Diablo Canyon Power Plant (DCPP) Units 1 and 2
Response to Second Round Request for Additional Information
Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors"

Note: For the licensee's reference, the staff has linked the below issues to question numbers in the staff's RAI package for Diablo Canyon dated August 1, 2008 (ML082050608).

NRC RAI 2:

This RAI questioned the basis for comparability/use of jet impingement testing resulting in zones of influence (ZOIs) with a 3.5 inch jet when much larger jets could be experienced in a loss-of-coolant accident (LOCA). The staff had noted that the licensee had deviated from the NEI 04-07 Guidance Report (GR) by assuming plant-specific ZOI radii based on jet impingement testing conducted by Westinghouse at a Wyle Laboratories facility, as documented in WCAP-16720-P. In its review of the licensee's RAI response, the staff noted that the licensee provided additional information on the testing conducted by Westinghouse as reported in WCAP-16720-P. This additional information on the testing conducted to define the ZOIs for the site-specific insulation system installations did not address the intent of the question. Also, since the original RAI No. 2 was developed for Diablo Canyon, the staff has performed additional evaluations of the methodology utilized by Westinghouse during the debris generation testing for licensees. This evaluation resulted in a more detailed set of questions regarding the debris generation testing. The RAI response indicates that similar methodology was used for the Diablo Canyon testing. Therefore, RAI 2 is replaced with the following list of questions. Although this list of questions was based on, and specifically references, different WCAPs than were used by Diablo Canyon in its evaluation, it is expected that similar concerns exist with WCAP-16720-P since the staff understands the methods were similar. The below RAIs are numbered incrementally from the staff's August 1, 2008 letter.

14. *Although the ANSI/ANS standard predicts higher jet centerline stagnation pressures associated with higher levels of subcooling, it is not intuitive that this would necessarily correspond to a generally conservative debris generation result. Please justify the initial debris generation test temperature and pressure with respect to the plant-specific reactor coolant system (RCS) conditions, specifically the plant hot and cold leg operating conditions. If ZOI reductions are also being applied to lines connecting to the pressurizer, then please also discuss the temperature and pressure conditions in these lines. Please discuss whether any tests were conducted at alternate temperatures and pressures to assess the variance in the destructiveness of the test jet to the initial test condition specifications, and if so, provide that assessment.*

15. *Please describe the jacketing/insulation systems used in the plant for which the testing was conducted and compare those systems to the jacketing/insulation systems tested. Demonstrate that the tested jacketing/insulation system adequately represented the plant jacketing/insulation system. The description should include differences in the jacketing and banding systems used for piping and other components for which the test results are applied, potentially including steam generators, pressurizers, reactor coolant pumps, valves, etc. At a minimum, the following areas should be addressed:*

    a. *How did the characteristic failure dimensions of the tested jacketing/insulation compare with the effective diameter of the jet at the axial placement of the target? The characteristic failure dimensions are based on the primary failure mechanisms of the jacketing system, e.g., for a stainless steel jacket held in place by three latches where all three latches must fail for the jacket to fail, then all three latches must be effectively impacted by the pressure for which the ZOI is calculated. Applying test results to a ZOI based on a centerline pressure for relatively low length to diameter (L/D) nozzle to target spacing would be non-conservative with respect to impacting the entire target with the calculated pressure.*
    b. *Was the insulation and jacketing system used in the testing of the same general manufacture and manufacturing process as the insulation used in the plant? If not, what steps were taken to ensure that the general strength of the insulation system tested was conservative with respect to the plant insulation? For example, it is known that there were generally two very different processes used to manufacture calcium silicate whereby one type readily dissolved in water but the other type dissolves much more slowly. Such manufacturing differences could also become apparent in debris generation testing, as well.*
    c. *The information provided should also include an evaluation of scaling the strength of the jacketing or encapsulation systems to the tests. For example, a latching system on a 30-inch pipe within a ZOI could be stressed much more than a latching system on a 10-inch pipe in a scaled ZOI test. If the latches used in the testing and the plants are the same, the latches in the testing could be significantly under-stressed. If a prototypically sized target were impacted by an undersized jet it would similarly be under-stressed. Evaluations of banding, jacketing, rivets, screws, etc., should be made. For example, scaling the strength of the jacketing was discussed in the Ontario Power Generation report on calcium silicate debris generation testing.*

16. *There are relatively large uncertainties associated with calculating jet stagnation pressures and ZOIs for both the test and the plant conditions based on the models used in the WCAP reports. Please describe what steps were taken to ensure that the calculations resulted in conservative estimates of these values. Please provide the inputs for these calculations and the sources of the inputs.*

17. *Please describe the procedure and assumptions for using the ANSI/ANS-58-2-1988 standard to calculate the test jet stagnation pressures at specific locations downrange from the test nozzle.*

    a. *Please discuss why the analysis was based on the initial condition of 530°F whereas the initial test temperature was specified as 550°F (if applicable to WCAP-16720-P).*
    b. *Describe whether the water subcooling used in the analysis was that of the initial tank temperature or was it the temperature of the water in the pipe next to the rupture disk. Test data indicated that the water in the piping had cooled below that of the test tank.*
    c. *The break mass flow rate is a key input to the ANSI/ANS-58-2-1988 standard. Describe how the associated debris generation test mass flow rate was determined. If the experimental volumetric flow was used, then explain how the mass flow was calculated from the volumetric flow given the considerations of potential two-phase flow and temperature dependent water and vapor densities. If the mass flow was analytically determined, then describe the analytical method used to calculate the mass flow rate.*
    d. *Noting the extremely rapid decrease in nozzle pressure and flow rate illustrated in the test plots in the first tenths of a second, discuss how the transient behavior was considered in the application of the ANSI/ANS-58-2-1988 standard. Specifically, address whether the inputs to the standard represent the initial conditions or the conditions after the first extremely rapid transient, e.g., say at one tenth of a second..*
    e. *Given the extreme initial transient behavior of the jet, justify the use of the steady state ANSI/ANS-58-2-1988 standard jet expansion model to determine the jet centerline stagnation pressures rather than experimentally measuring the pressures.*

18. *Please describe the procedure used to calculate the isobar volumes used in determining the equivalent spherical ZOI radii using the ANSI/ANS-58-2-1988 standard by addressing the following questions.*

    a. *What were the assumed plant-specific RCS temperatures and pressures and break sizes used in the calculation? Note that the isobar volumes would be different for a hot leg break than for a cold leg break since the degrees of subcooling is a direct input to the ANSI/ANS-58-2-1988 standard and which affects the diameter of the jet. Note that an under calculated isobar volume would result in an under calculated ZOI radius.*
    b. *What was the calculational method used to estimate the plant-specific and break-specific mass flow rate for the postulated plant loss-of-coolant (LOCA), which was used as input to the standard for calculating isobar volumes?*
    c. *Given that the degree of subcooling is an input parameter to the ANSI/ANS-58-2-1988 standard and that this parameter affects the pressure isobar volumes, what steps were taken to ensure that the isobar volumes*

conservatively match the plant-specific postulated LOCA degree of subcooling for the plant debris generation break selections? Were multiple break conditions calculated to ensure a conservative specification of the ZOI radii?

19. *Please provide a detailed description of the test apparatus specifically including the piping from the pressurized test tank to the exit nozzle including the rupture disk system.*

    a. *Based on the temperature traces in the test reports it is apparent that the fluid near the nozzle was colder than the bulk test temperature. How was the fact that the fluid near the nozzle was colder than the bulk fluid accounted for in the evaluations?*
    b. *How was the hydraulic resistance of the test piping which affected the test flow characteristics evaluated with respect to a postulated plant-specific LOCA break flow where such piping flow resistance would not be present?*
    c. *What was the specified rupture differential pressure of the rupture disks?*

20. *Please address the following questions relating to the testing:*

    a. *Was any analysis or parametric testing conducted to get an idea of the sensitivity of the potential to form a shock wave at different thermal-hydraulic conditions? Were temperatures and pressures prototypical of PWR hot legs considered?*
    b. *Was the initial lower temperature of the fluid near the test nozzle taken into consideration in the evaluation? Specifically, was the damage potential assessed as a function of the degree of subcooling in the test initial conditions?*
    c. *What is the basis for scaling a shock wave from the reduced-scale nozzle opening area tested to the break opening area for a limiting rupture in the actual plant piping?*
    d. *How is the effect of a shock wave scaled with distance for both the test nozzle and plant condition?*

21. *Please provide the basis for concluding that a jet impact on piping insulation with a 45° seam orientation is a limiting condition for the destruction of insulation installed on steam generators, pressurizers, reactor coolant pumps, and other non-piping components in the containment, if the testing was applied to these components. For instance, considering a break near the steam generator nozzle, once insulation panels on the steam generator directly adjacent to the break are destroyed, the LOCA jet could impact additional insulation panels on the generator from an exposed end, potentially causing damage at significantly larger distances than for the insulation configuration on piping that was tested. Furthermore, it is not clear that the banding and latching mechanisms of the insulation panels on a steam generator or other RCS components provide the same measure of protection*

22. *Some piping oriented axially with respect to the break location (including the ruptured pipe itself) could have insulation stripped off near the break. Once this insulation is stripped away, succeeding segments of insulation will have one open end exposed directly to the LOCA jet, which appears to be a more vulnerable configuration than the configuration tested by Westinghouse. As a result, damage would seemingly be capable of propagating along an axially oriented pipe significantly beyond the distances calculated by Westinghouse. Please provide a technical basis to demonstrate that the reduced ZOIs calculated for the piping configuration tested are prototypical or conservative of the degree of damage that would occur to insulation on piping lines oriented axially with respect to the break location.*

23. *WCAP-16710-P noted damage to the cloth blankets that cover the fiberglass insulation in some cases resulting in the release of fiberglass. The tears in the cloth covering were attributed to the steel jacket or the test fixture and not the steam jet. It seems that any damage that occurs to the target during the test would be likely to occur in the plant. Discuss whether the potential for damage to plant insulation from similar conditions was considered. For example, the test fixture could represent a piping component or support, or other nearby structural member. The insulation jacketing is obviously representative of itself. Describe the basis for the statement in the WCAP that damage similar to that which occurred to the end pieces in not expected to occur in the plant. It is likely that a break in the plant will result in a much more chaotic condition than that which occurred in testing. Therefore, it would be more likely for the insulation to be damaged by either the jacketing or other objects nearby. If the testing referenced by the plant noted similar damage mechanisms and did not account for debris created by such, please provide a basis for the determination that the debris generation would not occur in the plant.*

PG&E Response:

[PWR Owner’s Group Program addressing these issues]

NRC RAI 5:

The staff requested that the licensee state whether unjacketed debris and fire stops would be exposed to runoff from spray drainage and describe whether this effect was accounted for in the spray erosion testing. The licensee's response, dated November 3, 2008, described erosion testing performed for both unjacketed insulation and for fire stops in cable trays. Regarding the unjacketed insulation tests, the runoff flow was modeled as impacting the insulation with a velocity of 0.4 ft/s, while the spray nozzle exit velocity was modeled as being greater than or equal to 15.75 ft/s. Although a basis was provided for the spray nozzle exit velocity, the response did not adequately demonstrate that 0.4 ft/s is a conservative or prototypical velocity for drainage runoff to impact unjacketed insulation. Furthermore, since the test results of the unjacketed insulation subjected to runoff were used as a justification not to conduct testing of vertical cable tray fire stops exposed to runoff drainage, the choice of 0.4 ft/s as a velocity for runoff drainage also affects the vertical cable tray fire stop testing. Therefore, please provide a technical basis to demonstrate that 0.4 ft/s is a conservative or prototypical velocity for drainage runoff that could impact unjacketed insulation and vertical cable tray fire stops in order to show that the erosion testing and assumptions made for these materials are justified.

PG&E Response:

As noted in the initial response to RAI No. 5, unjacketed insulation outside of the crane wall has the potential of being exposed to runoff of spray drainage streams, whereas fire stops are not exposed to runoff of spray drainage streams. The initial response provided information to show that fire stops are protected from runoff of spray drainage streams by either a cable tray cover or by a cable tray above. Therefore, fire stops are not subjected to flow erosion. The unjacketed insulation targets outside the crane wall that are susceptible to erosion by runoff of spray drainage streams are fabricated with either Temp-Mat or Cerablanket.

The flow erosion testing of unjacketed insulation material was performed at a bulk water flow velocity of 0.4 ft/sec. The flow erosion tests were originally performed to understand the magnitude of erosion on small pieces of insulation that may be distributed along the flooded containment floor caused by the flow of water during recirculation. A water flow velocity of 0.4 ft/sec was originally selected as this value would envelope the tumbling velocity of any of the small insulation material that may be distributed along the containment floor, i.e., a velocity greater than 0.4 ft/sec would transport the entire insulation piece thus negating any erosive effects. The flow erosion tests were conducted for a continuous duration of eight hours. It should be noted that our analysis did not consider the erosion of small pieces of fibrous insulation within the flooded containment floor as any Temp-Mat encapsulated insulation targets within the tested ZOI of 3.7D was conservatively assumed to be destroyed as 100 percent fines. There are no Cerablanket targets inside any ZOI (Reference DCL-08-059, Section 3c).

The erosion due to water flow was measured as 0.0% for Temp-Mat and for Cerablanket.

There are fourteen unjacketed insulation debris sources outside the crane wall in Unit 1 and thirteen locations in Unit 2. All of these debris sources were reviewed for the impact of erosion due to runoff of spray drainage streams. Of these unjacketed insulation debris sources outside the crane wall only the unjacketed insulation sources installed on vertical pipe runs are susceptible to any significant runoff due to containment spray. Of the unjacketed insulation debris sources, there are only four sources installed in a vertical orientation in each Unit. Per a review of all of the unjacketed fibrous debris insulation sources it was determined that these debris sources would be susceptible to either the predominate effects of either containment spray erosion or runoff flow erosion. That is the insulation pad would be in a installed position where the effects of containment spray was the predominate erosion phenomena (horizontally installed sources) or runoff flow would be the predominate erosion phenomena (vertically installed sources), e.g., an insulation pad installed on horizontal pipe run would be affected by containment spray, whereas an insulation pad installed on a vertical pipe run would not see the affects of containment spray, however, the insulation pad would be affected by runoff flow.

Based upon containment spray and flow erosion testing, containment spray erosion is considered more conservative and the values of containment spray erosion were used for all unjacketed fibrous debris susceptible to containment spray or runoff of spray drainage streams.

<u>NRC RAI 7</u>:

The staff requested additional information regarding how stirring affected the results of the head loss test. The licensee provided information that justified that excessive debris settlement did not occur. However, it is also possible that the stirring affected the debris bed non-prototypically such that debris did not accumulate uniformly over the strainer surface as would occur if added turbulence was not present. Post-test photographs and inspection of the strainer showed that an unexpected non-uniform distribution of debris on the strainer occurred. It was particularly unusual that photographs showed less debris accumulation near the bottom of the strainer than elsewhere. Additionally, the test resulted in a significantly increased deposition of paint chips on the strainer compared to what would be expected in the plant. The licensee should provide information that justifies that the debris bed formed during testing is a realistic or conservative representation of what would occur in the plant.

<u>PG&E Response</u>:

The post-test photographs and inspection of the strainer test article convincingly show that there is no wash-away at the edges of the strainer due to stirring. The debris bed pattern has remained the same throughout the DCPP strainer testing program. The stirring ensures that the debris bed is a homogeneous mixture that matches the output of the debris transport analysis. The stirring ensures that there are no settling or near-field effects of the debris.

The paint chip particle size is chosen to be the worst case – large enough to plug a hole in the screen and small enough to be easily transported. Stirring ensures that the paint chips remain in suspension and do not "hide out" or accumulate in piles away from the strainer suction.

The debris pattern on the screen is directly relatable to the flow characteristics of the strainer. The strainer has a vertical screen with three separate horizontal flow channels to a rear plenum. The minimum-resistance flow-path is in the middle channel. Thus, as the photographs show, debris first accumulates in the middle channel at the plenum and then builds outward from there in "bullet-shaped" debris loading pattern. This pattern has been consistent throughout the DCPP testing program.

Thus each of these elements of the DCPP testing program:

- Stirring
- Homogeneous mixture of debris
- Paint chip size that will plug screen holes yet is transportable
- Three-channel strainer with lowest middle channel resistance
- Consistent "bullet-shaped" debris accumulation pattern
- Undisturbed debris at the edges of the screen, no "wash-away"
- Reproducible debris beds

is intended to produce the worst-case head loss effects on the strainer. These elements conservatively show the worst-case debris effects and prove that the DCPP strainer will have clean screen area and that there is not enough debris quantity available to fully cover and clog the screen.

These elements of the Diablo Canyon testing program are examined and explained in the following detailed discussion.

Tested Debris Quantity

The Diablo Canyon Power Plant (DCPP) Supplemental Response dated July 10, 2008 documents the debris that is generated due to the worst-case breaks and the debris that is transported to containment sump strainer. [Ref 7-2, Pages 67 and 68] The DCPP analysis does not credit any near-field debris settling effects. Thus the entire amount of debris that is transported to the strainer is available to clog the screen.

We have physical evidence from our 2005 testing at Alion in Chicago (witnessed by the NRC staff) that paint chips and particulate debris will settle out in front of the screen. When the debris was poured into the flume in the fluid flow-path, the debris settled to the bottom of the flume and was not transported to the screen surface. We presume this is what is meant in the NRC RAI 7 statement: "Additionally, the test resulted in a significantly increased deposition of paint chips on the strainer compared to what would be expected in the plant." While we would agree with the NRC's observation as prototypical expectations of debris settling, clearly the worst-case for strainer head loss is if the entire amount of debris is available in suspension at the strainer entrance. This worst-case modeling is exactly what occurs in the DCPP strainer testing program.

The other element of tested debris is that the worst-case size distribution is chosen for testing. The paint chip debris size distribution is chosen to ensure that the chip will be easily transportable and yet the size will be large enough plug a perforation in the screen. For unqualified coating which fails outside the ZOI, paint chips were fabricated and sized appropriately (from 1/2 inch x 1/2 inch to 1/8 inch x 1/8 inch). [Ref 7-2, Page 101] A paint chip with this size distribution will cause the worst-case head loss as a debris load on the DCPP strainer with 3/32 inch holes in perforated plates. Consistent debris preparation ensures that each debris component is prepared in exactly the same way for every test. This ensures that the results of different debris loads can be accurately compared throughout the DCPP testing program.

Front Sector Testing

The DCPP design basis debris testing program was performed using a sector of the front strainer. [Figure 7-1] This front strainer test sector produced the worst case head loss of any of the strainer test articles. Recall that the rear strainer module test article with a plenum on the bottom produced significantly less head loss with equivalent debris load. Additionally, recall that the rear strainer module test article produced less head loss than did a rear strainer test sector with equivalent debris load. The test article that produced the worst case head loss was the front strainer sector. [Ref 7-2, Page 68]

The front strainer test sector consists of one strainer gap with a plenum in the back. Each side of the gap is constructed with a strainer flow channel. The inside gap surface is a screen with 3/32 –inch perforated plates. The outside of each strainer flow channel is a solid-plate with no perforations (no holes). Each strainer flow channel is divided into three separate horizontal flow paths: a middle flow path to the plenum and a top and a bottom flow path to the plenum. [Figure 7-1] Even with suction at the bottom of the plenum, the least-resistant flow path is the middle channel. This can be easily and consistently observed in the debris patterns on the debris-laden screen. Debris first accumulates at the middle of the plenum and then builds near the plenum, and then builds out from the middle flow channel. Debris pattern results have shown a consistent preference for debris build-up on the middle channel first, then on the top channel and then finally on the bottom channel. These debris patterns are due to the different channel flow path resistances and are not related to debris stirring or agitation. [Ref 7-2, Section 3f, Figure 7 through Figure 21]

Rear Sector Testing

Rear Sector Head Loss Test 2-RSHL was conducted on December 14 and 15, 2007. A rear sector is similar to the front sector in that it is test article with one gap. The rear sector has vertical screen discs with the plenum on the bottom. Test 2-RSHL was witnessed by the NRC staff. The test set up for the rear sector was performed in a different test tank than the front sector testing. A picture of the rear sector test set up is shown in Figure 7-2. Note the six agitators mounted around the test article. Figure 7-3 shows the debris pattern on each disc at the conclusion of the test. Note that the pattern starts at the center of the plenum and builds outward and upward from the center. This is the same debris pattern as the front sector. [Ref. 7-4, NRC Question 7, Figures 1 through 5]

Debris Agitation

With a front strainer sector test article, the entire outside surface is solid stainless steel plate. The test flume has six agitators to ensure a homogeneous mixture of debris. There are two agitators vertically down, one on each side of the plenum. There are four agitators installed next to the outside solid stainless steel surface and are crossed at an angle of approximately 60 degrees down. The propellers on these 4 agitators are approximately 6-inches from the floor. Note by comparison the screen is only 1-inch above the floor. Thus the strainer gap is completely protected from the direct flow of any agitator. Each agitator has a variable-speed motor and is set to develop a relatively gentle eddy current with no preferential direction of the debris material. This arrangement ensures that there is no disruption of debris at the edges of the strainer and no debris "wash-away."

The function of the agitators is to maintain a homogeneous mixture of debris. The agitators provide a gentle stirring at various angles and with no preferential flow. The agitators are far enough away from the edges of the screen so as to avoid disturbing debris formation on the edges or to cause any debris wash away. The placement of the agitators is based on considerable experience and is proven by the reproducibility of the debris beds.

In the NRC RAI 7 question above there is an inference that stirring affected the debris bed non-prototypically such that debris did not accumulate uniformly over the surface as would occur if added turbulence were not present. The DCPP testing has shown that stirring enhances uniform debris accumulation. The purpose of the DCPP strainer back flush capability testing was to determine if we could successfully accommodate the full plant debris load, prior to steam generator replacement. Two tests were performed with different debris loads: Alternate Break and Base Case. The Alternate Break debris load was comparable to Design Basis Test 15 [Ref 7-2, page 68] except the Alternate Break debris load had no cal-sil and 10 times the Rock Wool (fiber). In the "time to blockage" tests, the strainer passed the test with no agitators. "No back flush was performed for this test because there was essentially no head loss measured across the test article."

The Base Case debris load represented approximately six times the fibrous debris load and greater than ten times the amount of calcium-silicate than our current limiting debris load tested in our design basis (Test 15). The strainer failed this test when the agitators were turned on. (Note: Only one back flush was required to return to no head loss.) Thus while we would agree with the NRC observations that testing without agitation is more prototypical of plant conditions, testing without agitation is not worst case. DCPP intentionally maintains a homogeneous debris mixture using agitators because we have proven that this condition produces the worst case head loss results.

Consistent Test Results

One consistent element in the DCPP Strainer Testing Program is the direct participation and oversight provided by the DCPP Quality Verification (QV) Assessor. The DCPP QV Assessor was present at every DCPP strainer test of record. His presence ensured consistency of debris preparation, debris sequence additions, test protocols and procedures, test termination criteria and debris bed patterns. This consistency of test performance ensures that the test results are valid and can be correctly applied to confirm strainer performance.

Ultimately the documented failures in the DCPP testing program have provided assurance that when the tests are performed and pass, the results can be applied with confidence. The QV Assessor's oversight validates this confidence.

Conclusion

The DCPP strainer testing program is one of the most comprehensive sump screen proving protocols in the industry. DCPP continually tested and reduced debris until the test results proved that the strainer passed the head loss with the worst case test conditions. By selecting the worst-case elements for the testing program including stirring and debris size distribution, DCPP has shown that the debris bed formed during testing is a conservative representation of what would occur in the plant. The results of the testing confirm that the installed strainers will maintain clean screen area during worst case debris loading conditions. The clean screen area has been proven to ensure the necessary and adequate flow to cool the core during a design basis event.

References

7-1 PG&E Letter to the NRC DCL-08-002 "Supplemental Response to Generic Letter 2004-02", February 1, 2008.
7-2 PG&E Letter to the NRC DCL-08-059 "Supplemental Response to Generic Letter 2004-02 (Revision 1)", July 10, 2008.
7-3 NRC Letter to PG&E "Diablo Canyon Units 1 and 2 - Request for Additional Information Regarding Supplemental Response to Generic Letter 2004-02", August 1, 2008.

7-4 PG&E Letter to the NRC DCL-08-094 "Response to Request for Additional Information Regarding Supplemental Response to Generic Letter 2004-02", November 3, 2008.

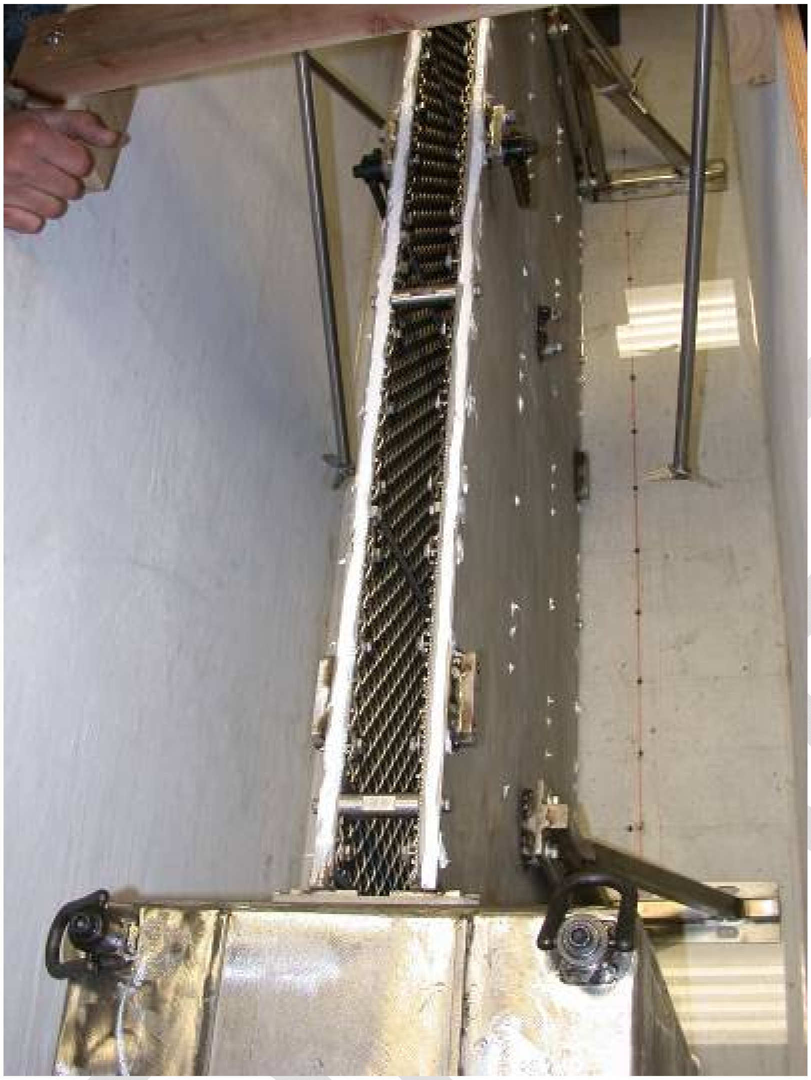

Figure 7-1 Front Sector Test Article Mounted in Test flume with Agitators

Continuum Dynamics Inc. of Ewing, New Jersey has been performing containment Sump Strainer Testing for Diablo Canyon. The test article was manufactured by General Electric. The test article is a passive structure made entirely of stainless steel. The test article models one gap in the front strainer. There are two screen sections (disks) approximately 27.5 inches high by 62 inches deep by 1.2 inches thick. The frame of each disk is made up of square hollow channel with two additional square hollow channel support pieces mounted horizontally at 9 inches and 18 inches down from the top channel. The interior side of each screen section has 3/32 inch – hole perforated plate covered with a ¾ inch wire mesh. The exterior side of each screen is covered with a solid stainless steel plate. The two screen sections attach to a plenum that is about 30 inches high by 9 inches deep by 18 inches wide.

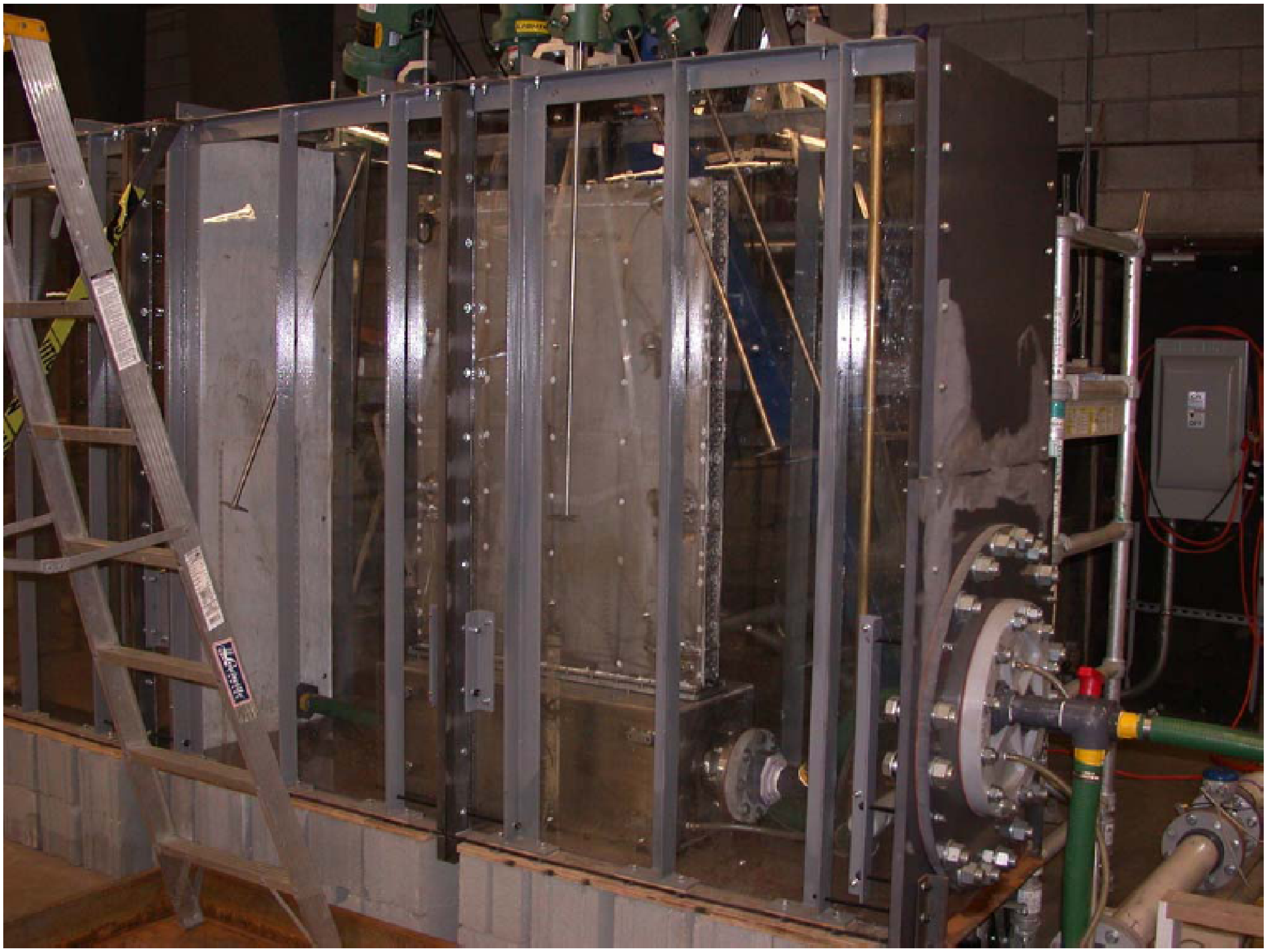

Figure 7-2 Rear Sector Head Loss Test 2-RSHL December 14, 2007
Test Tank Set Up Showing Agitators

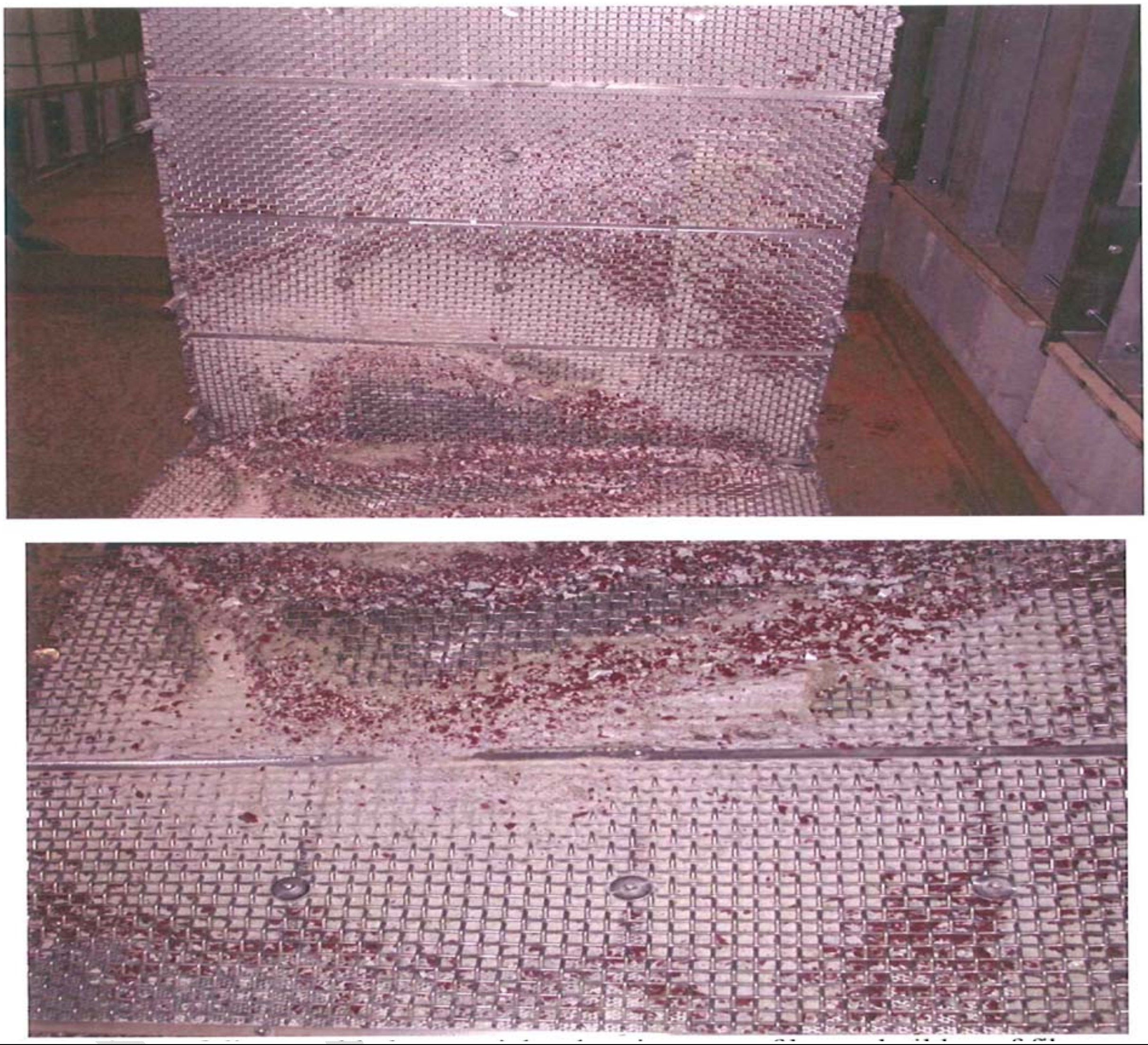

Figure 7-3   Rear Sector Head Loss Test 2-RSHL

Debris pattern on rear sector (with the plenum at the bottom) is similar to the debris pattern on the front sector (with the plenum on the rear or side).

NRC RAI 12:

The staff requested that the licensee provide a revised table showing the results of the net positive suction head margin calculation without including the head loss from accumulated debris. The table provided by the licensee on page 29 of the November 3, 2008, supplemental response showed the individual contributions from the increased containment water level assumed by the licensee, as well as the impact of the strainer and debris bed head losses. The licensee indicated that the previous net positive suction head calculations conservatively did not take credit for minimum sump water levels. The staff questions this response because a 5-ft level increase was credited for cold-leg recirculation, whereas only a 2-ft level increase was credited for hot-leg recirculation. The staff expected that the minimum water level available for hot-leg recirculation would be greater than or equal to the minimum cold-leg recirculation water level. Furthermore, the licensee's response, dated July 10, 2008, indicates that the minimum pool depth is 1.8 ft for a small-break LOCA and 2.6 ft for a large-break LOCA. Even at the point when the containment spray pumps are secured, this supplemental response states that the calculated minimum pool level could be a minimum of 3.5 ft. Therefore, the basis for crediting a 5 ft increase in water level for the cold-leg recirculation case to account for the minimum containment water level was not clear to the staff, since it appeared that a minimum level of 5 ft could not be assured post-LOCA. In light of the discussion above, please provide a technical basis to demonstrate that the increased water levels credited for cold-leg and hot-leg recirculation are justified in light of the minimum containment water levels for Diablo Canyon, or provide a different level with justification.

PG&E Response:

The changes in water level reflect differences in the assumptions used in the analyses. Figure 12-1 illustrates the physical changes credited in both the cold-leg and hot-leg recirculation NPSH analyses.

The Diablo Canyon containment floor is at elevation 91'-0". The containment sump floor elevation is at 88'-0", three feet below the containment floor. This difference in elevation is the reason there is a five foot level difference in the cold-leg recirculation NPSH analysis and only a two foot difference in the water level assumed in the hot-leg recirculation NPSH analysis.

The new sump is required to be submerged to be fully functional during a large-break loss-of-coolant accident (LOCA). Full submergence is required to eliminate vortex-induced voids into the pump suction. This is not the case for a small-break LOCA where the RHR pump suction flow and the NPSHR are significantly reduced. License Amendments 199 (Unit 1) and 200 (Unit 2) increased the minimum required RWST water inventory to ensure a minimum water level of 93.6' in the containment to submerge the new sump when the first RHR pump is started for a worst-case large-break LOCA. This increased level provides 2.6' of water above the 91'-0" containment floor elevation during cold leg recirculation alignment. The increased RWST water inventory corresponds to a containment water level to at least 94.5' for the hot leg recirculation phase long after containment spray pumps are secured. This 94.5' provides 3.5 ft of water above the 91'-0" containment floor elevation as referenced in our letter dated on July 10, 2008.

In the cold-leg recirculation phase analyses, the previous analysis did not credit any water collected in the sump, only the sump floor elevation of 88'-0" was credited. The revised analysis conservatively credits the minimum water level of 93.0', instead of 93.6', in the containment for the NPSH margin determination for the new sump. Thus, there is an additional 5-ft of water credited in the new analysis that was not credited in the previous analysis.

The minimum water level credited for the hot-leg recirculation phase is higher than the water level credited for cold-leg recirculation. This is because the RWST water inventory has only been partially transported to the sump at the time the RHR pumps are started during cold leg recirculation alignment. Water addition continues after the start of cold-leg recirculation and most of the RWST water inventory has been transported to the sump when the hot-leg recirculation phase is initiated. The previous hot-leg recirculation analysis credited a water level of 92.5', or 1.5' above the containment floor. Again, License Amendments 199/200 increased the water level in the containment sump to at least 94.5' or 3.5' above the 91'-0", yet the revised analysis for the hot-leg recirculation phase conservatively only credited 94.3', or 3.3' above the containment floor for the NPSH margin determination. The water level credited for the hot-leg recirculation phase is higher than the water level credited for cold-leg recirculation.

The following table provides a summary of the current NPSH margin for DCPP and considers the most recent water level calculations and strainer head loss calculations.

Pump	Case	Flow (gpm)	NPSHA (ft)	NPSHR (ft)	Credited Water El. (ft)	NPSH Margin (ft)
RHRP1	Cold-leg Recirculation	4542	24.5	19	93	5.6
RHRP2	Cold-leg Recirculation	4309	24.2	18	93	6.3
RHRP1	Hot-leg Recirculation	4891	25	24	95.5	1.3
RHRP2	Hot-leg Recirculation	4699	28	21	95.5	7.3

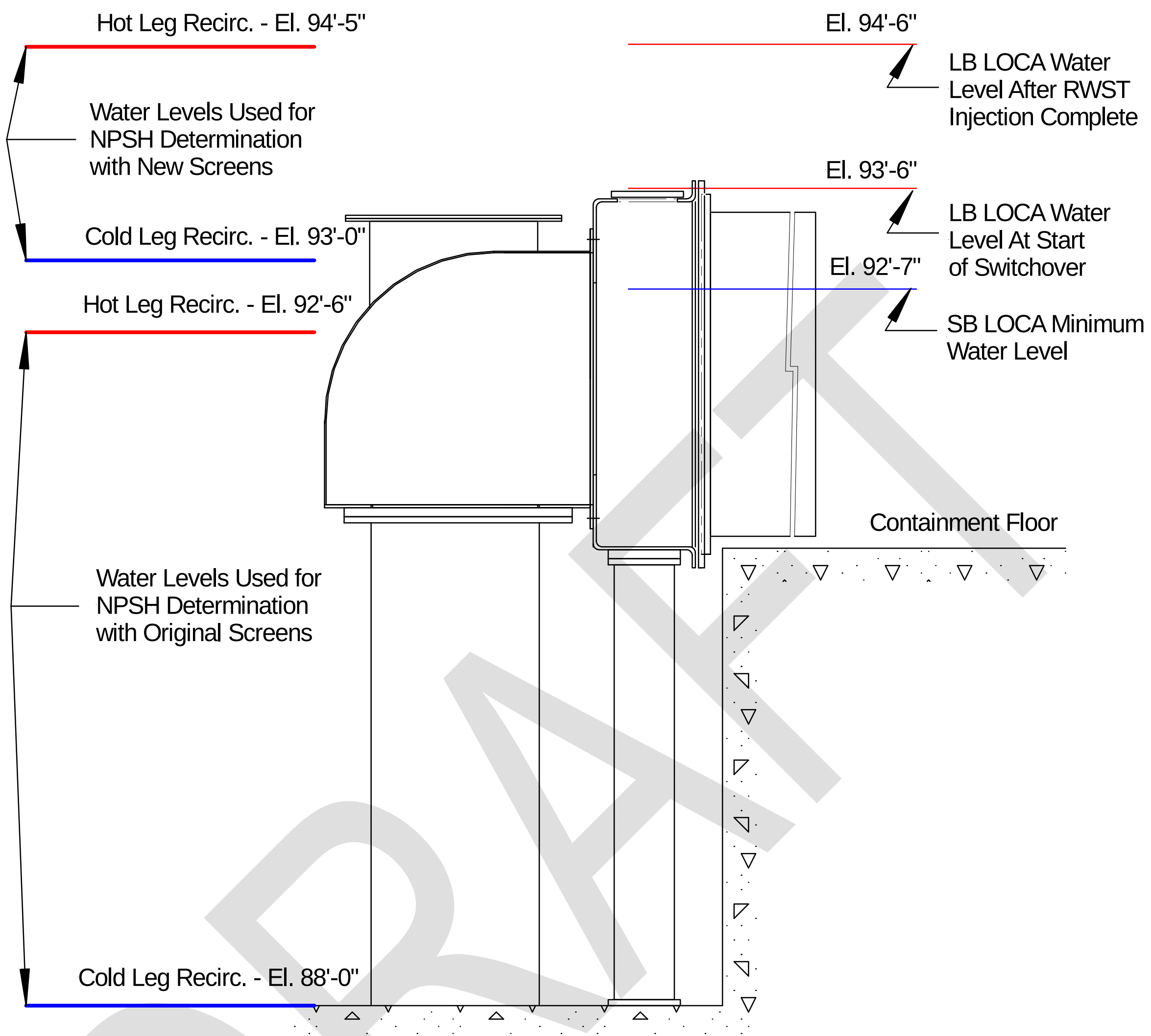

FIGURE 12-1 Water Levels Used in NPSH Analysis

NRC RAI 24:

One additional question has arisen in the staff's review of other licensee's submittals for GL 2004-02, and the staff requests that the Diablo Canyon licensee address it. Specifically:

The potential for deaeration of the coolant as it passes through the debris bed should be considered. Please provide an evaluation of the potential for deaeration of the fluid as it passes through the debris bed and strainer and whether any entrained gasses could reach the pump suction. If detrained gasses can reach the pump suction, please evaluate whether pump performance could be affected as described in Appendix A of Regulatory Guide 1.82, Revision 3.

PG&E Response:

Deaeration is not expected to be a concern for the DCPP sump. Evaluation of the dissolved air content of the sump water can be evaluated using the solubility curves for nitrogen. From 167 to 212 degrees F at 400 psia, the dissolved gas fraction of nitrogen is 0.28 ml/g. At the same temperature and 100 psia, the value is 0.08 ml/g. Since the solubility relationship is effectively linear to 0 psia, the effective degassing of sump fluid is (0.28-0.08)/(400-100) = 0.00067 ml/gram of water per psi of pressure drop. (Industrial And Engineering Chemistry, Vol 44)

The maximum screen pressure drop is 0.8" or 0.3 psid. Thus, assuming that the sump water is saturated at the elevated pressure and temperature conditions present inside containment at the start of recirculation, the total void fraction of the water flowing through the sump downstream of the sump screen would be 0.00067 ml/gram/psi X 0.3 psid = 0.00018, or 0.018 percent of void fraction. The deaeration would manifest itself as microbubbles which do not have much buoyancy and would remain entrained in the flow and not accumulate in the sump structure.

As the void migrates down the RHR suction pipe, the hydrostatic pressure from the sump to the pump inlet will compress the entrained bubbles and further reduce the void fraction. The miniscule void fraction of 0.018 percent is much less than the steady state void fraction of 1 percent – 2 percent, which is the level of concern raised by GL 2008-01. Any actions taken to address GL 2008-01 will be more than sufficient to address the concerns raised in this RAI. Therefore, deaeration across the sump screen does not present a challenge to the operation of the emergency core cooling system pumps.