WSRC-TR-93-085

FLOWTRAN-TF User Guide (U)

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Publication Date: February, 1993

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TASK NUMBER: 89-021-1
DOCUMENT TITLE: FLOWTRAN-TF User Guide (U)
DOCUMENT NUMBER: WSRC-TR-93-085
REVISION NUMBER: 0

Acknowledgements

The FLOWTRAN-TF code development effort was initiated in early 1989. Several members of the Code Development Group have contributed to FLOWTRAN-TF development as summarized alphabetically below:

Contributor	Principal Contributions
Sebastian Aleman	Axial wall drag, neutronic power distribution, splines, code architecture, documentation, coding, graphics, testing
Roger Cooper	Coding, graphics
Greg Flach	Program leadership, interfacial drag, axial wall drag, phase transition logic, fluid finite-differencing and solution methods, equations of state, documentation, coding, testing, benchmarking
Larry Hamm	Program concept, initiation and leadership, all aspects of physical model development and computational implementation, interfacial heat and mass transfer, code architecture, coding, testing, benchmarking
Andrea Kielpinski	Interfacial heat and mass transfer coefficients, flow regime map, documentation
Larry Koffman	Documentation
Si Young Lee	Channel inlet void distribution, CCFL correlation, inter-subchannel mixing, interfacial heat and mass transfer coefficients, rib void model, equations of state, documentation, coding, testing, benchmarking
Andy Shadday	Azimuthal wall drag, documentation, testing
Frank Smith	Solid heat conduction, neutronic power distribution, wall heat transfer, interfacial heat and mass transfer, fluid finite differencing and solution methods, code architecture and I/O, documentation, coding, testing, benchmarking

The developers are grateful to the many technical reviewers of FLOWTRAN-TF. These include Ken Moore, Garry Gose, Ken Katsma and M. Paulsen of Computer Simulation & Analysis, Inc. and Steve Hensel and Jeff Jerrell of WSRC. The helpful suggestions of the DOE Independent Review Panel (DIRP) are also appreciated.

The developers also appreciate the support of the DOE, former WSRC Nuclear Engineering Section manager Ken Huffman and present manager Al Garrett, and former Code Development Group managers Larry Hamm and Bill Horton and current manager Dave Crowley.

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Detailed instructions and guidelines to aid users in constructing and interpreting FLOWTRAN-TF input and output files are given in this report for version 1.2 of the source code. The user is assumed to be familiar with the FLOWTRAN-TF Software Design report, SRS fuel assembly hardware, and two-phase flow. The FLOWTRAN-TF code proprietor is responsible for defining formal training requirements and user qualifications. FLOWTRAN-TF reference documents include

- FLOWTRAN-TF Code Development Technical and QA Plan, Rev. 0 (Flach, 1991)
- FLOWTRAN-TF Software Requirements Specification, Rev. 1 (Flach, 1993a)
- FLOWTRAN-TF Software Test Plan, Rev. 1 (Flach, 1993b)
- "FLOWTRAN-TF Software Design (U)", WSRC-TR-92-532 (Aleman et al., 1993a)
- "FLOWTRAN-TF Software Testing (U)", WSRC-TR-93-084 (Aleman et al., 1993b)
- "FLOWTRAN-TF v1.2 Source Code (U)", WSRC-TR-93-086 (Aleman et al., 1993c)

This User Guide satisfies the requirements of Quality Assurance Procedure QAP IV-4, Rev. 0 "Software Design and Implementation" in the 1Q34 manual.

The User Guide is divided into three parts. First, general code capabilities and input options are summarized. Then, detailed instructions for creating and interpreting code input files are given next. Also, a sample input deck and corresponding output files are listed for reference and illustration. Variable and subroutine names as well as input values are denoted by the `Courier` typeface in general.

General Code Capabilities and Input Options

FLOWTRAN-TF is a two-phase thermal-hydraulics code of similar technology to existing commercial reactor codes such as RELAP and TRAC but customized for Savannah River Site applications. Briefly, the main features and capabilities of FLOWTRAN-TF are

- Detailed Mk22 fuel assembly ribbed annular geometry
- Conjugate heat transfer
- Detailed neutronic power distribution
- Three-dimensional heat conduction in Mk22 fuel and target tubes
- Two-dimensional coolant flow in channels (axial, azimuthal)
- Single-phase and/or two-phase fluid (gas, liquid and/or gas-liquid)
- Two-component (air, water)

- Constitutive models applicable to low pressure air-water downflow in ribbed annular channels.

The user is referred to the FLOWTRAN-TF Software Design report and Software Requirements Specifications for more information on the intended applications of FLOWTRAN-TF and the software design. The FLOWTRAN-TF Software Design and Software Testing reports define the accuracy and limitations of the code.

The code may be used to simulate solid components, fluid coolant flow and solid-fluid heat transfer, or fluid flow only (adiabatic flow channels). Pure component water or two-component air-water flows may be modeled. A variety of materials may be chosen for the solid tubes separating flow channels. FLOWTRAN-TF is fundamentally a transient analysis tool. However, the code is capable of detecting steady-state conditions during a transient calculation. Steady-state results can be easily generated by using the false transient option of the code, also. Fluid and solid conditions at the end of calculation may be saved in a restart file. The restart file may be binary, which saves the exact values, or ASCII, which allows the restart file to used across computer systems. Calculations may start from user specified initial conditions or from a previously saved restart file. The user may choose between fixed power calculations or iterative power calculations. For iterative power calculations, FLOWTRAN-TF searches automatically for the power which satisfies user specified thermal-hydraulic criteria. Sensitivity analyses involving important code parameters may be performed through input. Time and spatially varying quantities are specified through either linear or cubic splines giving the user great flexibility. FLOWTRAN-TF is maintained on VAX, CRAY and IBM 6000 computer systems.

Fluid Options

The fluid computational mesh capabilities are fully discussed in the FLOWTRAN-TF Software Design report. The user has sufficient flexibility in specifying the coolant channel geometry to model existing fuel assemblies and experimental rigs. The code is basically capable of handling thermal-hydraulic problems in a cylindrical channel geometry. The fluid mesh is comprised of Top, Middle and Bottom sections. The Top and Bottom sections are one-dimensional (z coordinate). The Middle section most generally contains multiple flow channels, each with axial and azimuthal discretization (z, θ coordinates respectively). As special cases, the Middle section may be a single, one-dimensional channel, multiple one-dimensional channels, or a single two-dimensional channel, among others. The convention for the positive directions in the x-z coordinate system is clockwise azimuthally and downward axially. Cell lengths, flow areas, hydraulic parameters may generally vary arbitrarily throughout the mesh. Notable exceptions are the axial cell lengths in the Middle section. Here the azimuthal cells of all channels must share a common axial discretization scheme (which is not necessarily uniform).

Axial cell numbers in the Top and Bottom sections start with `1` and end with `nzt` and `nzb`, respectively. The user should be aware that two different numbering schemes are used for the Middle section axial cells. The Middle section computational mesh contains 2 extra rows of axial cells, called 'fictitious' cells, which overlap the last cell of the Top section and first cell of the Bottom section. For `nz` non-overlapping cells in the Middle section, the internal cell numbering starts with `1` in the upper row of fictitious cells and ends with `nz+2` in the lower row of fictitious cells. Error messages and warnings use this internal numbering system. However, the output to units 11 and 20 designates the first non-overlapping cell by `1` and the last non-overlapping cell by `nz`. That is, the output shifts the axial cell numbers by `1`.

Several boundary condition options are available as discussed in the FLOWTRAN-TF Software Design report. The basic boundary conditions at the input and outlet are prescribed pressure, void fraction, gas temperature, liquid temperature and air mass fraction. Alternatively, the user may prescribe gas and/or liquid flowrates at the inlet. Initial conditions are basically set by interpolating between the initial boundary conditions for a fresh start, or by using the conditions previously saved in a restart file. For the fresh start, axial velocities are set by a user defined flowrates and azimuthal velocities in the Middle section are set to be zero initially.

Interfacial mass transfer in the bulk fluid and/or at the wall may be turned off through user-specified flags.

All fluid input parameters may be entered in SI dimensional units (m , m^2 , m^3 , Pa , m^3/s, °C) or 'SRS' units (in, in^2, in^3, psia, gpm , °C). The output dimensional units correspond with the chosen input units.

Solid Options

The solid mesh is comprised of nested tubes creating the annular flow channels of the fluid mesh. The solid cylinders may be discretized axially, radially and azimuthally for a full three-dimensional heat conduction calculation. Special cases include radial, radial-axial and radial-azimuthal calculations however. The fundamental calculation is a transient one. If steady-state conditions are desired, the approach to steady-state can be accelerated by artificially reducing the heat capacity of the solid. The following materials may be chosen from: Uranium, Aluminum, 304L Stainless Steel, Lithium-Aluminum Alloy, Uranium-Aluminum Alloy, 6063 Aluminum, Macor, Inconel 600 and Flame Sprayed Oxide.

Four wall heat transfer options are available. Options 1 and 2 are complete boiling curves based on the Mikic and Chen correlations, respectively. For options -1 and and 0 only non-boiling forced convection correlations are used regardless of wall temperature. The Sieder-Tate correlation is selected by 0 and the SRS correlation by -1. The non-boiling forced convection only options are useful for $T_{wall} \leq T_{sat}$ calculations because they typically speed-up the calculation without affecting the final converged power.

Power Options

The user may choose between detailed neutronic power input applicable to a reactor fuel assembly or abbreviated input adequate for describing an experimental rig. The code is capable of iterating for the pre-incident power which satisfies one or more user selected thermal-hydraulic acceptance criteria. The criteria options are

- Bulk fluid temperature below local saturation temperature ($T_{fluid} \leq T_{sat}$)
- Maximum instantaneous metal surface temperature below local fluid saturation temperature (instantaneous $T_{wall} \leq T_{sat}$)
- Maximum running time averaged metal surface temperature below local fluid saturation temperature (average $T_{wall} \leq T_{sat}$)
- Counter-current flow limitation correlation not exceeded.

Numerical Considerations

During each time advancement, three iterations are performed. At the highest level is the NEWTON iteration which determines converged values for the new time step pressure, void fraction, gas temperature, liquid temperature and air mass fraction. The INNER iteration within the NEWTON iteration determines pressure updates after the fluid equation set has been reduced to a pressure-only problem. Also within the NEWTON iteration is the GAMMAI iteration for bulk fluid interfacial heat and mass transfer rates.

For 2-D fluid calculations in the Middle section the recommended INNER iteration scheme is the alternating axial-azimuthal scheme with coarse mesh rebalance given by `ischem` = 3, `irebal` = 1 and `ncmr` = 1.

Convergence tolerances and maximum numbers of iteration are specified by the user as discussed in detail below. The user should be aware that the convergence tolerances for the INNER and GAMMAI calculations should be smaller than those for the NEWTON iteration; that is, the NEWTON iteration requires input information more accurate than its requested accuracy. Suggested values are given for each parameter. If highly accurate transient results are desired, the user may want to repeat the computation with smaller values for these quantities to ensure that the convergence criteria are sufficiently small.

The maximum change in the interfacial steam mole fraction and air mass fraction iterates in the GAMMAI and NEWTON iterations is 0.04. During phase transitions these parameters may change from approximately 0 to 1 or vice versa during a single time-step. Therefore, the maximum number of GAMMAI and NEWTON iterations must exceed 25. A value of 50 is suggested for both.

Phase transitions challenge FLOWTRAN-TF's ability to iterate to a correct solution. For example, in transitioning from single-phase liquid to two-phase flow the air mass fraction goes from 0 to near 1 and the gas temperature goes from the saturation temperature to approximately the fluid temperature as the void fraction goes from 0 to 0.001. In this sensitive region the NEWTON iteration convergence tolerances may need to be relaxed on X_a and T_g to achieve a successful simulation.

Also, since the large changes in X_a and T_g cannot be handled by the basic Newton iteration method, FLOWTRAN-TF limits the amount of change of the iterates to prevent a divergent iteration. This 'damped' Newton method is robust and yields a converged solution virtually all the time. However, the method is known to fail occasionally. If problems are encountered in transitioning from single-phase flow to two-phase flow or vice versa, the user should consider whether a 'seed' void fraction of 0.001 or more can be added to the single-phase portion of the simulation without significantly affecting the relevant physics. Then the simulation is two-phase throughout and difficult phase transitions are avoided.

Many FLOWTRAN-TF applications involve sufficiently low liquid flowrates that the liquid forms a pool in the bottom portion of the channel which more or less blocks air throughput. The upper portion of the channel is highly voided. The gas velocity typically oscillates between positive and negative values with an average value near zero. During FLOWTRAN-TF development involving such cases, non-physical values of air mass fraction and sometimes gas temperature were observed on either side of a cell face with a gas velocity switching between positive and negative values between each time step. One cell would have an air mass fraction of 1.000 and the other cell would have a low air mass fraction. Under isothermal room temperature conditions the air mass fraction should be slightly less than one, instead.

The non-physical values observed are an inherent result of the explicit donoring scheme used by FLOWTRAN-TF. Gas phase properties at cell faces are defined to be the properties of the adjacent cell from which the gas flows at the old time level. The explicit donoring scheme is appropriate if the gas velocity does not change direction between time steps. For occasional velocity reversals, no difficulties are encountered. If the velocity reverses for every time step the explicit donoring scheme is not appropriate as the Figure 1 illustrates. Figure 1 shows a two cell sealed container with a two-phase air-water mixture present. The gas velocity is shown to reverse from time step to time step. The air mass fractions are initialized to different values. Mass transfer between the liquid and gas phases of water is neglected for the moment. For time step n+1 the lower cell air mass fraction stays the same because the incoming flow and the lower cell both have the same X_a. The upper cell air mass fraction decreases because the outgoing X_a is greater than the upper cell X_a. For the n+2 time step, the upper cell remains unchanged while X_a increases in the lower cell. As the process continues, the air mass fractions diverge unbounded with non-physical results as the outcome.

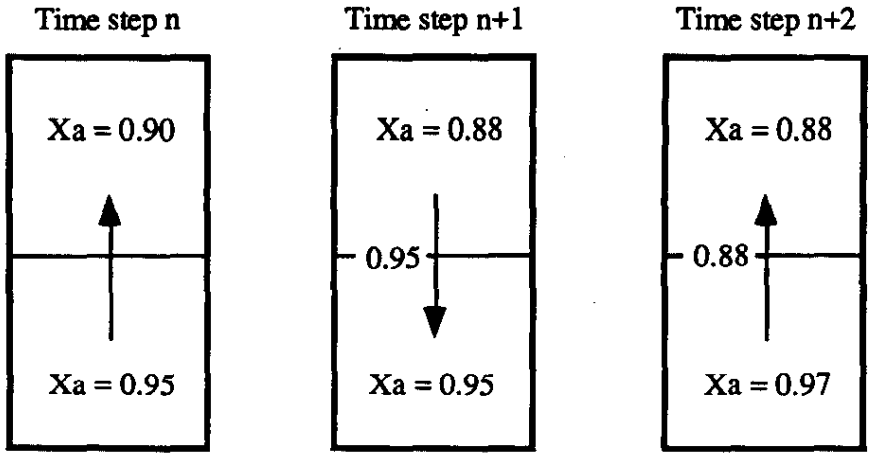


Figure 1 Illustration of continuous velocity reversals leading to non-physical results.

Interfacial mass transfer between the liquid and gas phases counteracts the above process. In Figure 1, water vapor will condense in the upper cell and liquid will vaporize in the lower cell tending to bring the air mass fractions back to equilibrium values. Unfortunately, in the annular flow regime the default interfacial mass transfer rates are too small to overcome the process shown in Figure 1. One remedy is to increase the interfacial mass transfer rate by setting `xkgi` to say `100.0` (see Input Specifications). The gas temperature may also diverge on either side of an oscillating gas velocity. One remedy is to increase the interfacial gas side heat transfer rate by setting `xhgi` to say `10.0` (see Input Specifications).

The time step is usually limited by the numerical stability constraint or the solution accuracy control logic of subroutine `ACCCHK`. If a very small solution accuracy tolerance (`tol` parameter) is specified the computational effort will increase due to small time steps.

I/O Files

FORTRAN unit numbers for the various data files are assigned by FLOWTRAN-TF to be

5 primary input file

7 modified primary input file stripped of comments, etc. (scratch file)

8 output binary dump file for post-plotting results

9 input restart file

10 output restart file

11 primary output

20 secondary output

The files associated with units 5, 11 and 20 are ASCII formatted. The unit 8 file is binary. The files for units 9 and 10 may be binary or ASCII depending on the option selected. The unit 7 file is a scratch file not accessible to the user. All input data for unit 5 are read in free format. Restart dumps are written and read by unformatted read and write statements.

Computer Systems Supported

The source code is stored under the VAX CMS system. Configured source and executable versions of the code are maintained under SCMS on the VAX and CRAY computer systems and under NES CMS on the NES IBM 6000 workstations. See the FLOWTRAN-TF code proprietor, the SCMS custodian, and/or the NES CMS custodian for specific information about access controls.

Sample Code Run

The input deck used to perform VOID Rig benchmarking results for -1 psig plenum pressure, 12" tank level, and 8 gpm, and corresponding output, are given below to illustrate typical FLOWTRAN-TF input and output files. The application is fully described in the FLOWTRAN-TF Software Testing report.

References

Aleman, et al., 1993a, "FLOWTRAN-TF Software Design (U)", WSRC-TR-92-532.

Aleman, et al., 1993b, "FLOWTRAN-TF Software Testing (U)", WSRC-TR-93-084

Aleman, et al., 1993c, "FLOWTRAN-TF v1.2 Source Code (U)", WSRC-TR-93-086.

Flach, G. P., 1991, FLOWTRAN-TF Code Development Technical and QA Plan, Rev. 0, 8/1/91, QA task number 89-021-1.

Flach, G. P., 1993a, FLOWTRAN-TF Software Requirements Specification, Rev. 1, 1/14/93, QA task number 89-021-1.

Flach, G. P., 1993b, FLOWTRAN-TF Software Test Plan, Rev. 1, 1/29/93, QA task number 89-021-1.

Input Specifications

A detailed guide to input deck creation and interpretation is given in this section. All data input is free format.

The required input described below may be augmented with additional descriptive comments by making use of the '!' character. All exclamation points and trailing characters are considered by FLOWTRAN-TF to be extraneous comments and are ignored.

The '$' and '&' characters also take on special meanings and are used to abbreviate the input. In many instances repetitive lines of input are required. Rather than explicitly specifying each line, the repeating line may be identified with a dollar sign and the number of occurrences of the line placed after the numerical input. If a group of lines repeats, the first line is identified with '$ ##' and the additional lines are marked with a '&'.

For example

```
! optional comments
commnt
1.0   2.0   3   4   $ 3  ! optional comments
5     6              &    ! optional comments
! optional comments
```

is equivalent to

```
commnt
1.0   2.0   3   4
5     6
1.0   2.0   3   4
5     6
1.0   2.0   3   4
5     6
```

The remainder of this section specifies in detail the input information required by FLOWTRAN-TF. The user is assumed to be familiar with the FLOWTRAN-TF Software Design report. The sample input deck given in the next section is provided for example. The FLOWTRAN-TF source listing (WSRC-TR-93-086) may be used for further clarification of physical models or input requirements as needed.

Section 1 — Input file title

The first section of the input file is a single comment line read by subroutine INOPTS giving a title or other descriptive information about the input. Section 1 has the form

```
commnt
```

where

commnt ≡ Input file title

Section 2 Run time, time step limits, print time intervals

The second section starts with a comment line followed by a second line containing the run time, time step limits and print time intervals. Section 2 is read by subroutine INOPTS and takes the form

```
commnt

runsec     dtmin     dtmax     dtpfld     dtpsld     dtppwr     dtpdmp
```

where

commnt ≡ Section label

runsec ≡ End time of calculation (s)

dtmin ≡ Minimum permitted time step (s). A value of 10^{-5} or smaller is suggested

dtmax ≡ Maximum permitted time step (s). A value of approximately 0.5 is suggested.

dtpfld ≡ Print time interval for fluid output (s)

dtpsld ≡ Print time interval for solid output (s)

dtppwr ≡ Print time interval for power output (s)

dtpdmp ≡ Print time interval for binary data output (s)

Section 3 Boundary condition, units, restart and print flags

The section starts with a comment line followed by a second line containing several boundary condition, dimensional units, restart and print option parameters. Section 3 is read by subroutine INOPTS and takes the form

```
commnt

ibond   iunits   istart   isave   iprint   iexp   icrit   iscrn   iword   istdy   ippu
```

where

commnt ≡ Section label

ibond ≡ Inlet boundary condition option number. Options are
1 for prescribed pressure
2 for prescribed liquid volumetric flowrate
3 for prescribed gas volumetric flowrate
4 for prescribed liquid and gas volumetric flowrates

iunits ≡ Units selector for fluid input (only). Options are
1 for SI units (m , m^2 , m^3 , Pa , m^3/s, °C)
2 for SRS units (in, in^2, in^3, psia, gpm , °C)

`istart` ≡ Initialization from restart file flag. Options are

0 for initial conditions set by this input file
with `tsec` initialized to 0

1 for initial conditions set by a *binary* restart file
with `tsec` initialized to the value of `runsec` in the restart file

2 for initial conditions set by a *binary* restart file
with `tsec` initialized to *0*

3 for initial conditions set by a *binary* restart file
with tsec initialized to `tcrmax` in this input file

−1 for initial conditions set by a *ASCII* restart file
with `tsec` initialized to the value of `runsec` in the restart file

−2 for initial conditions set by a *ASCII* restart file
with `tsec` initialized to *0*

−3 for initial conditions set by a *ASCII* restart file
with tsec initialized to `tcrmax` in this input file

`isave` ≡ Restart file creation flag. Options are

0 for no restart file containing conditions at `runsec` saved

1 for a *binary* restart file containing conditions at `runsec` saved
with `tsec` equal to `runsec` (unchanged)

2 for a *binary* restart file containing conditions at `runsec` saved
with `tsec` set to *0*

3 for a *binary* restart file containing conditions at `runsec` saved
with `tsec` set to `tcrmax`

−1 for a *ASCII* restart file containing conditions at `runsec` saved
with `tsec` equal to `runsec` (unchanged)

−2 for a *ASCII* restart file containing conditions at `runsec` saved
with `tsec` set to *0*

−3 for a *ASCII* restart file containing conditions at `runsec` saved
with `tsec` set to `tcrmax`

`iprint` ≡ Fluid print flag. Options are

1 for short print (pressure, void fraction, temperatures and velocities)

2 for long print (above plus interfacial heat and mass transfer information, densities and enthalpies, flowrates, and superficial velocities)

3 for medium print (pressure, void, temperatures, phasic and superficial velocities, and volumetric flowrates)

`iexp` ≡ Power input flag. Options are
0 for full power input
1 for abbreviated 'experimental rig' power input

`icrit` ≡ Criteria print flag. Options are
0 for no printing of power iteration criteria messages
1 for printing of power iteration criteria messages

`iscrn` ≡ Screen print flag. Options are

0 for no print of time step summary information to screen

1 for short print of time step information to screen

2 for long print of time step information to screen (not recommended in general)

`iword` ≡ Word length flag used for binary dumps. Options are
1 for 1 byte per word (VAX)
2 for 8 bytes per word (CRAY, IBM 6000)

`istdy` ≡ Steady-state flag. Options are

0 for a transient calculation starting from the initial value of `tsec` and ending at `runsec`

1 for a transient calculation starting from the initial value of `tsec` and ending when steady-state conditions are reached, `nstdy` is exceeded, or `tsec` = `runsec`, whichever occurs first. See `tolss` parameter below.

2 for a steady-state calculation (`tsec` is not advanced) using the boundary conditions at the initial value of `tsec`. Calculations end when steady-state conditions are reached or `nstdy` is exceeded, whichever occurs first. `runsec` must be greater than the initial value of `tsec`. See `tolss` parameter below.

3 for a steady-state calculation as with option 2 automatically followed by a transient calculation as with option 0. See `tolss` parameter below.

`ippu` ≡ Plenum pressure update flag. Options are

0 for no update

1 for update always

2 for update only when the plenum void fraction is less than `alphs` defined below.

Section 4 Liquid component flag, reference pressure, ...

The section starts with a comment line followed by a second line containing a variety of parameters as specified below. Section 4 is read by subroutine `INOPTS` and takes the form

```
commnt

ilq pref factor vminz vminx tol tolss nstdy tsupw htdamp cidamp xdelt xturb xa0
```

where

`commnt` ≡ Section label

`ilq` ≡ Liquid component flag. Options are
1 for light water (H_2O)
2 for heavy water (D_2O)

`pref` ≡ Reference pressure used in conjunction with the relative tolerance for INNER pressure iterations, `epsin`, to determine the absolute tolerance. (Default is 101325 Pa or 14.696 psia)

`factor` ≡ Liquid compressibility factor. `factor` is a multiplier to $\partial\rho_f/\partial P$ in the liquid equation of state model. See comments below

`vminz` ≡ Minimum axial velocity for full donoring. The units of `vminz` are m/s *regardless of the value of* `iunits`. (Typical selection is `0.0` to `0.05` m/s)

`vminx` ≡ Minimum azimuthal velocity for full donoring. The units of `vminx` are m/s *regardless of the value of* `iunits`. (Typical selection is `0.0` to `0.05` m/s)

`tol` ≡ Tolerance for change between time steps used to control calculation accuracy. `TIMSTP` controls Δt such that `tol` is not exceeded anywhere in the mesh by the

- relative change in pressure, $|P^{n+1} - P^n|/P^n$
- absolute change in void fraction $|\alpha^{n+1} - \alpha^n|$
- relative change in gas temperature, $|T_g^{n+1} - T_g^n|/T_g^n$
- relative change in liquid temperature, $|T_f^{n+1} - T_f^n|/T_f^n$
- absolute change in air mass fraction, $|X_a^{n+1} - X_a^n|$

`tolss` ≡ Tolerance on the rate of change of mixture extensive enthalpy, dH_{mix}/dt, for defining when steady-state conditions have been reached (J/m^3s) (`istdy` = 1, 2 or 3)

`nstdy` ≡ Maximum number of time steps allowed during an attempt to reach steady-state conditions (`istdy` = 1, 2 or 3)

`tsupw` ≡ Wall temperature bias in power iteration criteria #2 and #3 (ΔT_{sup})

`htdamp` ≡ Solid-fluid wall heat transfer damping factor used as follows

$$q_{wk}^{n+1} \leftarrow (\texttt{htdamp})q_{wk}^{n+1} + (1 - \texttt{htdamp})q_{wk}^{n}$$

`cidamp` ≡ Interfacial drag and heat/mass transfer rate coefficient damping parameter. The magnitude is the value of the time constant τ used as described below. The sign selects between two damping schemes. An exponential decay factor is first computed as

$$\gamma^n = 2^{-\frac{\Delta t^n}{\tau}}$$

where $\tau \equiv$ |`cidamp`|. If `cidamp` is *positive* then the interfacial drag coefficient is computed using the 'averager' option as

$$C_i^n \leftarrow \gamma^n C_i^{n-1} + \left(1-\gamma^n\right) C_i^n$$

If `cidamp` is *negative* then the 'limiter' option is used:

$$C_i^n \leftarrow \max\left[\min\left(C_i^n, \frac{C_i^{n-1}}{\gamma^n}\right), C_i^{n-1}\gamma^n\right]$$

Analogous operations apply to the interfacial heat and mass transfer rate coefficients. Small `cidamp` gives large weight to the new time step value (small time constant = fast response)

`xdelt` ≡ Multiplier to Δt in solid calculations for `istdy` ≥ `1`. `xdelt` greater than `1` has the effect of decreasing heat capacity of the solid and thus speeding progress towards a steady-state solution. (`xdelt` does not affect steady-state results)

`xturb` ≡ Multiplier to the inter-subchannel turbulent mixing terms. Can be used for sensitivity studies or to turn mixing off (`xturb` = `0`). Default value is `1.0`.

`xa0` ≡ Reference air mass fraction in Γ_a model. Must be set to zero.

Single-phase liquid calculations are frequently difficult to initiate with a prescribed liquid flowrate boundary condition because water is nearly incompressible. With this boundary condition, large pressure changes typically occur in the first time-step in making pressures consistent with the imposed flowrate.

Large pressure changes also occur whenever the prescribed flowrate forcing function is not continuous through the first derivative. In fact, an infinite inlet pressure change is required to make any discontinuous change in flowrate of an incompressible fluid as can be seen from Newton's second law of motion. If the slope dQ_f/dt is discontinuous, then inlet pressure is a discontinuous for an incompressible fluid. Water is compressible but only slightly.

Increasing the liquid compressibility will reduce the changes in pressure in both cases discussed above. This may be done by changing `pref` from the default of `1.0` to say `10.0` or `100.0`.

Section 5 Boiling curve and interphase transport options

The section starts with a comment line followed by a second line containing boiling curve and interfacial heat and mass transfer parameters. Section 5 is read by subroutine INOPTS and takes the form

```
commnt

iboil    ichf    matgas    persat    igami    igamw
```

where

commnt ≡ Section label

iboil ≡ Boiling curve flag. Options are

−1 for nonboiling, forced convection SRS correlation (regardless of wall temperature even if superheated)

0 for nonboiling, forced convection Sieder-Tate correlation (regardless of wall temperature even if superheated)

1 for Mikic boiling curve

2 for Chen boiling curve

ichf ≡ Critical heat flux (CHF) correlation flag. Options are
1 for SRS correlation
2 for Biasi correlation

matgas ≡ Dissolved gas material. Options are
1 for helium dissolved in water
2 for air dissolved in water

persat ≡ Percent saturation of dissolved gas (0.0-100.0)

igami ≡ Bulk interfacial heat and mass transfer flag. Options are

0 for simple nonphysical IHMT model used for code development and testing purposes. For this model $\Gamma = 0$ and $E_i = 10000(T_f - T_g)$

1 for physically-based IHMT model to be used for all applications work

igamw ≡ Wall interfacial heat and mass transfer flag. Options are
0 for no wall interfacial mass and energy transfer
1 for wall interfacial mass and energy transfer

iboil options −1 and 0 are useful for $T_{wall} = T_{sat}$ power iterations for which there is no boiling when $T_{wall} = T_{sat}$. Frequently during power iterations, an iterate will significantly exceed the $T_{wall} = T_{sat}$ power and calculations will slow down due to a ACCCHK restriction on time-step size or other factor. Choosing iboil = −1 or 0 prevents boiling and small time-steps without affecting the results when $T_{wall} = T_{sat}$.

Section 6 — Solid parameters

The section starts with a comment line followed by a second line containing parameters for the solid heat conduction calculations. Section 6 is read by subroutine INOPTS and takes the form

```
commnt

isolid    iaxial    wss    ncms    tsolid    tsrfac
```

where

`commnt` ≡ Section label

`isolid` ≡ Solid calculations flag. Options are
0 for no solid calculations and no wall heat transfer to fluid
1 for solid calculations and wall heat transfer to fluid

`iaxial` ≡ Axial heat conduction flag. Options are
0 for no axial heat conduction
1 for axial heat conduction

`wss` ≡ Weighting factor between n and n+1 time quantities in spatial differenced terms. `wss` must be between `0.0` and `1.0`. Example selections are

`0.0` for fully explicit

`1.0` for fully implicit

`ncms` ≡ Number of coarse mesh rebalances

`tsolid` ≡ Initial solid internal temperature (°C)

`tsrfac` ≡ Initial solid surface temperature (°C)

Section 7 — INNER, GAMMAI and NEWTON iteration parameters

The section starts with a comment line followed by 3 lines containing iteration control parameters for the INNER, GAMMAI and NEWTON iterations, respectively. Section 7 is read by subroutine INOPTS and takes the form

```
commnt

ischem    irebal    ncmr    epsin                                    initmx

                            epsy    epsf                             nitysi

                            epsp    epsalp    epstg    epstf    epsxa    nitmax
```

where

`commnt` ≡ Section label

`ischem` ≡ Solution strategy flag for INNER pressure-only problem. Options are
1 for axial tridiagonal scheme
2 for azimuthal tridiagonal scheme
3 for alternating axial and azimuthal tridiagonal schemes

`irebal` ≡ Coarse mesh rebalance flag. Options are
0 for no coarse mesh rebalance
1 for a coarse mesh rebalance on the first overall iteration pass only
2 for a coarse mesh rebalance on each overall iteration pass

`ncmr` ≡ Number of coarse mesh rebalances per pass when `irebal` = 1 or 2

`epsin` ≡ INNER iteration convergence tolerance for relative pressure change. The reference pressure is `pref` specified in section 4 above. (For `pref` = 1 atm default is about 10^{-4})

`initmx` ≡ Maximum number of INNER iterations allowed. (Default is 50)

`epsy` ≡ GAMMAI iteration convergence tolerance for relative change in interface steam mole fraction, y_{si}. GAMMAI constrains the resulting absolute tolerance, `epsy*ysi`, to be greater than or equal to 10^{-6}, however. (Default is 10^{-4})

`epsf` ≡ GAMMAI iteration convergence tolerance for

$$F(y_{si}) = \Gamma(1 - y_{si} + \phi\Delta y_s) - K_g\Delta y_s$$

(Default is 0.1)

`nitysi` ≡ Maximum number of GAMMAI iterations. (Default is 50)

`epsp` ≡ NEWTON iteration convergence tolerance for absolute pressure change (Pa). (Default is about 100.0)

`epsalp` ≡ NEWTON iteration convergence tolerance for absolute void fraction change. (Default is about 0.005)

`epstg` ≡ NEWTON iteration convergence tolerance for absolute gas temperature change (°C). (Default is 0.05)

`epstf` ≡ NEWTON iteration convergence tolerance for absolute liquid temperature change (°C). (Default is about 0.05)

`epsxa` ≡ NEWTON iteration convergence tolerance for absolute air mass fraction change. (Default is about 0.005)

`nitmax` ≡ |`nitmax`| is the maximum number of NEWTON iterations. If `nitmax` is positive and |`nitmax`| iterations are reached then the computations proceed to the next time using m=`nitmax` iteration values. For negative `nitmax` and m=`nitmax`, the time step is aborted and reattempted with reduced Δt.. (Default is 50)

For 2-D fluid calculations in the Middle section the recommended INNER iteration scheme is the alternating axial-azimuthal scheme with coarse mesh rebalance given by ischem = 3, irebal = 1 and ncmr = 1.

INNER iterations cease when the epsin criterion is satisfied or initmx is exceeded. GAMMAI iterations cease when the epsy criterion is satisfied and $F(y_{si}) < epsf$ or nitysi is exceeded. NEWTON iterations cease when the epsp, epsalp, epstg, epstf and epsxa criteria are all satisfied or nitmax is exceeded.

The user should be aware that the convergence tolerances for the INNER and GAMMAI calculations should be smaller than those for the NEWTON iteration; that is, the NEWTON iteration requires input information more accurate than its requested accuracy. The maximum change in the interfacial steam mole fraction and air mass fraction iterates in the GAMMAI and NEWTON iterations is 0.04. During phase transitions these parameters may change from approximately 0 to 1 or vice versa during a single time-step. Therefore, the maximum number of GAMMAI and NEWTON iterations must exceed 25. A value of 50 is suggested for both.

Section 8 — Number of spline profiles and data points

The section starts with a comment line followed by a line specifying the number of spline data groups (ndata), the maximum number of radial points in power shapes, and the number of time snapshots for axial power profiles. The next ndata lines contain the number of data points per data set and the number of data sets per group. Section 8 is read by subroutine INOPTS and takes the form

```
commnt

ndata,  mnrp,  itime

npdat(1)       nset(1)

npdat(2)       nset(2)

  ⋮              ⋮

npdat(ndata)   nset(ndata)
```

where

commnt ≡ Section label

ndata ≡ Number of data groups

mnrp ≡ Maximum number of radial points in power shapes

itime ≡ Number of time snapshots for axial power profiles

npdat(i) ≡ Number of data points per data set

nset(i) ≡ Number of data sets per group

As an illustration, consider the 7 data pairs (x,y), (x,z), (a,b), (a,c), (a,d), and (a,e) grouped in the last section of the input file as shown below:

x_1 y_1 z_1
x_2 y_2 z_2
x_3 y_3 z_3
x_4 y_4 z_4

a_1 b_1 c_1 d_1 e_1
a_2 b_2 c_2 d_2 e_2
a_3 b_3 c_3 d_3 e_3

For this example, `ndata = 2`, `npdat(1) = 4`, `nset(1) = 2`, `npdat(2) = 3` and `nset(2) = 4`.

Section 9 — Geometric dimensions

The section starts with a comment line followed by a line specifying the geometric dimensions of the solid and fluid meshes. Section 9 is read by subroutine `INOPTS` and takes the form

```
commnt

nchn   nxmax   ncyln   na   nrmax   nzt   nz   nzb
```

where

`commnt` ≡ Section label

`nchn` ≡ Number of flow channels in the Middle section of the fluid mesh

`nxmax` ≡ Maximum number of fluid azimuthal cells per channel (≥ 1)

`ncyln` ≡ Number of solid cylinders (≥ 1)

`na` ≡ Number of solid azimuthal cells (≥ 1)

`nrmax` ≡ Maximum number of solid radial cells (≥ 3)

`nzt` ≡ Number of Top section axial fluid cells (≥ 2)

`nz` ≡ Number of Middle section axial cell layers (≥ 3)

`nzb` ≡ Number of Bottom section axial fluid cells (≥ 2)

Section 10 — Active core parameters

The section starts with a comment line followed by a line specifying active core parameters. Section 10 is read by subroutine `INOPTS` and takes the form

```
commnt

izht    izhb    gap    tmod0    itmod    hmod    iradbc    douts    emisi    emiso
```

where

commnt ≡ Section label

izht ≡ Number of first heated cell in Middle section ($1 \leq izht \leq nz$)

izhb ≡ Number of last heated cell in Middle section ($izht \leq izhb \leq nz$)

gap ≡ Gap distance from active core to tank bottom

tmod0 ≡ Multiplier to moderator spline function. The printed output assumes that the spline function (selected by itmod) starts with 1.0 making tmod0 the initial moderator temperature

itmod ≡ Number of the data set from which the spline function defining moderator temperature is to be constructed.

hmod ≡ Moderator heat transfer coefficient (W/m^2K or $BTU/hr\ ft^2\ ^\circ F$ depending on iunits selection)

iradbc ≡ Thermal radiation outer boundary condition flag. Options are

0 for no radiation heat transfer

1 for radiation heat transfer between the outer surface of the outer solid tube and another annular tube of diameter douts, emissivity emiso and temperature equal to that of the moderator.

douts ≡ Diameter of radiating outer boundary surface

emisi ≡ Emissivity of outer surface of outer solid tube

emiso ≡ Emissivity of radiating outer boundary surface

Convection heat transfer from the outer surface of the outer solid tube only occurs over the wetted portion of the tube as defined by tank level. Radiative heat transfer, if selected by iradbc = 1, occurs only over the dry portion of the outer tube. See section 2.5.1 of FLOWTRAN-TF Software Design report for more detailed information.

Section 11 Power iteration input

The section starts with a comment line followed by a line specifying power iteration parameters. Section 11 is read by subroutine INOPTS and takes the form

```
commnt

asypwr    maxpi    tolpow    ncrit
```

where

commnt ≡ Section label

asypwr ≡ Multiplier to the spline function(s) defining the transient power response (kW)

maxpi ≡ Maximum number of power iterations (Recommended as 10 or less)

tolpow ≡ Convergence tolerance for power

ncrit ≡ Total number of power iteration criteria (Must specify 4)

The printed output assumes the power spline function starts with 1.0 making power the initial power level but this is not a requirement. Also, power may take on any positive, zero or negative value.

Section 12 — Sensitivity parameters

The section starts with a comment line followed by a line generally specifying numerous parameters enabling the user to perform sensitivity calculations through input. Section 12 is read by subroutine INOPTS and takes the form

```
commnt

xcofh  xreh  xcofl  xrel  xkmet  xcvmet  xhfi  xhgi  xkgi  xphi  cizfac  cixfac  iribv
xfric  plnht  cipln  formhs  alphs  alb2  als2  ala2  expbs  expsa  delp1  delp2
sigai  sigam  sigfi  sigfm  dalsub  theta0
```

where

commnt ≡ Section label

xcofh ≡ Multiplier to the leading coefficient in the dispersed regime forced convection heat transfer correlation given by equation (2.5.1-4a) in the FLOWTRAN-TF Software Design report. Appears in subroutines SRLHTC and MIKIC.

xreh ≡ Multiplier to the Reynolds number exponent in the dispersed regime forced convection heat transfer correlation given by equation (2.5.1-4a) in the FLOWTRAN-TF Software Design report. Appears in subroutines SRLHTC and MIKIC.

xcofl ≡ Multiplier to the leading coefficient in the annular regime forced convection heat transfer correlation given by equation (2.5.1-5a) in the FLOWTRAN-TF Software Design report. Appears in subroutines SRLHTC and MIKIC.

xrel ≡ Multiplier to the Reynolds number exponent in the annular regime forced convection heat transfer correlation given by equation (2.5.1-5a) in the FLOWTRAN-TF Software Design report. Appears in subroutines SRLHTC and MIKIC.

`xkmet` ≡ Multiplier to the solid thermal conductivity

`xcvmet` ≡ Multiplier to the solid heat capacity

`xhfi` ≡ Multiplier to the fluid-side interfacial heat transfer rate coefficient

`xhgi` ≡ Multiplier to the gas-side interfacial heat transfer rate coefficient

`xkgi` ≡ Multiplier to the gas-side interfacial mass transfer rate coefficient

`xphi` ≡ Multiplier to the ϕ parameter associated with the Ackermann mass transfer rate correction

`cizfac` ≡ Axial interfacial drag coefficient multiplier or value, depending on sign. If `cizfac` is positive, `cizfac` is a multiplier to the axial interfacial drag coefficient. If `cizfac` is negative, `cizfac` is the axial interfacial drag coefficient ((Pa/m)*(m/s)$^{-2}$ regardless of `iunits` value).

`cixfac` ≡ Azimuthal interfacial drag coefficient multiplier or value, depending on sign. If `cixfac` is positive, `cixfac` is the azimuthal interfacial drag coefficient ((Pa/m)*(m/s)$^{-2}$ regardless of `iunits` value). If `cixfac` is negative, `cixfac` is a multiplier to the azimuthal interfacial drag coefficient. Default value is $+10^9$.

Note that `cizfac` and `cixfac` use opposite sign conventions. The default for both is a positive value however.

`iribv` ≡ Rib void fraction correlation flag. Options are

0 for rib void fraction equal to cell average void fraction

1 for rib void fraction defined by equation (2.5.7-5) in the FLOWTRAN-TF Software Design report.

`xfric` ≡ Multiplier to the frictional component of axial wall drag.

`plnht` ≡ Channel vertical height H in the horizontal, stratified flow model at the junction between the Plenum and Top section. See section 3.6 of the FLOWTRAN-TF Software Design report for more information.

`cipln` ≡ Interfacial drag coefficient $C^z_{i,strat}$ in the horizontal, stratified flow model ((Pa/m)*(m/s)$^{-2}$ regardless of `iunits` value)

`formhs` ≡ Form loss coefficient K^z_{strat} in the horizontal, stratified flow model

`alphs` ≡ Magnitude is the void fraction α_{strat} in the horizontal, stratified flow model which defines the breakpoint between dispersed and separated flow. The sign determines which of two approximations of the void gradient term is used. For `alphs` positive, the finite difference approximation

$$\frac{\partial \alpha}{\partial z} \rightarrow \frac{(\alpha_{t1} - \alpha_{pl})A_{cz,1/2}}{V_{z,1/2}}$$

is used. For `alphs` negative,

$$\frac{\partial \alpha}{\partial z} \rightarrow \frac{(1 - \alpha_{pl})A_{cz,1/2}}{V_{z,1/2}}$$

is used whenever $\alpha_{t1} > \alpha_{pl}$. See the FLOWTRAN-TF Software Design report for a discussion of these choices.

`alb2` ≡ Flow regime map parameter α_b^{**}. (Default value is `0.25`)

`als2` ≡ Flow regime map parameter α_s^{**}. (Default value is `0.52`)

`ala2` ≡ Flow regime map parameter α_a^{**}. (Default value is `0.75`)

`expbs` ≡ Flow regime map parameter n_{bs}. (Default value is `4.0`)

`expsa` ≡ Flow regime map parameter n_{sa}. (Default value is `4.0`)

`delp1` ≡ Mk22 channel inlet void distribution parameter. $\Delta P <$ `delp1` is classified as an adverse pressure gradient. The units of `delp1` are Pa regardless of iunits value. (Default value is 0 Pa)

`delp2` ≡ Mk22 channel inlet void distribution parameter. $\Delta P >$ `delp2` is classified as a favorable pressure gradient. The units of `delp1` are Pa regardless of iunits value. (Default value is 200 Pa)

`sigai` ≡ Mk22 channel inlet void distribution sensitivity parameter augmenting the adverse-inner channel correlation given by equation (2.5.6-13) in the FLOWTRAN-TF Software Design report as

$$\alpha_i^{adv} = \text{r.h.s. of equation (2.5.6-13)} + 4\alpha(1-\alpha)\sigma_{ai}$$

where $\sigma_{ai} \equiv$ `sigai`. Default value is 0.

`sigam` ≡ Mk22 channel inlet void distribution sensitivity parameter augmenting the adverse-middle channel correlation given by equation (2.5.6-14) in the FLOWTRAN-TF Software Design report as

$$\alpha_m^{adv} = \text{r.h.s. of equation (2.5.6-14)} + 4\alpha(1-\alpha)\sigma_{am}$$

where $\sigma_{am} \equiv$ `sigam`. Default value is 0.

`sigfi` ≡ Mk22 channel inlet void distribution sensitivity parameter augmenting the favorable-inner channel correlation given by equation (2.5.6-15) in the FLOWTRAN-TF Software Design report as

$$\alpha_i^{fav} = \text{r.h.s. of equation (2.5.6-15)} + 4\alpha(1-\alpha)\sigma_{fi}$$

where $\sigma_{fi} \equiv$ `sigfi`. Default value is 0.

`sigfm` ≡ Mk22 channel inlet void distribution sensitivity parameter augmenting the favorable-middle channel correlation given by equation (2.5.6-16) in the FLOWTRAN-TF Software Design report as

$$\alpha_m^{fav} = \text{r.h.s. of equation (2.5.6-16)} + 4\alpha(1-\alpha)\sigma_{fm}$$

where $\sigma_{fm} \equiv$ `sigfm`. Default value is 0.

`dalsub` ≡ Middle section subchannel inlet void maldistribution magnitude. The Middle section subchannel inlet void fractions are modified as

$$\alpha_{ix,ic} \leftarrow \alpha_{ix,ic} + \Delta\alpha\cos(\theta - \theta_0)$$

where $\Delta\alpha$ is `dalsub`, θ is the orientation of the subchannel cell center, and θ_0 is defined below. Default value is 0.

`theta0` ≡ Middle section subchannel inlet void maldistribution orientation in degrees. Peak void (lowest liquid flow) occurs at $\theta = \theta_0$. Azimuthal cell face number 1 in channel 1 is 0°.

Section 13 — Plenum boundary cell geometry

The section starts with a comment line followed by a line specifying the Plenum cell volume and cell center area. Section 13 is read by subroutine `GEOFLD` and takes the form

```
commnt

volpl    acpl
```

where

`commnt` ≡ Section label

`volpl` ≡ Volume of Plenum boundary cell

`acpl` ≡ Cell center area of Plenum boundary cell

Section 14 Top section cell geometry and hydraulic parameters

Section 14 is read by subroutine GEOFLD and takes on one of four forms depending on the values of iuform:

For iuform = 1 and then 1

```
commnt

iuform

dztot

iuform

volume  areat  areac  cosine  diamtr  absr  fmlt  fre  form  deff  fldm  fldc  c0b
c0s  ckb  cks
```

For iuform = 2 and then 1

```
commnt

iuform

dzt(1)    dzt(2)    dzt(3)  ...  dzt(nzt)

iuform

volume  areat  areac  cosine  diamtr  absr  fmlt  fre  form  deff  fldm  fldc  c0b
c0s  ckb  cks
```

For iuform = 1 and then 2

```
commnt

iuform

dztot

iuform

 volt(1)    act(1)    azt(1)  cost(1)   dht(1)  absrt(1)  fmltt(1)  fret(1)  formt(1)
defft(1)  fldmt(1)  fldct(1)  c0bt(1)  c0st(1)   ckbt(1)   ckst(1)
 volt(2)    act(2)    azt(2)  cost(2)   dht(2)  absrt(2)  fmltt(2)  fret(2)  formt(2)
defft(2)  fldmt(2)  fldct(2)  c0bt(2)  c0st(2)   ckbt(2)   ckst(2)
        .
        .
        .
volt(nzt)    act(nzt)    azt(nzt)   cost(nzt)    dht(nzt)  absrt(nzt)  fmltt(nzt)
fret(nzt)  formt(nzt)  defft(nzt)  fldmt(nzt)  fldct(nzt)   c0bt(nzt)   c0st(nzt)
ckbt(nzt)   ckst(nzt)
```

For `iuform` = 2 and then 2

```
commnt

iuform

dzt(1)    dzt(2)    dzt(3)  ...  dzt(nzt)

iuform

 volt(1)    act(1)    azt(1)  cost(1)   dht(1)  absrt(1)  fmltt(1)  fret(1)  formt(1)
defft(1)  fldmt(1)  fldct(1)  c0bt(1)  c0st(1)   ckbt(1)   ckst(1)
 volt(2)    act(2)    azt(2)  cost(2)   dht(2)  absrt(2)  fmltt(2)  fret(2)  formt(2)
defft(2)  fldmt(2)  fldct(2)  c0bt(2)  c0st(2)   ckbt(2)   ckst(2)
       .
       .
       .
volt(nzt)    act(nzt)    azt(nzt)   cost(nzt)    dht(nzt)  absrt(nzt)  fmltt(nzt)
fret(nzt)  formt(nzt)  defft(nzt)  fldmt(nzt)  fldct(nzt)   c0bt(nzt)   c0st(nzt)
ckbt(nzt)   ckst(nzt)
```

where

`commnt` ≡ Section label

`iuform` ≡ Uniformity flag. Options are
1 for uniform cell parameters
2 for individually specified cell parameters

`dztot` ≡ Total length of Top section

`dzt(jz)` ≡ Length of cell `jz`, Δz

`volume/volt(jz)` ≡ Cell volume, V_c

`areat/act(jz)` ≡ Face area, A_{cz}

`areac/azt(jz)` ≡ Cell area, A_{zz}

`cosine/cost(jz)` ≡ Face direction cosine, $\cos\theta$. Specify `+1.0` for a gravitational vector aligned with the positive z direction.

`diamtr/dht(jz)` ≡ Face hydraulic diameter, D_h

`absr/absrt(jz)` ≡ Face absolute wall roughness, ε

`fmlt/fmltt(jz)` ≡ Face frictional drag multiplier

`fre/fret(jz)` ≡ Face hydraulic diameter correction factor, K_h.

`form/formt(jz)` ≡ Face form loss coefficient, K^z

`deff/defft(jz)` ≡ Face characteristic dimension for the slug flow regime, D_c

`fldm/fldmt(jz)` ≡ Face parameter m in CCFL correlation

`fldc/fldct(jz)` ≡ Face parameter C in CCFL correlation

`c0b/c0bt(jz)` ≡ Face distribution coefficient for the bubbly regime, C_{0b}

`c0s/c0st(jz)` ≡ Face distribution coefficient for the slug regime, C_{0s}

`ckb/ckbt(jz)` ≡ Face drift velocity correlation coefficient for the bubbly regime, K_b

`cks/ckst(jz)` ≡ Face drift velocity correlation coefficient for the slug regime, K_s

Note that wall frictional drag may be turned-off by specifying `fmlt/fmltt(jz) = 0.`

Section 15 — Middle section cell lengths

Section 15 is read by subroutine `GEOFLD` and takes on one of two forms depending on the value of `iuform`:

For `iuform = 1`

```
commnt

iuform    bow    omega

dztot
```

For `iuform = 2`

```
commnt

iuform    bow    omega

dz(1)    dz(2)    dz(3) ...    dz(nz+1)
```

where

`commnt` ≡ Section label

`iuform` ≡ Uniformity flag. Options are
1 for uniform cell parameters
2 for individually specified cell parameters

`bow` ≡ Lateral distance axial center of Middle section bows. (δ in section 2.1 in FLOWTRAN-TF Software Design report)

`omega` ≡ Orientation of bowing (ω in section 2.1 in FLOWTRAN-TF Software Design report)

`dztot` ≡ Total length of Middle section

`dz(jz)` ≡ Length of cell `jz`

Section 16 Channel 1

Section 16 is read by subroutine GEOFLD and takes on the form:

```
commnt

nsub    di    do
```

where

commnt ≡ Section label

nsub ≡ Number of subchannels

di ≡ Inner diameter of channel

do ≡ Outer diameter of channel

Section 17 Channel 1 azimuthal cell geometry and hydraulic parameters

Section 17 is read by subroutine GEOFLD and takes on one of three forms:

For iuform = 1 (axial and azimuthal uniformity)

```
commnt

iuform

gap1    gap2    cosine    diamtr    absr    fmlt    fre    form
```

For iuform = 2 (axial uniformity)

```
commnt

iuform

  acx(2,1,1)     axx(2,1,1)     cosx(2,1,1)    dhx(2,1,1)    absrx(2,1,1)
fmltx(2,1,1)    frex(2,1,1)    formx(2,1,1)
  acx(2,2,1)     axx(2,2,1)     cosx(2,2,1)    dhx(2,2,1)    absrx(2,2,1)
fmltx(2,2,1)    frex(2,2,1)    formx(2,2,1)
  acx(2,3,1)     axx(2,3,1)     cosx(2,3,1)    dhx(2,3,1)    absrx(2,3,1)
fmltx(2,3,1)    frex(2,3,1)    formx(2,3,1)
  acx(2,4,1)     axx(2,4,1)     cosx(2,4,1)    dhx(2,4,1)    absrx(2,4,1)
fmltx(2,4,1)    frex(2,4,1)    formx(2,4,1)
```

For `iuform = 3`

```
commnt

iuform

  acx(2   ,1,1)      axx(2   ,1,1)    cosx(2   ,1,1)      dhx(2   ,1,1)
absrx(2   ,1,1)    fmltx(2   ,1,1)    frex(2   ,1,1)    formx(2   ,1,1)
  acx(2   ,2,1)      axx(2   ,2,1)    cosx(2   ,2,1)      dhx(2   ,2,1)
absrx(2   ,2,1)    fmltx(2   ,2,1)    frex(2   ,2,1)    formx(2   ,2,1)
  acx(2   ,3,1)      axx(2   ,3,1)    cosx(2   ,3,1)      dhx(2   ,3,1)
absrx(2   ,3,1)    fmltx(2   ,3,1)    frex(2   ,3,1)    formx(2   ,3,1)
  acx(2   ,4,1)      axx(2   ,4,1)    cosx(2   ,4,1)      dhx(2   ,4,1)
absrx(2   ,4,1)    fmltx(2   ,4,1)    frex(2   ,4,1)    formx(2   ,4,1)
  acx(3   ,1,1)      axx(3   ,1,1)    cosx(3   ,1,1)      dhx(3   ,1,1)
absrx(3   ,1,1)    fmltx(3   ,1,1)    frex(3   ,1,1)    formx(3   ,1,1)
  acx(3   ,2,1)      axx(3   ,2,1)    cosx(3   ,2,1)      dhx(3   ,2,1)
absrx(3   ,2,1)    fmltx(3   ,2,1)    frex(3   ,2,1)    formx(3   ,2,1)
  acx(3   ,3,1)      axx(3   ,3,1)    cosx(3   ,3,1)      dhx(3   ,3,1)
absrx(3   ,3,1)    fmltx(3   ,3,1)    frex(3   ,3,1)    formx(3   ,3,1)
  acx(3   ,4,1)      axx(3   ,4,1)    cosx(3   ,4,1)      dhx(3   ,4,1)
absrx(3   ,4,1)    fmltx(3   ,4,1)    frex(3   ,4,1)    formx(3   ,4,1)
       .
       .
       .
  acx(nz+1,1,1)      axx(nz+1,1,1)    cosx(nz+1,1,1)      dhx(nz+1,1,1)
absrx(nz+1,1,1)    fmltx(nz+1,1,1)    frex(nz+1,1,1)    formx(nz+1,1,1)
  acx(nz+1,2,1)      axx(nz+1,2,1)    cosx(nz+1,2,1)      dhx(nz+1,2,1)
absrx(nz+1,2,1)    fmltx(nz+1,2,1)    frex(nz+1,2,1)    formx(nz+1,2,1)
  acx(nz+1,3,1)      axx(nz+1,3,1)    cosx(nz+1,3,1)      dhx(nz+1,3,1)
absrx(nz+1,3,1)    fmltx(nz+1,3,1)    frex(nz+1,3,1)    formx(nz+1,3,1)
  acx(nz+1,4,1)      axx(nz+1,4,1)    cosx(nz+1,4,1)      dhx(nz+1,4,1)
absrx(nz+1,4,1)    fmltx(nz+1,4,1)    frex(nz+1,4,1)    formx(nz+1,4,1)
```

where

`commnt` ≡ Section label

`iuform` ≡ Uniformity flag. Options are
1 for axially and azimuthally uniform cell parameters
2 for axially uniform cell parameters
3 for individually specified cell parameters

`gap1/acx(jz,ix,ic)` ≡ Face radial *gap* (Rib gap). See comment below

`gap2/axx(jz,ix,ic)` ≡ Cell radial *gap* (Channel gap). See comment below

`cosine/cosx(jz,ix,ic)` ≡ Face direction cosine. Specify `0.0` for a gravitational vector aligned with the positive z direction.

`diamtr/dhx(jz,ix,ic)` ≡ Face hydraulic diameter

`absr/absrx(jz,ix,ic)` ≡ Face absolute wall roughness

`fmlt/fmltx(jz,ix,ic)` ≡ Face frictional drag multiplier

`fre/frex(jz,ix,ic)` ≡ Face hydraulic diameter correction factor, K_h.

`form/formx(jz,ix,ic)` ≡ Face form loss coefficient

For convenience, the rib and channel gaps are read temporarily into the `acx` and `axx` arrays. The code converts these to areas based on the cell lengths `dz(jz)`.

Section 18 Channel 1 axial cell geometry and hydraulic parameters

Section 18 is read by subroutine `GEOFLD` and takes on one of three forms:

For `iuform` = 1 (axial and azimuthal uniformity)

```
commnt

iuform

areaf    areac    cosine    diamtr    absr    fmlt    fre    form    deff    fldm
fldc    c0b    c0s    ckb    cks
```

For `iuform` = 2 (axial uniformity)

```
commnt

iuform

  acz(2   ,1,1)      azz(2   ,1,1)     cosz(2   ,1,1)      dhz(2   ,1,1)
absrz(2   ,1,1)    fmltz(2   ,1,1)     frez(2   ,1,1)    formz(2   ,1,1)
deffz(2   ,1,1)    fldmz(2   ,1,1)    fldcz(2   ,1,1)
 c0bz(2   ,1,1)     c0sz(2   ,1,1)     ckbz(2   ,1,1)     cksz(2   ,1,1)
  acz(2   ,2,1)      azz(2   ,2,1)     cosz(2   ,2,1)      dhz(2   ,2,1)
absrz(2   ,2,1)    fmltz(2   ,2,1)     frez(2   ,2,1)    formz(2   ,2,1)
deffz(2   ,2,1)    fldmz(2   ,2,1)    fldcz(2   ,2,1)
 c0bz(2   ,2,1)     c0sz(2   ,2,1)     ckbz(2   ,2,1)     cksz(2   ,2,1)
  acz(2   ,3,1)      azz(2   ,3,1)     cosz(2   ,3,1)      dhz(2   ,3,1)
absrz(2   ,3,1)    fmltz(2   ,3,1)     frez(2   ,3,1)    formz(2   ,3,1)
deffz(2   ,3,1)    fldmz(2   ,3,1)    fldcz(2   ,3,1)
 c0bz(2   ,3,1)     c0sz(2   ,3,1)     ckbz(2   ,3,1)     cksz(2   ,3,1)
  acz(2   ,4,1)      azz(2   ,4,1)     cosz(2   ,4,1)      dhz(2   ,4,1)
absrz(2   ,4,1)    fmltz(2   ,4,1)     frez(2   ,4,1)    formz(2   ,4,1)
deffz(2   ,4,1)    fldmz(2   ,4,1)    fldcz(2   ,4,1)
 c0bz(2   ,4,1)     c0sz(2   ,4,1)     ckbz(2   ,4,1)     cksz(2   ,4,1)
```

For `iuform = 3`

```
commnt

iuform

  acz(2   ,1,1)      azz(2   ,1,1)      cosz(2   ,1,1)      dhz(2   ,1,1)
absrz(2   ,1,1)    fmltz(2   ,1,1)      frez(2   ,1,1)    formz(2   ,1,1)
deffz(2   ,1,1)    fldmz(2   ,1,1)    fldcz(2   ,1,1)
 c0bz(2   ,1,1)     c0sz(2   ,1,1)     ckbz(2   ,1,1)     cksz(2   ,1,1)
  acz(2   ,2,1)      azz(2   ,2,1)      cosz(2   ,2,1)      dhz(2   ,2,1)
absrz(2   ,2,1)    fmltz(2   ,2,1)      frez(2   ,2,1)    formz(2   ,2,1)
deffz(2   ,2,1)    fldmz(2   ,2,1)    fldcz(2   ,2,1)
 c0bz(2   ,2,1)     c0sz(2   ,2,1)     ckbz(2   ,2,1)     cksz(2   ,2,1)
  acz(2   ,3,1)      azz(2   ,3,1)      cosz(2   ,3,1)      dhz(2   ,3,1)
absrz(2   ,3,1)    fmltz(2   ,3,1)      frez(2   ,3,1)    formz(2   ,3,1)
deffz(2   ,3,1)    fldmz(2   ,3,1)    fldcz(2   ,3,1)
 c0bz(2   ,3,1)     c0sz(2   ,3,1)     ckbz(2   ,3,1)     cksz(2   ,3,1)
  acz(2   ,4,1)      azz(2   ,4,1)      cosz(2   ,4,1)      dhz(2   ,4,1)
absrz(2   ,4,1)    fmltz(2   ,4,1)      frez(2   ,4,1)    formz(2   ,4,1)
deffz(2   ,4,1)    fldmz(2   ,4,1)    fldcz(2   ,4,1)
 c0bz(2   ,4,1)     c0sz(2   ,4,1)     ckbz(2   ,4,1)     cksz(2   ,4,1)
  acz(3   ,1,1)      azz(3   ,1,1)      cosz(3   ,1,1)      dhz(3   ,1,1)
absrz(3   ,1,1)    fmltz(3   ,1,1)      frez(3   ,1,1)    formz(3   ,1,1)
deffz(3   ,1,1)    fldmz(3   ,1,1)    fldcz(3   ,1,1)
 c0bz(3   ,1,1)     c0sz(3   ,1,1)     ckbz(3   ,1,1)     cksz(3   ,1,1)
  acz(3   ,2,1)      azz(3   ,2,1)      cosz(3   ,2,1)      dhz(3   ,2,1)
absrz(3   ,2,1)    fmltz(3   ,2,1)      frez(3   ,2,1)    formz(3   ,2,1)
deffz(3   ,2,1)    fldmz(3   ,2,1)    fldcz(3   ,2,1)
 c0bz(3   ,2,1)     c0sz(3   ,2,1)     ckbz(3   ,2,1)     cksz(3   ,2,1)
  acz(3   ,3,1)      azz(3   ,3,1)      cosz(3   ,3,1)      dhz(3   ,3,1)
absrz(3   ,3,1)    fmltz(3   ,3,1)      frez(3   ,3,1)    formz(3   ,3,1)
deffz(3   ,3,1)    fldmz(3   ,3,1)    fldcz(3   ,3,1)
 c0bz(3   ,3,1)     c0sz(3   ,3,1)     ckbz(3   ,3,1)     cksz(3   ,3,1)
  acz(3   ,4,1)      azz(3   ,4,1)      cosz(3   ,4,1)      dhz(3   ,4,1)
absrz(3   ,4,1)    fmltz(3   ,4,1)      frez(3   ,4,1)    formz(3   ,4,1)
deffz(3   ,4,1)    fldmz(3   ,4,1)    fldcz(3   ,4,1)
 c0bz(3   ,4,1)     c0sz(3   ,4,1)     ckbz(3   ,4,1)     cksz(3   ,4,1)
       .
       .
       .
  acz(nz+2,1,1)      azz(nz+2,1,1)      cosz(nz+2,1,1)      dhz(nz+2,1,1)
absrz(nz+2,1,1)    fmltz(nz+2,1,1)      frez(nz+2,1,1)    formz(nz+2,1,1)
deffz(nz+2,1,1)    fldmz(nz+2,1,1)    fldcz(nz+2,1,1)
 c0bz(nz+2,1,1)     c0sz(nz+2,1,1)     ckbz(nz+2,1,1)     cksz(nz+2,1,1)
  acz(nz+2,2,1)      azz(nz+2,2,1)      cosz(nz+2,2,1)      dhz(nz+2,2,1)
absrz(nz+2,2,1)    fmltz(nz+2,2,1)      frez(nz+2,2,1)    formz(nz+2,2,1)
deffz(nz+2,2,1)    fldmz(nz+2,2,1)    fldcz(nz+2,2,1)
 c0bz(nz+2,2,1)     c0sz(nz+2,2,1)     ckbz(nz+2,2,1)     cksz(nz+2,2,1)
  acz(nz+2,3,1)      azz(nz+2,3,1)      cosz(nz+2,3,1)      dhz(nz+2,3,1)
absrz(nz+2,3,1)    fmltz(nz+2,3,1)      frez(nz+2,3,1)    formz(nz+2,3,1)
deffz(nz+2,3,1)    fldmz(nz+2,3,1)    fldcz(nz+2,3,1)
 c0bz(nz+2,3,1)     c0sz(nz+2,3,1)     ckbz(nz+2,3,1)     cksz(nz+2,3,1)
  acz(nz+2,4,1)      azz(nz+2,4,1)      cosz(nz+2,4,1)      dhz(nz+2,4,1)
absrz(nz+2,4,1)    fmltz(nz+2,4,1)      frez(nz+2,4,1)    formz(nz+2,4,1)
deffz(nz+2,4,1)    fldmz(nz+2,4,1)    fldcz(nz+2,4,1)
 c0bz(nz+2,4,1)     c0sz(nz+2,4,1)     ckbz(nz+2,4,1)     cksz(nz+2,4,1)
```

where

`commnt` ≡ Section label

`iuform` ≡ Uniformity flag. Options are
1 for axially and azimuthally uniform cell parameters
2 for axially uniform cell parameters
3 for individually specified cell parameters

`areaf/acz(jz,ix,ic)` ≡ Face area

`areac/azz(jz,ix,ic)` ≡ Cell area

`cosine/cosz(jz,ix,ic)` ≡ Face direction cosine. Specify `+1.0` for a gravitational vector aligned with the positive z direction.

`diamtr/dhz(jz,ix,ic)` ≡ Face hydraulic diameter

`absr/absrz(jz,ix,ic)` ≡ Face absolute wall roughness

`fmlt/fmltz(jz,ix,ic)` ≡ Face frictional drag multiplier

`fre/frez(jz,ix,ic)` ≡ Face hydraulic diameter correction factor, K_h.

`form/formz(jz,ix,ic)` ≡ Face form loss coefficient

`deff/deffz(jz,ix,ic)` ≡ Face characteristic dimension for the slug flow regime

`fldm/fldmz(jz,ix,ic)` ≡ Face parameter m in CCFL correlation

`fldc/fldcz(jz,ix,ic)` ≡ Face parameter C in CCFL correlation

`c0b/c0bz(jz,ix,ic)` ≡ Face distribution coefficient for the bubbly regime

`c0s/c0sz(jz,ix,ic)` ≡ Face distribution coefficient for the slug regime

`ckb/ckbz(jz,ix,ic)` ≡ Face drift velocity correlation coefficient for the bubbly regime

`cks/cksz(jz,ix,ic)` ≡ Face drift velocity correlation coefficient for the slug regime

The number of cells in the Middle section is `nz` (numbered internally from 2 to `nz+1`) while the number of faces is `nz+1` (numbered internally from 2 to `nz+2`). Input is read for `jz` = 2 to `nz+2`. The value read for `azz(nz+2, ix, 1)` is extraneous and not used by the code.

Sections 18 + 1 through 18 + 3(nchn - 1)

Sections 16, 17 and 18 are repeated for each additional channel in the Middle section.

Section 19+3(nchn - 1) Bottom section cell geom. and hydr. parameters

Section 19+3(nchn - 1) is read by subroutine GEOFLD and takes on one of four forms depending on the values of iuform:

For iuform = 1 and then 1

```
commnt

iuform

dztot

iuform

volume  areab  areac  cosine  diamtr  absr  fmlt  fre  form  deff  fldm  fldc  c0b
c0s  ckb  cks
```

For iuform = 2 and then 1

```
commnt

iuform

dzb(1)    dzb(2)    dzb(3)  ...  dzb(nzb)

iuform

volume  areab  areac  cosine  diamtr  absr  fmlt  fre  form  deff  fldm  fldc  c0b
c0s  ckb  cks
```

For iuform = 1 and then 2

```
commnt

iuform

dztot

iuform

 volb(1)    acb(1)    azb(1)  cosb(1)   dhb(1)  absrb(1)  fmltb(1)  freb(1)  formb(1)
deffb(1)  fldmb(1)  fldcb(1)  c0bb(1)  c0sb(1)   ckbb(1)   cksb(1)
 volb(2)    acb(2)    azb(2)  cosb(2)   dhb(2)  absrb(2)  fmltb(2)  freb(2)  formb(2)
deffb(2)  fldmb(2)  fldcb(2)  c0bb(2)  c0sb(2)   ckbb(2)   cksb(2)
        .
        .
        .
volb(nzb)    acb(nzb)    azb(nzb)   cosb(nzb)    dhb(nzb)  absrb(nzb)  fmltb(nzb)
freb(nzb)  formb(nzb)  deffb(nzb)  fldmb(nzb)  fldcb(nzb)   c0bb(nzb)   c0sb(nzb)
ckbb(nzb)   cksb(nzb)
```

For `iuform` = 2 and then 2

```
commnt

iuform

dzb(1)    dzb(2)    dzb(3)   ...  dzb(nzb)

iuform

 volb(1)    acb(1)    azb(1)  cosb(1)   dhb(1)  absrb(1)  fmltb(1)  freb(1)  formb(1)
deffb(1)  fldmb(1)  fldcb(1)  c0bb(1)  c0sb(1)   ckbb(1)   cksb(1)
 volb(2)    acb(2)    azb(2)  cosb(2)   dhb(2)  absrb(2)  fmltb(2)  freb(2)  formb(2)
deffb(2)  fldmb(2)  fldcb(2)  c0bb(2)  c0sb(2)   ckbb(2)   cksb(2)
       .
       .
       .
volb(nzb)    acb(nzb)    azb(nzb)   cosb(nzb)    dhb(nzb)  absrb(nzb)  fmltb(nzb)
freb(nzb)  formb(nzb)  deffb(nzb)  fldmb(nzb)  fldcb(nzb)   c0bb(nzb)   c0sb(nzb)
ckbb(nzb)   cksb(nzb)
```

where

`commnt` ≡ Section label

`iuform` ≡ Uniformity flag. Options are
1 for uniform cell parameters
2 for individually specified cell parameters

`dztot` ≡ Total length of Bottom section

`dzb(jz)` ≡ Length of cell `jz`

`volume/volb(jz)` ≡ Cell volume

`areab/acb(jz)` ≡ Face area

`areac/azb(jz)` ≡ Cell area

`cosine/cosb(jz)` ≡ Face direction cosine. Specify `+1.0` for a gravitational vector aligned with the positive z direction.

`diamtr/dhb(jz)` ≡ Face hydraulic diameter

`absr/absrb(jz)` ≡ Face absolute wall roughness

`fmlt/fmltb(jz)` ≡ Face frictional drag multiplier

`fre/freb(jz)` ≡ Face hydraulic diameter correction factor, K_h.

`form/formb(jz)` ≡ Face form loss coefficient

`deff/deffb(jz)` ≡ Face characteristic dimension for the slug flow regime

`fldm/fldmb(jz)` ≡ Face parameter m in CCFL correlation

fldc/fldcb(jz) ≡ Face parameter C in CCFL correlation

c0b/c0bb(jz) ≡ Face distribution coefficient for the bubbly regime

c0s/c0sb(jz) ≡ Face distribution coefficient for the slug regime

ckb/ckbb(jz) ≡ Face drift velocity correlation coefficient for the bubbly regime

cks/cksb(jz) ≡ Face drift velocity correlation coefficient for the slug regime

Section 20 + 3(nchn - 1) Tank Bottom boundary cell geometry

The section starts with a comment line followed by a line specifying the Tank Bottom cell volume and cell center area. Section 20 + 3(nchn - 1) is read by subroutine GEOFLD and takes the form

```
commnt

voltb    actb
```

where

commnt ≡ Section label

volpl ≡ Volume of Tank Bottom boundary cell

acpl ≡ Cell center area of Tank Bottom boundary cell

Section 21 + 3(nchn - 1) Solid cylinder 1 dimensions

Section 21 + 3(nchn - 1) is read by subroutine GEOSLD and takes the form

```
commnt

dinner    nsect

douter    ncell       (isect = 1)

douter    ncell       (isect = 2)
      .
      .
      .
douter    ncell       (isect = nsect)
```

where

commnt ≡ Section label

dinner ≡ Inner diameter (in)

nsect ≡ Number of radial sections

douter ≡ Outer diameter of section (in)

ncell ≡ Number of radial cells in section

Section 22 + 3(nchn - 1) Solid cylinder 1 rib characteristics

Section 22 + 3(nchn - 1) is read by subroutine GEOSLD and takes the form

```
commnt

iorib(1)    ribl(1)    ribt(1)
```

where

commnt ≡ Section label

iorib(icyln) ≡ Rib presence flag. Options are
0 for no ribs
1 for ribs on outer surface of solid cylinder
-1 for ribs on inner surface of solid cylinder

ribl(icyln) ≡ Rib length (in)

ribt(icyln) ≡ Rib *half* thickness (in)

Section 23 + 3(nchn - 1) Solid cylinder 1 material composition

Section 23 + 3(nchn - 1) is read by subroutine GEOSLD and takes the form

```
commnt

ioxid(1)    wt(1)    nsect

iz2    mat(1,1  ,1)    mat(2,1  ,1)  ...  mat(nri,1  ,1)  (isect = 1)

iz2    mat(1,iz1,1)    mat(2,iz1,1)  ...  mat(nri,iz1,1)  (isect = 2)
       .
       .
       .
iz2    mat(1,iz1,1)    mat(2,iz1,1)  ...  mat(nri,iz1,1)  (isect = nsect)
```

where

commnt ≡ Section label

ioxid(icyln) ≡ Not used. Specify 0

wt(icyln) ≡ Weight percent of U or Li in U-Al or Li-Al alloy

nsect ≡ Number of axial material sections

iz2 ≡ Number of last axial layer in each material section

`iz1` ≡ Number of first axial layer in material section

`nri` ≡ Total number of radial cells

`mat(ir,iz1,icyln)` ≡ Material identification flag. Options are
1 for Uranium
2 for Aluminum
3 for 304L Stainless Steel
4 for Lithium -Aluminum Alloy
5 for Uranium-Aluminum Alloy
6 for 6063 Aluminum
7 for Macor
8 for Inconel 600
9 for Flame Sprayed Oxide

Axial layers `iz`, where `iz2-previous line` < `iz` ≤ `iz2-current line`, are assigned the material identification number given on the `iz2` line. The last `iz2` must agree with `nz` specified above.

Sections 23 + 1 + 3(nchn - 1) through 23 + 3(ncyln - 1) + 3(nchn - 1)

Sections 21, 22 and 23 are repeated for each additional solid cylinder in the Middle section.

Section 24 + 3(nchn - 1) + 3(ncyln - 1) Surface criteria checking flags

Section 24 + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine GEOSLD and takes the form

```
commnt

ichks(1)    ichks(2)  ...  ichks(nsurf)
```

where

`commnt` ≡ Section label

`ichks(isurf)` ≡ Power iteration criteria checking flag for surface number `isurf`. Options are

0 for no criteria checking
1 for criteria checking

`nsurf` ≡ Number of solid surfaces (`ncyln` + `nchn` + 1)

Section 25 + 3(nchn - 1) + 3(ncyln - 1) Plenum boundary conditions

Section 25 + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INBOND and takes the form

```
commnt

commnt

  ppl0      ippl

alppl0     ialpl

 tfpl0     itfpl

 tgpl0     itgpl

 xapl0     ixapl
```

where

commnt ≡ Section label (e.g. "BOUNDARY CONDITION INPUT SECTION")

commnt ≡ Section label (e.g. "PLENUM")

ppl0 ≡ Pressure spline function multiplier

ippl ≡ Pressure spline function number

alppl0 ≡ Void fraction spline function multiplier

ialpl ≡ Void fraction spline function number

tfpl0 ≡ Liquid temperature spline function multiplier

itfpl ≡ Liquid temperature spline function number

tgpl0 ≡ Gas temperature spline function multiplier

itgpl ≡ Gas temperature spline function number

xapl0 ≡ Air mass fraction spline function multiplier

ixapl ≡ Air mass fraction spline function number

Section 26 + 3(nchn - 1) + 3(ncyln - 1) Tank Bottom boundary conditions

Section 26 + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INBOND and takes the form

```
commnt

  ptb0      iptb

alptb0     ialtb

 tftb0     itftb

 tgtb0     itgtb

 xatb0     ixatb
```

where

commnt ≡ Section label (e.g. "TANK BOTTOM")

ptb0 ≡ Pressure spline function multiplier

iptb ≡ Pressure spline function number

alptb0 ≡ Void fraction spline function multiplier

ialtb ≡ Void fraction spline function number

tftb0 ≡ Liquid temperature spline function multiplier

itftb ≡ Liquid temperature spline function number

tgtb0 ≡ Gas temperature spline function multiplier

itgtb ≡ Gas temperature spline function number

xatb0 ≡ Air mass fraction spline function multiplier

ixatb ≡ Air mass fraction spline function number

Section 27 + 3(nchn - 1) + 3(ncyln - 1) Inlet flowrates

Section 27 + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INBOND and takes the form

```
commnt

qfin0     iqfin

qgin0     iqgin
```

where

commnt ≡ Section label

qfin0 ≡ Multiplier to inlet liquid volumetric flowrate spline function

iqfin ≡ Inlet liquid volumetric flowrate spline function number

qgin0 ≡ Multiplier to inlet gas volumetric flowrate spline function

iqgin ≡ Inlet gas volumetric flowrate spline function number

Section 28 + 3(nchn - 1) + 3(ncyln - 1) Initial inlet flowsplits

Section 28 + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INBOND and takes the form

```
commnt

fsplt(1)    fsplt(2)  ...  fsplt(nchn)
```

where

commnt ≡ Section label

fsplt(ic) ≡ Flow split for channel ic. fsplt(ic) is normalized according to

$$\texttt{fsplt(ic)} \leftarrow \frac{\texttt{fsplt(ic)}}{\sum \texttt{fsplt(ic)}}$$

so fsplt(ic) may be specified as a fraction or percentage.

Section 29 + 3(nchn - 1) + 3(ncyln - 1) Tank level

Section 29 + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INBOND and takes the form

```
commnt

tnklv0    itnklv
```

where

commnt ≡ Section label

tnklv0 ≡ Multiplier to tank level spline function

itnklv ≡ Tank level spline function number

Section 30 + 3(nchn - 1) + 3(ncyln - 1) Criteria checking flags

Section 30 + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INBOND and takes the form

```
commnt

ichkc(1)    ichkc(2)  ...  ichkc(ncrit)

pkfac(1)    pkfac(2)  ...  pkfac(ncrit)
```

where

commnt ≡ Section label

ichkc(ic) ≡ Checking flag for criterion number ic. Options are
0 for no checking of criterion ic
1 for checking of criterion ic

pkfac(ic) ≡ ϕ_1 in section 3.10 of the FLOWTRAN-TF Software Design report if ic = 1

ΔT_{sup} in section 3.10 of the FLOWTRAN-TF Software Design report if ic = 2 or 3

ϕ_4 in section 3.10 of the FLOWTRAN-TF Software Design report if ic = 4

Section 31 + 3(nchn - 1) + 3(ncyln - 1) Criteria checking time

Section 31 + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INBOND and takes the form

```
commnt

tcrmax
```

where

commnt ≡ Section label

tcrmax ≡ Time to begin criteria checking

Section 31 + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) Assembly exposure ...

Section 31 + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INPOWR *only if* iexp = 0 (otherwise omit this section) and takes the form

```
commnt

expose    delmod    deldry
```

where

commnt ≡ Section label

expose ≡ Assembly exposure in MWD or % U-235 burn-up

delmod ≡ Fraction of deposited power from moderated decay heat

deldry ≡ Fraction of deposited power from dry decay heat

Section 32 + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) Fission power - tube region power fractions

Section 32 + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INDPWR and takes the form

```
commnt

ncylnp    ncoeff

pfcore(1    ,     1)    pfinnr(1    ,     1)    pfoutr(1    ,     1)
pfcore(1    ,     2)    pfinnr(1    ,     2)    pfoutr(1    ,     2)
       :
pfcore(1    ,ncoeff)    pfinnr(1    ,ncoeff)    pfoutr(1    ,ncoeff)

pfcore(2    ,     1)    pfinnr(2    ,     1)    pfoutr(2    ,     1)
pfcore(2    ,     2)    pfinnr(2    ,     2)    pfoutr(2    ,     2)
       :
pfcore(2    ,ncoeff)    pfinnr(2    ,ncoeff)    pfoutr(2    ,ncoeff)

       .
       .
       .

pfcore(ncyln,     1)    pfinnr(ncyln,     1)    pfoutr(ncyln,     1)
pfcore(ncyln,     2)    pfinnr(ncyln,     2)    pfoutr(ncyln,     2)
       :
pfcore(ncyln,ncoeff)    pfinnr(ncyln,ncoeff)    pfoutr(ncyln,ncoeff)
```

where

commnt ≡ Section label

ncylnp ≡ Number of cylinders (must be same as ncyln specified above)

`ncoeff` ≡ Number of polynomial coefficients in each power fraction

`pfcore(icyln,ncf)` ≡ `ncf`th coefficient for power fraction polynomial in exposure for core region of cylinder `icyln`

`pfinnr(icyln,ncf)` ≡ `ncf`th coefficient for power fraction polynomial in exposure for inner clad region of cylinder `icyln`

`pfoutr(icyln,ncf)` ≡ `ncf`th coefficient for power fraction polynomial in exposure for outer clad region of cylinder `icyln`

See section 3.2 of the FLOWTRAN-TF Software Design report for more information.

Section 33 +(1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) Fission power - radial power shapes

Section 33 +(1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INDPWR and takes the form

```
commnt

nset    nrpa    ncoeff

ncyl(1)    ncyl(2)   ...  ncyl(ncyln)

coeff(     1,   1,   1)    coeff(     2,   1,   1)  ...  coeff(ncoeff,   1,   1)
coeff(     1,   2,   1)    coeff(     2,   2,   1)  ...  coeff(ncoeff,   2,   1)
      :
coeff(     1,nrps,   1)    coeff(     2,nrps,   1)  ...  coeff(ncoeff,nrps,   1)
coeff(     1,   1,   2)    coeff(     2,   1,   2)  ...  coeff(ncoeff,   1,   2)
coeff(     1,   2,   2)    coeff(     2,   2,   2)  ...  coeff(ncoeff,   2,   2)
      :
coeff(     1,nrps,   2)    coeff(     2,nrps,   2)  ...  coeff(ncoeff,nrps,   2)
             :
coeff(     1,   1,nset)    coeff(     2,   1,nset)  ...  coeff(ncoeff,   1,nset)
coeff(     1,   2,nset)    coeff(     2,   2,nset)  ...  coeff(ncoeff,   2,nset)
      :
coeff(     1,nrps,nset)    coeff(     2,nrps,nset)  ...  coeff(ncoeff,nrps,nset)
```

where

`commnt` ≡ Section label

`nset` ≡ Number of sets of radial profiles

`nrpa` ≡ Number of radial points in each set

`ncoeff` ≡ Number of coefficients in each set

`coeff(nc,np,ns)` ≡ `nc`th coefficient for radial power polynomial in exposure for point `np` and cylinder set `ns`

See section 3.2 of the FLOWTRAN-TF Software Design report for more information.

Section 34 +(1 - iexp)+3(nchn - 1)+3(ncyln - 1)
Moderated decay power - tube region power fractions

Section 34 +(1 - iexp)+3(nchn - 1)+3(ncyln - 1) is read by subroutine INDPWR and takes on one of two forms

For iskip = 0

```
commnt

iskip
```

For iskip = 1

```
commnt

iskip

ncylnp    ncoeff

pfcore(1    ,     1)    pfinnr(1    ,     1)    pfoutr(1    ,     1)
pfcore(1    ,     2)    pfinnr(1    ,     2)    pfoutr(1    ,     2)
       :
pfcore(1    ,ncoeff)    pfinnr(1    ,ncoeff)    pfoutr(1    ,ncoeff)

pfcore(2    ,     1)    pfinnr(2    ,     1)    pfoutr(2    ,     1)
pfcore(2    ,     2)    pfinnr(2    ,     2)    pfoutr(2    ,     2)
       :
pfcore(2    ,ncoeff)    pfinnr(2    ,ncoeff)    pfoutr(2    ,ncoeff)

       .
       .
       .

pfcore(ncyln,     1)    pfinnr(ncyln,     1)    pfoutr(ncyln,     1)
pfcore(ncyln,     2)    pfinnr(ncyln,     2)    pfoutr(ncyln,     2)
       :
pfcore(ncyln,ncoeff)    pfinnr(ncyln,ncoeff)    pfoutr(ncyln,ncoeff)
```

where

commnt ≡ Section label

iskip ≡ Moderated decay power flag. Options are
0 – use fission power shape data for moderated decay
1 – read and process moderated decay data

ncylnp ≡ Number of cylinders (must be same as ncyln specified above)

ncoeff ≡ Number of polynomial coefficients in each power fraction

pfcore(icyln,ncf) ≡ ncf^{th} coefficient for power fraction polynomial in exposure for core region of cylinder icyln

`pfinnr(icyln,ncf)` ≡ ncf^{th} coefficient for power fraction polynomial in exposure for inner clad region of cylinder `icyln`

`pfoutr(icyln,ncf)` ≡ ncf^{th} coefficient for power fraction polynomial in exposure for outer clad region of cylinder `icyln`

See section 3.2 of the FLOWTRAN-TF Software Design report for more information.

Section 34 + `iskip` + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1)
Fission power - radial power shapes

Section 34 + `iskip` + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INDPWR *only if* `iskip` = *1 above* and takes the form

```
commnt

nset    nrpa    ncoeff

ncyl(1)    ncyl(2)  ...  ncyl(ncyln)

coeff(    1,   1,   1)    coeff(    2,   1,   1)  ...  coeff(ncoeff,   1,   1)
coeff(    1,   2,   1)    coeff(    2,   2,   1)  ...  coeff(ncoeff,   2,   1)
      ⋮
coeff(    1,nrps,   1)    coeff(    2,nrps,   1)  ...  coeff(ncoeff,nrps,   1)
coeff(    1,   1,   2)    coeff(    2,   1,   2)  ...  coeff(ncoeff,   1,   2)
coeff(    1,   2,   2)    coeff(    2,   2,   2)  ...  coeff(ncoeff,   2,   2)
      ⋮
coeff(    1,nrps,   2)    coeff(    2,nrps,   2)  ...  coeff(ncoeff,nrps,   2)
          ⋮
coeff(    1,   1,nset)    coeff(    2,   1,nset)  ...  coeff(ncoeff,   1,nset)
coeff(    1,   2,nset)    coeff(    2,   2,nset)  ...  coeff(ncoeff,   2,nset)
      ⋮
coeff(    1,nrps,nset)    coeff(    2,nrps,nset)  ...  coeff(ncoeff,nrps,nset)
```

where

`commnt` ≡ Section label

`nset` ≡ Number of sets of radial profiles

`nrpa` ≡ Number of radial points in each set

`ncoeff` ≡ Number of coefficients in each set

`coeff(nc,np,ns)` ≡ nc^{th} coefficient for radial power polynomial in exposure for point `np` and cylinder set `ns`

See section 3.2 of the FLOWTRAN-TF Software Design report for more information.

Section 35 + iskip + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1)
Dry decay power - tube region power fractions

Section 35 + iskip + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INDPWR and takes on one of two forms

For iskip = 0 or 2

```
commnt

iskip
```

For iskip = 1

```
commnt

iskip

ncylnp    ncoeff

pfcore(1    ,     1)    pfinnr(1    ,     1)    pfoutr(1    ,     1)
pfcore(1    ,     2)    pfinnr(1    ,     2)    pfoutr(1    ,     2)
       :
pfcore(1    ,ncoeff)    pfinnr(1    ,ncoeff)    pfoutr(1    ,ncoeff)

pfcore(2    ,     1)    pfinnr(2    ,     1)    pfoutr(2    ,     1)
pfcore(2    ,     2)    pfinnr(2    ,     2)    pfoutr(2    ,     2)
       :
pfcore(2    ,ncoeff)    pfinnr(2    ,ncoeff)    pfoutr(2    ,ncoeff)

       .
       .
       .

pfcore(ncyln,     1)    pfinnr(ncyln,     1)    pfoutr(ncyln,     1)
pfcore(ncyln,     2)    pfinnr(ncyln,     2)    pfoutr(ncyln,     2)
       :
pfcore(ncyln,ncoeff)    pfinnr(ncyln,ncoeff)    pfoutr(ncyln,ncoeff)
```

where

commnt ≡ Section label

iskip ≡ Moderated decay power flag. Options are
0 – use fission power shape data for dry decay
1 – read and process dry decay data
2 – use moderated decay data for dry decay

ncylnp ≡ Number of cylinders (must be same as ncyln specified above)

ncoeff ≡ Number of polynomial coefficients in each power fraction

pfcore(icyln,ncf) ≡ ncf^{th} coefficient for power fraction polynomial in exposure for core region of cylinder icyln

`pfinnr(icyln,ncf)` ≡ `ncf`th coefficient for power fraction polynomial in exposure for inner clad region of cylinder `icyln`

`pfoutr(icyln,ncf)` ≡ `ncf`th coefficient for power fraction polynomial in exposure for outer clad region of cylinder `icyln`

See section 3.2 of the FLOWTRAN-TF Software Design report for more information.

Section 35 + `iskip`(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) Fission power - radial power shapes

Section 35 + `iskip`(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine `INDPWR` *only if* `iskip` = 1 *above* and takes the form

```
commnt

nset    nrpa    ncoeff

ncyl(1)    ncyl(2)  ...  ncyl(ncyln)

coeff(    1,   1,   1)    coeff(    2,   1,   1)  ...  coeff(ncoeff,   1,   1)
coeff(    1,   2,   1)    coeff(    2,   2,   1)  ...  coeff(ncoeff,   2,   1)
      :
coeff(    1,nrps,   1)    coeff(    2,nrps,   1)  ...  coeff(ncoeff,nrps,   1)
coeff(    1,   1,   2)    coeff(    2,   1,   2)  ...  coeff(ncoeff,   1,   2)
coeff(    1,   2,   2)    coeff(    2,   2,   2)  ...  coeff(ncoeff,   2,   2)
      :
coeff(    1,nrps,   2)    coeff(    2,nrps,   2)  ...  coeff(ncoeff,nrps,   2)
          :
coeff(    1,   1,nset)    coeff(    2,   1,nset)  ...  coeff(ncoeff,   1,nset)
coeff(    1,   2,nset)    coeff(    2,   2,nset)  ...  coeff(ncoeff,   2,nset)
      :
coeff(    1,nrps,nset)    coeff(    2,nrps,nset)  ...  coeff(ncoeff,nrps,nset)
```

where

`commnt` ≡ Section label

`nset` ≡ Number of sets of radial profiles

`nrpa` ≡ Number of radial points in each set

`ncoeff` ≡ Number of coefficients in each set

`coeff(nc,np,ns)` ≡ `nc`th coefficient for radial power polynomial in exposure for point `np` and cylinder set `ns`

See section 3.2 of the FLOWTRAN-TF Software Design report for more information.

Section 36 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) Azimuthal power shapes

Section 36 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INPOWR and takes the form

```
commnt

nset    naz

ncyl(1)    ncyl(2)  ...  ncyl(ncyln)

azmet(  1,   1)    azmet(  2,   1)  ...  azmet(naz,   1)
azmet(  1,   2)    azmet(  2,   2)  ...  azmet(naz,   2)
       :
azmet(  1,nset)    azmet(  2,nset)  ...  azmet(naz,nset)
```

where

commnt ≡ Section label

nset ≡ Number of sets of azimuthal profiles

naz ≡ Number of azimuthal points in each set (must equal na)

ncyl(icyln) ≡ Azimuthal set assigned to cylinder icyln

azmet(ia,ns) ≡ Azimuthal power shape for azimuthal position ia and azimuthal profile set ns

See section 3.2 of the FLOWTRAN-TF Software Design report for more information.

Section 37 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) Power profile spline pointers

Section 37 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INPOWR and takes the form

```
commnt

ifissn    imodh    idryh    iconh
```

where

commnt ≡ Section label

ifissn ≡ Number of spline function for fission power transient

imodh ≡ Number of spline function for moderated decay power transient

idryh ≡ Number of spline function for dry decay power transient if iexp = 0 or experimental rig power transient if iexp = 1

iconh ≡ Number of spline function for conservative decay heat multiplier

The conservative decay heat multiplier is not used when iexp = 1.

Section 38 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1)
Power profile spline pointers

Section 38 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INPOWR and takes the form

```
commnt

iaxlp(1)   timet(1)   iaxlp(1)   timet(1)  ...  iaxlp(itime)   timet(itime)
```

where

commnt ≡ Section label

iaxlp(itsec) ≡ Number of spline function specifying axial power shape at at time timet(itsec)

timet(itsec) ≡ Time of iaxlp(itsec)

Section 39 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1)
Spline input comment

Section 39 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INSPLN and takes the form

```
commnt
```

where

commnt ≡ Section label (e.g. "SPLINE DATA INPUT")

Section 40 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) Spline data input

Section 40 + iskip(dry, if =1) + iskip(moderated) + (1 - iexp) + 3(nchn - 1) + 3(ncyln - 1) is read by subroutine INSPLN and takes the form

```
commnt

label

                  itype(       1)   ...  itype(       nset(1))

xtp(       1)     ytp(       1,1)   ...  ytp(       1,nset(1))
xtp(       2)     ytp(       2,1)   ...  ytp(       2,nset(1))
       :
xtp(npdat(1))     ytp(npdat(1),1)   ...  ytp(npdat(1),nset(1))

label

                           itype(       nset(1)+1)   ...  itype(       nset(1)+1)

xtp(npdat(1)+       1)     ytp(       1,nset(1)+1)   ...  ytp(       1,nset(1)+1)
xtp(npdat(1)+       2)     ytp(       2,nset(1)+1)   ...  ytp(       2,nset(1)+1)
       :
xtp(npdat(1)+npdat(2))     ytp(npdat(2),nset(1)+1)   ...  ytp(npdat(2),nset(1)+1)


       .
       .
       .

(Through ndata data groups)
```

where

commnt ≡ Section label

label ≡ Data group label

itype(ispln) ≡ Spline type flag. Options are
0 for natural cubic spline
1 for linear spline

xtp() ≡ x value of (x,y) data pair

ytp() ≡ y value of (x,y) data pair

Sample Input File

The input file used to generate the VOID Rig benchmarking results for -1 psig plenum pressure, 12" tank level and 8 gpm is listed below for the purpose of illustrating a typical FLOWTRAN-TF input file. The FLOWTRAN-TF Software Testing report describes the application in detail. The input file is saved as `test_31_01_m08.in` and read from unit number 5.

```
/test_31_01_m08.in/
! Input Deck Description:
!
!    VOID Rig, 12" tank bottom, -1 psig plenum,  8 gpm (nominal), Test #01
!
! General Comments:
!    *The number of solid cylinders can be the same or one
!     greater than the number of fluid channels only
!     i.e. nclyn - nchn = 0 or 1
!    *The solid input units are
!        [T] = C
!        [r] = in
!    *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 runtime
!           min. time step
!                    max. time step
!                             fluid print interval
!                                      solid print interval
!                                               power print interval
!                                                        dump interval
!-------------------------------------------------------------------------------
! runsec,    dtmin,    dtmax,    dtpfld,    dtpsld,    dtppwr,    dtpdmp
  55.0       0.00001   0.50      55.0       1000.0     1000.0     1000.0      !>
!-------------------------------------------------------------------------------
!
/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)
! 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 = tcrmax)
! 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 tcrmax
! iprint: 1 = short print
!         2 = long print
! iexp:   0 = not an experimental rig
!         1 = experimental rig
! icrit:  0 = no printing of criteria messages
!         1 = print criteria messages
! iscrn:  0 = no screen print
```

```
!         1 = screen print
! iword:  1 = 1 byte  per word on VAX
!         2 = 8 bytes per word on CRAY
! istdy:  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
!-------------------------------------------------------------------------------
! ibond,  iunits,  istart,  isave,  iprint
  2       1        0        0       2                                        !>
! iexp,   icrit,   iscrn,   iword,  istdy,  ippu
  1       0        0        1       0       0                                !>
!-------------------------------------------------------------------------------
!
/REFERENCE PRESSURE, COMPRESSIBILITY FACTOR, .../
!   pref: reference pressure used in subroutine inner to compute
!         the 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
!  vminx: minimum absolute velocity for full donoring in x direction
!    tol: accchk parameter
!  tolss: steady state tolerance on dhmix/dt, (J/m^3-s)
!  nstdy: maximum iterations for steady-state (istdy > 0)
!  dtsup: wall superheat reduction, C
! htdamp: solid-fluid heat transfer damping factor
! cidamp: interfacial drag damping factor
!  xdelt: solid heat capacity multiplier for steady state calculations
!-------------------------------------------------------------------------------
! ilq,   pref,    factor,    vminz,    vminx,    tol,    tolss,    nstdy
  1      1.0e+5   1.0        0.05      0.0       1.00    10.       9000  !>@
! dtsup,   htdamp,    cidamp,   xdelt,   xturb,  xa0
  0.0      0.1        0.1       1.0      0.0     0.0                      !>
!-------------------------------------------------------------------------------
!
/BOILING CURVE AND INTERPHASE TRANSPORT OPTIONS/
!  iboil: -1 = forced convection (SRL)
!          0 = forced convection (Sieder-Tate)
!          1 = Mikic-Rohsenow interpolation
!          2 = 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
 -1         1         2          100.0    1         0                      !>
!-------------------------------------------------------------------------------
!
/SOLID PARAMETERS/
! isolid: 0 = no solid calculations
!         1 = solid calculations
! iaxial: 0 = no axial conduction
!         1 = axial conduction
!    wss: 0.0 = explicit
!         1.0 = implicit
!   ncms: number of coarse mesh rebalances
! tsolid: initial solid temperature
! tsrfac: initial surface temperature
!-------------------------------------------------------------------------------
```

```
! isolid,   iaxial,   wss,   ncms,   tsolid,   tsrfac
  0         0         1.0    3      20.0      20.0                              !>
!-------------------------------------------------------------------------------
!
/INNER ITERATION OPTIONS & NEWTON ITERATION PARAMETERS/
! ischem: 1 = axial tridiagonal scheme
!         2 = azimuthal tridiagonal scheme
!         3 = alternating axial and azimuthal schemes
! 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.
!-------------------------------------------------------------------------------
! ischem, irebal, ncmr,  epsin,                                  initmx
  1       1       1      1.0e-5                                  50              !>
!                        epsy,     epsf,                        nitysi
                         1.0e-5    0.01                         50              !>
!                        epsp,  epsalp,  epstg, epstf, epsxa,   nitmax
                         50.0   0.0005   0.05   0.05   0.005   -50             !>
!-------------------------------------------------------------------------------
!
/NUMBER OF SPLINE PROFILES AND DATA POINTS/
! ndata: number of data groups
!  mnrp: maximum number of radial points in power shapes
! itime: number of time snapshots for axial power profiles
!-------------------------------------------------------------------------------
! ndata,  mnrp,  itime
  5       2      2                                                              !>
!-------------------------------------------------------------------------------
! npdat: number of data points per data set
!  nset: number of data sets in data group
!-------------------------------------------------------------------------------
! npdat  nset
  3      1       !>
  3      1       !>
  6      1       !>
  3      1       !>
  6      1       !>
!-------------------------------------------------------------------------------
!
/GEOMETRIC DIMENSIONS:/
!  nchn: number of flow channels
! nxmax: max. number of azimuthal flow cells (>=1)
! ncyln: number of solid cylinders
!    na: number of solid azimuthal cells (>=1)
! nrmax: maximum number of solid radial cells (>=3)
!   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,  nxmax,  ncyln,  na,  nrmax,  nzt,  nz,  nzb
```

```
  1      1       2       1    3       2     15   2                              !>
!-------------------------------------------------------------------------------
!
/ACTIVE CORE PARAMETERS/
! izht: first heated cell in middle section
! izhb: last  heated cell in middle section
! tmod: moderator temp.
! hmod: moderator heat transfer coeff.
!  gap: gap between active core and tank bottom
!-------------------------------------------------------------------------------
!izht,   izhb,   gap,   tmod0,  itmod
 1       15      0.0     0.0    1           !>
!hmod,  iradbc,   douts,   emisi,   emiso
 0.0    0         0.       1.       1.      !>
!-------------------------------------------------------------------------------
!
/POWER ITERATION INPUT/
! asypwr: assembly power in kW
!  maxpi: maximum number of power iterations
! tolpow: tolerance on power limit
!  ncrit: number of criteria used to check for power limit
!-------------------------------------------------------------------------------
! asypwr,  maxpi,   tolpow,   ncrit
  0.0      1        0.005     4    !> @@
!-------------------------------------------------------------------------------
!
! SENSITIVITY VARIABLES INPUT SECTION
!
/SENSITIVITY PARAMETERS/
! cizfac: axial interfacial drag multiplying factor
! cixfac: azimuthal interfacial drag MULTIPLYING FACTOR if cixfac < 0
!         applied as cix = cixfac*ciz
!         azimuthal interfacial drag COEFFICIENT if cixfac > 0
! USED ONLY IF nchn=3:
!  delp1: starts transition from adverse to favorable channel inlet void
!         correlation
!  delp2: ends transition from adverse to favorable channel inlet void
!         correlation
!-------------------------------------------------------------------------------
! 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,  cixfac,   iribv
  1.0       1.e9      1                                                        !>
!
! xfric,  plnht,  cipln,   formhs,  alphs
  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                                        !>
!
! delp1,  delp2,  sigai,  sigam,  sigfi,  sigfm,  dalsub,  theta0
  0.0     200.0   0.0     0.0     0.0     0.0     0.0      0.0                 !>
!
!-------------------------------------------------------------------------------
! FLUID GEOMETRY AND MOMENTUM CLOSURE INPUT SECTION
!
/TOP BOUNDARY CELL: PLENUM VOLUME AND AREA/
! volpl: plenum volume
!  acpl: plenum mid-cell area
!-------------------------------------------------------------------------------
```

```
! volpl,     acpl
  1.814e-4   1.19e-3   !>
!-------------------------------------------------------------------------------
!
/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   dztot
  2        0.                                                                !>
! (dzt(jz),i=1,nzt)
  0.1524   !> 1
  0.1524   !> 2
!-------------------------------------------------------------------------------
!
! 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( )
  1.814e-4    1.19e-3    1.19e-3    1.0         7.41e-3                     !>
! 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            !>
!-------------------------------------------------------------------------------
!
/MIDDLE SECTION GEOMETRY/
! iuform: 1 = uniform axial mesh spacing
!         2 = individually specified values
!  dztot: total axial length if iuform = 1
!    bow: displacement of mid-plane from center due to bowing
!  omega: direction of bow, degrees
!     dz: axial cell lengths if iuform = 2
!-------------------------------------------------------------------------------
! iuform,  bow,  omega
  2        0.    0.0                                                         !>
! (dz(jz),jz=1,nz)
```

```
  0.1524       !> 1
  0.2860  $13  !> 2-14
  0.1524       !> 15
!-------------------------------------------------------------------------------
/CHANNEL 1/
! nsub: number of subchannels
!   di: inner diameter of channel
!   do: outer diameter of channel
!-------------------------------------------------------------------------------
! nsub,     di,        do
  1         0.0940     0.1019                                                !>
!-------------------------------------------------------------------------------
!
/CHANNEL 1 X GEOMETRY/
! iuform: 1 = axially and azimuthally uniform cell x-direction geometry
!         2 = individually specified cell x-direction geometry
!     other = individually specified values
!-------------------------------------------------------------------------------
! iuform
  1                                                                          !>
!-------------------------------------------------------------------------------
!   acx(jz,ix,ic): (face) ENTER RIB CLEARANCE; CODE CONVERTS TO x-area
!   axx(jz,ix,ic): (face) CHANNEL CLEARANCE; CODE CONVERTS TO x-area
!  cosx(jz,ix,ic): (face) cos(theta) for x-direction
!   dhx(jz,ix,ic): (face) hydraulic diameter in x-direction
! absrx(jz,ix,ic): (face) absolute roughness
! fmltx(jz,ix,ic): (face) friction multiplier (0 or 1 normally)
!  frex(jz,ix,ic): (face) 64/fRe
! formx(jz,ix,ic): (face) form loss k factor
! (jz loop inside ix loop)
!-------------------------------------------------------------------------------
! acx( ),      axx( ),     cosx( ),  dhx( )
  1.0e-3       1.0e-3      0.0       1.0e-3   !> (NOT USED BECAUSE CHN. IS 1D)
! absrx( ),    fmltx( ),   frex( ),  formx( )
  1.524e-6     0.0         1.0       10.0     !>
!-------------------------------------------------------------------------------
/CHANNEL 1 Z GEOMETRY/
! iuform: 1 = axially and azimuthally uniform cell z-direction
!         2 = individually specified cell z-direction geometry
!     other = individually specified values
! iuform
  1       !>
!
! iuform=1
!-------------------------------------------------------------------------------
!   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
! (jz loop inside ix loop)
!-------------------------------------------------------------------------------
! acz( ),      azz( ),     cosz( ),  dhz( )
  1.19e-3      1.19e-3     1.0       7.41e-3                                 !>
```

```
! 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
!         (must be specified however)
!dzt(jz): axial cell lengths if iuform=2
!-------------------------------------------------------------------------------
! iuform   dztot
  2        0.                                                                   !>
! (dzb(jz),i=1,nzb)
  0.1524  !> 1
  0.1524  !> 2
!-------------------------------------------------------------------------------
!
! 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( )
  1.814e-4    1.19e-3    1.19e-3    1.0         7.41e-3                        !>
! 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
  1.814e-4    1.19e-3                                                           !>
!-------------------------------------------------------------------------------
!
! SOLID GEOMETRY INPUT SECTION
!
```

```
/CYLINDER #1/
! dinner: inner diameter of cylinder
! nsect: number of radial sectors
!-------------------------------------------------------------------------------
! dinner,  nsect
  0.0876   1                                                                !>
!-------------------------------------------------------------------------------
! douter: outer diameter of radial sector
! ncell: number of radial subdivisions per radial sector
!-------------------------------------------------------------------------------
! douter,  ncell (loop from 1 to nsect)
  0.0940   3                                                                !>
!-------------------------------------------------------------------------------
/RIB GEOMETRY/
! iorib: 0 = no rib
!        1 = outside
!       -1 = inside
! ribl: rib length
! ribt: 1/2 rib thickness
!-------------------------------------------------------------------------------
! iorib(icyln),  ribl(icyln),  ribt(icyln)
  0              0.0           0.0                                          !>
!-------------------------------------------------------------------------------
/ALLOY WEIGHT PERCENT, AXIAL SECTIONS/
! wt: weight percent of Ur(or Li) in Ur-Al (or Li-Al) alloy
! nsect: number of axial sectors
!-------------------------------------------------------------------------------
! ioxid(icyln),  wt(icyln),  nsect
  0              0.0         1                                             !>
!-------------------------------------------------------------------------------
! iz2: axial layers iz, where iz2,previous < iz <= iz2,
!      are assigned the material id number given on the iz2 line
!      The last iz2 must agree with nz specified above
! mat: material identification number
!      1 = Ur
!      2 = Al
!      3 = 304L SS
!      4 = Li-Al
!      5 = Ur-Al
! nri: number of radial cells (specified above)
!-------------------------------------------------------------------------------
! iz2,  (mat(ir,iz1,icyln), ir=1,nri)
  15    2 2 2                                                               !>
!-------------------------------------------------------------------------------
/CYLINDER #2/
! dinner: inner diameter of cylinder
! nsect: number of radial sectors
!-------------------------------------------------------------------------------
! dinner,  nsect
  0.1019   1                                                                !>
!-------------------------------------------------------------------------------
! douter: outer diameter of radial sector
! ncell: number of radial subdivisions per radial sector
!-------------------------------------------------------------------------------
! douter,  ncell (loop from 1 to nsect)
  0.1044   3                                                                !>
!-------------------------------------------------------------------------------
/RIB GEOMETRY/
! iorib: 0 = no rib
!        1 = outside
!       -1 = inside
! ribl: rib length
! ribt: 1/2 rib thickness
!-------------------------------------------------------------------------------
```

```
! iorib(icyln),  ribl(icyln),  ribt(icyln)
  0              0.0           0.0                                                    !>
!-------------------------------------------------------------------------------
/ALLOY WEIGHT PERCENT, AXIAL SECTIONS/
! wt: weight percent of Ur(or Li) in Ur-Al (or Li-Al) alloy
! nsect: number of axial sectors
!-------------------------------------------------------------------------------
! ioxid(icyln),  wt(icyln),  nsect
  0              0.0         1                                                      !>
!-------------------------------------------------------------------------------
! iz2: axial layers iz, where iz2,previous < iz <= iz2,
!      are assigned the material id number given on the iz2 line
!      The last iz2 must agree with nz specified above
! mat: material identification number
!      1 = Ur
!      2 = Al
!      3 = 304L SS
!      4 = Li-Al
!      5 = Ur-Al
! nri: number of radial cells (specified above)
!-------------------------------------------------------------------------------
! iz2, (mat(ir,izl,icyln), ir=1,nri)
  15   2 2 2                                                                        !>
!-------------------------------------------------------------------------------
/SURFACE CHECKING FLAGS/
! surface flags  0 means criteria not applied
! surface flags  1 means criteria are applied
!
!surface  #1   #2   #3   #4
           1    1    1    1                                                        !>
!
/BOUNDARY CONDITION INPUT SECTION/
/PLENUM/
!   ppl0: multiplier to P transient profile
!   ippl: P transient identifier
! alppl0: 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
!  xapl0: multiplier to Xa transient profile
!  ixapl: Xa transient identifier
!-------------------------------------------------------------------------------
! ppl0,       ippl
   92839.0    1        !> @$$
! alppl0,     ialpl
  0.535       1        !>
! tfpl0,      itfpl
  20.0        1        !>
! tgpl0,      itgpl
  20.0        1        !>
! xapl0,      ixapl
  0.986       1        !>
!-------------------------------------------------------------------------------
!
/TANK 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 @
  102731.0    1       !>
! alptb0,     ialtb
  0.535       1       !>
! tftb0,      itftb
  20.0        1       !>
! tgtb0,      itgtb
  20.0        1       !>
! xatb0,      ixatb
  0.986       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,      iqfin
  6.30833e-5  2       !> Qf = 1.0 gpm
! qgin0,      iqgin
  0.0         1       !> Qg = 1.0 gpm
!-------------------------------------------------------------------------------
!
/INITIAL FLOW SPLITS TO MIDDLE CHANNELS/
! The following data is used only to initialize
! middle section axial velocities
! fsplt(ic): flow split for channel ic.
!            fsplt is normalized according to   fsplt(i)      subsequently
!                                               -------------
!                                               sum[fsplt(j)]
!            so fsplt may be specified as fractions or percents
!-------------------------------------------------------------------------------
! fsplt(ic) ic=1,nchn
  1.0                                                                    !>
!-------------------------------------------------------------------------------
/POINTER TO TANK LEVEL TRANSIENT/
! tnklv0: initial tank level
! itnklv: tank level transient identifier
!-------------------------------------------------------------------------------
! tnklv0, itnklv
  12.0    1                                                              !>
!-------------------------------------------------------------------------------
/CRITERIA CHECKING FLAGS AND PEAKING FACTORS/
!  checking flag for criteria  #1     #2     #3     #4
                                0      0      0      0    !>@
!peaking factors for criteria  #1     #2     #3     #4
                              1.0    1.0    1.0    1.0    !>
/CRITERIA CHECKING TIME/
! time to begin criteria checking, sec
!-------------------------------------------------------------------------------
! tcrmax
  0.0     !>
!-------------------------------------------------------------------------------
!
! POWER INPUT
!
```

```
/POWER FRACTIONS/
!
! power specification for each cylinder
!  ncyln - number of cylinders
! ncoeff - number of polynomial coefficients in each power fraction
!   ncyln,  ncoeff
    2       1                                                              !>
! power fractions for each part of cylinder
!         core    inner clad   outer clad
          0.5       0.0          0.0
          0.5       0.0          0.0
/RADIAL SHAPES/
!   nset - number of sets of radial profiles
! npoint - number of radial points in each set
! ncoeff - number of coefficients in each set
!   nset,  npoint,  ncoeff
    1      2        1
!
!   set specification for each cylinder
!   i.e. cylinder 1 is in set 1
!
    1  1
!   radial shape at each point
       1.0
       1.0
/WET TANK DECAY POWER FRACTIONS/
    0
/DRY TANK DECAY POWER FRACTIONS/
    0
/AZIMUTHAL SHAPES/
! nset - number of sets of azimuthal profiles
!  naz - number of azimuthal points in each set (must equal na)
!     nset   naz
      1      1
!
!     set specification for each cylinder
!     i.e. cylinder 1 is in set 1
!
      1  1
!
!     azimuthal shape at each point
!
      1.0
/POWER PROFILE SPLINE POINTERS/
!  at-power  moderated tank   dry tank      delta multipliers for
!                          (experimental)  conservative decay heat
   4         4                 4              4
/AXIAL SPLINE POINTERS AND TIMES/
   1   0.0        1  200.00
!
/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   !>
```

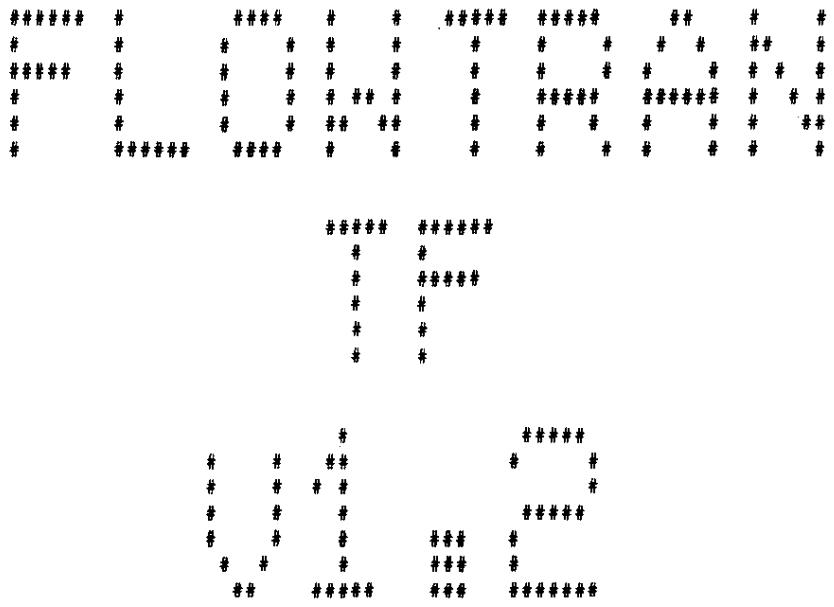
```
    5.0   1.0   !>
  100.0   1.0   !>
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 2/
!-------------------------------------------------------------------------------
data set 2 - FLOWRATE
!          itype
           1         !>
! x(ipt), y(ipt)    ipt=1,npts
    0.0   8.09      !> @
   10.0   8.09      !>
  100.0   8.09      !>
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 3/
!-------------------------------------------------------------------------------
data set 3 - NOT USED
!          itype
           1         !>
! x(ipt), y(ipt)    ipt=1,npts
  0.0     1.0       !>
  1.0     1.0       !>
  2.0     1.0       !>
  3.0     1.0       !>
  4.0     1.0       !>
  5.0     1.0       !>
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 4/
!-------------------------------------------------------------------------------
data set 4 - POWER
!          itype
           1         !>
! x(ipt), y(ipt)    ipt=1,npts
    0.0   1.0         !> @
    1.0   1.0         !>
 1000.0   1.0         !>
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 5/
!-------------------------------------------------------------------------------
data set 5 - NOT USED
!          itype
           1         !>
! x(ipt), y(ipt)    ipt=1,npts
  0.0     1.0       !>
  1.0     1.0       !>
  2.0     1.0       !>
  3.0     1.0       !>
  4.0     1.0       !>
  5.0     1.0       !>
!-------------------------------------------------------------------------------
!
/END OF INPUT FILE/
```

Output Description

The various output options and quantities printed for each option have been broadly discussed in the Input Specifications section. The Sample Output File section below effectively describes the output in detail. FLOWTRAN-TF output values are clearly identified with self-explanatory labels. Dimensional units are given. The user may consult the FLOWTRAN-TF v1.2 FORTRAN source code listing and/or code proprietor for additional clarification if necessary.

Sample Output File

The output files corresponding to the above input file are listed below for the purpose of illustrating typical FLOWTRAN-TF output. The following file saved as `test_31_01_m08.out` was written to unit number 11:



```
NES Code Management System, TP-92-049, Rev 0
IBM RISC System/6000, Model 530
AIX Version 3 for RISC System/6000, 03.01.0005.0012
IBM AIX XL FORTRAN Compiler, 02.02.0000.0000
Compiler options: -O -qautodbl=dblpad
Loader   options: -berok
Built 29-JAN-1993 by S.E.Aleman @ x52986 at 773-11A
Status of Code - TESTING


/test_31_01_m08.in/
```

```
  **     time step control parameters    **

           total run time =   55.000     seconds
         minimum time step =  .10000E-04 seconds
         maximum time step =  .50000     seconds
       fluid printouts every  55.000     seconds
       solid printouts every  1000.0     seconds
       power printouts every  1000.0     seconds
   plotting data dumps every  1000.0     seconds


  ** boundary condition, units, restart  **

              boundary condition flag =  2
            units chosen (1=SI, 2=SRS) =  1
  restart option (0=new, 1,2,3=restart) =  0
  create restart file (0=no, 1,2,3=yes) =  0
     restart options: 1 - time = current tsec
                      2 - time = zero
                      3 - time = tcrmax
     Note:  negative value creates ascii file
         print option (1=short, 2=long) =  2
         experimental rig (0=no, 1=yes) =  1
        criteria printing (0=no, 1=yes) =  0
    screen print (0=no, 1=yes, 2=short) =  0
           Vax or Cray (1=Vax, 2=Cray) =  1
steady-state solution (0=no, 1,2,3=yes) =  0
update plenum pressure (ibond=2 or 4)   =  0
 options: 0 - no
          1 - update based on liq mom
          2 - update if alppl < abs(alphs)


  **  constant factors for calculations  **

    liquid identifier (1=H2O 2=D2O) = 1
                reference pressure =   .10000E+06 Pa
      liquid compressibility factor =   1.0000
   min vel for full donoring: z-dir =   .50000E-01m/s
   min vel for full donoring: x-dir =   .00000E+00m/s
           accuracy check tolerance =   1.0000
             steady-state tolerance =   10.000
    max iterations for steady-state = 9000
       subcooling adjustment factor =   .00000E+00 C
      wall heat flux damping factor =   .10000
    interfacial drag damping factor =   .10000
steady-state solid delt multiplier =   1.0000
     turbulent exchange multiplier =   .00000E+00
                Xa reference value =  .000


  ** additional options (boiling curve) **

        nucleate boiling (1=Mikic, 2=Chen) = -1
          CHF correlation (1=SRL, 2=Biasi) =  1
           dissolved gas (1=helium, 2=air) =  2
          dissolved gas percent saturation =   100.00
interface bulk mass transfer (0=off, 1=on) =  1
interface wall mass transfer (0=off, 1=on) =  0


  **  solid heat conduction parameters   **

  solid calcs performed (0=no, 1=yes) =  0
```

```
  axial heat conduction (0=no, 1=yes) =  0
implicit conduction (0.0=no, 1.0=yes) =  1.0
       number of rebalance iterations =   3
            initial solid temperature =   20.000 C
          initial surface temperature =   20.000 C


  ** inner pressure solution parameters  **

 inner iteration calculation method =   1
   inner iteration rebalance option =   1
     number of rebalance iterations =   1
       tolerance on inner iteration =   .10000E-04
 maximum number of inner iterations =   50


  ** ysi iteration parameters  **

               tolerance on ysi =   .10000E-04
          tolerance on f(ysi) =   .10000E-01
 maximum number of ysi iterations =   50


  **      newton iteration tolerances      **

            tolerance on pressure =   50.000
        tolerance on void fraction =   .50000E-03
      tolerance on gas temperature =   .50000E-01
    tolerance on liquid temperature =   .50000E-01
     tolerance on air mass fraction =   .50000E-02
maximum number of newton iterations =  -50


  **     spline profile specifications     **

   number of spline data sets specified =     5
         number of spline profiles used =     5
 total number of points in all profiles =    21
number of points in radial power shapes =     2
 number of times for axial power shapes =     2


  **   geometric input data for problem  **

               number of flow channels =   1
maximum number of fluid azimuthal cells =   1
            number of metal cylinders =   2
  fixed number of solid azimuthal cells =   1
   maximum number of radial solid cells =   3
   number of axial cells in top section =   2
number of axial cells in middle section =  15
number of axial cells in bottom section =   2


  **  active core input data for problem **

   first heated cell in active core =   1
    last heated cell in active core =  15
gap from active core to tank bottom =   .00000E+00 m
      initial moderator temperature =   .00000E+00 C
moderator heat transfer coefficient =   .00000E+00 W/m**2-C
 radiation b. c. flag (0=off, 1=on) = 0
      diameter of radiating surface =   .00000E+00 m
        emissivity of inner surface =   1.0000
```

```
        emissivity of outer surface =   1.0000


   **      power iteration parameters      **

            initial assembly power =   .00000E+00 kW
 maximum number of power iterations =   1
       tolerance on power iteration =   .50000E-02
        number of criteria to check =  4


   **       sensitivity parameters        **

 multipliers for:
 turbulent heat transfer correlation =   1.0000
 turbulent heat transfer Re exponent =   1.0000
   annular heat transfer correlation =   1.0000
   annular heat transfer Re exponent =   1.0000
          metal thermal conductivity =   1.0000
                metal heat capacity =   1.0000
     interfacial fluid heat transfer =   1.0000
       interfacial gas heat transfer =   1.0000
           interfacial mass transfer =   1.0000
      interfacial enhanced transport =   1.0000

   **         momentum parameters          **

       axial interfacial drag factor =   1.0000
   azimuthal interfacial drag factor =   .10000E+10
            rib void model selection =  1
     global wall friction multiplier =   1.0000
        plenum height for weir model =   8.7500
     interfacial drag for weir model =   1.0000
            form drag for weir model =   5.3820
min void fraction for stratification =   .50000E-01
     bubble-to-slug transition point =   .25000
                    pure slug point =   .52000
    slug-to-annular transition point =   .75000
  bubble-slug interpolation exponent =   4.0000
 slug-annular interpolation exponent =   4.0000


   **    channel inlet void parameters    **

  start of chn inlet void transition =   .00000E+00
    end of chn inlet void transition =   200.00
  sigma - adverse   - inner channel =   .00000E+00
  sigma - adverse   - middle channel =   .00000E+00
  sigma - favorable - inner channel =   .00000E+00
  sigma - favorable - middle channel =   .00000E+00
  del alpha for subchannel void tilt =   .00000E+00
orientation of subchannel void tilt =   .00000E+00


  1 azimuthal cells are in channel  1


surface criteria checking flags (0=off, 1=on)
surface   checking flag
-------------------------
   1            1
   2            1
   3            1
```

```
   4            1

cylinder #  1:   alloy weight percent =   .00000E+00
                      rib orientation =  0
                       rib length (m) =   .00000E+00
                    rib half width (m) =   .00000E+00

diameter (m)
------------
  .87600E-01
  .89733E-01
  .91867E-01
  .94000E-01

material id array
-----------------
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2

cylinder #  2:   alloy weight percent =   .00000E+00
                      rib orientation =  0
                       rib length (m) =   .00000E+00
                    rib half width (m) =   .00000E+00

diameter (m)
------------
  .10190
  .10273
  .10357
  .10440

material id array
-----------------
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
 2 2 2
```

```
 criteria checking flags and peaking factors
 criteria   checking flag   peaking factor

     1            0            1.0000
     2            0            1.0000
     3            0            1.0000
     4            0            1.0000


 Time at which criteria checking begins =     .0 sec

1 input power data as read from unit  7


0     ********************   at-power    power fraction data*********************
 number of cylinders                              =   2
 number of coefficients in exposure polynomial =   1
   --cylinder--   --coeff no.--   -------------region coefficients-------------
                                   ----core----    -inner clad-   -outer clad-
       1              1              .50000         .00000E+00     .00000E+00
       2              1              .50000         .00000E+00     .00000E+00
0   at-power    power fraction assignments in assembly: exposure =   .00000E+00
 -reg-  -power fract- ---core---  --in clad-  -out clad-
   1      .50000          xxx
   2      .00000E+00                  xxx
   3      .00000E+00                              xxx
   4      .50000          xxx
   5      .00000E+00                  xxx
   6      .00000E+00                              xxx


 ******************pointwise radial    at-power    shape data******************
 number of cylinder sets in radial shape data  =   1
 number of data points in each cylinder core   =   2
 number of coefficients in exposure polynomial =   1

 radial shape data for cylinder  1 is in set #  1
 radial shape data for cylinder  2 is in set #  1
0   --cyl set--   --point--   --coeff no.--   --coefficient--
         1            1             1             1.0000
         1            2             1             1.0000
levaluated    at-power    power shape data for flowtran-tf: exposure    .0000E+00


0--cyln--   --point--   --radial power density--
     1          1             1.0000
     1          2             1.0000
     2          1             1.0000
     2          2             1.0000
0control flag for wet tank decay shape data:  0
    0 = use at-power data, no decay data provided
    1 = read in and process decay data
    2 = use wet tank data for dry tank


0control flag for dry tank decay shape data:  0
    0 = use at-power data, no decay data provided
    1 = read in and process decay data
    2 = use wet tank data for dry tank
```

```
    ********************azimuthal shape data*********************
 number of cylinder sets in azimuthal data =   1
 number of azimuths in each cylinder core  =   1
 shape data for cylinder  1 is in set #  1
 shape data for cylinder  2 is in set #  1
0   --cyl set--   --azimu--   --shape factr--
         1            1           1.0000
0--cyln--   --ia--   --azimut power density--
     1         1            1.0000
     2         1            1.0000
1spline fits to input data:



 spline profile number  1
data set 1 - UNIFORM
 number of axial data points in profile   3

 snapshot  1 at   .00000E+00 seconds

 --point--   --z (norm)--   ------------------coefficients------------------
      1        .00000E+00     .00000E+00
      2        5.0000         .00000E+00
      3        100.00         .00000E+00


 spline profile number  2
data set 2 - FLOWRATE
 number of axial data points in profile   3

 --point--   ----time----   ------------------coefficients------------------
      1        .00000E+00     .00000E+00
      2        10.000         .00000E+00
      3        100.00         .00000E+00


 spline profile number  3
data set 3 - NOT USED
 number of axial data points in profile   6

 --point--   ----time----   ------------------coefficients------------------
      1        .00000E+00     .00000E+00
      2        1.0000         .00000E+00
      3        2.0000         .00000E+00
      4        3.0000         .00000E+00
      5        4.0000         .00000E+00
      6        5.0000         .00000E+00


 spline profile number  4
data set 4 - POWER
 number of axial data points in profile   3

 --point--   ----time----   ------------------coefficients------------------
      1        .00000E+00     .00000E+00
      2        1.0000         .00000E+00
      3        1000.0         .00000E+00


 spline profile number  5
data set 5 - NOT USED
```

number of axial data points in profile 6

--point--	----time----	----------coefficients----------
1	.00000E+00	.00000E+00
2	1.0000	.00000E+00
3	2.0000	.00000E+00
4	3.0000	.00000E+00
5	4.0000	.00000E+00
6	5.0000	.00000E+00

**********radshp**********

Coeff Index	Cylinder Index	rphi (data)	rphi (calc)
1	1	1.000000	1.000000
2	1	1.000000	1.000000

ir	icyln	radius inner	outer	frdim
1	1	.438000E-01	.448667E-01	1.000000
2	1	.448667E-01	.459333E-01	1.000000
3	1	.459333E-01	.470000E-01	1.000000

Coeff Index	Cylinder Index	rphi (data)	rphi (calc)
1	2	1.000000	1.000000
2	2	1.000000	1.000000

ir	icyln	radius inner	outer	frdim
1	2	.509500E-01	.513667E-01	1.000000
2	2	.513667E-01	.517833E-01	1.000000
3	2	.517833E-01	.522000E-01	1.000000

**********radshp**********

Coeff Index	Cylinder Index	rphi (data)	rphi (calc)
1	1	1.000000	1.000000
2	1	1.000000	1.000000

ir	icyln	radius inner	outer	frdim
1	1	.438000E-01	.448667E-01	1.000000
2	1	.448667E-01	.459333E-01	1.000000
3	1	.459333E-01	.470000E-01	1.000000

Coeff Index	Cylinder Index	rphi (data)	rphi (calc)
1	2	1.000000	1.000000
2	2	1.000000	1.000000

ir	icyln	radius inner	outer	frdim
1	2	.509500E-01	.513667E-01	1.000000
2	2	.513667E-01	.517833E-01	1.000000

```
3       2       .517833E-01    .522000E-01  1.000000

********************radshp*******************

Coeff       Cylinder        rphi          rphi
Index        Index         (data)        (calc)
-------------------------------------------------
  1            1          1.000000      1.000000
  2            1          1.000000      1.000000

                          radius
ir    icyln        inner          outer       frdim
-------------------------------------------------------
1       1       .438000E-01    .448667E-01  1.000000
2       1       .448667E-01    .459333E-01  1.000000
3       1       .459333E-01    .470000E-01  1.000000

Coeff       Cylinder        rphi          rphi
Index        Index         (data)        (calc)
-------------------------------------------------
  1            2          1.000000      1.000000
  2            2          1.000000      1.000000

                          radius
ir    icyln        inner          outer       frdim
-------------------------------------------------------
1       2       .509500E-01    .513667E-01  1.000000
2       2       .513667E-01    .517833E-01  1.000000
3       2       .517833E-01    .522000E-01  1.000000

lsolid edit at time =    .00000E+00 seconds


surface heat fluxes to liquid (kW/m**2):
surface      2           3           4
iz ia
_____
 1  1          .000        .000        .000
 2  1          .000        .000        .000
 3  1          .000        .000        .000
 4  1          .000        .000        .000
 5  1          .000        .000        .000
 6  1          .000        .000        .000
 7  1          .000        .000        .000
 8  1          .000        .000        .000
 9  1          .000        .000        .000
10  1          .000        .000        .000
11  1          .000        .000        .000
12  1          .000        .000        .000
13  1          .000        .000        .000
14  1          .000        .000        .000
15  1          .000        .000        .000

surface heat fluxes to gas (kW/m**2):
surface      2           3           4
iz ia
_____
 1  1          .000        .000        .000
 2  1          .000        .000        .000
 3  1          .000        .000        .000
 4  1          .000        .000        .000
 5  1          .000        .000        .000
 6  1          .000        .000        .000
 7  1          .000        .000        .000
```

8	1	.000	.000	.000
9	1	.000	.000	.000
10	1	.000	.000	.000
11	1	.000	.000	.000
12	1	.000	.000	.000
13	1	.000	.000	.000
14	1	.000	.000	.000
15	1	.000	.000	.000

cylinder surface temperatures (C):

surface		2	3	4
iz	ia			
1	1	20.00000	20.00000	20.00000
2	1	20.00000	20.00000	20.00000
3	1	20.00000	20.00000	20.00000
4	1	20.00000	20.00000	20.00000
5	1	20.00000	20.00000	20.00000
6	1	20.00000	20.00000	20.00000
7	1	20.00000	20.00000	20.00000
8	1	20.00000	20.00000	20.00000
9	1	20.00000	20.00000	20.00000
10	1	20.00000	20.00000	20.00000
11	1	20.00000	20.00000	20.00000
12	1	20.00000	20.00000	20.00000
13	1	20.00000	20.00000	20.00000
14	1	20.00000	20.00000	20.00000
15	1	20.00000	20.00000	20.00000

interior temperatures (C) in cylinder 1

radius		1	2	3
iz	ia			
1	1	20.00000	20.00000	20.00000
2	1	20.00000	20.00000	20.00000
3	1	20.00000	20.00000	20.00000
4	1	20.00000	20.00000	20.00000
5	1	20.00000	20.00000	20.00000
6	1	20.00000	20.00000	20.00000
7	1	20.00000	20.00000	20.00000
8	1	20.00000	20.00000	20.00000
9	1	20.00000	20.00000	20.00000
10	1	20.00000	20.00000	20.00000
11	1	20.00000	20.00000	20.00000
12	1	20.00000	20.00000	20.00000
13	1	20.00000	20.00000	20.00000
14	1	20.00000	20.00000	20.00000
15	1	20.00000	20.00000	20.00000

interior temperatures (C) in cylinder 2

radius		1	2	3
iz	ia			
1	1	20.00000	20.00000	20.00000
2	1	20.00000	20.00000	20.00000
3	1	20.00000	20.00000	20.00000
4	1	20.00000	20.00000	20.00000
5	1	20.00000	20.00000	20.00000
6	1	20.00000	20.00000	20.00000
7	1	20.00000	20.00000	20.00000
8	1	20.00000	20.00000	20.00000
9	1	20.00000	20.00000	20.00000
10	1	20.00000	20.00000	20.00000
11	1	20.00000	20.00000	20.00000

12	1	20.00000	20.00000	20.00000
13	1	20.00000	20.00000	20.00000
14	1	20.00000	20.00000	20.00000
15	1	20.00000	20.00000	20.00000

1$ fluid edit at time = .00000E+00 seconds
time step size = 5.0000 seconds
Courant step size = .00000E+00 seconds
Section (1-T,2-M,3-B) = 0
Channel (0 for T/B) = 0
Axial = 0
Azimuthal = 0

top section fluid variables:

	jz	pressure (kPa)	void	xair	t gas (C)	t fld (C)	u gas (m/s)	u fld (m/s)
plenum		92.8390	.5350	.986	20.00	20.00		
	1	93.1541	.5350	.986	20.00	20.00	.00	.92
	2	93.4692	.5350	.986	20.00	20.00	.00	.92

@middle section fluid variables:

ic	ix	jz	pressure (kPa)	void	xair	t gas (C)	t fld (C)	u gas (m/s)	u fld (m/s)	w gas (m/s)	w fld (m/s)
1	1	1	93.7842	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	2	94.2374	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	3	94.8287	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	4	95.4199	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	5	96.0112	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	6	96.6025	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	7	97.1937	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	8	97.7850	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	9	98.3763	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	10	98.9675	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	11	99.5588	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	12	100.1501	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	13	100.7413	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	14	101.3326	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	15	101.7858	.5350	.986	20.00	20.00	.00	.92	.00	.00
1	1	16						.00	.92		

bottom section fluid variables:

	jz	pressure (kPa)	void	xair	t gas (C)	t fld (C)	u gas (m/s)	u fld (m/s)
	1	102.1008	.5350	.986	20.00	20.00	.00	.92
	2	102.4159	.5350	.986	20.00	20.00	.00	.92
tank bot.		102.7310	.5350	.986	20.00	20.00		

top section interfacial properties:

jz	tsat (C)	bulk ys mole frc	ti (C)	gamma(i) (g/s)	egi (kJ/s)
1	97.63	.022	18.33	.0000	.0000
2	97.73	.022	18.38	.0000	.0000

middle section interfacial properties:

ic	ix	jz	tsat (C)	bulk ys mole frc	ti (C)	gamma(i) (g/s)	egi (kJ/s)	gamma(w) (g/s)

1	1	1	97.82	.022	18.44	.0000	.0000	.0000
1	1	2	97.95	.022	18.51	.0000	.0000	.0000
1	1	3	98.13	.022	18.61	.0000	.0000	.0000
1	1	4	98.30	.022	18.71	.0000	.0000	.0000
1	1	5	98.48	.022	18.81	.0000	.0000	.0000
1	1	6	98.65	.022	18.91	.0000	.0000	.0000
1	1	7	98.82	.022	19.01	.0000	.0000	.0000
1	1	8	98.99	.022	19.10	.0000	.0000	.0000
1	1	9	99.16	.022	19.20	.0000	.0000	.0000
1	1	10	99.33	.022	19.30	.0000	.0000	.0000
1	1	11	99.50	.022	19.39	.0000	.0000	.0000
1	1	12	99.66	.022	19.49	.0000	.0000	.0000
1	1	13	99.83	.022	19.58	.0000	.0000	.0000
1	1	14	100.00	.022	19.68	.0000	.0000	.0000
1	1	15	100.12	.022	19.75	.0000	.0000	.0000

bottom section interfacial properties:

jz	tsat (C)	bulk ys mole frc	ti (C)	gamma(i) (g/s)	egi (kJ/s)
1	100.21	.022	19.80	.0000	.0000
2	100.30	.022	19.85	.0000	.0000

top section densities and enthalpies:

jz	rho gas (kg/m^3)	rho fld (kg/m^3)	h gas (kJ/kg)	h fld (kJ/kg)
plenum	1.09	997.84	324.566	83.216
1	1.10	997.84	324.565	83.216
2	1.10	997.84	324.565	83.216

middle section densities and enthalpies:

ic	ix	jz	rho gas (kg/m^3)	rho fld (kg/m^3)	h gas (kJ/kg)	h fld (kJ/kg)
1	1	1	1.11	997.84	324.564	83.216
1	1	2	1.11	997.84	324.564	83.216
1	1	3	1.12	997.84	324.563	83.216
1	1	4	1.12	997.84	324.562	83.216
1	1	5	1.13	997.84	324.561	83.216
1	1	6	1.14	997.84	324.560	83.216
1	1	7	1.15	997.84	324.559	83.216
1	1	8	1.15	997.84	324.558	83.216
1	1	9	1.16	997.84	324.557	83.216
1	1	10	1.17	997.84	324.556	83.216
1	1	11	1.17	997.84	324.556	83.216
1	1	12	1.18	997.84	324.555	83.216
1	1	13	1.19	997.84	324.554	83.216
1	1	14	1.19	997.84	324.553	83.216
1	1	15	1.20	997.84	324.552	83.216

bottom section densities and enthalpies:

jz	rho gas (kg/m^3)	rho fld (kg/m^3)	h gas (kJ/kg)	h fld (kJ/kg)
1	1.20	997.84	324.552	83.216
2	1.21	997.84	324.551	83.216
tank bot.	1.21	997.84	324.551	83.216

top section volumetric and mass flowrates:

Qz gas	Qz fld	mz gas	mz fld

jz	(l/s)	(l/s)	(g/s)	(kg/s)
1	.000	.510	.000	.509
2	.000	.510	.000	.509

middle section volumetric and mass flowrates:

ic	ix	jz	Qz gas (l/s)	Qz fld (l/s)	mz gas (g/s)	mz fld (kg/s)	Qx gas (l/s)	Qx fld (l/s)	mx gas (g/s)	mx fld (kg/s)
1	1	1	.000	.510	.000	.509	.000	.000	.000	.000
1	1	2	.000	.510	.000	.509	.000	.000	.000	.000
1	1	3	.000	.510	.000	.509	.000	.000	.000	.000
1	1	4	.000	.510	.000	.509	.000	.000	.000	.000
1	1	5	.000	.510	.000	.509	.000	.000	.000	.000
1	1	6	.000	.510	.000	.509	.000	.000	.000	.000
1	1	7	.000	.510	.000	.509	.000	.000	.000	.000
1	1	8	.000	.510	.000	.509	.000	.000	.000	.000
1	1	9	.000	.510	.000	.509	.000	.000	.000	.000
1	1	10	.000	.510	.000	.509	.000	.000	.000	.000
1	1	11	.000	.510	.000	.509	.000	.000	.000	.000
1	1	12	.000	.510	.000	.509	.000	.000	.000	.000
1	1	13	.000	.510	.000	.509	.000	.000	.000	.000
1	1	14	.000	.510	.000	.509	.000	.000	.000	.000
1	1	15	.000	.510	.000	.509	.000	.000	.000	.000
1	1	16	.000	.510	.000	.509				

bottom section volumetric and mass flowrates:

jz	Qz gas (l/s)	Qz fld (l/s)	mz gas (g/s)	mz fld (kg/s)
1	.000	.510	.000	.509
2	.000	.510	.000	.509

```
1                    power edit at time   .00000E+00 sec


 current assembly power is .........   .00000E+00 W
 pre-incident assembly power was ...   .00000E+00 W
 mode flag  1 (0=reactor limit, 1=expt mock-up)

0                   detailed power distributions


 --axial shape--    ------------------decreasing axial height------------------>
 initial shape        .66667E-01  .66667E-01  .66667E-01  .66667E-01  .66667E-01
 initial shape        .66667E-01  .66667E-01  .66667E-01  .66667E-01  .66667E-01
 initial shape        .66667E-01  .66667E-01  .66667E-01  .66667E-01  .66667E-01
 current shape        .66667E-01  .66667E-01  .66667E-01  .66667E-01  .66667E-01
 current shape        .66667E-01  .66667E-01  .66667E-01  .66667E-01  .66667E-01
 current shape        .66667E-01  .66667E-01  .66667E-01  .66667E-01  .66667E-01
0

  power (W) deposited in metal

0 for cylinder number  1
    axial level number  1
    --azimuth--     ---------------------increasing radii--------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  2
    --azimuth--     ---------------------increasing radii--------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  3
    --azimuth--     ---------------------increasing radii--------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  4
```

```
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  5
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  6
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  7
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  8
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  9
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number 10
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number 11
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number 12
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number 13
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number 14
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number 15
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
0 for cylinder number  2
    axial level number  1
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  2
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  3
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  4
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  5
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  6
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  7
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  8
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number  9
    --azimuth--     ----------------------increasing radii---------------------->
          1           .00000E+00  .00000E+00  .00000E+00
    axial level number 10
```

```
    --azimuth--      ----------------------increasing radii---------------------->
          1            .00000E+00  .00000E+00  .00000E+00
    axial level number 11
    --azimuth--      ----------------------increasing radii---------------------->
          1            .00000E+00  .00000E+00  .00000E+00
    axial level number 12
    --azimuth--      ----------------------increasing radii---------------------->
          1            .00000E+00  .00000E+00  .00000E+00
    axial level number 13
    --azimuth--      ----------------------increasing radii---------------------->
          1            .00000E+00  .00000E+00  .00000E+00
    axial level number 14
    --azimuth--      ----------------------increasing radii---------------------->
          1            .00000E+00  .00000E+00  .00000E+00
    axial level number 15
    --azimuth--      ----------------------increasing radii---------------------->
          1            .00000E+00  .00000E+00  .00000E+00


1$ fluid edit at time  =   55.116     seconds
       time step size  =   .14188     seconds
    Courant step size  =   .14188     seconds
 Section (1-T,2-M,3-B) =           1
   Channel (0 for T/B) =           0
               Axial   =           2
           Azimuthal   =           0


 top section fluid variables:
          jz  pressure  void    xair  t gas    t fld  u gas  u fld
              (kPa)                     (C)      (C)   (m/s)  (m/s)

      plenum   92.8390   .5350  .986  20.00    20.00
           1   93.1363   .5543  .985  20.00    20.00    .28    .92
           2   93.4373   .5565  .985  20.00    20.00    .27    .96

@middle section fluid variables:
                pressure  void    xair  t gas    t fld  u gas  u fld  w gas  w fld
  ic  ix  jz    (kPa)                     (C)      (C)   (m/s)  (m/s)  (m/s)  (m/s)
---------------------------------------------------------------------------------
   1   1   1   93.7345   .5562  .985  20.00    20.00    .27    .97    .00    .00
   1   1   2   94.1639   .5555  .985  20.00    20.00    .27    .97    .00    .00
   1   1   3   94.7275   .5547  .984  20.00    20.00    .26    .96    .00    .00
   1   1   4   95.2956   .5538  .985  20.00    20.00    .26    .96    .00    .00
   1   1   5   95.8685   .5529  .985  20.00    20.00    .26    .96    .00    .00
   1   1   6   96.4461   .5520  .985  20.00    20.00    .26    .96    .00    .00
   1   1   7   97.0282   .5511  .985  20.00    20.00    .26    .96    .00    .00
   1   1   8   97.6149   .5502  .985  20.00    20.00    .26    .96    .00    .00
   1   1   9   98.2064   .5493  .985  20.00    20.00    .26    .95    .00    .00
   1   1  10   98.8028   .5484  .985  20.00    20.00    .26    .95    .00    .00
   1   1  11   99.4039   .5475  .985  20.00    20.00    .26    .95    .00    .00
   1   1  12  100.0097   .5466  .985  20.00    20.00    .25    .95    .00    .00
   1   1  13  100.6203   .5457  .985  20.00    20.00    .25    .95    .00    .00
   1   1  14  101.2356   .5449  .986  20.00    20.00    .25    .94    .00    .00
   1   1  15  101.7110   .5435  .986  20.00    20.00    .25    .94    .00    .00
   1   1  16                                           .25    .94

 bottom section fluid variables:
          jz  pressure  void    xair  t gas    t fld  u gas  u fld
              (kPa)                     (C)      (C)   (m/s)  (m/s)

           1  102.0455   .5419  .986  20.00    20.00    .25    .94
           2  102.3847   .5393  .986  20.00    20.00    .25    .93
   tank bot.  102.7310   .5350  .986  20.00    20.00
```

top section interfacial properties:

jz	tsat (C)	bulk ys mole frc	ti (C)	gamma(i) (g/s)	egi (kJ/s)
1	97.63	.024	20.00	.0002	.0005
2	97.72	.024	20.00	.0001	.0002

middle section interfacial properties:

ic	ix	jz	tsat (C)	bulk ys mole frc	ti (C)	gamma(i) (g/s)	egi (kJ/s)	gamma(w) (g/s)
1	1	1	97.80	.025	20.00	.0000	.0000	.0000
1	1	2	97.93	.025	20.00	.0000	.0000	.0000
1	1	3	98.10	.025	20.00	.0002	.0005	.0000
1	1	4	98.27	.024	20.00	-.0001	-.0003	.0000
1	1	5	98.43	.024	20.00	.0002	.0004	.0000
1	1	6	98.60	.024	20.00	.0001	.0004	.0000
1	1	7	98.77	.024	20.00	.0002	.0005	.0000
1	1	8	98.94	.024	20.00	-.0001	-.0003	.0000
1	1	9	99.11	.024	20.00	-.0002	-.0004	.0000
1	1	10	99.28	.024	20.00	.0002	.0005	.0000
1	1	11	99.45	.023	20.00	-.0001	-.0003	.0000
1	1	12	99.63	.023	20.00	.0001	.0003	.0000
1	1	13	99.80	.023	20.00	-.0001	-.0003	.0000
1	1	14	99.97	.023	20.00	-.0001	-.0003	.0000
1	1	15	100.10	.023	20.00	-.0001	-.0002	.0000

bottom section interfacial properties:

jz	tsat (C)	bulk ys mole frc	ti (C)	gamma(i) (g/s)	egi (kJ/s)
1	100.20	.023	20.00	.0001	.0002
2	100.29	.023	20.00	-.0001	-.0001

top section densities and enthalpies:

jz	rho gas (kg/m^3)	rho fld (kg/m^3)	h gas (kJ/kg)	h fld (kJ/kg)
plenum	1.09	997.84	324.566	83.216
1	1.10	997.84	326.808	83.215
2	1.10	997.84	327.529	83.215

middle section densities and enthalpies:

ic	ix	jz	rho gas (kg/m^3)	rho fld (kg/m^3)	h gas (kJ/kg)	h fld (kJ/kg)
1	1	1	1.10	997.84	327.744	83.215
1	1	2	1.11	997.84	327.679	83.215
1	1	3	1.12	997.84	327.957	83.214
1	1	4	1.12	997.84	327.567	83.215
1	1	5	1.13	997.84	327.544	83.214
1	1	6	1.14	997.84	327.285	83.215
1	1	7	1.14	997.84	327.163	83.215
1	1	8	1.15	997.84	326.699	83.215
1	1	9	1.16	997.84	326.584	83.215
1	1	10	1.16	997.84	326.538	83.215
1	1	11	1.17	997.84	326.108	83.215
1	1	12	1.18	997.84	326.020	83.215
1	1	13	1.19	997.84	325.749	83.215
1	1	14	1.19	997.84	325.510	83.216

```
  1   1  15      1.20    997.84    325.418     83.216
```

bottom section densities and enthalpies:

jz	rho gas (kg/m^3)	rho fld (kg/m^3)	h gas (kJ/kg)	h fld (kJ/kg)
1	1.20	997.84	325.450	83.215
2	1.21	997.84	325.113	83.216
tank bot.	1.21	997.84	324.551	83.216

top section volumetric and mass flowrates:

jz	Qz gas (l/s)	Qz fld (l/s)	mz gas (g/s)	mz fld (kg/s)
1	.177	.510	.194	.509
2	.177	.510	.194	.509

middle section volumetric and mass flowrates:

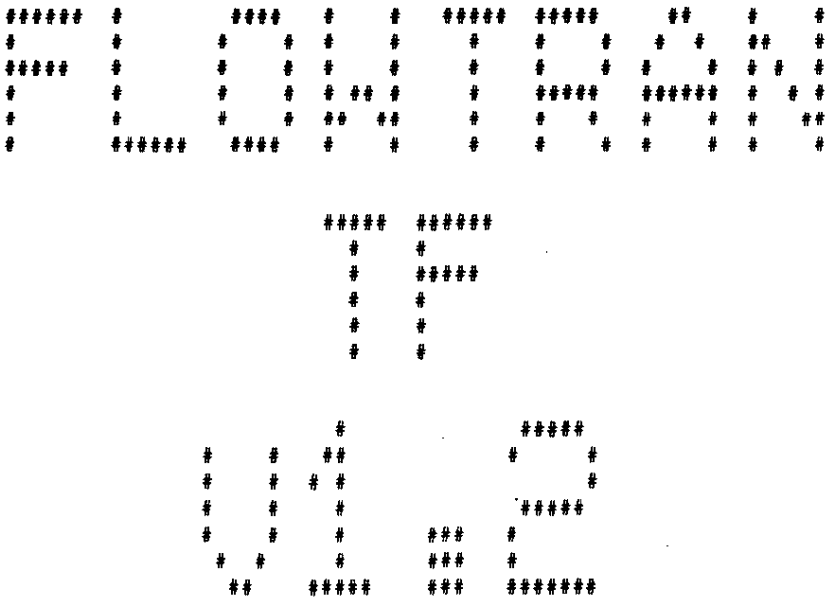
ic	ix	jz	Qz gas (l/s)	Qz fld (l/s)	mz gas (g/s)	mz fld (kg/s)	Qx gas (l/s)	Qx fld (l/s)	mx gas (g/s)	mx fld (kg/s)
1	1	1	.176	.510	.194	.509	.000	.000	.000	.000
1	1	2	.176	.510	.194	.509	.000	.000	.000	.000
1	1	3	.175	.510	.194	.509	.000	.000	.000	.000
1	1	4	.174	.510	.194	.509	.000	.000	.000	.000
1	1	5	.173	.510	.194	.509	.000	.000	.000	.000
1	1	6	.172	.510	.194	.509	.000	.000	.000	.000
1	1	7	.171	.510	.194	.509	.000	.000	.000	.000
1	1	8	.170	.510	.194	.509	.000	.000	.000	.000
1	1	9	.169	.510	.194	.509	.000	.000	.000	.000
1	1	10	.168	.510	.194	.509	.000	.000	.000	.000
1	1	11	.167	.510	.194	.509	.000	.000	.000	.000
1	1	12	.166	.510	.194	.509	.000	.000	.000	.000
1	1	13	.165	.510	.194	.509	.000	.000	.000	.000
1	1	14	.164	.510	.194	.509	.000	.000	.000	.000
1	1	15	.163	.510	.194	.509	.000	.000	.000	.000
1	1	16	.162	.510	.194	.509				

bottom section volumetric and mass flowrates:

jz	Qz gas (l/s)	Qz fld (l/s)	mz gas (g/s)	mz fld (kg/s)
1	.161	.510	.194	.509
2	.161	.510	.194	.509

initial power is zero - a nonzero initial power must be used to calculate power iterations

The following file saved as `test_31_01_m08.out2` was written to unit number 20:



```
NES Code Management System, TP-92-049, Rev 0
IBM RISC System/6000, Model 530
AIX Version 3 for RISC System/6000, 03.01.0005.0012
IBM AIX XL FORTRAN Compiler, 02.02.0000.0000
Compiler options: -O -qautodbl=dblpad
Loader   options: -berok
Built 29-JAN-1993 by S.E.Aleman @ x52986 at 773-11A
Status of Code - TESTING


1$fluid edit at time =   .00000E+00 seconds
     time step size =   5.0000     seconds
               ppln =      92839.0 Pa
              tgpln =       293.15 K
              xapln =      .986000
 avg middle sec void =      .535000
 stp corr. (25C/1atm)=      .931877

 top section superficial velocities:
                 jf       jg       j          Qg           Qg           Qf
          jz   (m/s)    (m/s)    (m/s)      (cfm)        (gpm)        (gpm)

           1     .429     .000     .429       .00000       .00000      8.08911
           2     .429     .000     .429       .00000       .00000      8.08911

 middle section superficial velocities:
                 jf       jg       j          Qg           Qg           Qf
  ic  ix  jz   (m/s)    (m/s)    (m/s)      (cfm)        (gpm)        (gpm)

   1   1   1     .429     .000     .429       .00000       .00000      8.08911
   1   1   2     .429     .000     .429       .00000       .00000      8.08911
   1   1   3     .429     .000     .429       .00000       .00000      8.08911
```

1	1	4	.429	.000	.429	.00000	.00000	8.08911
1	1	5	.429	.000	.429	.00000	.00000	8.08911
1	1	6	.429	.000	.429	.00000	.00000	8.08911
1	1	7	.429	.000	.429	.00000	.00000	8.08911
1	1	8	.429	.000	.429	.00000	.00000	8.08911
1	1	9	.429	.000	.429	.00000	.00000	8.08911
1	1	10	.429	.000	.429	.00000	.00000	8.08911
1	1	11	.429	.000	.429	.00000	.00000	8.08911
1	1	12	.429	.000	.429	.00000	.00000	8.08911
1	1	13	.429	.000	.429	.00000	.00000	8.08911
1	1	14	.429	.000	.429	.00000	.00000	8.08911
1	1	15	.429	.000	.429	.00000	.00000	8.08911
1	1	16	.429	.000	.429	.00000	.00000	8.08911

bottom section superficial velocities:

jz	jf (m/s)	jg (m/s)	j (m/s)	Qg (cfm)	Qg (gpm)	Qf (gpm)
1	.429	.000	.429	.00000	.00000	8.08911
2	.429	.000	.429	.00000	.00000	8.08911

1$fluid edit at time = 55.116 seconds
time step size = .14188 seconds
ppln = 92839.0 Pa
tgpln = 293.15 K
xapln = .986000
avg middle sec void = .550181
stp corr. (25C/1atm)= .931877

top section superficial velocities:

jz	jf (m/s)	jg (m/s)	j (m/s)	Qg (cfm)	Qg (gpm)	Qf (gpm)
1	.429	.149	.578	.37490	2.80448	8.08911
2	.429	.148	.577	.37441	2.80078	8.08837

middle section superficial velocities:

ic	ix	jz	jf (m/s)	jg (m/s)	j (m/s)	Qg (cfm)	Qg (gpm)	Qf (gpm)
1	1	1	.429	.148	.577	.37344	2.79355	8.08801
1	1	2	.429	.148	.576	.37229	2.78489	8.08820
1	1	3	.429	.147	.576	.37057	2.77203	8.08812
1	1	4	.429	.146	.575	.36867	2.75786	8.08872
1	1	5	.429	.145	.574	.36623	2.73958	8.08825
1	1	6	.429	.144	.573	.36424	2.72469	8.08897
1	1	7	.429	.144	.573	.36225	2.70981	8.08945
1	1	8	.429	.143	.572	.36036	2.69570	8.09005
1	1	9	.429	.142	.571	.35801	2.67807	8.08956
1	1	10	.429	.141	.570	.35559	2.66000	8.08912
1	1	11	.429	.140	.569	.35365	2.64551	8.09000
1	1	12	.429	.139	.568	.35134	2.62821	8.08946
1	1	13	.429	.139	.567	.34932	2.61312	8.09021
1	1	14	.429	.138	.567	.34702	2.59591	8.08956
1	1	15	.429	.137	.566	.34469	2.57844	8.08949
1	1	16	.429	.136	.565	.34301	2.56590	8.08885

bottom section superficial velocities:

jz	jf (m/s)	jg (m/s)	j (m/s)	Qg (cfm)	Qg (gpm)	Qf (gpm)
1	.429	.136	.564	.34194	2.55786	8.08955
2	.429	.135	.564	.34069	2.54854	8.08958

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