Calculation of Byron 1/ Braidwood 1 D4 Steam Generator Tube Support Plate Loads with RELAP5M3

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Abstract

This report documents a series of calculations performed to develop differential pressure loading time histories for the principal tube support plates in the Model D4 steam generators under Main Steam Line Break (MSLB) conditions from Hot Zero Power. These loads when multiplied by an appropriate factor, are intended to form the input for detailed structural evaluations. This work is being performed in support of the 3 mv IPC submittal.

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1. Introduction

During a main steam line break event, the rapid blowdown of the faulted steam generator can lead to significant loads on the tube support plates. Transient thermal hydraulic calculations on the Byron 1/Braidwood 1 Model D4 steam generators have been performed in support of structural calculations regarding the extent of tube support plate deformation. The geometrical properties of the D4 generators are derived from previous thermal hydraulic analyses performed by Westinghouse. This information is applied in the RELAP5M3 computer code to obtain loads based on the most current computer code available. In the course of this work, a problem was noted in the non-equilibrium modeling of RELAP5M3. Methods were developed to circumvent this problem and obtain conservative, appropriate loads. This report documents the models created for this purpose and details the results obtained.

2. Methodology/Model Description and Assumptions

2.1 Computer Code

The RELAP5M3 Version 1.1 computer code as implemented on the ComEd HP 735 workstation network was employed for this calculation. This code is installed in the NFS test library. The sample problems supplied were run and reviewed to ensure proper installation and operation of the code. In addition, the MB2 test was modeled with this code using similar nodalizations to further assess the ability of the code and modeling methods to properly predict the transient differential pressures on the tube support plates during MSLB events.

This computer code has the ability to model full non-equilibrium conditions, and employs a six equation/ two fluid model. The developmental assessment problems were reviewed to verify that the code has an appropriate basis for the performance of this calculation. The GE "One-foot" and "Four-foot" blowdown tests are most representative of this problem, and demonstrate that the code will conservatively and appropriately model saturated steam blowdowns with level swell. In addition, this code has been extensively tested in LOCA type calculations, and has been used for licensing applications by vendors and utilities.

2.2 RELAP5M3 Model of D4 Steam Generator

The model developed for use in this calculation is depicted in Figure 1. This model is based heavily on the TRANFLO input description provided by Westinghouse. The primary side of the model used a nodalization essentially identical to that used by Westinghouse. Key secondary side flowpaths have been checked to ensure that appropriate values of inertia and pressure drop information are being consistently applied. Calculations of fluid path inertia and loss coefficients of the principal flow paths for the TRANFLO model and the corresponding RELAP input are provided in Appendix C. As can be seen, the RELAP model uses consistent, and slightly conservative values. This model was developed using RELAP5M2 in a prior calculation (Reference 1) and was converted to RELAP5M3 for this application.

2.3 Initial Conditions

Prior vendor calculations (Reference 2) indicate that the limiting case occurs at hot zero power conditions with water levels at normal values. The water level is at 487" , just below the swirl vanes in the separators. The temperature of the water and steam are uniform at 557 F, and saturation conditions are assumed. The primary system is at equilibrium conditions with the steam generator. The primary system is modeled with time dependent boundary conditions that specify the hot leg temperature to be constant at 557 F. It should be noted that setting initial conditions for the partially voided volumes required some effort, since RELAP requires specification of fluid quality, but the value needed is void fraction. Inspections of resultant void fractions, and total SG mass were helpful in adjusting the model to start at the correct liquid levels.

This calculation concerns the HZP case, since this is the limiting condition with respect to TSP pressure loads. This condition leads to high TSP loads as a result of the acceleration of a nearly solid column of fluid past the TSPs early in the event. Full power conditions are less limiting since the tube bundle is heavily voided, with much less overall inventory in the SG. This leads to a more "cushioned" effect and lower resultant loads on the TSPs as indicated by prior vendor analysis.

2.4 Break Model

The break is modeled using a motor valve component with an opening rate of 1 millisecond. The generator nozzle is specifically modeled to provide appropriate treatment of fluid inertia and flow limitation. The break is assumed to occur directly outside the nozzle.

2.5 Tube Support Plate Differential Pressure Calculation

The calculation of tube support plate differential pressures was accomplished by subdividing the tube sections of the steam generator to include thin (.2 ft) volumes on either side of the support plates (A-P). The pressure difference between these volumes was then calculated via a control variable to provide the time dependent differential pressure. This method was applied on all the support plates with the exception of the preheater sections. With this approach, it is desirable to use the smallest volumes possible, since the control system calculation includes a conservative bias related to the elevation head. Since this approach leads to a combination of small nodes adjacent to significantly larger nodes, a sensitivity study was performed to demonstrate that the loads are not significantly affected by the choice of nodalization.

2.6 Special Modeling Considerations

2.6.1 Non-equilibrium Models

During the course of this work, it was noted that using the full non-equilibrium model selection led to the generation of non-physical spiking in the tube bundle region. An investigation of this behavior found that the spiking could be traced to the interfacial heat transfer behavior, allowing excessive amounts of liquid superheat to exist in the bundle region and then instantly resolving the discrepancy. (Reference 3) To avoid the non-physical behavior, the volume control words in the tube bundle and lower downcomer were set to e=1. This forces a high heat transfer coefficient to exist between phases, and effectively precludes the instability. Full nonequilibrium behavior is modeled throughout the rest of the model. This approach was demonstrated to render more physical and appropriate response by performing comparison studies to the MB2 steam blowdown tests.

2.6.2 Tube Bundle Interface Drag Modeling

The modeling of the tube bundle region was performed in accordance with the latest guidance available in the April-June 1995 RELAP5 Newsletter. The TSP areas are set to be equal to the flow area of the bundle, and the loss coefficients are adjusted to provide the equivalent K-value. This change allows for more appropriate application of the EPRI bundle interface drag correlations.

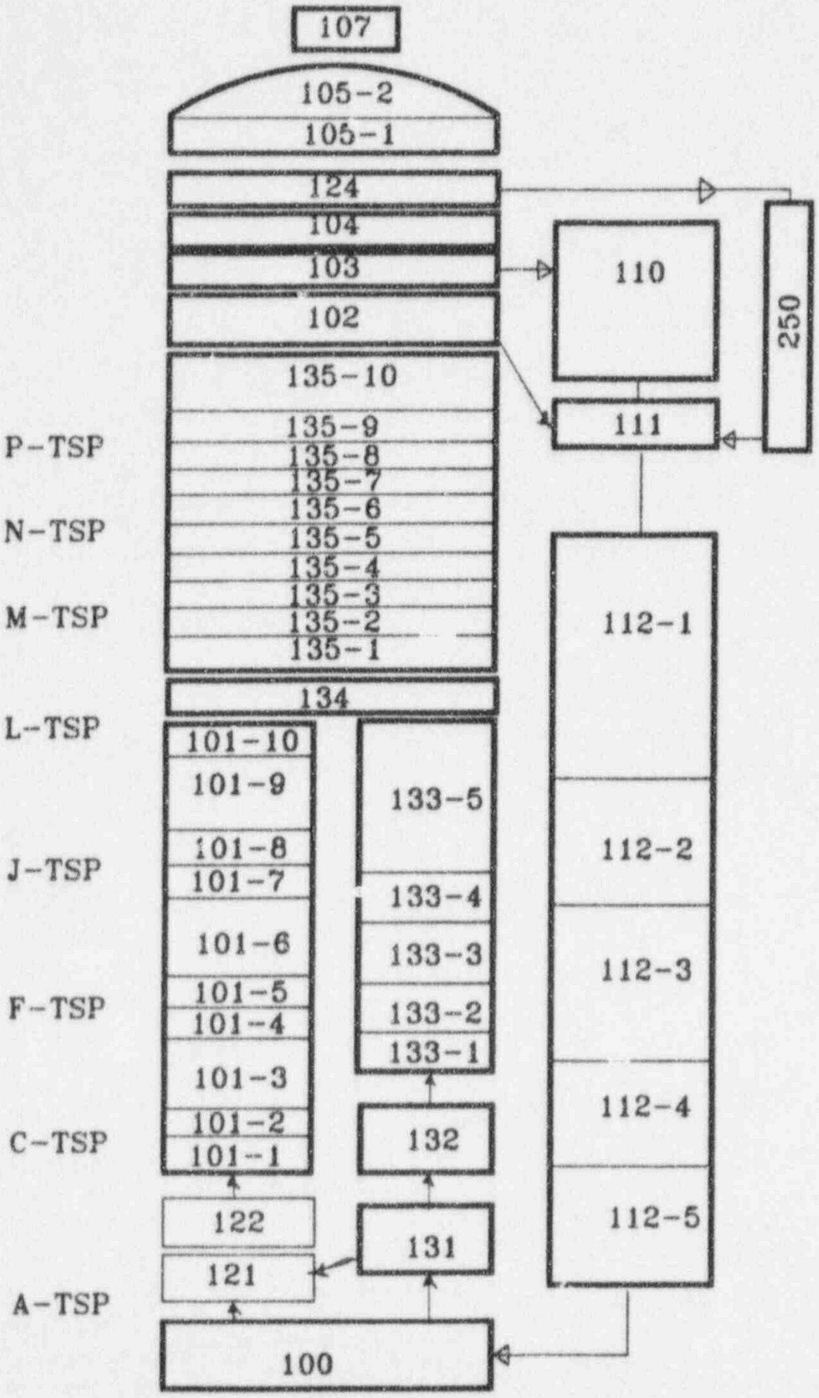
2.6.3 Crossflow Resistance Modeling

A review of the Westinghouse input/output for TRANFLO indicated that a crossflow resistance across the tube bundle was accounted for. An independent approach for calculating the crossflow resistance was developed based on the Zukauskus correlation as presented in Reference 4. The results of this correlation were compared to Westinghouse at the .57 second output edit, and showed comparable pressure drops. The pressure drop information calculated in this way was then converted into K-values to be added as crossflow corrections at selected junctions. This approach was used for the upper tube region(135-5) , downcomer entrance (100), and preheater (133) areas.

2.6.4 Vertical Stratification Modeling in the Dome Regions

Based on review of initial calculations, it was noted that the dome region volumes were deentraining fluid and preventing the two phase mixture from reaching the break. The vertical stratification models were switched off in the upper SG regions (103 and 104) in the final case. This has no effect on the load calculations, since the peak occurs well before any carryover effects are observed. This change was made to provide more appropriate long term mass/energy balance predictions in the model.

Figure 1 RELAP5 Model Diagram



RELAP5M3 D4 Steam Generator Model

3. Calculations

3.1 Base Case

The base case performed is the full MSLB from Hot Zero Power Conditions. The water level is assumed to be at normal levels (487"). The time dependent differential pressures on the tube support plates, along with the tube sheet transient differential pressure, are the primary output of interest. In addition, the average density adjacent to the TSPs is generated for use in the structural analysis. The base model employs equilibrium models in the tube region and lower downcomer volumes (volume control word e=1), with full nonequilibrium selected elsewhere. The default separator performance curves are applied.

3.2 Sensitivity Calculations

Several additional cases were run to assess the sensitivity of the base case model to variance in input parameters.

3.2.1 Separator Performance

The first set of sensitivity runs looked at the RELAP5 separator modeling of carryover/carryunder fractions. The base case used the default separator performance values (Vover=.5, Vunder=.15). Values of Vover ranging from 0.25 to 1.0 were input with default Vunder. Then Vunder was varied from the default value of 0.15 to 0.45, while holding Vover at its 0.5 default value.

3.2.2 TSP Loss Coefficient

In order to assess the appropriateness of the differential pressure modeling of the upper support plate, the loss coefficient for the P TSP were varied plus and minus 10% This allows the determination of whether the pressure drop is due to two-phase effects, or just the plate frictional losses by comparing the relative change in the differential pressures from the base case.

3.2.3 Variation in Flow Limiting Nozzle Area/Critical Flow Performance

The nozzle area is increased by 10% and 20% to determine the impact of variations in nozzle area. While the nozzle area is in fact well quantified, these cases provide an assessment of the effects of greater than expected break flow rates. While the uncertainty in critical flow rate is expected to be low, based on code assessment performance, this sensitivity is a good way to bound uncertainties in the overall code thermal hydraulic predictions. Only the high flow cases (area ratio>1) will be run, since reduced break flows will translate directly into reduced pressure drop at the TSPs.

3.2.4 Nodalization Sensitivity

As discussed in section 2.5, it is necessary to demonstrate that the small nodes used to obtain the differential pressures across the TSPs do not adversely affect the results generated by the model. To verify this, a "clean" model, with no thin slabs in the tube regions was created. This model is shown in Figure 2. Liquid velocities at TSP F, M, and P were generated for comparison with the base model. Since the differential pressure is directly related to the square of the fluid velocity, this provides a good test of the effects of the thin slab nodalization.

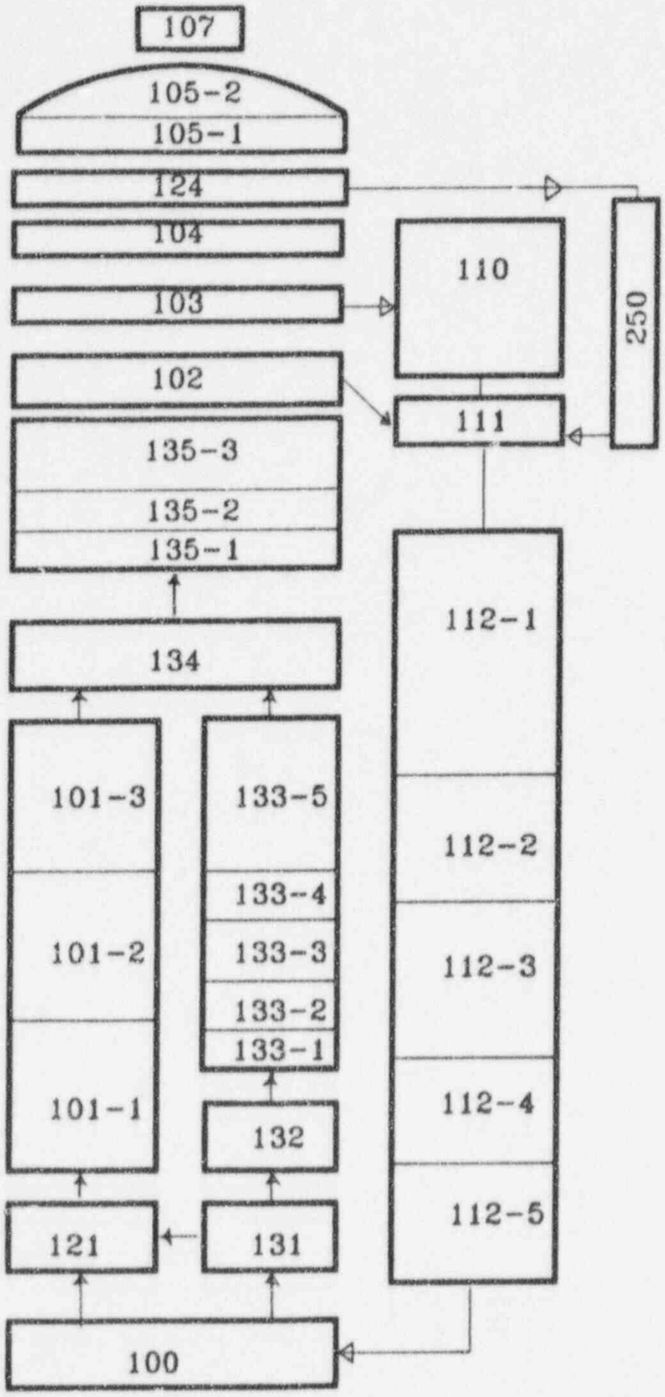
3.2.5 Variation in Initial Water Level

The base case is run at normal water level conditions. This case is run at the low water level condition, corresponding to the initiation setpoint of the auxiliary feedwater system. This provides a lower bound value for the initial water level, although it is recognized as a very unlikely point for any extended time while at HZP conditions.

3.2.6 Time Step Size

The base case is run with a selection of time steps to demonstrate that adequate convergence exists in the final solution presented.

Figure 2 Renodalization of Model without dp slabs



RELAP5M3 Nodalization Sensitivity Model

4. Results

4.1 Base Case

The base case was evaluated out to 4 seconds into the blowdown to ensure that the key load causing aspects of the MSLB were included. The base case resulted in a peak pressure of 1.916 psi across the P-TSP. The results of the base case are depicted in Figures 3 through 8. The dome pressure is shown in Figure 3. As can be seen, the pressure drops rapidly initially and then moderates to rates of approximately 100 psi/sec or less within .2 seconds. Break mass flow rate is shown in Figure 4. Break flow is initially all steam, with entrained liquid reaching the break at approximately 1.5 seconds, causing an increase in the mass flow rate. This is approximately twice as long as was seen in prior RELAP5M2 calculations, and is expected based on the code differences. Liquid void fraction in the volume adjacent to the inlet to TSP P is shown in Figure 5. The liquid void fraction remains relatively high throughout the peak dynamic load period, and review of the flow regimes predicted indicates bubbly flow persists until after the peak load occurs. The differential pressures across the P, N, and M TSPs are shown in Figure 6. This shows a peak occurs about 0.3 seconds followed by a rapid decay to near steady-state conditions. liquid void fraction is shown in Figure 6. Figure 7 provides the differential pressures predicted for the F, J and L TSPs, located in the middle of the tube bundle. The lower support plates A and C differential pressure response is shown in Figure 8.

4.2 Results of Sensitivity Cases

4.2.1 Separator Model Sensitivity

The values of separator carryover and carryunder fractions were varied over a range of values to determine what impact the separator model has on the results. The values utilized and the corresponding results are displayed in Table 1. As can be seen, there is very little sensitivity to separator model inputs. This is most likely a result of early flooding of the separator, causing the separator model to shift to "same in/same out" behavior. The carryunder fraction is most likely insensitive due to flow reversal effects.

Case Output File	Vover	Vunder	Max DP at P-TSP psi	Percent Change
Base	.5	.15	1.9161	0
wsens4	.75	.15	1.9148	-.0678
wsens5	1.0	.15	1.9866	3.6793
wsens6	.25	.15	1.9802	3.3453
wsens8	.5	.3	1.9161	0
wsens7	.5	.45	1.9161	0

Table 1 Results of Separator Parametric Sensitivity

4.2.2 Effects of TSP Loss Coefficient

The loss coefficients for the P-TSP were varied by plus and minus 10%. The results are shown in Table 2. The results are as one would expect, with almost linear behavior of pressure drop with respect to loss coefficient.

Case Output File	RELAP input at Bundle Flow Area	K-Equivalent at Actual TSP Area	Max DP at P-TSP psi	Percent change
wsens9	12.5488	1.19	2.0877	8.9557
wsens10	10.2672	.972	1.7424	-9.0653
Base	11.408	1.08	1.9161	0

Table 2 Sensitivity to TSP Loss Coefficient

4.2.3 Variation in Nozzle Area/Critical Flow Uncertainty

These cases were run to determine the effects of increased steam flow through the break. This is comparable to the Coefficient of Discharge sensitivities run on LOCA calculations, but in this case, the more deleterious effect occurs if the break flow increases. Therefore the areas of the nozzle and break were increased as shown below. As can be seen, the break flow has a dominant effect on the calculated result. This is consistent with expectation, since the break flow area directly affects the vessel depressurization rate, which provides the driving force for the initial fluid surge. It should be noted that the flow restricting nozzle is well quantified and little uncertainty exists in its geometry. In addition, the code assessment problems demonstrate that RELAP5M3 characterizes the critical flow and depressurization rate of vessels very well. However, this sensitivity case provides a good way of defining margin for thermal hydraulic prediction uncertainties.

Case Output File	Nozzle Area ft2 (% of actual)	Max DP at P-TSP	Percent Change
wsens1	1.5268 (110%)	2.1688	13.1882
wsens2	1.6656 (120%)	2.4083	25.6876
Base	1.388 (100%)	1.9161	0

Table 3 Effect of Nozzle Area/Critical Flow Uncertainty

4.2.4 Nodalization Sensitivity

As noted in the previous section, this sensitivity is performed to assure that the use of thin slab nodes to facilitate TSP differential pressure prediction are not adversely affecting the hydraulic solution. A renodalization of the base model, shown in Figure 2, was run. Junction fluid velocities at F, M, and P TSPs were extracted for direct comparison with the base model case, and are shown in Table 4 below. As noted previously, the base model differential pressures conservatively include the elevation head. This is equivalent to about .06 psi (at the initial density of 45.5 lb/ft3), or about 3.1% of the peak load. As can be seen, the maximum effect on TSP loads attributable to the nodalization is comparable to the effects of including the density head into the computed load. Plots of the velocities at the three locations are provided in Figures 9, 10, and 11. These graphically demonstrate that the inclusion of the thin slabs in the base model does not significantly compromise the solution accuracy.

Case Output File	Velocity at F TSP at point of peak dp m/sec	Velocity at M TSP at point of peak dp m/sec	Velocity at P TSP at point of peak dp m/sec
wm3nod	.621	1.24	1.80
Base	.612	1.22	1.79
% effect on dp	2.96	3.305	1.12

Table 4 Nodalization Sensitivity Study Results

4.2.5 Variation in Initial Water Level

Previous studies indicated that the initial water level could have a significant effect on the TSP loads. To evaluate this effect, the water level was reduced in the base model to the entrance of the separator riser. (Volumes 102, 110, 111, and 250 had initial quality set equal to 1.0) This initial water level corresponds to a level above the tube sheet of approximately 380 inches, versus the 487 inch level in the base case. This level is well below the low-low water level point (40.7%), just slightly below the safety analysis limit used in the plant transient analysis (23.7%) for loss of normal feedwater calculations. This represents a conservative lower bound for the initial water level, since the AFW system would initiate prior to this point to restore the level to the normal range.

As expected, this case resulted in the most significant impact on the differential pressure loads at the TSPs. The results are shown below.

Case Output File	**Initial Water Level inches**	**Maximum dp at L TSP psi**	**Maximum dp at P TSP psi**
wsens3	380	1.7476	2.4375
Base	487	1.3540	1.9161
% effect on dp		29	27.2

Table 5 Effect of Initial Water Level

4.2.6 Effects of Time Step Size

A series of cases were run to determine the sensitivity of the solution to the time step size. The time steps used and the effect on the peak dp at P TSP is shown in Table 6. These results demonstrate good convergence of the solution, with the variation in time step size affecting the peak by only 1.1% for a factor of 10 in time step size. The 0.0001 time step was applied to the base case and all sensitivity studies for the first second of the transient to ensure consistent, conservative results.

Case Output File	**Time step size in first second of event**	**Max DP at P-TSP psi**
wsens11	0.001	1.8945
wsens12	0.0005	1.9055
wsens13	0.0001	1.9161

Table 6 Effect of Time Step Size

4.3 Design Margin

Since the RELAP5M3 computer code is considered to be a best estimate prediction tool, it is appropriate to consider additional factors to be applied to the loads generated to assure adequate design margin. Based on the sensitivity studies, a factor can be developed to assure that the structural design adequately bounds all anticipated loads. It can be seen that none of the sensitivity effects is greater than 30%. The results of the uncertainty calculation can be combined using square root sum of the squares methods (SRSS) to establish a maximum probable load. Combining the results from the sensitivity studies in this manner gives a load factor of 1.4. This is a highly conservative value since it combines the unlikely low water level with a 20% larger nozzle area. This factor provides assurance that uncertainties in thermal hydraulic prediction as well as anticipated ranges of plant conditions are bounded.

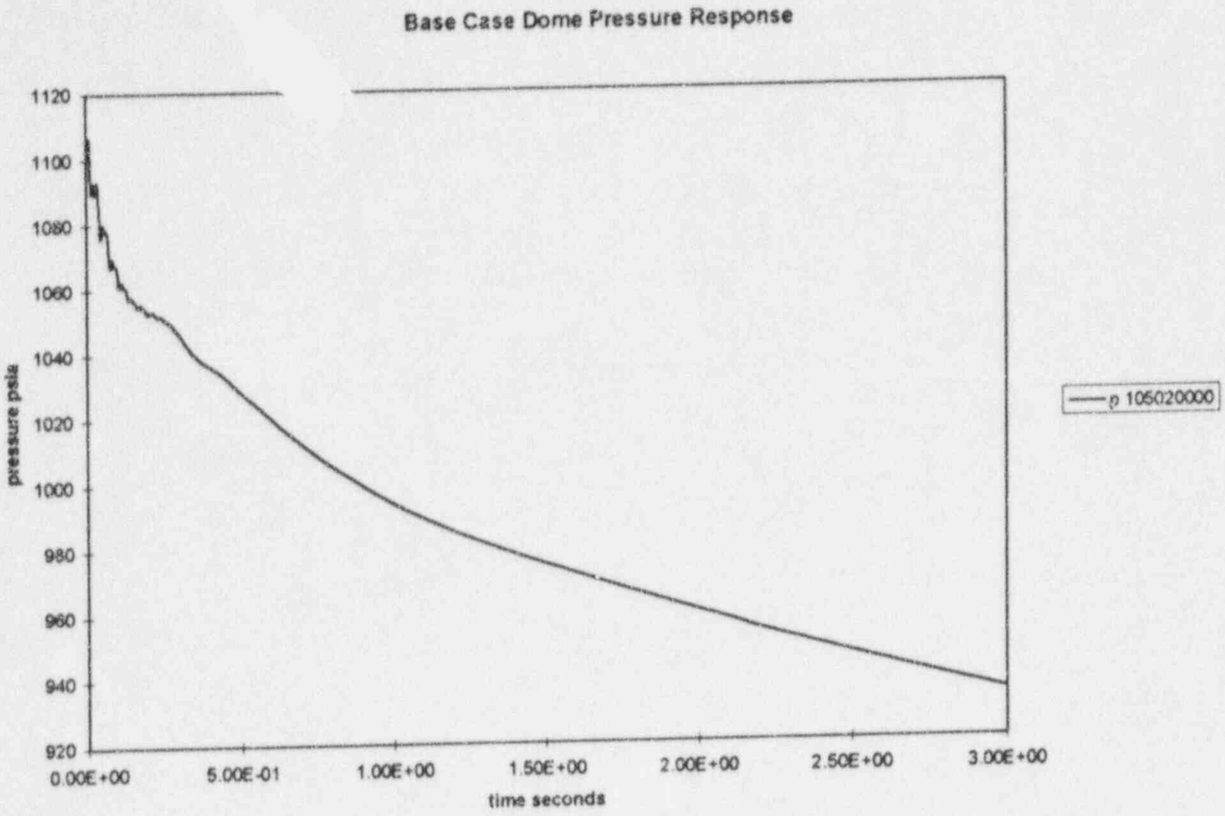


Figure 3 Base Case Dome Pressure Response

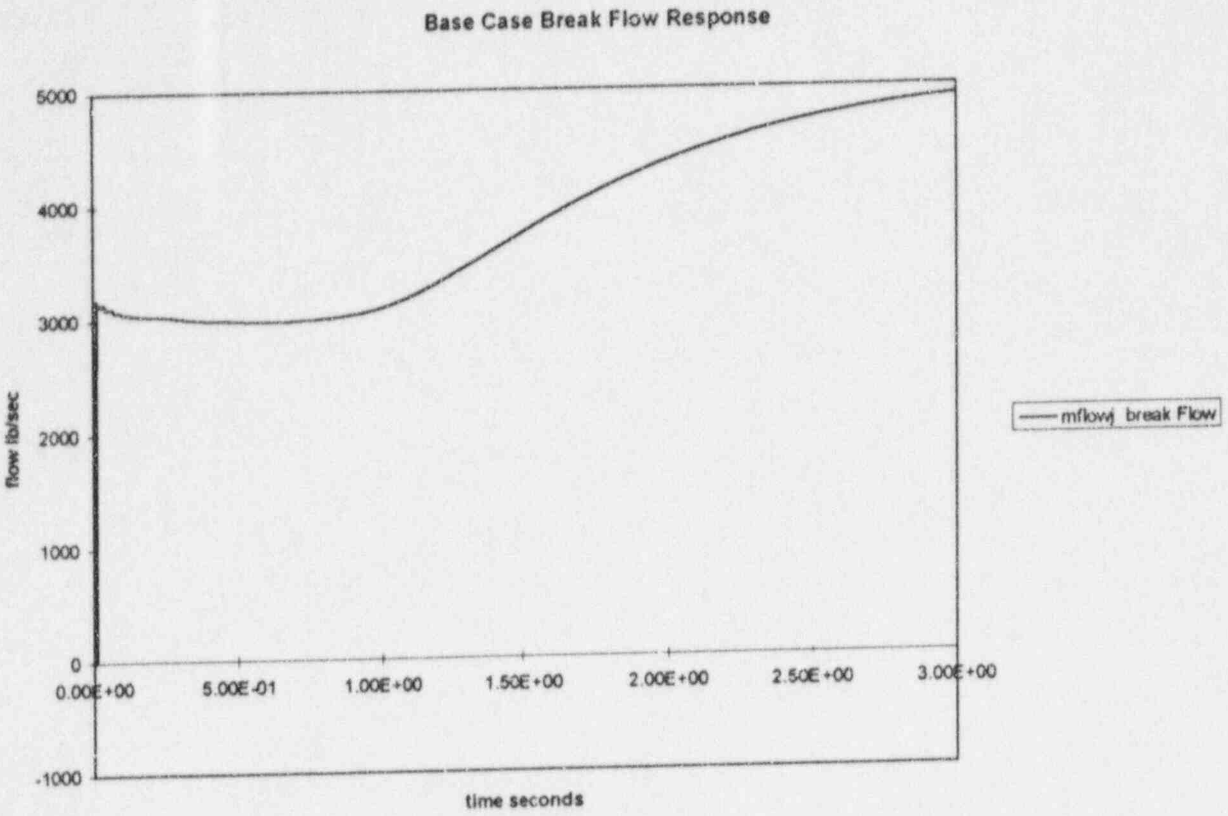


Figure 4 Base Case Break Flow Rate

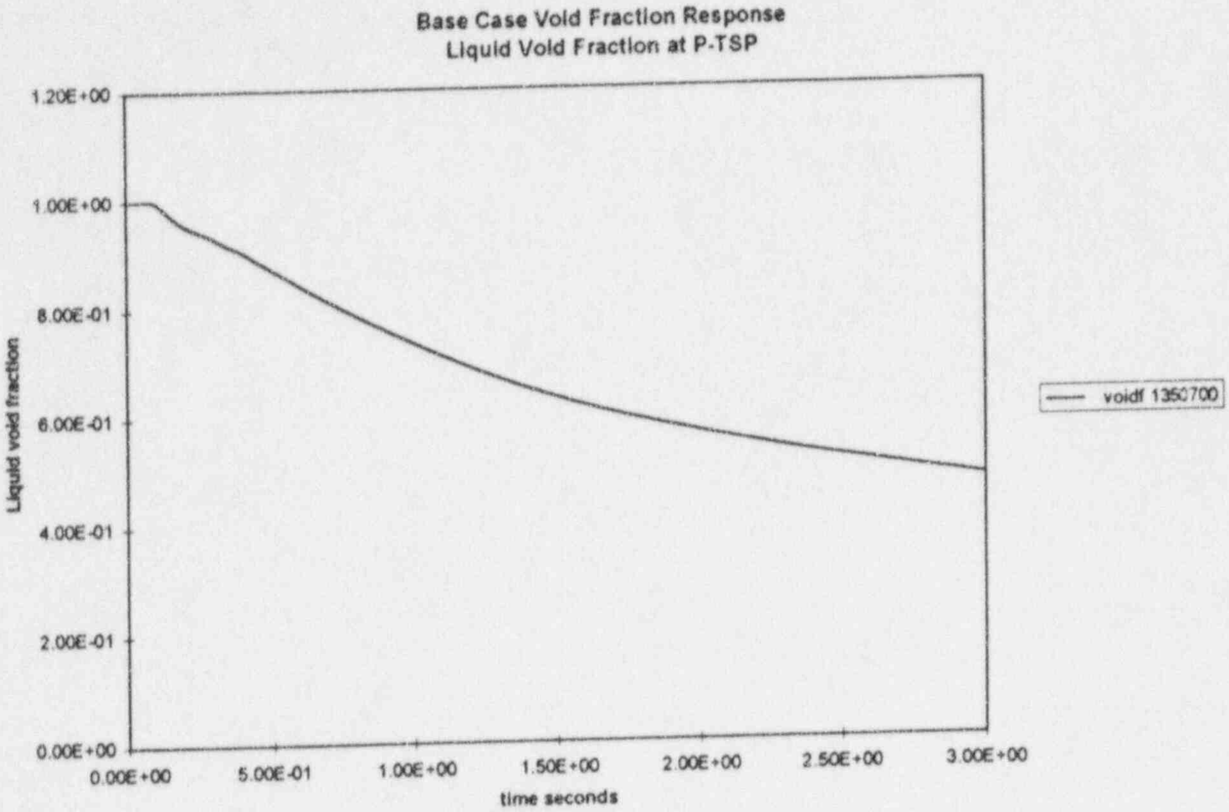


Figure 5 Base Case Liquid Void Fraction at P TSP

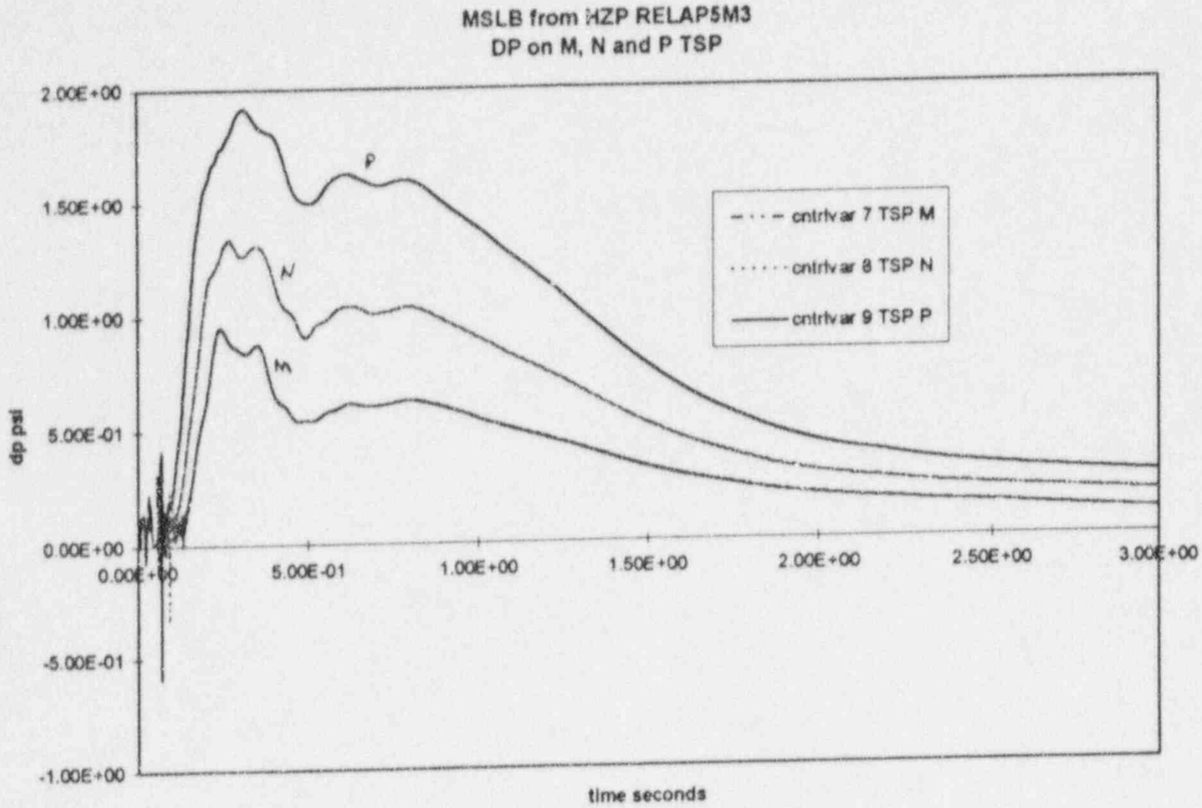


Figure 6 Base Case Differential Pressure on P, N, M TSPs

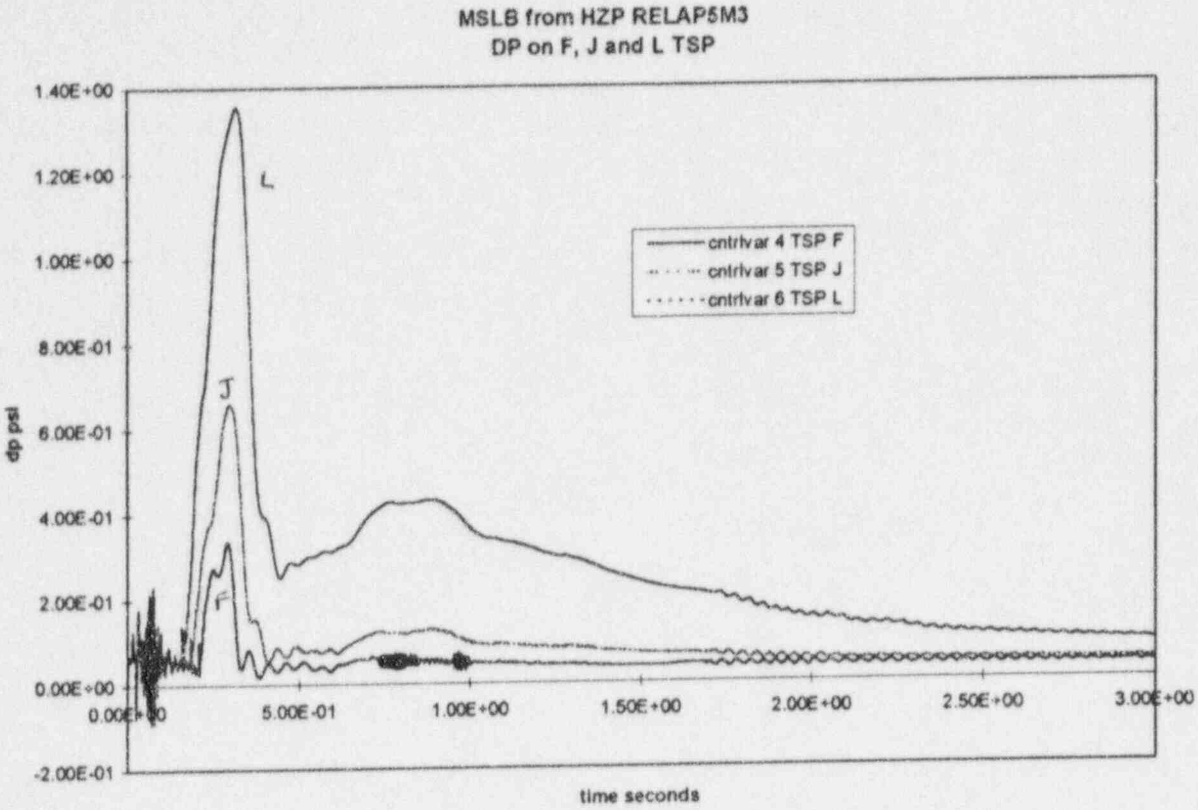


Figure 7 Base Case Differential Pressure at F, J, L TSPs

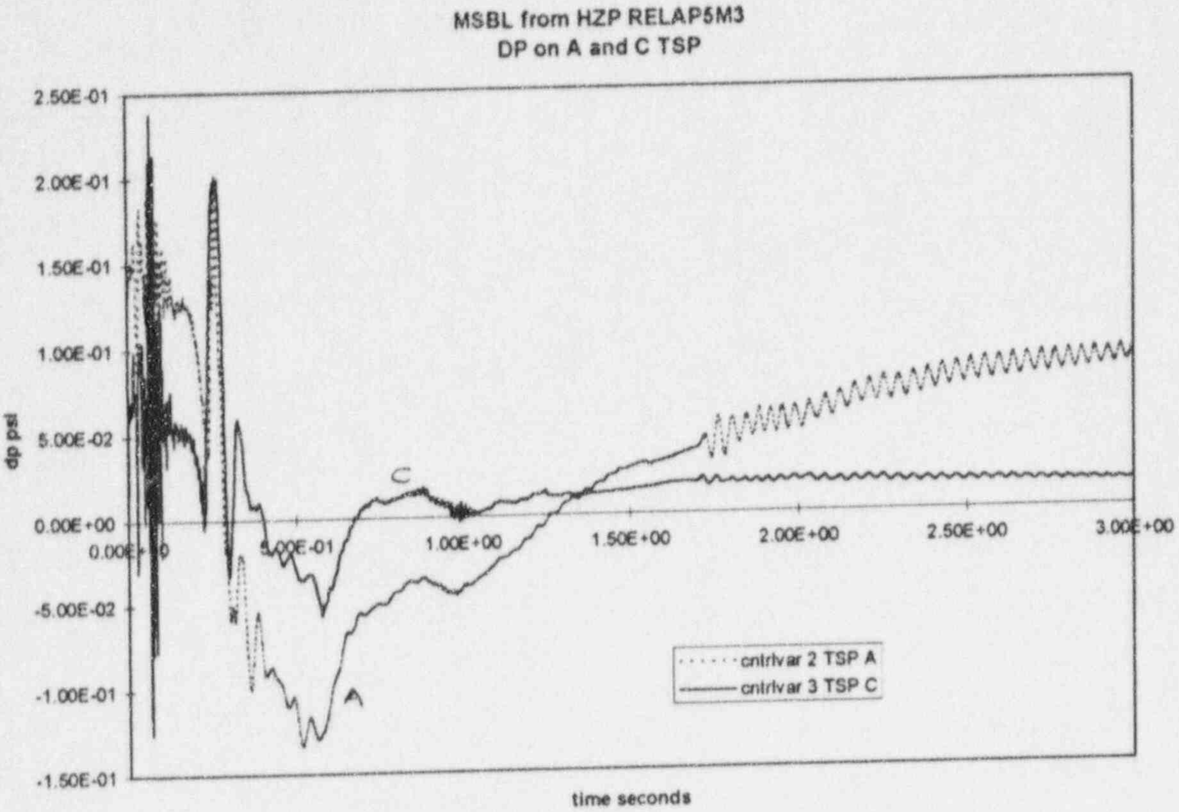


Figure 8 Base Case Differential Pressure at A, C TSPs

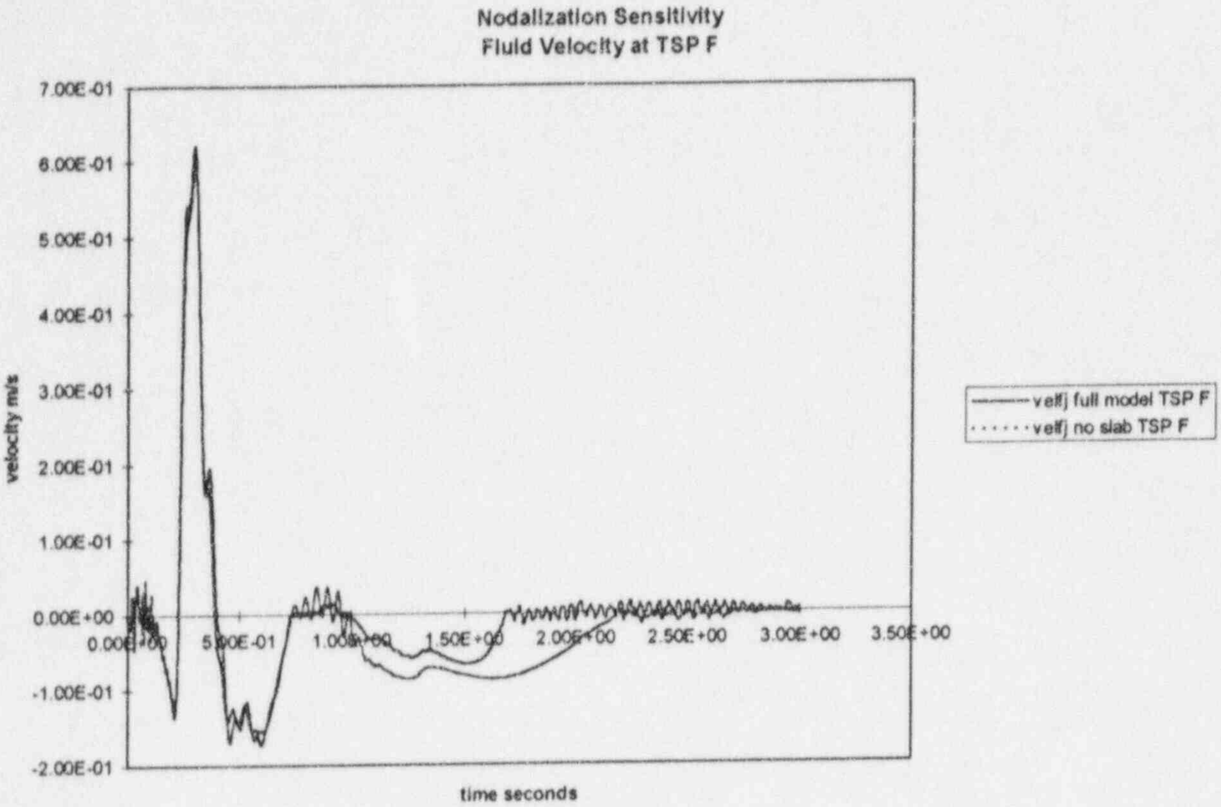


Figure 9 Nodalization Sensitivity Velocity at F TSP

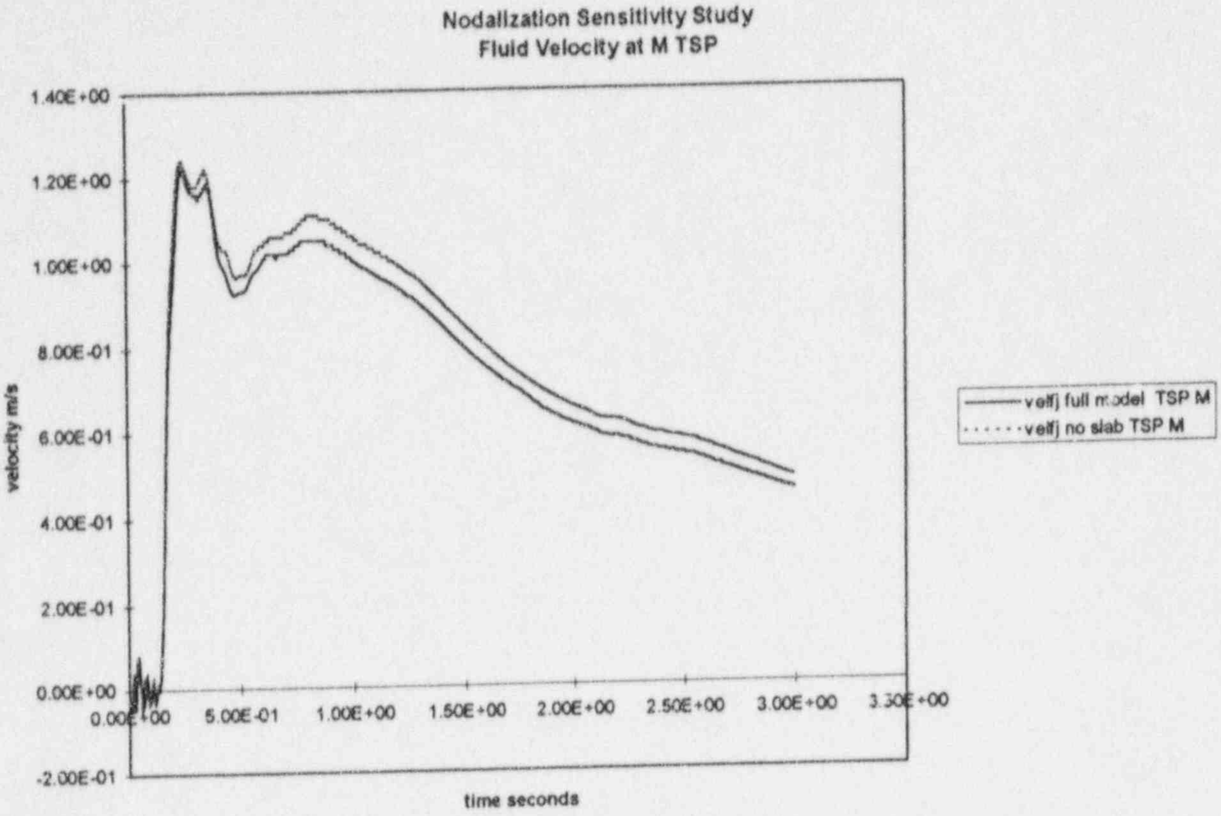


Figure 10 Nodalization Sensitivity Velocity at TSP M

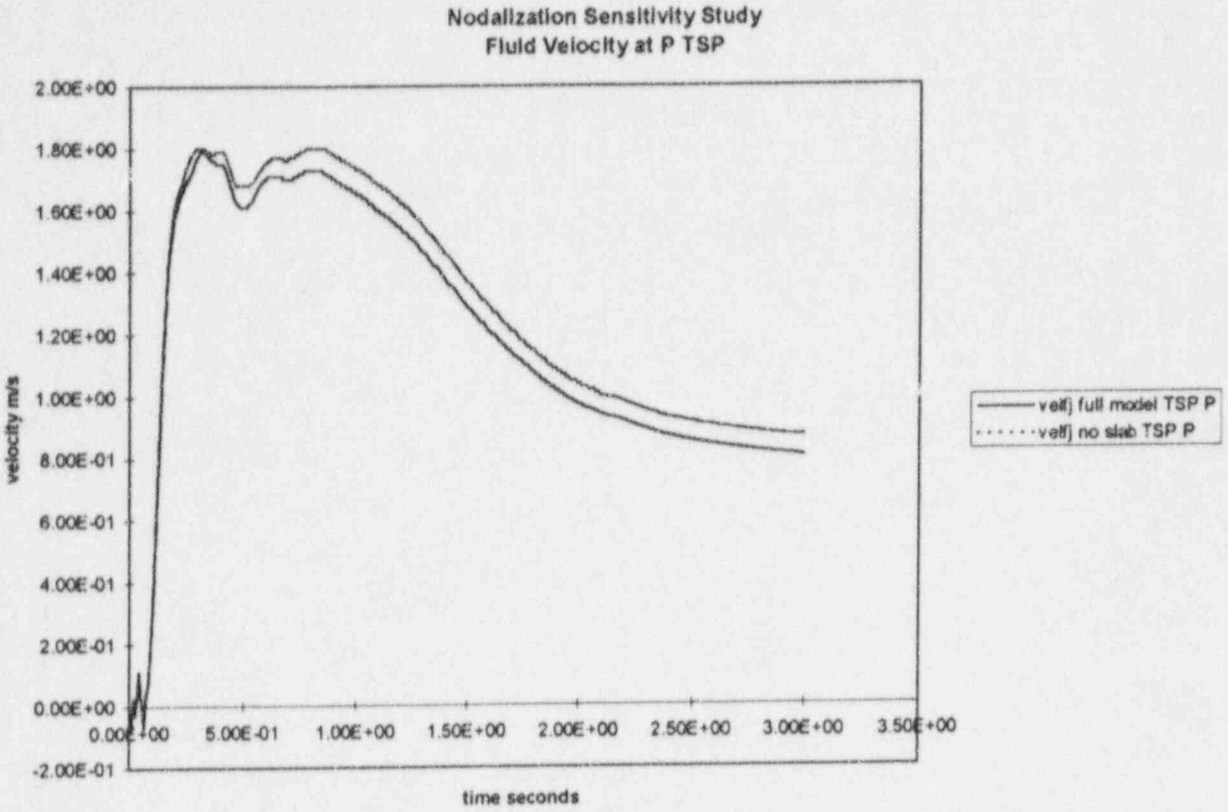


Figure 11 Nodalization Sensitivity Velocity at TSP P

5. Conclusions/Discussion

A detailed calculation of the time dependent differential pressure loadings on the tube support plates in a D4 steam generator under MSLB conditions from hot zero power has been completed. This calculation demonstrates that the loads are principally due to the initial fluid surge following initiation of the break. A series of sensitivity studies have been performed to demonstrate appropriate modeling methods have been applied, and to quantify an appropriate level of margin to be applied in subsequent structural analyses. The results calculated here compare favorably with loads calculated previously with other methods. Therefore, the loads, in combination with the design margin factor developed provide an adequate design basis for TSP displacement analysis.

6. References

1) "Calculation of Byron D4 SG Tube Support Plate Differential Pressures during MSLB with RELAP5M2", PSA-B-95-11. K. Ramsden , September 4, 1995.

2) "Technical Support for Alternate Plugging Criteria with Tube Expansion at TSP Intersections for Braidwood 1 and Byron 1 Model D4 Steam Generators", WCAP-14273, 1995.

3) "Additional Information Regarding the Increase in the Interim Plugging Criteria for Byron Unit 1 and Braidwood Unit 1" D. Saccomando to Office of Nuclear Reactor Regulation, dated October 3, 1995.

4) "Nuclear Systems I", N. Todreas and M. Kazimi, 1990.

Appendix A - File Index

File name	Description
Input Files	Location /nfs/sa/nfskr/btspload
westm3hem	Base model
westm3lwl	Low water level model
wm3nodal	Nodalization sensitivity model- no thin strips
Output Files	Location /nfs/sa/nfskr/btspload
satdat3/srst3	base case output file/restart file
wsens1	nozzle area +10%
wsens2	nozzle area +20%
wsens3	low water level output
wsens4	separator sensitivity vover=.75
wsens5	separator sensitivity vover=1.0
wsens6	separator sensitivity vover=.25
wsens7	separator sensitivity vunder=.45
wsens8	separator sensitivity vunder=.30
wsens9	P TSP K=+10%
wsens10	P TSP K=-10%
wsens11	time step=.001s
wsens12	time step=.0005
wsens13	time step=.0001
wsennode	nodal sensitivity

Data Files	Location /nfs/sa/nfskr/btspload
dpdat *	tsp load file (tubesht, A, C)
dpdat1 *	tsp load file (F, J, L)
dpdat2 *	tsp load file (M,N,P)
dendat *	density data (tubesht, A, C)
dendat1 *	density data (F, J, L)
dendat2 *	density data(M,N,P)
veldat	velocity data for base case
veldat1	velocity data for renodalization

* = Data sets transmitted to Westinghouse on 9/30/95 via rftp connection

Appendix B - Input Data Set Protection Form

Station: B/B **Unit:** 1 **Cycle/Analysis:** TSP load Calculations

	Current File Location[1]	[Shaded Area for SA Admin. Only] **Copy To**[2]	**CheckSum #**[3]	
			sum -r	**sum -p**
1.	/nfskrl btspload/westm3hem	/bb/tsp load/westm3hem	09915	3123598649 ✓
2.				

Notes: 1) **/nfs/sa** is not required. Begin each file location with user id. File name should be descriptive and include a means of identifying associated computer code.
2) Station, Unit, and Cycle/Analysis will define part of the destination location in **/nfs.databank/SA** therefore, these are not need in the "Copy To" column.
3) The SA Admin will place a check mark next to the verified checksum numbers.

Author: K. B. **Reviewer:** Randall **SA Admin:** Randall **Date:** 10/11/95

Appendix C - Checks of Frictional Losses and Inertial Terms

Summary of Principal Path Nozzle to TSP Parameters for TRANFLO D4 Model

Junction	Segment	Area	Length	K	L/A	K/A2	Hyd dia	calc hyd
23	1	129.35	1.77625	0	0.013732122	0	12.83	12.83369
	2	1.388	1.5	0	1.080691643	0	0.5025	1.329423
	3	5	0.5	0	0.1	0	2.45	2.52321
24	1	74.94	3.7242	0	0.049695757	0	11.02	9.76844
	2	129.35	1.77625	0	0.013732122	0	12.83	12.83369
25	1	179.54	0.37	40	0.002060822	0.001240902	0.0417	15.1199
	2	63.49	3.725	0.5	0.058670657	0.000124039	11.02	8.99127
28	1	70.75	3.725	0.5	0.052650177	9.98889E-05	3.92	9.491429
	2	179.54	0.37	0	0.002060822	0	0.0417	15.1199
29	1	152.67	1.1146	0	0.007300714	0	14.04	13.94265
	2	77.74	3.78	0	0.048623617	0	4.07	9.949257
30	1	24.89	0.6354		0.025528325	0	1.625	5.629643
	2	11.49	0.25	0.86	0.02175805	0.00651416	1.1042	3.824973
	3	152.67	1.1146	0	0.007300714	0	14.04	13.94265
37	1	24.89	6.2148	0	0.249690639	0	1.625	5.629643
	2	22.01	0.25	13.9	0.011358473	0.028692918	1.0729	5.293932
	3	24.89	0.6979	0	0.028039373	0	1.625	5.629643
38	1	92.13	3.59375	0	0.039007381	0	10.82	10.83101
	2	24.89	6.2148	0	0.249690639	0	1.625	5.629643
39	2	16.9996	0.0625	1.08	0.003676557	0.0037372	0.0417	4.652514
	3	36.39	4.25	0	0.116790327	0	0.1234	6.807057
Totals					2.182058931	0.040409108		

Summary of Principal Path Nozzle to TSP Parameter for RELAP5M2 Model

Volume		Area	Length	K	L/A	K/A2	hyd
107		1.388	1.5	0	1.080692	0	0.5025
1051		63.49	7.45	0	0.117341	0	11.02
1052		98.79	3.55	0	0.035935	0	12.83
124		171.4	0.708	0	0.004131	0	0.0417
124-104		70.75		0.5		9.99E-05	
124-105		63.49		5.502		0.001365	
104		70.75	7.45	0	0.1053	0	
103		151.32	2.35	0	0.01553	0	14.04
j102-103		11.49	0	0.86	0	0.006514	
103-104		77.74		0		0	
102		25.8121	14.1567	0	0.548452	0	1.625
j135-102		22.01	0	13.9	0	0.028693	
135		55.25	8.1566	0	0.147631	0	
j135tsp		55.25	0	11.408	0	0.003737	
Totals					2.055012	0.040409	

Summary of Dryer Drain Path Parameters for TRANFLO D4 Model

Junction	Segment	Area	Length	K	L/A	K/A2	Hyd dia	calc hyd
23	1	129.35	1.77625	0	0.013732	0	12.83	12.83369
	2	1.388	1.5	0	1.080692	0	0.5025	1.329423
	3	5	0.5	0	0.1	0	2.45	2.52321
24	1	74.94	3.7242	0	0.049696	0	11.02	9.76844
	2	129.35	1.77625	0	0.013732	0	12.83	12.83369
25	1	179.54	0.37	40	0.002061	0.001241	0.0417	15.1199
	2	63.49	3.725	0.5	0.058671	0.000124	11.02	8.99127
26	1	20.36	3.7242	0	0.182917	0	0.6767	5.091635
	2	2.0211	8.1925	0.5	4.053486	0.122404	1.6042	1.604214
27	1	2.0211	8.1925	0.5	4.053486	0.122404	1.6042	1.604214
	2	126.49	3.9635	0	0.031334	0	4.51	12.69102
64/34	1	126.5	3.935	0	0.031107	0	4.51	12.69152
	2	5.7356	15.8125	0	2.756904	0	0.3442	2.702451
36/35	1	5.7356	15.8125	0.5	2.756904	0.015199	0.3442	2.702451
	2	3.1184	1.1068	0	0.354926	0	0.1234	1.992665
Totals					15.53965	0.261371		

Summary of Dryer Drain Path Parameters for RELAP5M2 Model

Volume		Area	Length	K	L/A	K/A2	hyd
107		1.388	1.5	0	1.080692	0	0.5025
1051		63.49	7.45	0	0.117341	0	11.02
1052		98.79	3.55	0	0.035935	0	12.83
124		171.4	0.708	0	0.004131	0	0.0417
124-250		2.0211		0.5		0.122404	
124-105		63.49		5.502		0.001365	
250		2.02	16.5408	0	8.188515	0	
111		111.07	0.2202	0	0.001983	0	0
j250-111		2.02	0	0.5	0	0.122537	
111-112		5.7356		0		0	
1121		5.74	2.814292	0	0.490295	0	0.3442
1122		5.74	1.001	0	0.17439	0	0.3442
1123		5.74	6.570134	0	1.144623	0	0.3442
1124		5.74	10.38443	0	1.809134	0	0.3442
1125		5.74	10.38443	0	1.809134	0	0.3442
100		56.45	0.5	0	0.008857	0	
112-100		5.7356	0	0.5	0	0.015199	
Totals					14.86503	0.261504	

Note: K for 112 does not include crossflow resistance term

Summary of Deck plate drain Path Parameters for TRANFLO D4 Model

Junction	Segment	Area	Length	K	L/A	K/A2	Hyd dia	calc hyd
23	1	129.35	1.77625	0	0.013732	0	12.83	12.83369
	2	1.388	1.5	0	1.080692	0	0.5025	1.329423
	3	5	0.5	0	0.1	0	2.45	2.52321
24	1	74.94	3.7242	0	0.049696	0	11.02	9.76844
	2	129.35	1.77625	0	0.013732	0	12.83	12.83369
25	1	179.54	0.37	40	0.002061	0.001241	0.0417	15.1199
	2	63.49	3.725	0.5	0.058671	0.000124	11.02	8.99127
28	1	70.75	3.725	0.5	0.05265	9.99E-05	3.92	9.491429
	2	179.54	0.37	0	0.002061	0	0.0417	15.1199
29	1	152.67	1.1146	0	0.007301	0	14.04	13.94265
	2	77.74	3.78	0	0.048624	0	4.07	9.949257
62	1	152.67	1.177	0	0.007709	0	14.04	13.94265
	2	7.29	0.0625	1.7	0.008573	0.031988	0.1667	3.046717
	3	104.07	2.9167	0	0.028026	0	3.1026	11.51148
33	1	104.07	2.9167	0	0.028026	0	3.1026	11.51148
	2	27.91	0.0625	1.28	0.002239	0.001643	0.8333	5.9614
	3	126.49	3.9635	0	0.031334	0	4.51	12.69102
64/34	1	126.5	3.935	0	0.031107	0	4.51	12.69152
	2	5.7356	15.8125	0	2.756904	0	0.3442	2.702451
36/35	1	5.7356	15.8125	0.5	2.756904	0.015109	0.3442	2.702451
	2	3.1184	1.1068	0	0.354926	0	0.1234	1.992665
Totals					7.434969	0.050295		

Summary of Deck plate Drain Parameters for RELAP5M2 Model

Volume		Area	Length	K	L/A	K/A2	hyd
107		1.388	1.5	0	1.080692	0	0.5025
1051		63.49	7.45	0	0.117341	0	11.02
1052		98.79	3.55	0	0.035935	0	12.83
124		171.4	0.708	0	0.004131	0	0.0417
124-104		70.75		0.5		9.99E-05	
124-105		63.49		5.502		0.001365	
104		70.75	7.45	0	0.1053	0	
103		151.32	2.35	0	0.01553	0	14.04
j103-110		11.49	7.29	1.77	0.634465	0.013407	
103-104		77.74		0		0	
110		111.07	14.1567	0	0.127457	0	0
111		111.07	0.2202	0	0.001983	0	0
j110-111		111.07	0	0	0	0	
111-112		5.7356		0		0	
1121		5.74	2.814292	0	0.490295	0	0.3442
1122		5.74	1.001	0	0.17439	0	0.3442
1123		5.74	6.570134	0	1.144623	0	0.3442
1124		5.74	10.38443	0	1.809134	0	0.3442
1125		5.74	10.38443	0	1.809134	0	0.3442
100		56.45	0.5	0	0.008857	0	
112-100		5.7356	0	0.5	0	0.015199	
Totals					7.559267	0.030071	

Summary of Separator drain Path Parameters for TRANFLO D4 Model

Junction	Segment	Area	Length	K	L/A	K/A2	Hyd dia	calc hyd
23	1	129.35	1.77625	0	0.013732	0	12.83	12.83369
	2	1.388	1.5	0	1.080692	0	0.5025	1.329423
	3	5	0.5	0	0.1	0	2.45	2.52321
24	1	74.94	3.7242	0	0.049696	0	11.02	9.76844
	2	129.35	1.77625	0	0.013732	0	12.83	12.83369
25	1	179.54	0.37	40	0.002061	0.001241	0.0417	15.1199
	2	63.49	3.725	0.5	0.058671	0.000124	11.02	8.99127
28	1	70.75	3.725	0.5	0.05265	9.99E-05	3.92	9.491429
	2	179.54	0.37	0	0.002061	0	0.0417	15.1199
29	1	152.67	1.1146	0	0.007301	0	14.04	13.94265
	2	77.74	3.78	0	0.048624	0	4.07	9.949257
30	1	24.89	0.6354		0.025528	0	1.625	5.629643
	2	11.49	0.25	0.86	0.021758	0.006514	1.1042	3.824973
	3	152.67	1.1146	0	0.007301	0	14.04	13.94265
31	1	24.89	0.6979		0.028039	0	1.625	5.629643
	2	19.78	2.9167	0.5	0.147457	0.001278	0.5417	5.018588
32	1	19.78	2.9167	0.5	0.147457	0.001278	0.5417	5.018588
	2	104.07	2.9167	0	0.028026	0	3.1026	11.51148
33	1	104.07	2.9167	0	0.028026	0	3.1026	11.51148
	2	27.91	0.0625	1.28	0.002239	0.001643	0.8333	5.9614
	3	126.49	3.9635	0	0.031334	0	4.51	12.69102
64/34	1	126.5	3.935	0	0.031107	0	4.51	12.69152
	2	5.7356	15.8125	0	2.756904	0	0.3442	2.702451
36/35	1	5.7356	15.8125	0.5	2.756904	0.015199	0.3442	2.702451
	2	3.1184	1.1068	0	0.354926	0	0.1234	1.992665
Totals					7.796226	0.027377		

Summary of Separator Drain path Parameter for RELAP5M2 Model

Volume		Area	Length	K	L/A	K/A2	hyd
107		1.388	1.5	0	1.080692	0	0.5025
1051		63.49	7.45	0	0.117341	0	11.02
1052		98.79	3.55	0	0.035935	0	12.83
124		171.4	0.708	0	0.004131	0	0.0417
124-104		70.75		0.5		9.99E-05	
124-105		63.49		5.502		0.001365	
104		70.75	7.45	0	0.1053	0	
103		151.32	2.35	0	0.01553	0	14.04
j102-103		11.49	0	0.86	0	0.006514	
103-104		77.74		0		0	
102		25.8121	14.1567	0	0.548452	0	1.625
j111-102		19.78	0	1	0	0.002556	
111		111.07	0.2202	0	0.001983	0	0
j110-111		111.07	0	0	0	0	
111-112		5.7356		0		0	
1121		5.74	2.814292	0	0.490295	0	0.3442
1122		5.74	1.001	0	0.17439	0	0.3442
1123		5.74	6.570134	0	1.144623	0	0.3442
1124		5.74	10.38443	0	1.809134	0	0.3442
1125		5.74	10.38443	0	1.809134	0	0.3442
100		56.45	0.5	0	0.008857	0	
112-100		5.7356	0	0.5	0	0.015199	
Totals					7.345797	0.025734	

Summary of Principal Path through tube sheets for TRANFLO D4 Model

Junction	Segment	Area	Length	K	L/A	K/A2	Hyd dia	calc hyd
46	1	28.225	0.25	0	0.008857396	0	0.1234	5.994947
	2	6.4488	0.0625	1.25	0.009691726	0.030057454	0.0093	2.865549
	3	27.9	1.21875	0	0.043682796	0	0.1234	5.960332
45	1	27.9	1.21875	0	0.043682796	0	0.1234	5.960332
	2	8.0485	0.0625	1.1	0.007765422	0.016980981	0.0417	3.201296
	3	27.9	1.46875	0	0.052643369	0	0.1234	5.960332
44	1	27.9	1.46875	0	0.052643369	0	0.1234	5.960332
	2	8.0485	0.0625	1.1	0.007765422	0.016980981	0.0417	3.201296
	3	27.9	1.46875	0	0.052643369	0	0.1234	5.960332
43	1	27.9	1.46875	0	0.052643369	0	0.1234	5.960332
	2	7.8717	0.0625	1.13	0.007939835	0.018236495	0.0417	3.16594
	3	27.9	1.7604	0	0.063096774	0	0.1234	5.960332
42	1	27.9	1.7604	0	0.063096774	0	0.1234	5.960332
	2	7.0398	0.0625	1.2	0.008878093	0.024213669	0.0417	2.993978
	3	28.25	1.7604	0	0.062315044	0	0.1234	5.997601
41	1	56.45	1.7604	0	0.03118512	0	0.1234	8.478135
	2	16.9149	0.0625	1.08	0.003694967	0.003774721	0.0417	4.640909
	3	56.45	1.7604	0	0.03118512	0	0.1234	8.478135
40	1	56.45	1.7604	0	0.03118512	0	0.1234	8.478135
	2	16.9996	0.0625	1.08	0.003676557	0.0037372	0.0417	4.652514
	3	56.45	1.7604	0	0.03118512	0	0.1234	8.478135
39	1	56.45	1.7604	0	0.03118512	0	0.1234	8.478135
	2	16.9996	0.0625	1.08	0.003676557	0.0037372	0.0417	4.652514
	3	36.39	4.25	0	0.116790327	0	0.1234	6.807057
Totals					0.821109561	0.117718703		

Summary of Tube Sheet Path Parameters for RELAP5M3 Model

Volume		Area	Length	K	L/A	K/A2	hyd
100		56.45	0.5	0	0.008857	0	0.1234
j 100-121		27.9	0	23.39	0	0.030048	0
121		27.9	0.4	0	0.014337	0	0.1234
121-122		27.9				0	
122		27.9	1.837		0.065842		0.1234
j123		27.9		0		0	
1011		27.9	0.2	0	0.007168	0	0.1234
1012		27.9	0.2	0	0.007168	0	0.1234
1013		27.9	2.6	0	0.09319	0	0.1234
1014		27.9	0.2	0	0.007168	0	0.1234
1015		27.9	0.2	0	0.007168	0	0.1234
1016		27.9	2.6	0	0.09319	0	0.1234
1017		27.9	0.2	0	0.007168	0	0.1234
1018		27.9	0.2	0	0.007168	0	0.1234
1019		27.9	3.1833	0	0.114097	0	0.1234
10110		27.9	0.2	0	0.007168	0	0.1234
j1		27.9	0	13.218	0	0.016981	0.1234
j4		27.9	0	13.218	0	0.016981	0.1234
j7		27.9	0	14.2	0	0.018242	0.1234
134		56.45	0.2	0	0.003543	0	0.1234
j101-134		27.9	0	18.85	0	0.024216	
134-135		55.25		0		0	
1351		56.45	3.12	0	0.05527	0	0.1234
1352		56.45	0.2	0	0.003543	0	0.1234
1353		56.45	0.2	0	0.003543	0	0.1234
1354		56.46	3.1833	0	0.056382	0	0.1234
1355		56.45	0.2	0	0.003543	0	0.1234
1356		56.45	0.2	0	0.003543	0	0.1234
1357		56.45	2.9733	0	0.052671	0	0.1234
1358		56.45	0.21	0	0.00372	0	0.1234
1359		55.25	0.21	0	0.003801	0	0.1234
13510		55.25	8.1566	0	0.147631	0	0.1234
j2		56.45	0	11.909	0	0.003737	0.1234
j5		56.45	0	11.909	0	0.003737	0.1234
j8		55.25	0	11.408	0	0.003737	0.1234
Totals					0.776882	0.11768	

Calculation of Crossflow Resistance Term

The crossflow resistance of the tube bundle needs to be accounted for, particularly at the U-bend portion of the tubes. This will be handled by calculating a K value to be added to the separator inlet loss coefficient, using a correlation by Zukauskas obtained from p390 of "Nuclear Systems I" Kazimi/Todreas. The values for crossflow length and area are taken from the TRANFLO output previously provided.

$g := 32.2$

$\rho := 45.5$ Density of fluid

$\mu := 19.7 \cdot 10^{-7} \cdot g$ viscosity of sat liq at 1000 psi

$D := .1234$ hydraulic dia from TRANFLO INPUT

$G := \frac{11000}{36.39}$ Mass flux from TRANFLO Output at .57 sec

$S := \frac{.0885}{\left(\frac{.75}{12}\right)}$ $S = 1.416$ Tube lattice aspect pitch over dia

$Re := G \cdot \frac{D}{\mu}$ $Re = 5.88 \cdot 10^{5}$ Reynolds number needed to obtain f

$f := 0.24$ f-factor from figure

$Z := 1$ square lattice, no Z correction

$N := \frac{4.25}{.0885}$ number of rows of tubes, estimate by crossflow junction length/pitch

$DP := \frac{f \cdot N \cdot G^{2}}{2 \cdot \rho \cdot 144 \cdot g} \cdot Z$ DP at estimated flow

$DP = 2.496$

At a flow of 11000 lb/sec the expected dp is about 2.5 psi. This compares with the TRANFLO generated dp of 2.84 at .57 seconds. Now need to convert this dp into a K value to be added to the separator inlet.

$A_{sep} := 22.01$ $W := 11000$

$$K := \frac{DP \cdot A_{sep}{}^{2} \cdot 144 \cdot g \cdot 2 \cdot \rho}{W^{2}}$$

$K = 4.216$

This is added to the losses associated with the junction between 102 and 135-5.

Similarly for the entrance to the tube bundle

$g := 32.2$

$\rho := 45.5$

$\mu := 19.7 \cdot 10^{-7} \cdot g$

$D := .1234$

$G := \frac{2600}{1.559}$

$Re := G \cdot \frac{D}{\mu}$ $\qquad Re = 3.244 \cdot 10^{6}$

$S := \frac{.0885}{\left(\frac{.75}{12}\right)}$ $\qquad S = 1.416$

$f := 0.24$

$Z := 1$

$N := \frac{1.107}{.0885}$

$$DP := \frac{f \cdot N \cdot G^{2}}{2 \cdot \rho \cdot 144 \cdot g} \cdot Z$$

$DP = 19.788$

At a flow of 2600 lb/sec the expected dp is about 19.7 psi. This compares with the TRANFLO generated dp of 18 at .57 seconds. Now need to convert this dp into a K value to be added to the downcomer inlet.

$A_{in} := 5.7356$

$W := 2600$

$$K := \frac{DP \cdot A_{in}^{2} \cdot 144 \cdot g \cdot 2 \cdot \rho}{W^{2}}$$

$K = 40.633$

This is being added to the junction between the downcomer and the entrance regions to the tube region 112-5 to 100.

Similarly for connector 52

$g := 32.2$

$\rho := 45.5$

$\mu := 19.7 \cdot 10^{-7} \cdot g$

$D := .1234$

$$G := \frac{830}{4.2478}$$

$$Re := G \cdot \frac{D}{\mu} \qquad Re = 3.801 \cdot 10^{5}$$

$$S := \frac{.0885}{\left(\frac{.75}{12}\right)} \qquad S = 1.416$$

$f := 0.24$

$$N := \frac{4.0729}{.0885}$$

$Z := 1$

$$DP := \frac{f \cdot N \cdot G^{2}}{2 \cdot \rho \cdot 144 \cdot g} \cdot Z$$

$DP = 0.999$

At a flow of 830 lb/sec the expected dp is about 1 psi. This compares with the TRANFLO generated dp of 1.038 at .57 seconds. Now need to convert this dp into a K value to be added to the preheater junctions.

$A_{in} := 4.2478$

$W := 830$

$$K := \frac{DP \cdot A_{in}^{2} \cdot 144 \cdot g \cdot 2 \cdot \rho}{W^{2}}$$

$K = 11.045$

This value will be used for connector 56 as well as connector 54/58 due to similarity.In the RELAP model these junctions are in volume 133 and the entrance to 133.

Appendix D Base Model Listing

```
=stand alone steam generator model for d4 sg
* hot standby  equilibrium models used/inel guidance used on tsp models
***************************************************
*this deck is based on westinghouse tranflow d4   *
*model used for tube support plate dp calculation *
***************************************************
* this model contains more detail in dome area
***************************************************
*                                                 *
*          this data is contained in              *
*          nfskr.relap5.westm3hem                 *
*  includes two more small nodes at all tsps      *
*  models upper dome with explicit w volumes      *
*  includes .2 ft slabs for tsp dp calc           *
*  includes crossflow resistances                 *
***************************************************
*
*
100 new transnt
*
*
102  british   british
105
*
**********************************************
*------- time step cards
*
*     end  dtmin    dtmax  opt min  maj  rstrt
201    1.0  1.d-7    0.0001  3    5  4000 2500
202    2.0  1.d-7    0.0005   3  2   4000 2500
203   10.5  1.d-7    0.001   3    5   4000 2500
*
*
**********************************************
*--------- minor edit variables
*
*  variable code   parameter   location
301    cntrlvar     2 * a
302    cntrlvar     3 * c
303    cntrlvar     4 * f
304    cntrlvar     5 * j
305    cntrlvar     6 *  l
306    cntrlvar     7 * m
307    cntrlvar     8 * n
308    cntrlvar     9 * p
*******************************************
*----------- trip input data
*
*variable trip cards
*   variable  param   relation  variable param   cons  latch
501   time      0        ge       null     0        1.  l
502   time      0        ge       null     0        .01 l
503   time      0        ge       null     0      100.   l
*===========================================================
*
```

```
*--------------------------
```

```
*      trip identifier   Î
*                        Î
*   501 =>problem stop   Î
*--------------------------
*
*trip stop advancement card
*   trp no.
600   501
********************************************
*----------- hydrodynamic components
*
*------------------------------------------
*  primary side model                     Î
*  plenums and tubes modelled explicitly  Î
*  hot leg and cold leg represented by tdvsÎ
*------------------------------------------
*
*==============================
0420000   inplen       tmdpvol
*
*         flowa      l    vol     azi    incl     dz   rough  hyd  pvbfe
0420101   0.0     5.2183 147.64  0.0     0.0     0.0   0.0   0.0  00000
0420101   0.0     5.2183 5000.   0.0     0.0     0.0   0.0   0.0  00000
*
*        ebt
0420200   3
*
*         time  press   temp
0420201   0.0  2250.00  557.000
0420202  1.0e6 2250.00  557.000
*==============================
0470000   outplen      tmdpvol
*
*         flowa      l    vol     azi    incl     dz   rough  hyd  pvbfe
0470101   0.0     5.2183 147.64  0.0     0.0     0.0   0.0   0.0  00000
0470101   0.0     5.2183 5000.   0.0     0.0     0.0   0.0   0.0  00000
*
*        ebt
0470200   3
*
*         time  press   temp
0470201   0.0  2206.77  557.
0470202  1.0e6 2206.77  557.
*==============================
1510000   tubes   pipe
*
*         nv
1510001   21
*
```

```
*          flowa     nv
1510101   11.0088    21
*
*         length   nv
1510301     .5625   1
1510302   2.5       2
1510303   3.0       3
```

```
1510304   3.5833    8
1510305   3.445     10
1510306   3.5833    14
1510307   1.5       19
1510308   1.0       20
1510309    .5625    21
*
*         volume     nv
1510401     0.0      21
*
*      incline angle     nv
1510601     90.0          8
1510602    90.0           9
1510603   -90.0           10
1510604   -90.0           21
*
*        elev cng       nv
*510701     1.7525       1
*510702     2.5          2
*510703    3.0      3
*510704    3.5833   8
*510705    3.445    9
*510706   -3.445    10
*510707   -3.5833   14
*510708   -1.5      19
*510709   -1.0      20
*510710    -.5625   21
*
*          rough  hyd dia   nv
1510801    0.0   .0553333  21
*
*          pvbfe    nv
1511001    00000    21
*
*        fvcahs nj
1511101  001000  9
1511102  001000 10
1511103  001000 20
*
*        flag   p      t       dummy dummy dummy nv
1511201   3   2250.0  557.0     0.0   0.      0.  21
*
*          flag=1 => (lbm/sec)
```

```
1511300    1
*
*          lflow       vflow  interface flow        nj
1511301     9763.12     0.0           0.0           20
*=================================================
1500000    junct  tmdpjun
*
*         from         to        area
1500101 042000000 151000000     1.0
*
*         flag
1500200    1
*
```

```
*          time    lflow        vflow    intflow
1500201    0.0    9763.12       0.0      0.0
1500202    1.0e6  9763.12       0.0      0.0
*=================================================
1590000    junct  sngljun
*
*         from          to        area       fjunf   fjunr    fvcahs
1590101 151010000 047000000  9.823515     0.0     0.0      021000
*
*         flag      lflow     vflow     intflow
1590201    1        9763.12    0.0       0.0
*=================================================
*
*
*
*
*-----------------------------------------
*  secondary side model                    Î
*  90% - 10% feed flow split               Î
*  bound cnds represented by time dependentÎ
*  junctions and tme dependent volumes     Î
*-----------------------------------------
*
*=================================================
9020000    mnfeed  tmdpvol
*
*          flowa  flowl   vol     azi    incl     dz    rough   hyd   pvbfe
9020101    0.0    31.1533 147.64  0.0    0.0      0.0    0.0    0.0   00000
9020101    0.0    31.1533 5000.   0.0    0.0      0.0    0.0    0.0   00000
*
*         ebt
9020200   003
*
*          time  press   temp
9020201    0.0   1200.0  435.0
9020202  1.0e6   1200.0  435.0
*=================================================
```

```
3020000   fljun   tmdpjun
*
*          from         to       ajun
3020101 902000000  132000000  1.0
*
*         flag
3020200   1
*
*         time  lflow    vflow    int flow
3020201   0.0      0.      0.0      0.0
3020202  1.0e6     0.      0.0      0.0
*=================================================
1000000   riser  branch
*
*         nj    flag
1000001   3      1
*
*         flowa    flowl     vol    azi incl    dz      rough  hyd     pvbfe
1000101  56.45      0.0     28.22   0.0  90.  .4999 .00015   .1234  00101
```

```
*
*         flag    p       x
1000200    2   1119.15  0.00
1000200    1    557.0   0.00
*
*          from         to        ajun     fjun  fjunr   fvcahs
1001101 112010000  100000000  5.7356    .50     .50    000000
*add crossflow resistance
1001101 112010000  100000000  5.7356  41.1  41.1    000000
1002101 100010000  121000000  6.4488  1.25   1.25    010000
1003101 100010000  131000000  6.1798  1.28   1.28    010000
1002101 100010000  121000000  27.9   23.39   23.39   010000
1003101 100010000  131000000  28.225  26.7   26.7    010000
*
*         lflow      vflow  int flow
1001201     0.0       0.0      0.0
1002201     0.0       0.0      0.0
1003201     0.0       0.0      0.0
*ccfl/junction hyd diam info
*           hyddia    floodcorr  gasint   slope   nj
1001110      .1234      0.         1.       1.
*use hyd of 112 for junc 1 since reverse flow dominates
1001110      .3442      0.         1.       1.
1002110      .1234      0.         1.       1.
1003110      .1234      0.         1.       1.
*
1220000   slab    snglvol
*
*         flowa    flowl     vol   azi incl    dz      rough  hyd     pvbfe
1220101    27.9    1.837      0.0  0.0   90.   1.837   0.00015 0.1234 00101
*         flag      p        x
```

```
1220200   001    557.     0.
***********
1230000   conn sngljun
*
*        from        to        area    fjunf fjunr  fvcahs
1230101 122010000 101000000  27.9      0.0    0.0  010000
*
*        flag   lflow     vflow     int flow
1230201   1       0.0       0.0        0.0
*
*           hyddia    floodcorr  gasint   slope   nj
1230110       .1234      0.         1.        1.
******
1210000   riser1 branch
*
*         nj     flag
1210001   2       1
*
*         flowa    flowl     vol    azi incl    dz      rough  hyd     pvbfe
1210101  27.9       0.0     68.01    0.0  90.  2.437  .00015  .1234  00101
1210101  27.9       2.237    0.0     0.0  90.  2.237  .00015  .1234  00101
1210101  27.9       .4     0.0    0.0  90.   .4  .00015   .1234  00101
*
*         flag    p       x
1210200    2   1118.67  0.00
```

```
1210200    1    557.0   0.00
*
*          from         to        ajun    fjun  fjunr   fvcahs
1212101 121010000  101000000  8.0485  1.1    1.1    010000
1212101 121010000  101000000  27.9  13.218    13.218    010000
1212101 121010000  122000000  27.9    0.0       0.0    010000
1211101 131000000  121000000  2.7297   .38   0.34   010000
*
*         lflow     vflow  int flow
1211201     0.0      0.0      0.0
1212201     0.0      0.0      0.0
*ccfl/junction hyd diam info
*           hyddia    floodcorr  gasint   slope   nj
1211110       .1234      0.         1.        1.
1212110       .1234      0.         1.        1.
*
1310000   riser2 branch
*
*         nj     flag
1310001   0       1
*
*         flowa    flowl     vol    azi incl    dz      rough  hyd     pvbfe
1310101  28.225    0.0     26.46    0.0  90.  0.937  .00015 0.1234  00101
*
*         flag    p       x
```

```
1310200    2   1118.67  0.00
1310200    1    557.00  0.00
*
*          from        to        ajun     fjun  fjunr    fvcahs
*
*         lflow     vflow  int flow
*ccfl/junction hyd diam info
*           hyddia     floodcorr  gasint    slope    nj
*1311110      .1234       0.          1.         1.
*============================
1320000   riser3 branch
*
*         nj     flag
1320001   2        1
*
*         flowa    flowl      vol    azi incl    dz      rough  hyd     pvbfe
1320101  27.9       0.0     40.11    0.0  90.  1.437  .00015 0.1234  00101
*
*         flag     p       x
1320200    2   1118.67  0.00
1320200    1    557.00  0.00
*
*          from        to        ajun     fjun  fjunr    fvcahs
1321101 132000000  131010000  0.7975  1.80    1.80    010000
1322101 132010000  133000000  4.42     6.18   6.18    010000
1322101 132010000  133000000  26.3462   219.6  219.6    01000
*
*         lflow     vflow  int flow
1321201      0.0       0.0       0.0
1322201      0.0       0.0       0.0
*ccfl/junction hyd diam inf
```

```
*           hyddia     floodcorr  gasint    slope    nj
1321110      .00175      0.          1.         1.
1322110      .1234     0.          1.         1.
*============================
*============================
1340000   uprsr  branch
*
*         nj     flag
1340001   3       1
*
*         flowa    flowl      vol    azi incl    dz      rough  hyd     pvbfe
1340101  56.45      0.0    0.0    0.0  90.  3.52  .00015  0.1234  00101
1340101  56.45      0.2    0.0    0.0  90.  .2  .00015  0.1234  00101
*
*         flag     p       x
1340200    2   1114.68  0.00
1340200    1    557.00  0.00
*
*          from        to        ajun     fjun  fjunr    fvcahs
```

```
1341101 101010000  134000000  7.0398  1.20    1.20    010000
1342101 133010000  134000000  7.0398  1.2     1.2     010000
1343101 134010000  135000000 16.9149  1.08    1.08    010000
1341101 101010000  134000000  27.9  18.85    18.85    010000
1342101 133010000  134000000  27.9  18.85     18.85    010000
1343101 134010000  135000000  55.25  11.408    11.408    010000
1343101 134010000  135000000  55.25  0.        0.0      010000
*
*        lflow     vflow  int flow
1341201     0.0      0.0      0.0
1342201     0.0      0.0      0.0
1343201     0.0      0.0      0.0
*ccfl/junction hyd diam info
*          hyddia    floodcorr  gasint   slope   nj
1341110      .1234      0.         1.       1.
1342110      .1234      0.         1.       1.
1343110      .1234      0.         1.       1.
*==============================
1010000   boil2-5 pipe
*
*         nv
1010001   10
*
*         flowa    nv
1010101   27.9     10
*
*         jarea    nj
1010201   8.0485   1
1010202   7.8717   2
1010201   27.9   1
1010202   27.9   9

*
*         length   nv
1010301    3.0     2
1010302    3.5833  3
1010301    .2      2
```

```
1010302    2.6      3
1010303    .2        5
1010304    2.6       6
1010305    .2        8
1010306    3.1833     9
1010307    .2          10
*
*         volume     nv
1010401     0.0      10
*
*       incline angle     nv
1010601     90.0          10
*
```

```
*        elev cng       nv
*1010701    3.0          2
*1010702    3.5833       3
*
*         rough  hyd dia  nv
1010801  .00015 0.1234     10
*
*         fjunf     fjunr    nj

1010901    13.218   13.218   1
1010902    0.       0.       3
1010903    13.218       13.218       4
1010904    0.       0.       6
1010905    14.2      14.2     7
1010906    0.       0.        9
*
*         pvbfe   nv
1011001   00101    10
*
*        fvcahs nj
1011101  000000 9
*
*        flag   p        x         dummy  dummy   dummy nv
1011201   2  1117.80   .0          0.      0.       0.   1
1011202   2  1116.85   .0          0.      0.       0.   2
1011203   2  1115.81   .0          0.      0.       0.   3
1011201   1   557.00   .0          0.      0.       0.   1
1011202   1   557.00   .0          0.      0.       0.   2
1011203   1   557.00   .0          0.      0.       0.   10
*
*         flag=0 => (lbm/sec)
1011300   1
*
*         lflow        vflow  interface flow       nj
1011301   0.0          0.0          0.0            9
*
*ccfl/junction hyd diam info
*            hyddia    floodcorr  gasint   slope   nj
1011401       .1234      0.         1.       1.      9
*=====================================================
*============================
1330000   prheat  pipe
*
```

```
*         nv
1330001   5
*
*         flowa    nv
1330101   26.3462  3
1330101   27.9     5
*
```

```
*          jarea   nj
1330201   4.2478   1
1330202   4.2478   2
1330203   4.2478   3
1330204   7.0398   4
1330204   27.9    4
*add bypass area to flow path
*1330201   4.9938   1
*1330202   4.9938   2
*1330203   4.9938   3
*1330204   7.0398   4
*
*          length   nv
1330301     1.5    4
1330302    3.5833  5
1330302    3.6463      5
*
*          volume     nv
1330401      0.0      5
*
*        incline angle    nv
1330601     90.0           5
*
*         elev cng       nv
1330701     1.5          4
1330702    3.5833        5
1330702    3.6463        5
*
*          rough  hyd dia   nv
1330801 .00015  0.1234     5
*
*          fjunf     fjunr    nj
1330901     9.16      9.16     1
1330902     5.92      5.92     2
1330903     5.48      5.48     3
1330904     1.2       1.2      4
*add crossflow resistance of 11 to first 3 junctions
1330901    20.16     20.16     1
1330902    16.92     16.92     2
1330903    16.48     16.48     3
1330904     18.85    18.85     4
*
*          pvbfe   nv
1331001    00101    5
*
*         fvcahs nj
1331101   000000 4
*
*         flag   p        x        dummy  dummy   dummy nv
```

```
1331201   2  1118.04   .0        0.     0.        0.   1
```

```
1331202   2  1117.56   .0          0.     0.        0.   2
1331203   2  1117.09   .0          0.     0.        0.   3
1331204   2  1116.62   .0          0.     0.        0.   4
1331205   2  1115.81   .0          0.     0.        0.   5
1331201   1    557.00  .0          0.     0.        0.   1
1331202   1    557.00  .0          0.     0.        0.   2
1331203   1    557.00  .0          0.     0.        0.   3
1331204   1    557.00  .0          0.     0.        0.   4
1331205   1    557.00  .0          0.     0.        0.   5
*
*         flag=0 => (lbm/sec)
1331300   1
*
*         lflow       vflow  interface flow        nj
1331301   0.0          0.0          0.0            4
*ccfl/junction hyd diam info
*           hyddia    floodcorr  gasint    slope   nj
1331401      .1234      0.          1.        1.    4
*=====================================================
1350000   upriser pipe
*
*         nv
1350001   10
*
*         flowa     nv
1350101   56.45     8
1350102   55.25     10
*
*         jarea     nj
1350201   16.9996   1
1350201   56.45   7
1350202   55.25    9
*1350202   55.25     2
*1350203   16.9996   3
*1350204   55.25     4
*
*
*         length    nv
1350301    3.12  1
1350302    .2   2
1350303    .2   3
1350304    3.1833 4
1350305    .2         6
1350306    2.9733  7
1350307     .21     9
*1350302     2.9733  2
*1350303       .31    4
1350308    8.1566  10
*
*         volume     nv
1350401     0.0     10
*
*      incline angle      nv
1350601     90.0           10
*
```

```
*        elev cng      nv
*1350701    3.5833      2
*1350702    8.1666      3
*
*         rough  hyd dia   nv
1350801 .00015  0.1234     10
*
*         fjunf      fjunr    nj
1350901    0.0       0.0        1
1350902    11.408       11.408  2
1350902    11.909       11.909  2
1350903     .0         .0       4
1350904    11.408       11.408     5
1350904    11.909       11.909    5
1350905     .0         .0       7
1350906    11.408       11.408  8
1350907     .0         .0       9
*test sensitivity of loss coeff at P TSP
*1350906    12.5488      12.5488  8  *10% high
*1350906   10.2672      10.2672  8  *10% low

*
*         pvbfe   nv
1351001   00101    10
*
*        fvcahs nj
1351101  000000 1
1351102  000000 2
1351103  000000 3
1351104  000000 9
*
*        flag   p       x       dummy  dummy   dummy nv
1351201   2  1113.55   .0        0.      0.       0.   1
1351202   2  1112.42   .0        0.      0.       0.   2
1351203   2  1110.59   .0        0.      0.       0.   3
1351203   2  1110.59   1.0       0.      0.       0.   3
1351201   1   557.00   .0        0.      0.       0.   1
1351202   1   557.00   .0        0.      0.       0.   2
1351203   1   557.00   .0        0.      0.       0.   10
*1351203   1   557.00   1.0       0.      0.       0.   3
*
*         flag=0 => (lbm/sec)
1351300   1
*
*         lflow       vflow  interface flow        nj
1351301   0.0          0.0          0.0            9
*ccfl/junction hyd diam info
*           hyddia    floodcorr  gasint    slope   nj
1351401      .1234     0.          1.        1.    9
*===================================================
1020000   sep     separatr
*
*        nj   flag
1020001   3     1
*
```

```
*        flowa    flowl   vol      azi incl   dz     rough    hyd    pvbfe
```

```
1020101     0.0  14.1567 365.4148  0.0 90.  14.1567 .00015 1.625  00010
*
*       flag    p      uf           ug            vg
1020200     2 1107.31 .227
1020200     2 1107.31 1.0
1020200     1  557.00 1.0
*1020200     1  557.00  .3494
 1020200     1  557.00  .03
*1020200     1  557.00  .015
*
*          from        to        ajun    fjun     fjunr  fvcahs   vflim
1021101 102010000  103000000 22.01    13.9     13.90   000000
1022101 102000000  111000000 19.78    0.5       0.5    000000
1023101 135010000  102000000 24.8873 0.5       1.0    000000
* rearrange losses
1021101 102010000  103000000 11.49    0.86      0.86   000000
1022101 102000000  111000000 19.78    1.0       1.0    000000
1023101 135010000  102000000 22.01    13.9     13.9    000000
*add crossflow resistance term
1023101 135010000  102000000 22.01    18.12    18.12   000000
* sensitivity values of vover/vunder
*1021101 102010000  103000000 11.49    0.86      0.86  000000    0.5
*1022101 102000000  111000000 19.78    1.0       1.0    000000 .45
*
*          lflow    vflow      int flow
1021201      0.0      0.0         0.0
1022201      0.0      0.0         0.0
1023201      0.0      0.0         0.0
*ccfl/junction hyd diam info
*           hyddia    floodcorr  gasint    slope    nj
*1021110      1.625      0.          1.        1.
*=====================================================
1030000   dome    branch
*
*        nj   flag
1030001   2     1
*
*        flowa    flowl   vol      azi incl   dz     rough    hyd    pvbfe
1030101  123.051 5.       0.0      0.0 90.    5.     .00015 1.625  00000
1030101  123.051 5.       0.0      0.0 90.    5.     .00015 0.0    00000
1030101  151.32  0.     356.23     0.0 90.  2.35415 .00015 14.04  01000
*
*       flag    p      uf           ug            vg
1030200     2 1107.31 1.0
1030200     1  557.00 1.0
*
*          from        to       ajun    fjun     fjunr  fvcahs   vflim
1031101 103000000  110010000  7.29    1.77     1.77   010000
1032101 103010000  104000000 77.74    0.       0.     010000
```

```
*1033101 103000000  110010000 19.78    0.5      0.5    010000
*
*         lflow    vflow      int flow
1031201     0.0      0.0          0.0
1032201     0.0      0.0          0.0
*1033201     0.0      0.0          0.0
*ccfl/junction hyd diam info
```

```
*           hyddia    floodcorr  gasint    slope   nj
1031110      3.05      0.          1.         1.
1032110      4.07      0.          1.         1.
*=====================================================
1040000   udc    snglvol
*
*         flowa    flowl      vol    azi incl    dz      rough  hyd    pvbfe
1040101    70.75     0.0     527.08  0.0   0.    0.0      0.00015 4.07 01000
*
*         flag      p        x
1040200   001     557.     1.0
*=====================================================
2500000   dryerdrn  snglvol
*
*         flowa    flowl      vol    azi incl    dz      rough  hyd    pvbfe
2500101   2.02    16.5108     0.0  0.0 -90.   -16.5108 0.00015  0.0   00000
*
*         flag      p        x
2500200   001     557.     .025
************
1240000  dryer    branch
*
*        nj   flag
1240001   3     1
*
*        flowa   flowl   vol       azi incl    dz    rough    hyd    pvbfe
1240101  171.4   0.      121.41    0.0 00.     0.0   .00015 .0417  01000
*
*       flag     p      uf           ug            vg
1240200    1  557.00 1.0
*
*          from        to        ajun    fjun      fjunr  fvcahs  vflim
1241101 104010000  124000000 70.75     .5        .5     030000
1242101 124010000  105000000 63.49     5.502    5.502  030000
1243101 250000000  124000000  2.0211  0.5       0.5    010000
*
*         lflow    vflow      int flow
1241201     0.0      0.0          0.0
1242201     0.0      0.0          0.0
1243201     0.0      0.0          0.0
*ccfl/junction hyd diam info
*           hyddia    floodcorr  gasint    slope   nj
1241110      .0417      0.          1.         1.
```

```
1242110      11.02      0.          1.         1.
1243110      1.604      0.          1.         1.
**********************************
1050000   dome pipe
*
*         nv
1050001   2
*
*         flowa     nv
1050101   63.49     1
1050102   98.79     2
*
*         jarea     nj
```

```
1050201   74.94     1
*
*
*         length    nv
1050301    0.       2
*
*         volume     nv
1050401   473.0      1
1050402   350.7      2
*
*       incline angle     nv
1050601    00.0           1
1050602    90.0           2
*
*
*         rough  hyd dia  nv
1050801 .00015  11.02      1
1050802 .00015  12.83      2
*
*         fjunf      fjunr    nj
1050901     .0         .00     1
*
*         pvbfe   nv
1051001   00000    2
*test effect of vertical stratification in dome
1051001   01000    2
*
*        fvcahs nj
1051101  000000 1
*
*        flag   p       x        dummy  dummy    dummy nv
1051201   1   557.00  1.0         0.     0.        0.   2
*
*         flag=0 => (lbm/sec)
1051300   1
*
*         lflow       vflow  interface flow        nj
```

```
1051301   0.0            0.0            0.0           1
*
*ccfl/junction hyd diam info
*          hyddia    floodcorr  gasint    slope   nj
1051401      12.83      0.          1.        1.    1
*=====================================================
*=====================================================
**********
1060000   nozzle sngljun
*
*        from          to          area     fjunf fjunr  fvcahs
1060101 105010000 107000000  1.388     0.0     0.0  010100
*1060101 105010000 107000000  1.5268      0.0     0.0  010100 * 10% increase
*1060101 105010000 107000000  1.6656      0.0     0.0  010100 * 20% increase
*
*        flag   lflow     vflow     int flow
1060201   1       0.0       0.0        0.0
*******
1070000   nozzle sngl vol
```

```
*
*          flowa     flowl      vol    azi incl    dz       rough   hyd     pvbfe
1070101    1.388     1.5        0.0    0.0  90.    1.5    .00015 0.5025  00000
*change flow area of flow limiter to check effects of choked flow increase
*1070101    1.5268     1.5        0.0   0.0  90.    1.5    .00015 0.5025  00000 *10%
*1070101    1.6656     1.5        0.0   0.0  90.    1.5    .00015 0.5025  00000 *20%
*          flag       p       x
1070200    002    1106.     1.0
1070200    001     557.     1.0
*=====================================================
3000000    break   valve
*
*           from          to         ajun
3000101 107010000  900000000  1.388    0.0  0.0  00100
*increase in flow limiter size for brk flow
*3000101 107010000  900000000  1.5268    0.0  0.0  00100 *10%
*3000101 107010000  900000000  1.6656    0.0  0.0  00100 *20%
*
*
*          time  lflow     vflow    intflow
3000201  1  0.0    0.0      0.0
3000300 mtrvlv
3000301  502  503  1000. 0.0
*3000301  502  503    2.0 0.0
*=====================================================
9000000    break   tmdpvol
*
*          flowa  flowl   vol     azi    incl     dz   rough   hyd   fe
9000101    0.0    31.1533 147.64  0.0    0.0      0.0   0.0    0.0   00
9000101    5.0     0.0    9999.   0.0    0.0      0.0   0.0    0.0   00
*
```

```
*       ebt
9000200  002
*
*        time  press    x
9000201   0.0    14.7   1.0
9000202  1.0e6   14.7   1.0
*=====================================================
1110000   udc1   branch
*
*         nj  flag
1110001   3    1
*
*         flowa     flowl     vol    azi incl   dz  rough     hyd      pvbfe
1110101 111.07      13.76     0.0    0.0 -90. -13.76  0.00015 0.0    00000
1110101 111.07        .2192   0.0    0.0 -90. -.2192  0.00015 0.0    00000
1110101 111.07        .2202   0.0    0.0 -90. -.2202  0.00015 0.0    00000
*
*         flag     p      x
1110200     2   1107.0  0.0
1110200     1    557.0  1.0
 1110200     1    557.0  0.0
*
*         from         to          ajun     fjun    fjunr    fvcahs
1111101  111010000 112000000  5.7356     1.15     1.28    000000
1111101  111010000 112000000  5.7356     0.0      0.00    000000
```

```
1112101  111000000 110000000  5.7356     0.0      0.0     000000
1112101  111000000 110000000  111.07     0.0      0.0     000000
1113101  250010000 111000000    2.02     0.5      0.5     000000
*
*         lflow    vflow      int flow
1111201      0.0    0.0        0.0
1112201      0.0    0.0        0.0
1113201      0.0    0.0        0.0
*
*ccfl/junction hyd diam info
*             hyddia     floodcorr  gasint    slope   nj
1111110        .3442      0.           1.         1.
1112110         11.89      0.           1.         1.
1113110       1.604      0.           1.         1.
=====================================================
*=====================================================
1100000   udc    snglvol
*
*         flowa     flowl      vol    azi  incl   dz      rough  hyd     pvbfe
1100101   111.07  13.5408     0.0    0.0  90.  13.5408  0.0  0.0       00000
1100101   111.07  14.1567     0.0    0.0  90.  14.1567  0.0  0.0       00000
*
*         flag     p         x
1100200   002   1106.      0.22
1100200   001    557.      1.0
```

```
*1100200   001    557.      0.3494
 1100200   001    557.      0.03
*1100200   001    557.      0.015
*=====================================================
1120000   ldc1-3  pipe
*
*         nv
1120001   5
*
*         flowa     nv
1120101   6.99203   5
1120101   5.74      5
*
*         length       nv
1120301    2.814292  1
1120302    1.0       2
1120302    1.001     2
1120303    6.570134  3
1120304   10.384433  5
*
*         volume     nv
1120401     0.0      5
*
*       incline angle     nv
1120601    -90.0           5
*
*          elev cng     nv
1120701    -2.814292     1
1120702    -1.0          2
1120703    -6.570134     3
1120704  -10.384433      5
```

```
*
*         rough   hyd dia   nv
1120801   0.0     .4067     5
1120801   0.00015  .3442     5
*
*         pvbfe    nv
1121001   00001    5
*
*        fvcahs nj
1121101  000000 4
*
*        flag    p         x         dummy  dummy    dummy nv
1121201   1    557.00  1.0         0.      0.        0.   2
1121202   1    557.00    .629      0.      0.        0.   3
1121202   1    557.00    .07       0.      0.        0.   3
1121203   1    557.00  0.0         0.      0.        0.   5
 1121201   1    557.00  0.0         0.      0.        0.   2
 1121202   1    557.00  0.0         0.      0.        0.   3
 1121203   1    557.00  0.0         0.      0.        0.   5
```

```
*
*          flag=0 => (lbm/sec)
1121300    1
*
*          lflow        vflow  interface flow        nj
1121301      0.0         0.0           0.0           4
*
*ccfl/junction hyd diam info
*            hyddia    floodcorr  gasint   slope   nj
1121401       .3442      0.          1.        1.    4
***********************************************************************
*---------- heat structure input
*
*general data
*          nh  np   geo  ss     left coord.
11511000  21  11    2    1      0.02766665
*========================================
*mesh flags
*         location flg        format flag
11511100      0                   2
*========================================
*mesh data
*         mesh interval   int #
11511101 .000358335        10
*========================================
*composition data
*           comp. #      int #
11511201       1           10
*========================================
*heat distribution data
*         source   int #
11511301   0.0      10
*========================================
*initial temperature data
*            temp.      int #
11511401    557.0        11
*============================================================
```

```
*left bc cards
*           bvl      inc  type  surf      cyl ht      struct #
11511501  151010000  0000 1      0       447.65         1
11511502  151020000  0000 1      0      1989.54         2
11511503  151030000 10000 1      0      2387.45         4
11511504  151050000 10000 1      0      2851.67         8
11511505  151090000 10000 1      0      2741.59        10
11511506  151110000 10000 1      0      2851.67        14
11511507  151150000 10000 1      0      1193.72        19
11511508  151200000  0000 1      0      795.82         20
11511509  151210000  0000 1      0       447.65        21
*============================================================
*right b[illegible] cards
```

```
*         bvr      inc  type  surf      cyl ht      struct #
11511601  100010000  0    1     0     505.62          1
11511602  122010000  0000 1     0    2247.22          2
11511603  101030000  0000 1     0    2696.66          3
11511604  101060000  0000 1     0    2696.66          4
11511605  101090000  0000 1     0    3221.02          5
11511606  135010000  0000 1     0    3221.02          6
11511607  135040000  0000 1     0    3221.02          7
11511608  135070000  0000 1     0    3221.02          8
11511609  135100000  0000 1     0    3096.67         10
11511610  135070000  0000 1    0    3221.02        11
11511611  135040000  0000 1    0    3221.02        12
11511612  135010000  0000 1     0    3221.02         13
11511613  133050000  0000 1     0    3221.02         14
11511614  133040000 -10000 1    0    1348.33         18
11511615  132010000   0000 1    0    1348.33         19
11511616  131010000  0    1     0     898.89         20
11511617  100010000  0    1     0     505.62         21
*============================================================
*source data
*         source  mult     ldh     rdh   struct #
11511701    0     0.0      0.0     0.0      21
*============================================================
*left boundary cards
*          hdiam  hlf      hlr    gridf   gridr   grdlssf grdlssr lbf struct #
11511801    0.    10.0      10.0    1.5  1.5     0.0          0.0   1.    21
*============================================================
*right boundary cards
*          hdiam  hlf      hlr    gridf   gridr   grdlssf grdlssr lbf struct #
11511901    0.    10.0      10.0    1.5  1.5     0.0          0.0   1.    21
*************************************************************
*----- heat structure thermal property data
*
*composition type and data format
*          material type    flag    flag
20100100       tbl/fctn      1       1     * inconel
*=====================================================
*
*
*-------------------------------------------------------------------
* thermal conductivity data (btu/sec-ft/deg f) and volumetric heat  Î
* capacity  data (btu/ft**3-deg f) versus temperature for above     Î
* composition                                                       Î
```

```
*-------------------------------------------------------------------
*
*
*
*=====================================================
*inconel 600 thermal conductivity data
*          temperature      thermal conductivity
```

```
20100101       70.0                 2.3843e-03
20100102      200.0                 2.5232e-03
20100103      400.0                 2.8009e-03
20100104      600.0                 3.0787e-03
20100105      800.0                 3.3565e-03
20100106     1000.0                 3.6574e-03
20100107     1200.0                 3.9815e-03
20100108     1400.0                 4.3056e-03
20100109     1600.0                 4.6296e-03
*=====================================================
*inconel 600 volumetric heat capacity data
*          temperature      heat capacity
20100151       70.0               55.6831
20100152      200.0               55.5227
20100153      400.0               55.2607
20100154      600.0               54.9895
20100155      800.0               54.7069
20100156     1000.0               54.3982
20100157     1200.0               54.0907
20100158     1400.0               53.7516
20100159     1600.0               53.4205
20100160     1800.0               53.0796
*=====================================================
*
*--------- control system for measuring sg level
*
*
*-------------------------------------------------------------
*  note: the following control system is to work in britsh     Î
*        units ( lbm, lbf, ft, s, p=lbf/sqin). in relap5        Î
*        the quantities stored in arrays are in si units.       Î
*        therefore, conversions from si to british units        Î
*        must be made.                                          Î
*-------------------------------------------------------------
*
*
*--------- control variable card type
20500000      999
*
*--------- control component cards
*
*
*    compute pressure difference
*
*          name     type    scale(psi/pa) init      flag
20500100  deltpp    sum       1.45003e-04   0.0         1
*         a0   a1  var   vol         a2  var   vol
20500101  0.0  1.0, p, 042010000   -1.0, p, 100010000
*
```

```
*          name     type    scale(psi/pa) init      flag
```

```
20500200  deltpn    sum       1.45003e-04   0.0          1
*         a0   a1  var   vol          a2  var   vol
20500201  0.0 -1.0, p, 121010000   1.0, p, 100010000
*
*          name      type    scale(psi/pa) init       flag
20500300  deltpn    sum       1.45003e-04   0.0          1
*         a0   a1  var   vol          a2  var   vol
20500301  0.0 -1.0, p, 101020000   1.0, p, 101010000
*          name      type    scale(psi/pa) init       flag
*
*          name      type    scale(psi/pa) init       flag
20500400  deltpp    sum       1.45003e-04   0.0          1
*         a0   a1  var   vol          a2  var   vol
20500401  0.0 -1.0, p, 101050000   1.0, p, 101040000
*
*          name      type    scale(psi/pa) init       flag
20500500  deltpp    sum       1.45003e-04   0.0          1
*         a0   a1  var   vol          a2  var   vol
20500501  0.0 -1.0, p, 101080000   1.0, p, 101070000
*
*          name      type    scale(psi/pa) init       flag
20500600  deltpp    sum       1.45003e-04   0.0          1
*         a0   a1  var   vol          a2  var   vol
20500601  0.0 -1.0, p, 134010000   1.0, p, 101100000
*
*          name      type    scale(psi/pa) init       flag
20500700  deltpp    sum       1.45003e-04   0.0          1
*         a0   a1  var   vol          a2  var   vol
20500701  0.0 -1.0, p, 135030000   1.0, p, 135020000
*
*          name      type    scale(psi/pa) init       flag
20500800  deltpp    sum       1.45003e-04   0.0          1
*         a0   a1  var   vol          a2  var   vol
20500801  0.0 -1.0, p, 135060000   1.0, p, 135050000
*
*          name      type    scale(psi/pa) init       flag
20500900  deltpp    sum       1.45003e-04   0.0          1
*         a0   a1  var   vol          a2  var   vol
20500901  0.0 -1.0, p, 135090000   1.0, p, 135080000
**************************************************************
**************************************************************
**************************************************************
*********************************************
*                                           *
* end of input deck - problem end           *
*                                           *
*********************************************
```