	2									
41	10	3	5	155	156	157	197	228	227	226	196
42	10	3	5	153	154	155	196	226	225	224	195
42	3	3									
43	10	3	5	159	160	161	199	232	231	230	198
44	10	3	5	157	158	159	198	230	229	228	197
44	3	4									
45	10	3	5	163	164	165	201	236	235	234	200
46	10	3	5	161	162	163	200	234	233	232	199
46	3	5									
47	10	3	5	167	168	169	203	240	239	238	202
48	10	3	5	165	166	167	202	238	237	236	201
48	3	6									
49	10	3	5	171	172	173	205	244	243	242	204
50	10	3	5	169	170	171	204	242	241	240	203
50	3	7									
51	10	3	5	175	176	177	207	248	247	246	206
52	10	3	5	173	174	175	206	246	245	244	205
52	3	8									
53	10	3	5	179	180	181	209	252	251	250	208
54	10	3	5	177	178	179	208	250	249	248	207
54	3	9									
55	10	3	5	183	184	185	211	256	255	254	210
56	10	3	5	181	182	183	210	254	253	252	209

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```

56   3   10
57  10   3   3  187  188  189  213  260  259  258  212
58  10   3   5  185  186  187  212  258  257  256  211
58   3   11
!
!-----
! FLUID GEOMETRY AND MOMENTUM CLOSURE INPUT SECTION
!
/TOP BOUNDARY CELL: PLENUM VOLUME AND AREA/
! volpl: plenum volume
! acpl: plenum mid-cell area
!-----
! volpl,          acpl
! 680.0e-5        680.0e-4                                !>
!-----
!
/TOP SECTION GEOMETRY/
!
! Axial mesh spacing
!
! iuform: 1 = uniform axial mesh spacing
!         2 = individually specified values
! dztot: total axial length if iuform=1; not used if iuform=2
!        (must be specified however)
! dzt(jz): axial cell lengths if iuform=2
!-----
! iuform
! 1                                !>
! dztot
! 0.1                             !>
!-----
!
! iuform: 1 = uniform mass cell volumes and junction variables
!         2 = individually specified values
!-----
! iuform
! 1                                !>
!-----
!
! volt(jz): (cell) volume
! act(jz): (face) junction area
! azt(jz): (cell) mid-cell or volume-averaged area
! cost(jz): (face) cos(theta)
! dht(jz): (face) hydraulic diameter
! absrt(jz): (face) absolute roughness
! fmltt(jz): (face) friction multiplier (0 or 1 normally)
! fret(jz): (face) 64/fRe
! formt(jz): (face) form loss k factor
! defft(jz): (face) characteristic dimension for slug regime
! fldmt(jz): (face) m constant in flooding correlation
! fldct(jz): (face) c constant in flooding correlation
! c0bt(jz): (face) C0 for bubbly regime
! c0st(jz): (face) C0 for slug regime
! ckbt(jz): (face) Kb for bubbly regime
! ckst(jz): (face) Ks for slug regime
!
!-----
! volt( ),      act( ),      azt( ),      cost( ),      dht( )
! 680.0e-5      680.0e-4      680.0e-4      1.0          4.00e-2      !>
! absrt( ),      fmltt( ),      fret( ),      formt( ),      defft( )
! 1.524e-6      1.0          0.712          0.0          0.154          !>
! fldmt( ),      fldct( ),      c0bt( ),      c0st( ),      ckbt( ),      ckst( )
! 0.694          0.487          1.285          1.350          3.40          0.418      !>

```

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```

!-----
!
! /MIDDLE SECTION GEOMETRY/
! iuform: 1 = uniform axial mesh spacing
!         2 = individually specified values
! dztot: total axial length if iuform = 1
! dz: axial cell lengths if iuform = 2
!-----
! iuform
! 1 !>
!-----
! dztot
! 4.0 !>
!-----
! iuform: 1 = axially and azimuthally uniform cell z-direction
!         2 = individually specified cell z-direction geometry
!         other = individually specified values
!
! with iuform=1 in each channel below, specify
! acz(jz,ix,ic): (face) junction area
! azz(jz,ix,ic): (cell) mid-cell area
! cosz(jz,ix,ic): (face) cos(theta) for z-direction
! dhz(jz,ix,ic): (face) hydraulic diameter in z-direction
! absrz(jz,ix,ic): (face) absolute roughness
! fmltz(jz,ix,ic): (face) friction multiplier (0 or 1 normally)
! frez(jz,ix,ic): (face) 64/fRe
! formz(jz,ix,ic): (face) form loss k factor
! deffz(jz,ix,ic): (face) characteristic dimension for slug regime
! fldmz(jz,ix,ic): (face) m constant in flooding correlation
! fldcz(jz,ix,ic): (face) c constant in flooding correlation
! c0bz(jz,ix,ic): (face) C0 for bubbly regime
! c0sz(jz,ix,ic): (face) C0 for slug regime
! ckbz(jz,ix,ic): (face) Kb for bubbly regime
! cksz(jz,ix,ic): (face) Ks for slug regime
!-----
! /CHANNEL 1/
!-----
! /CHANNEL 1 Z GEOMETRY/
! iuform
! 1 !>
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
! 19.48e-4     19.48e-4     1.0             0.47e-2
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
! 1.524e-6     1.0          0.712          0.0          0.154
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
! 0.694        0.487        1.285         1.350        3.40         0.418
!-----
! /CHANNEL 2/
!-----
! /CHANNEL 2 Z GEOMETRY/
! iuform
! 1 !>
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
! 19.48e-4     19.48e-4     1.0             0.47e-2
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
! 1.524e-6     1.0          0.712          0.0          0.154
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
! 0.694        0.487        1.285         1.350        3.40         0.418
!-----
! /CHANNEL 3/

```

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```

!-----
/CHANNEL 3 Z GEOMETRY/
! iuform
1
!>
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
19.48e-4      19.48e-4      1.0          0.47e-2
!>
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
1.524e-6      1.0          0.712        0.0          0.154
!>
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
0.694         0.487        1.285        1.350        3.40         0.418
!>
!-----
/CHANNEL 4/
!-----
/CHANNEL 4 Z GEOMETRY/
! iuform
1
!>
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
19.48e-4      19.48e-4      1.0          0.47e-2
!>
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
1.524e-6      1.0          0.712        0.0          0.154
!>
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
0.694         0.487        1.285        1.350        3.40         0.418
!>
!-----
/CHANNEL 5/
!-----
/CHANNEL 5 Z GEOMETRY/
! iuform
1
!>
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
19.48e-4      19.48e-4      1.0          0.47e-2
!>
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
1.524e-6      1.0          0.712        0.0          0.154
!>
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
0.694         0.487        1.285        1.350        3.40         0.418
!>
!-----
/CHANNEL 6/
!-----
/CHANNEL 6 Z GEOMETRY/
! iuform
1
!>
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
19.48e-4      19.48e-4      1.0          0.47e-2
!>
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
1.524e-6      1.0          0.712        0.0          0.154
!>
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
0.694         0.487        1.285        1.350        3.40         0.418
!>
!-----
/CHANNEL 7/
!-----
/CHANNEL 7 Z GEOMETRY/
! iuform
1
!>
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
19.48e-4      19.48e-4      1.0          0.47e-2
!>
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
1.524e-6      1.0          0.712        0.0          0.154
!>
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )

```

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```

0.694      0.487      1.285      1.350      3.40      0.418      !>
!-----
/CHANNEL 8/
!-----
/CHANNEL 8 Z GEOMETRY/
! iuform
1
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
19.48e-4      19.48e-4      1.0      0.47e-2      !>
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
1.524e-6      1.0      0.712      0.0      0.154      !>
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
0.694      0.487      1.285      1.350      3.40      0.418      !>
!-----
/CHANNEL 9/
!-----
/CHANNEL 9 Z GEOMETRY/
! iuform
1
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
19.48e-4      19.48e-4      1.0      0.47e-2      !>
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
1.524e-6      1.0      0.712      0.0      0.154      !>
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
0.694      0.487      1.285      1.350      3.40      0.418      !>
!-----
/CHANNEL 10/
!-----
/CHANNEL 10 Z GEOMETRY/
! iuform
1
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
19.48e-4      19.48e-4      1.0      0.47e-2      !>
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
1.524e-6      1.0      0.712      0.0      0.154      !>
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
0.694      0.487      1.285      1.350      3.40      0.418      !>
!-----
/CHANNEL 11/
!-----
/CHANNEL 11 Z GEOMETRY/
! iuform
1
!-----
! acz( ),      azz( ),      cosz( ),      dhz( )
19.48e-4      19.48e-4      1.0      0.47e-2      !>
! absrz( ),    fmltz( ),    frez( ),      formz( ),    deffz( )
1.524e-6      1.0      0.712      0.0      0.154      !>
! fldmz( ),    fldcz( ),    c0bz( ),      c0sz( ),      ckbz( ),      cksz( )
0.694      0.487      1.285      1.350      3.40      0.418      !>
!-----
!
/BOTTOM SECTION GEOMETRY/
!
! Axial mesh spacing
!
! iuform: 1 = uniform axial mesh spacing
!        2 = individually specified values
! dztot: total axial length if iuform=1; not used if iuform=2

```

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```
!           (must be specified however)
!dzt(jz): axial cell lengths if iuform=2
!-----
! iuform
!   1                                           !>
! dztot
!   0.1                                         !>
!-----
!
! iuform: 1 = uniform mass cell volumes and junction variables
!         2 = individually specified values
! iuform
!   1                                           !>
!-----
! volb(jz): (cell) volume
! acb(jz): (face) junction area
! azb(jz): (cell) mid-cell or volume-averaged area
! cosb(jz): (face) cos(theta)
! dhb(jz): (face) hydraulic diameter
! absrb(jz): (face) absolute roughness
! fmltb(jz): (face) friction multiplier (0 or 1 normally)
! freb(jz): (face) 64/fRe
! formb(jz): (face) form loss k factor
! deffb(jz): (face) characteristic dimension for slug regime
! fldmb(jz): (face) m constant in flooding correlation
! fldcb(jz): (face) c constant in flooding correlation
! c0bb(jz): (face) C0 for bubbly regime
! c0sb(jz): (face) C0 for slug regime
! ckbb(jz): (face) Kb for bubbly regime
! cksb(jz): (face) Ks for slug regime
!
!-----
! volb( ),   acb( ),   azb( ),   cosb( ),   dhb( )
! 680.0e-5   680.0e-4   680.0e-4   1.0       4.00e-2           !>
! absrb( ),   fmltb( ),   freb( ),   formb( ),   deffb( )
! 1.524e-6    1.0       0.712     0.0       0.154             !>
! fldmb( ),   fldcb( ),   c0bb( ),   c0sb( ),   ckbb( ),   cksb( )
! 0.694       0.487     1.285     1.350     3.40      0.418       !>
!-----
!
/BOTTOM BOUNDARY CELL: TANK BOTTOM VOLUME AND AREA/
! voltb: tank bottom volume
! actb: tank bottom mid-cell area
!-----
! voltb,      actb
! 680.0e-5    680.0e-4                                           !>
!-----
/BOUNDARY CONDITION INPUT SECTION/
/INLET PLENUM (TOP)/
! ppl0: multiplier to P transient profile
! ippl: P transient identifier
! alpp0: multiplier to alpha transient profile
! ialpl: alpha transient identifier
! tfpl0: multiplier to Tf transient profile
! itfpl: Tf transient identifier
! tgpl0: multiplier to Tg transient profile
! itgpl: Tg transient identifier
! xap10: multiplier to Xa transient profile
! ixapl: Xa transient identifier
!-----
! ppl0,      ippl
! 720000.0    1           !>
```


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```

! alpp10,    ialpl
!   1.0      4      !>
! tf010,    itfpl
!   53.0     1      !>
! tgpl0,    itgpl
!   53.0     1      !>
! xapl0,    ixapl
!   0.9      1      !>
!-----
!
! /OUTLET PLENUM (BOTTOM)/
!   ptb0: multiplier to P transient profile
!   iptb: P transient identifier
!   alptb0: multiplier to alpha transient profile
!   ialtb: alpha transient identifier
!   tftb0: multiplier to Tf transient profile
!   itftb: Tf transient identifier
!   tgtb0: multiplier to Tg transient profile
!   itgtb: Tg transient identifier
!   xatb0: multiplier to Xa transient profile
!   ixatb: Xa transient identifier
!-----
!   ptb0,    iptb
!   584000.0  1      !>
!   alptb0,  ialtb
!   1.0      4      !>
!   tftb0,    itftb
!   53.0     1      !>
!   tgtb0,    itgtb
!   53.0     1      !>
!   xatb0,    ixatb
!   0.9      1      !>
!-----
!
! /INLET FLOW DATA/
! The following inlet flow data is always used to initialize
! axial velocities and will also be used to define the
! appropriate prescribed flowrate for t > 0 if ibond = 2, 3, or 4.
! qfin0: multiplier to Qf transient profile
! iqfin: Qf transient identifier
! qgin0: multiplier to Qg transient profile
! iqgin: Qg transient identifier
! qfin0 = Nominal APT total flow 12 half channels, transient
!-----
!   qfin0,    iqfin
!   -0.0072288 1      !> 0.09036 (100% of 89 kg/s); 0.0036144 (4% of 89 kg/s)
!   qgin0,    iqgin
!   0.0      1      !>
!-----
!
! /INITIAL CONDITION INPUT SECTION/
! If iset0 > 0 then initial conditions are
! input for fluid parameters at each axial level
! iset0
!   0
!-----
!
! /CRITERIA CHECKING FLAGS AND PEAKING FACTORS/
! checking flags for criteria #1 #2 #3 #4 #5 #6 #7 #8
!                               0 0 0 0 0 0 0 0 !>
! peaking factors for criteria #1 #2 #3 #4 #5 #6 #7 #8
!                               1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 !>

```

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```
/CRITERIA CHECKING TIME/
! time to begin criteria checking, sec
!-----
! tcrit0
!      0.0          !>
!-----
!
! POWER INPUT
!
/POWER PROFILE SPLINE POINTERS/
! DECAY HEAT TRANSIENT
!      2          !>
!
/AXIAL SPLINE POINTERS AND TIMES/
!      3      0.0          3      300.00
!
/TRANSIENT DATA SET INPUT SECTION/
/ DATA SET NUMBER 1/
! enter data set label below
!-----
data set 1 - UNIFORM
!-----
! itype: 1 = linear spline
!          0 = cubic spline
! x, y: data pairs
!-----
!          itype
!          1          !>
! x(ipt), y(ipt)      ipt=1,npts
!      0.0      1.0          !>
!      5.0      1.0          !>
!     100.0      1.0          !>
!-----
!
!
/ DATA SET NUMBER 2/
!-----
data set 2 - DECAY POWER SHAPE
!          itype
!          1          !>
! x(ipt), y(ipt)      ipt=1,npts
!      0.0      1.0          !>
!      1.0      1.0          !>
!     10.0      1.0          !>
!    100.0      1.0          !>
!-----
!
!
/ DATA SET NUMBER 3/
!-----
data set 3 - NON-UNIFORM AXIAL POWER PROFILE
!          itype
!          1          !>
! x(ipt), y(ipt)      ipt=1,npts
!      0.00000      0.08000
!      0.14286      0.10507
!      0.28571      0.17903
!      0.42857      0.29817
!      0.57143      0.45651
!      0.71429      0.64612
!      0.85714      0.85748
!      1.00000      1.08000
!      1.14286      1.30252
!      1.28571      1.51388
```

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1.42857	1.70349
1.57143	1.86183
1.71429	1.98097
1.85714	2.05493
2.00000	2.08000
2.14286	2.05493
2.28571	1.98097
2.42857	1.86183
2.57143	1.70349
2.71429	1.51388
2.85714	1.30252
3.00000	1.08000
3.14286	0.85748
3.28571	0.64612
3.42857	0.45651
3.57143	0.29817
3.71429	0.17903
3.85714	0.10507
4.00000	0.08000

```
!-----
/DATA SET NUMBER 4/
! enter data set label below
!-----
data set 4 - VOID
!-----
! itype: 1 = linear spline
!       0 = cubic spline
! x, y: data pairs
!-----
!       itype
!       1      !>
! x(ipt), y(ipt)  ipt=1,npts
!       0.0  0.0      !>
!       5.0  0.0      !>
!      100.0  0.0      !>
!-----
/END OF INPUT FILE/
```

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