A RELAP5M3 Comparison of Model Boiler 2
MSLB from HZP Test

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Abstract

This calculation has been performed to validate the methods and models utilized with the RELAP5M3 computer code to calculate the time dependent differential pressure on the tube support plates (TSPs) during Main Steam Line Break (MSLB) events from Hot Zero Power (HZP) conditions. This event is the limiting event with respect to dynamic loading of the TSPs and accurate characterization of these loads is required as input to structural analyses of these structures being performed in support of the 3mv IPC submittals. This calculation utilizes a model similar to that employed in the Model D4 analysis to predict the response of the MB2 test facility to a full size MSLB from HZP. This comparison provides benchmarking support for the manner and methods employed in the generation of transient analysis of the Model D4 steam generators for Byron 1 and Braidwood 1.

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1. Introduction

The MB2 test facility is a 0.8% power scaled, full height test facility that was built to test the design of the Model F steam generator. A series of tests were performed with this facility and were documented in references 1 and 2. This calculation utilizes data recovered from these tests to demonstrate the ability of RELAP5M3 to adequately and conservatively characterize the MSLB event from HZP conditions. Specifically, Test 2013, a MSLB from HZP and normal water level, was modeled to demonstrate that with appropriate input selection, RELAP5M3 will calculate representative pressure loads on the TSPs.

This calculation has two primary purposes. The first is to demonstrate that RELAP5M3 can model the TSP loads conservatively. The second is to demonstrate that key modeling options and model configurations used in the Model D4 analyses, when employed in the Model Boiler comparison, yield appropriate results. The primary modeling option of concern is the use of the equilibrium model in the tube regions. This is necessary to preclude pressure oscillations related to the non-equilibrium model interfacial heat transfer, that although small from a system perspective, cause erroneous loads to be predicted. The primary model configuration to be supported is the use of a detailed bundle nodalization, which represents a balance between optimal modeling practice and the desire to obtain differential pressure information as close to the tube support plates as achievable.

2. 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 utilized for this analysis. The installation of this code was verified specifically for this analysis by direct comparison of supplied sample problems output files. This computer code employs a state of the art two fluid model to calculate thermal hydraulic behavior of complex systems. A review of the code assessment problems indicates that this code has been tested and predicts well, the behavior of steam and water-filled vessels undergoing rapid depressurization.

2.2 Test Facility Description

A detailed summary of the test facility geometry is provided in Appendix C.

2.3 Description of RELAP5M3 model

The RELAP model nodalization diagram is provided in Figure 1. This model is a direct analogue of the Model D4 SG model developed for Byron 1 and Braidwood 1. The total volumes have been scaled to be representative of the test facility. A listing of the base model is provided in Appendix D.

2.3.1 Initial Conditions

The initial mass of the model compares favorably with that measured in the test, 1260 pounds in the RELAP model vs 1211 pounds as indicated by the test data reports. The initial water level has been initialized within two inches of the 441 inch level reported in the test. The test was initiated from 2% power, to be representative of HZP conditions with some decay heat removal. The RELAP5 model was initiated at a zero power condition, to yield the highest loads possible, as was modeled in the D4 analysis. The RELAP model initializes all volumes at 560 F, which results in an initial dome pressure of 1132 psia. The initial pressure in the test facility was 1090 psia.

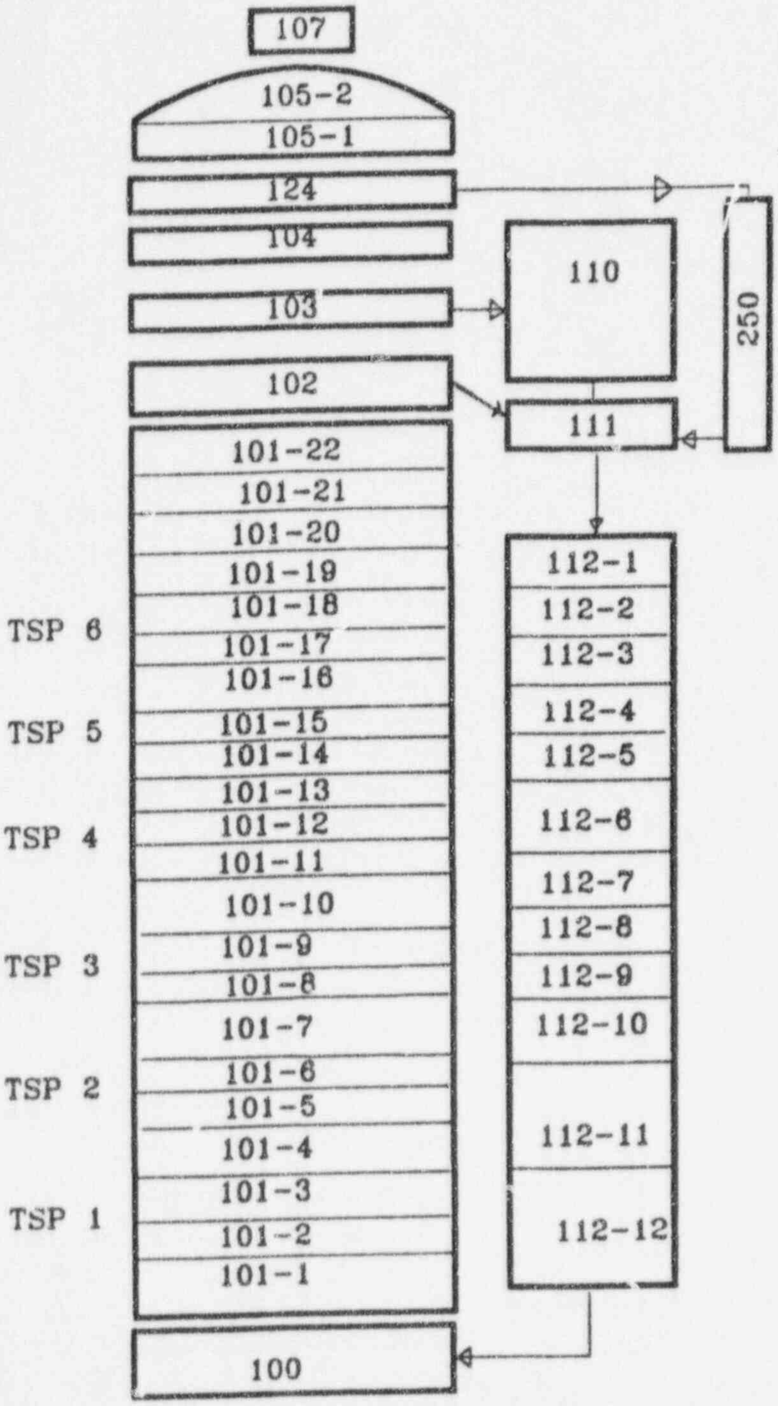
2.3.2 Tube Bundle Modeling

Tube bundle interphase drag modeling is based on the use of the rodded bundle correlations (EPRI). The model represents the TSPs as having the same area as the bundle flow area, with the loss coefficient adjusted accordingly. This approach was utilized in the D4 model as well, and is the method recommended by the RELAP5 newsletter (April-July 1995). In the tube regions (Volume 101), a series of small nodes (.2ft) have been inserted on either side of the TSPs in order to predict the transient differential pressure load on the TSPs. Since MB2 is a full height test facility, this is directly comparable to the Model D4 nodalization scheme. Crossflow frictional terms were calculated identically to the methods applied in the Model D4 calculation, and the data sheets are enclosed in Appendix D. In initial steady state testing, Westinghouse found it necessary to increase the effective crossflow resistance by a mean factor of 8.5 to obtain the appropriate pressure drop at the U-bend. This factor is also applied in this model.

2.3.3 Break Flow Modeling

The flow restricting orifice was modeled in junction 106 at the exit of the steam generator. The break is simulated in the line directly downstream of the orifice by the use of an MOV model. This valve was assumed to have an opening rate of 100 msec to be typical of the air operated valve actually employed in the test. To evaluate the potential effects of increased piping resistance in the test apparatus, a series of cases was performed using reduced nozzle area, comparable to C/D reductions in LOCA analysis.

Figure 1 RELAP5M3 Model Diagram of MB2 Facility



RELAP5M3 Model Diagram of MB2

3. Calculations

3.1 Base Case

The base case run utilized equilibrium modeling in the tube bundle and lower downcomer regions, comparable to the D4 model. This case used the full nozzle area, based on a throat diameter of 1.3 inches.

3.2 Non-Equilibrium Case

This case was identical to the base case, with the exception that the non-equilibrium models were enabled throughout the model.

3.3 Nozzle Size Sensitivity

Cases were run with 70% and 80% effective flow limiting nozzle area. These cases were identical in all other respects to the base case,

4. Results

4.1 Base Case

The model was allowed to run to a null transient for the first second to ensure an initially steady state. The break was initiated at 1 second, and the effects of the resulting transient were computed for a ten second period. Auxiliary feedwater at 97 degrees F was injected into volume 111 at a rate of .23 gpm increasing linearly to .35 gpm from 1 second to 11 seconds, as described in the test. The dome pressure behavior is shown in Figure 2. As can be seen, the overall pressure response is comparable to the test, but with a slightly higher rate of pressure decrease over the 10 second period. The break flow, shown in Figure 3, is higher than that indicated by steam flow measurements in the test steam line. This behavior is consistent with the pressure response observed, and prompted the sensitivity study on nozzle area. Test data was recovered from microfiche for the differential pressure data on the TSPs at a .1 second interval for the first 2 seconds of the event. The RELAP model predictions of transient TSP differential pressures are plotted against the test data for all six TSPs in Figures 4 through 9. Due to the location of the test instruments relative to the nodes available in the RELAP nodalization, some elevation head induced bias exists as demonstrated in the plots. The relative pressure changes are representative however, and provide a good indication of the ability of the code to reproduce the transient response. Of particular interest is the TSP 5 response, since the location of the test instrumentation includes not only the TSP, but a tube section as well. This geometry demonstrates the ability of the code to predict the TSP DP plus the tube bundle friction losses. The plots of the lower support plate behavior indicate that very little reverse flow occurred in the lower bundle region, and that the RELAP model consistently reproduces this effect. From the TSP DP plots, it can be seen that the equilibrium model produces pressure increases at the TSPs that are consistent in timing and conservative in magnitude.

4.2 Non-Equilibrium Case

The dome pressure and break flow rates for this case are shown in Figures 10 and 11. There is effectively no difference in these predictions from that of the base case. The TSP differential pressures are shown in Figures 12 through 17. These plots, particularly the upper three support plate responses (TSP 4-6) serve to illustrate the effects of the pressure oscillations. The initial response is not unreasonable, but highly oscillatory. At approximately .7 seconds into the event, the model predicts a large spike in pressure, when in fact the test data shows a declining pressure behavior. Figure 18 provides the saturation, liquid and vapor temperatures for volume 101-13, and illustrates the metastable nature of the nonequilibrium model that is believed to be the cause of this behavior. Forcing the model to maintain consistent fluid temperatures, as in the base case, eliminates this behavior, and produces results more closely related to the test data.

4.3 Nozzle Area Sensitivity Study

As noted above, the base case depressurization rate and steam flow based on the flow limiting nozzle dimensions appeared high relative to the test data. To ensure that the conservative overprediction of loads by the RELAP model was not solely a function of excessive blowdown rate, calculations were performed at 70% and 80% effective nozzle area. The 80% case yielded depressurization rates and steam flow rates still somewhat higher than the test data supported. The 70% case provided steam flow rates that were closer to those measured in the test, and a depressurization rate consistent, and slightly less than that observed, as shown in Figures 19 and 20. This provides a means of enveloping the pressure response. The TSP loads for this case are provided in Figures 21 through 26, and show that at the reduced depressurization rates and steam flows, that RELAP5 provides conservative prediction of the TSP loads.

5. Conclusions

As stated in the Introduction, this calculation had two purposes: to demonstrate that RELAP5M3 can be effectively used to develop conservative differential pressure loads on TSPs under MSLB conditions, and to demonstrate that the model options and nodalizations used in the D4 analysis yield appropriate responses when utilized to model applicable test data. The results obtained in this calculation demonstrate both of these points. RELAP5M3 does reproduce the test data results on the TSPs with reasonable conservatism. The model options used in the Model D4 analysis provide the best match to test data, both in timing and magnitude.

The results of the nonequilibrium case highlight the pressure oscillations caused by metastable behavior in the interfacial heat transfer models. It should be noted that this type of analysis is a special case that is severely impacted by what are in fact relatively small oscillations in the macroscopic pressure behavior. This problem has been brought to the attention of the code developers for resolution. The good agreement with long term vessel pressure and TSP load suggest that this problem would have minimal effect on most applications of the code. It appears that only in fast depressurization transients where differential versus integral behavior is the focus that this problem is of concern.

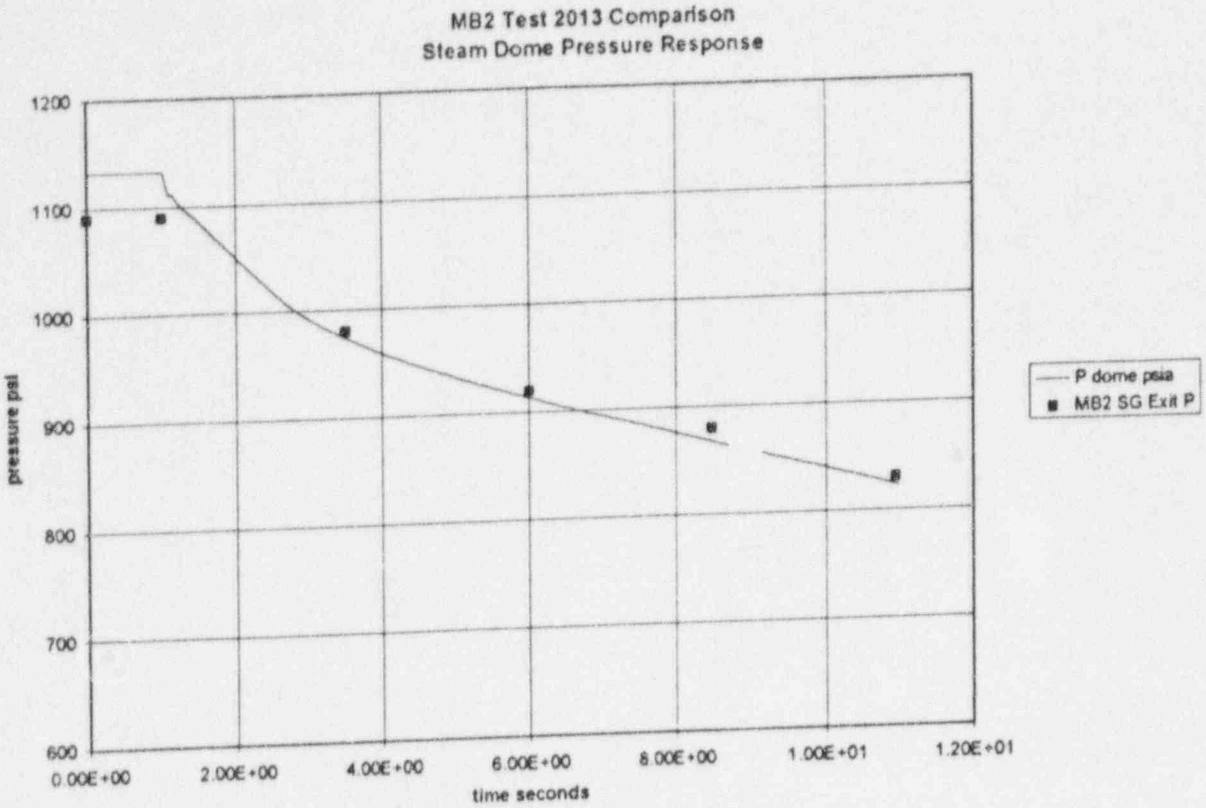


Figure 2 Base Case Dome Pressure Response

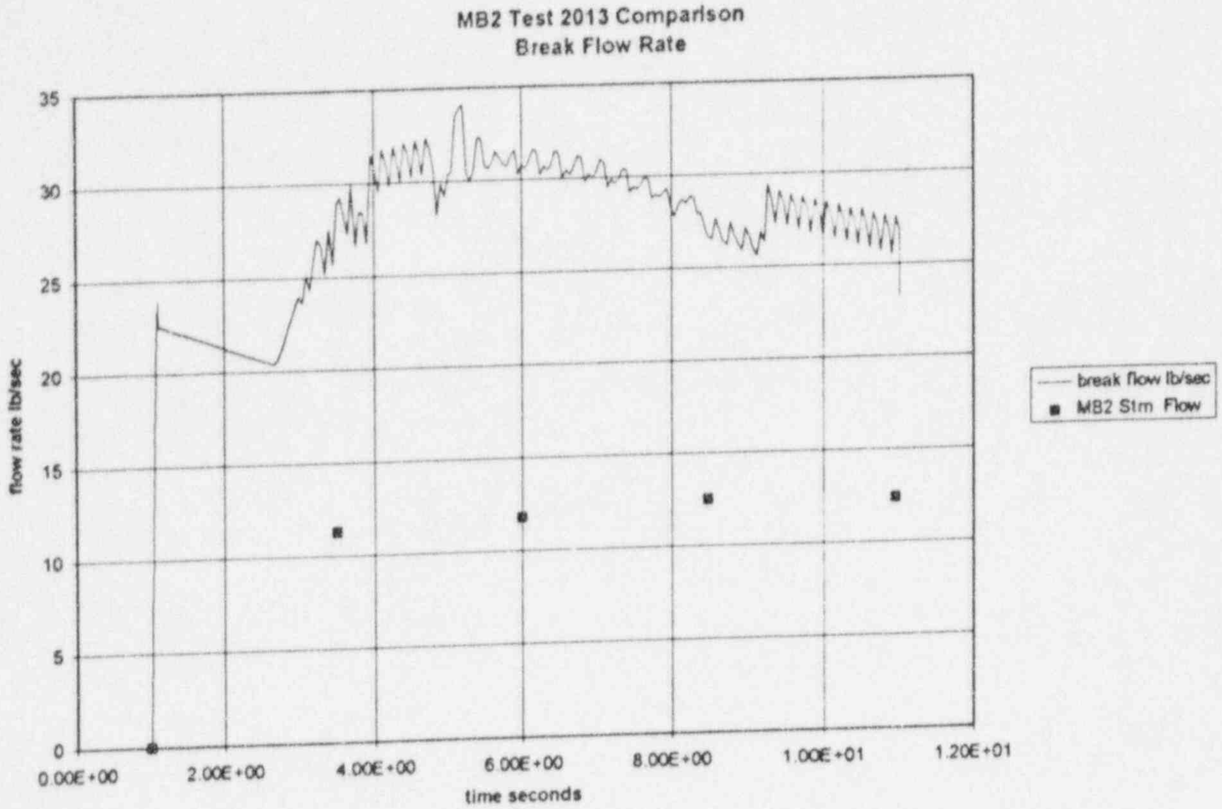


Figure 3 Base Case Break Flow Rate

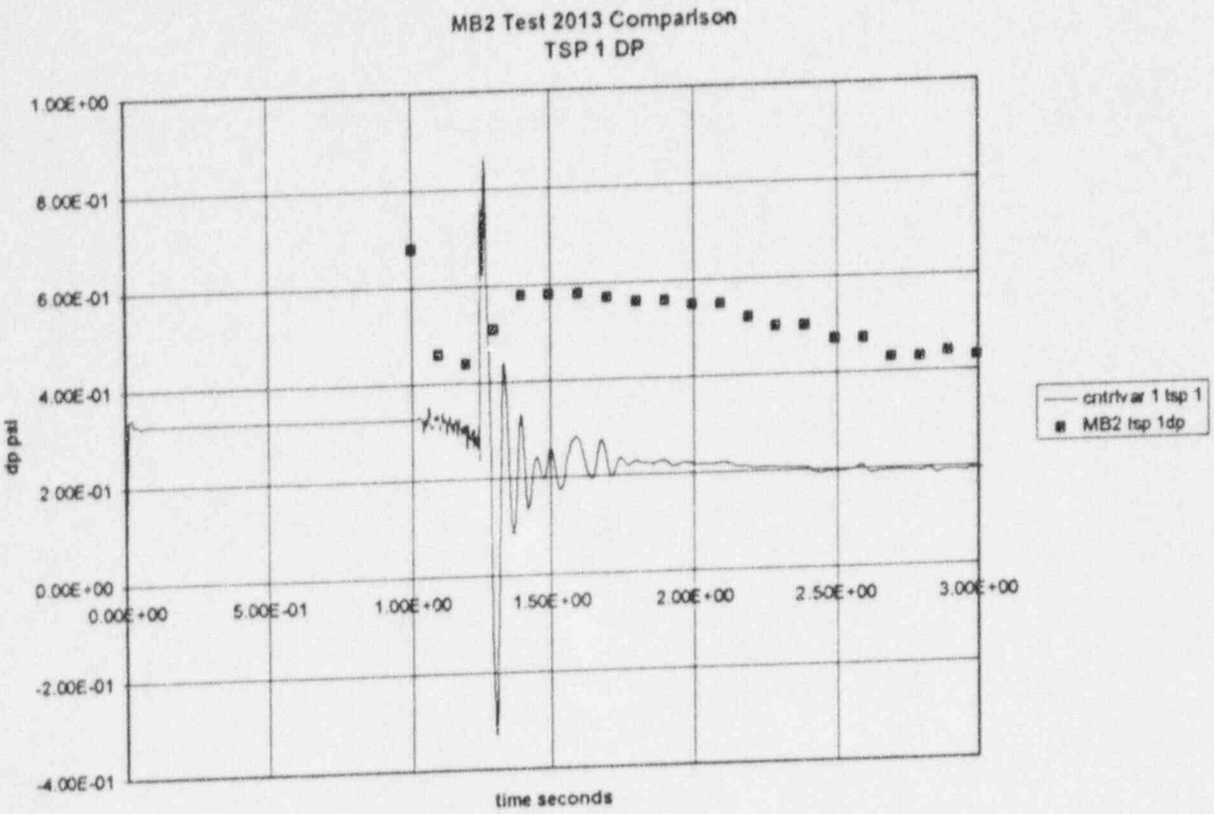


Figure 4 Base Case TSP 1 DP

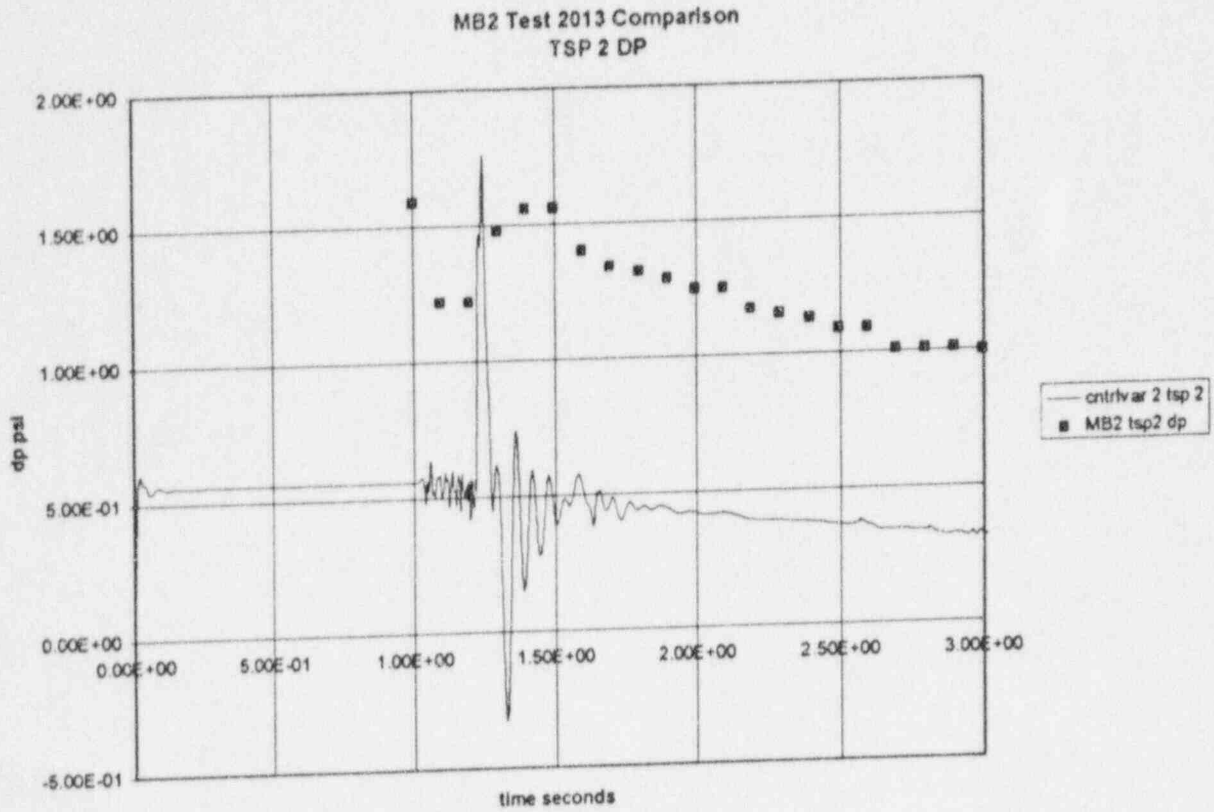


Figure 5 Base Case TSP 2 DP

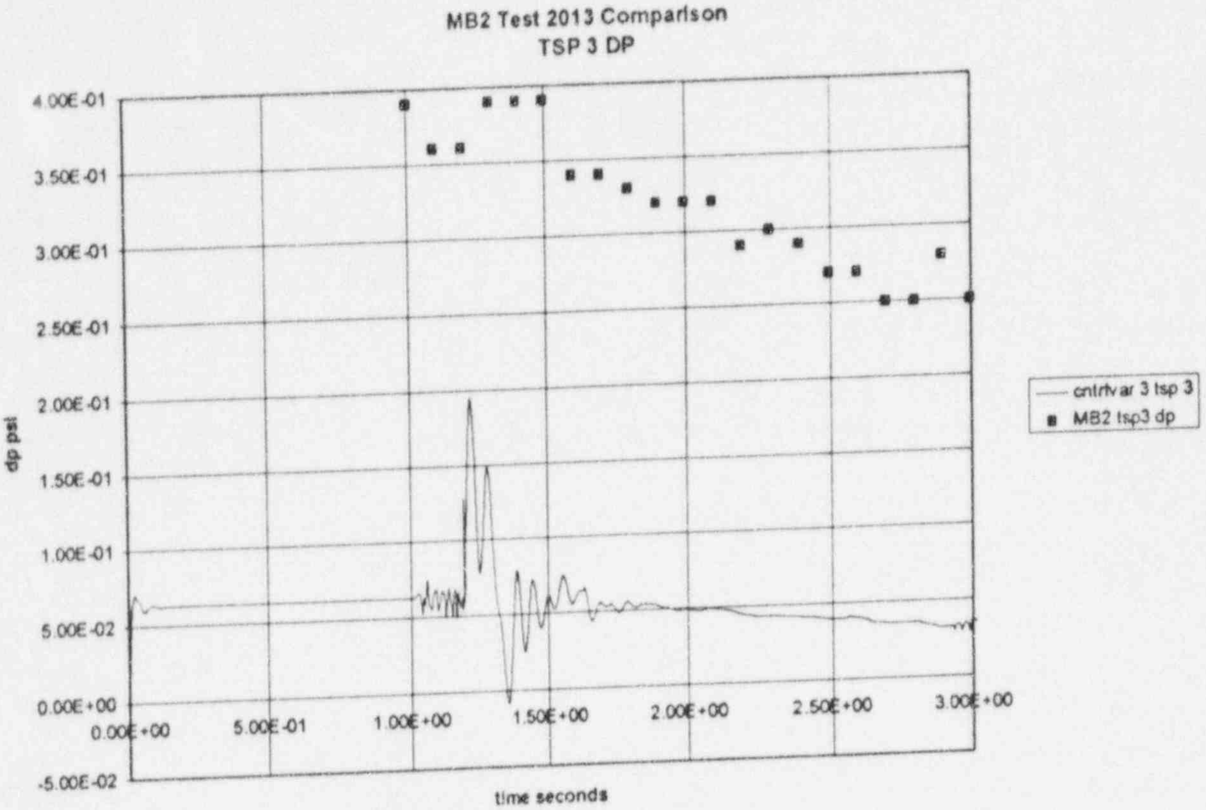


Figure 6 Base Case TSP 3 DP

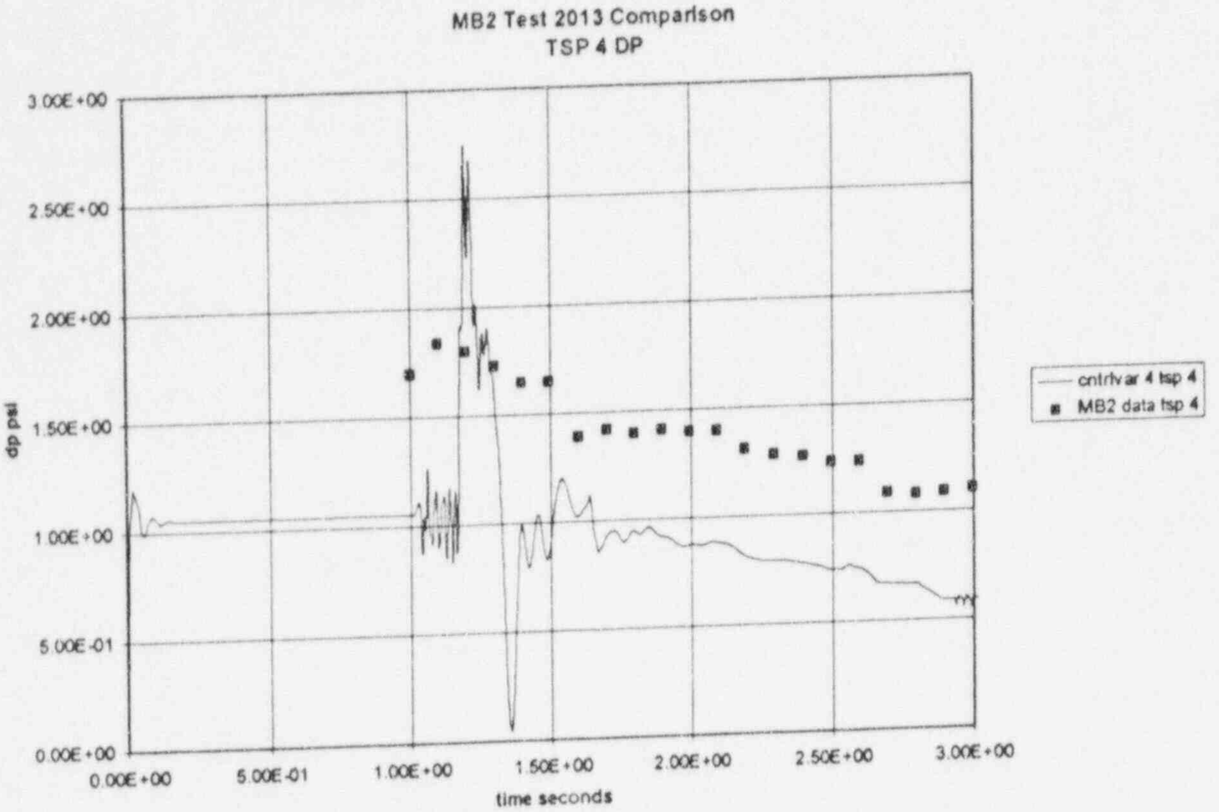


Figure 7 Base Case TSP 4 DP

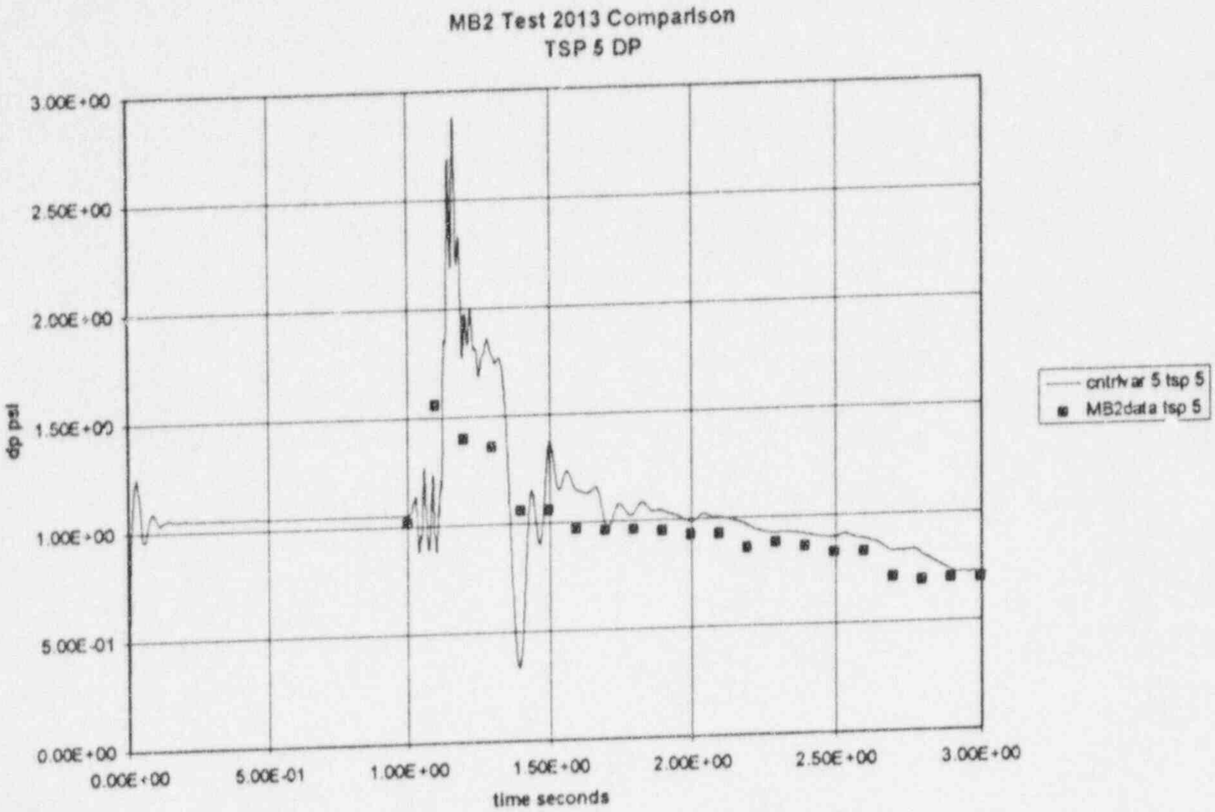


Figure 8 Base Case TSP 5 DP

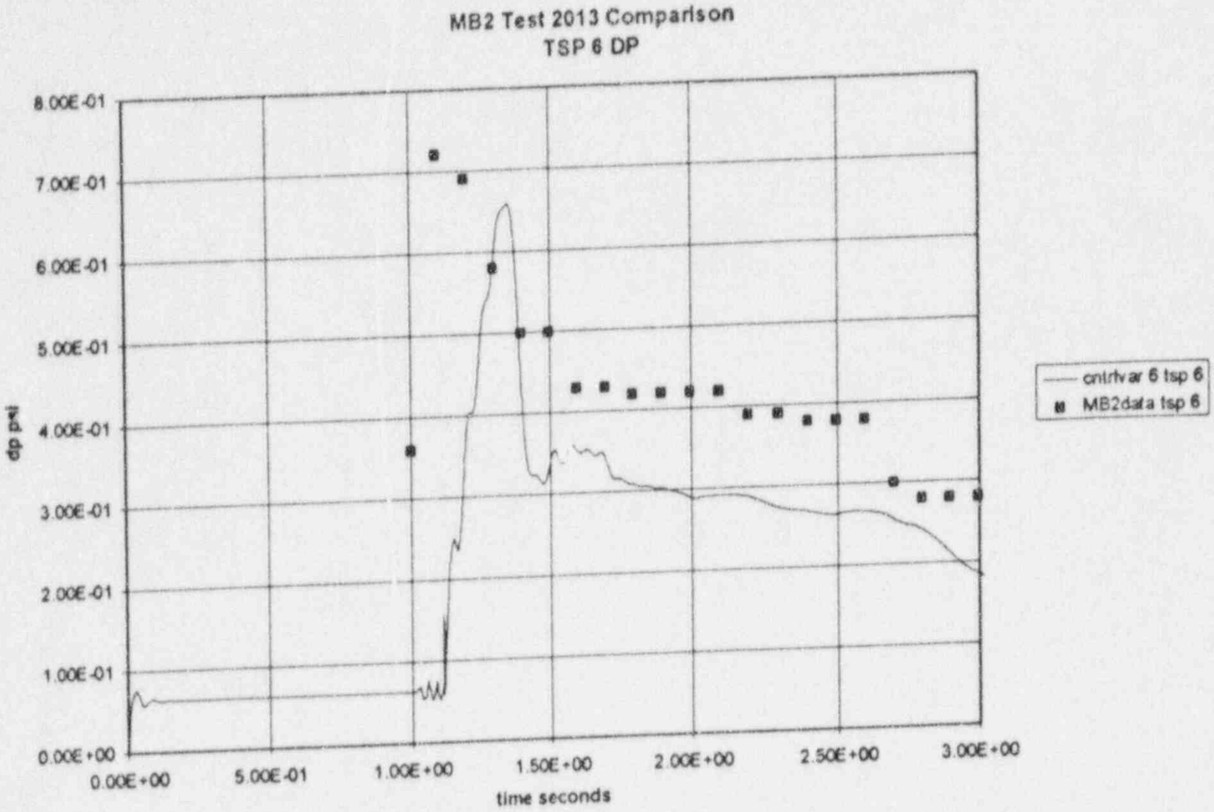


Figure 9 Base Case TSP 6 DP

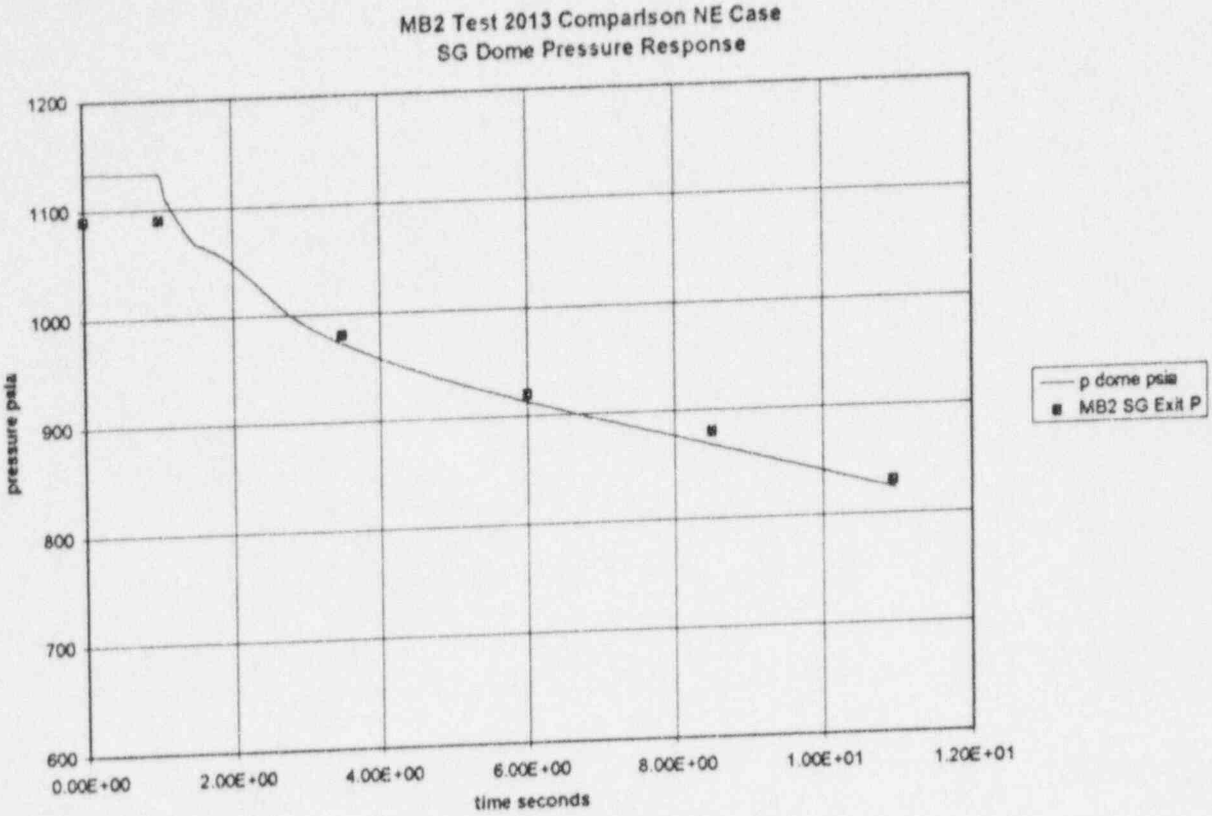


Figure 10 Non-Equil. Case Dome Pressure Response

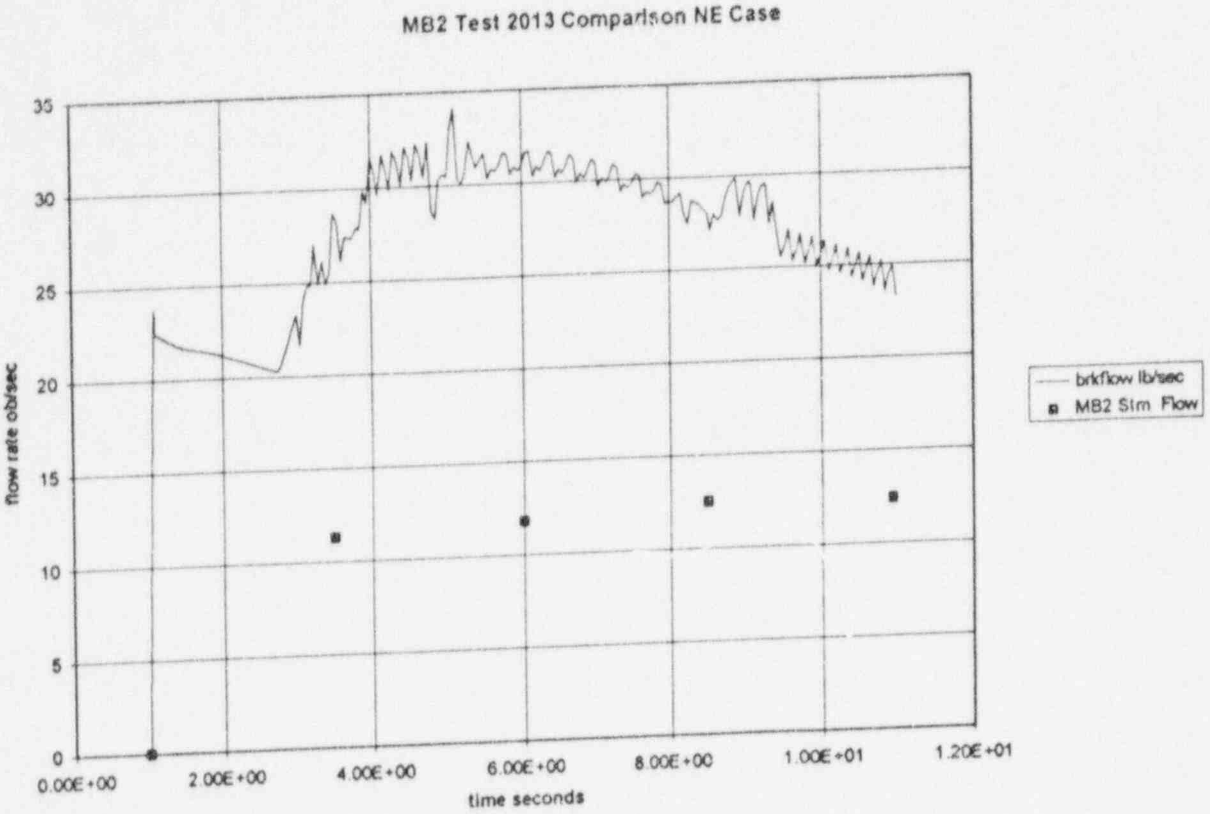


Figure 11 Non-Equil. Case Break Flow Rate

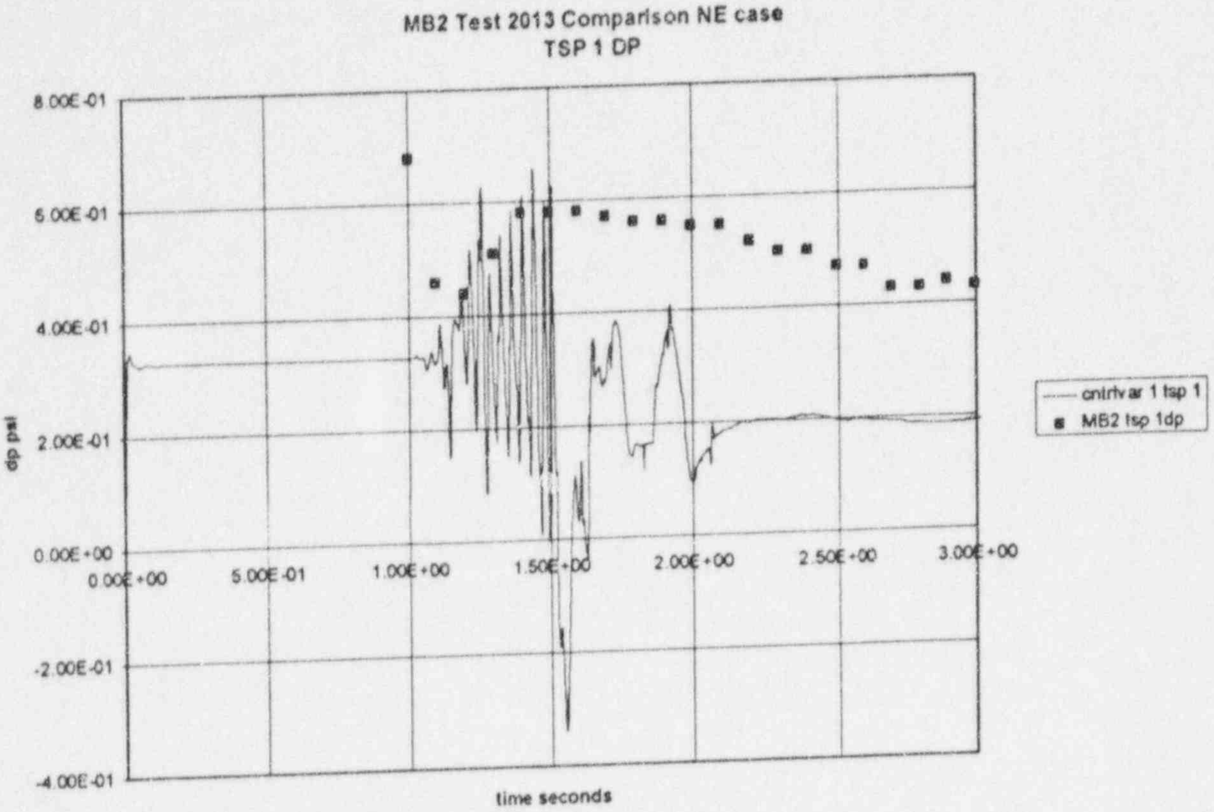


Figure 12 Non-Equil. Case TSP 1 DP

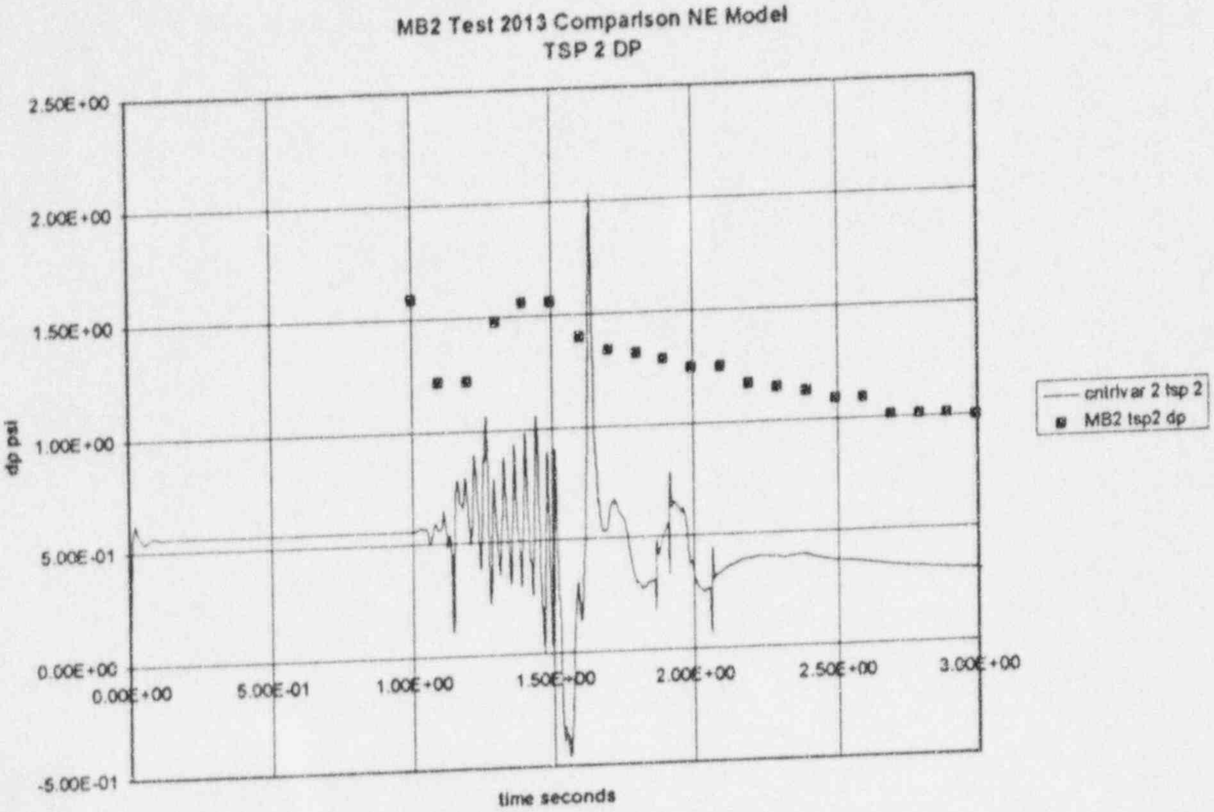


Figure 13 Non-Equil. Case TSP 2 DP

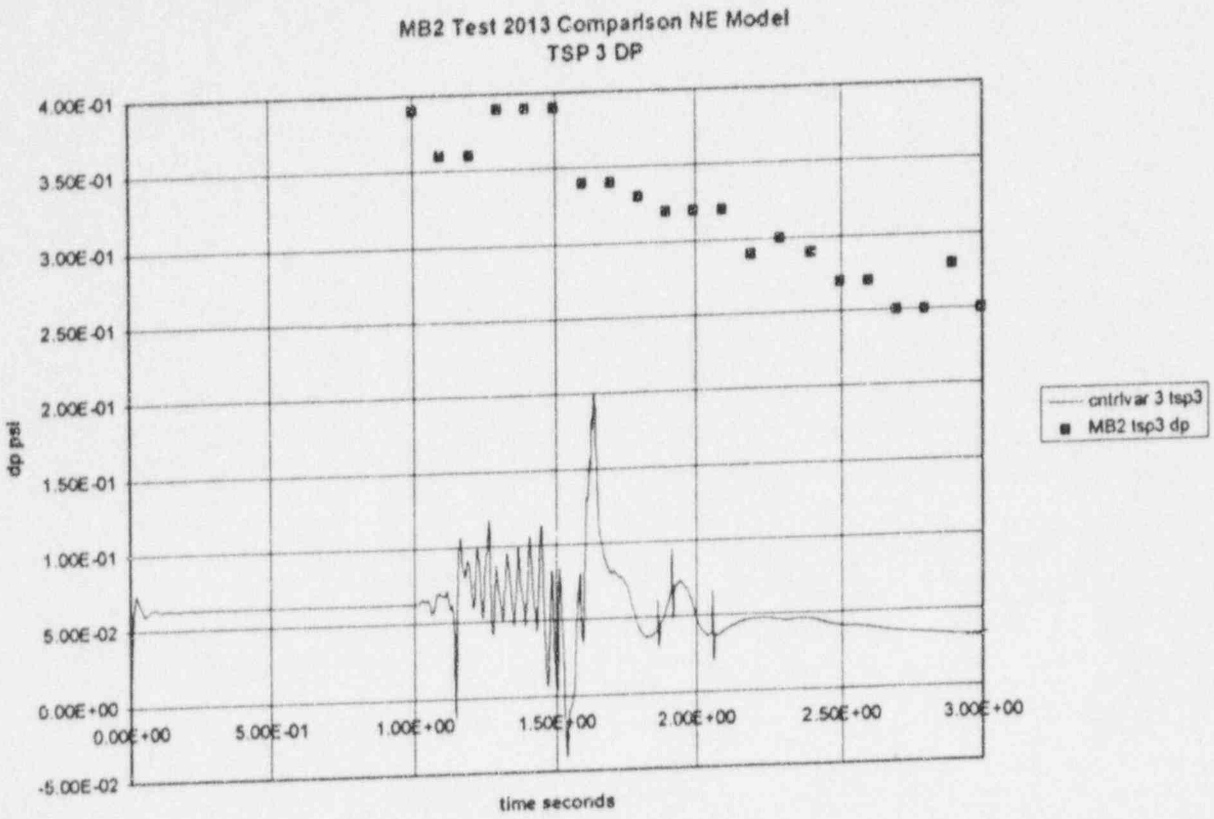


Figure 14 Non-Equil. Case TSP 3 DP

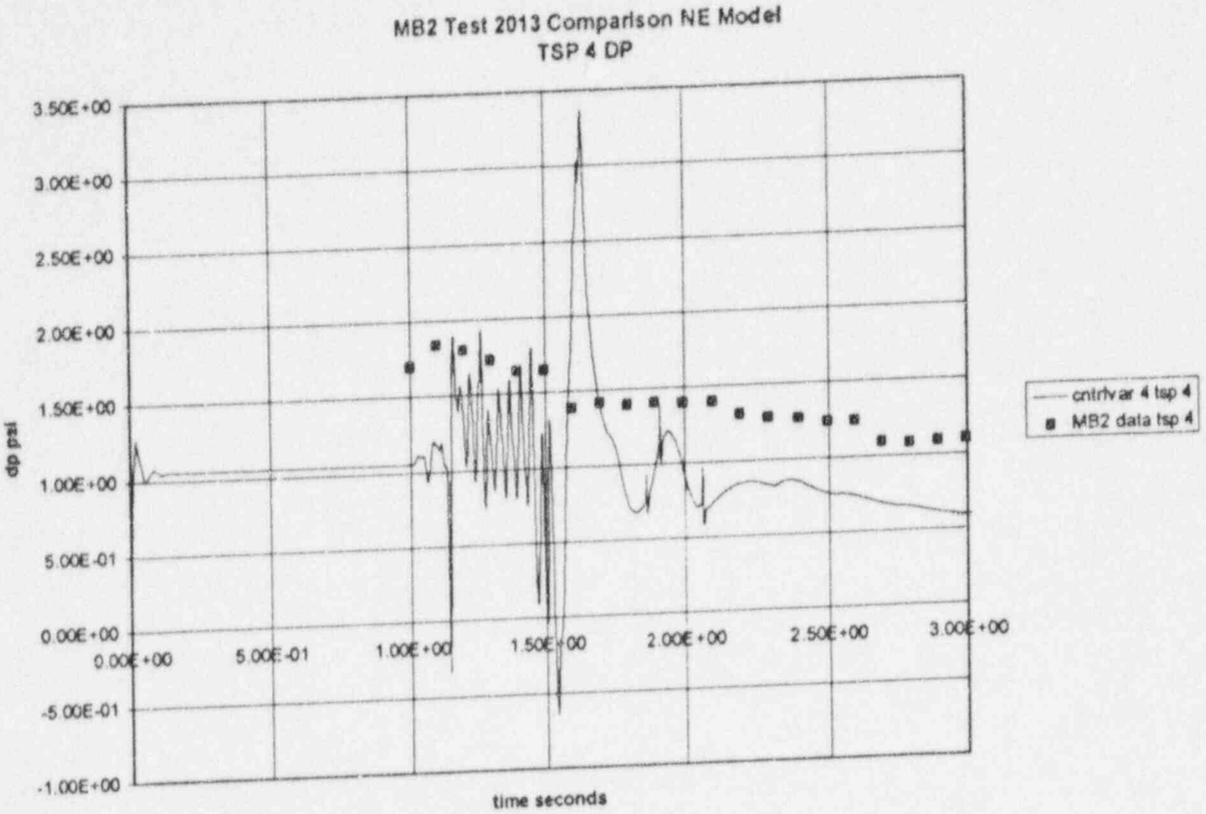


Figure 15 Non-Equil. Case TSP 4 DP

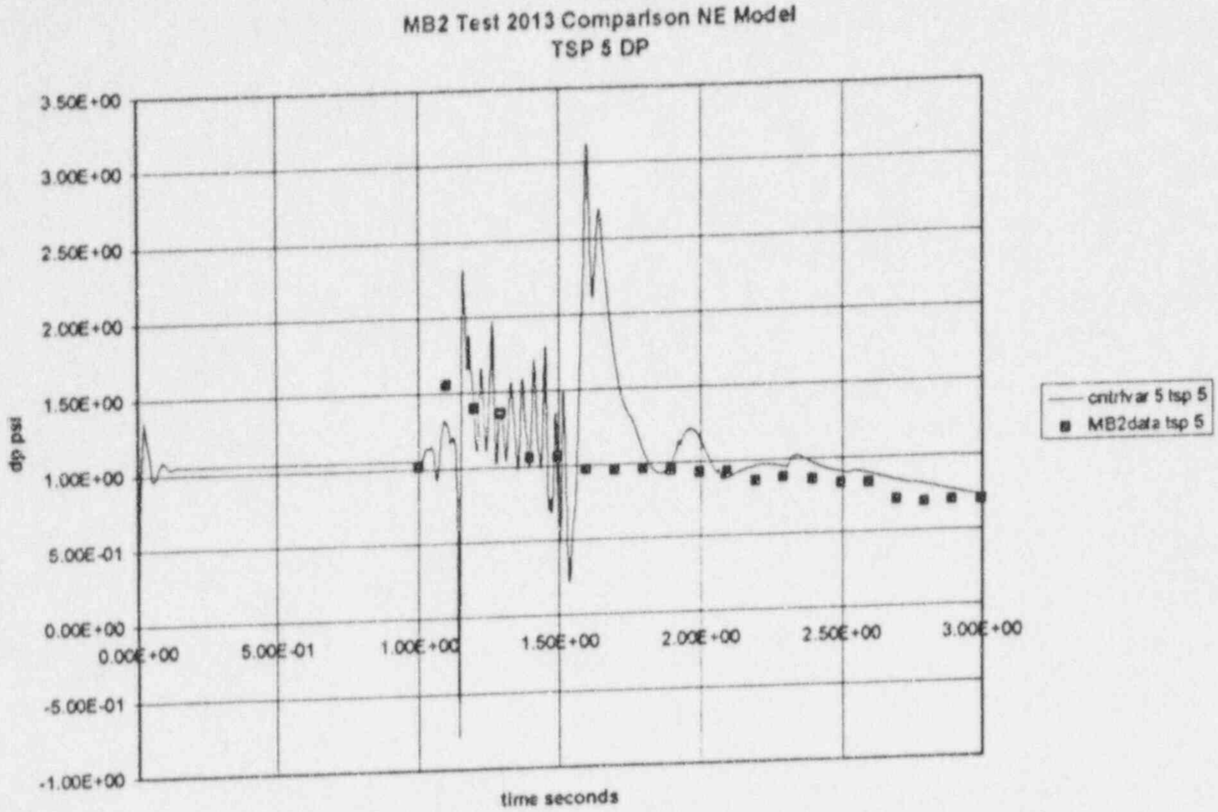


Figure 16 Non-Equil Case TSP 5 DP

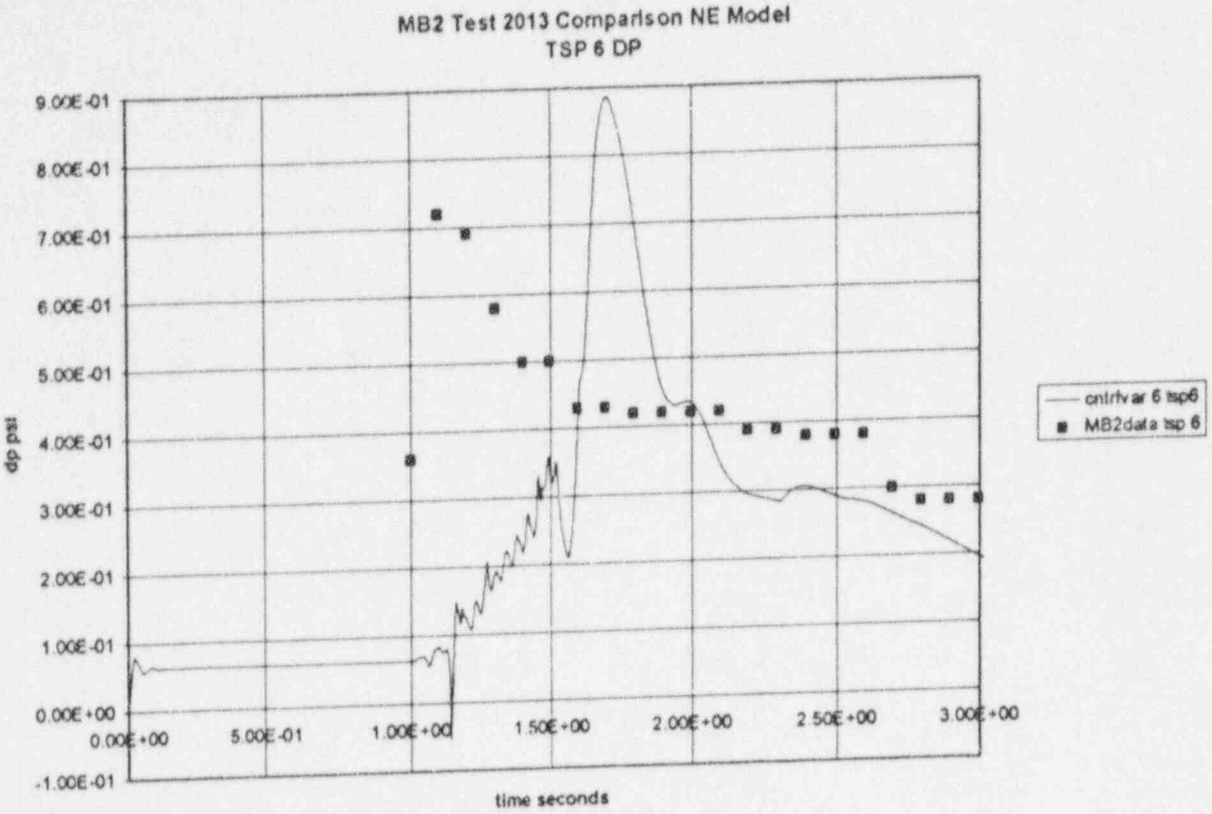


Figure 17 Non-Equil. Case TSP 6 DP

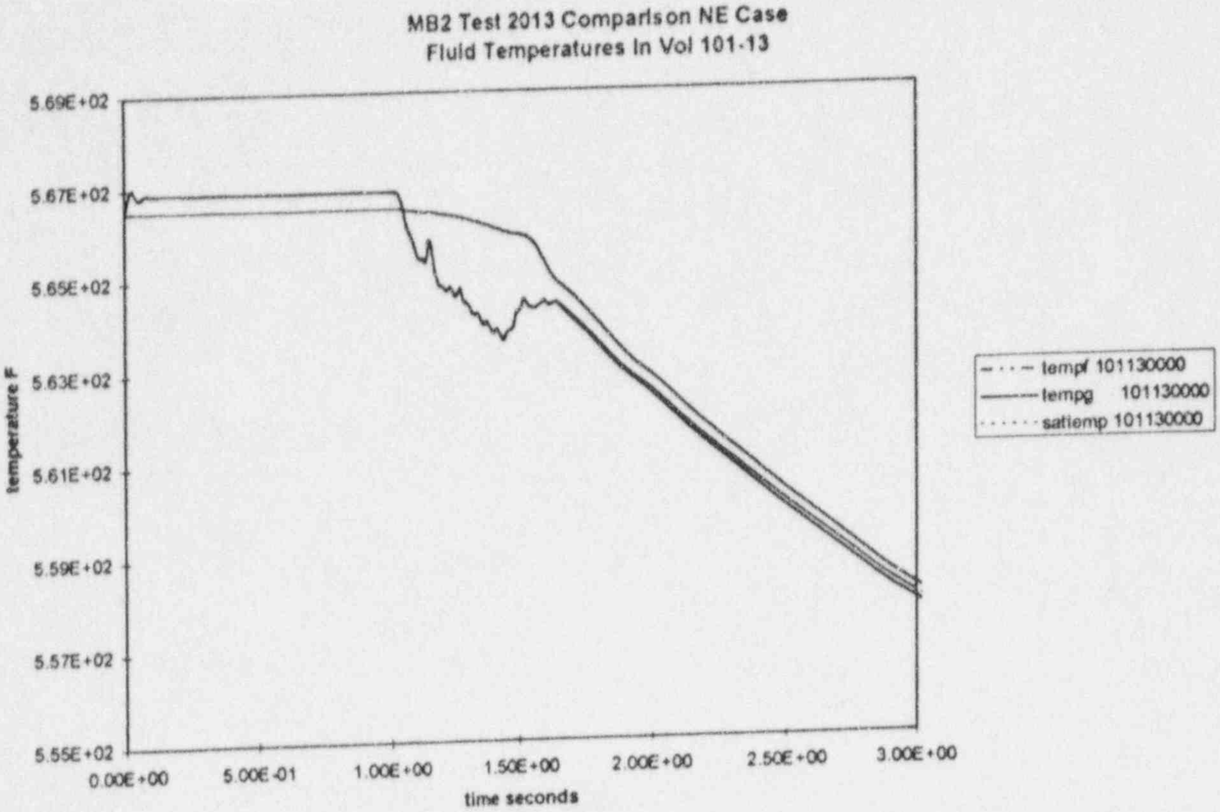


Figure 18 Non-Equil. Case Temperature Response in 101-13

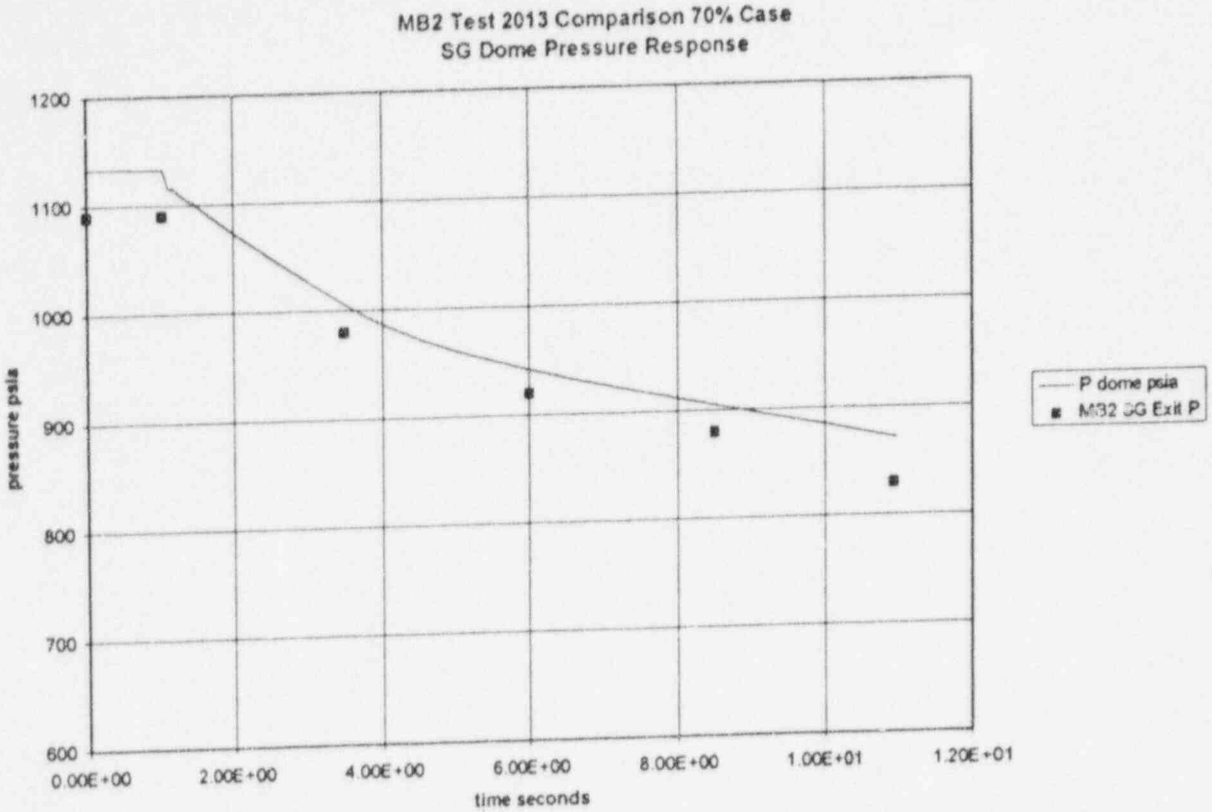


Figure 19 Dome Pressure Response 70% Case

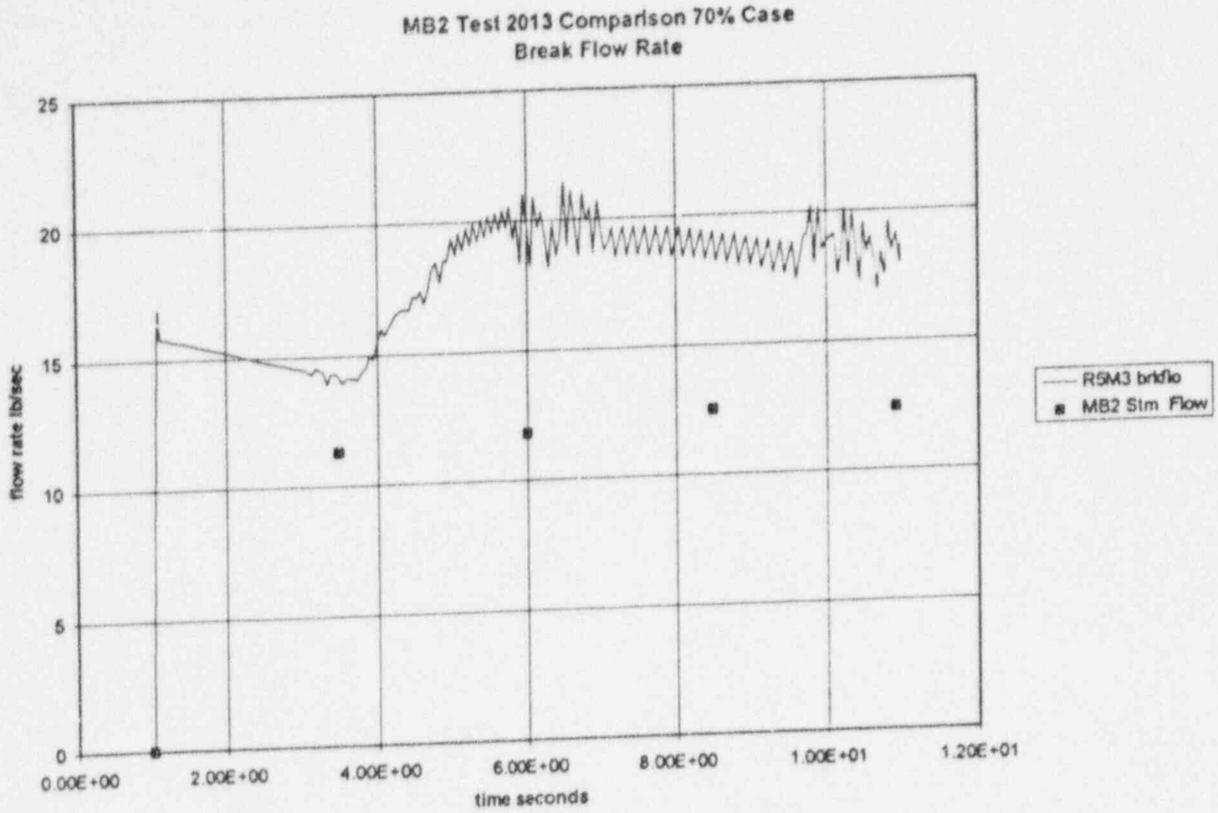


Figure 20 Break Flow Rate 70% Case

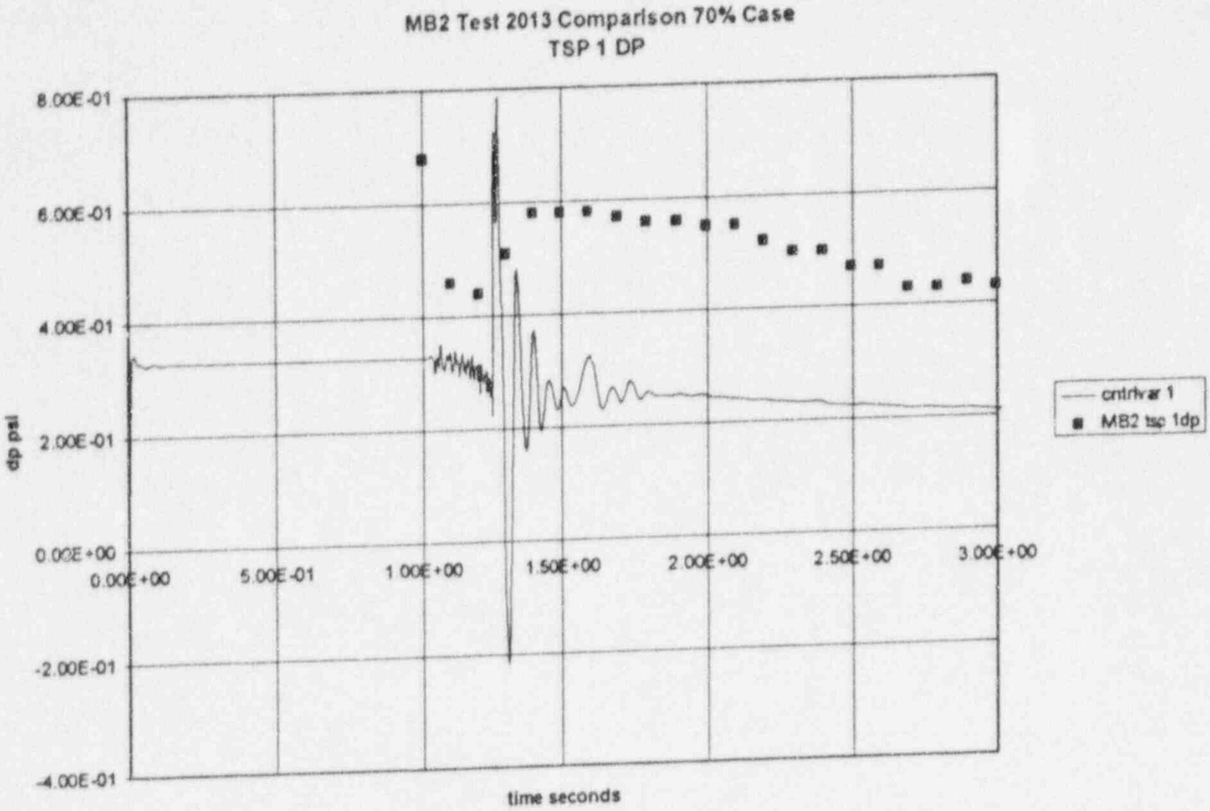


Figure 21 TSP 1 DP 70% Case

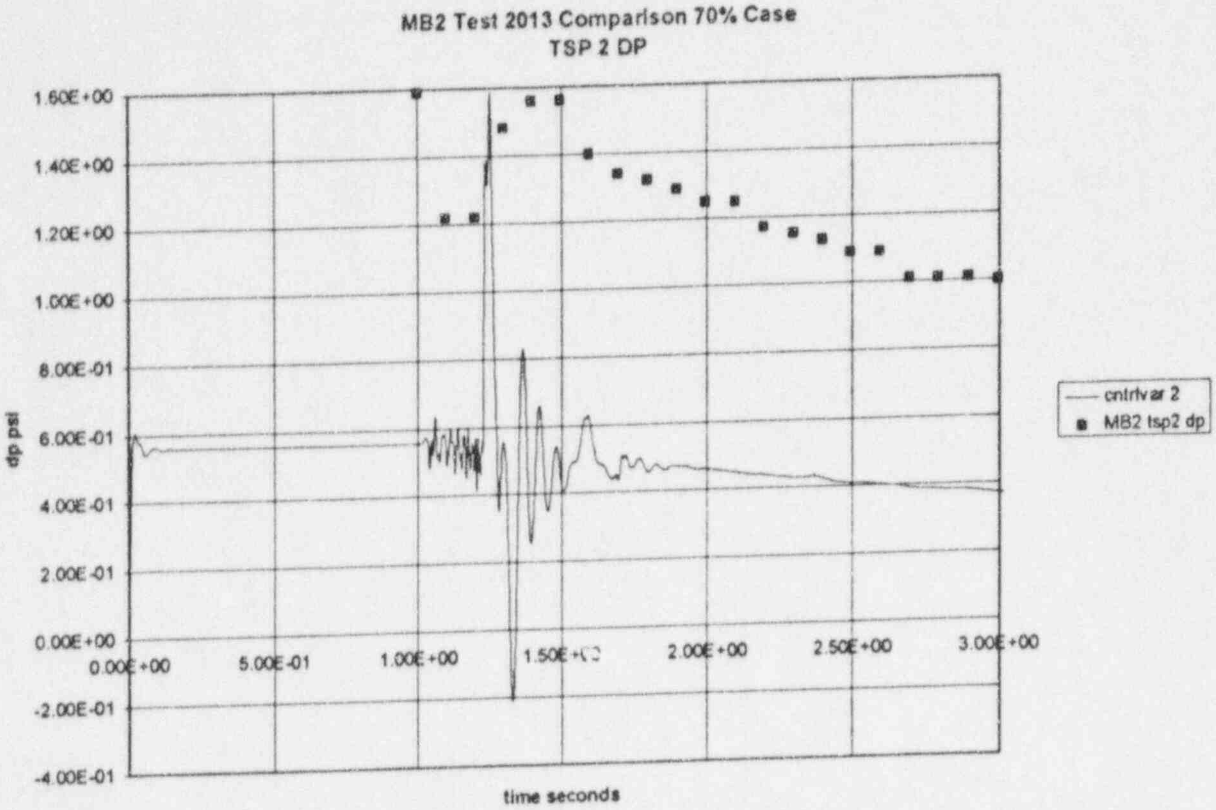


Figure 22 TSP 2 DP 70% Case

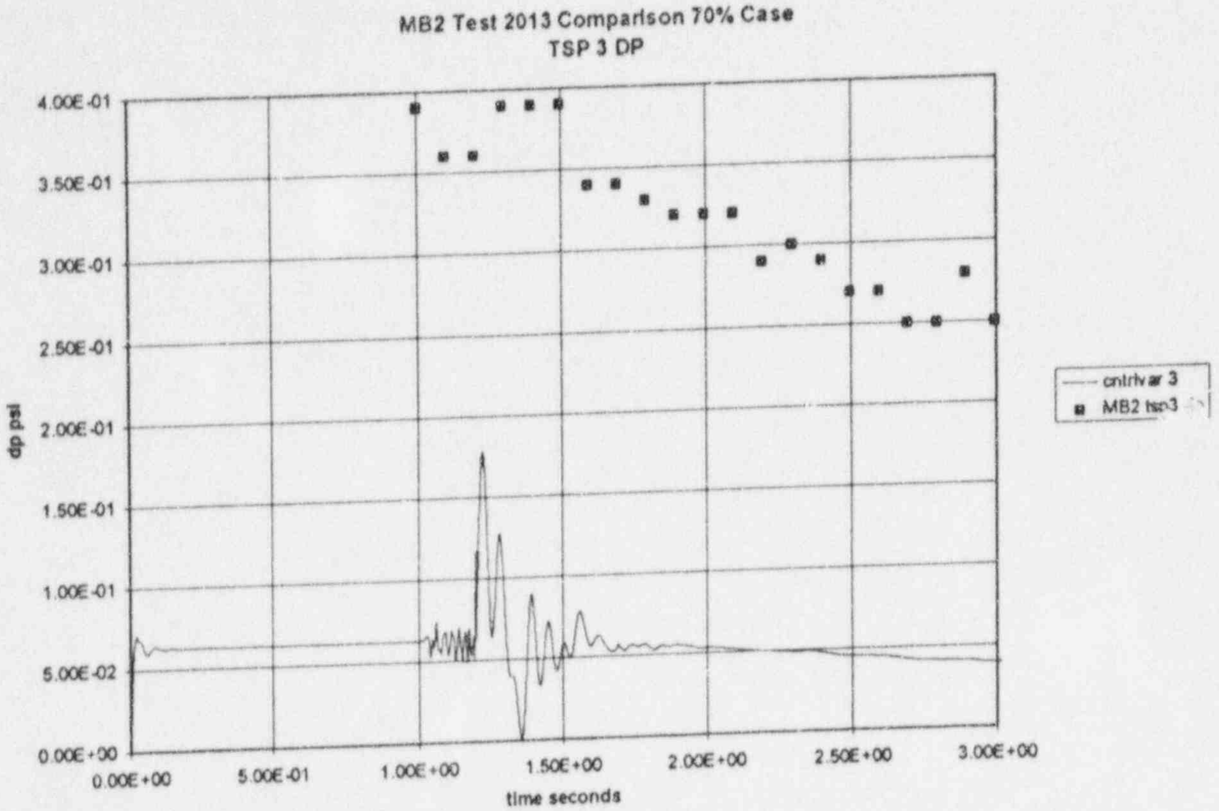


Figure 23 TSP 3 DP 70% Case

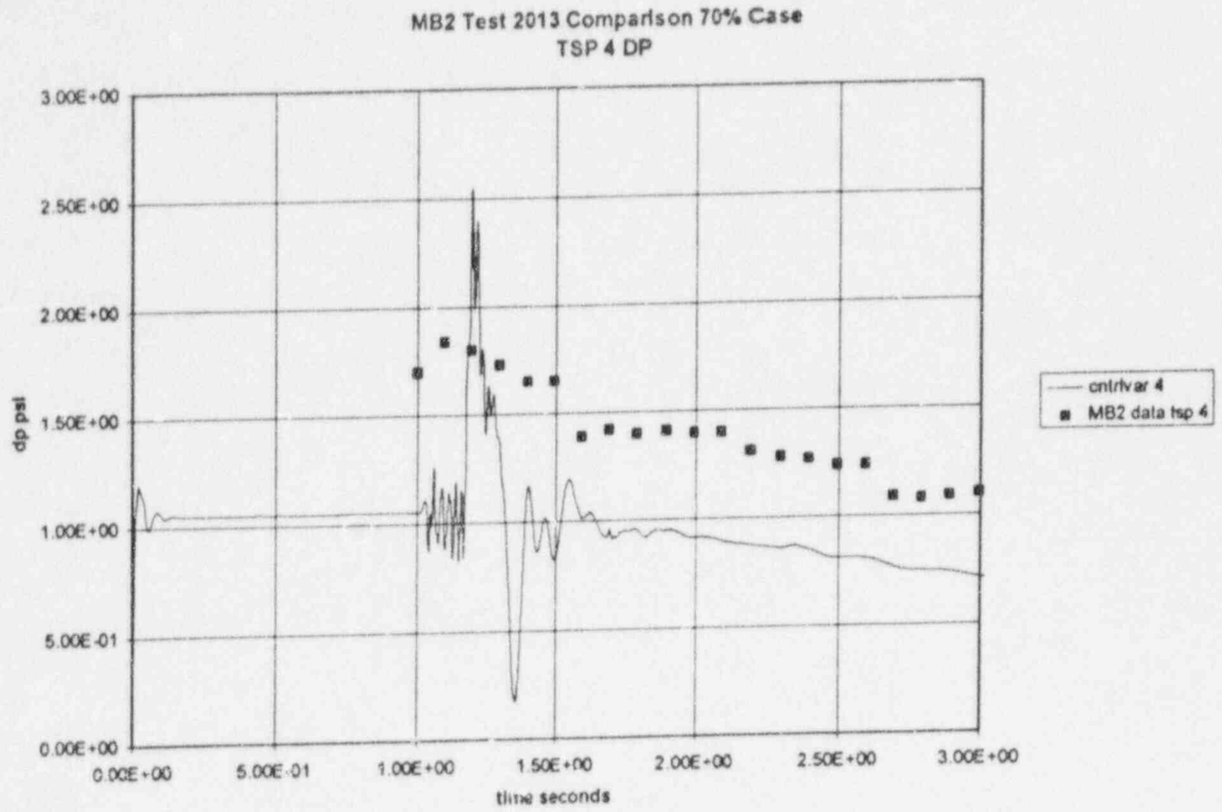


Figure 24 TSP 4 DP 70% Case

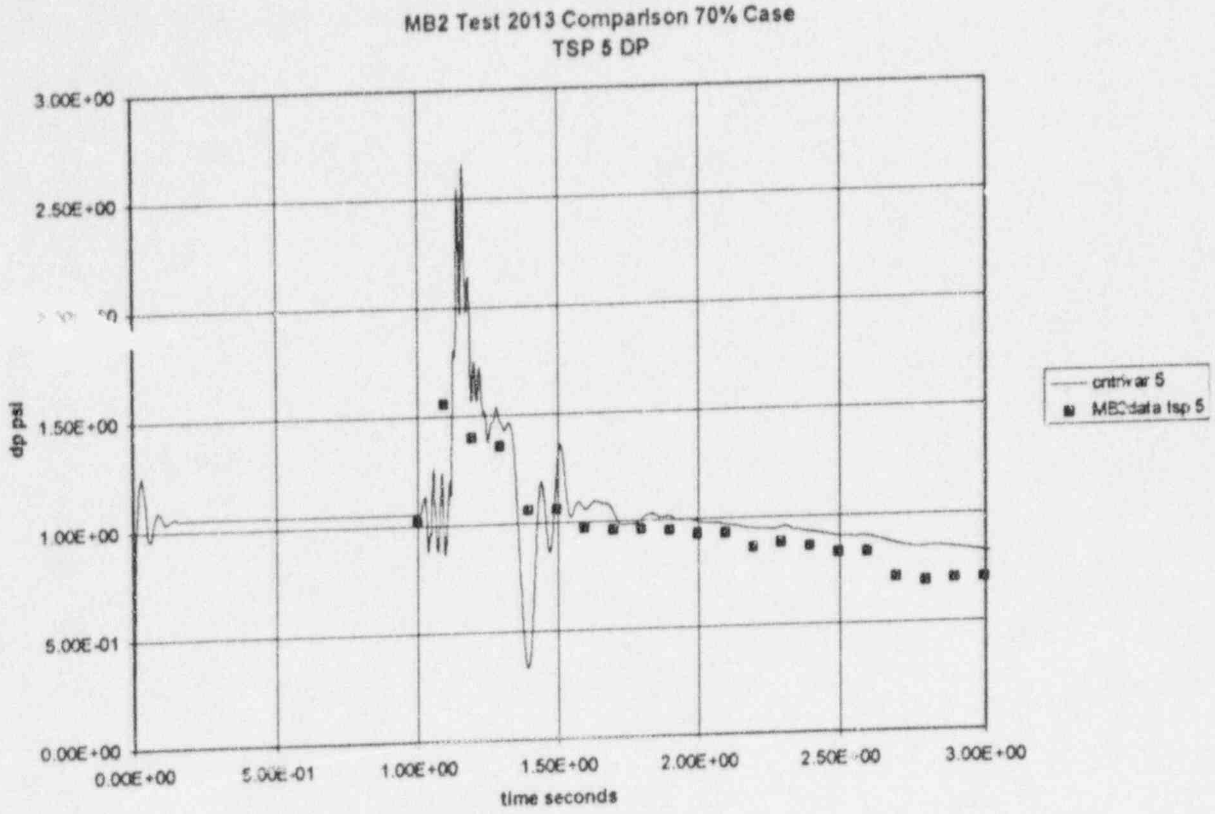


Figure 25 TSP 5 DP 70% Case

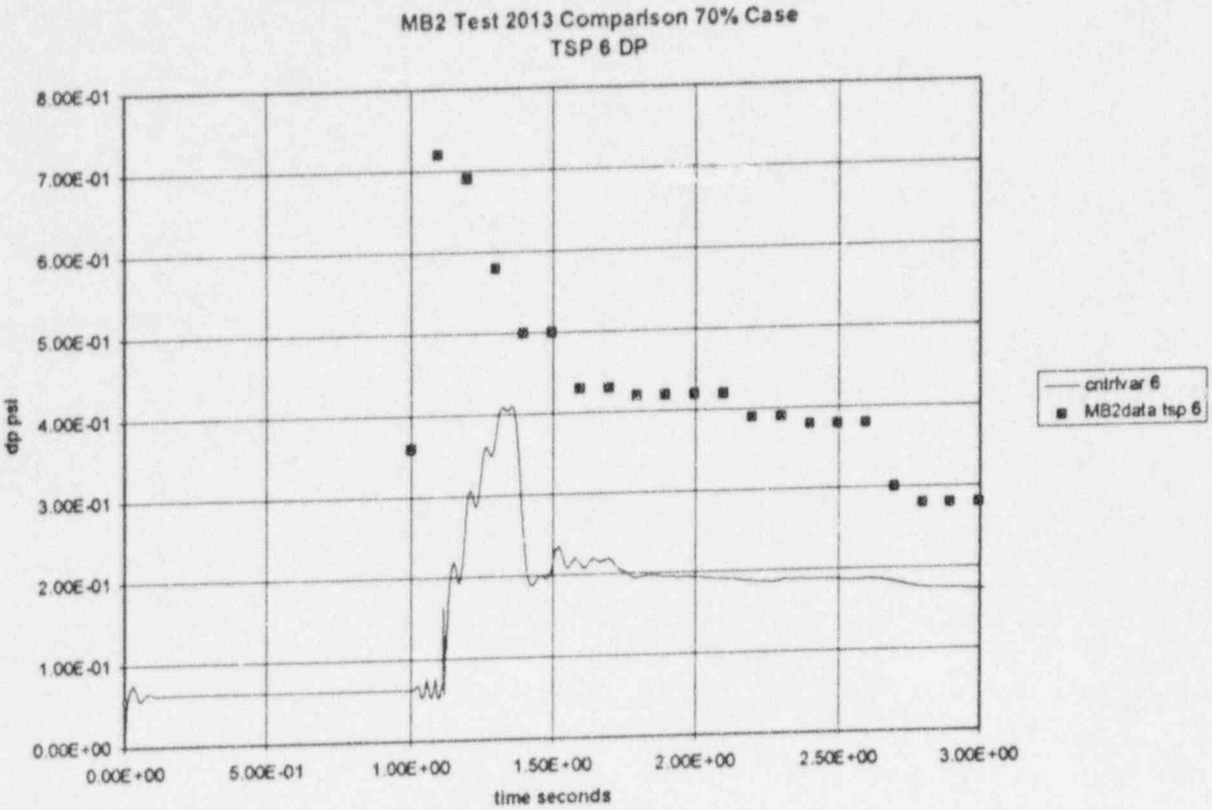


Figure 26 TSP 6 DP 70% Case

6. References

1) NUREG CR-4751

2) NUREG CR-4752

Appendix A - Data Set Index

Dataset	**Description**
Input	
mb2mod	base deck equilibrium case
mb2modne	base case nonequilibrium
output	
mb2mout1	base case
mb2mout2	NE case
mb2mout3	80% nozzle area
mb2mout4	70% nozzle area

Appendix B - Input Data Set Protection Form

Station: Byron/Braidwood **Unit:** 1-2 **Cycle/Analysis:** SG TSP

	Current File Location¹	(Shaded Area for SA Admin. Only) Copy To²	CheckSum #³ sum -r	 sum -p
1.	~~[illegible]~~ nfskb/relap5/mb2mod	bb/tspload/ml.mb2_9518	22064	3501909178 ✓
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: **Reviewer:** **SA Admin:** **Date:** 10/12/95

Appendix C - MB2 Facility Description and Information

Section 2

THE MB-2 TEST FACILITY

2-1. MB-2 BACKGROUND AND HISTORY

With the introduction of a new steam generator model, it is desirable to verify the various current features incorporated in the design. Although these features are generally verified in individual component tests, it may be appropriate to perform an integrated test which considers several design features to confirm that no unexpected synergistic effects exist. The Model Boiler No. 2 (MB-2) -- an approximately 0.8-percent power-scaled representation of the Model F steam generator unit -- is the third in a series of integrated steam generator test models constructed and tested in the last 10 years by Westinghouse at its Engineering Test Facility in Tampa, Florida. The previous two test models were built to investigate the thermal performance of a once-through steam generator, and a preheat design (steam generator Models D4 and E).

Based on the experience gained in the first two tests, it was concluded that the design objective of the MB-2 is to make it as prototypical as possible. Hence, to minimize uncertainties associated with scaling-down, use was made of steam generator tubes of the same material, dimensions, and tube pitch as specified for Model F. Prototypical primary and secondary temperatures, pressures, and mass velocities were also specified so that the performance of the model was directly applicable to the full-size unit, wherever possible. The 7-meter-(23 ft) high tube bundle, together with the primary moisture separator, provided a nearly prototypical driving head for the secondary circulation loop. Using prototypical fluid temperatures, hydraulic resistances in the tube bundle, tube support plates, primary swirl vane separator, and downcomer regions, it was possible to achieve a representative pressure-drop distribution and secondary flow in the circulation loop.

The MB-2 was extensively used for the measurement of Model F steady-state performance and for the qualification of a number of computer codes used in the design and analysis of full-size steam generators. The use of prototypical features, where possible, has reduced the uncertainty in interpreting test results and applying them to the performance of the full-size steam generator.

2-2. MODEL BOILER DESCRIPTION

The Model Boiler No. 2 (MB-2) is an approximately 0.8-percent power-scaled model of the Model F steam generator, a feedring-type unit. It is designed to be geometrically and thermal-hydraulically similar to the Model F in important areas, and is capable of generating a maximum of 10 MWt. At 100-percent power (6.67 MWt) it produces dry, saturated steam at 6.9 MPa (1000 psia), the same as Model F. A schematic rendering of the model, as configured for the LOF and SGTR tests, is shown in figures 2-1a and 2-1b, and the configuration used for the SLB tests is shown in figure 2-2. A typical Model F steam generator is shown in figure 2-3.

Within the model, dry saturated steam is generated by the transfer of heat from high-pressure water at 15.5 MPa (2250 psia) on the primary side to a steam and water mixture on the secondary side. The primary water enters the inlet side of the channel head, flows through the U-tubes, and leaves through the exit side of the channel head.

On the secondary side, feedwater or auxiliary feedwater enters the unit cell surrounding the primary separator, mixes with the recirculating water, flows down the downcomer pipes, and flows through the wrapper box cutout into the bundle just above the tubesheet. Directed by the flow distribution baffle, the flow sweeps across the tubesheet before turning upward through the bundle. As the fluid travels upward, a steam-water mixture is generated. Leaving the top of the tube bundle, the mixture flows through a cone into the riser. At the top end of the riser, the primary separator removes the water by centrifugal action and returns it to the downcomer circuit. The steam, with entrained moisture, then enters the secondary separator where the moisture is removed by a single-tier vane-type separator. The steam is again returned to the downcomer circuit via the disengagement tank (which is used to measure the flow rate of the moisture removed) in the LOF and SGTR tests (figure 2-1a), or via a straight pipe in the SLB tests (figure 2-2). The steam, exiting the vessel through the outlet nozzle, is saturated and essentially dry.

2-2-1. Tube Bundle

The MB-2 tube bundle is composed of 52 tubes arranged in a rectangular array, having 13 tube rows and 4 tube columns, as shown in figure 2-4. All tubes are fabricated from Inconel 600. They have the same outside diameter (1.75 cm or 11/16 in.), and wall thickness (1 mm or 0.040 in.) as the tubes in Model F and are configured in the same 2.49 cm (0.98 in.) square-pitch array. As a result, the primary and secondary unit cell flow areas for the model and the full-size steam generator are identical.

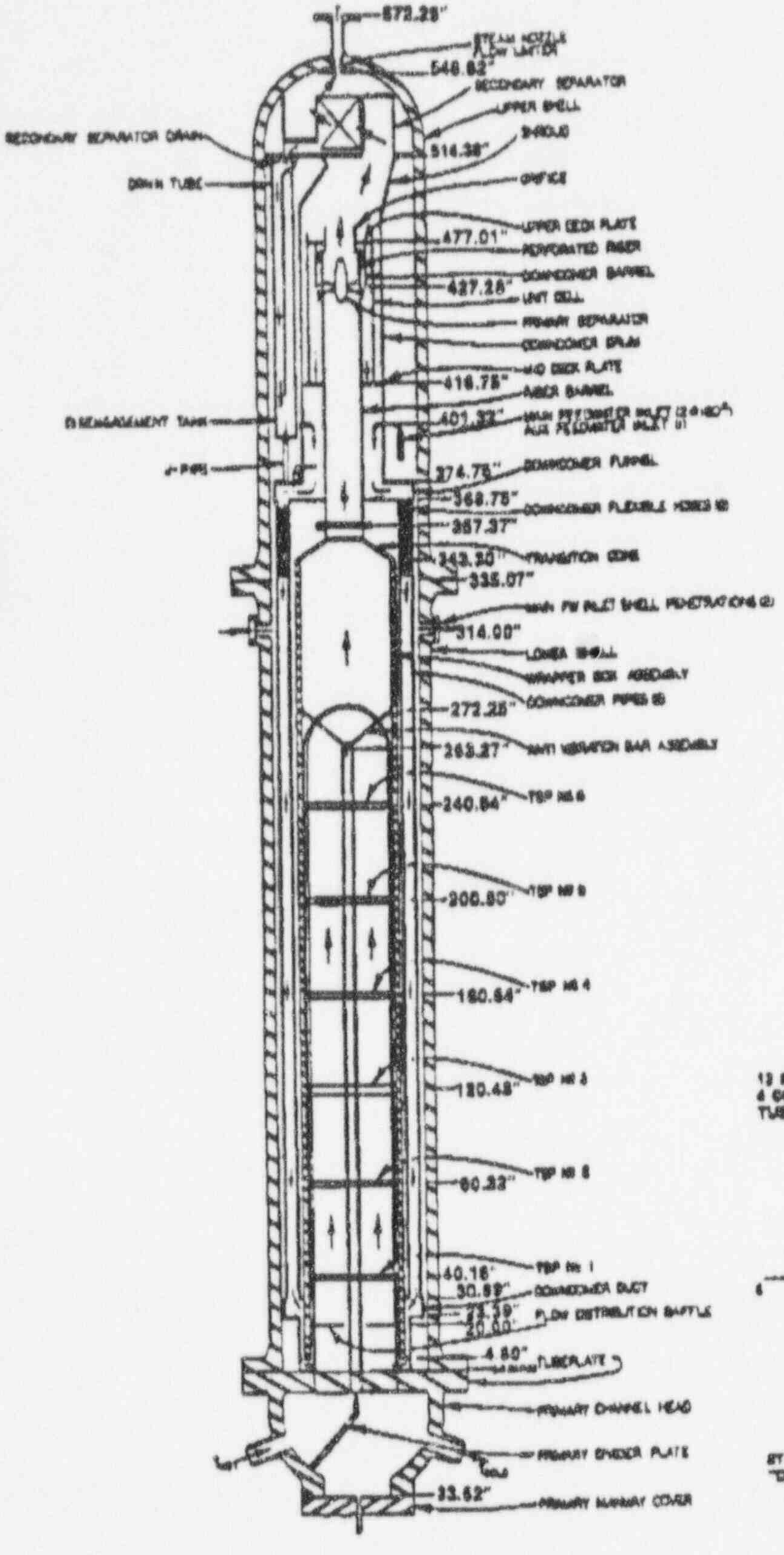


Figure 2-1a. Model Boiler No.2 Configuration for LOF and SGTR Tests

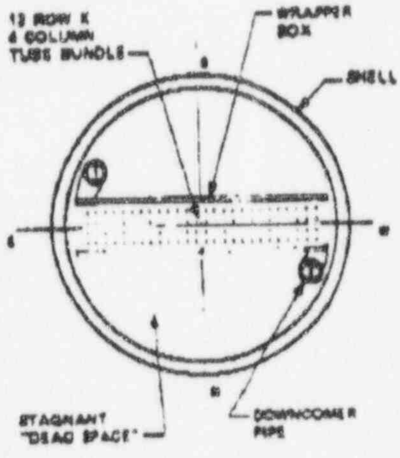


Figure 2-1b MB-2 Cross Section Through Tube Bundle

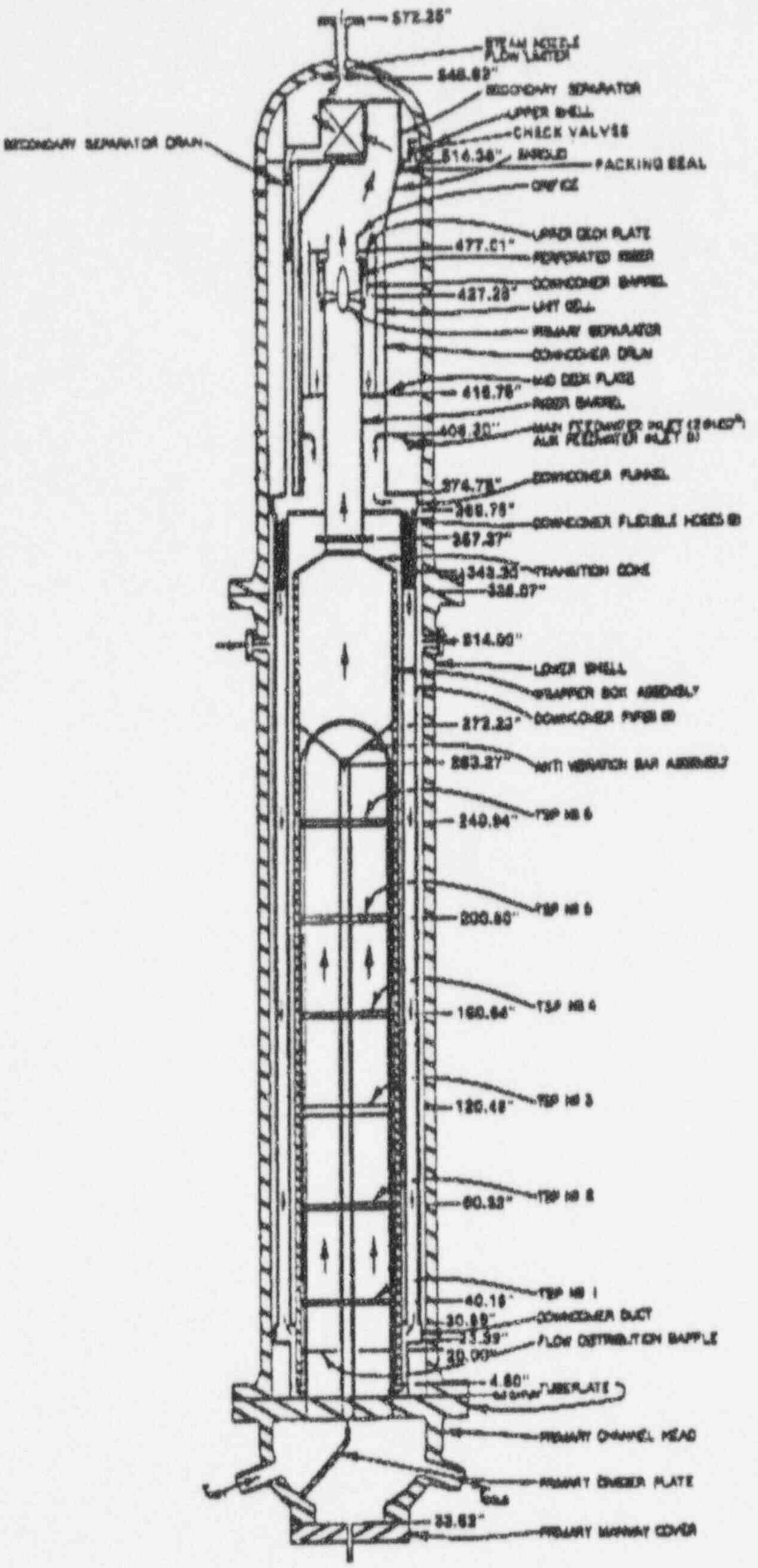


Figure 2-2. Model Boiler No. 2 Configuration for SLB Tests

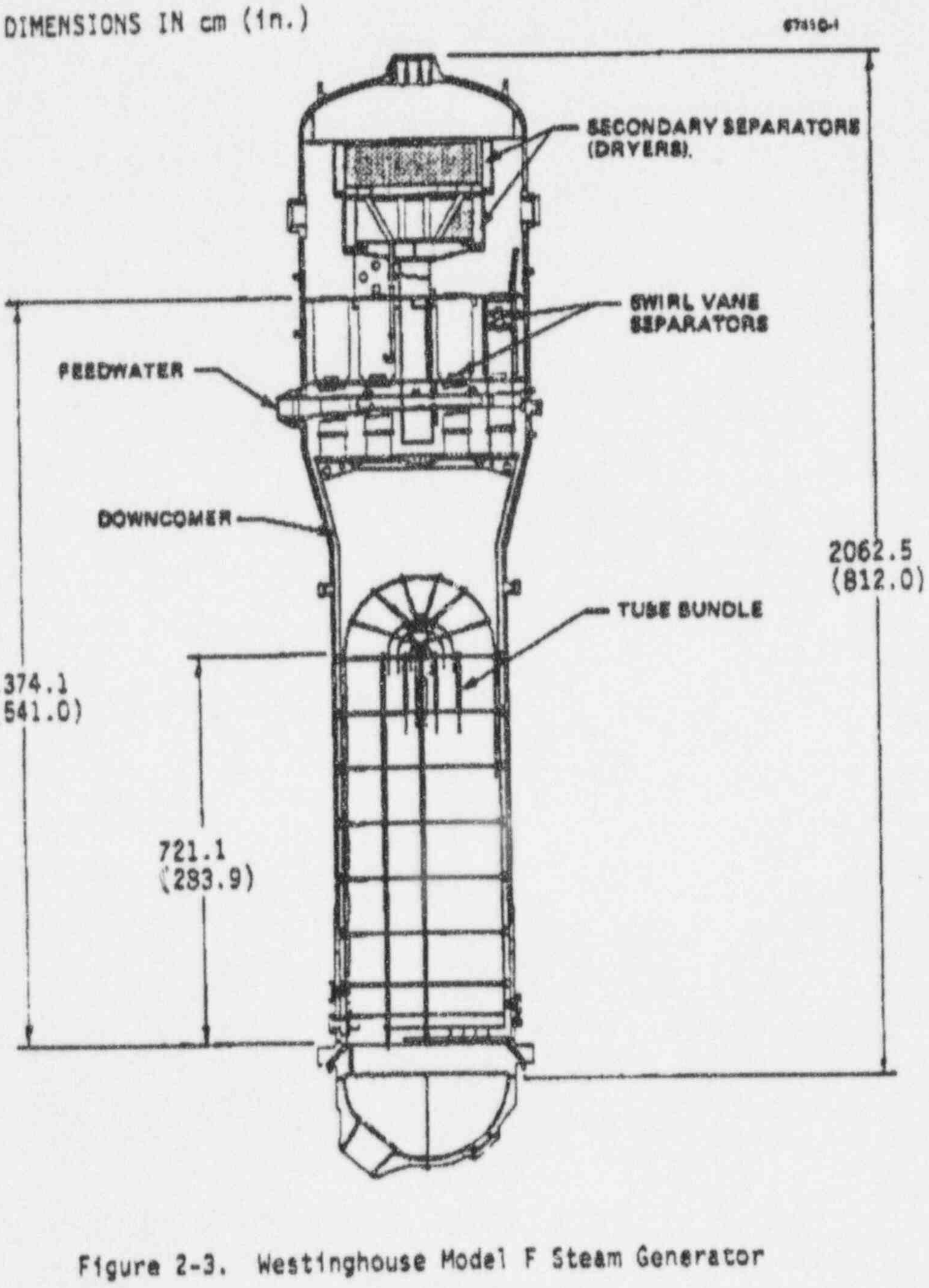


Figure 2-3. Westinghouse Model F Steam Generator

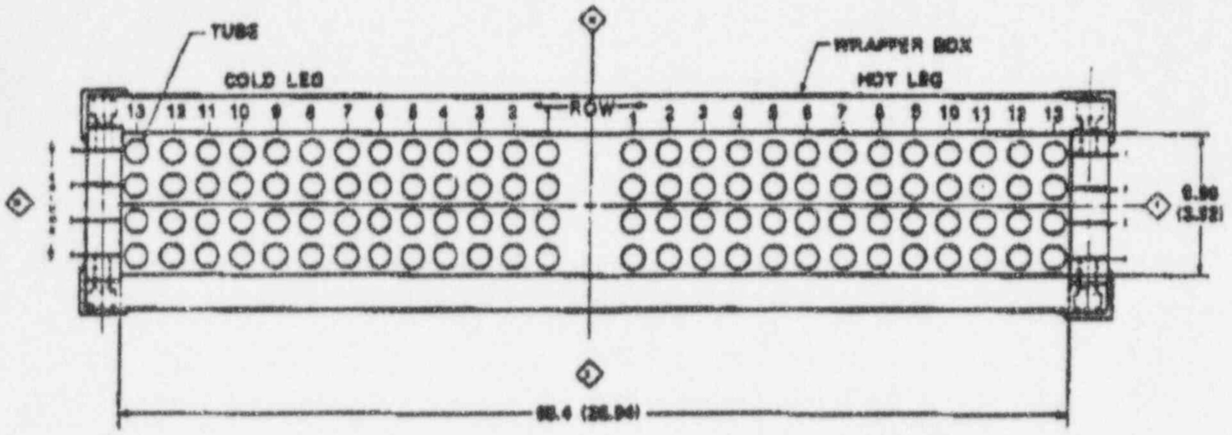


Figure 2-4. MB-2 Cross Section

The straight length of the tube bundle is 6.69 meters (21.94 ft.), which is about 0.5 meter (20 in.) shorter than in Model F. The radii of the U-bends and the length of the tubes are defined in figure 2-5.

There are six tube supports in the MB-2 bundle, compared to seven supports in Model F, and also a flow distribution baffle (see figure 2-1a). The tube support plates utilized in MB-2 provide a full-size simulation of the tube/support plate juncture in a representative environment. The plates, exclusive of the grid at the third support location, have the same thickness and make use of the same quatrefoil broached hole configuration used in the full-size Model F. The support plates in MB-2 are partially composed of alternate broached and drilled hole designs. The axial spacing of the tube supports was selected to be identical to that which exists in Model F, 1.02 m (40.16 in.). The flow distribution baffle is located 0.5 m (20 in.) above the top of the tubesheet, as in Model F. It is partially configured with oversized drilled holes and an alternate "mini-broached" quatrefoil hole design. This baffle also includes a central cutout which simulates the effect of the central cutout in the Model F.

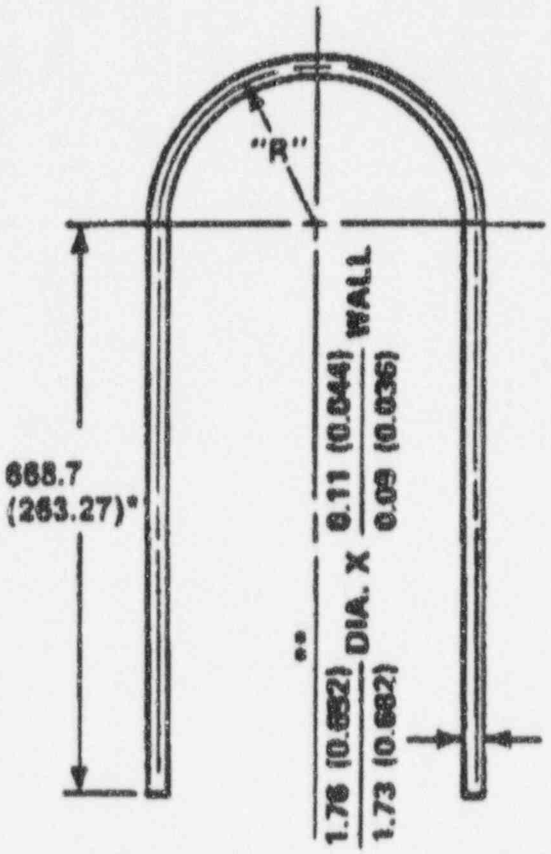
The heat transfer area of the MB-2 tube bundle is 39.75 m^2 (428 ft.^{2}). Utilizing this area, a scaling philosophy was adopted which maintains the same bundle average heat flux as exists in Model F. The power scaling was subsequently used in sizing the flow areas for the downcomers and the primary and secondary separators to provide velocities and mass fluxes comparable to those of Model F. This scaling approach, as it applies to transient testing, is described in more detail in reference (5).

For this test program, the model was completely retubed and reinstrumented. The instrumentation layout and method of attachment is described in section 3.

2-2-2. MB-2 Upper Shell Region

Portions of the internals in the upper shell region were modified for the MB-2 Transient Test Program. Modifications were made to: the primary separator assembly, the deck plate drainage and venting, the downcomer, the secondary separator drain, and the feedwater inlet configuration. The steam shroud, located in the gravity-separation region between the primary and secondary separators, is the same as that used in the previous MB-2/Model F verification tests, along with the single-tier secondary separator.

ROW	"R" cm (in.)
1	3.10 (1.22)
2	5.59 (2.200)
3	8.08 (3.180)
4	10.57 (4.160)
5	13.06 (5.140)
6	15.54 (6.120)
7	18.03 (7.100)
8	20.52 (8.080)
9	23.01 (9.060)
10	25.50 (10.040)
11	27.99 (11.020)
12	30.48 (12.000)
13	32.97 (12.980)



* MEASURED FROM TOP OF TUBESHEET

** MAXIMUM / MINIMUM DRAWING TOLERANCE

Figure 2-5. MB-2 U-Tube Dimensions

Figure 2-6 is a scheme of the revised upper shell region. This region is presented in further detail in figure 2-7. A cross-sectional view at the deckplate is shown in figure 2-8. Detailed descriptions of the modified components are provided in the following sections.

2-2-2-1. Modular Primary Separator. The modular primary separator concept involves the use of a large number of small (17.8 cm or 7 in. diameter) primary swirl vane separator assemblies, rather than a much smaller number of large diameter -- 50.8 cm (20 in.), 129 cm (51 in.) or 142 cm (56 in.) -- separators. Modular separators have been installed and are operating in several Westinghouse nuclear plant steam generators. It should be noted that an array of modular separators is also used in the Combustion Engineering System 80 steam generators.

The decision to install the modular separator in the MB-2, rather than a scaled-down Model F separator, was based on a number of considerations. Some of these were:

- Since there exists such a large variety of primary separator configurations presently in both Westinghouse and other units, no one separator could directly represent more than a small portion of the total steam generator population.
- The modular separator has an advantage because it is prototypical. This alleviates any scaling uncertainties associated with the large-diameter field units and their scaled-down counterparts used in testing, at least for the Model F design.
- The modular separator is more efficient at removing moisture, therefore providing higher-quality steam at the exit from the steam generator. Under transient conditions the separator can be expected to produce higher-quality flow. Since this higher-quality flow leads to increased cooldown of the steam generator secondary, the MB-2 SLB test results should provide data for a relatively severe SLB transient. Hence, the more efficient modular separator should provide data which can be applied directly to design calculations, as well as model verification.

The MB-2 modular separator employs four swirl vane blades oriented at 37° from the horizontal, the same as specified in some existing designs. The hub of the swirl vane is slightly elongated and is more streamlined than earlier units. The major design change, aside from the overall size reduction, is that the riser downstream of the hub is perforated with 0.8 cm (0.31 in.) diameter holes, evenly spaced around the circumference. These holes allow the liquid, which has been forced to the periphery of the riser pipe by the centrifugal motion imparted by the blades, to exit the riser and enter the annulus formed by the riser and the riser barrel. The remaining steam/liquid mixture continues to flow upward into the orifice, which also strips off some portion of the liquid. Figure 2-9 provides a view of the steam

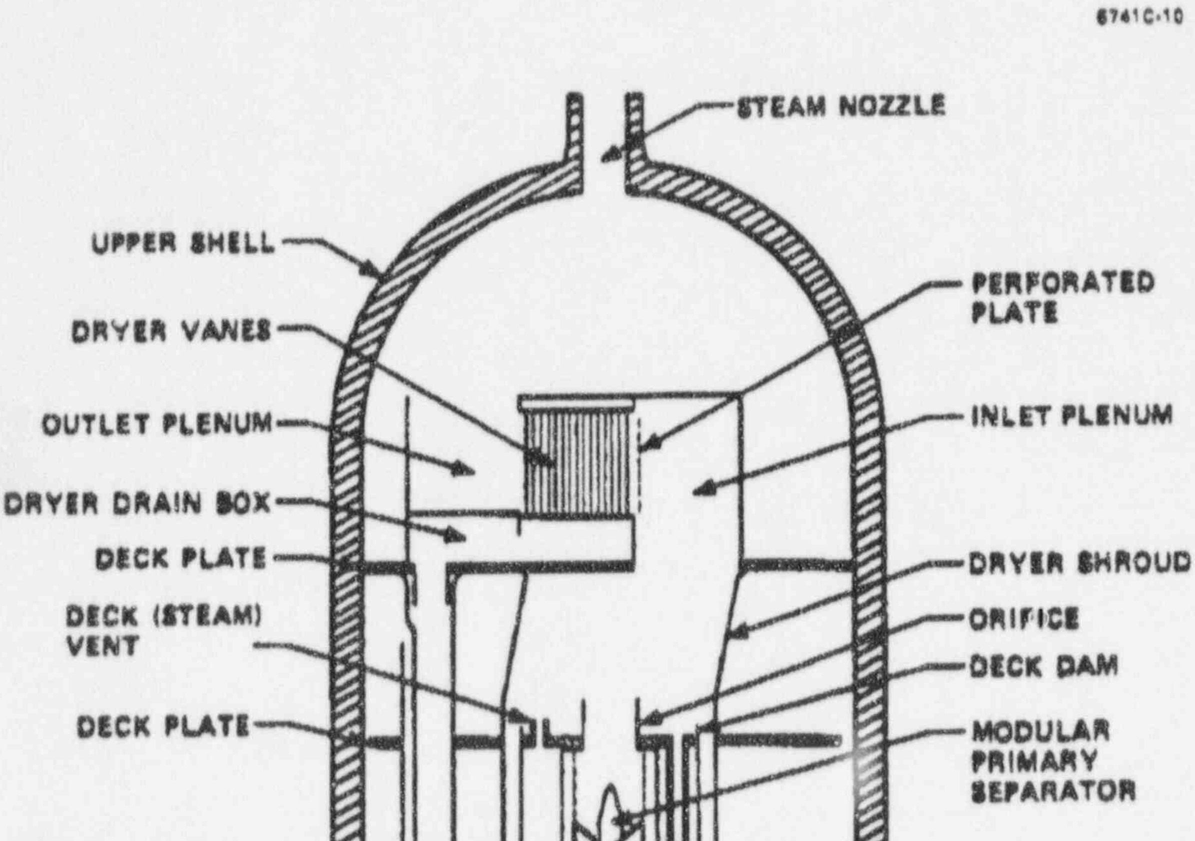


Figure 2-6. Revised MB-2 Upper Shell Region (LOF and SGTR Tests)

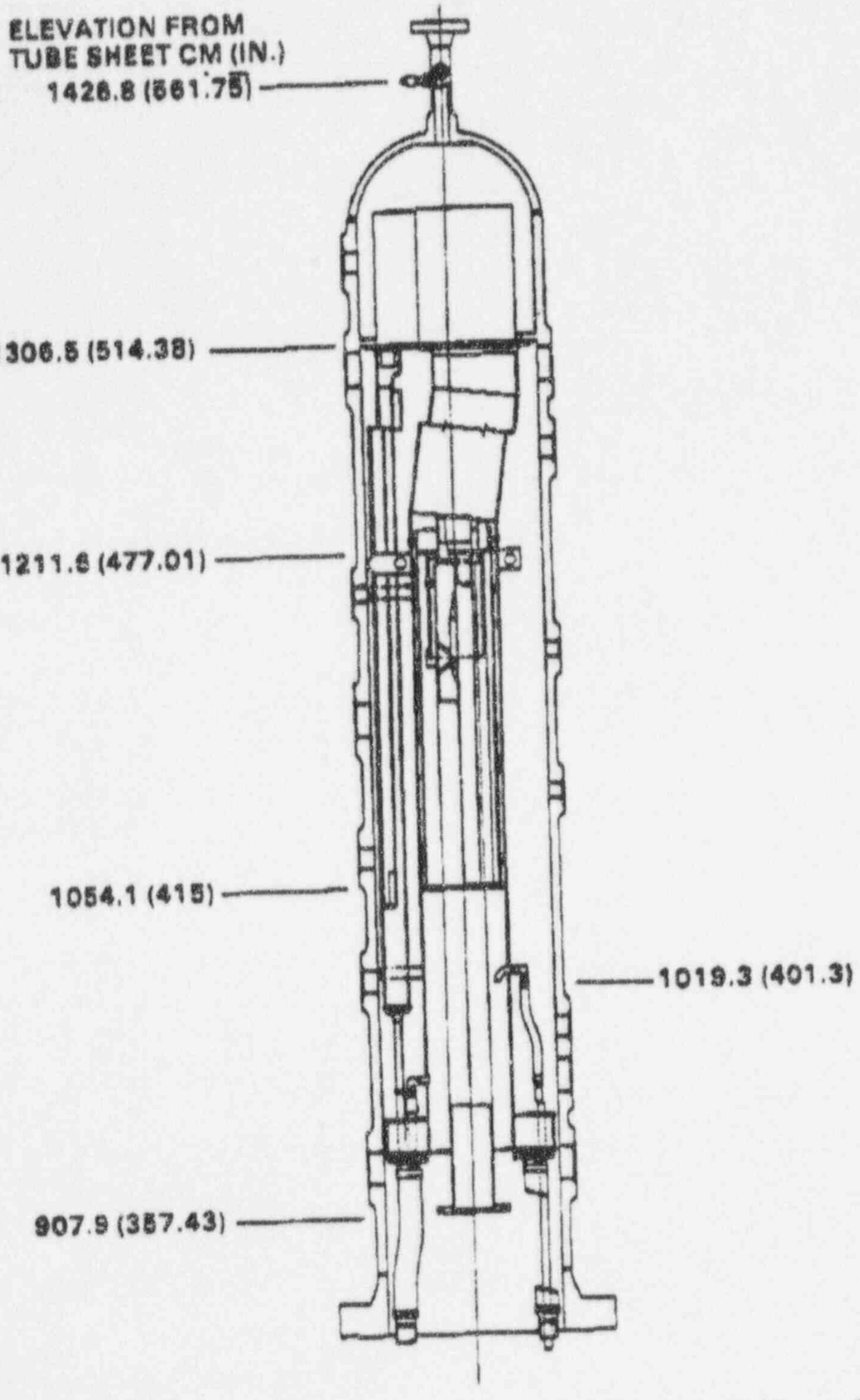


Figure 2-7. MB-2 with Modified Upper Shell and Downcomer (LOF and SGTR Tests)

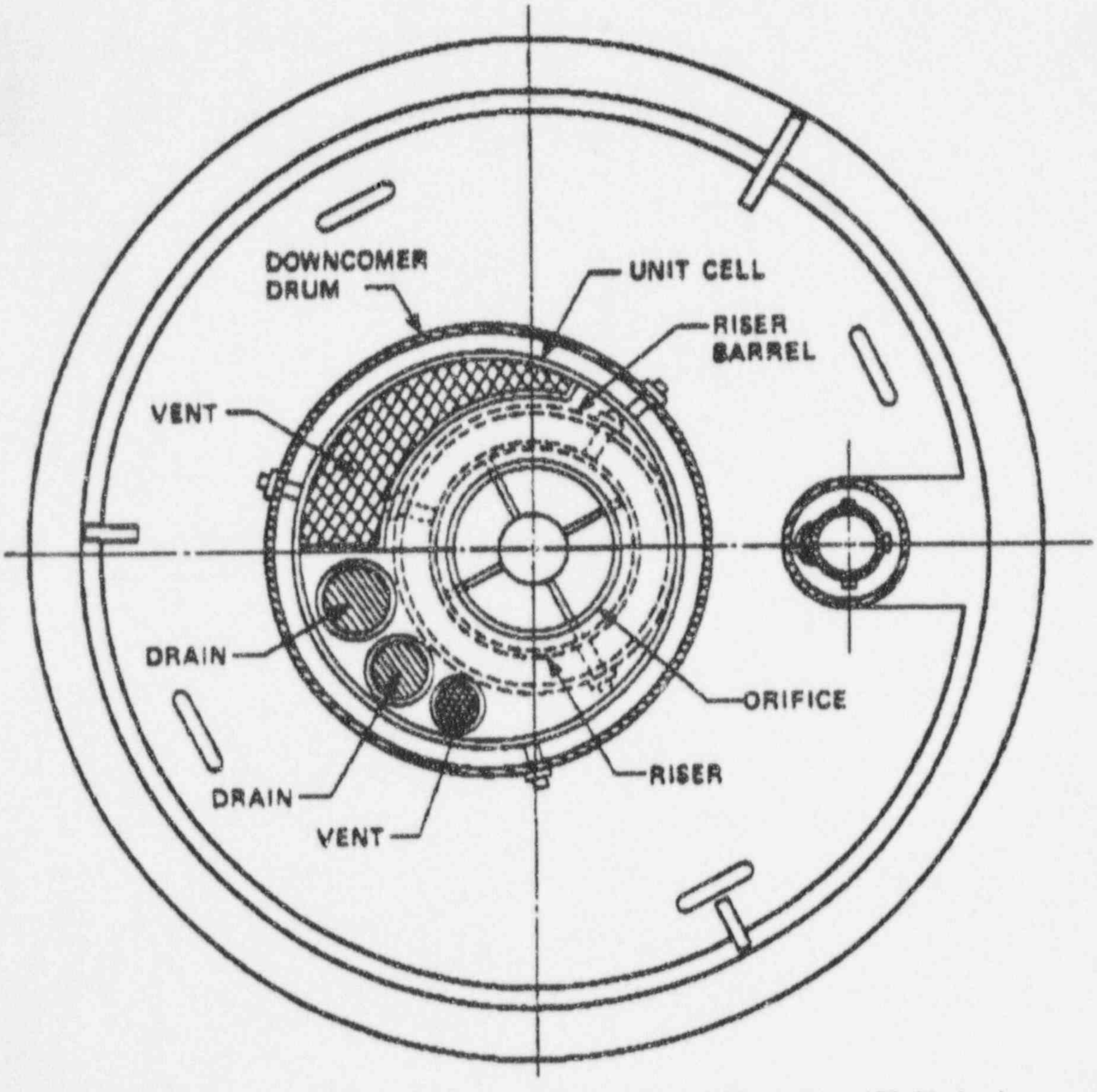


Figure 2-8. MB-2 Cross Section at Deck Plate (Elevation 477.01 in.)

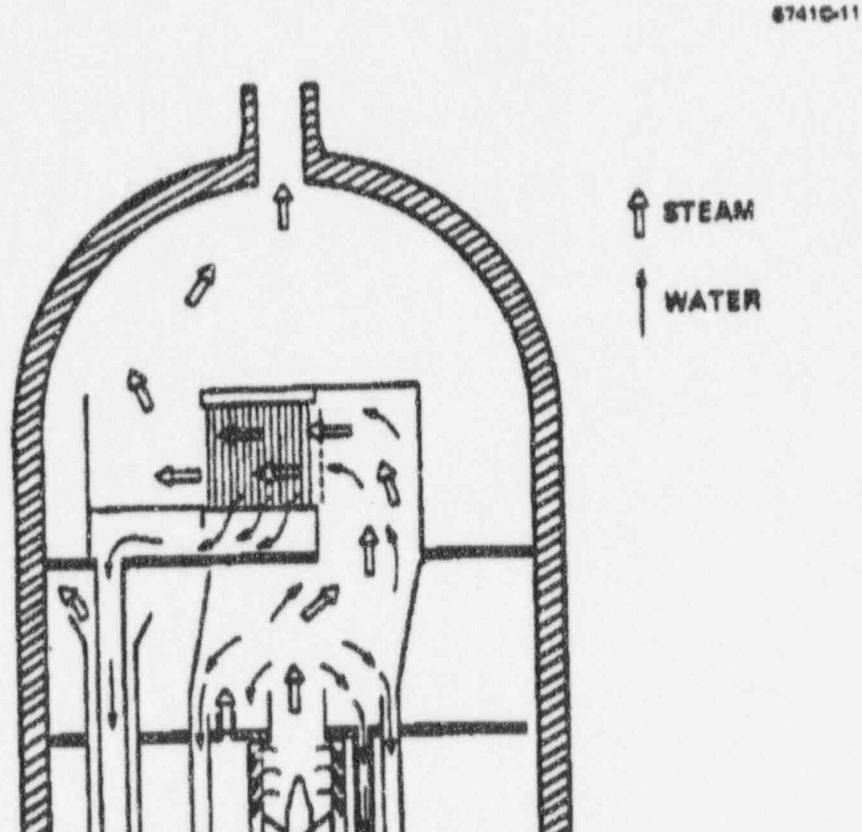


Figure 2-9. Flow Paths in MB-2 Upper Shell Region (LOF and SGTR Tests)

and liquid flow paths in the upper shell region. The riser barrel extends down approximately 48 cm (19 in.) below the deck plate. Both the riser and riser barrel cylinders are concentrically located about the center of the MB-2 shell (figure 2-8).

Outside of the riser barrel, the unit cell cylinder serves to define the local cross-sectional area which is associated with a single modular separator in a full-size steam generator. A unit cell partition is necessary because the cross-sectional area enclosed within the MB-2 shell is much too large for a single modular separator. The unit cell also encloses the appropriate areas for liquid drainage and steam venting through the deck plate. Liquid which collects on the deck plate is removed by drain pipes extending from the deck plate down to the intermediate deck plate. The vent area is represented by a pipe which extends 12.7 cm (5 in.) above the deck plate. The extension is provided to minimize the potential for reentrainment of any liquid which may be present on the deck plate. Additional vent area is also provided within the unit cell to represent a portion of the steam vent area present in the annular space between the deck plate and shell in the full-size steam generator. The edge of the deck plate is ringed with a 10 cm (4 in.) dam that limits the possibility of liquid reentrainment in the steam vented through the deck-plate-to-downcomer-drum gap. The sizing and layout of these various components are discussed in more detail in the following paragraph.

The riser and riser barrel cylinders used in the MB-2 are identical to those of the prototype modular separator, along with the swirl vane, hub, and orifice. The selection of the appropriate cross-sectional areas within the unit cell, downcomer drum, liquid drain and steam vents was based on matching the areas present in a typical modular separator configured in a Model F shell. Figure 2-10 provides a schematic representation of a Model F upper shell region configured with 130 modular separators. The separators are arranged in a 26 cm (10.25 in.) square-pitch array. The specific arrangement of separators is constrained by the available space enclosed by the feedwater distribution ring. Within the array there are 90 interstitial deck drains and 25 deck vents. In addition, there is a larger cylindrical drain in the center of the array. In the annular space between the edge of the deck plate and the shell there is approximately 4.5 m^2 (48 ft.^{2}) of area also available for steam venting. This annular area is more accessible to the modular separators located on the periphery of the array. Separators positioned in the interior of the array would not be influenced by this free space. Hence, a variety of separator situations exist from the outside to the inside of the array. It was decided to assign one-half of this peripheral area (on a per-separator basis) to the region which lies within the unit cell for use in defining an average or typical modular separator configuration for the MB-2. This portion is therefore

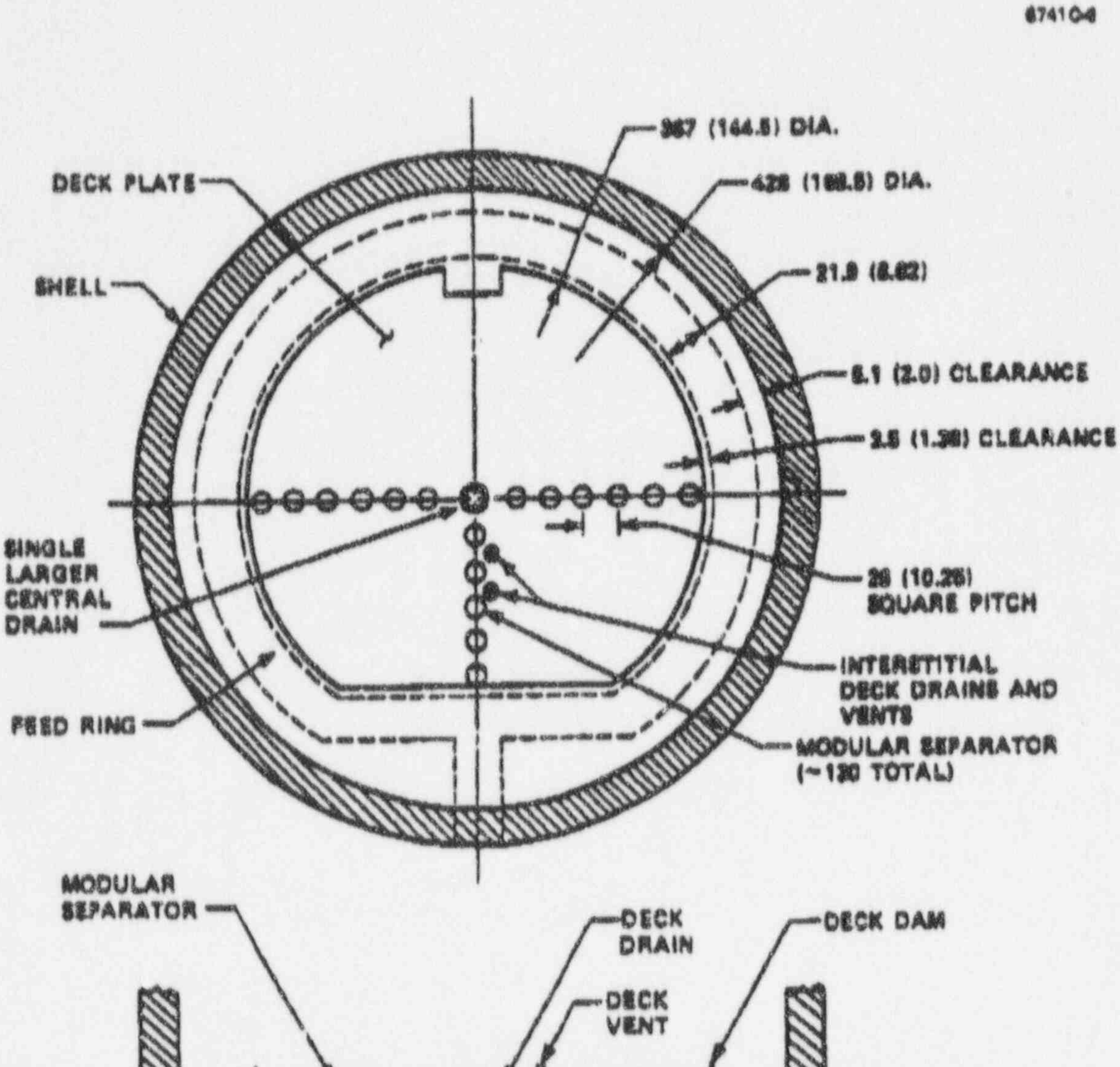


Figure 2-10. Modular Separators Configured in a Model F Shell

more local to the operation of the separator. The remaining one-half of the peripheral area will be contained within the downcomer drum, which, in effect, serves as a new shell for the single modular separator assembly. The calculations in table 2-1 summarize the derivation of the various areas in the Model F primary separator region and the corresponding areas specified for the MB-2.

The small differences between the desired areas and the actual MB-2 areas are primarily due to the use of commercially-available pipes for the various components.

2-2-2-2. Downcomer. As discussed previously, a cylindrical downcomer drum, 38.7 cm (15.25 in.) in diameter, has been used to limit the upper downcomer cross-sectional area to a value which corresponds to the area associated with a single modular separator configured in a Model F steam generator. The revised cross-sectional area enables the model to more closely represent the transient response of the downcomer liquid in the full-size unit. The previous large downcomer "dead space", between the wrapper box and the lower shell, has been eliminated from the downcomer circuit for the same reason. The lower downcomer volume therefore includes only the water contained within the two 7.8 cm (3.07 in.) ID pipes that feed into the hot and cold leg wrapper openings to the bundle. These pipes were scaled to represent the cross-sectional area in the Model F lower downcomer annulus.

A funnel was needed to link the upper cylindrical drum to the lower downcomer pipes (see figure 2-6). The design specified for the funnel is such that the enclosed water volume is minimized, again to better simulate the Model F downcomer response.

Table 2-2 provides a comparison of the downcomer cross-sectional areas and component volumes in the modified MB-2 and Model F. The differences between desired and actual values are a result of use of commercially-available material.

2-2-2-3. Secondary Separator Drain. The original MB-2 configuration included a drain pipe connected to the secondary separator drain box. This pipe was enclosed within a slightly-larger-diameter guide tube. The liquid flowing in the inner drain pipe discharged into a much larger reservoir called the disengagement tank. The pool of water enclosed in this tank permitted any steam bubbles, which may have been entrained in the secondary drain liquid, to vent to the free space above the deck plate. A 2.54 cm (1 in.) diameter J-tube was connected to the bottom outlet from the disengagement tank. The water flowing through this tube was measured using three differential pressure devices (pitot tube, elbow taps, and a venturi tube).

Table 2-1
COMPARISON OF MODEL F AND MB-2 AREAS

MODEL F

Total area within shell = 14.39 m^2 (154.9 ft^2)

Number of modular separators = 130

Shell area for each separator = 0.111 m^2 (1.19 ft^2)

Total annular area between edge of deck plate and shell = 4.47 m^2 (48.1 ft^2)

Portion of total annular area to assign to each separator = 0.34 m^2 (0.37 ft^2)

Number of deck drains (3.5 in. Sch. 40 pipes, 9.89 $in.^2$ inside) = 90

Central drain area = 0.045 m^2 (0.49 ft^2)

Total deck drain area = 0.62 m^2 (6.7 ft^2)

Deck drain area for each separator = 0.0047 m^2 (0.051 ft^2)

Number of deck vents (3.5 in. Sch. 40 pipes, 9.89 $in.^2$ inside) = 25

Total deck vent area = 0.16 m^2 (1.71 ft^2)

Deck vent area for each separator = 0.00123 m^2 (0.0132 ft^2)

[desired Model F value]

MB-2

Downcomer drum: outer diameter = 40 cm (15.75 in.)
inner diameter = 38.7 cm (15.25 in.)

Unit cell: outer diameter = 34.9 cm (13.75 in.)
inner diameter = 33.6 cm (13.25 in.)

Area enclosed within downcomer drum (excluding unit cell piping metal) = 1110 cm^2 (172.1 $in.^2$)
[1106 cm^2 (171.5 $in.^2$)]

Area enclosed within unit cell = 890 cm^2 (137.9 $in.^2$)
[935 cm^2 (144.9 $in.^2$)]

Deck drain area (2 and 2 1/2 in. Sch. 40 pipes) = 52.9 cm^2 (8.2 $in.^2$)
[47.4 cm^2 (7.4 $in.^2$)]

Deck vent area (1 1/2 in. Sch. 40 pipe) = 13.2 cm^2 (2.04 $in.^2$)
[12.26 cm^2 (1.9 $in.^2$)]

Additional vent area included within unit cell to account for 1/2 peripheral vent area assigned to a typical modular separator ~ 176.8 cm^2 (27.4 $in.^2$)
[171.6 cm^2 (26.6 $in.^2$)]

Table 2-2

DOWNCOMER VOLUME/AREA COMPARISON

Component	Modified MB-2 Configuration	Model F
Volumes m^3 (ft^3)		
a. Upper downcomer	0.148 (5.24)	19.47 (687)
b. Secondary separator disengagement pipe, J tube, and extension	0.011 (0.38)	-
c. Downcomer funnel	0.025 (0.89)	-
d. Downcomer dead space	-	-
e. Downcomer pipes and ducts	0.087 (3.09)	12.89 (455)
f. Total	0.272 (9.60)	32.36 (1142)
Volume Ratios		
a. Upper downcomer / Lower downcomer	2.11	1.51
b. Lower downcomer / Secondary bundle	0.29	0.29
c. Total downcomer / Secondary bundle	0.89	0.73
MB-2 Cross-Sectional Areas m^2 (ft^2)		
a. Upper downcomer (typical)	0.086 (0.93)	
b. Lower downcomer pipes	0.009 (0.10)	

Appendix A

TEST MODEL DRAWINGS, DIMENSIONS, FLOW AREAS, VOLUMES, AND SUPPORT PLATE LOSS COEFFICIENTS

Table A-1

MB-2 TEST SECTION GEOMETRIC DATA

Wrapper box inner dimensions, length x width, in.	26.94 x 3.92
Wrapper wall thickness, in.	1.0
Tube outer diameter, in.	0.6875
Tube wall thickness, in.	0.040
Tube pitch, in.	0.98, square
Wrapper opening height, in.	4.60
Wrapper opening area, $in.^2$	18.032
Vertical height of straight portion of tubes from top of tubesheet, in.	263.27
Height of straight portion of wrapper box, in.	343.3
Inner diameter of riser, in.	7.0
Height of riser, in.	127.7
Downcomer inner diameter, in.	3.068
Height of downcomer pipe, in.	337.9
Height of lower downcomer annulus, in.	23.4
Height of downcomer duct, in.	7.5
Inner diameter of outer shell, in.	32.0
Flow distribution plate center cutout areas on each side of centerline, in.	2.69 x 3.92
Flow distribution baffle thickness, in.	0.75
Flow distribution baffle hole diameter, in.	0.760
Elevations of flow distribution baffle and support plates above top of tubesheet, in.:	
Flow distribution baffle	20.0
Support plate 1	40.16
Support plate 2	80.32
Support plate 3	120.48
Support plate 4	160.64
Support plate 5	200.80
Support plate 6	240.96
Flow distribution baffle center cutout, $in.^2$	13.85
Material area of flow distribution baffle, $in.^2$	46.11
Material area of plates 1, 2, 4 and 5, $in.^2$	39.68
Material area of plate 3, $in.^2$	30.48
Material area of plate 6, $in.^2$	40.08

Table A-2

MB-2 FLOW AREAS

Lower downcomer annulus (elev. 0 - 23.39 in.), in.^{2}	5.57
Downcomer ducts (elev. 23.39 - 30.89 in.), in.^{2}	64.72
Downcomer pipes (elev. 30.89 - 368.75 in.), in.^{2}	14.78
Downcomer funnel (elev. 368.75 - 374.75 in.), in.^{2}	237.31
Downcomer barrel (elev. 374.75 - 477.01 in.), in.^{2}	138.48
Dryer drain pipe (SLB tests)	3.56
Between tubesheet & TSP1; between TSPs; between TSP6 and 263.27 in., in.^{2}	67.00
Between top of U-bends and bottom of transition cone (elev. 276.25 - 343.30 in.), in.^{2}	105.60
Riser pipe (elev. 349.30 to 477.01 in., excluding the swirl vane), in.^{2}	38.48
Steam shroud (elev. 477.01 - 513.88 in.), in.^{2}	182.65
Net flow area of plates 1, 2, 4 and 5	27.31
Net flow area of plate 3	36.51
Net flow area of plate 6	26.91
Net flow area of flow distribution baffle	20.88

Table A-3

MB-2 SECONDARY SIDE VOLUMES

Lower downcomer annulus (elev. 0-23.39 in.), ft^3	0.172
Downcomer ducts (elev. 23.39-30.89 in.), ft^3	0.266
Downcomer pipes (elev. 30.89-368.75 in.), ft^3	2.891
Downcomer funnel (elev. 368.75-374.75 in.), ft^3	0.824
Downcomer barrel (elev. 374.75-477.01 in.), ft^3	8.195
Dryer drain pipe (SLB tests; Elev. 374.75-513.88 in.), ft^3	0.287
Tubesheet to TSP1 (elev. 0-40.16 in.), ft^3	1.506
TSP1 to TSP2 (elev. 40.16-80.32 in.), ft^3	1.514
TSP2 to TSP3 (elev. 80.32-120.48 in.), ft^3	1.535
TSP3 to TSP4 (elev. 120.48-160.64 in.), ft^3	1.535
TSP4 to TSP5 (elev. 160.64-200.80 in.), ft^3	1.514
TSP5 to TSP6 (elev. 200.80-240.96 in.), ft^3	1.514
TSP6 to top of U-bends (elev. 240.96-276.25 in.), ft^3	1.387
Top of U-bends to transition cone (elev. 276.25 - 343.30 in.), ft^3	4.098
Transition cone (elev. 343.30 - 349.30 in.), ft^3	0.436
Riser pipe (elev. 349.30 to 477.01 in.), ft^3	2.813
Steam shroud (elev. 477.01 - 513.88 in.), ft^3	3.922
Steam dome (elev. 514.25 - 551.25 in.), ft^3	13.370

Table A-4

FLOW AREA FRACTIONS AND LOSS COEFFICIENTS FOR MB-2 SUPPORT PLATES

Component	Flow Area Fraction (σ)(1)	Loss Coefficient(K)(2)
Flow distribution baffle	0.312	11.0
Support plates 1, 2, 4 and 5	0.408	5.0
Support plate 3	0.545	0.85
Support plate 6	0.402	5.4

---

(1) σ- component flow area/approach flow area

(2) Based on test data from an earlier MB-2 model using the same support plate design. $K = \Delta P\rho/(V^2/2g_c)$, where the velocity (V) is based on the approach flow area.

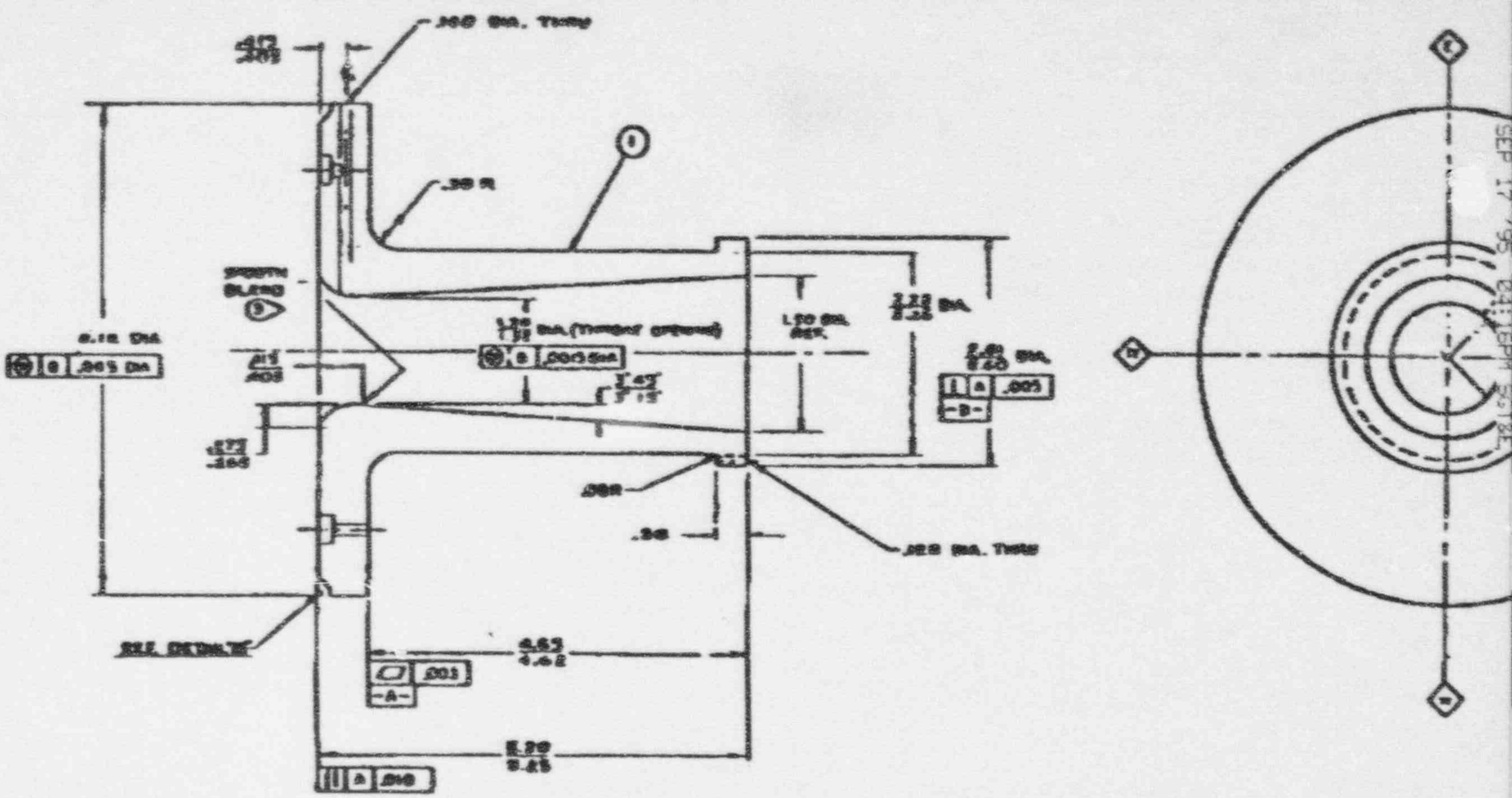


Figure A-2. MB-2 Steam Nozzle Flow Restrictor

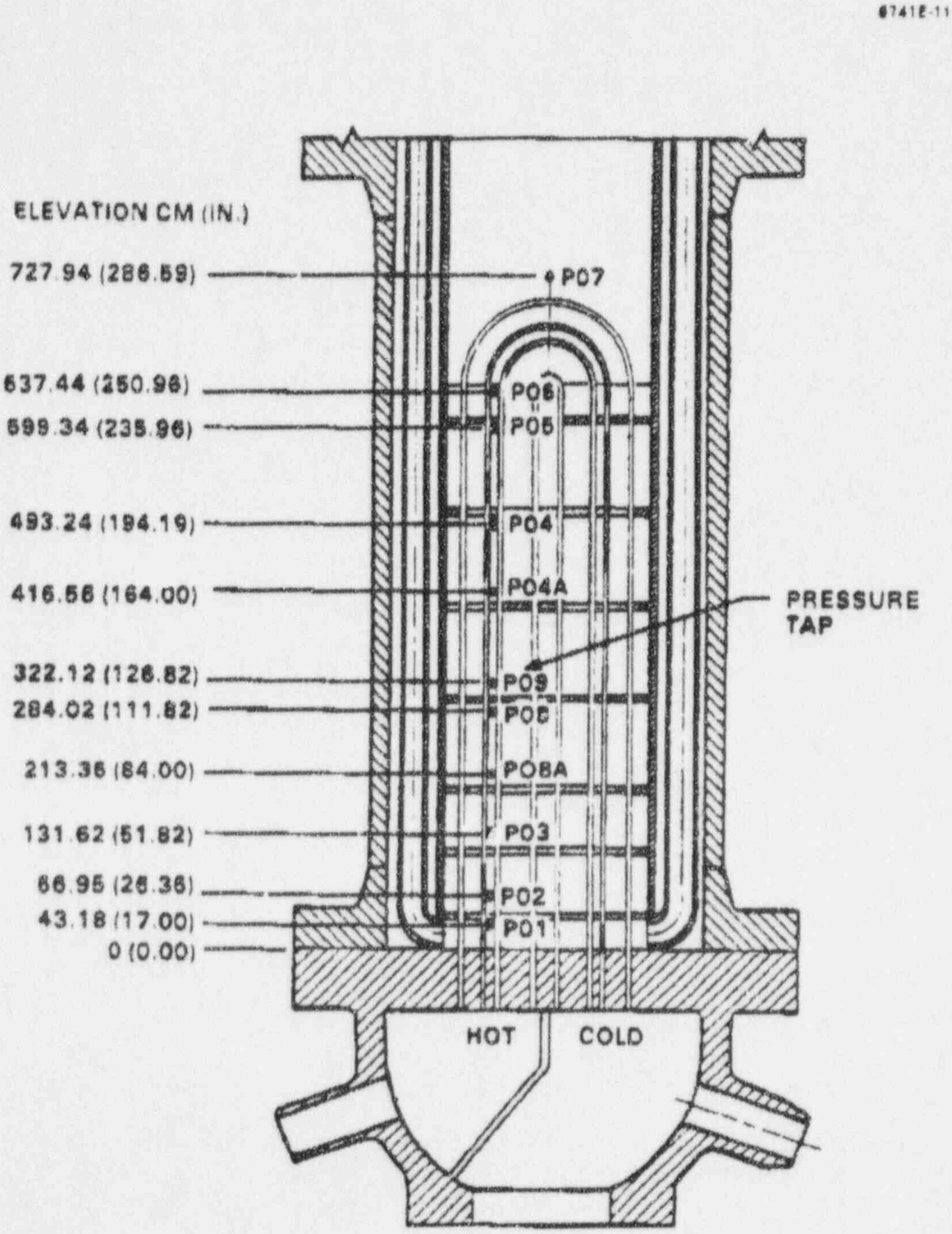


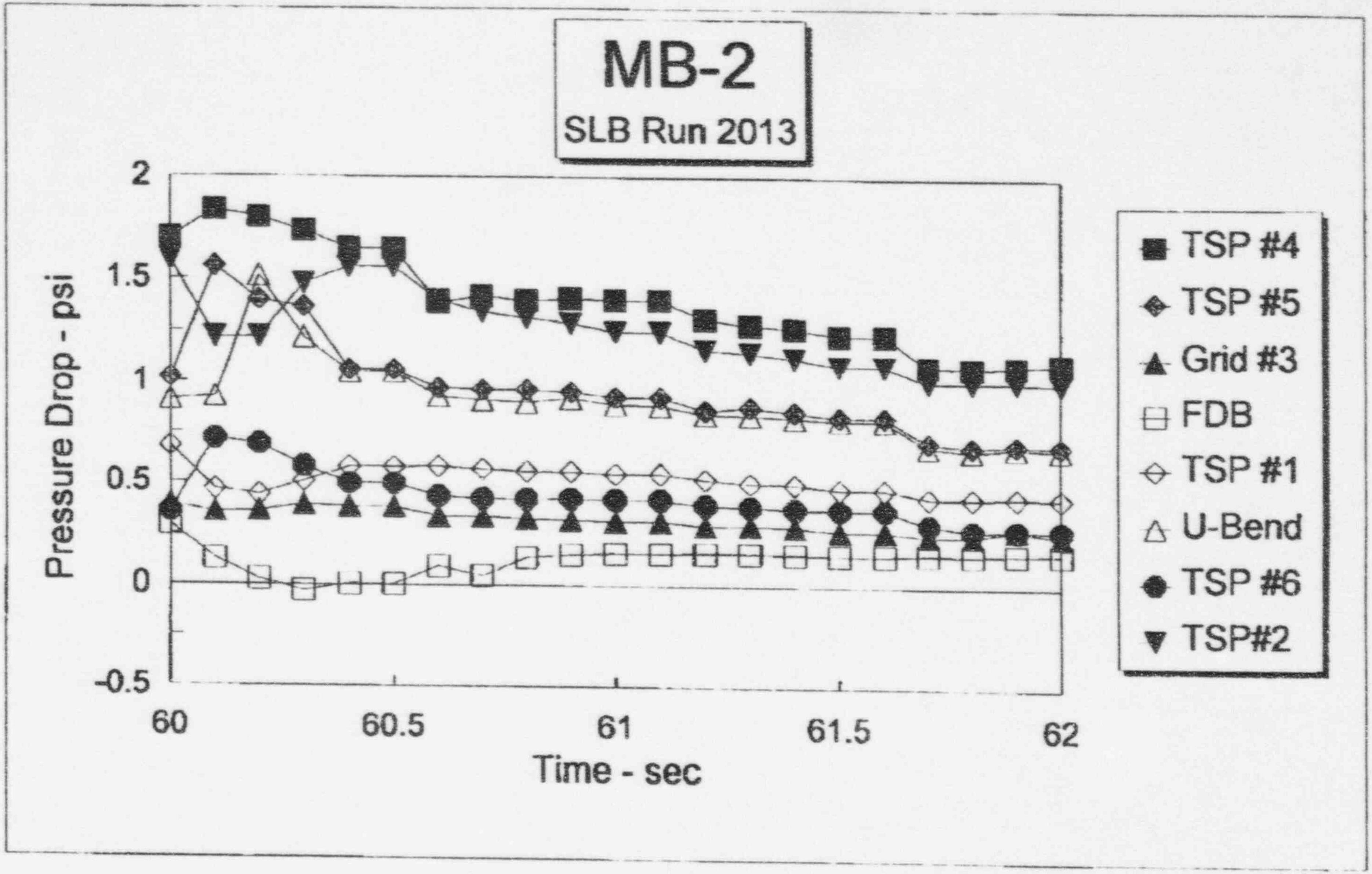
Figure 3-7. Secondary Side Pressure Taps Within Tube Bundle

Table 5-7
BOUNDARY CONDITIONS PRIOR TO SLB

SLB Size (%)	Test Run No.	SG Water Level (in.)	Primary System Pressure (psia)	Primary T_{hot} (°F)	Primary Fluid Flow (lbm/sec)	Secondary Pressure (psia)	Aux. Feedwater Temp. (°F)
100	T-2009	491	2070	560	91	1090	103
100	T-2013	441	2070	560	91	1080	97
100	T-2015	389	2070	560	91	1090	102
100	T-2017	389	2070	560	91	1100	99
100	T-2021	440	2070	561	91	1100	100
100	T-2023	442	2075	560	91	1100	104
50	T-2025	439	2080	562	91	1100	102
8	T-2029	437	1830	581	6.0	988	106
8	T-2031	499	1825	581	6.2	990	100
8	T-2032*	440	1825	581	6.0	1000	102
8	T-2035	440	1825	580	6.0	998	103
8	T-2036*	497	1825	580	6.0	998	103

---

*10-second burst tests


MB-2
SLB Run 2013
Pressure Drop - psi
2
1.5
1
0.5
0
-0.5
60
60.5
61
61.5
62
Time - sec
■ TSP #4
◆ TSP #5
▲ Grid #3
□ FDB
◇ TSP #1
△ U-Bend
● TSP #6
▼ TSP#2

MB-2 SLB Run 2013

Time-sec	Ch. 227 0904 TSP#4	Ch. 240 0405 TSP#5	Ch. 244 0809 Grid#3	Ch. 246 0102 FDB	Ch. 247 0203 TSP#1	Ch. 249 0607 U-Bend	Ch. 255 506 TSP #6	Ch. 260 308 TSP #2
60.0	1.70	1.02	0.39	0.29	0.68	0.91	0.36	1.59
60.1	1.84	1.56	0.36	0.12	0.46	0.92	0.72	1.22
60.2	1.80	1.40	0.36	0.03	0.44	1.52	0.69	1.22
60.3	1.73	1.36	0.39	-0.03	0.51	1.22	0.58	1.48
60.4	1.65	1.06	0.39	0.00	0.58	1.05	0.50	1.56
60.5	1.65	1.06	0.39	0.00	0.58	1.05	0.50	1.56
60.6	1.39	0.97	0.34	0.09	0.58	0.93	0.43	1.40
60.7	1.42	0.86	0.34	0.04	0.57	0.91	0.43	1.34
60.8	1.40	0.96	0.33	0.14	0.56	0.90	0.42	1.32
60.9	1.41	0.95	0.32	0.15	0.56	0.92	0.42	1.29
61.0	1.40	0.93	0.32	0.15	0.55	0.89	0.42	1.25
61.1	1.40	0.93	0.32	0.15	0.55	0.89	0.42	1.25
61.2	1.31	0.86	0.29	0.16	0.52	0.84	0.39	1.17
61.3	1.28	0.88	0.30	0.16	0.50	0.84	0.39	1.15
61.4	1.27	0.86	0.29	0.15	0.50	0.83	0.38	1.13
61.5	1.24	0.83	0.27	0.15	0.47	0.82	0.38	1.09
61.6	1.24	0.83	0.27	0.15	0.47	0.82	0.38	1.09
61.7	1.09	0.71	0.25	0.16	0.43	0.69	0.30	1.01
61.8	1.08	0.69	0.25	0.16	0.43	0.67	0.28	1.01
61.9	1.09	0.70	0.28	0.16	0.44	0.68	0.28	1.01
62.0	1.10	0.69	0.25	0.16	0.43	0.67	0.28	1.00

Appendix D RELAP5M3 MB2 Model Input Listing

```
=mb2 test model mslb at hot standby test 2013
* hot standby nonequilibrium models used/inel guidance used on tsp models
*****************************************************
*this deck is based on mb2 facility descriptions   *
*****************************************************
*                                                   *
*          this data is contained in                *
*          nfskr.relap5(mb2mod)                    *
*****************************************************
*
*
100 new transnt
*
*
102  british   british
105
*
*************************************************
*------- time step cards
*
*     end   dtmin    dtmax  opt min  maj  rstrt
201    1.  1.d-7    0.005  3   2  4000 2500
202   3.0  1.d-7    0.0005    3  2   4000 2500
203  1000.  1.d-7    0.005  3    10   4000 2500
*
*
*************************************************
*--------- minor edit variables
*
*  variable code   parameter   location
301    mflowj       106000000  *breakflow
302    p            105010000  *p81
303    cntrlvar      1           *dp tsp1
304    cntrlvar      2           *dp tsp2
305    cntrlvar      3           *dp tsp3
306    cntrlvar      4           *dp tsp4
307    cntrlvar      5           *dp tsp5
308    cntrlvar      6           *dp tsp6
309    cntrlvar      7           *dp bundle
*305    mflowj         112060000   *dc flow
*306    mflowj       300000000 *break flow
*307    velfj        101060000  *void frac
*308    velfj        101070000  *sg water mass
*
**********************************************
*----------- trip input data
*
*variable trip cards
*   variable  param   relation  variable param   cons  latch
501   time       0        ge        null      0      11.  1
502   time       0        ge        null      0        1.001 l
503   time       0        ge        null      0      100.   l
*=============================================================
*
*-----------------------
```

```
*      trip identifier    Î




Oct 12 14:02 1995  rrunner:/nfs/sa/nfskr/relap5/mb2mod Page 2


*                          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  2070.00  560.000
0420202  1.0e6 2070.00  560.000
*=============================
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  2026.77  560.
0470202  1.0e6 2026.77  560.
*=============================
1510000   tubes   pipe
*
*         nv
1510001   16
*
*            flowa    nv
```

```
1510101     .10467   16
*
*          length    nv
1510301    1.6667    1
1510302    1.68      2
1510303    3.34667   7
1510304    2.785     9
```

```
1510305    3.34667  14
1510306    1.68     15
1510307    1.6667   16
*
*          volume     nv
1510401      0.0      16
*
*        incline angle      nv
1510601      90.0            8
1510602   -90.0             16
*
*          elev cng        nv
*510701      1.6667         1
*510702      1.68           2
*510703    3.3467           7
*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    .050625    16
*
*          pvbfe    nv
1511001    00000    16
*
*         fvcahs nj
1511101   001000  15
*
*         flag    p        t       dummy dummy  dummy nv
1511201    3   2070.0   560.0    0.0    0.      0.   16
*
*          flag=1 => (lbm/sec)
1511300    1
*
*          lflow        vflow  interface flow        nj
1511301       91.00      0.0          0.0             15
*=======================================================
1500000    junct  tmdpjun
*
```

```
*        from        to        area
1500101 042000000 151000000     .10467
*
*        flag
1500200   1
*
*         time    lflow        vflow    intflow
1500201   0.0      91.0         0.0     0.0
1500202   1.0e6    91.0         0.0     0.0
*=======================================================
1590000   junct  sngljun
*
*        from        to        area       fjunf    fjunr    fvcahs
```

```
1590101 151010000 047000000  .10467       0.0      0.0       021000
*
*        flag      lflow     vflow     intflow
1590201   1          91.0     0.0        0.0
*=======================================================
*
*
*
*
*-----------------------------------------------
*  secondary side model
*-----------------------------------------------
*
*=======================================================
9020000  auxfeed  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   97.0
9020202  1.0e6  1200.0   97.0
*=======================================================
3020000   fljun   tmdpjun
*
*          from        to       ajun
3020101 902000000  111000000  1.0
*
*         flag
3020200   1
*
*         time  lflow    vflow    int flow
3020201   0.0      0.      0.0      0.0
```

```
3020202   1.0      0.      0.0       0.0
3020203   1.01   0.25      0.0       0.0
3020204  11.01   0.34      0.0       0.0
3020205  11.01   0.0       0.0       0.0
3020206  1.0e6     0.      0.0       0.0
*=====================================================
1000000   tubesht branch
*
*         nj     flag
1000001   2       1
*
*         flowa   flowl     vol    azi incl    dz      rough  hyd     pvbfe
1000101  0.4653  1.6667  0.0      0.0  90. 1.6667 .00015   .09093  00101
*
*         flag    p       x
1000200    1    560.0   0.00
*
*          from        to        ajun    fjun  fjunr   fvcahs
1001101 112010000  100000000  0.03868  1.0    1.0     000000
```

```
1001101 112010000  100000000  0.03868  4.12  4.12    000000
1002101 100010000  101000000  0.4653  11.0  11.0     010000
*
*         lflow      vflow  int flow
1001201     0.0       0.0      0.0
1002201     0.0       0.0      0.0
*ccfl/junction hyd diam info
*           hyddia    floodcorr  gasint   slope   nj
1001110       .09093     0.          1.        1.
*use hyd of 112 for junc 1 since reverse flow dominates
*1001110       .3442      0.          1.        1.
1002110       .09093     0.          1.        1.
*
*=============================
1010000   boiler  pipe
*
*         nv
1010001   22
*
*         flowa     nv
1010101   .4653     19
1010102   .7333     21
1010103   .2672     22
*
*         jarea     nj
1010201   .4653  18
1010202   .7333  20
1010203   .2672  21
*
*         length    nv
1010301    1.68     1
```

```
1010302     3.3467  6
1010303     2.9408  7
1010304     5.5875  8
1010305     0.5     9
1010306     1.6205    10
1010301     1.48    1
1010302     0.2     3
1010303     [illegible]9467  4
1010304     [illegible].2     6
1010305     2.9467  7
1010306     0.2     9
1010307     2.9467  10
1010308     0.2     12
1010309     2.9467  13
1010310     0.2     15
1010311     2.9467  16
1010312     0.2     18
1010313     2.7408  19
1010314     5.5875  20
1010315     0.5     21
1010316     1.6205    22
*
*          volume     nv
1010401      0.0      22
*
```

```
*        incline angle     nv
1010601     90.0           22
*
*         elev cng        nv
*010701     3.0           2
*010702     3.5833        3
*
*          rough  hyd dia   nv
1010801   .00015 0.09093    19
1010802   .00015 0.0        22
*
*          fjunf      fjunr     nj
1010901      5.0        5.0      2
1010902      0.85       0.85     3
1010903      5.0        5.0      5
1010904      5.4      5.4        6
1010905      7.23       7.23       7  *add xflow resist here
1010905      61.45       61.45       7  *add xflow resist here with w mult
1010906      0.0      0.0        9
1010901      0.0        0.0      1
1010902      5.0        5.0      2
1010903      0.0        0.0      4
1010904      5.0        5.0      5
1010905      0.0        0.0      7
1010906      0.85       0.85     8
```

```
1010907      0.0         0.0     10
1010908      5.0         5.0     11
1010909      0.0         0.0     13
1010910      5.0         5.0     14
1010911      0.0         0.0     16
1010912      5.4        5.4      17
1010913      0.0         0.0     18
1010914      61.45        61.45      19  *add xflow resist here with w mult
1010915      0.0         0.0     21
*
*         pvbfe    nv
1011001   00101     19
1011002   00001     22
*
*        fvcahs nj
1011101  000000 21
*
*        flag   p        x       dummy  dummy    dummy nv
1011201   1   560.00   .0        0.     0.        0.   1
1011202   1   560.00   .0        0.     0.        0.   2
1011203   1   560.00   .0        0.     0.        0.   22
*
*         flag=0 => (lbm/sec)
1011300   1
*
*         lflow        vflow  interface flow        nj
1011301   0.0           0.0           0.0           21
*
*ccfl/junction hyd diam info
*            hyddia    floodcorr  gasint   slope   nj
1011401       .09093    0.         1.        1.     18
```

```
1011402      0.0          0.         1.         1.     21
*=====================================================
*=====================================================
1020000    sep      separatr
*
*        nj   flag
1020001   3     1
*
*        flowa   flowl   vol       azi incl   dz    rough    hyd    pvbfe
1020101  .2672  9.0220   0.0      0.0 90.  9.0220  .00015 0.000  00010
*
*       flag    p     uf           ug           vg
 1020200    1  560.00  0.
 1020200    1  560.00  0.025  * initialize to 441 in level
*
*           from        to        ajun   fjun     fjunr  fvcahs  vflim
* rearrange losses
1021101 102010000  103000000 .2672   0.86      0.86    000000
1022101 102000000  111010000 .1854   1.0       1.0     000000
```

```
1023101 101010000  102000000 .2672   1.0      1.0    000000
1023101 101010000  102000000 .2672   19.1   19.1   000000
*
*         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   unit    branch
*
*        nj   flag
1030001   2    1
*
*        flowa   flowl    vol       azi incl    dz     rough    hyd   pvbfe
1030101  1.2684  1.        0.0      0.0 90.     1.     .00015 0.0    00000
*
*       flag     p     uf           ug            vg
1030200    1  560.00 0.0
1030200    1  560.00 1.0  * initialize to 441 inch level
*
*          from        to        ajun   fjun    fjunr  fvcahs  vflim
1031101 103000000  110010000  .204    0.0     0.0    010000
1032101 103010000  104000000 1.2684  0.      0.     010000
*
*         lflow    vflow      int flow
1031201     0.0      0.0         0.0
1032201     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   unit   snglvol
*
```

```
*         flowa     flowl      vol    azi incl    dz      rough   hyd     pvbfe
1040101   1.2684     1.0    0.0      0.0  90.    1.0      0.00015 0.00 00000
*
*         flag      p        x
1040200   001     560.    1.0
*==================================================
2500000   dryerdrn  snglvol
*
*         flowa    flowl       vol   azi incl    dz      rough   hyd     pvbfe
2500101   .02472  10.522      0.0  0.0 -90.   -10.522    0.00015  0.0  00000
*
*         flag      p         x
2500200   001     560.        .5
```

```
2500200   001    560.      .045 *initialize at 441 in
************
1240000  dryer    branch
*
*        nj   flag
1240001   3     1
*
*        flowa    flowl    vol       azi incl    dz     rough    hyd    pvbfe
1240101  1.2684  1.0725    0.0      0.0 90.  1.0725  .00015 0.000   00000
*
*       flag    p     uf            ug             vg
1240200    1  560.00 1.0
*
*          from         to         ajun    fjun     fjunr  fvcahs  vflim
1241101 104010000  124000000 1.2864    .0       .0     030000
1242101 124010000  105000000 1.2864    0.       0.     030000
1243101 250000000  124000000  .02472  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   4.2933   2
*
*         jarea    nj
1050201   4.2933   1
*
*
*         length   nv
1050301    0.      2
*
```

```
*         volume    nv
1050401   6.685     2
*
*       incline angle    nv
1050601    90.0          2
*
*
```

```
*         rough  hyd dia  nv
1050801 .00015   0.0      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   560.00  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  0.0092175 0.0     0.0  000100
*1060101 105010000 107000000  0.007374 0.0     0.0  000100  *80% area case at noz
*1060101 105010000 107000000  0.00645225 0.0     0.0  000100  *70% area case at n
*
*        flag   lflow     vflow     int flow
1060201   1       0.0       0.0        0.0
*******
1070000   nozzle snglvol
*
*         flowa    flowl     vol   azi incl   dz     rough  hyd    pvbfe
1070101   0.014    1.5       0.0   0.0  90.   1.5   .00015 0.0     00000
*
*         flag     p        x
1070200   002   1106.     1.0
1070200   001    560.     1.0
*====================================================
3000000   break   valve
```

```
*
```

```
*        from       to       ajun
3000101 107010000  900000000  0.014   0.0  0.0  00100
*
*
*        time  lflow    vflow    intflow
3000201  1  0.0   0.0     0.0
3000300 mtrvlv
3000301  502  503  10. 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  funnel  branch
*
*        nj  flag
1110001   3    1
*
*        flowa    flowl    vol   azi incl   dz  rough     hyd     pvbfe
1110101  1.648       .50    0.0   0.0 -90. -0.50   0.00015 0.0    00000
*
*        flag     p       x
 1110200     1    560.0  0.0
*
*        from        to         ajun     fjun    fjunr    fvcahs
1111101  111010000 112000000  .10264    0.5     1.0     000000
1112101  111000000 110000000  .96167    0.0     0.0     000000
1113101  250010000 111000000  .02472    1.0     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   .96167   8.522     0.0   0.0  90.   8.522   0.0  0.0      00000
```

```
 *
 *         flag     p        x
 1100200   001    560.      0.033
*=====================================================
1120000   ldc1-3  pipe
*
*         nv
1120001   12
*
*         flowa     nv
1120101   0.10264  10
1120102   0.44944  11
1120103   0.0368   12
*
*         length      nv
1120301    2.81548    10
1120302    .625       11
1120303    1.9492     12
*
*         volume     nv
1120401     0.0      12
*
*       incline angle     nv
1120601   -90.0          12
*
*          elev cng     nv
1120701   -2.81548        10
1120702   -.625           11
1120703   -1.9492         12
*
*         rough  hyd dia   nv
1120801   0.0    0.        12
*
*         pvbfe   nv
1121001   00001   12
*
*        fvcahs nj
1121101  000000 11
*
*        flag   p        x        dummy  dummy    dummy nv
 1121201   1   560.00  0.0         0.     0.        0.  12
*
*         flag=0 => (lbm/sec)
1121300   1
*
*         lflow        vflow  interface flow        nj
1121301      0.0        0.0            0.0          11
*
*ccfl/junction hyd diam info
*           hyddia    floodcorr  gasint   slope   nj
*1121401      0.0        0.        1.         1.   14
***********************************************************************
***********************************************************************
*---------- heat structure input
*
```

```
*general data
```

```
*          nh  np   geo  ss    left coord.
11511000  16  11    2   1     0.0253125
*=========================================
*mesh flags
*       location flg       format flag
11511100     0                  2
*=========================================
*mesh data
*       mesh interval   int #
11511101 .00033333          10
*=========================================
*composition data
*           comp. #      int #
11511201       1          10
*=========================================
*heat distribution data
*        source   int #
11511301   0.0       10
*=========================================
*initial temperature data
*           temp.       int #
11511401    560.0        11
*=============================================================
*left bc cards
*           bvl      inc  type  surf      cyl ht      struct #
11511501  151010000  0000 1      0        13.784        1
11511502  151020000  0000 1      0        13.8943       2
11511503  151030000 10000 1      0        27.6783       7
11511504  151080000 10000 1      0        23.0325       9
11511505  151100000 10000 1      0        27.6783      14
11511506  151150000  0000 1      0        13.8943      15
11511507  151160000  0000 1      0        13.784       16
*=============================================================
*right bc cards
*           bvr      inc  type  surf      cyl ht      struct #
11511601  100010000  0    1      0       15.5992        1
11511602  101010000  0000 1      0       15.724       2
11511603  101040000 30000 1      0       31.3232        7
11511604  101070000  0000 1      0       26.06558         9
11511605  101160000 -30000 1     0       31.3232       14
11511609  101010000  0000 1      0       15.724      15
11511610  100010000  0000 1      0       15.5992       16
*=============================================================
*source data
*          source  mult      ldh      rdh   struct #
11511701     0     0.0       0.0      0.0      16
*=============================================================
*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.   16
*=============================================================
*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.   16
**************************************************************
*----- 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     I
*        units ( lbm, lbf, ft, s, p=lbf/sqin). in relap5        I
*        the quantities stored in arrays are in si units.       I
*        therefore, conversions from si to british units        I
*        must be made.                                          I
*----------------------------------------------------------------
*
*
*--------- 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, 101030000   1.0, p, 101010000
*
*          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, 101060000   1.0, p, 101040000
*
*          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, 101090000   1.0, p, 101080000
*          name      type    scale(psi/pa) init       flag
 20500400  deltpn    sum      1.45003e-04   0.0         1
*         a0   a1  var   vol         a2  var   vol
 20500401  0.0 -1.0, p, 101120000   1.0, p, 101090000
*          name      type    scale(psi/pa) init       flag
 20500500  deltpn    sum      1.45003e-04   0.0         1
*         a0   a1  var   vol         a2  var   vol
 20500501  0.0 -1.0, p, 101170000   1.0, p, 101140000
*          name      type    scale(psi/pa) init       flag
 20500600  deltpn    sum      1.45003e-04   0.0         1
*         a0   a1  var   vol         a2  var   vol
 20500601  0.0 -1.0, p, 101180000   1.0, p, 101170000
*          name      type    scale(psi/pa) init       flag
 20500700  deltpn    sum      1.45003e-04   0.0         1
*         a0   a1  var   vol         a2  var   vol
 20500701  0.0 -1.0, p, 101200000   1.0, p, 101010000
*          name      type    scale(psi/pa) init       flag
```

```
*
***************************************************************
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***********************************************
*                                             *
* end of input deck - problem end             *
*                                             *
***********************************************
.
```