Evaluation of Main Steamline Break Inside Containment Analysis for Dresden and Quad Cities Stations

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Abstract

This report has been prepared to document a confirmatory analysis performed to verify vendor calculations of the core shroud lifting forces during a Main Steam Line Break inside the drywell event. The RETRAN2 Mod5 computer code is used to model the event with the Quad Cities basedeck, modified to match vendor assumptions. The results of this calculation demonstrate the validity/conservatism of the vendor calculations as applied to Quad Cities and Dresden stations. This calculation is a best estimate calculation performed for information purposes only, and is not intended to replace the design basis analysis.

1.0 Introduction

The purpose of this calculation is to provide an audit calculation for comparison to the vendor generated differential pressures on the core shroud during a steam line break inside drywell event. Two different peak pressures exist for the Dresden and Quad Cities stations, even though the geometry is effectively identical with respect to this event [References 1 and 2]. This situation is believed to result from several factors, principal of them being that the Quad Cities calculation was redone with more modern codes and with assumptions of increased core flow (108%) in 1986. The differential pressure values are important to the core shroud H-5 flaw evaluations, including the determination of the upward pressure loads and the extent of lifting that may occur. Therefore an audit calculation has been performed to corroborate the vendor analysis, and demonstrate that the safety evaluation assumptions, based on Quad Cities MSLB analysis, are conservative.

2.0 Methodology/Model Description and Assumptions

The main steam line break inside containment typically has been modeled by the vendor using a 5 node vessel model with a break junction of area comparable to a main steam line plus a flow restrictor (for return flow from the intact steamlines). Differences in the early generation Dresden analysis and the Quad Cities analysis are apparent when observing the calculational results. Probably the most significant of these is the break flow model. The Dresden FSAR results indicate that vessel depressurization is fairly minor, reportedly due to the effects of the two phase mixture impingement on the break. Vessel pressure decreases to approximately 900 psi during the 10 seconds that the event is modeled. In contrast, the Quad Cities calculation reports a pressure decrease to approximately 650 psi in the same time frame.

The RETRAN calculation performed for verification employs the nodalization shown in Figure 1. This model was prepared for benchmarking calculations to plant startup tests, and features 100% flow control balancing, point kinetics model, and full control systems modeling (Feedwater, Pressure Control, and Recirc Flow Control). As can be seen from the figure, the nodalization is fairly detailed, and allows levels to be tracked both inside and outside the shroud, through the use of bubble rise models for the separator and upper downcomer regions. This is both a strength and a weakness with regard to modeling this event, since the level swell is extensive, and some numerical instabilities occur when the mixture level sweeps through the top of the bubble rise volume.

For the purposes of this calculation, the break is simulated by adjusting the area of a steam safety valve to the area used by the original calculation, and opening in 1 millisecond via a trip. The trip is activated at one second to demonstrate that a steady state balance exists prior to initiation of the event. The use of a valve at this location is appropriate since the combined steam line model does not account for the flow limiter area reductions prior to this valve location. The Moody (saturated) and Extended Henry (subcooled) critical flow correlations are applied at the break junction.

The base model was altered to maximize the depressurization rate obtained. This was done to obtain the worst anticipated differential pressures on the core shroud. The reactor was assumed to trip at the initiation of the event (1 second). Feedwater flow is also tripped off at event initiation, to minimize the addition of preheated fluid to the vessel.

Figure 1 RETRAN Nodalization

3.0 Calculations/Acceptance Criteria/Basedeck Changes

No additional calculations were performed to prepare the basedeck for the case described above. Since this effort is intended to provide insight into the basis of the differential pressure results reported for the Dresden and Quad Cities MSLB event inside drywell, no specific criteria apply. The key consideration applied in the performance of this analysis was that the model yield reasonable physical results and deliver stable numerical performance.

To facilitate the calculation of differential pressures on the shroud head, a simple set of control systems cards (inputs and summing blocks) was added to the model.

4.0 Results

4.1 Description of RETRAN Calculation Results

The results of the RETRAN calculation are presented in the following figures. As noted earlier, the transient is initiated at 1 second to demonstrate that a valid steady state initialization is achieved prior to beginning the event. A converged steady state is apparent in the following figures. Figures 2 and 3 illustrate the reactor kinetic behavior, with core power reducing rapidly as a result of void increase during the depressurization, followed by the insertion of the reactor scram, rapidly reducing core power to decay heat levels. Figure 4 shows the behavior of the pressure control system, rapidly reducing the steam flow to the turbine following the break. Figure 5 shows the feedwater flow, which is forced to zero at event initiation as an input assumption. Figure 6 shows the break flow out the valve simulating the pipe break. As can be seen, the break flow rapidly rises to approximately 200% of full power steam flow as saturated steam flows through the break, and the break mass flux increases later in the event as the break flow becomes two phase. Figure 7 provides the pressure response of the vessel steam dome volume (Volume 100). The pressure decreases rapidly initially during the single phase portion of the blowdown, and then continues to decrease at a more gradual rate as the water levels swell changing the blowdown content to an increasingly moist two phase mixture. A key point in the pressure plot is that the pressure continues to decrease during the event, which is expected since the size of the break is sufficient to remove decay heat, even during the two phase flow portion of the blowdown.

The shroud differential pressure, shown in Figure 8, calculated as the pressure in volume 22 minus the pressure in volume 16, shows an increase at .25 seconds into the event of approximately 10 psi over the initial steady state value. The RETRAN generated differential pressures show numerical instabilities later in the event. These are believed to be caused by the mixture level sweeping through the top of the bubble rise volumes (volumes 18 and 20). While the code option to "smooth" the transition of the mixture level through the top of the volume is active, it is not totally effective in eliminating small pressure surges. The mixture levels for these volumes are plotted in Figures 9 and 10, and show a very close correlation between mixture level crossing the top of the volume and the numerical spiking shown in Figure 8. Since the principal pressure peak of interest occurs prior to any of the numerical "noise", the pressure comparison is considered valid. Prior to employing the RETRAN model for detailed loads definition, a nodalization study would be warranted to assess means of smoothing or eliminating the mixture level effects.

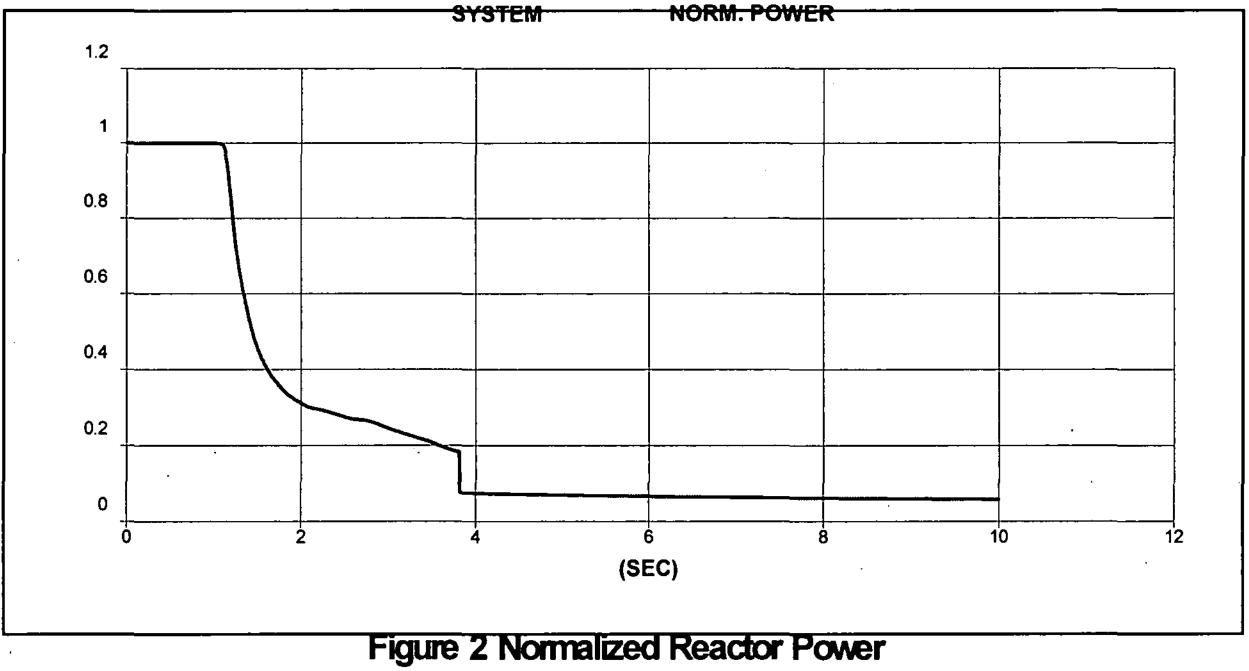

Figure 2 Normalized Reactor Power

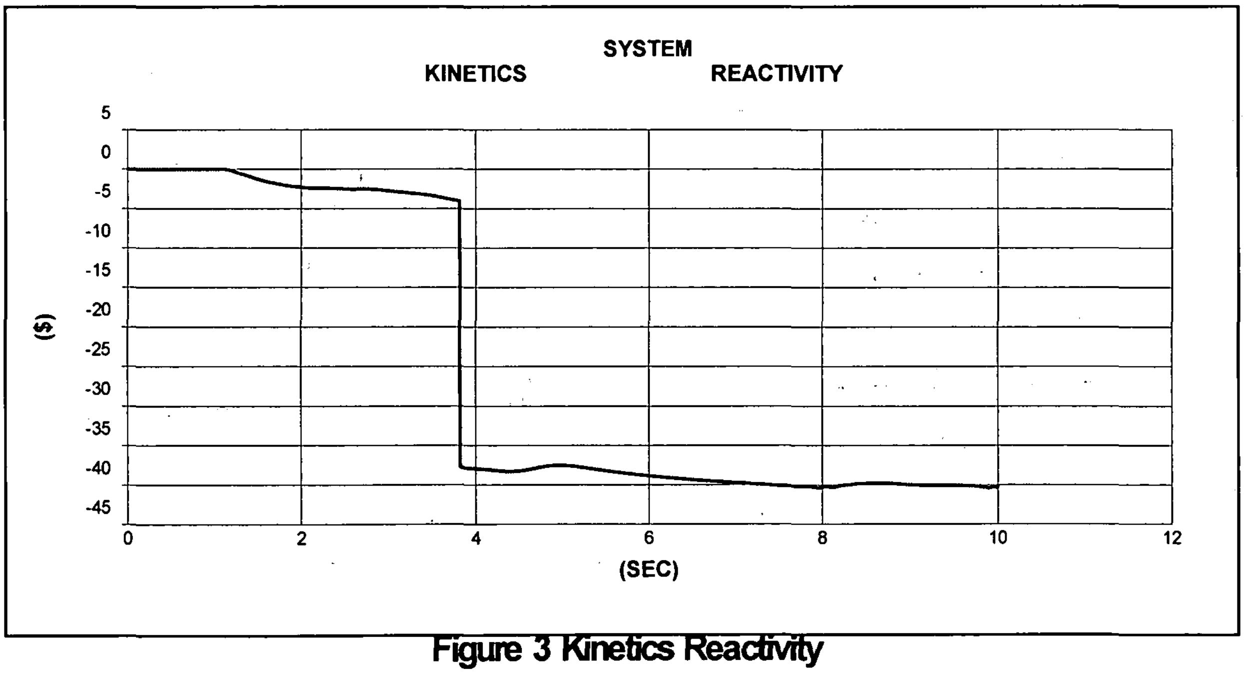

Figure 3 Kinetics Reactivity

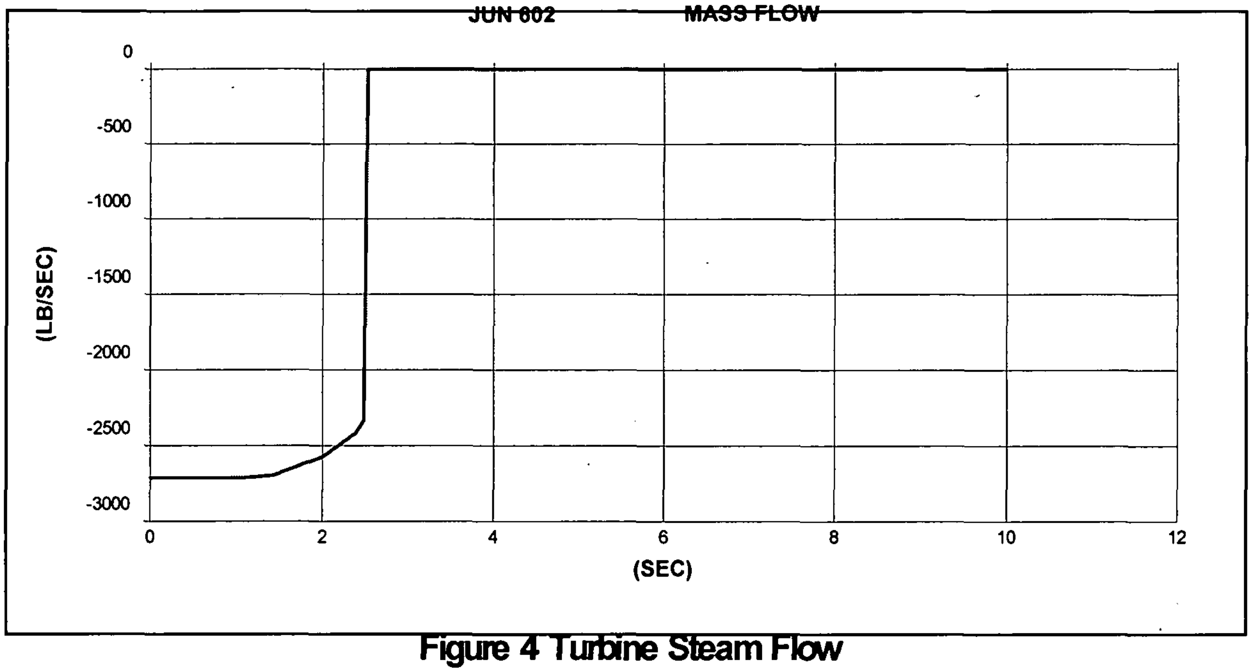

Figure 4 Turbine Steam Flow

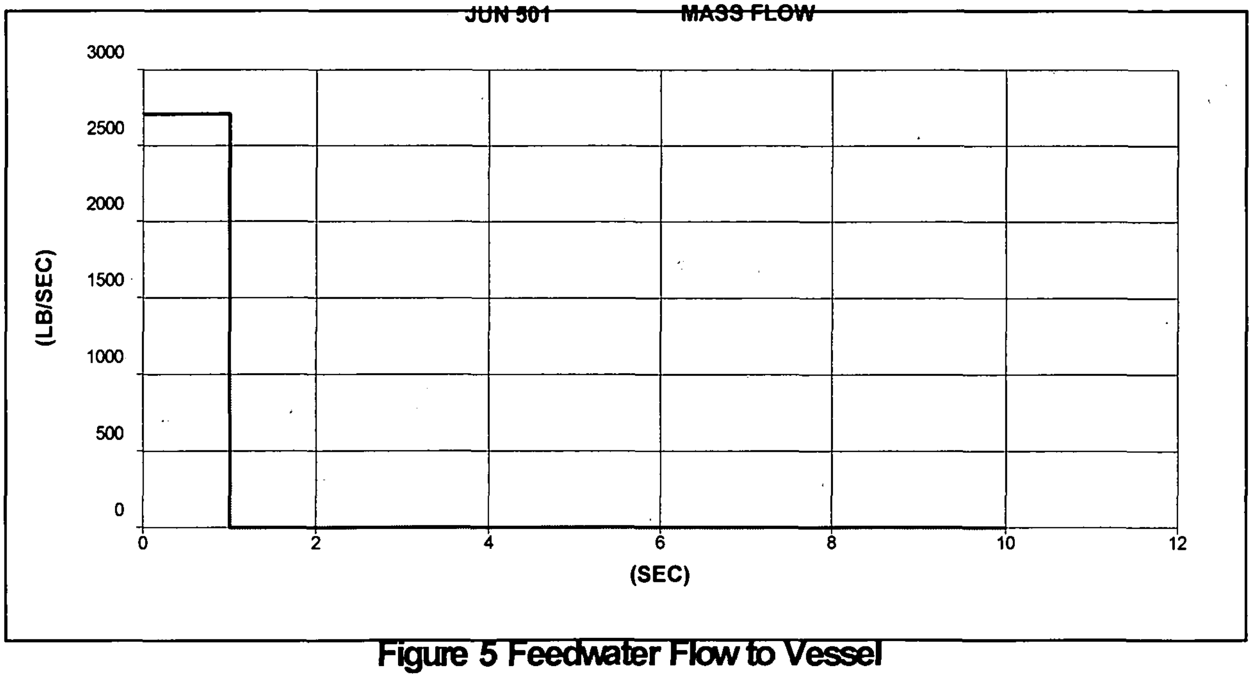

Figure 5 Feedwater Flow to Vessel

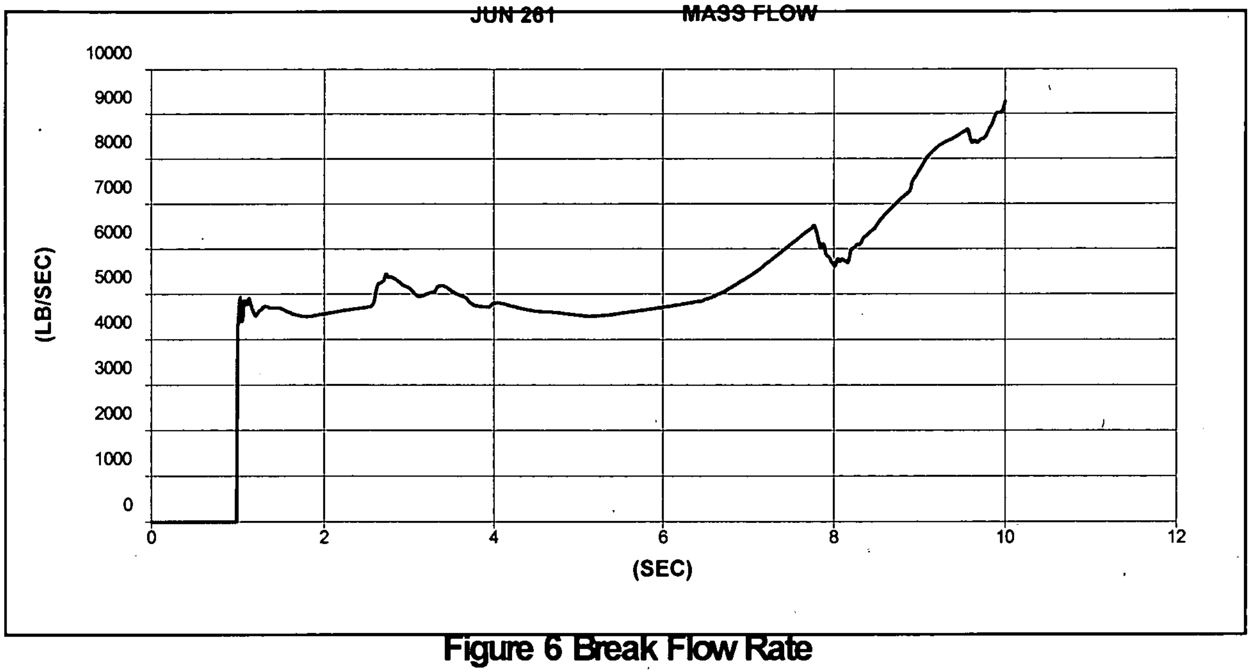

Figure 6 Break Flow Rate

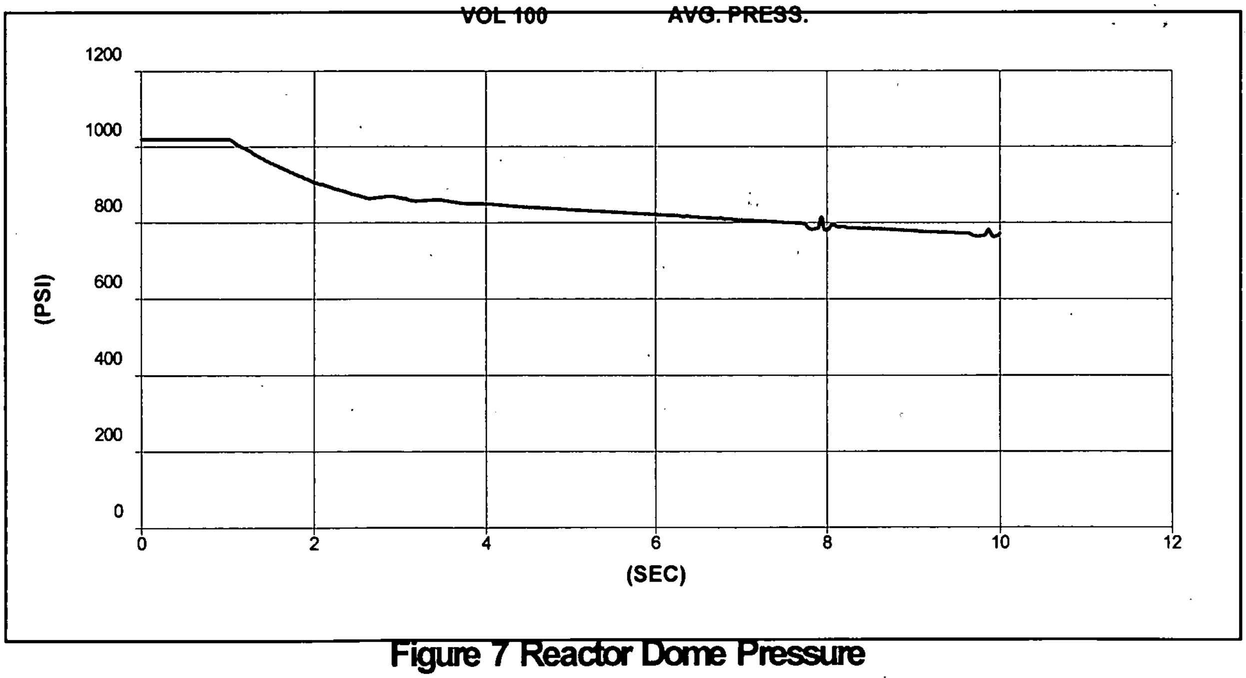

Figure 7 Reactor Dome Pressure

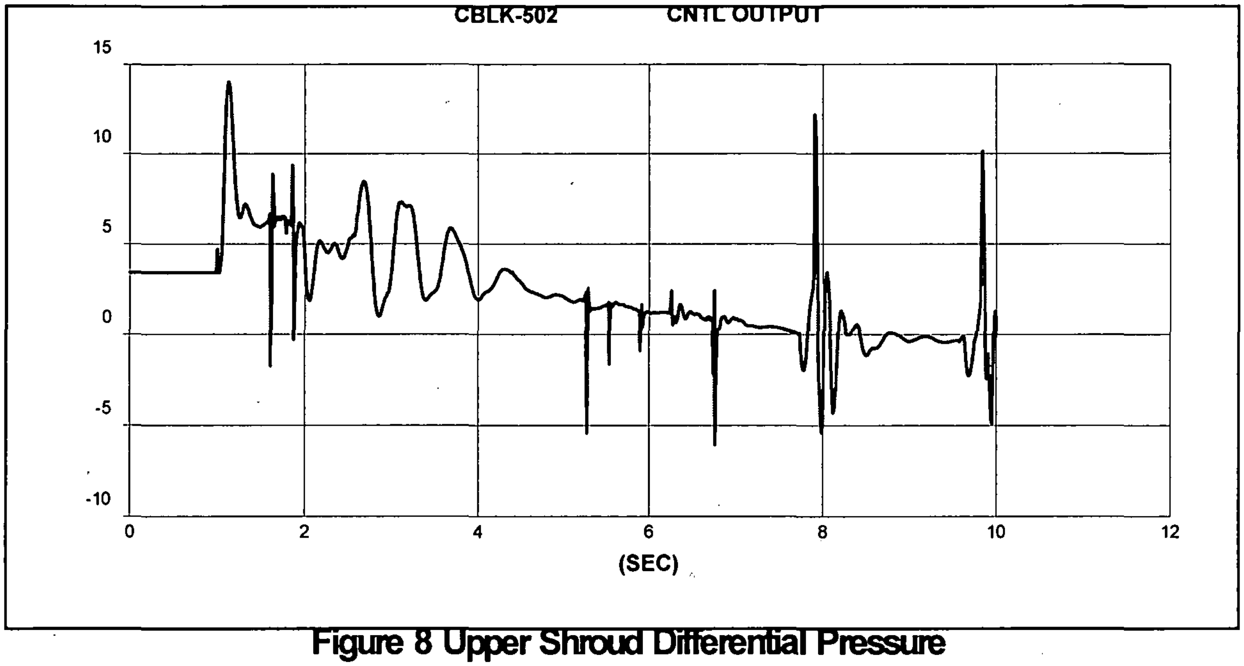

Figure 8 Upper Shroud Differential Pressure

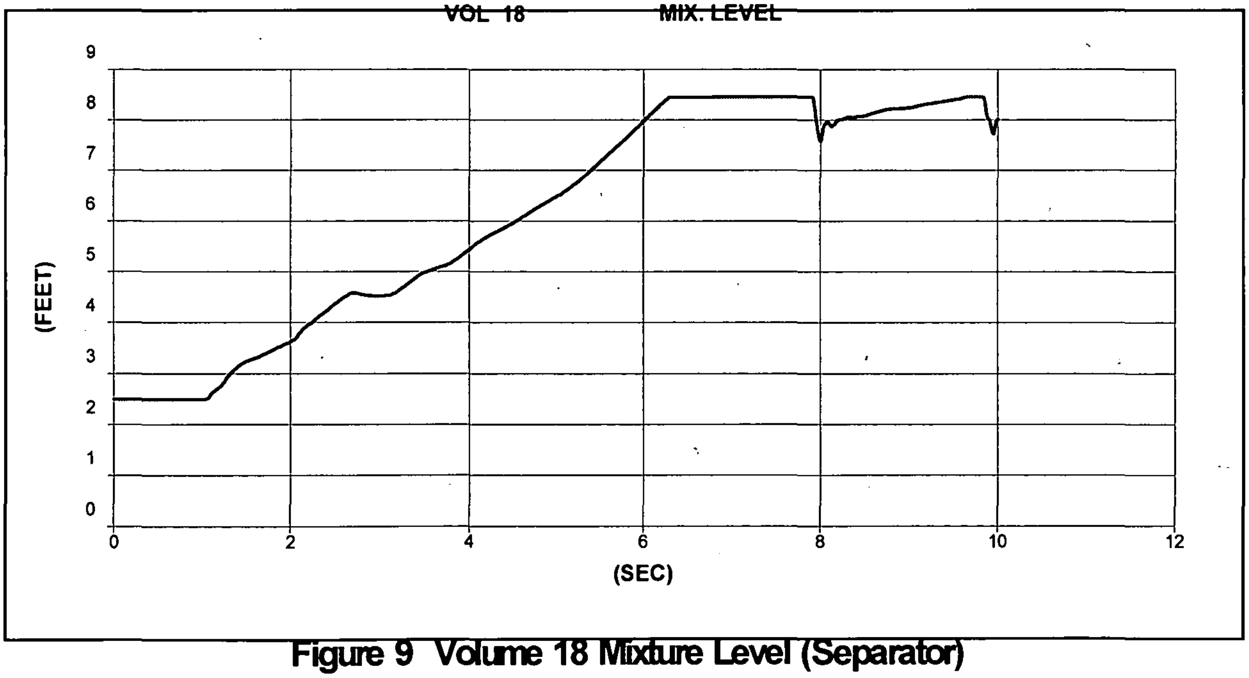

Figure 9 Volume 18 Mixture Level (Separator)

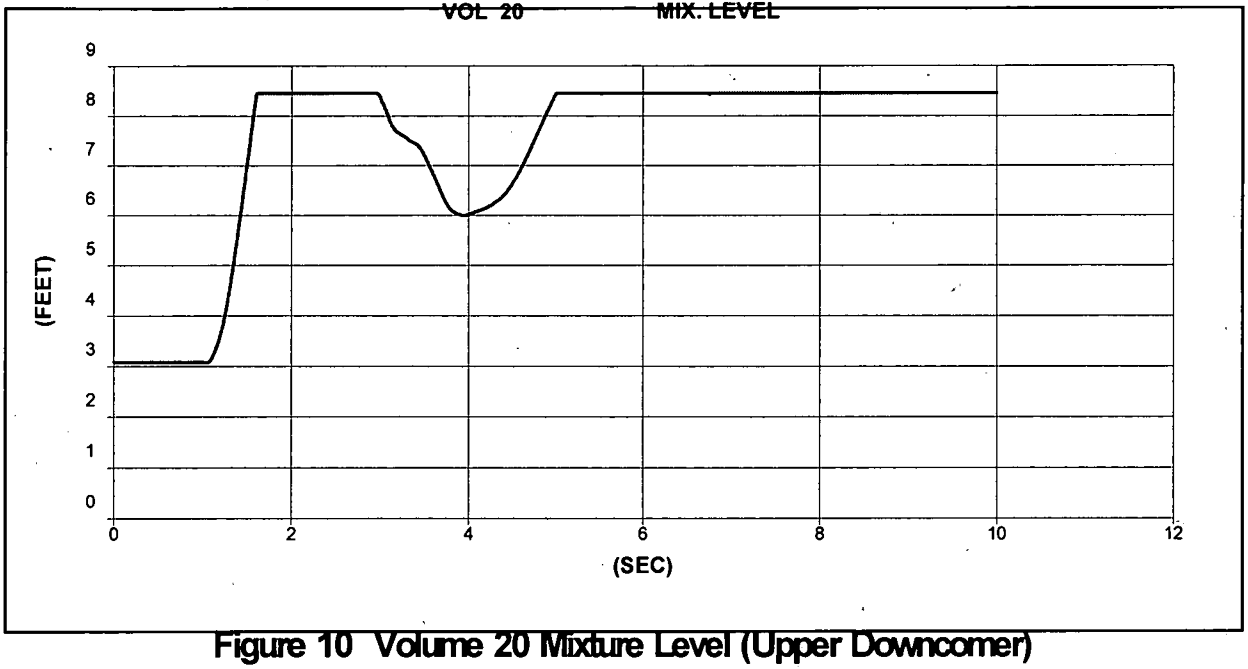

Figure 10 Volume 20 Mixture Level (Upper Downcomer)

4.2 Comparison to Vendor Calculations

The values of shroud head differential pressure reported in the QC UFSAR are 8 psi at operating conditions and 20 psi peak during a MSLB. These were generated with a 5 node vessel model. Since the RETRAN model employed has a more detailed nodalization, direct comparison of the pressures would require reconciliation of volume centroids and the resultant effects on elevation heads at different locations, as well as frictional pressure drop information from the vendor model that is not readily available. Therefore, for simplicity, this discussion will focus on the relative changes in differential pressures.

The change in shroud head pressure calculated with the RETRAN model was 10 psi (approximately 4 to 14 psi). This value compares favorably with the vendor calculated value of 12 psi change (8 to 20 reported in the QC UFSAR). The RETRAN model is based on a 100% core flow model, while the vendor calculation is believed to be based on an increased core flow assessment (108% core flow), which would cause some, if not all of the difference. The Dresden UFSAR reports an increase of 5 psi (7 psi steady state to 12 psi during the MSLB event). Selected points from the UFSAR analysis are plotted along with the RETRAN results on Figure 11. (Note that the UFSAR values are biased to the RETRAN steady state pressure to allow direct comparison of change in value).

The comparison of dome pressure is shown in Figure 12. As can be seen, the RETRAN and QC UFSAR results show similar trends. The Dresden results differ considerably, with pressure reducing only to 900 psi and then leveling off for the remainder of the transient. The relatively slower depressurization rate from the Dresden UFSAR results during the first second of the event (where the peak differential pressures occur) is probably a causal factor for the lower shroud lift pressures noted above. The Dresden UFSAR reports that depressurization proceeds until the two phase transition of the break, at which point pressure remains constant. The RETRAN and QC UFSAR results appear to be more consistent with physical expectations for this event, in that the size and location of the break should allow continued depressurization, even after transition to two phase blowdown, since the break flow is more than required to remove decay heat.

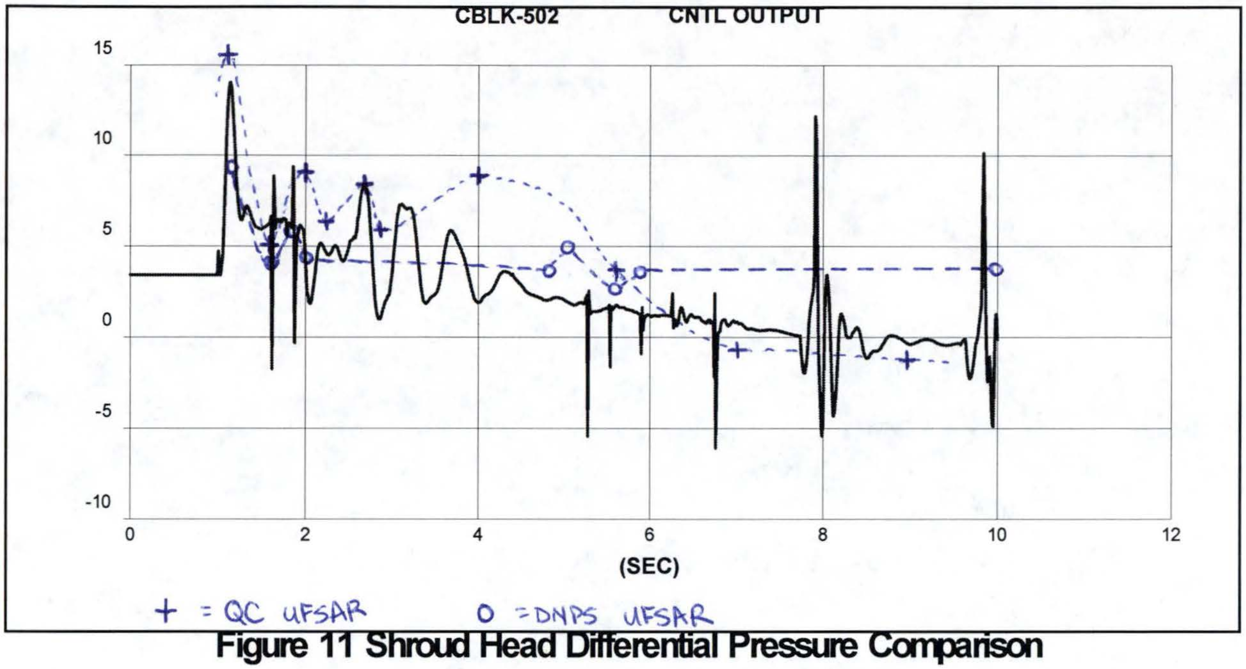

Figure 11 Shroud Head Differential Pressure Comparison

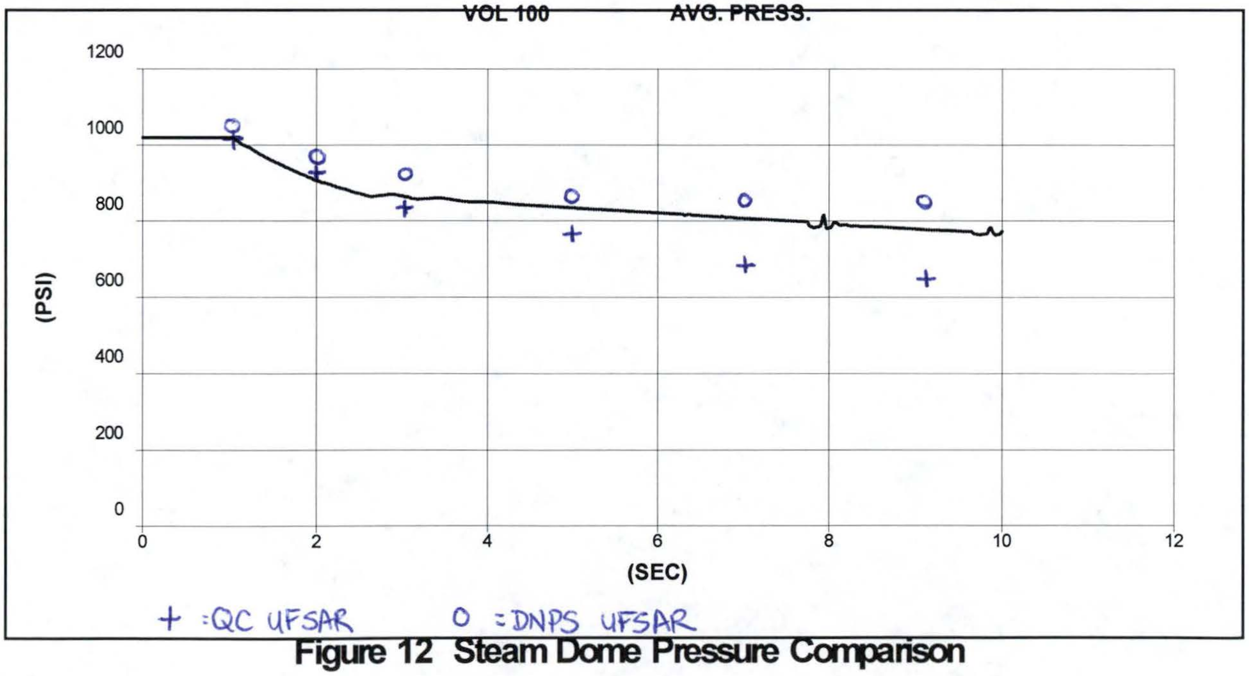

Figure 12 Steam Dome Pressure Comparison

5.0 Conclusions/Discussion

Based on the best estimate calculations performed, it is concluded that the Quad Cities UFSAR represents a bounding load definition for use in determining core shroud uplift pressures. The bases for this conclusion are:

1. The vessel depressurization bounds the best estimate calculation and follows anticipated physical trends.

2. The uplift pressures bound the best estimate calculation by approximately 20%. This margin is believed to be at least partially a function of the Increased Core Flow (ICF) assumptions utilized in the QC UFSAR calculations.

The Dresden UFSAR calculations do not conform well to either the QC or the RETRAN calculations. The shroud uplift pressure is significantly lower than the other calculations and the vessel depressurization rates deviate significantly as well. The Quad Cities UFSAR results bound the Dresden UFSAR calculations and can be utilized for safety evaluation at both sites. The Dresden design and licensing basis should be reconciled with the Quad Cities UFSAR results and be revised as appropriate.

6.0 References

1) Quad Cities UFSAR section 3.9

2) Dresden UFSAR section 3.9