Dominion Nuclear Connecticut, Inc.
5000 Dominion Boulevard, Glen Allen, Virginia 23060
Web Address: www.dom.com

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March 13, 2009

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

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DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNITS 2 AND 3
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING GENERIC LETTER 2004-02, POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

In letters dated March 4, September 1 and November 29, 2005, November 15, 2007, February 29 and December 18, 2008, Dominion Nuclear Connecticut, Inc. (DNC) submitted information in response to Generic Letter (GL) 2004-02 for Millstone Power Station Units 2 and 3.

In a letter dated December 17, 2008, the Nuclear Regulatory Commission (NRC) transmitted a request for additional information (RAI) regarding GL 2004-02. The responses to RAI questions 1 through 11 for Millstone Unit 2 are provided in Attachment 1 to this letter. The responses to RAI questions 1 through 14 for Millstone Unit 3 are provided in Attachment 2.

Should you have any questions in regard to this submittal, please contact Mrs. Wanda Craft at 804-273-4687.

Sincerely,

J. Alan Price
Vice President – Nuclear Engineering

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by J. Alan Price, who is Vice President - Nuclear Engineering of Dominion Nuclear Connecticut, Inc. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 13 day of March, 2009.

My Commission Expires: 4/30/13.

Notary Public

GINGER L. ALLIGOOD
Notary Public
Commonwealth of Virginia
310847
My Commission Expires Apr 30, 2013

Commitments made in this letter: None

Attachments:

1. Attachment 1: Response to Request for Additional Information (RAI) Regarding Generic Letter 2004-02 for MPS2
2. Attachment 2: Response to Request for Additional Information (RAI) Regarding Generic Letter 2004-02 for MPS3

cc: U.S. Nuclear Regulatory Commission
Region I
Regional Administrator
475 Allendale Road
King of Prussia, PA 19406-1415

Ms. C. J. Sanders
Project Manager
U.S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Mail Stop O8-B3
Rockville, MD 20852-2738

NRC Senior Resident Inspector
Millstone Power Station

Director
Bureau of Air Management
Monitoring and Radiation Division
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127

ATTACHMENT 1

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION (RAI) REGARDING GENERIC LETTER 2004-02

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

Request for Additional Information Regarding GL 2004-02
Millstone Power Station Unit 2 (MPS2)

NRC Question 1

DNC's strainer head loss testing, including chemical effects, was not complete at the time the February 2008 supplemental response was developed. To the extent it was not provided in the February 2008 submittal, please provide the information requested under item 3.f, "Head Loss and Vortexing," in the "Revised Content Guide for Generic Letter 2004-02 Supplemental Response," dated November 2007 (ADAMS Accession No. ML073110389). Specifically, please provide an update to the final head loss and vortexing evaluation based on completed testing.

DNC Response

The updated information requested in question 1 is provided in DNC's supplemental response dated Dec 18, 2008 (ADAMS Accession No. ML083650005). The testing described in DNC's December 18, 2008 submittal represents the worst-case head loss expected for the installed strainer. These results include head loss due to fibrous and particulate debris as well as chemical precipitants that may form long-term in the post-LOCA sump water. No additional vortex testing was done as part of the chemical effects testing.

NRC Question 2

Please state and provide the basis for the assumed particulate filtration fraction at the strainer for downstream wear evaluations.

DNC Response

The assumed particulate filtration fraction at the strainer is zero for downstream wear evaluations. This ensures conservatism in the component wear calculations.

NRC Question 3

Please explain and justify whether a disturbance could occur to a water surface impacted by a break flow rate of thousands of gallons per minute falling from approximately 20 ft, such that significant quantities of air could be ingested into the strainer. Discuss both small and large breaks from this perspective. Please explain the role of the non-QA (quality assurance) cover plate in providing protection against this impinging water.

DNC Response

The planned non-QA cover plate has not been installed over the strainer. The function of the plate was only to prevent incidental damage from things such as dropped tools during a refueling outage.

The possibility of air ingestion into the strainer was addressed in section E of Attachment 1 of the February 2008 supplemental response. In that discussion, it was concluded that air ingestion would not adversely impact strainer or Emergency Core Cooling System (ECCS) performance. Additional detail is provided below to support that conclusion.

The waterfall from a postulated break for the first eight hours after the Loss of Coolant Accident (LOCA) (prior to initiation of simultaneous hot leg and cold leg recirculation) will have a maximum of approximately 1370 gpm of water falling from the break. A portion of this injection water will turn to steam (to match reactor vessel boil off) and not impact the water surface. This waterfall is likely to be dispersed due to structural concrete, steel and grating, as well as equipment interferences (such as ventilation ducts) below the reactor coolant pipes. After initiation of simultaneous hot leg and cold leg recirculation (a minimum of 8 hours post-LOCA), a maximum of approximately 3500 gpm of water could fall from the break. The balance of the ECCS flow in both cases (approximately 3300 gpm) goes to containment spray. For a Small Break Loss of Coolant Accident (SBLOCA), significantly less water will issue from the break and thus, the discussion of air ingestion applies to both the SBLOCA and Large Break Loss of Coolant Accident (LBLOCA). In order to entrain air into the strainer fins, the waterfall would need to fall immediately adjacent to the fins for two reasons. First, the horizontal movement of water (and any entrained air) is very low due to the large strainer surface area and, second, air bubbles rise rapidly. Additionally the strainer header, to which the fins are attached, is designed with baffles to encourage even flow through all strainer modules. This design will limit the flow through any one module. Only a very small fraction of the air entrained in the waterfall will fall near enough to the fin surface to be potentially entrained. Since the debris bed is not formed at the start of recirculation, air drawn into a fin will likely escape from either the fin it enters or a nearby fin due to buoyancy and the corrugated shape of the fins. The movement of air out of the fins due to buoyancy and the action of the waterfall near a few of the fins would tend to prevent debris bed formation in a portion of the fins.

Any air that is ingested into the strainer fins that did not escape from other fins could travel horizontally along the top of the header. A 1-½" opening (covered with perforated plate) is installed in the top of the strainer as the two headers enter the solid enclosure. This solid enclosure completely surrounds the recirculation pipes. Air drawn into the enclosure could escape via this vent. Any remaining air which collected in the solid enclosure would not be drawn into the pipes since the Froude number in the enclosure is low (less than 0.1). For a Froude number less than 0.31, the inertial force represented by the liquid velocity is much less than the buoyancy force such that the air bubbles will rise and not be drawn into the ECCS suction pipes. The water level above the ECCS suction pipes, combined with the cruciform vortex suppressors mounted on top of the pipes prevents the formation of a vortex inside the solid enclosure. Thus, if air were ingested into the strainer and traveled to the solid enclosure, it would escape from the vent and not be drawn into the ECCS suction piping.

NRC Question 4

Please provide results of a flashing evaluation for the strainer once the final head loss numbers have been determined.

DNC Response

The minimum margin to flashing in the strainer is 0.61 ft water using the LBLOCA water level of 5.5 ft. The following inputs were used to arrive at this conservative value:

- The LBLOCA minimum water level is 5.6 ft above the floor.
- The top of strainer is at 3.7 feet above the floor.
- The clean strainer head loss is 0.094 ft water at 210°F for a flow of 6800 gpm.
- The allowable head loss for the debris bed is 0.94 ft water at 210°F for a flow of 6800 gpm.
- The sump water is assumed to be saturated.
- No accident overpressure is credited.
- The worst-case debris bed is fully formed on the strainer surface when the ECCS pumps begin drawing water through the strainer.
- The viscosity of water is conservatively increased 12% above that of pure water. This is based on Integrated Chemical Effects Testing (ICET) data which indicates that the increase in water viscosity of containment water due to dissolved chemicals is about 9% at 60°C and about 12% at 23°C (see Figures 4-7 and 4-8 of NUREG/CR-6914 Vol. 1). From the MPS2 test solution, the observed increase in viscosity was 1.6% at 40°C and 0.2% at 21°C. The temperature effect on the viscosity of the test solution is the inverse of the ICET result. As the ICET data bounds the values for viscosity increase of the test solution, the viscosity effect was analyzed using the ICET data.

The maximum observed head loss for the RIG 89 tests was 1.04 psia at 40°C (104°F). This is 0.14 psia above the allowable head loss of 0.9 psia at 40°C. Using the proportional relationship between viscosity and head loss, 1.04 psia at 40°C equates to a debris bed head loss of 1.05 ft water at 210°F. This head loss increase occurs due to particulate formed as a result of potential aluminum corrosion which occurs only many hours or days after the LOCA. Thus, the margin to flashing is not impacted.

For a SBLOCA, minimum water level is 4.5 ft above the floor. Positive margin to flashing exists across the strainer for a SBLOCA due to the following factors:

- The debris bed takes significant time (greater than 3 hours based on test results) to form, and no significant debris bed is likely to exist at the time of pump start. The maximum sump water temperature is <200°F approximately two hours after the LOCA. This provides >2 psia (>4.8 feet at 200°F) of subcooling margin. Assuming that no significant debris bed head loss exists when recirculation starts, the minimum margin to flashing for a clean strainer (for a SBLOCA) is calculated from the margin to flashing for a LBLOCA adjusted for the differences in water level and debris bed head loss. For a SBLOCA, the margin to flashing from the LBLOCA, 0.61 ft, is reduced by 1 ft due to a lower water level and increased by 0.94 ft due to the lack of a debris bed. Thus the margin to flashing is 0.61 ft – 1 ft + 0.94 ft = 0.55 ft for a clean strainer.

- The maximum sump water temperature at the start of recirculation for any accident is 207°F. Saturation pressure for 207°F is 13.3 psia. Minimum containment pressure at the start of the accident is 14.2 psia. Subcooling may be credited to provide 0.9 psia of margin (equivalent to 2.2 ft water) to strainer flashing for a SBLOCA. This subcooling margin is sufficient to offset the difference between the SBLOCA and LBLOCA minimum water levels.

- For a SBLOCA, much less particulate debris will form, resulting in a lower worst-case debris bed head loss than tested. Additionally, the time to initiation of recirculation will be much greater (1-2 hours) than for the limiting LBLOCA. This will allow significantly more time for debris settling and containment atmosphere cooling from the safety-related Containment Air Recirculation (CAR) fans. For the limiting SBLOCA water level, which assumes that the Reactor Coolant System (RCS) remains full, once recirculation begins injection flow rates will be lower and thus flow through the sump strainer will be lower. This will lead to lower debris transport and lower head losses through any debris bed that does eventually form.

Long-term, significant sump water subcooling occurs and thus the margin to strainer flashing increases with time, even though the debris bed head loss increases with increasing water viscosity. The reduction in saturation pressure at lower water temperature has a greater beneficial effect towards margin to flashing.

NRC Question 5

Please provide information that shows that stirring of the tank used to test strainer performance did not adversely affect formation of the debris bed on the strainer during thin-bed testing. Although the staff has found the debris preparation and introduction practices used at Atomic Energy of Canada Limited (AECL) to be generally adequate, the potential exists that stirring of the tank results in non-prototypical transport of fibrous debris shreds to the strainer

during thin-bed testing. These shreds could disturb the formation of fine debris into a bed and reduce the head losses recorded during testing.

DNC Response

RIG 33 was used for the initial Dominion thin-bed testing. This test rig has a mechanical stirrer that is designed to keep most debris suspended before it is carried onto the strainer, thus minimizing settling within the tank. The question raised is whether encouraging all sizes of fibrous debris (shreds as well as fines) to deposit on the strainer could be non-conservative, because shreds may be more likely to settle out and they are more likely to produce a more porous debris bed. In fact, the fibrous debris for all thin-bed testing was prepared in such a way that there were essentially no shreds, only fines (individual fibers). Consequently, this issue did not arise in RIG 33. Evidence for this is that the debris bed that formed on the fins was uniform. Thus, formation of the debris bed was not affected by stirring.

NRC Question 6

The NRC staff has been interacting with AECL and Dominion Energy Kewaunee, Inc., Dominion Nuclear Connecticut, Inc., and Virginia Electric and Power Company (collectively Dominion) regarding the current ongoing chemical effects testing for MPS2 and the other Dominion nuclear sites (RIG-89), which starts with a complete non-chemically laden debris bed of fibers and particulates. The NRC staff has noted that the non-chemical head losses (head loss prior to chemical additions) in the current chemical effects tests are significantly lower than for the similarly scaled debris loads in the previous non-chemical large scale and reduced scale tests. Please provide a comparison of the non-chemical head losses determined during the previous large- and reduced-scale testing to the non-chemical head losses obtained during the current chemical effects testing. Please provide justification for the final chemically laden head loss number used in the strainer evaluation considering that previous non-chemical head losses were significantly higher than the non-chemical head losses determined in association with the recent chemical testing.

DNC Response

The requested information is provided in DNC's December 18, 2008 supplemental response.

NRC Question 7

The assumptions that were made in the supplemental response that led to a change in the limiting net positive suction head (NPSH) margin from 0.83 ft to 1.05 ft are not identified in the licensees submittal. Some assumptions, involving

consideration of additional water holdup mechanisms, would lead to decreasing margins. The additional assumptions that more than compensated for these were not identified. Please provide a discussion of the changes to the NPSH calculation that result in the limiting NPSH margin increasing from 0.83 ft to 1.05 ft, and the resulting changes in the NPSH margin values that are presented in Table 3.6.2-1 of the NRC Audit Report.

DNC Response

The revision to the limiting net positive suction head (NPSH) margin was the result of a comprehensive revision of the hydraulic flow calculation for the ECCS system. Results of the hydraulic flow calculation produced revised NPSH margins for each ECCS pump in each design basis lineup. The resulting minimum NPSH margin (1.05 ft) is for the High Pressure Safety Injection (HPSI) pump in the recirculation lineup with maximum flow and the failure of a single train of ECCS. All other NPSH margin values for the ECCS pumps are larger. The most significant change which led to the increased NPSH margin is the change in the minimum water level used in the hydraulic flow calculation from 4.23 feet to 5.5 feet above the containment floor. In the calculation revision, changes were made in the hydraulic model to ensure conservatism in the maximum position of the HPSI throttle valves. This led to an increase in the maximum open position for the HPSI pump throttle valves, which led to higher HPSI pump flows and higher required HPSI pump NPSH values. This increase in required NPSH (due to increased flow) offset much of the increased available NPSH from the increase in minimum water level. Thus, the minimum NPSH margin for the HPSI pump increased only 0.2 ft (approximately 2.6 inches).

Additional water holdup mechanisms were included in a revision to the water holdup calculation. These changes to water holdup are detailed in Sections G and L of Attachment 1 of the February 2008 supplemental response (ADAMS Accession No. ML080650561). The minimum water level used in the revision to the ECCS hydraulic calculation reflects the changes made in the water holdup calculation.

The minimum water level used for the hydraulic calculation (5.5 feet) is bounded by the minimum LBLOCA water level but not the minimum SBLOCA water level. The prior minimum water level used (4.23 ft) was a minimum SBLOCA water level. Justification for using the LBLOCA minimum water level is included in Section G of Attachment 1 of the February 2008 supplemental response (ADAMS Accession No. ML080650561).

The following table is an updated version of Table 3.6.2-1 from the NRC Audit Report. The updated table shows the limiting pump flows and NPSH margins. Both flows and NPSH margins listed in the table below come from the ECCS hydraulic calculation.

Case	HPSI Pumps				LPSI Pumps				CSS Pumps				Total Sump Flow (gpm)[2]
	P41 A/B[1]		P41 B[1]/C		P42A		P42B		P43A		P43B		
	Flow (gpm)	NPSH Margin (ft)	Flow (gpm)	NPSH Margin (ft)	Flow (gpm)	NPSH Margin (ft)	Flow (gpm)	NPSH Margin (ft)	Flow (gpm)	NPSH Margin (ft)	Flow (gpm)	NPSH Margin (ft)	
Two Train recirculation (2A2a)	685.5	1.53	684.9	1.75	N/A		N/A		1630.5	2.88	1615.7	3.13	4616.5
One train recirculation (2B2a)	694.2	1.05	N/A		N/A		N/A		1630.5	2.88	N/A		2324.6
Max strainer flow--two train	686.3	1.27	409.9	12.34	2408.3	12.73	N/A		1630.0	2.62	1615.7	3.15	6750.2
Max strainer flow--one train	N/A		417.6	11.69	N/A		3616.9	7.0	N/A		1614.9	2.7	5649.5

Note 1 -HPSI pump P41B is the spare "swing" HPSI pump that can be aligned as a substitute for either the P41A or P41C Pump.
Note 2 -Totals are different from sum of flows in each row due to independent rounding.

NRC Question 8

The supplemental response stated that operators would be capable of terminating flow from a low pressure safety injection (LPSI) pump which failed to stop at switchover to sump recirculation (by closing LPSI injection valves). However, no information was provided on how this action is to be prioritized. Please provide a summary of the emergency operating procedure guidance that directs operators to resolve this single failure scenario and prioritizes these operator actions. Please discuss operator recognition time and response times.

DNC Response

At MPS2, the Emergency Operating Procedures (EOPs) are written in a two column format, with instructions in the left hand column and contingency actions in the right hand column. If the instruction cannot be successfully accomplished, the operator immediately carries out the contingency action.

Following a Loss of Coolant Accident (LOCA) inside containment, the EOPs contain the following instruction step:

"If break is inside containment AND the RWST [Refueling Water Storage Tank] level is less than or equal to 9%, ENSURE the following:"

1) Sump Recirculation Actuation Signal (SRAS) has actuated,
2) Both LPSI pumps have stopped,
3) Both containment sump outlet valves are open,
4) Both reactor building closed cooling water outlet valves from the shutdown cooling heat exchanger are open, and
5) Both safety injection/containment spray minflow isolation valves are closed.

By the design of MPS2, the above 5 actions should happen automatically. If the actions do not occur automatically, the word "ENSURE" in the instruction step means that the operator will take manual action to attempt completion of the specified action. In the event that the operator cannot complete the specified action, the operator is directed to carry out the right hand column contingency.

For the first instruction sub-step listed above, ensure the SRAS has actuated, there is no contingency action, as there is no postulated single failure that could result in the inability to actuate a SRAS automatically or manually. The second instruction sub-step listed above is to ensure both LPSI pumps have stopped. As we indicated in our supplemental response dated February 29, 2008, DNC concluded that the failure of a LPSI pump to stop on SRAS is a possible single failure. The change that was made to the EOPs noted in this supplemental response was to add a contingency action to this second sub-step. That contingency action is:

"IF LPSI pumps cannot be stopped, PERFORM the following:

1) CLOSE SI-635, LPSI injection valve
2) ENSURE **TWO** of the following valves are fully closed and only **ONE** of the valves is fully open:
   - SI-615, LPSI injection valve
   - SI-625, LPSI injection valve
   - SI-645, LPSI injection valve"

By closing three of the four LPSI injection valves, the total ECCS flow through the ECCS suction strainer is reduced to less than the strainer design maximum flow of 6800 gpm. Closing LPSI injection valve SI-635 (and any other two LPSI injection valves) was selected because it partially anticipates the valve alignment necessary for simultaneous hot and cold side ECCS injection 8-10 hours following a LOCA with LPSI injecting into the hot legs.

The SRAS is automatically generated by the Engineered Safeguards Actuation System when indicated RWST level drops to 9%. In addition to the operator monitoring RWST level following the initiation of the event, when level in the RWST drops to 9%, an annunciator on control room panel C-01 will alarm, alerting the operator to this condition. Since either stopping the LPSI pumps or closing the LPSI injection valves is the second action the operator would take following the RWST level dropping to 9%, and these actions can be accomplished from inside the control room, these actions would be completed within a few minutes of a SRAS, certainly within much less than one half hour following SRAS. In our supplemental response, DNC indicated that the time to build a debris bed on a strainer has been shown in extensive head loss testing to be several hours, even with the debris deposited immediately adjacent to the strainer. As such, there are large margins between the time LPSI flow would be reduced to less than the strainer design maximum flow 6800 gpm and the time a significant debris bed is built on the strainer. Because of this, the action to either stop a LPSI pump on SRAS or close three of the four LPSI injection valves is not considered a time critical operator action.

<u>NRC Question 9</u>

Please provide the information regarding ex-vessel downstream effects requested under item 3.m, "Downstream effects - Components and Systems," in the "Revised Content Guide for Generic Letter 2004-02 Supplemental Response," dated November 2007.

DNC Response

The requested information is provided in DNC's December 18, 2008 supplemental response.

NRC Question 10

The NRC staff considers in-vessel downstream effects to not be fully addressed at MPS2 as well as at other pressurized water reactors (PWRs). DNC's submittal refers to Revision 0 of the PWR Owners Group (PWROG) topical report WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." At this time, the NRC staff has not issued a final safety evaluation (SE) for this topical report since the PWROG intends to submit Revision 1 to address several issues identified by the Advisory Committee on Reactor Safeguards and the NRC staff. The licensee may demonstrate that in-vessel downstream effects issues are resolved for MPS2 by showing that the licensee's plant conditions are bounded by the revised version of WCAP-16793 and the corresponding final NRC staff SE, and by addressing the conditions and limitations in the final SE. The licensee may also resolve this item by demonstrating, without reference to WCAP-16793 or the NRC staff SE that in-vessel downstream effects have been addressed at MPS2. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on WCAP-16793. The NRC staff is developing a Regulatory Issue Summary to inform the industry of the staff's expectations and plans regarding resolution of this remaining aspect of Generic Safety Issue (GSI-191), "Assessment of [Effect of] Debris Accumulation on PWR Sump Performance."

DNC Response

DNC has a corrective action to complete the above evaluation within 90 days of issuance of the final NRC staff SE on WCAP-16793. This action will be tracked by DNC's Corrective Action Program.

NRC Question 11

Please provide the results of the bench top testing to determine quantities of chemical precipitates formed. Also, please provide the results of the reduced-scale head loss testing that utilized the findings of the bench top tests.

DNC Response

The requested information is provided in DNC's December 18, 2008 supplemental response.

ATTACHMENT 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION (RAI) REGARDING GENERIC LETTER 2004-02

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

Request for Additional Information Regarding GL 2004-02 Millstone Power Station Unit 3 (MPS3)

NRC Question 1

The licensee's strainer head loss testing, including chemical effects, was not complete at the time the February 2008 supplemental response was developed. To the extent it was not provided in the February 2008 submittal, please provide the information requested under item 3.f, "Head Loss and Vortexing," in the "Revised Content Guide for Generic Letter 2004-02 Supplemental Response," dated November 2007 (ADAMS Accession No. ML073110389). Specifically, please provide an update to the final head loss and vortexing evaluation based on completed testing.

DNC Response

Head loss information as well as significant margins and conservatisms for final debris bed testing (with chemical precipitants) is provided in DNC's supplemental response dated December 18, 2008 (ADAMS Accession No. ML083650005). The testing described in the December 2008 submittal represents the worst-case head loss expected for the installed strainer. These results include head loss due to fibrous and particulate debris as well as chemical precipitants that may form long-term in the post-LOCA sump water. No additional vortex testing was done as part of the chemical effects testing.

Vortex testing previously reported found no vortexing for water levels as low as 10 inches above the floor (strainer not submerged) and for water levels equal to the top of the strainer (zero submergence). The minimum SBLOCA water level has changed as a result of the recently completed power uprate at MPS3. The new SBLOCA minimum water level is 44 inches vice the 52 inches reported in the February 2008 supplemental response (ADAMS Accession No. ML080650561). This minimum value occurs just after Recirculation Spray System (RSS) pump start when the RSS system is full. This lower value of SBLOCA minimum water level impacts the available head loss as well as margins to suction line flashing, strainer flashing, and RSS pump NPSH as discussed in answers to the questions below. The minimum LBLOCA water level remains at 52 inches. The strainer is fully submerged at RSS pump start using the water level of 44 inches, but submergence of the strainer is essentially zero as discussed in the answer to question 2 below. The ultimate strainer submergence is a minimum of 4 feet and a maximum of approximately 9 feet which occurs after the Quench Spray System (QSS) pumps stop adding water from the RWST. The minimum strainer submergence of approximately 4 feet is used in discussions below of strainer flashing and margin to suction line flashing. The reduced minimum SBLOCA water level has no impact on air evolution downstream of the strainer because the debris bed buildup will not occur until the QSS pumps stop adding water to the containment sump and submergence of the strainer is at least 4 feet.

NRC Question 2

Please provide results of a flashing evaluation for the strainer once the final head loss numbers have been determined.

DNC Response

A flashing evaluation analyzes the potential for strainer flashing for both LBLOCA and SBLOCA.

The minimum margin to strainer flashing is calculated for the RSS pump effective time and for the time when the RWST is at the level at which the QSS pumps stop. The RSS pump effective time occurs shortly after the RSS pump start time when the RSS pump suction and discharge piping are full and the containment sump water level is at its minimum value. The RWST is approximately half full at RSS start. The QSS pumps stop taking suction from the RWST at a maximum of approximately 3 hours post-accident.

For the RSS pump effective time, the minimum margin to flashing in the strainer is 0.7 inches for a SBLOCA and 3.4 inches water for the LBLOCA. The following inputs were used to arrive at these conservative values:

- The SBLOCA minimum water level is 44 inches above the floor and the LBLOCA minimum water level is 52 inches above the floor.
- The top of strainer is 44 inches above the floor. The strainer has a solid cap on each fin which extends down 1 inch from the top of each fin. Thus, the highest holes in the fins are submerged by 1 inch which allows for a small margin to flashing for a SBLOCA even when conservatively assuming sump water is saturated.
- The clean fin head loss is 83.7 Pa (0.3 inches water) at 100°F for a flow of 8220 gpm.
- No debris bed is postulated to be on the strainer at the RSS pump effective time.
- The sump water is assumed to be saturated.
- No accident overpressure is credited.
- The viscosity of water is conservatively increased 12% above that of pure water. This is based on ICET data which indicates that the increase in water viscosity of containment water due to dissolved chemicals is about 9% at 60°C and about 12% at 23°C (see Figures 4-7 and 4-8 of NUREG/CR-6914 Vol. 1). Based on the MPS3 test solution, the observed increase in viscosity was 4.4% at 40°C and 1.3% at 21°C. The temperature effect on the viscosity of the test solution is the inverse of the ICET result. As the ICET data bounds the values for viscosity increase of the test solution, the viscosity effect was analyzed using the ICET data.

For the time when QSS pumps stop taking suction from the RWST, the minimum margin to flashing in the strainer is 4.2 ft for a SBLOCA and 0.4 inches for a LBLOCA. The following inputs were used to arrive at these conservative values:

- The minimum water level for both a SBLOCA and LBLOCA is 4 feet above the top of the strainer (92 inches above the containment floor).
- The clean strainer head loss is 0.382 ft water at 100°F for a flow of 8220 gpm for both a SBLOCA and LBLOCA (conservatively includes fin losses and flow losses in channel below fins).
- The worst-case LBLOCA debris bed (5.1 ft water at 104°F) is postulated to be on the strainer when the RWST is empty for both a SBLOCA and a LBLOCA.
- The sump water is assumed to be saturated for a LBLOCA. Minimum sump water subcooling is credited for a SBLOCA three hours post-LOCA.
- No accident overpressure is credited.
- Increased viscosity of sump water above that of pure water due to dissolved chemicals is neglected since the debris bed head loss value used is not corrected for the lower viscosity, which would occur for the lowest possible saturated sump water temperature of 195°F.

For a SBLOCA, the following conservatisms provide additional assurance of a positive margin to flashing across the strainer.

- All of the SBLOCA analyzed break scenarios show that the water is subcooled at the time of RSS pump start. The SBLOCA scenario, which results in the highest temperature (215°F), is dependent on a containment pressure of approximately 10 psi, which would produce subcooled sump water. All of the remaining SBLOCA scenarios show maximum sump water temperatures less than 200°F with pressures above one atmosphere. Subcooling provides adequate assurance of no flashing for the SBLOCA scenario.
- For any scenario in which the RSS pumps start, the QSS pumps continue spraying water into containment from the RWST. The RSS pumps start when just over half of the RWST has been put into containment; thus, almost half the RWST is sprayed in after RSS pump start. This results in a continuously rising sump water level for almost three hours following RSS pump start, providing additional submergence and additional margin to flashing inside the strainer.
- The clean strainer head loss (as provided in the hydraulic report) is dominated by shock and flow losses in the sump and in the channel leading to the sump. These head losses occur at the bottom of the fins, which is 36 inches below the top of the strainer. There is an insignificant head loss as the water enters the fins. Thus, there will be no flashing inside the strainer even in the limiting SBLOCA water level scenario with saturated water.
- The minimum SBLOCA water level is calculated by including several significant conservatisms. The calculation uses a set of limiting conditions which are not linked to any particular SBLOCA scenario. The most conservative of these is the assumption that the reactor and RCS remain completely filled and that additional

water is added to maintain these filled as the water temperature drops. The resulting water level is a conservatively bounding minimum water level for any SBLOCA scenario.

Long-term, significant sump water subcooling occurs and thus the margin to strainer flashing increases with time even though the debris bed head loss increases with increasing water viscosity. The reduction in saturation pressure at lower water temperature has a greater beneficial effect towards margin to flashing.

NRC Question 3

Please provide information that shows that stirring of the tank used to test strainer performance did not adversely affect formation of the debris bed on the strainer during thin-bed testing. Although the NRC staff has found the debris preparation and introduction practices used at Atomic Energy of Canada Limited (AECL) to be generally adequate, the potential exists that stirring of the tank results in non-prototypical transport of fibrous debris shreds to the strainer during thin-bed testing. These shreds could disturb the formation of fine debris into a bed and reduce the head losses recorded during testing.

DNC Response

RIG 33 was used for the initial Dominion thin-bed testing. This test rig has a mechanical stirrer that is designed to keep most debris suspended before it is carried onto the strainer, thus minimizing settling within the tank. The question raised is whether encouraging all sizes of fibrous debris (shreds as well as fines) to deposit on the strainer could be non-conservative, because shreds may be more likely to settle out and they are more likely to produce a more porous debris bed. In fact, the fibrous debris for all thin-bed testing was prepared in such a way that there were essentially no shreds, only fines (individual fibers). Consequently, this issue did not arise in RIG 33. Evidence for this is that the debris bed that formed on the fins was uniform. Thus, formation of the debris bed was not affected by stirring.

NRC Question 4

The explanation for higher peak head loss that occurred during large-scale strainer performance testing stated that air was released from solution when head loss across the debris bed lowered the pressure in the debris bed below the static pressure of water on top of the debris bed. This air release apparently resulted in higher peaks in head loss. The explanation of this phenomenon is unclear. It is also unclear as to why this phenomenon would not occur during the reduced-scale testing since the head losses and submergence were similar. Please provide additional details and evaluation of the cause of the peak head loss that occurred during this testing.

DNC Response

In containment post-LOCA, the final level of the sump water is at least four feet (and as much as 9 feet) above the top of the strainer. This occurs within about 3 hours post-accident. Debris bed formation takes many hours as demonstrated in the test tank even when the debris bed is carefully and deliberately built (as it was in the test tank) to maximize head loss. Debris bed formation, then, will occur with a significant static head of water on the strainer which will prevent significant air release from solution. This result was seen in the RIG 89 test tank where a head tank was installed several feet above the test header to simulate final submergence. No air generation in the debris bed or the strainer test module was evident anytime during the RIG 89 testing for MPS3. Even when the level of the water was lowered to simulate only 4 feet of submergence on the test module (below the minimum water level expected), no air generation was evident though the test was continued for several days after this. Submergence for the reduced scale (RIG 33) and large scale testing was approximately 8 inches.

The water in the sump post-LOCA is likely to be air-saturated water due to initial blowdown, break flow turbulence and continuous sprays. The water in the test tank was similarly nearly air saturated due to stirring, recirculation, and addition of fiber which contained trapped air. Generation of air in the debris bed and the strainer resulted when the absolute pressure in the debris bed fell below the saturation pressure (the pressure at which air will come out of solution). If the water was completely air-saturated, then the air generation began as soon as the debris bed head loss exceeded the static head of water. The test water temperature is 104°F and density is 62 lb/ft^3. For a submerged depth of 8 inches, air generation will start at approximately 0.29 psi debris bed head loss (at the top of the fins) and 1.9 psi at the bottom of the fins. The air generated would accumulate in the debris bed, in the fins and in the plenum below the fins. This air caused head loss beyond the existing debris bed head loss.

Air generation was observed in both large scale and reduced scale tests. In the tests where air generation was apparent, the shape of the head loss spikes with sharp increases occurring as soon as the first fibers reached the debris bed and the increases stopping when the fiber additions were completed, was not typical of a fiber bed trapping circulating particulate. Rather, the slower rise and long stabilization time observed in tests where air generation was clearly not occurring in significant amounts are more typical. The air-induced head loss spikes, in both the reduced scale and large scale tests for MPS3 were initiated by the arrival of the fiber at the debris bed, not particulate capture. Microscopic examination of fibers prepared in a similar fashion to the MPS3 large and reduced scale tests (i.e. using a pressure washer to agitate and break up the clumps of fiber) showed that air bubbles were attached to the fibers. These air bubbles, in combination with the non-prototypical submergence, initiated the head loss spikes.

As soon as the fibers and bubbles reached the debris bed, the bubbles started to migrate into the debris bed, blocking flow area and causing the head loss to increase. The increasing head loss caused the generation of more bubbles within the bed, which, in turn, caused a further increase in head loss. Once debris addition was completed and no new bubbles were arriving at the debris bed, the continuing migration of air bubbles through the debris bed into the fins caused the quantity of air in the debris bed to begin to decrease, unblocking flow area and causing further head loss decreases. Eventually, the rate of air generation decreased to become equal to the rate of air migration, and the head loss stabilized at a lower value than the peak value.

Some of the reduced scale tests conducted prior to the large scale tests also had significant spikes. These spikes were the result of biological activity or air. Based on the large-scale test results and the RIG 33 chemical test results (discussed in the answer to question 5 below), air is likely to have been a significant contributor to the head loss spikes, although it is not possible to quantify how much head loss came from each source. The plots of the head loss during tests where air is suspected to be a factor have sudden spikes up in head loss followed by some up and down behavior with a generally decreasing trend. These spikes are similar to those observed in the large scale testing and in the RIG 33 chemical testing.

NRC Question 5

During an NRC staff visit to the AECL test facility, the acceptance criterion for strainer head loss appeared to have been exceeded during a chemical effects reduced-scale test. Please provide information that demonstrates whether the results of this testing are applicable to the existing installation at MPS3, or show that the criterion was not exceeded.

DNC Response

The test referred to in the above question is likely the reduced-scale test with chemicals, which was run in the RIG 33 facility during April and May 2008. This was a test intended to determine the difference in head loss due to chemical effects prior to availability of RIG 89 for final chemical effects testing. The RIG 89 test result is the test intended and reported as the final worst-case head loss for the MPS3 strainer. RIG 33 is the same 90-inch diameter open plastic tank in which all of the reduced scale tests without chemicals were run for MPS3. The same strainer test module used for the previous reduced scale testing was used for this test with chemicals. The maximum fill height of this tank is 56 inches. The submergence of the strainer test module in this tank started at 6 inches and increased to 14 inches after addition of all debris and chemicals.

Significant head loss oscillations occurred during the building of the debris bed due to air evolution as described in the response to question 4 above. The head loss spikes most likely occurred due to inadequate submergence of the strainer test module and debris bed.

The results of the RIG 33 chemical test are not applicable to the installation in the MPS3 containment due to the inadequate submergence of the test rig. Submergence in the MPS3 containment in the presence of fiber and chemical additions was shown to be adequate to prevent air-induced head loss spikes in the RIG 89 testing.

NRC Question 6

The staff has been interacting with AECL and Dominion Energy Kewaunee, Inc., Dominion Nuclear Connecticut, Inc., and Virginia Electric and Power Company (collectively Dominion) regarding the current ongoing chemical effects testing for MPS3 and the other Dominion nuclear sites (RIG-89), which starts with a complete non-chemically laden debris bed of fibers and particulates. The NRC staff has noted that the non-chemical head losses (head loss prior to chemical additions) in the current chemical effects tests are significantly lower than for the similarly scaled debris loads in the previous non-chemical large scale and reduced scale tests. Please provide a comparison of the non-chemical head losses determined during the previous large- and reduced-scale testing to the non-chemical head losses obtained during the current chemical effects testing. Please provide justification for the final chemically laden head loss number used in the strainer evaluation considering that previous non-chemical head losses were significantly higher than the non-chemical head losses determined in association with the recent chemical testing.

DNC Response

The information requested in this question is provided in DNC's supplemental response dated December 18, 2008.

NRC Question 7

Please provide information that demonstrates that adequate net positive suction head (NPSH) margins are maintained throughout the post-loss of coolant accident mission time. If a time-based approach is taken, provide clear illustrations of the factors that result in the head loss values and the pump NPSH required, including an evaluation of the margin at each postulated condition.

DNC Response

See the response to question 10 for a description of the calculation of NPSH margin and margin to suction line flashing without the strainer and debris bed.

Evaluation shows adequate NPSH margin and adequate margin to suction line flashing exists throughout the period during which decay heat removal is required.

Maximum required NPSH for each RSS pump is 4 ft at 3000 gpm. This flow rate exceeds any single pump flow rate which could exist in any design basis lineup after RSS fill is complete. The maximum flow that could be seen by any RSS pump during system fillup only (with instrument uncertainty) is 3150 gpm, for which required NPSH is 4.5 ft.

Minimum available NPSH starts with the minimum elevation of the water (for a SBLOCA) above the pump impeller centerline (26.7 ft), and subtracts the maximum debris bed head loss (5.1 ft water, equivalent to 2.2 psi at 100°F), the piping head loss at a flow of 3012 gpm (3.8 ft), and the maximum clean strainer head loss of 0.382 ft. Thus, available NPSH is 17.4 ft. For the higher flow rates which could briefly occur at pump startup, the available NPSH is not limiting since no debris bed is formed.

Minimum NPSH margin is 13.4 ft for a flow rate of 3000 gpm. The NPSH margin for the RSS pumps only increases from this value post-LOCA as more water is added to the containment sump (as the RWST is emptied) and sump water cools over time due to heat transfer to Long Island Sound.

Suction line flashing for the RSS pumps is more limiting than NPSH due to the configuration of the RSS pump suction piping. The piping contains a high point prior to the pump suction. Flashing in the suction line would lead to degraded available NPSH and thus is to be avoided. The answer to question 10 shows that adequate margin to suction line flashing exists without considering the strainer or debris bed. The following discussion shows that adequate margin to suction line flashing also exists throughout the post-accident mission time in the presence of the worst-case debris bed head loss and maximum clean strainer head loss.

Using the minimum sump water level for a SBLOCA and the maximum elevation of the suction piping, the minimum elevation head in the suction piping is 8.3 ft. Total piping head loss for the maximum steady state single RSS pump flow is 2.6 ft of water. Maximum debris bed head loss is 5.1 ft and maximum clean strainer head loss is 0.382 ft. This gives the minimum suction line flashing margin of just over 2 inches for a SBLOCA. Since the LBLOCA minimum water level is 8 inches higher, the margin to suction line flashing is also 8 inches higher for a LBLOCA. This margin to suction line flashing is conservatively calculated prior to adding all available water from the RWST and making the conservative assumption that the debris bed is fully formed when the RSS pumps start when, in fact, the debris bed will take several hours to form.

NRC Question 8

Please clarify whether water holdup due to steam in the containment atmosphere was included in the minimum water level calculation, and, if not, please justify its omission.

DNC Response

Water holdup due to steam in the containment atmosphere is included in the minimum water level calculation.

NRC Question 9

For the minimum water level calculation at switchover, the supplemental response states that drainage from the refueling cavity is not credited. However, the NRC staff questions whether drainage from the refueling cavity is credited in the long term. In other words, if water from the recirculation sprays continues to drain into the cavity until it fills completely, would the results of the minimum water level calculation at switchover remain bounding, and how is this accomplished within the calculation? If not, then please describe the refueling cavity drain and the basis for assuming that debris blockage would not affect the flow of water through this drain during recirculation.

DNC Response

In the minimum water level calculation, the refueling cavity saddle volume, prior to spillover into the reactor cavity, is calculated to be 99% full prior to RSS pump start. Spillover from the refueling cavity saddles fills the reactor cavity and instrumentation tunnel prior to spilling onto the containment floor. The additional water trapped in the refueling cavity after RSS pump start is insignificant and does not impact the calculated minimum sump water level.

NRC Question 10

The results of the NPSH margin calculation, in the absence of the strainer or debris bed, should be clearly presented, such that the assumed pump operating states, pump flow rates, break size and pump configuration (i.e., cold leg recirculation or two-path recirculation) associated with the each analyzed case are specified.

DNC Response

Details of the NPSH margin calculation in the absence of the strainer or debris bed:

- NPSH is calculated assuming saturated water: Available NPSH = $Head_{elev}$ - $Head_{friction}$.
- Elevation head is calculated using minimum SBLOCA water level (4.4 inches) above -24 ft 6 inches floor elevation. Total elevation head is 26.7 ft.
- Suction piping and component friction loss is calculated using standard hydraulic methods. Total friction head loss is 3.8 ft.
- Flow rate used for available NPSH calculation is 3012 gpm, which is the maximum RSS single pump flow rate in any mode (limited by an installed pump discharge orifice). This is a transient flow rate which only exists during RSS fill.
- Use of maximum single pump flow rate renders the minimum available NPSH in any pump configuration. Maximum single pump flow rate of 3012 gpm bounds the maximum steady state flow rate seen in any pump configuration (i.e. cold leg recirculation or two-path recirculation).
- Required NPSH is 4 ft at 3000 gpm.
- Available NPSH = 26.7 ft – 3.8 ft = 22.9 ft.
- NPSH margin without strainer or debris bed is the difference between available and required NPSH which is 22.9 ft – 4 ft = 18.9 ft. Due to the large NPSH margin, no significant impact is seen from using a potentially higher single RSS pump flow rate of 3150 gpm, which includes instrument uncertainty during system fill.

Due to the RSS pump suction line configuration, the margin to suction line flashing is more limiting than NPSH margin.

Details of the Suction Line Flashing margin calculation in the absence of the strainer or debris bed:

- Suction Line Flashing margin is calculated assuming saturated water: Flashing Margin = $Head_{elev}$ - $Head_{friction}$.
- Elevation Head is calculated as the difference between the minimum SBLOCA water level and the highest point in the suction piping. Total elevation head for suction line flashing = 8.3 ft.
- Suction piping and component friction loss is calculated using standard hydraulic methods. Total friction head loss is 3.8 ft.
- Flow rate used for suction line flashing margin calculation is 3012 gpm, which exceeds the maximum steady state RSS single pump flow rate in any mode after system fill (limited by an installed pump discharge orifice). Additional piping head loss caused by higher flow rates possible during RSS system fill (up to 3150 gpm) is approximately 0.4 ft water which does not significantly impact the margin to suction line flashing.
- Use of maximum single pump flow rate renders the minimum available suction line flashing margin in any pump configuration. Maximum single pump flow rate of 3012 gpm bounds the maximum steady-state flow rate seen in any pump configuration (i.e. cold leg recirculation or two-path recirculation).

- Suction line flashing margin without the strainer or debris bed is: 8.3 ft – 3.8 ft = 4.5 ft.
- Once the RSS is full (approximately 2 minutes after pump start), maximum steady state flow rate is 2500 gpm in any pump configuration.
- Use of 2500 gpm lowers the suction piping and component head loss to 2.6 ft.
- Suction line flashing margin without the strainer or debris bed after steady state flow is attained is: 8.3 ft – 2.6 ft = 5.7 ft.

NRC Question 11

The basic assumptions and methodology used in the analysis for computing the strainer flashing margins should be described in sufficient detail to show that the results are conservative. In particular, the response should address the technical basis for the 2450 gallons per minute (gpm) Recirculation Spray System (RSS) pump flow rate used in the flashing analysis. Discuss the basis for neglecting higher RSS pump flow rates that are possible immediately after recirculation (i.e., 3150 gpm), for which the flashing margin could be negative.

DNC Response

The strainer flashing evaluation is described above in the answer to question #2. The flashing analysis described above uses 8220 gpm as the largest steady state value of RSS pump flow (combined flow rate from all four RSS pumps) which will be seen through the strainer. Individual RSS pump flow rates as high as approximately 3150 gpm are possible immediately after RSS pump start while the RSS piping is filling.

Flow into the strainer enters the strainer fins and drops vertically down either directly into the sump or into a channel which flows to the sump. Eight of the strainer modules are positioned directly over the sump and the other nine are positioned directly over a flow channel which leads to the sump.

The worst-case clean strainer head losses are for uniform flow through all the fins. Lower head losses will result for non-uniform flow. For a clean strainer, which will be the condition existing when the RSS pumps start, the flow will be non-uniform because flow will preferentially travel through the modules directly over the sump due to the lower head loss in that path. For the limiting case of uniform flow, the following table shows the major components of the clean strainer head loss.

Clean Strainer Head Loss Components

Fin Duct Losses	11.5 Pa
Losses at the Merge between the Fin Duct and Collector Channel	71.3 Pa
Friction and Shock Losses in Channel and Sump	1051 Pa

As can be seen from the table, the clean strainer head loss is dominated by the flow losses in the channel and the sump, which are below the bottom of the fins. Over 90% of the clean strainer head loss occurs at the containment floor level, which is submerged by the minimum sump water level of 44 inches. The fin duct losses are the only losses that could occur near the surface of the water and much of these losses also occur well below the water surface since the fins are mounted vertically. Thus, there is essentially no clean strainer head loss near the surface of the water where flashing could occur. These results would not substantially change even with the potentially higher RSS pump flow rates, which occur during the approximately 2 minute RSS piping fill just after RSS pump start. Additional conservatism in the clean strainer head loss calculation is provided by the use of 100°F water in the calculation of clean strainer head loss. The actual temperature of the water at RSS pump start is likely to be much higher which would lead to lower density and viscosity and lower head loss. The lowest saturation temperature is 195°F, which corresponds to the lowest possible containment pressure at the beginning of the accident. Any temperature lower than this would involve subcooled water and thus, additional margin to flashing.

NRC Question 12

Please provide the information requested under item 3.m, "Downstream effects – Components and Systems," in the "Revised Content Guide for Generic Letter 2004-02 Supplemental Response," dated November 2007.

DNC Response

The requested information is provided in DNC's December 18, 2008 supplemental response.

NRC Question 13

The NRC staff considers in-vessel downstream effects to not be fully addressed at MPS3 as well as at other PWRs. MPS3's submittal refers to Revision 0 of the PWR Owners Group (PWROG) topical report WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." At this time, the NRC staff has not issued a final safety evaluation (SE) for this topical report since the PWROG intends to submit

Revision 1 to address several issues identified by the Advisory Committee on Reactor Safeguards and the NRC staff. The licensee may demonstrate that in-vessel downstream effects issues are resolved for MPS3 by showing that the licensee's plant conditions are bounded by the revised version of WCAP-16793 and the corresponding final NRC staff SE, and by addressing the conditions and limitations in the final SE. The licensee may also resolve this item by demonstrating without reference to WCAP-16793 or the staff SE that in-vessel downstream effects have been addressed at MPS3. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on WCAP-16793. The NRC staff is developing a Regulatory Issue Summary to inform the industry of the staff's expectations and plans regarding resolution of this remaining aspect of Generic Safety Issue GSI-191, "Assessment of [Effect of] Debris Accumulation on PWR Sump Performance."

DNC Response

DNC has a corrective action to complete the above evaluation within 90 days of issuance of the final NRC staff SE on WCAP-16793. This action will be tracked by DNC's Corrective Action Program.

NRC Question 14

Please provide the results of the bench top testing to determine quantities of chemical precipitates formed. Please provide the results of the reduced-scale head loss testing that utilized the findings of the bench top tests.

DNC Response

The requested information is provided in DNC's December 18, 2008 supplemental response.