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MFN 08-454, Supplement 1

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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 321 Related to the ESBWR Design Certification – Containment Systems – RAI Number 6.2-98 S02**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) responses to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by NRC letter No. 321 (Reference 1). GEH response to RAI Number 6.2-98 S02 is addressed in Enclosure 1. LTR NEDE-33440P "ESBWR Safety Analysis Additional Information" markups associated with this response are provided in Enclosure 2.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

D068
NRO

Reference:

1. MFN 09-196, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 321 Related To ESBWR Design Certification Application*, dated March 18, 2009

Enclosures:

1. Response to Portion of NRC Request for Additional Information Letter No. 321 Related to ESBWR Design Certification Application – Containment Systems – RAI Number 6.2-98 S02
2. Response to Portion of NRC Request for Additional Information Letter No. 321 Related to ESBWR Design Certification Application – Containment Systems – RAI Number 6.2-98 S02 – LTR NEDE-33440P Markups

cc:	AE Cubbage	USNRC (with enclosures)
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Enclosure 1

MFN 08-454, Supplement 1

Response to Portion of NRC Request for Additional Information Letter No. 321 Related to ESBWR Design Certification Application

Containment Systems

RAI Number 6.2-98 S02

NRC RAI 6.2-98 S02:

Add information to an LTR. In response to RAI 6.2-98, Supplement 1, GEH provided information in its letters dated January 9 and July 14, 2008. This information is acceptable. GEH should add this information to a licensing topical report and incorporated by reference into the DCD.

GEH Response:

The information provided in GEH letters MFN 08-011 dated January 9, 2008 and MFN 08-454 dated July 14, 2008 will be incorporated into Licensing Topical Report NEDE-33440P Revision 1 (as Sections 14 and 15, respectively) as requested by RAI 6.2-98 S02. The LTR is referenced from DCD Subsection 6.2.1.1.3 (Design Evaluation).

DCD or LTR Impact:

LTR NEDE 33440P Table 1.1 will be revised and Section 14 and Section 15 will be added in their entirety as noted in the attached markup.

Enclosure 2

MFN 08-454, Supplement 1

Response to Portion of NRC Request for Additional Information Letter No. 321 Related to ESBWR Design Certification Application

Containment Systems

RAI Number 6.2-98 S02

LTR NEDE-33440P Markups

Table 1.1

Miscellaneous RAIs.

RAI	MFN	Info requested/commitment
6.2-19	06-159	Sensitivity studies to justify time steps and nodalization.
6.2-20 Supplement 1	08-362	Justification on initial conditions assumed in the analysis.
6.2-22	06-159	Description of the piping system within a subcompartment that is assumed.
6.2-23	06-159	Provide the subcompartment nodalization information.
6.2-23 Supplement 1	06-159 Supplement 1	TRACG analysis related information
6.2-23 Supplement 2	08-270	Correct the velocity input errors and resubmit the corrected shield wall pressurization analyses.
6.2-23 Supplement 3	08-681	Provide the basis for selecting of inventory multiplier, updated results in graphical form and include responses to RAI 6.2-23 and associated supplements in a licensing document.
6.2-24	06-159	Provide graphs/results of the pressure responses.
6.2-25	06-159	Provide the mass and energy release data.
21.6-107	08-351	Provide the updated figures and associated description. This request is issued in RAI 21.6-107 S01.
21.6-98	08-545	Provide the response to Confirmatory Items 13 and 20.
21.6-96 S0	09-216	Provide the response to RAI 21.6-96 S02

6.2-98 S01	08-011	(A –D) Response to RAI. Understand TRACG calcs for bounding scenario
6.2-98 S01 Rev 1	08-454	(E) Response to RAI. Understand TRACG calcs for bounding scenario

14.0 RAI 6.2-98 S01

RAI 6.2-98 was a followup to RAI 6.2-53 (MFN 06-215). The intent of these RAIs was to understand the TRACG calculation for the bounding scenario. ESBWR DCD Tier 2 provides limited information that is insufficient to understand the analyses. These RAIs focused on key phenomena-the trapping and transient distribution of noncondensable gases in the drywell and subsequent transport to the wetwell.

(A) The limiting design basis accident changed from feed water line break (FWLB) to main steam line break (MSLB) as given in ESBWR DCD Tier 2 Revision 3. As a result, in RAI 6.2-141, the staff requested GEH to revisit RAIs that were affected by this change, specifically RAI 6.2-98. However, the GEH's response to RAI 6.2-98 was based only on the FWLB accident. The analyses results of the FWLB accident are important because of their closeness to that of the MSLB accident and the fact that FWLB is the second limiting accident. Please provide the analyses results of the MSLB accident.

(B) The addition of a double pipe connection, which was not modeled previously (MFN 06-215), significantly increased the transfer of nitrogen trapped in the GDCS during the GDCS period and subsequently released to the drywell and then to the wetwell. This modeling improvement reduced the amount of holdup of nitrogen in the GDCS from a ~10-12% of the total in the previous modeling to a ~ 5% of the total in the current modeling. The holdup of nitrogen of 5% of the total appears to result from the TRACG's inability to model mixing of gases in the GDCS tank open volume. Please (1) explain whether you chose the nodalization to minimize the nitrogen holdup in the GDCS pools and (2) quantify the effect of using a well mixed atmosphere in the GDCS pools open volume.

(C) As shown on Figure 6.2-98-5, the noncondensable gas holdup in the drywell head region at 72 hours resulting in a pressure of 50 KPa is significant. Please (1) provide the mass of noncondensables held up in the drywell head region and (2) quantify the effect on the drywell pressure, if the noncondensables held up in the drywell head and GDCS pools were transferred to the wetwell.

(D) After the opening of the DPVs, the long-term containment responses from FWLB accident to MSLB accidents are expected to be similar. However, the results show that they differ. Please (1) identify and justify the nodalization differences between FWLB and MSLB accidents and (2) explain the differences in results.

(E) During a phone call with the staff on September 24, 2007, GEH discussed a potential design change to add a drywell gas recirculation system to the PCCS which will start operating three days after the initiation of a LOCA to improve the PCCS's ability to remove thermal energy from the containment. In your response, please address the effect of the drywell gas recirculation system and any other systems that you plan to credit in your analyses.

14.1 GEH RESPONSE

The containment responses to a postulated main steam line break (MSLB) and feedwater line break (FWLB) are discussed in the following paragraphs and figures.

The bounding cases (DCD Tier 2, Revision 4, Figures 6.2-13a1 to 6.2-14d3) are used for these discussions. These cases assume a single failure of one depressurization valve (DPV) and bounding conditions (DCD Tier 2, Revision 4, Table 6.2-6), and assume 100% double-ended break.

(A) The change in limiting design basis accident from FWLB to MSLB is discussed in this section.

(A1) General Discussions [MSLB – Bounding Conditions]

(A1.1) Nodalization

Referring to the TRACG nodalization (Figures 6.2-98S01-1 and 6.2-98S01-2), the broken main steam line is located at Level 34 and discharges steam into the drywell (DW) at this elevation. Two pipes (per Gravity-Driven Cooling System (GDCS) airspace) are used to simulate the connection between the GDCS pool airspace and the DW (RAI 6.2-98 S01 Figure 6.2-98 S01-2), to purge the residual non-condensable (NC) gases in this airspace. For the NC gases, the nitrogen properties are used in these TRACG calculations.

(A1.2) Pressure Responses

RAI 6.2-98 S01 Figure 6.2-98 S01-3 shows the reactor pressure vessel (RPV), DW and wetwell (WW) pressures, and RAI 6.2-98 S01 Figure 6.2-98 S01-3a shows the same responses in short-term time scale.

Following the postulated loss-of-coolant accident (LOCA), the DW pressure increases rapidly leading to the clearing of the Passive Containment Cooling System (PCCS) and main vents. At approximately 79 seconds, the DW pressure reaches a peak value of 250 kPa (36.3 psia). This peak pressure is below the design pressure of 413.7 kPa (60 psia) with large margin. During this blowdown period, a significant amount of NC gas is purged into the WW and pressurizes the WW. The RPV continues to depressurize due to the break flow and the Automatic Depressurization System (ADS) flows. At approximately 0.2 hours, the RPV pressure drops below the pressure point at which the GDCS water is allowed to inject into the downcomer by gravity head. The subcooled GDCS water continues flowing into the RPV and reduces the steaming from the RPV and the DW pressure. At approximately 0.48 hours, the DW pressure drops below the WW pressure, causing the openings of vacuum breakers and allowing some NC gases to flow back into the DW. Consequently, the system pressures drop to a value of approximately 217 kPa.

Subsequently, the decay heat overcomes the subcooling of the GDCS water and steaming resumes (at ~ 0.66 hours, RAI 6.2-98 S01 Figure 6.2-98 S01-3a). The resumption of RPV steaming causes the DW pressure to increase again starting from 0.66 hours.

(A1.3) Level and Heat Removal Responses

RAI 6.2-98 S01 Figure 6.2-98 S01-4 shows the downcomer collapsed level, and RAI 6.2-98 S01 Figure 6.2-98 S01-5shows the GDCS pool water levels. After the initiation of the GDCS flow, the GDCS pool water level drops and consequently the downcomer collapsed level rises.

At approximately 17.1 hours, the downcomer water level swells up to the DPV elevation. This level swell causes a surge of DPV flow from the downcomer into the DW annulus. The addition of subcooled downcomer water condenses extra steam in the DW annulus and sets off a brief pressure reduction in the DW annulus region (RAI 6.2-98 S01

Figure 6.2-98 S01-3a). Because the pressure is lower in the DW annulus than those the DW head and GDCS pool airspace, the NC gases hidden in these airspaces start to move back to the DW annulus (Figures 6.2-98S01-12 and 6.2-98S01-13).

For the rest of the transient, the downcomer collapsed level maintains an equilibrium position below the elevation of the DPVs (stub tube elevation at 21.91 meters). The corresponding GDCS pool equilibrium level is approximately 21.4 meters.

RAI 6.2-98 S01 Figure 6.2-98 S01-6 compares the total heat removal by the PCCS with the decay heat. From 6 to 30 hours, approximately 90 to 95% of the decay heat is removed by the PCCS and discharged to the Isolation Condenser (IC) Passive Containment Cooling (PCC) pools, which are outside of the containment. The residual decay heat (approximately 5 to 10% not removed by the PCCS) corresponds to the reduction in RPV steaming rate. This reduction is due to that a small portion of the decay heat that is used to heat up the incoming cooler GDCS water. RAI 6.2-98 S01 Figure 6.2-98 S01-7 compares the GDCS pool water temperature with the downcomer water temperatures. In this design, the hot PCCS condensate (~105 °C) drains to the GDCS pools and mixes with the remaining water (for the MSLB case, ~ 1000 m^3) in the pools. The GDCS water injected into the RPV during the MSLB transient is at a temperature considerably lower than that for the PCCS condensate. After 60 hours, the mixture temperature approaches an equilibrium temperature of 100 °C (RAI 6.2-98 S01 Figure 6.2-98 S01-7).

RAI 6.2-98 S01 Figure 6.2-98 S01-8 shows the IC/PCC pool water level. The IC/PCC pool water level drops due to boiloff by the decay heat. At 35 hours, the pool level drops below the elevation of 29.6 m, (or top one-quarter portion of the PCCS condenser tube length uncovered). The connection valves open to allow the water from the dryer/separator storage pools to flow into the IC/PCC pools. This increase in PCCS condenser tube coverage causes a small increase in PCCS condensation power (RAI 6.2-98 S01 Figure 6.2-98 S01-6).

(A1.4) NC Gas Responses

RAI 6.2-98 S01 Figure 6.2-98 S01-9 through RAI 6.2-98 S01 Figure 6.2-98 S01-13 show the NC gas pressures in the DW annulus, lower DW, air gap between the RPV and the reactor shield wall, the DW head airspace, and the GDCS pool airspace. Most of the initial NC gases in the DW annulus are purged into the WW within 3 hours. It takes approximately 24 hours to purge most of the NC gases in the DW head airspace (RAI 6.2-98 S01 Figure 6.2-98 S01-12). It takes approximately 20 hours to purge most of the NC gases in the GDCS pool airspaces (RAI 6.2-98 S01 Figure 6.2-98 S01-13).

Figures 6.2-98S01-14 through 6.2-98S01-16 show the NC gas mass profiles in the DW head airspace, GDCS pool airspace and in the WW. Figures 6.2-98S01-14 and 6.2-98S01-15 show that there is essentially no NC gas remaining in the DW head and GDCS airspaces, after 24 hours into the transient. Significant increase in the total WW NC gas mass occurs in the first 3 hours (RAI 6.2-98 S01 Figure 6.2-98 S01-16), during this time period basically all the initial NC gases in the DW annulus are purged into the WW. The second step increase in the total WW NC gas mass occurs form 18 to 20 hours, corresponding to the purging of the remaining NC gas in the DW head and GDCS pool airspaces. The increase in WW NC gas after 20 hours corresponds to the radiolytic gases generated in the core and purged into the WW via the PCCS. The total NC gas mass in the WW at 72 hours is 15043 kg.

(A1.5) Suppression Pool and WW Responses

RAI 6.2-98 S01 Figure 6.2-98 S01-17 shows the water levels in the DW annulus and suppression pool. At 72 hours, the DW annulus collapsed level reaches to approximately 5 meters below the RPV bottom. The suppression pool level rises to 10.51 meters (reference to RPV bottom), due to the condensation of steam through the main vents during the blowdown and the early part of LOCA transient.

Figures 6.2-98S01-18 and 6.2-98S01-19 show the suppression pool water temperatures at different elevations in Ring 7 (next to the horizontal vents) and Ring 8 (away from the horizontal vents). Shortly after the blowdown period, the suppression pool stratification model prevents any mixing in the bottom three levels (Levels 25, 26 and 27) in the suppression pool. (The stratification model sets the flow areas to zero in the radial direction at these 3 levels when there is no discharge from the vent or safety-relief valve (SRV) discharge line to the lower level). RAI 6.2-98 S01 Figure 6.2-98 S01-19 shows that the water temperatures in these levels (in Ring 8) remain constant for the 72 hours transient after the initial heatup from the blowdown. After the blowdown, the pool surface temperatures (Level 29 in Rings 7 and 8) increase an additional 5°K as the result of the energy/steam in the PCCS vent flow and the increase in the WW air temperatures (Figures 6.2-98S01-20 and 6.2-98S01-21). The long-term pool surface temperature is 77°C.

Figures 6.2-98S01-20 and 6.2-98S01-21 show the WW gas temperatures at different elevations in Ring 7 (next to the vacuum breakers and leakage) and Ring 8 (away from the vacuum breakers). Air temperatures at Levels 29 and 30 follow closely with pool surface water temperatures. The increase for the gas temperature at the top WW corner next to the leakage path (Level 31, Ring 7) is larger than for other temperatures due to the inflow of hotter gas from the DW via the leakage path and the gas stratification model. The WW gas stratification model applies a large value of loss coefficient (100000) at the axial faces (Rings 7 and 8, between Levels 30 and 31) and restricts the mixing between the cells at Levels 30 and 31.

RAI 6.2-98 S01 Figure 6.2-98 S01-22 shows the WW total and NC gas pressures in Ring 7.

(A1.6) PCCS Inlet Conditions

RAI 6.2-98 S01 Figure 6.2-98 S01-23 shows the total mixture and NC gas mass flows at the PCCS inlet, and RAI 6.2-98 S01 Figure 6.2-98 S01-24 shows the mass flows with enlarged time scale. RAI 6.2-98 S01 Figure 6.2-98 S01-25 shows the moisture content at the PCCS inlet. The moisture content is calculated as (1 – void fraction) at the top of the DW next to the PCCS inlet. The calculated results show that there are no significant water droplets at the PCCS inlet location during this transient.

(A1.7) Effect of MSLB Steam Discharge Location (Level 34 Versus Level 23)

In the analyses prior to DCD Tier 2, Revision 3, the MSLB steam flow was assumed to discharge at Level 23 (in the DW region below the RPV bottom) and to force the NC gases in the DW to transfer into the WW. Parametric cases were performed to assess the impact of the discharge location for the steam break flow, at Level 23 versus at Level 34 (the same elevation as the main steam line). The results of these parametric studies show that the simulation with MSLB steam discharged at Level 34 generates slightly higher long-term DW pressure than that discharged at Level 23. These results were discussed in response to RAI 6.2-53 S01 (MFN 02-215, Supplement 1).

Based on these parametric studies, the broken main steam line for MSLB is simulated at Level 34 and discharges steam into the DW at this elevation.

(A1.8) Effect of 1-Pipe Connection Versus 2-Pipe Connection

In the analyses prior to DCD Tier 2, Revision 3, the TRACG nodalization used 1-pipe connection (per GDCS airspace) to simulate the flow path between the GDCS pool airspace and the DW. The TRACG nodalization was later modified to use 2-pipe connection (per GDCS airspace) to further promote the purging of the residual NC gas in the GDCS airspace. Parametric cases (using MSLB case) were performed to assess the effectiveness of 1-pipe versus 2-pipe connection. Results of these parametric studies show that the 2-pipe connection essentially purges all NC gas remaining in the GDCS pool airspace. Consequently, the calculated long-term DW pressure for MSLB is higher with 2-pipe connection than that with 1-pipe connection. These results were discussed in response to RAI 6.2-53 S01 (MFN 02-215, Supplement 1).

Based on these parametric studies, the TRACG nodalization is revised with 2-pipe connection (per GDCS airspace) for all breaks to maximize the calculated long term DW pressure.

(A1.9) Effect of Nitrogen Versus Air in the Containment

In the analyses prior to DCD Tier 2, Revision 4, the TRACG nodalization used air properties for the NC gases inside the containment. Parametric cases (using the MSLB bounding case as base case) were performed to assess the impact of nitrogen versus air properties. Results of these parametric studies show that the difference in the calculated maximum DW pressure at 72 hours is small (+0.53 kPa for nitrogen) comparing to the margin to the design pressure.

Based on these parametric studies, the TRACG nodalization is revised (in DCD Tier 2, Revision 4) with nitrogen properties for the NC gases for all breaks to maximize the calculated long-term DW pressure.

(A1.10) Effect of One DPV Failure Versus One SRV Failure

The MSLB bounding case assumes a single failure of one DPV. Parametric case with a single failure of one SRV was performed, to assess the impact of one DPV failure versus one SRV failure. Comparison of these two cases shows that the failure of one DPV generates higher long-term DW pressure. The calculated peak DW pressure for the case with a single failure of one DPV is 0.79 kPa higher at 72 hours than that for the case with one SRV failure.

(A2) General Discussions [FWLB – Bounding Conditions]

The containment responses to a postulated FWLB are discussed in the following paragraphs and figures. The bounding case (DCD Tier 2, Revision 4, Figures 6.2-13a1 to 6.2-13d3) is used for these discussions. This case assumes a single failure of one DPV and bounding conditions (DCD Tier 2, Revision 4, Table 6.2-6), and assumes 100% double-ended break.

(A2.1) Nodalization

Figures 6.2-98S01-1 and 6.2-98S01-2 show the TRACG nodalizations for the RPV and containment. DCD Tier 2, Revision 4, Figure 6.2-8b shows the nodalization for the feedwater line system. Two pipes (per GDCS airspace) are used to simulate the connection between the GDCS pool airspace and the DW (RAI 6.2-98 S01 Figure 6.2-98 S01-2), to purge the residual NC gases in this airspace. For the NC gases, the nitrogen properties are used in these TRACG calculations.

In the analyses prior to DCD Tier 2, Revision 4, the FWLB assumes a single failure of one SRV. Result of parametric study on the MSLB bounding case (see discussion in Paragraph A1.10 of this response) shows that the calculated peak DW pressure for the case with a single failure of one DPV is 0.79 kPa higher at 72 hours than that for the case with one SRV failure. The assumption of a single failure of one DPV is also used in the FWLB case to maximize the calculated containment pressure.

(A2.2) Pressure Responses

RAI 6.2-98 S01 Figure 6.2-98 S01-26 shows the RPV, DW and WW pressures, and RAI 6.2-98 S01 Figure 6.2-98 S01-27 and RAI 6.2-98 S01 Figure 6.2-98 S01-28 show the DW and WW pressures at different time scales.

Following the postulated LOCA, the DW pressure increased rapidly leading to the clearing of the PCCS and main vents. The DW pressure increase is terminated at approximately 70 seconds (RAI 6.2-98 S01 Figure 6.2-98 S01-27), when most of the NC gases in the DW annulus have been purged into the WW (RAI 6.2-98 S01 Figure 6.2-98 S01-32). The peak DW pressure prior to the GDCS flow initiation for this case is approximately 318 kPa (46.1 psia) (RAI 6.2-98 S01 Figure 6.2-98 S01-28), and occurred at 347 seconds, shortly after the opening of DPVs. This peak pressure is below the design pressure of 60 psia with large margin.

The GDCS flow initiates at approximately 507 seconds (DCD Tier 2, Revision 4, Table 6.2-7d). The subcooled GDCS water continues flowing into the RPV, reduces the steaming from the RPV and the DW pressure. At approximately 800 seconds, the DW pressure drops below the WW pressure, causing the openings of vacuum breakers and allowing some NC gases to flow back into the DW. Consequently, the system pressures drop to a value of approximately 260 kPa (RAI 6.2-98 S01 Figure 6.2-98 S01-28).

Subsequently, decay heat overcomes the subcooling in the GDCS water and steaming resumes (at ~ 1900 seconds, RAI 6.2-98 S01 Figure 6.2-98 S01-28). The resumption of RPV steaming causes the DW pressure to increase again starting from 2500 seconds. The DW pressure reaches the long-term peak of 351 kPa (51 psia) at 72 hours (RAI 6.2-98 S01 Figure 6.2-98 S01-26).

After 2500 seconds, the DW pressure is higher than the WW pressure. The PCCS takes steam/NC gas mixture from the DW and purges the NC gases into the WW. Most of the NC gases that returned to the DW due to the vacuum breaker openings are purged back into the WW in approximately 3 hours (RAI 6.2-98 S01 Figure 6.2-98 S01-31).

(A2.3) Level and Heat Removal Responses

RAI 6.2-98 S01 Figure 6.2-98 S01-29 compares the total heat removal by the PCCS with the decay heat. After the first 6 hours, the PCCS condensers are able to remove all the decay heat with some margin to spare. From this point on, all the decay heat generated by the core is transferred to the IC/PCC pools, which are located outside of the containment.

RAI 6.2-98 S01 Figure 6.2-98 S01-30 shows the IC/PCC pool water level. The IC/PCC pool water level drops due to boiloff by the decay heat. At 34.1 hours, the pool level drops below the elevation of 29.6 m, (or top one-quarter portion of the PCCS condenser tube length uncovered). The connection valves open to allow the water from the Dryer/Separator storage pools to flow into the IC/PCC pools.

(A2.4) NC Gas Responses

Figures 6.2-98S01-31 through 6.2-98S01-33 show the NC gas pressures in the DW annulus, the DW head airspace and the GDCS pool airspace. RAI 6.2-98 S01 Figure 6.2-98 S01-33 shows that most of the NC gases in the DW annulus are purged into the WW within 100 seconds. At approximately 800 seconds, some NC gases flows back to the DW annulus (RAI 6.2-98 S01 Figure 6.2-98 S01-33) after the opening of the vacuum breakers.

To maximize the calculated DW pressure during the post-GDCS draindown period, two pipes are used in the TRACG nodalization to simulate the connection between the GDCS airspace and the DW, to purge the residual NC gases in this airspace (see discussion in Paragraph A1.8 of this response). These two pipes are connected at the top two axial levels in the GDCS airspace (L35 and L34, RAI 6.2-98 S01 Figure 6.2-98 S01-2), one pipe per level (per GDCS airspace).

For MSLB, in which case the GDCS pool level stays above L33 (i.e., no air mass is stored in L33), the two-pipe model works effectively to purge the NC gas masses stored in the top two levels to minimal values in a few hours. For breaks other than MSLB, the GDCS pool level may drop into L33 during the draindown period and a small amount of NC gas mass remains in this bottom level. Since the pressure margins for the non-MSLB breaks are more than 10% higher than that for the MSLB (DCD Tier 2, Revision 4, Table 6.2-5,), this small amount of NC gas remaining in the GDCS airspace for non-MSLB breaks would not change the conclusion that MSLB is the limiting break.

Figures 6.2-98S01-34 through 6.2-98S01-36 show the NC gas mass profiles in the DW head airspace, the GDCS pool airspace and the WW. RAI 6.2-98 S01 Figure 6.2-98 S01-31 shows that there is essentially no NC gas remaining in the DW annulus region, after 3 hours into the transient. Significant increase in the total WW NC gas mass occurs in the first 3 hours (RAI 6.2-98 S01 Figure 6.2-98 S01-36), during this time period basically all the initial NC gases in the DW annulus are purged into the WW. The increase in WW NC gas after 12 hours corresponds to the radiolytic gases generated in the core and purged into the WW via the PCCS. The total NC gas mass in the WW at 72 hours is 14324 kg.

RAI 6.2-98 S01 Figure 6.2-98 S01-34 shows the NC gas mass profiles in the GDCS airspace. Initially, the GDCS water level is located at L34 (Level 34, DCD Tier 2, Revision 3, Figure 6.2-7), and the gas space includes L34 and L35 with initial NC gas masses stored in these levels. For the FWLB, the water level drops after the initiation of GDCS flow and drops to the pool bottom (L33) in approximately 4 hours. This creates a new bottom layer of gas space, which is approximately 6 meters below the connection pipes, to store NC gas mass. NC gas masses stored in the top 2 levels (L34 and L35) are purged to the minimal values in a few hours, by the connection pipes. At 72 hours, a total of 680 kg of NC gas is stored in the bottom two levels (L33 and L34). This amount is less than 5% of the total NC gas mass inside the containment (DW and WW).

It should be noted that for the MSLB the GDCS pool level stays above L33 (i.e., no NC gas mass is stored in L33). And, NC gas masses stored in the top 2 levels (L34 and L35) are purged to the minimal values in a few hours, through the connection pipes.

RAI 6.2-98 S01 Figure 6.2-98 S01-35 shows the DW head airspace NC mass. The total NC gas mass in the DW head airspace at 72 hours is 30 kg. This amount is approximately 0.2% of the total NC gas mass inside the containment (DW and WW).

(A2.5) Effect of Residue NC Gas Mass on the DW Pressure

At 72 hours, the total NC gas masses in the WW, GDCS airspace and DW head airspace are, 14324 kg, 680 kg and 30 kg. There is essentially no NC gas remaining in the DW annulus region. The total NC gas in these regions is 15034 kg. If the residue NC gas masses in the GDCS airspace and DW head airspace are purged completely into the WW, the DW pressure would increase by the NC gas mass ratio of (15034/14324 = 1.05).

For the FWLB case, the impact of residue NC gas mass is an increase of 5% in the calculated DW pressure. For the bounding FWLB case, the maximum DW pressure at 72 hours would increase from 351.7 kPa (DCD Tier 2, Revision 4, Table 6.2-5) to 369.3 kPa. The margin to design pressure of 45.3 psig would reduce from 19.9% to 14.2%.

The above assessment shows that the MSLB is still the limiting break.

(A2.6) Suppression Pool and WW Responses

RAI 6.2-98 S01 Figure 6.2-98 S01-37 compares the water levels in the DW annulus and suppression pool. The DW annulus water level rises due to the break flow discharges from the RPV and from the broken feedwater piping (from the feedwater heaters). In approximately 10 hours, the DW annulus water level reaches the quasi-equilibrium elevation of 9 meters. At this elevation, the DW annulus water level is approximately 3 meters below the spillover holes. The hot water in the DW annulus will remain in the DW and not enters into the suppression pool via the spillover holes.

Figures 6.2-98S01-38 through 6.2-98S01-40 show the DW gas temperature, WW gas temperature and suppression pool surface temperature.

(A2.7) Downcomer Level and FWLB Break Flow

RAI 6.2-98 S01 Figure 6.2-98 S01-41 shows the two-phase level in the RPV downcomer, and RAI 6.2-98 S01 Figure 6.2-98 S01-41a shows the two-phase level with enlarged time scale. The FWLB elevation is located at 18.915 meters (from the RPV bottom). RAI 6.2-98 S01 Figure 6.2-98 S01-41a shows that the two-phase level swells above the break elevation from 0.5 to 2.0 hours. During this time period, the downcomer two-phase mixture over-spills from the RPV into the DW annulus. RAI 6.2-98 S01 Figure 6.2-98 S01-42 shows the FWLB flow from the RPV. RAI 6.2-98 S01 Figure 6.2-98 S01-43 compares the downcomer liquid temperature (at L16) with the DW annulus vapor temperature. The FWLB elevation is located at L16 (RAI 6.2-98 S01 Figure 6.2-98 S01-1) and the GDCS injection is located at L10 (8.4 meters below the break elevation). The injected GDCS water mixes with the downcomer fluid. The subcooling of this mixture reduces as it moves upward towards the break elevation.

(A2.8) PCCS Inlet Conditions

RAI 6.2-98 S01 Figure 6.2-98 S01-44 shows the total mixture and air mass flows at the PCCS inlet, and RAI 6.2-98 S01 Figure 6.2-98 S01-45 shows the mass flows with enlarged time scale. 6.2-98S01-45a shows the moisture content at the PCCS inlet. This is calculated as (1–void fraction) at the top of the DW next to the PCCS inlet. The calculated results show that there are no water droplets at the PCCS inlet location during this transient.

(B) The NC gas holdup in the DW head and GDCS pool airspaces and effect of a well-mixed atmosphere in the GDCS open volume is discussed in this section.

(B1) Double Pipe Connection

Two pipes (per GDCS airspace) are used to simulate the connection between the GDCS pool airspace and the DW (RAI 6.2-98 S01 Figure 6.2-98 S01-2). This nodalization is selected to minimize the NC gas holdup in the DW head and GDCS pool airspaces. Parametric studies (using MSLB case) were performed earlier (response to RAI 6.2-53 S01, MFN 02-215, Supplement 1) to evaluate the effectiveness of the double pipe connection. The results show that there are essentially no NC gases remaining in the DW head and GDCS airspaces for the MSLB with double pipe connection. The current results (Paragraph A1.4 in this response) also show the same effect on the purging of NC gases.

The two pipes are connected at the top two axial levels in the GDCS airspace (L35 and L34, RAI 6.2-98 S01 Figure 6.2-98 S01-2), one pipe per level (per GDCS airspace). For MSLB, in which case the GDCS pool level stays above L33 (i.e., no air mass is stored in L33), the two-pipe model works effectively to purge the NC gas masses stored in the top two levels to minimal values in a few hours. For breaks other than MSLB, the GDCS pool levels drop into L33 (the pool level is approximately 6 meters below the lower connection pipes) during the draindown period and a small amount of NC gas mass remains in this bottom level. Since the pressure margins for the non-MSLB breaks are more than 10% higher than that for the MSLB (DCD Tier 2, Revision 4, Table 6.2-5), this small amount of NC gas remaining in the GDCS airspace for non-MSLB breaks would not change the conclusion that MSLB is the limiting break.

For the bounding FWLB (Paragraphs B2.4 and B2.5), the holdup NC gas mass is approximately 5% of the total NC gas mass in the containment. The impact of this holdup gas on the calculated DW pressure at 72 hours is a reduction of 5% in pressure margin (i.e., from 19.9% to 14.2%).

(B2) Effect of Well-Mixed Atmosphere in the GDCS Open Volume

A well-mixed atmosphere in the GDCS airspace that is opened to the DW annulus would eliminate the hideout volumes for the NC gases. The effect is a complete purging of NC gases from these hideout volumes and maximizing the calculated DW pressure.

For the MSLB, there are essentially no NC gases remaining in the DW head and GDCS airspaces (Paragraph A1.4). The calculated DW pressure accounts for the effect that all NC gases have been purged into the WW.

For the bounding FWLB (Paragraphs B2.4 and B2.5), the remaining NC gas mass in the DW head and GDCS airspace is approximately 5% of the total NC gas mass in the containment. The impact of this amount of holdup gas on the calculated DW pressure at 72 hours is an increase of 5% in DW pressure, or a reduction of 5% in pressure margin (i.e., from 19.9% to 14.2%).

(C)The NC gas holdup in the DW head and effect of transferring NC gas from the DW head and GDCS airspaces to the WW is discussed in this section.

(C1) NC Gas Mass

The NC gas mass profiles in the DW head, GDCS airspace and WW are discussed in Paragraph A1.4 and RAI 6.2-98 S01 Figure 6.2-98 S01-14 through 16 for the bounding MSLB case.

The NC gas mass profiles in the DW head, GDCS airspace and WW are discussed in Paragraph A2.4 and RAI 6.2-98 S01 Figure 6.2-98 S01-34 through 36 for the bounding FWLB case.

(C2) Effect of Residue NC Gas in the Holdup Volumes on the DW Pressure

For the bounding MSLB, there are essentially no NC gases remaining in the DW head and GDCS airspaces (Paragraph A1.4). The calculated DW pressure accounts for the effect that all NC gases have been purged into the WW.

For the bounding FWLB break (Paragraphs B2.4 and B2.5), the remaining NC gas mass in the DW head and GDCS airspace is approximately 5% of the total NC gas mass in the containment. The impact of this amount of holdup gas on the calculated DW pressure at 72 hours is an increase of 5% in DW pressure, or a reduction of 5% in pressure margin (i.e., from 19.9% to 14.2%).

(D) After the opening of the DPVs, the long-term containment responses from FWLB accident to MSLB accidents are expected to be similar. However, the results show that they differ. Please (1) identify and justify the nodalization differences between FWLB and MSLB accidents and (2) explain the differences in results.

(D1) Nodalization

The MSLB and the FWLB use the same nodalizations for the RPV and containment (Paragraphs A1.1 and A2.1). The differences between these two cases are the modeling of the break pipes (DCD Tier 2, Revision 4, Figure 6.2-8 for MSLB and Figure 6.2-8b for FWLB).

The difference in the DW pressures between these two cases is explained in the following paragraph.

(D2) Differences in LOCA Transient

The key factors that affect the long-term DW pressure are the suppression pool surface temperature, the NC gas hideout and the WW gas temperature. The suppression pool surface temperature affects the partial steam pressure in the WW, and consequently the DW pressure. Figures 6.2-98S01-46 to 6.2-98S01-48 compare the DW pressures, suppression pool surface temperatures and WW gas temperatures from these two cases.

During the blowdown period, the steam blowdown from the DW into the suppression pool via the main vents heats up the suppression pool water. The heatup in the suppression pool surface in the MSLB case is higher than that in the FWLB case (RAI 6.2-98 S01 Figure 6.2-98 S01-47). The same temperature difference is maintained (more or less) for the rest of the 72 hours transient. At 72 hours, the pool surface temperatures for the MSLB and FWLB are 76.7°C and 70.1°C, respectively. The corresponding partial steam pressures are 41.3 kPa and 31.3 kPa. The difference in the partial steam pressure between these two cases is 10.0 kPa. The impact of higher suppression pool surface temperature is 10 kPa on the long-term DW pressure in the FWLB case.

RAI 6.2-98 S01 Figure 6.2-98 S01-48 compares the WW gas temperature at the top of WW. As a result of higher suppression pool surface temperature, the WW gas temperature is a few degrees higher in the MSLB case than that in the FWLB case. At 72 hours, the WW gas temperatures are 116.3°C (389.4°K) and 112.9°C (386.0°K), respectively. The difference in the WW gas temperature is 3.4°C (3.4°K) between these two cases. The ratio of (3.4°K/389.4°K) is approximately 1%. The impact of higher WW gas temperature is +1% on the long-term DW pressure in the FWLB case, or 3.5 kPa.

For the bounding FWLB case (Paragraphs B2.4 and B2.5), the remaining NC gas mass in the DW head and GDCS airspace is approximately 5% of the total NC gas mass in the containment. The impact of this amount of holdup gas on the calculated DW pressure at 72 hours is an increase of 5% in DW pressure, or 17.6 kPa.

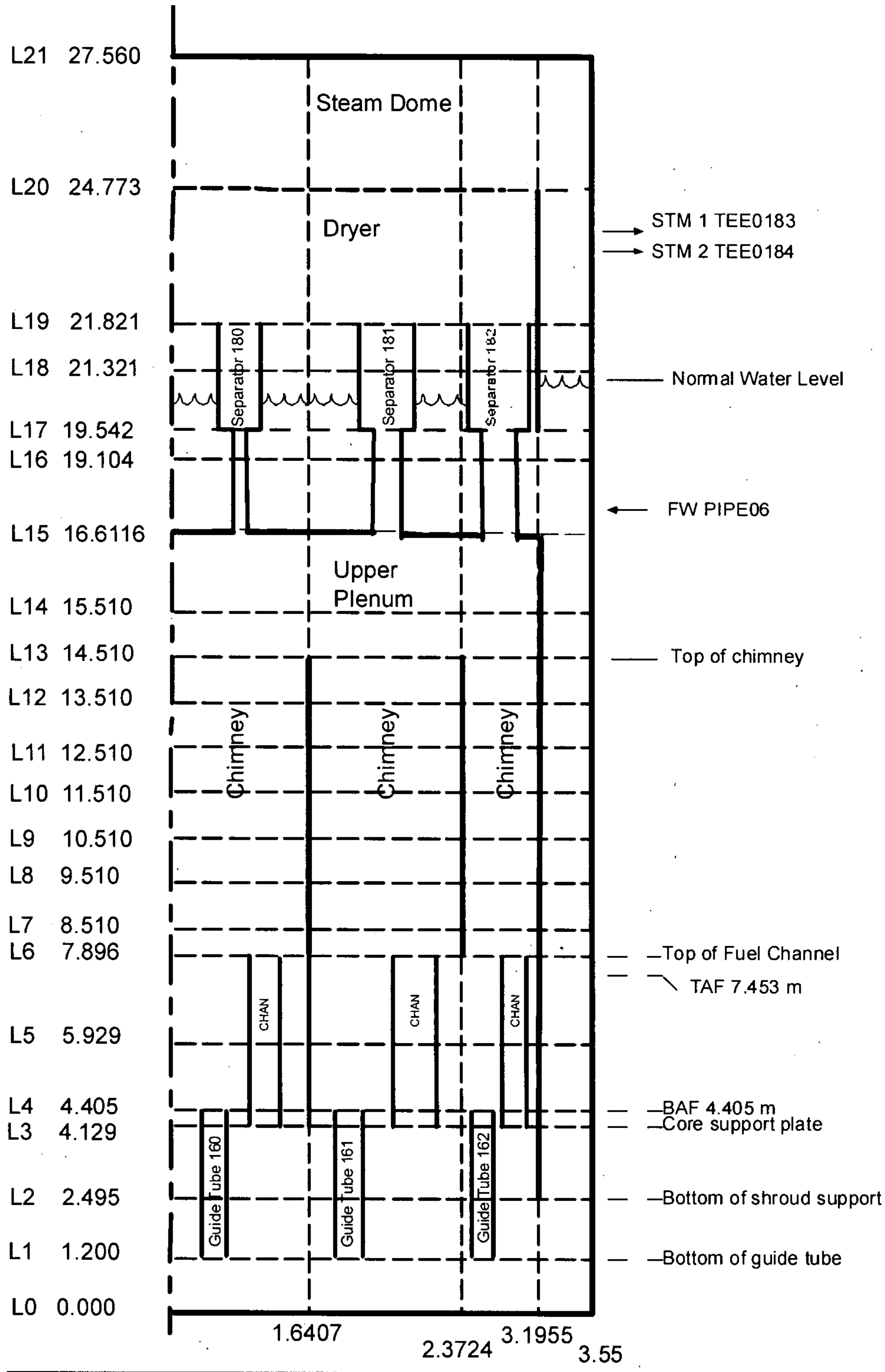
RAI 6.2-98 S01 Figure 6.2-98 S01-46 compares the DW pressures from these two cases. For the MSLB case, essentially all NC gases remaining in the DW head and GDCS airspaces (Paragraph A1.4) are purged into the WW after 20 hours. The calculated DW pressure in the MSLB case accounts for the effect that all NC gases have been purged into the WW. After 20 hours, the calculated DW pressures from these two cases are very similar in trend. The DW pressure in the MSLB case is higher than that in the FWLB case. The pressure difference is more or less constant through out the rest of the transient.

At 72 hours, the difference in DW pressure between these two cases is (384.6 kPa – 351.7 kPa) or 32.9 kPa (DCD Tier 2, Revision 4, Table 6.2-5). The calculated DW pressure is lower in the FWLB case is due to the lower suppression pool surface temperature, lower WW gas temperature and some hideout NC gas. The combined effect of these factors on the long-term DW pressure is an increase of (10.0 + 3.5 + 17.6) or

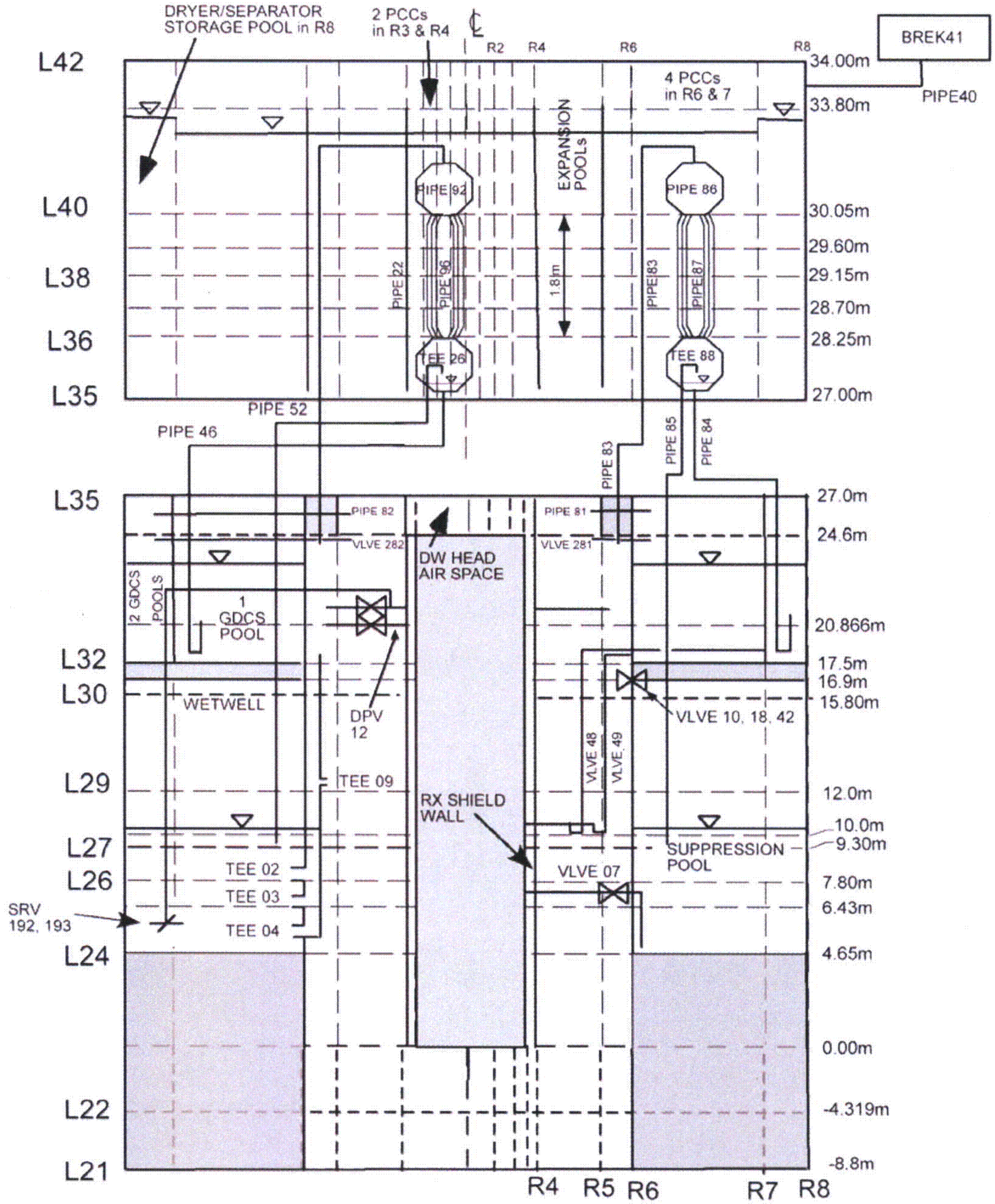
31.7 kPa. Accounting for this combined effect, the calculated DW pressure in the FWLB case agree very well with that calculated in the MSLB case.

It should be noted that approximately 41% of the difference in the DW pressures is due to the differences in the suppression pool surface and WW gas temperatures. These temperature differences are results of response to different blowdown transient from different break size and location.

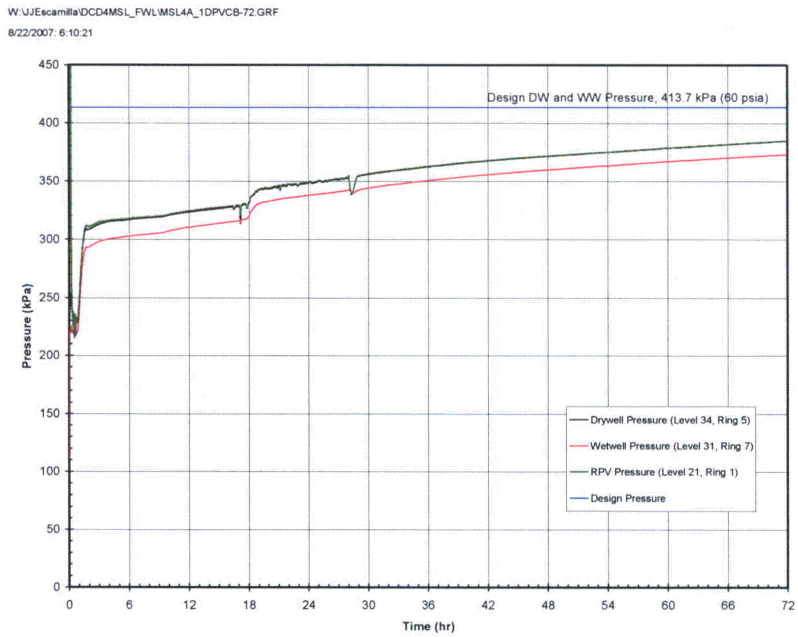
(E) The effect of the DW gas recirculation system and any other systems that may be credited in the long-term containment pressure and temperature analyses will be provided in a future RAI response.



RAI 6.2-98 S01 Figure 6.2-98 S01-1. DCD TRACG Nodalization of the ESBWR RPV

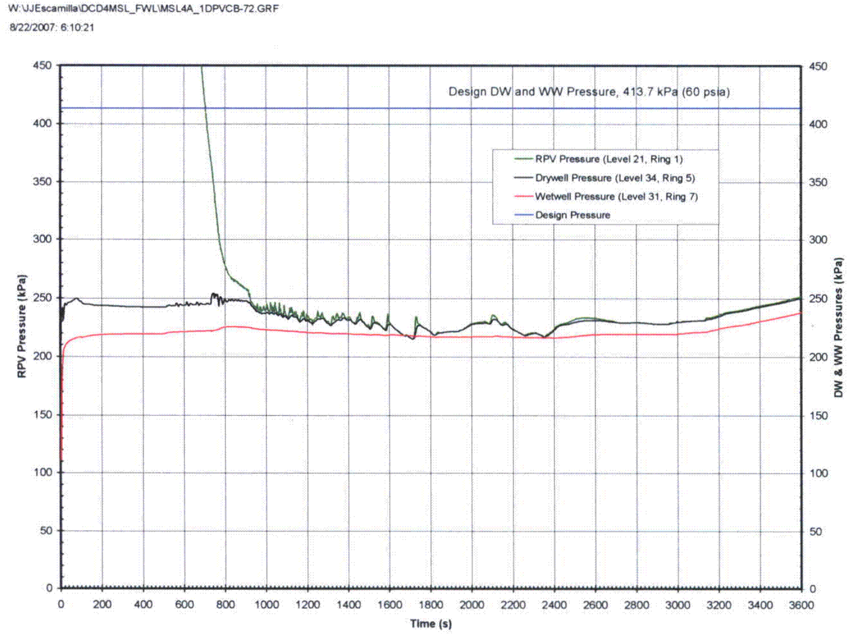


RAI 6.2-98 S01 Figure 6.2-98 S01-2. DCD TRACG Nodalization of the ESBWR Containment



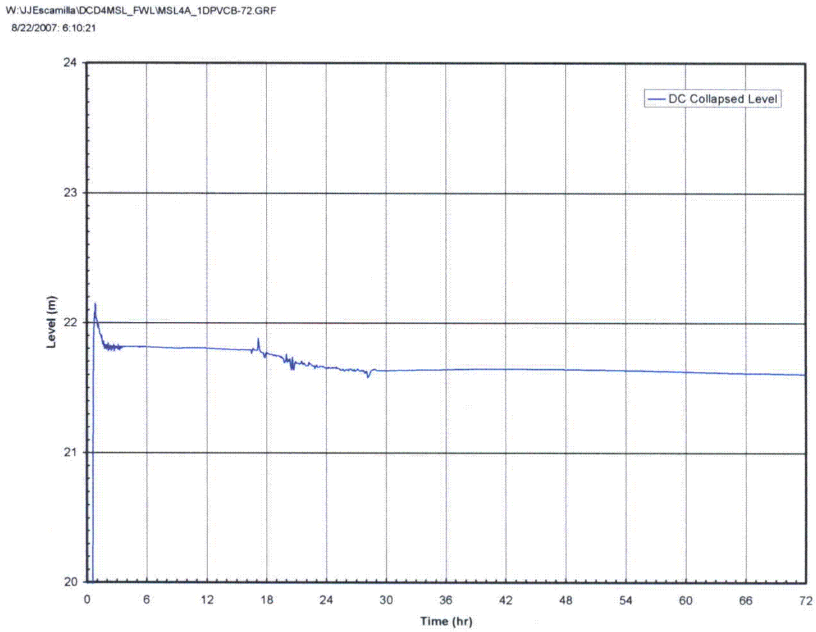
RAI 6.2-98 S01 Figure 6.2-98 S01-3. Containment Pressure Response (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



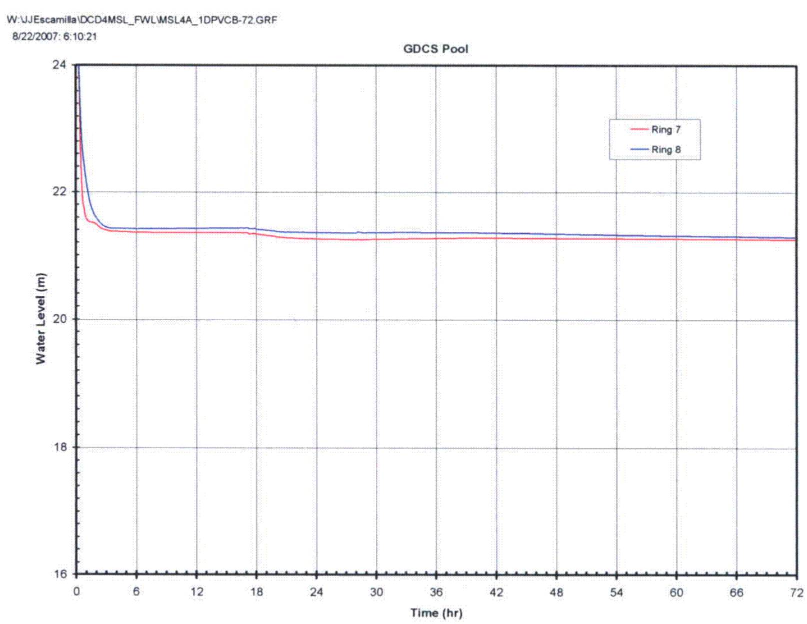
RAI 6.2-98 S01 Figure 6.2-98 S01-3a. Containment Pressure Response (Short-Term Time Scale) (3600 Seconds)

(MSLB: MSL4A_1DPVCB-72)



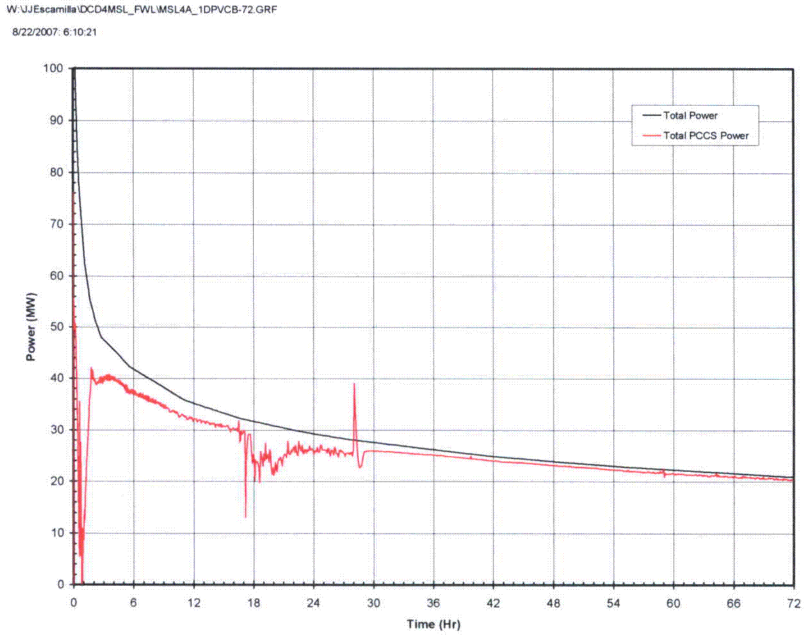
RAI 6.2-98 S01 Figure 6.2-98 S01-4. Downcomer Collapsed Level (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



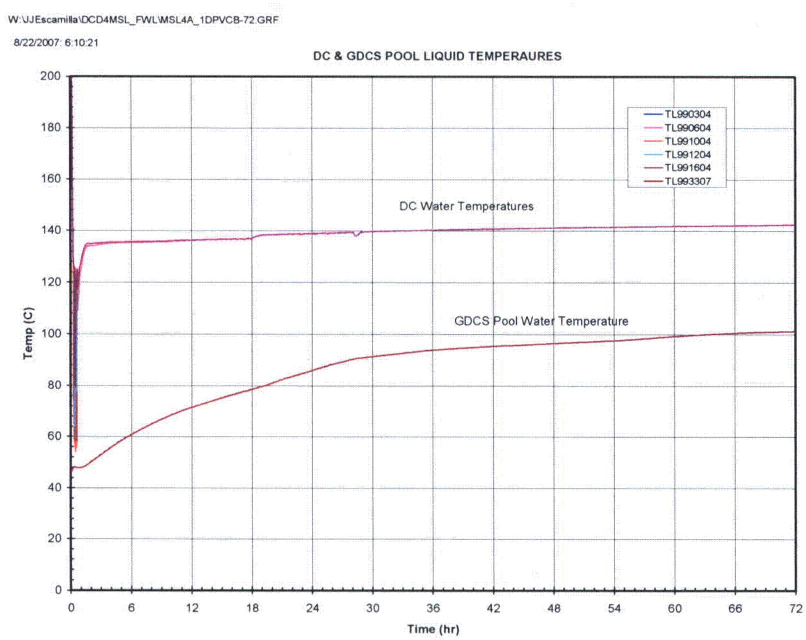
RAI 6.2-98 S01 Figure 6.2-98 S01-5. GDCS Pool Levels (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



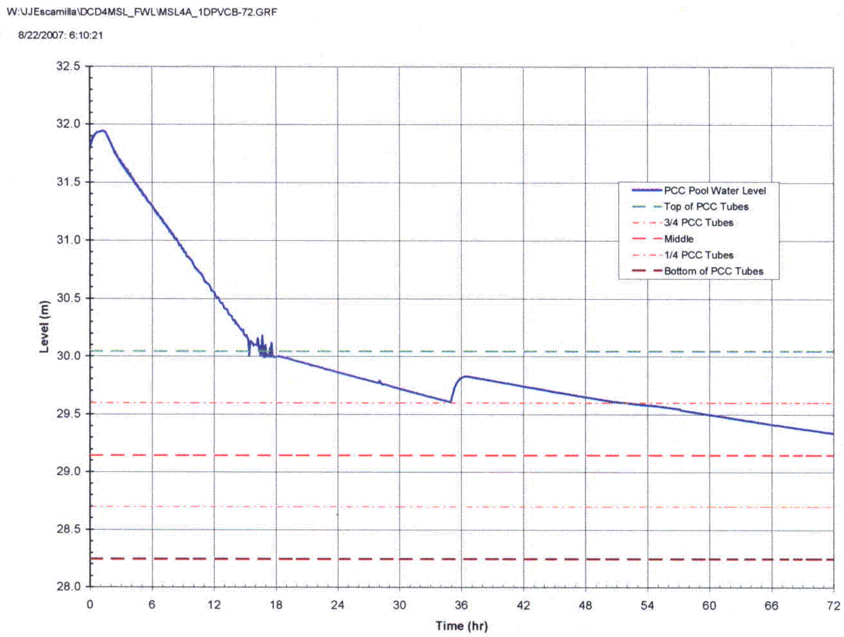
RAI 6.2-98 S01 Figure 6.2-98 S01-6. PCCS Heat Removal versus Decay Heat (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



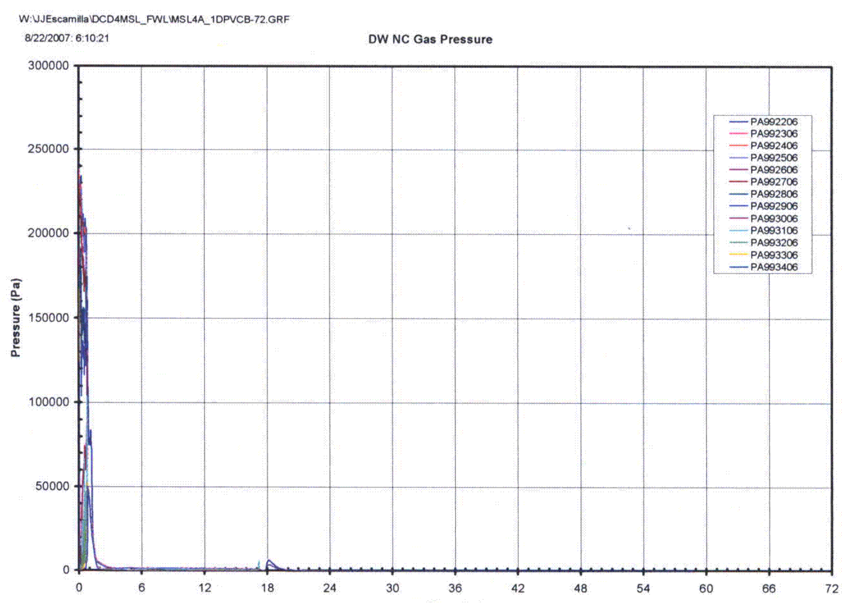
RAI 6.2-98 S01 Figure 6.2-98 S01-7. GDCS Pool Water Temperature (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



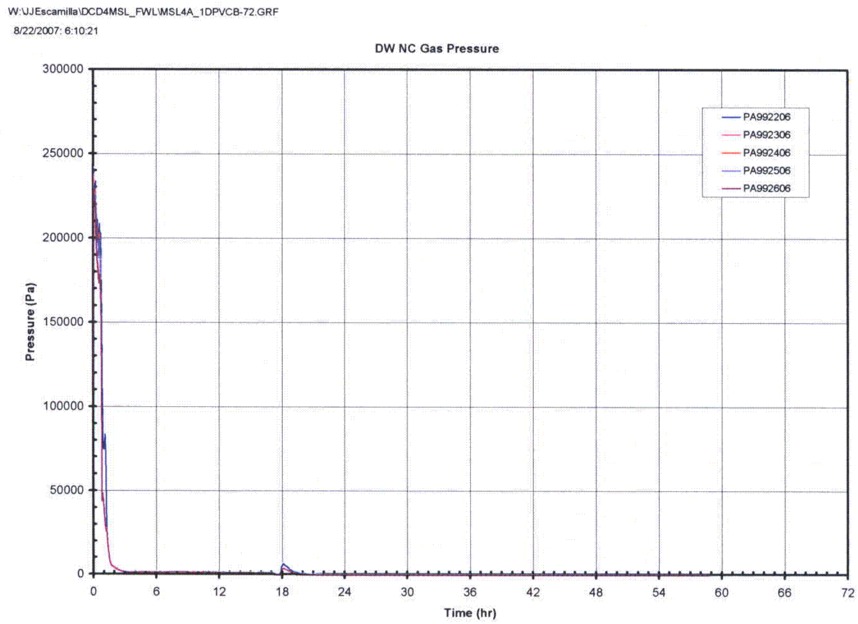
RAI 6.2-98 S01 Figure 6.2-98 S01-8. IC/PCC Pool Water Level (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



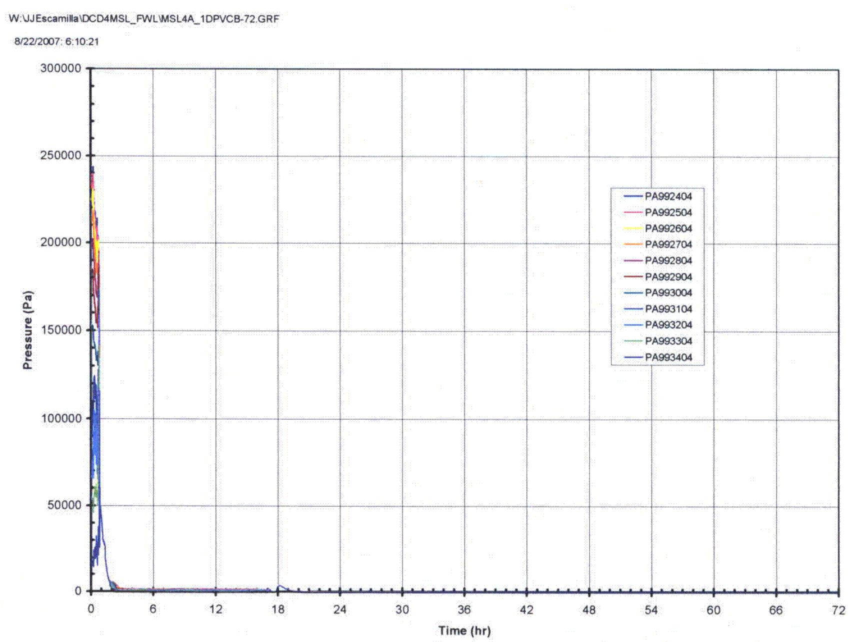
RAI 6.2-98 S01 Figure 6.2-98 S01-9. DW Annulus NC Gas Pressures (Level 23 - Second Level from Bottom, Level 34 - Top) (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



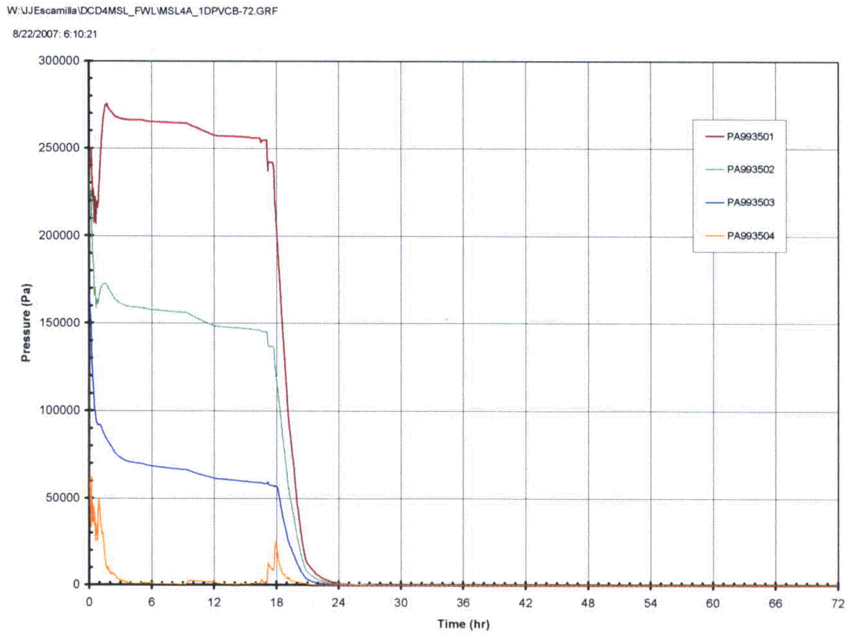
RAI 6.2-98 S01 Figure 6.2-98 S01-10. Lower DW NC Gas Pressures (Level 23 - Second Level from DW Bottom) (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



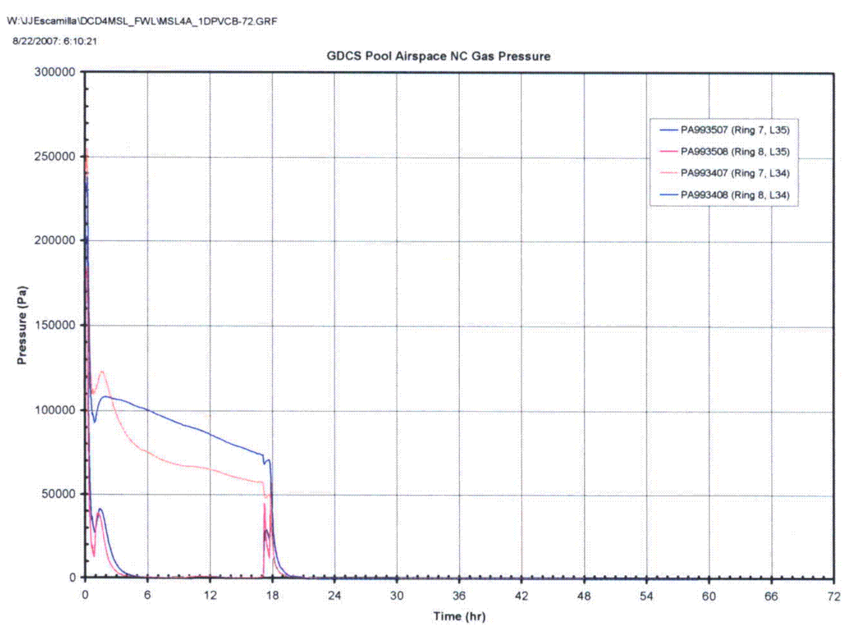
RAI 6.2-98 S01 Figure 6.2-98 S01-11. DW-Reactor Shield Wall NC Gas Pressures (Level 24 - Bottom, Level 34 - Top) (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



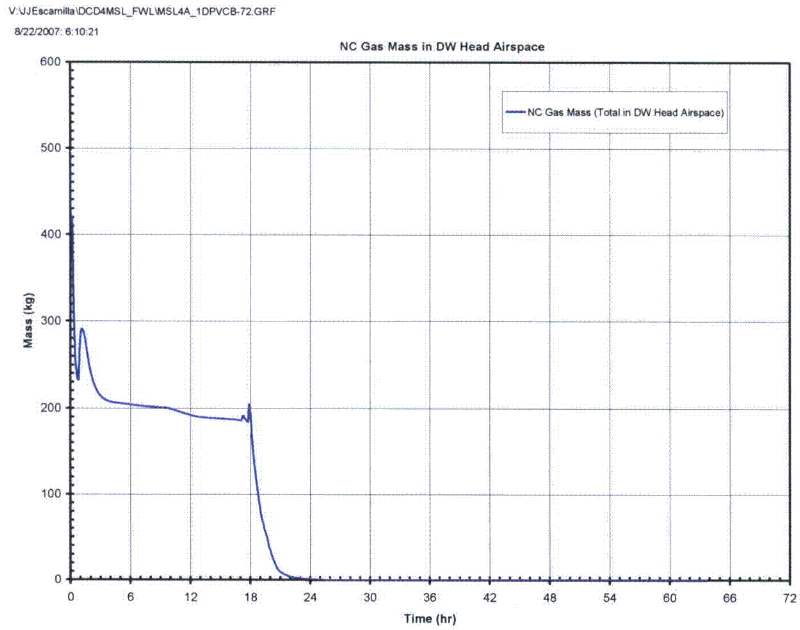
RAI 6.2-98 S01 Figure 6.2-98 S01-12. DW Head NC Gas Pressures (Level 35 - DW Head) (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



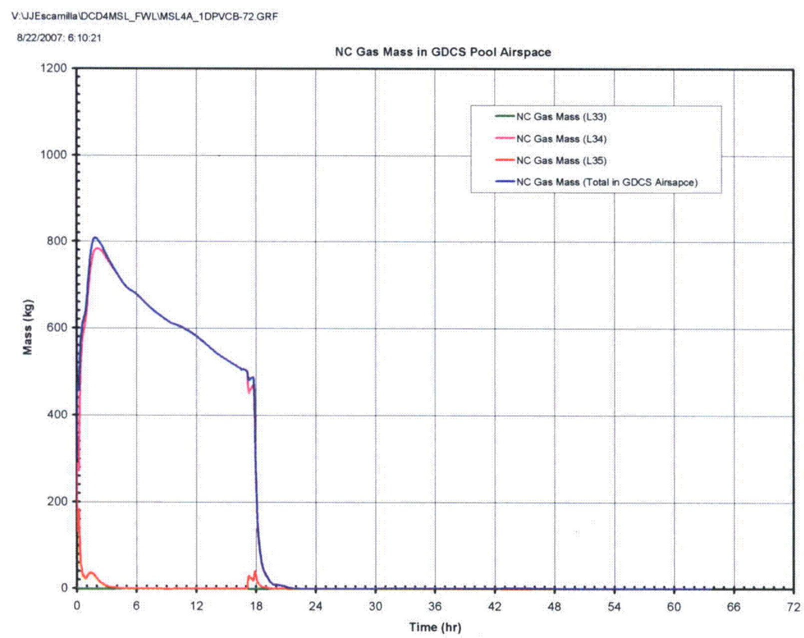
RAI 6.2-98 S01 Figure 6.2-98 S01-13. GDCS Pool Airspace NC Gas Pressures (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



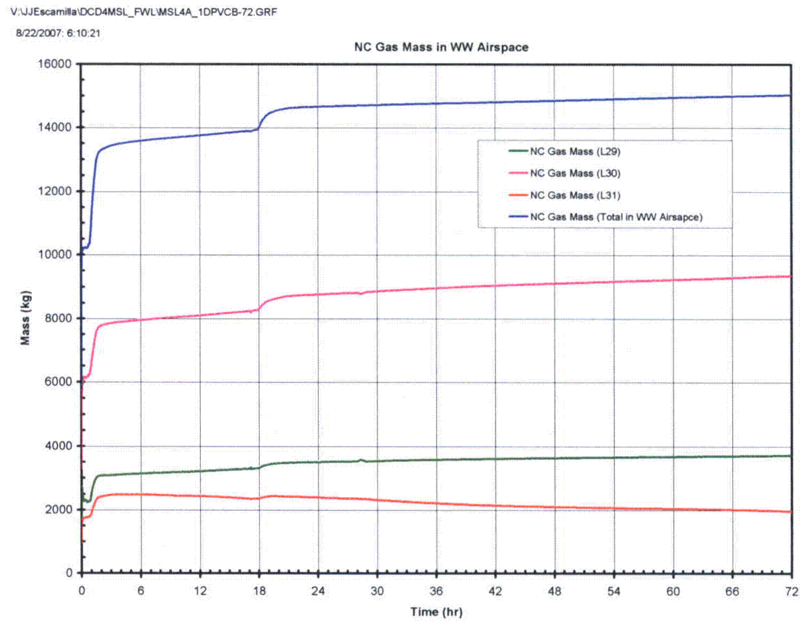
RAI 6.2-98 S01 Figure 6.2-98 S01-14. NC Gas Mass Profile in the DW Head Airspace (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



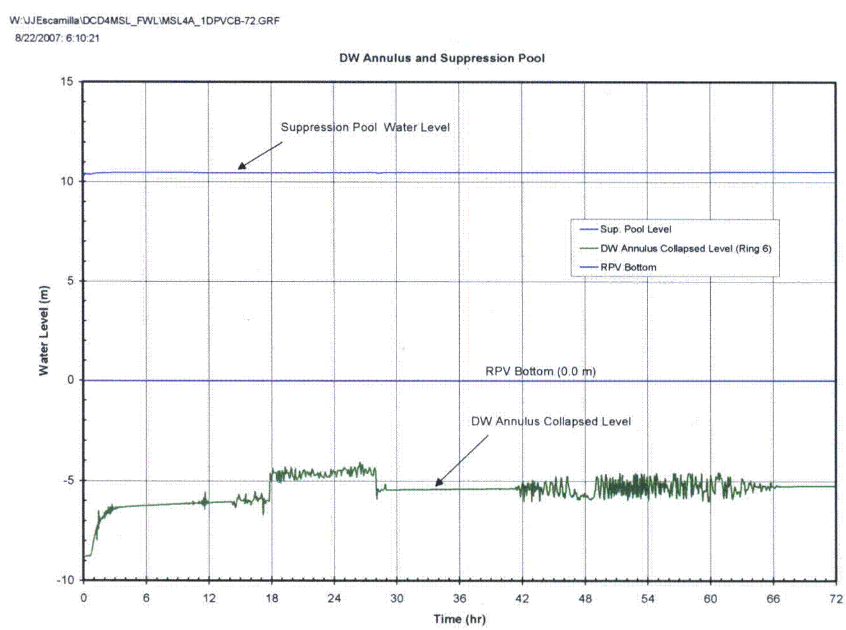
RAI 6.2-98 S01 Figure 6.2-98 S01-15. NC Gas Mass Profiles in the GDCS Pool Airspace (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



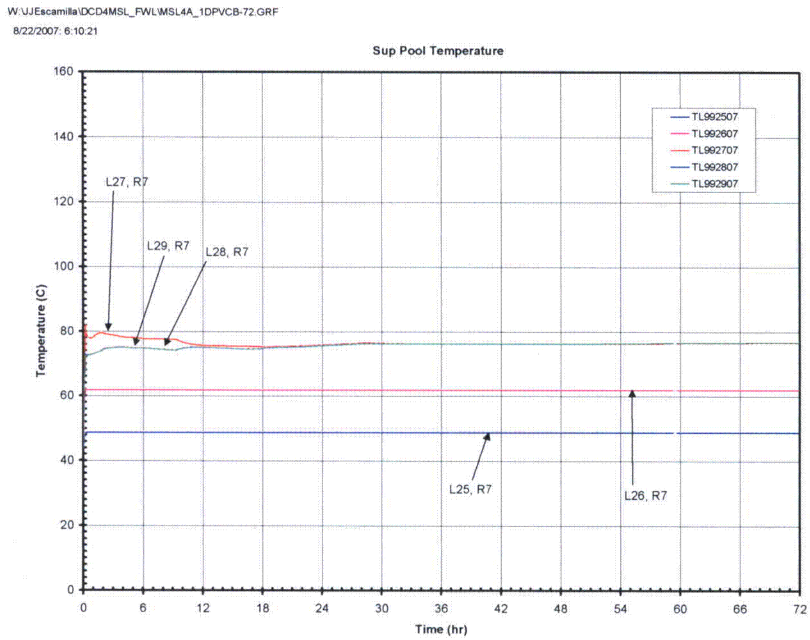
RAI 6.2-98 S01 Figure 6.2-98 S01-16. NC Gas Mass Profiles in the WW (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



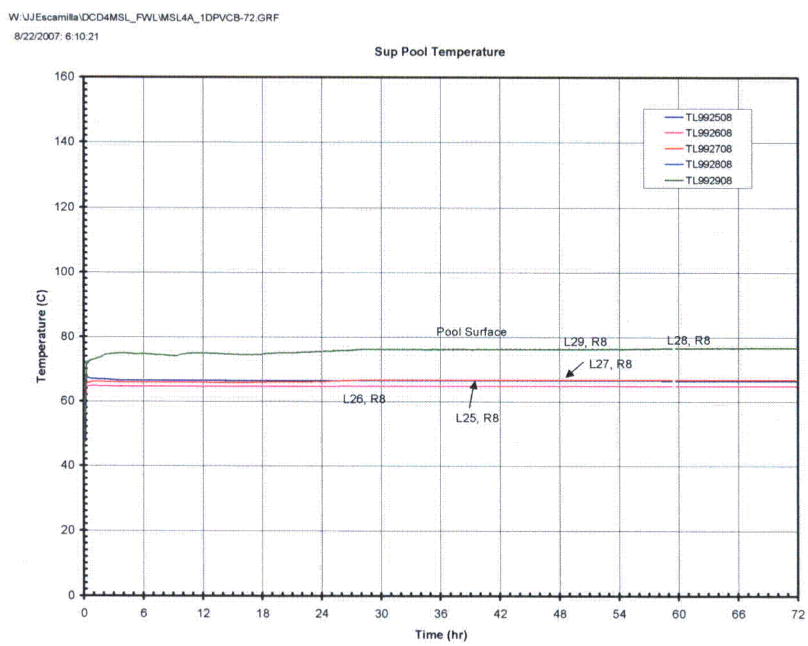
RAI 6.2-98 S01 Figure 6.2-98 S01-17. DW Annulus and Suppression Pool Levels (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



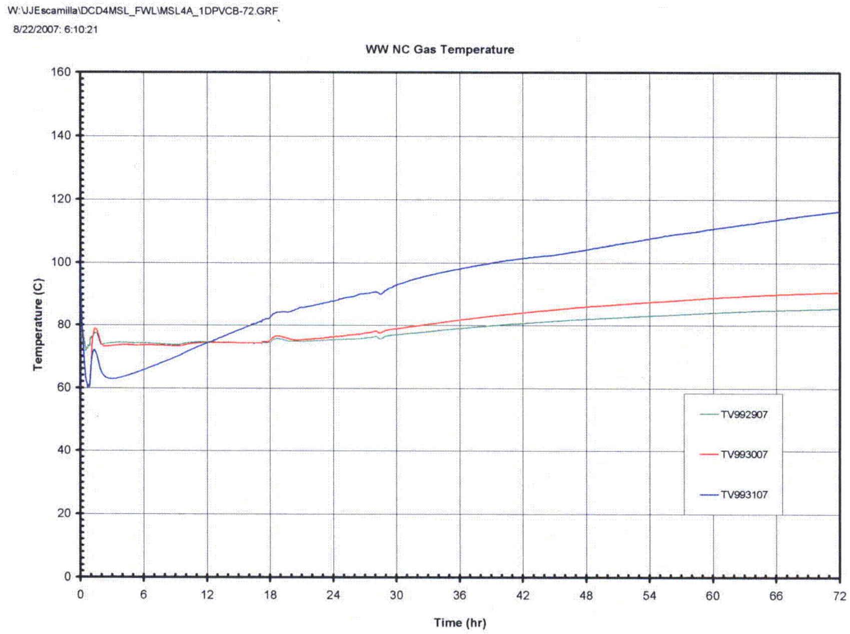
RAI 6.2-98 S01 Figure 6.2-98 S01-18. Suppression Pool Water Temperatures (at Ring 7) (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



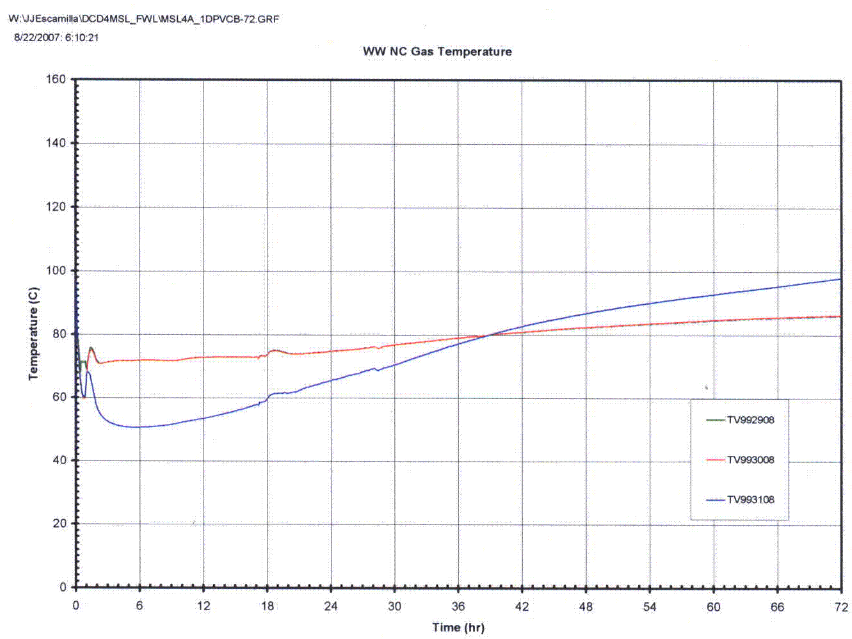
RAI 6.2-98 S01 Figure 6.2-98 S01-19. Suppression Pool Water Temperatures (at Ring 8) (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



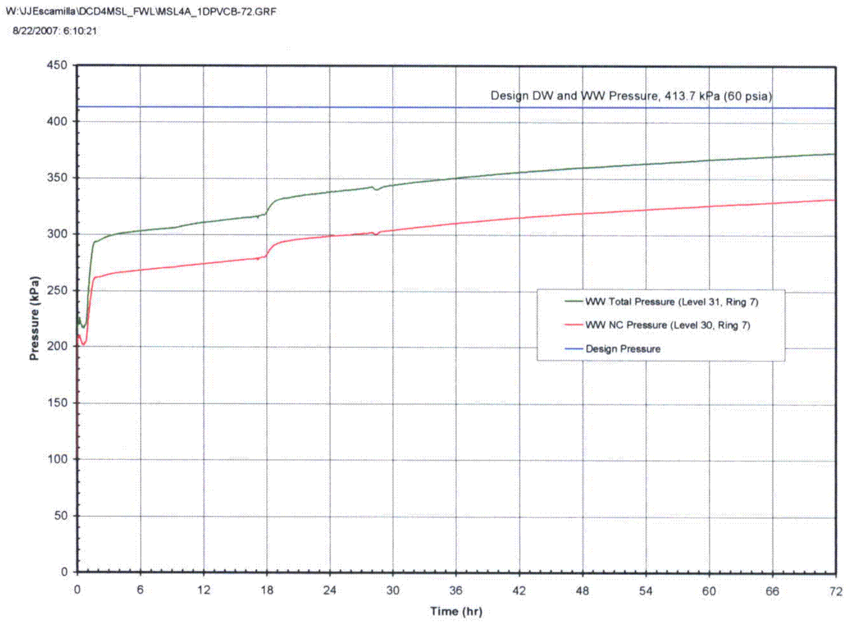
RAI 6.2-98 S01 Figure 6.2-98 S01-20. WW NC Gas Temperatures (at Ring 7) (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



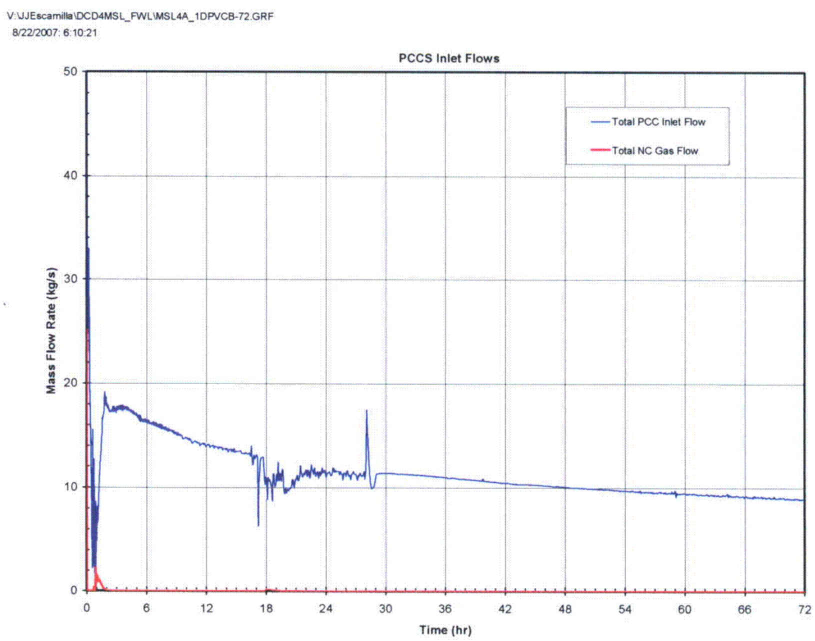
RAI 6.2-98 S01 Figure 6.2-98 S01-21. WW NC Gas Temperatures (at Ring 8) (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



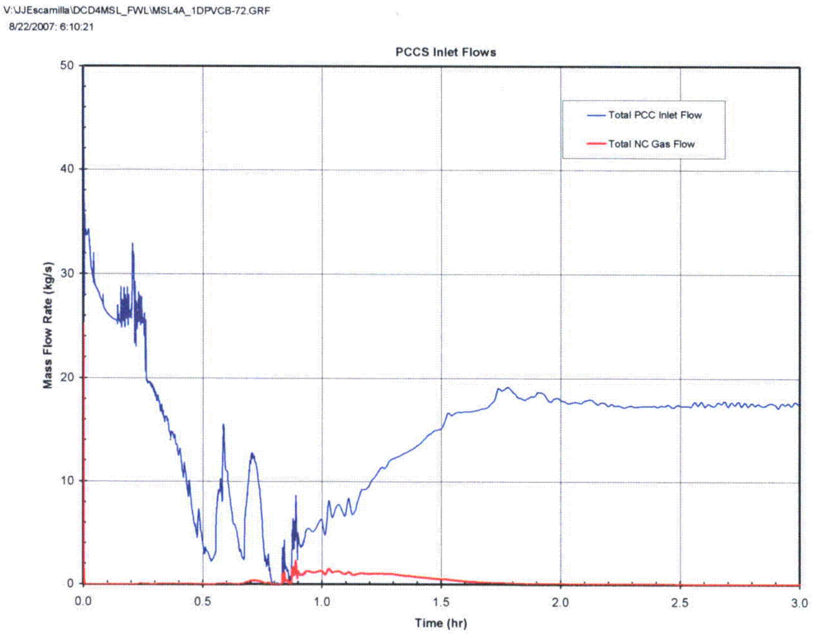
RAI 6.2-98 S01 Figure 6.2-98 S01-22. WW NC Gas Pressure (in Ring 7) (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



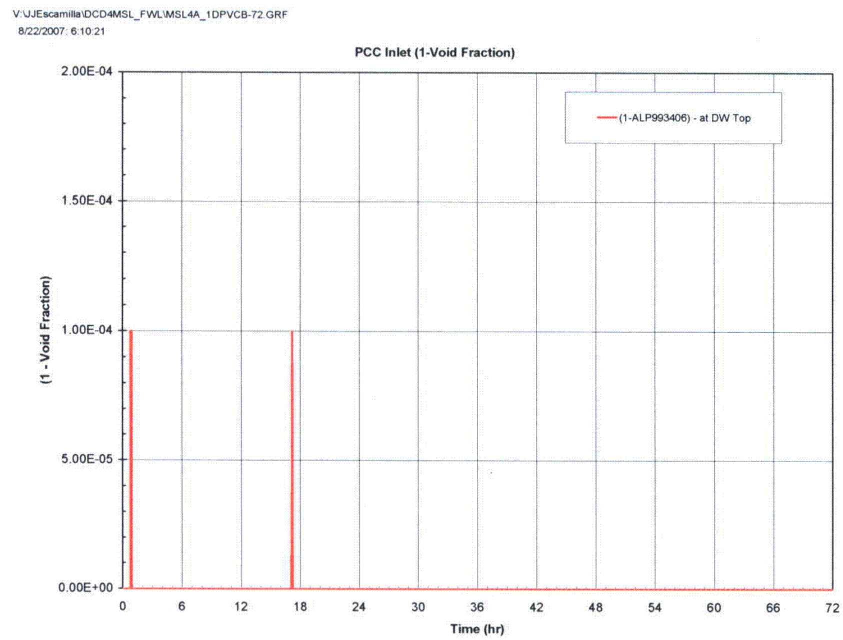
RAI 6.2-98 S01 Figure 6.2-98 S01-23. Total Mixture and NC Gas Mass Flows at the PCCS Inlet (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



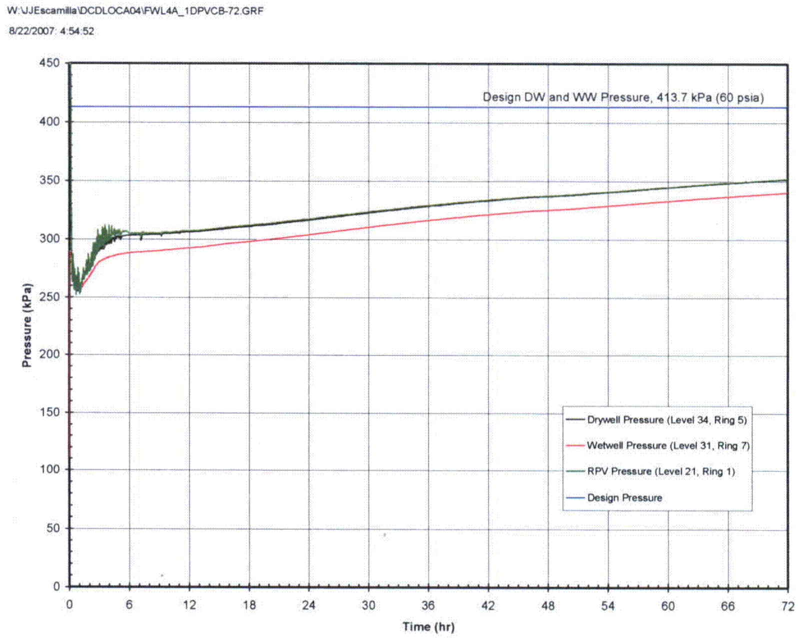
RAI 6.2-98 S01 Figure 6.2-98 S01-24. Total Mixture and NC Gas Mass Flows at the PCCS Inlet (3 Hours)

(MSLB: MSL4A_1DPVCB-72)



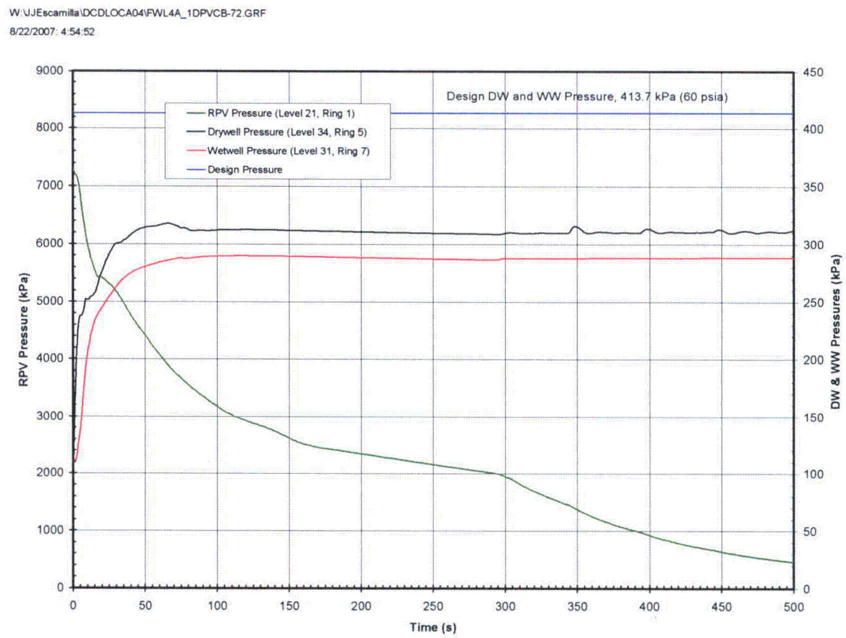
RAI 6.2-98 S01 Figure 6.2-98 S01-25. Mixture Content at the PCCS Inlet (72 Hours)

(MSLB: MSL4A_1DPVCB-72)



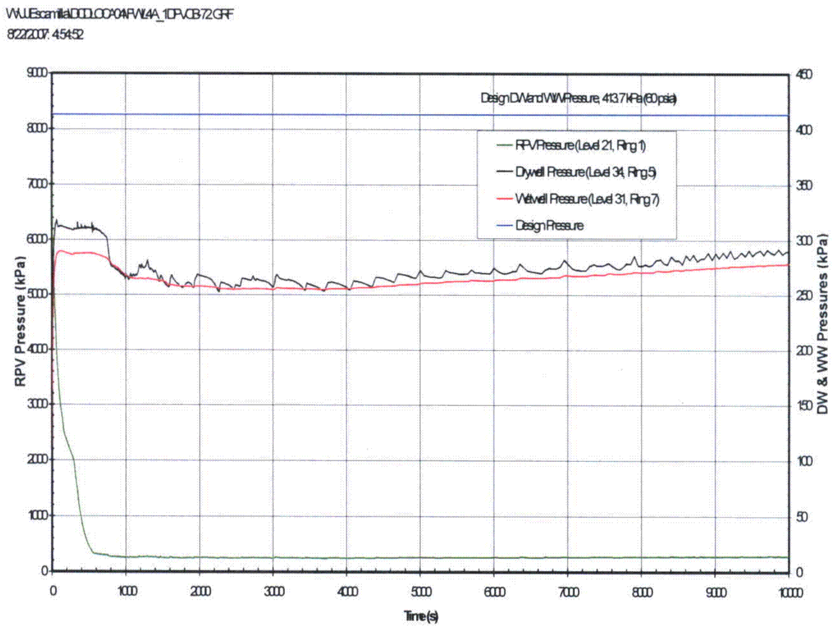
RAI 6.2-98 S01 Figure 6.2-98 S01-26. Containment Pressure Response (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



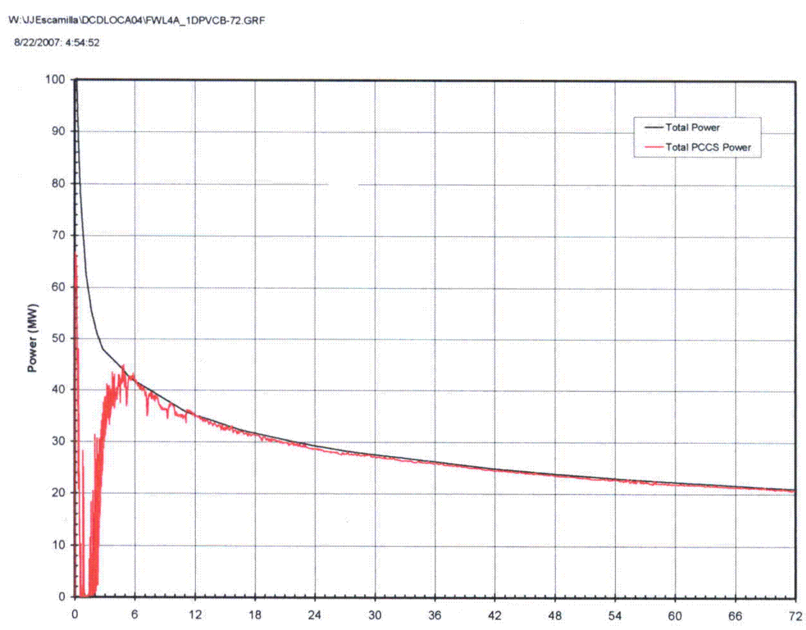
RAI 6.2-98 S01 Figure 6.2-98 S01-27. Containment Pressure Response (500 Seconds)

(FWLB: FWL4A_1DPVCB-72)



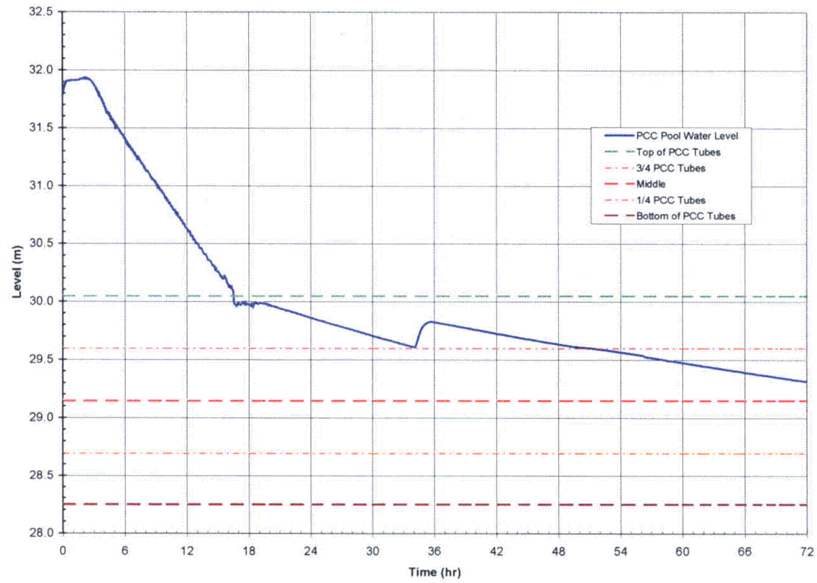
RAI 6.2-98 S01 Figure 6.2-98 S01-28. Containment Pressure Response (10000 Seconds)

(FWLB: FWL4A_1DPVCB-72)



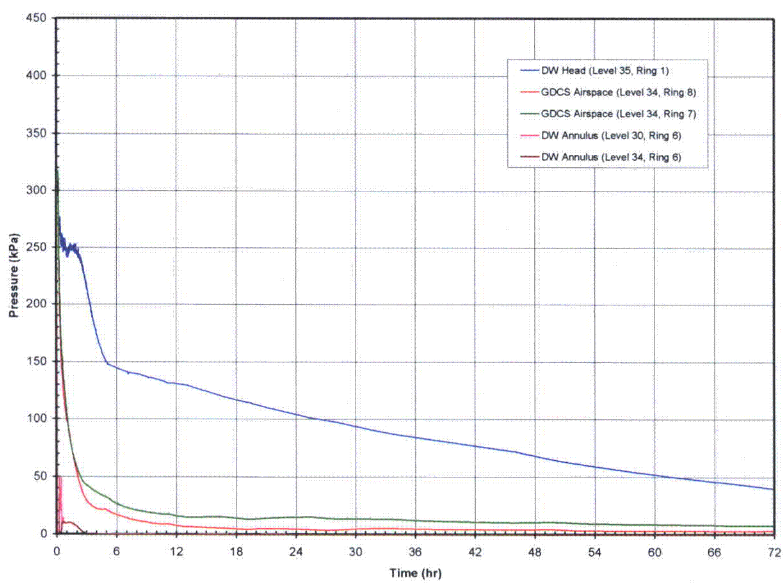
RAI 6.2-98 S01 Figure 6.2-98 S01-29. PCCS Heat Removal versus Decay Heat (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



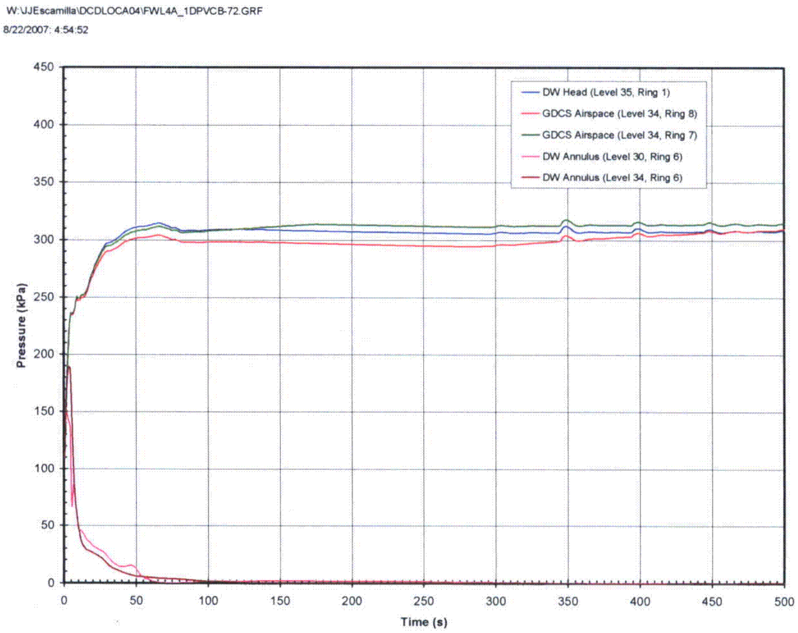
RAI 6.2-98 S01 Figure 6.2-98 S01-30. IC/PCC Pool Water Level (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



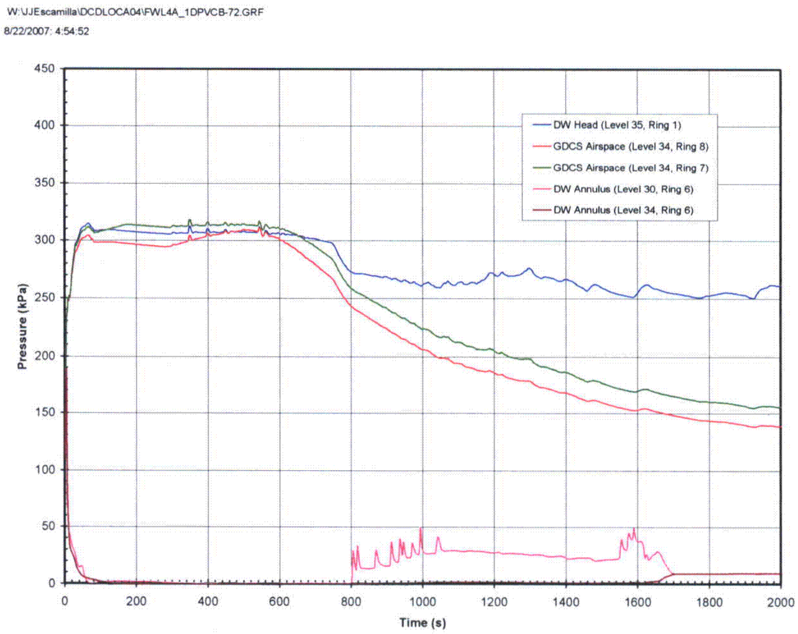
RAI 6.2-98 S01 Figure 6.2-98 S01-31. DW and GDCS NC Gas Pressures (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



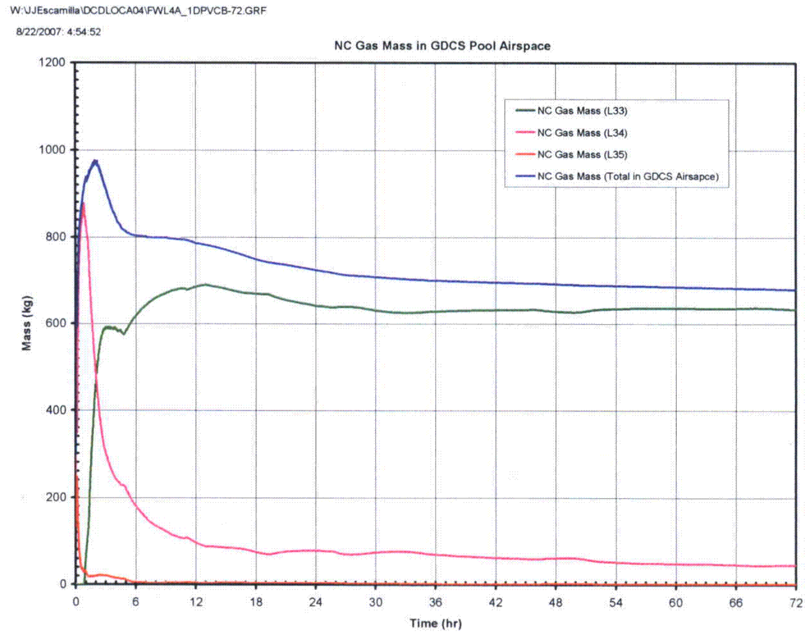
RAI 6.2-98 S01 Figure 6.2-98 S01-32. DW and GDCS NC Gas Pressures (500 Seconds)

(FWLB: FWL4A_1DPVCB-72)



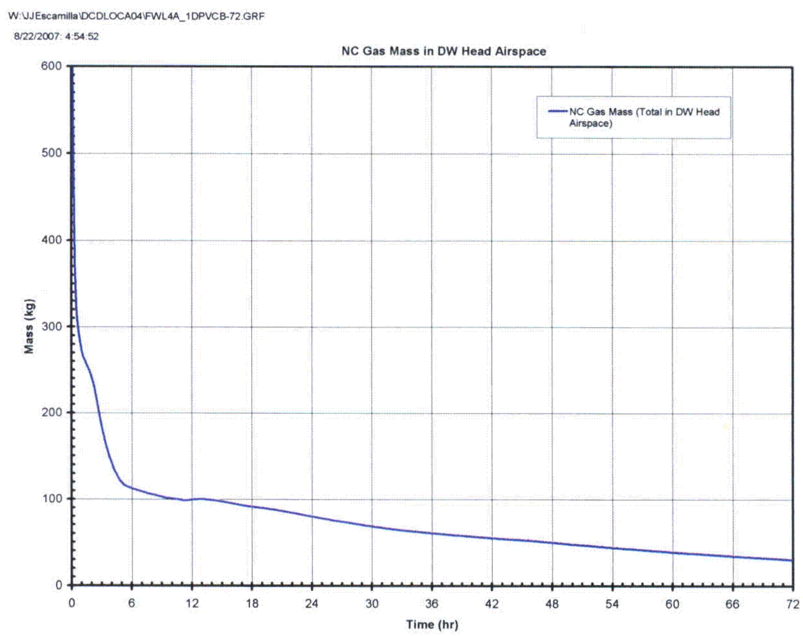
RAI 6.2-98 S01 Figure 6.2-98 S01-33. DW and GDCS NC Gas Pressures (2000 Seconds)

(FWLB: FWL4A_1DPVCB-72)



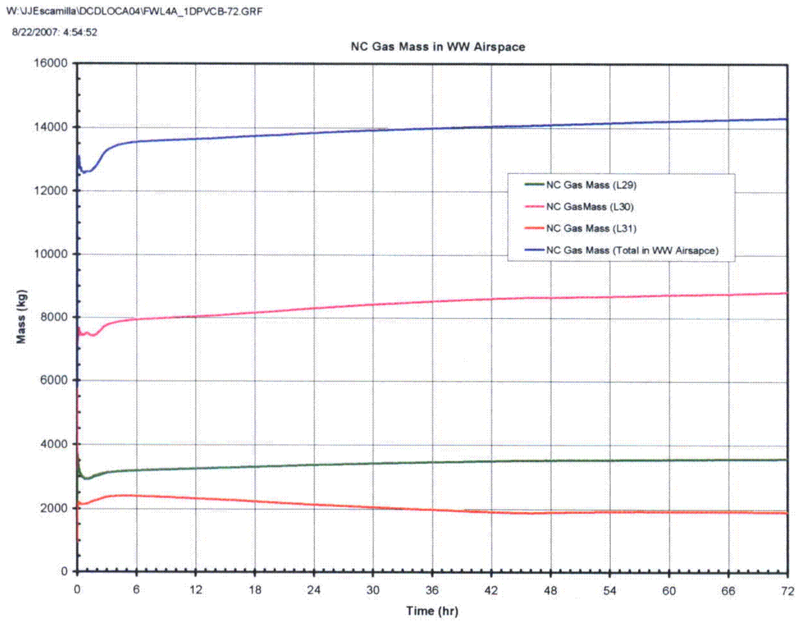
RAI 6.2-98 S01 Figure 6.2-98 S01-34. NC Gas Mass Profiles in the GDCS Airspace (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



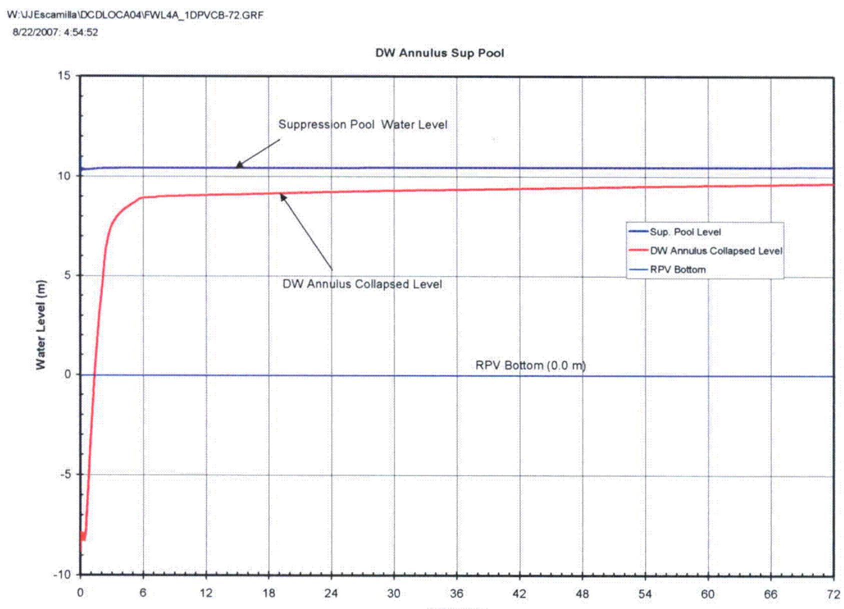
RAI 6.2-98 S01 Figure 6.2-98 S01-35. NC Gas Mass Profiles in the DW Head Airspace (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



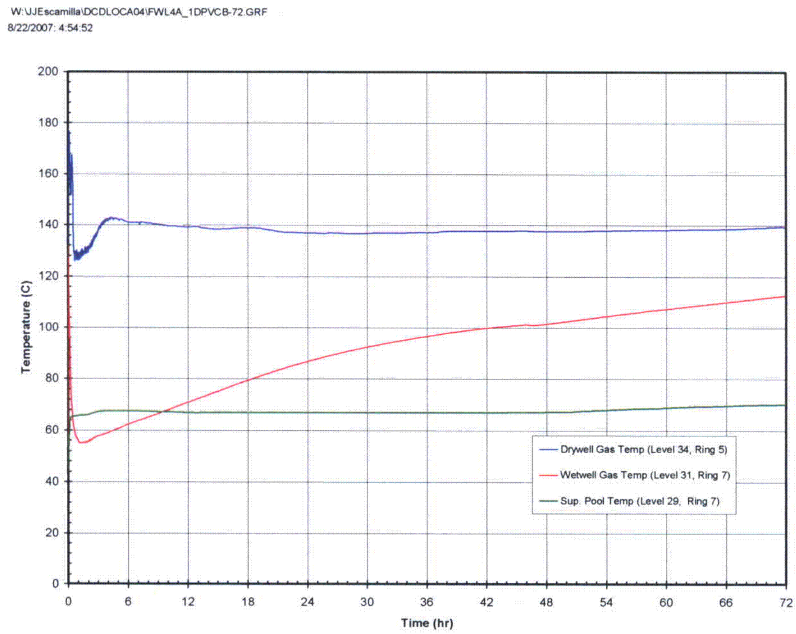
RAI 6.2-98 S01 Figure 6.2-98 S01-36. NC Gas Mass Profiles in the WW (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



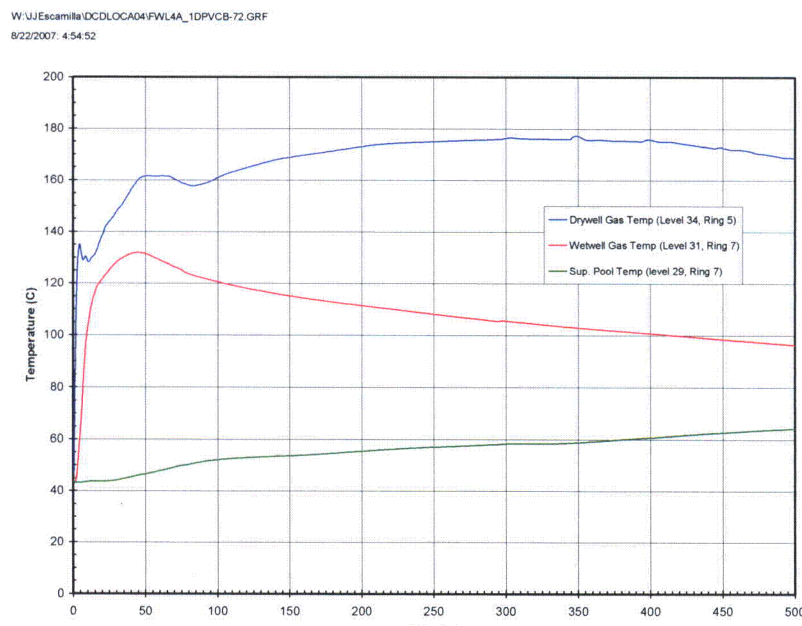
RAI 6.2-98 S01 Figure 6.2-98 S01-37. DW Annulus and Suppression Pool Levels (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



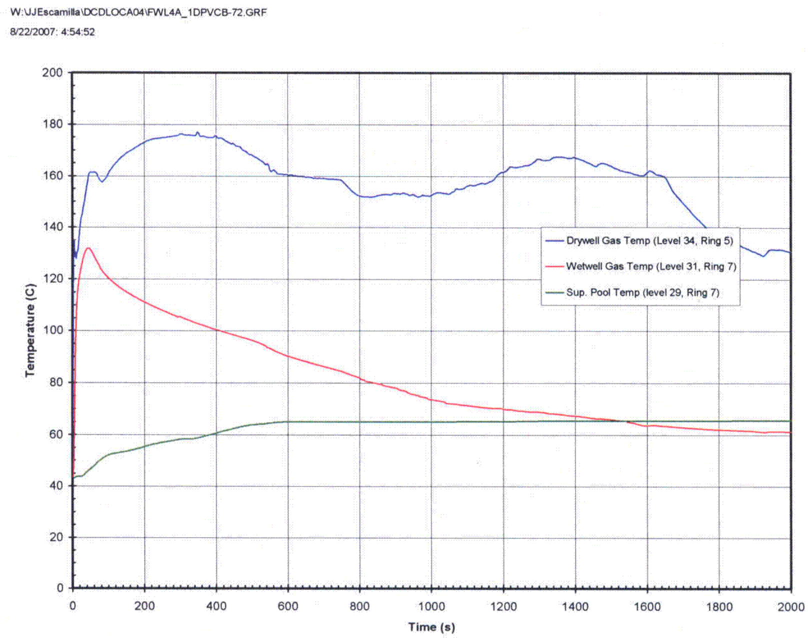
RAI 6.2-98 S01 Figure 6.2-98 S01-38. Containment Temperatures (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



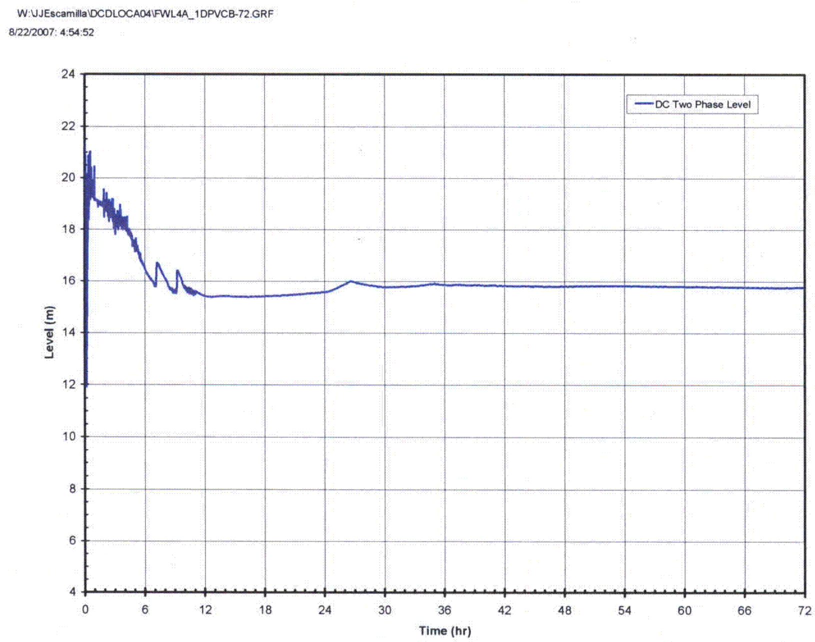
RAI 6.2-98 S01 Figure 6.2-98 S01-39. Containment Temperatures (500 Seconds)

(FWLB: FWL4A_1DPVCB-72)



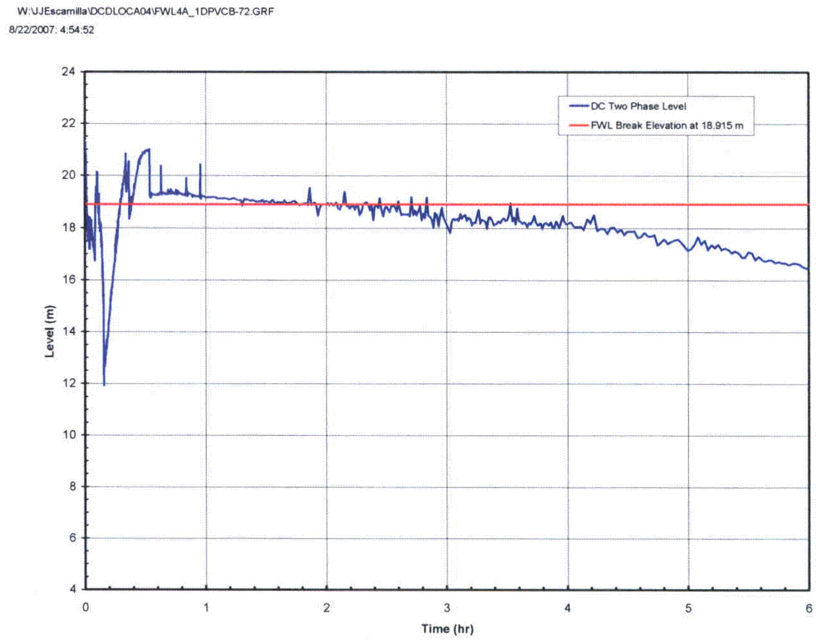
RAI 6.2-98 S01 Figure 6.2-98 S01-40. Containment Temperatures (2000 Seconds)

(FWLB: FWL4A_1DPVCB-72)



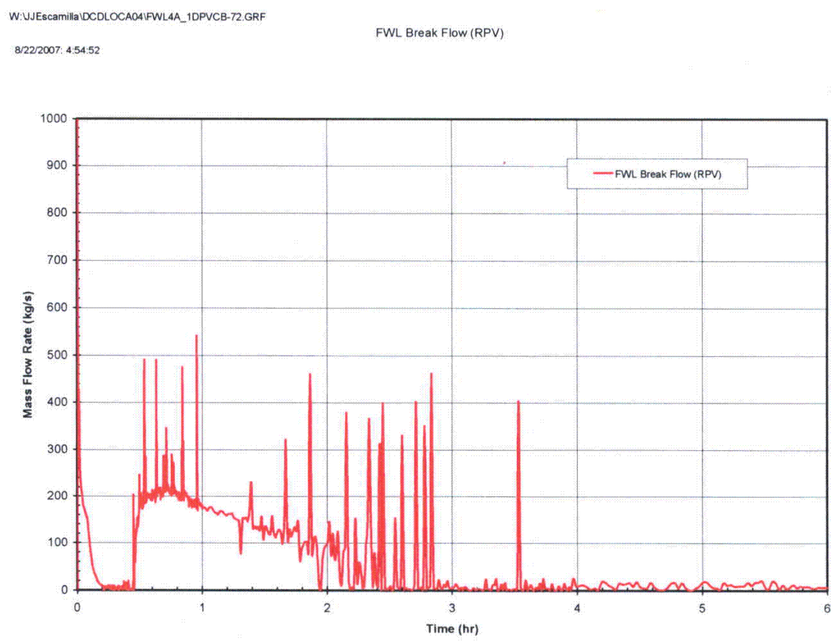
RAI 6.2-98 S01 Figure 6.2-98 S01-41. Two-Phase Level in the RPV Downcomer (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



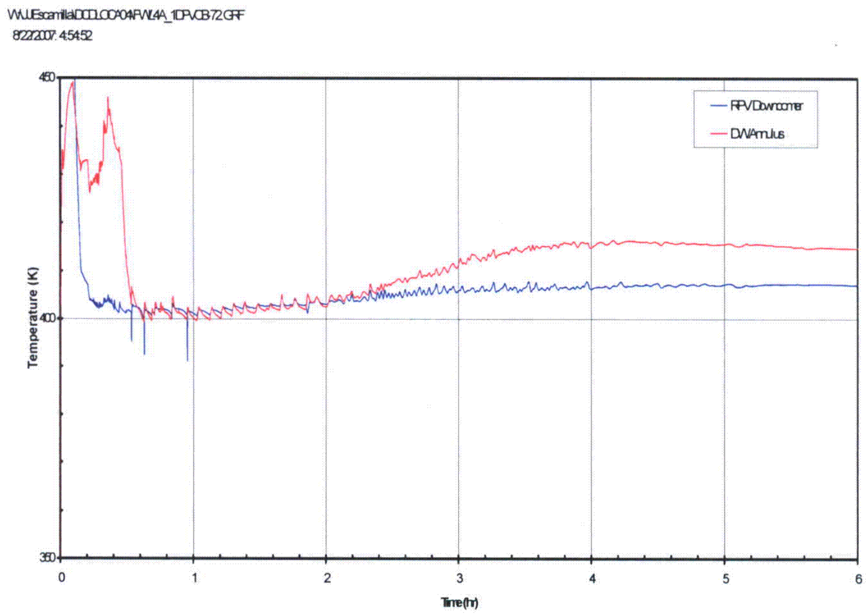
RAI 6.2-98 S01 Figure 6.2-98 S01-41a. Two-Phase Level in the RPV Downcomer (6 Hours)

(FWLB: FWL4A_1DPVCB-72)



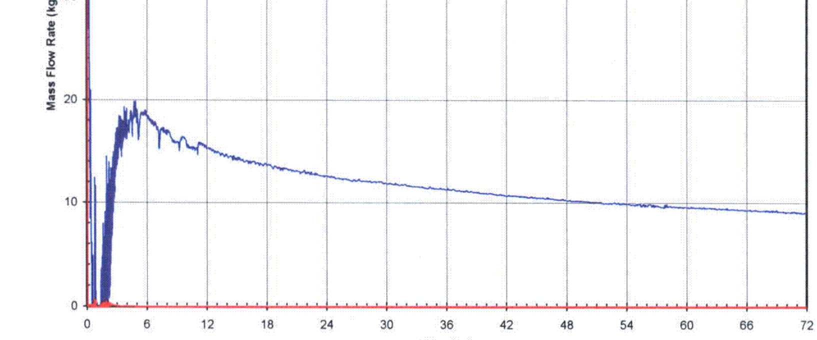
RAI 6.2-98 S01 Figure 6.2-98 S01-42. FWLB Break Flow from the RPV (6 Hours)

(FWLB: FWL4A_1DPVCB-72)



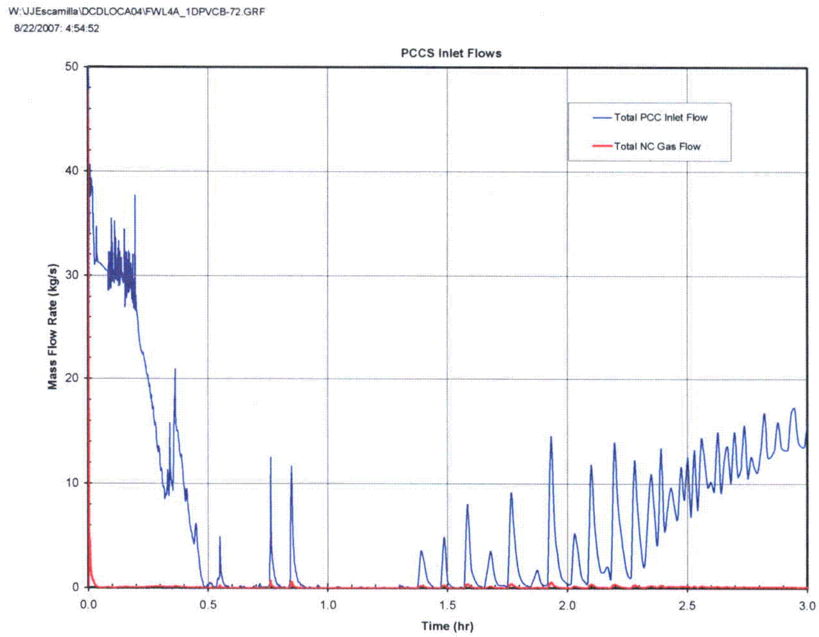
RAI 6.2-98 S01 Figure 6.2-98 S01-43. Temperatures in the RPV Downcomer and DW Annulus (6 Hours)

(FWLB: FWL4A_1DPVCB-72)



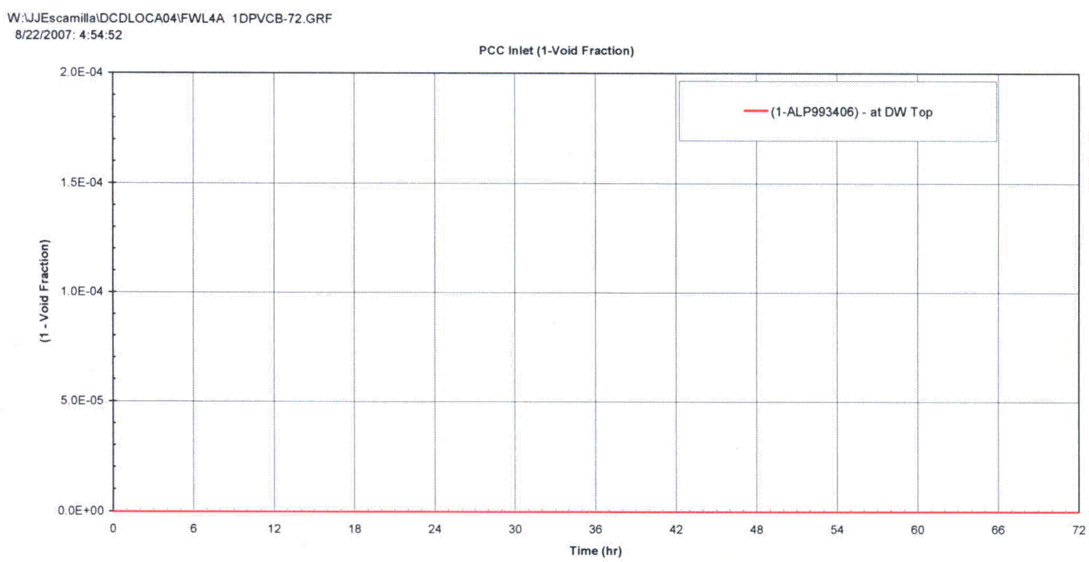
RAI 6.2-98 S01 Figure 6.2-98 S01-44. Total Mixture and NC Gas Mass Flows at the PCCS Inlet (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



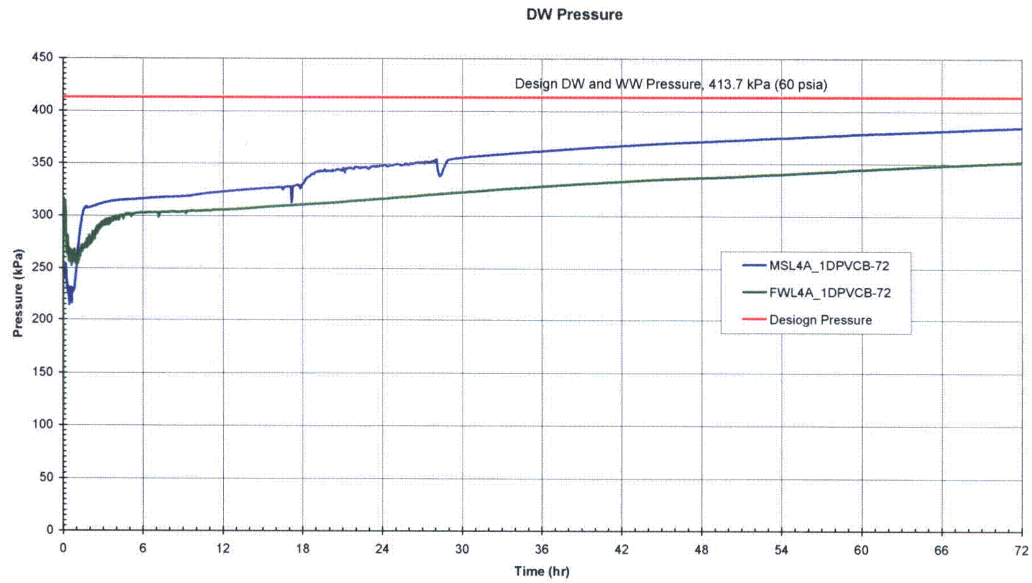
RAI 6.2-98 S01 Figure 6.2-98 S01-45. Total Mixture and NC Gas Mass Flows at the PCCS Inlet (3 Hours)

(FWLB: FWL4A_1DPVCB-72)



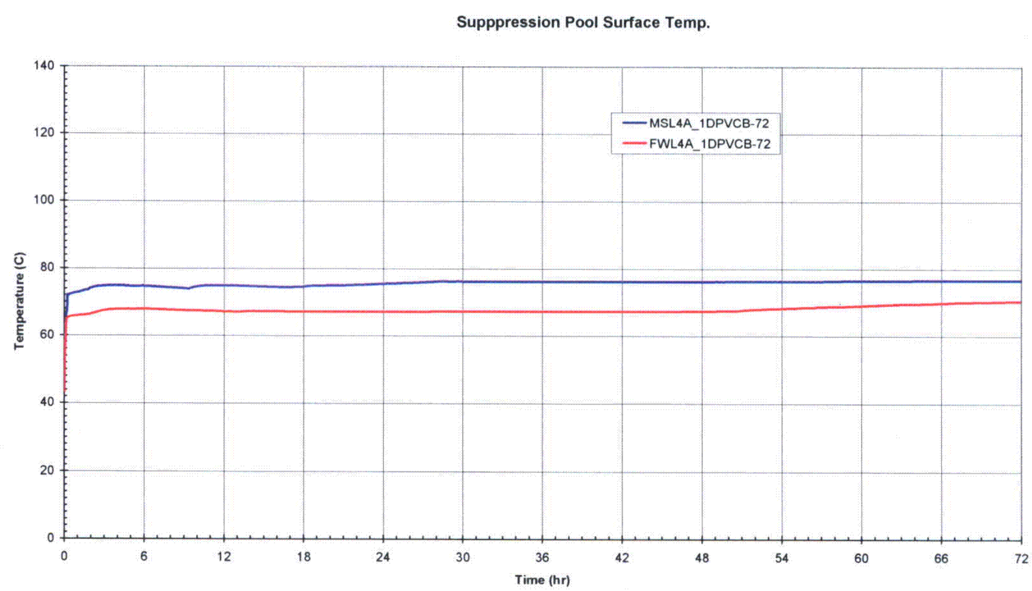
RAI 6.2-98 S01 Figure 6.2-98 S01-45a. Moisture Content at the PCCS Inlet (72 Hours)

(FWLB: FWL4A_1DPVCB-72)



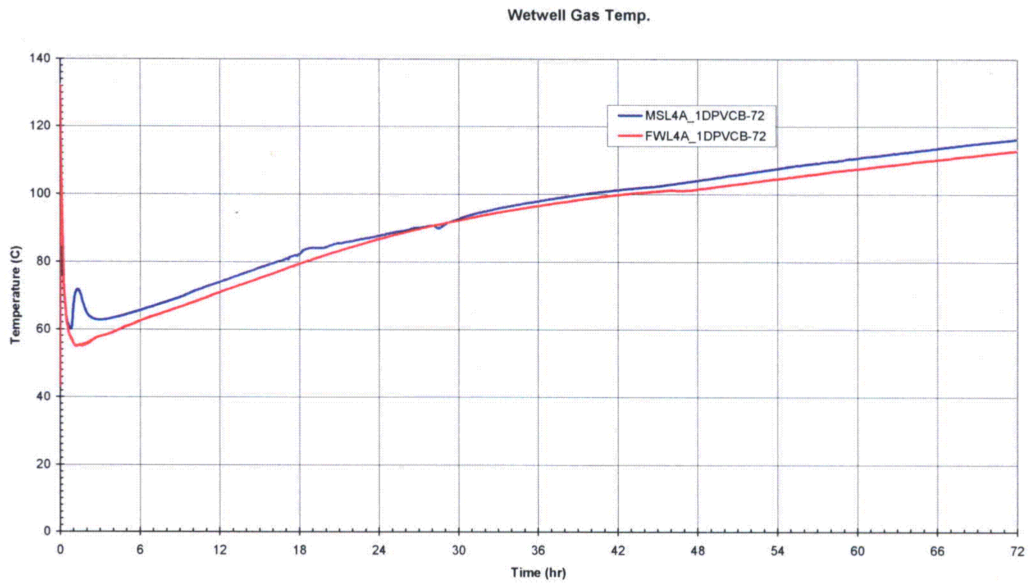
RAI 6.2-98 S01 Figure 6.2-98 S01-46. Comparison of DW Pressures – MSLB versus FWLB (72 Hours)

(MSLB: MSL4A_1DPVCB-72; FWLB: FWL4A_1DPVCB-72)



RAI 6.2-98 S01 Figure 6.2-98 S01-47. Comparison of Suppression Pool Surface Temperatures MSLB versus FWLB (72 Hours)

(MSLB: MSL4A_1DPVCB-72; FWLB: FWL4A_1DPVCB-72)



RAI 6.2-98 S01 Figure 6.2-98 S01-48. Comparison of WW Gas Temperatures MSLB versus FWLB (72 Hours)

(MSLB: MSL4A_1DPVCB-72; FWLB: FWL4A_1DPVCB-72)

15.0 NRC RAI 6.2-98 S01 Revision 1

RAI 6.2-98 was a follow up to RAI 6.2-53 (MFN 06-215). The intent of these RAIs was to understand the TRACG calculation for the bounding scenario. ESBWR DCD Tier 2 provides limited information that is insufficient to understand the analyses. These RAIs focused on key phenomena-the trapping and transient distribution of noncondensable gases in the drywell and subsequent transport to the wetwell.

(E) During a phone call with the staff on September 24, 2007, GEH discussed a potential design change to add a drywell gas recirculation system to the PCCS, which will start operating three days after the initiation of a LOCA to improve the PCCS's ability to remove thermal energy from the containment. In your response, please address the effect of the drywell gas recirculation system and any other systems that you plan to credit in your analyses.

15.1 GEH RESPONSE

(E) At three days after the initiation of a loss-of-coolant accident (LOCA), several mitigating measures would be in place to reduce the containment pressure and temperature, and to maintain them at reduced levels well below design limits. These measures are (1) to provide Isolation Condenser (IC)/Passive Containment Cooling (PCC) pool makeup water to improve the PCC condenser efficiency, (2) to activate the PCC vent fans (drywell gas recirculation system) to enhance the heat exchanger efficiency by removing the accumulation of non-condensable (NC) gases from the PCC condensers and circulating these gases to the Gravity-Driven Cooling System (GDCS) pool space and back to the drywell (DW), and (3) to take credit of the Passive Autocatalytic Recombiner System (PARS) in the analyses after three days. The effects of these measures on the containment pressure response have been analyzed and the key results are discussed in the response to RAI 6.2-139 (MFN 08-357, dated April 19, 2008). The response to RAI 6.2-139 also describes the PCC vent fan system, including functional arrangement and schematic diagram.

The following paragraphs provide additional discussions on the transient distribution of NC gases in the DW and GDCS pool space and subsequent transport to and from the wetwell (WW), before and after the activation of the PCC vent fans.

(1) Description of the Cases

The base case for this evaluation is a guillotine break in the main steam line under bounding conditions. For all cases described in this response, the steam bypass leakage area between the DW and WW is assumed to be the nominal value of 1 cm^2, with a single depressurization valve (DPV) failure-to-open occurrence. The following paragraphs discuss the effect of the PCC vent fans, based on an assumption of a nominal bypass leakage area of 1 cm^2. After the activation of PCC vent fans and IC/PCC pool refilling at 72 hours following a LOCA, the DW pressure drops to and remains at or below the value of WW pressure. The impact of steam bypass leakage on the containment pressure becomes very small or non-existent. Consequently, the effect of the PCC vent fans for the case with bypass leakage area of 2 cm^2 (licensing basis) is expected to be similar to those discussed below that assume a bypass leakage area of 1 cm^2.

From 0 to 72 hours following a LOCA, the analyses assume no credit from the PARS, PCC vent fans, or any other active systems. This part of the analyses is described in DCD Revision 3, Section 6.2, as the Main Steam Line Break bounding case ("MSL3_1DPVCB_NL2Pa-72").

From three to seven days following a LOCA, the analyses continue from the above calculation with no credit from the PARS. However, the IC/PCC pools are continuously refilled starting at 72 hours following a LOCA with 201 gpm of water at 100°F. Two cases are performed, one case with six PCC vent fans, (i.e., one PCC vent fan for each of the six PCC vent lines), and the other case with four PCC vent fans, (i.e., one PCC vent fan for each of the first four PCC vent lines, no vent fan for the other two PCC vent lines).

For these two cases, the PCC vent fans discharge the NC gases into the DW annulus. The effect of PCC vent fan discharge location on the DW pressure is discussed in Item (4) below. The effect of additional credit from the PARS on the DW pressure is discussed in Item (5) below.

(2) Discussions of the Key Transient Responses

RAI 6.2-98S01R01 Figure 6.2-98S01R01-1 and RAI 6.2-98S01R01 Figure 6.2-98S01R01-2 show the pressure and NC gas mass responses in the DW and WW from 0 to seven days (0 to 168 hours). RAI 6.2-98S01R01 Figure 6.2-98S01R01-3 shows the NC gas mass responses in the DW head and GDCS gas spaces from 0 to seven days (0 to 168 hours).

The key transient responses from 0 to 72 hours are discussed in Item (A1) of the response to RAI 6.2-139 (MFN 08-357, dated April 19, 2008). During the first three days of the transient, the IC/PCC pool level drops due to boil-off by the decay heat. At the end of 72 hours, the IC/PCC pool water covers about 65% of the PCC condenser tube length. At 72 hours, the PCC vent fans and the IC/PCC pool refilling are initiated. The PCC vent fans remove the accumulated NC gases from the bottom portion of the PCC condenser tubes and discharge them into the DW. The IC/PCC pool refilling continuously increases the portion of the PCC condenser tube that is covered by the IC/PCC pool water. Both actions enhance the PCC condenser heat removal rate, condensing more DW steam. As a result, the DW pressure drops rapidly shortly after the activation of these actions (RAI 6.2-98S01R01 Figure 6.2-98S01R01-1). Shortly after 72 hours, the DW pressure drops below the WW pressure, resulting in vacuum breaker (VB) openings and reversed leakage flow (i.e., from the WW to the DW). The gas mixture (mostly NC gases) flows back from the WW to the DW through the VBs and leakage path (RAI 6.2-98S01R01 Figure 6.2-98S01R01-4). This continued relocation of NC gases from the WW to the DW results in continued pressure reduction in the WW (RAI 6.2-98S01R01 Figure 6.2-98S01R01-1).

Transient Responses for the Case using Six PCC Vent Fans

Prior to 72 hours, there is a very small amount of NC gases remaining in the DW, DW head, and GDCS gas spaces (RAI 6.2-98S01R01 Figure 6.2-98S01R01-2 and RAI 6.2-98S01R01 Figure 6.2-98S01R01-3). After 72 hours, the gas mixture (mostly NC gases) flows from the WW to the DW through the VBs and the leakage path. While inside the DW, the NC gases mix with the steam (from the DPVs and break pipe) in the DW and enters into the PCC condensers. The PCC condensers condense the steam and the condensate drains to the GDCS pools. The PCC vent fans remove the NC gases accumulation from the bottom of the PCC condenser tubes, discharging them back into the DW (instead of purging the NC gases into the WW). This process results in steady accumulation of NC gases in the DW, DW head, and GDCS gas spaces. Correspondingly, the NC gas mass in the WW is reduced by the same amount that is transferred to the DW. The WW and DW pressures (RAI 6.2-98S01R01 Figure 6.2-98S01R01-1) decrease as the NC gas mass in the WW is reduced (and by the increased steam mixture flow through the PCC condensers caused by the increased differential pressure across the PCC condensers). The pressure reduction is proportional to the total amount of NC gases that are removed from the WW (and the differential pressure across the PCC condensers).

With the operation of PCC vent fans, the PCC condenser heat removal capacity depends on the steam mixture flow rate and the NC gas mass fraction at the inlet of the PCC condensers. For a fixed flow rate, the heat removal capacity is reduced as the PCC condenser inlet NC gas fraction is increased. The inlet NC gas fraction is increased as the amount of NC gas mass in the DW is increased. After 144 hours, the DW NC gas mass reaches a quasi-equilibrium level. At this level, the PCC condenser heat removal capacity matches the steaming rate into the DW. As a result, the DW pressure also reaches a quasi-equilibrium level at about 310 kPa (RAI 6.2-98S01R01 Figure 6.2-98S01R01-1).

RAI 6.2-98S01R01 Figure 6.2-98S01R01-5 shows the comparison between the decay heat and the PCC condenser heat removal rate for the case using six PCC vent fans. The six PCC condenser units are modeled as two separate components in the TRACG model; one component models two PCC condenser units and the other one models four PCC condenser units. This figure shows heat removal rates for the total and for the individual components. The heat loads are evenly distributed among these PCC components. At 72 hours, there is a surge of heat removal rate due to the initiation of PCC vent fans and IC/PCC pool refilling (negligible contribution from the refilling in such a short period of time).

Transient Responses for the Case using Four PCC Vent Fans

This case is analyzed using four PCC vent fans, (i.e., one PCC vent fan for each of the first four PCC vent lines, no vent fan for the other two PCC vent lines). RAI 6.2-98S01R01 Figure 6.2-98S01R01-1 to RAI 6.2-98S01R01 Figure 6.2-98S01R01-3 show the pressure and NC gas mass responses. RAI 6.2-98S01R01 Figure 6.2-98S01R01-6 shows the comparison between the decay heat and the PCC condensers heat removal rate for the case using four PCC vent fans.

The pressure drop responses are similar in pattern to that for the case using six PCC vent fans. At 72 hours, the DW and WW pressures drop rapidly shortly after the activation of the PCC vent fans and IC/PCC pool refilling. From 72 to 168 hours, the DW pressure remains at or below the WW pressure (RAI 6.2-98S01R01 Figure 6.2-98S01R01-1). During this time period, there are no PCC vent fans or pressure difference (DW – WW) to drive the steam gas mixture flowing through the component that models the two PCC condenser units with no PCC vent fans. As a result, NC gases are accumulated inside the PCC condenser tubes and shuts off these two PCC condenser units. The heat removal capacity of the two PCC components decreases to zero shortly after 72 hours (RAI 6.2-98S01R01 Figure 6.2-98S01R01-6).

Consequently, the four PCC components pick up the total heat load from the decay heat (RAI 6.2-98S01R01 Figure 6.2-98S01R01-6). On the basis of per unit of PCC in the four PCC component case, the heat load for the case using four PCC vent fans is about 50% higher than that for the case using six PCC vent fans. To achieve higher heat removal rate, the inlet NC gas mass fraction is necessary to remain at a lower value, and therefore lower NC gas mass can be stored in the DW. RAI 6.2-98S01R01 Figure 6.2-98S01R01-2 shows that the total amount of NC gas mass that can be redistributed back into the DW. This amount is proportional to the total PCC vent fan capacity. Similarly, the overall pressure reduction (RAI 6.2-98S01R01 Figure 6.2-98S01R01-1) is proportional to the total PCC vent fan capacity, because it depends on the total amount of NC gases that are removed from the WW and the pressure differential developed across the PCC condensers.

(3) Effect of Total PCC Vent Fan Capacity

Item (2) in this response discusses the transient responses for the cases using six PCC vent fans and using four PCC vent fans. The total amount of NC gas mass that can be redistributed back into the DW is proportional to the total PCC vent fan capacity (RAI 6.2-98S01R01 Figure 6.2-98S01R01-2). Similarly, the overall pressure reduction (RAI 6.2-98S01R01 Figure 6.2-98S01R01-1) is proportional to the total PCC vent fan capacity, because it depends on the total amount of NC gases that are removed from the WW and the pressure differential developed across the PCC condensers.

(4) Effect of PCC Vent Fan Discharge Location

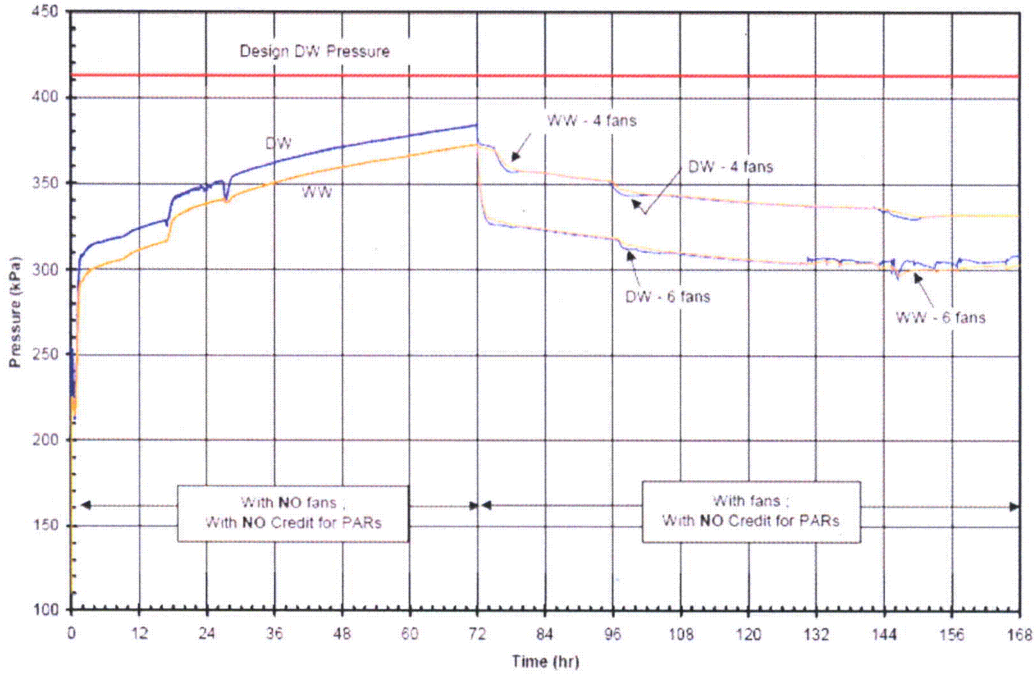
The key transient responses discussed in Items (2) and (3) are from cases where the PCC vent fans discharge to the DW annulus. Parametric cases have been performed to assess the effect of PCC vent fan discharge location (Figure 6.2-139-4 in the response to RAI 6.2-139 (MFN 08-357, dated April 19, 2008). The results show that there is a small improvement in the pressure response if the PCC vent fan discharge is relocated from the DW annulus to the GDCS pool compartment since some amount of NC gases is forced to reside in the GDCS pool space.

(5) Effect of PARS After the Activation of PCC Vent Fans

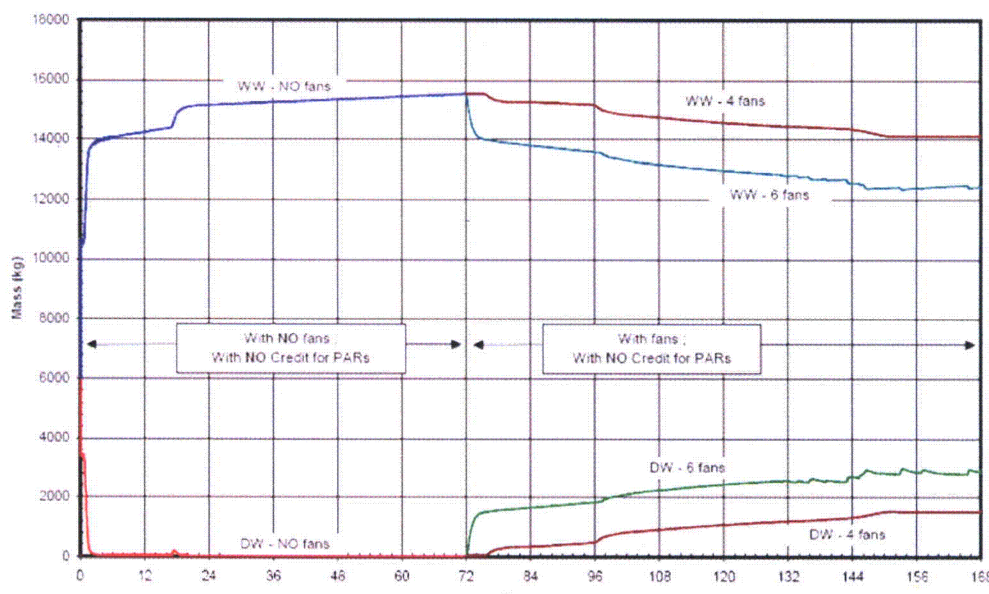
The key transient responses discussed in Items (2) and (3) are from cases with the PCC vent fans activated after 72 hours, but with no credit from the PARS. Parametric cases have been performed to assess the effect of PARS after the activation of PCC vent fans (Figure 6.2-139-5 in the response to RAI 6.2-139 (MFN 08-357, dated April 19, 2008)). When PARS is credited, the credit is simulated as the rate of production of NC gases equal to the rate of their recombination by the PARS. The results show that there is a small improvement in the pressure response when PARS is credited.

DCD Impact:

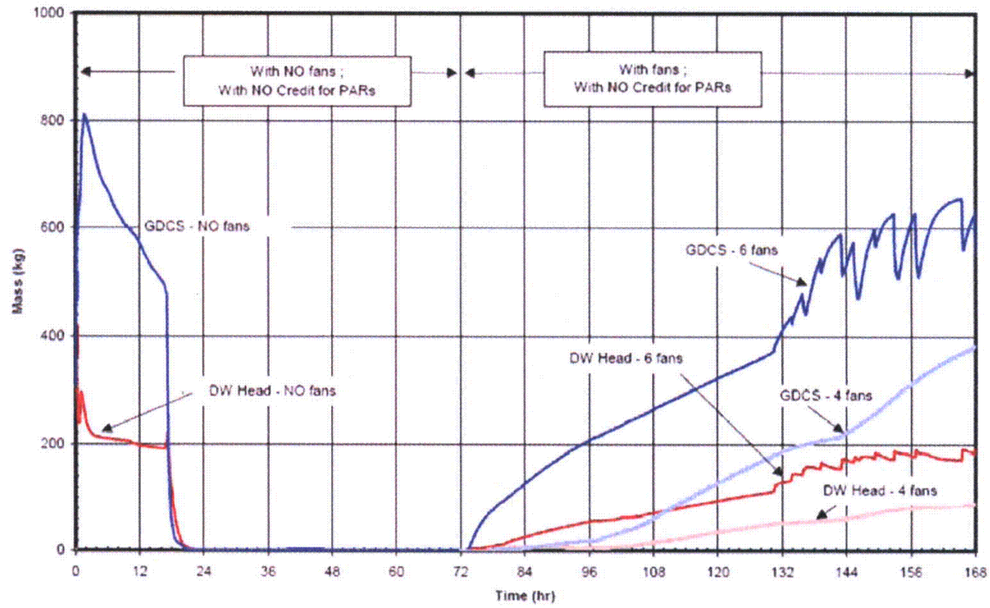
No DCD changes will be made in response to this RAI.



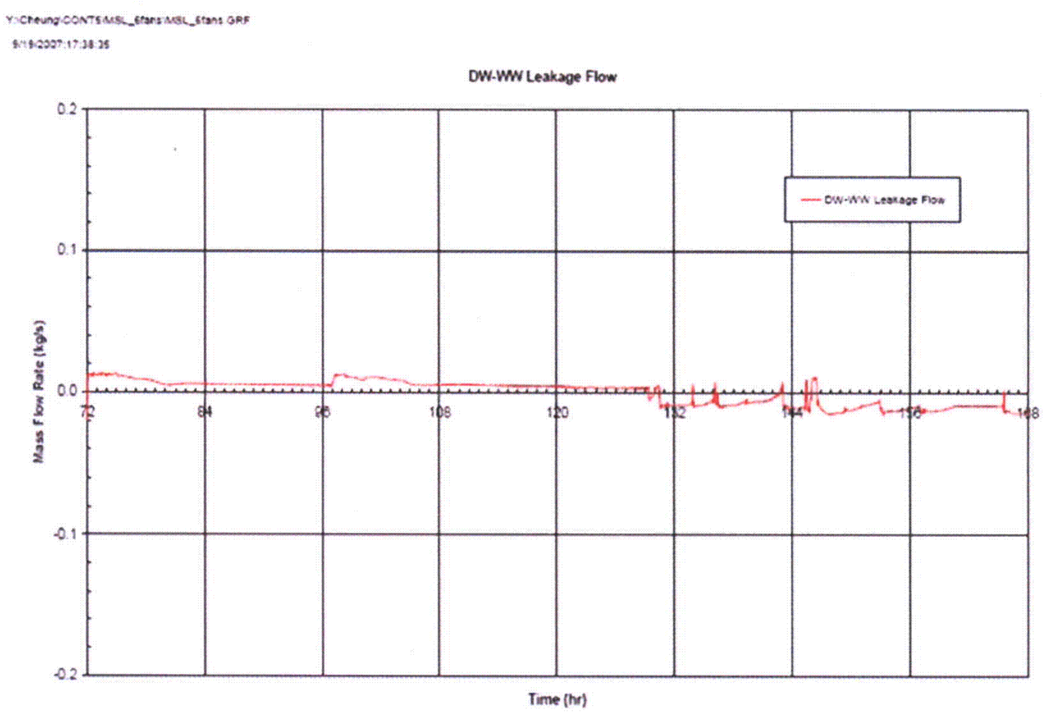
RAI 6.2-98S01R01 Figure 6.2-98S01R01-1. Pressure Responses in DW and WW



RAI 6.2-98S01R01 Figure 6.2-98S01R01-2. NC Gas Mass Responses in DW and WW

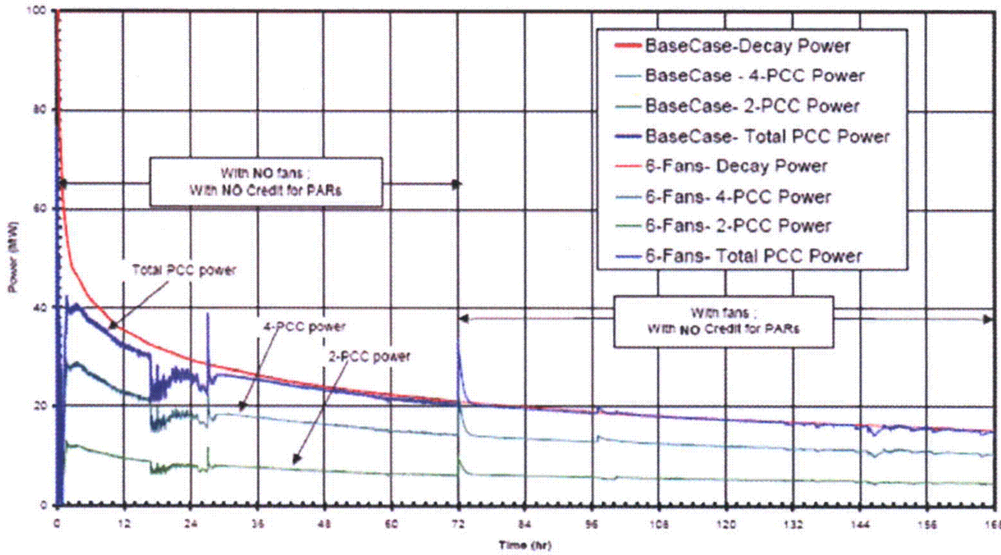


RAI 6.2-98S01R01 Figure 6.2-98S01R01-3. NC Gas Mass Responses in DW Head and GDCS Gas Spaces

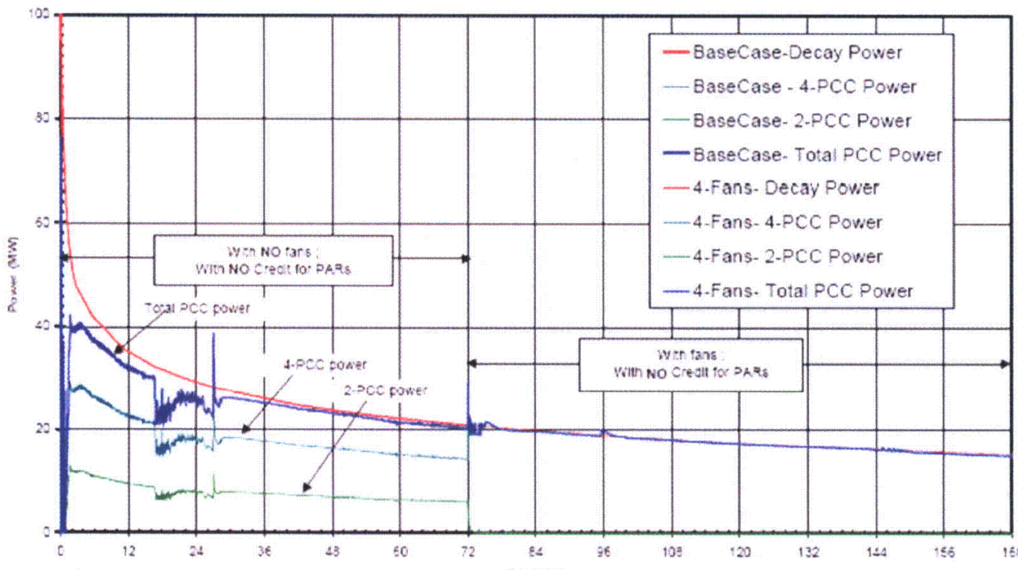


RAI 6.2-98S01R01 Figure 6.2-98S01R01-4. DW-WW Leakage Flow - Six PCC Vent Fans

(Negative value corresponding to leakage flow from DW to WW)



RAI 6.2-98S01R01 Figure 6.2-98S01R01-5. Decay Heat and PCC Condenser Heat Removal - Six PCC Vent Fans



RAI 6.2-98S01R01 Figure 6.2-98S01R01-6. Decay Heat and PCC Condenser Heat Removal – Four PCC Vent Fans