DRAFT

Response to Request for Additional Information
Generic Letter 2004-02

Surry Power Station Units 1 and 2

VIRGINIA ELECTRIC AND POWER COMPANY
(DOMINION)

Response to Request for Additional Information
Generic Letter 2004-02

Surry Power Station Units 1 and 2

By letters dated March 4, and September 1, 2005, November 15, 2007, February 29, 2008 and February 27, 2009 [Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML050630559, ML ML052500378, ML073190553, ML080650562 and ML090641018, respectively], Virginia Electric and Power Company (Dominion) submitted responses to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors," for Surry Power Station Units 1 and 2 (SPS 1 and 2).

In a letter dated June 18, 2009, the Nuclear Regulatory Commission (NRC) transmitted a request for additional information (RAI) regarding Dominion's February 29, 2008 and February 27, 2009 supplemental responses to GL 2004-02 for SPS 1 and 2. The NRC's questions and Dominion's responses are provided below.

NRC Question 1

Please describe how much aluminum surface area (from the reactor vessel insulation) would be exposed for a reactor coolant system (RCS) loop break at a reactor vessel nozzle. Please explain whether your chemical effects evaluation considered exposure of this material and whether a break at this location is potentially limiting with respect to potential for sump strainer clogging.

Dominion Response

As identified in the Surry Power Station Unit 1 and Unit 2 Containment Debris Walkdown Packages, the reactor vessel and nozzles are insulated with reflective metal insulation (RMI), i.e., stainless steel. Therefore, the break at the reactor vessel nozzle does not contribute to the aluminum inventory and/or chemical effects evaluation and is not limiting. A break inside the Steam Generator cubicle remains limiting with respect to potential containment sump strainer clogging.

NRC Question 2

Please describe the construction details for the asbestos and asbestos/Cal-Sil insulation at Surry and provide results of evaluation of the similarity of these materials in the plant to the Cal-Sil material whose testing formed the basis for the zone of influence (ZOI) value of 5.45D that is referenced in NEI 04-07 and the corresponding NRC safety evaluation, cited in the February 29, 2008, supplemental response as applicable to the Surry Power Station (SPS) asbestos and asbestos/Cal-Sil. Please also explain how the base material, jacketing, and banding for the material in the plant are similar to the properties of the tested material used to derive a 5.45 ZOI.

Dominion Response

During construction of SPS 1 and 2, asbestos and asbestos/cal-sil insulation was jacketed with a 1925 glass cloth jacketing system manufactured by J.P. Stevens & Co. The jacketing was attached with Benjamin-Foster 30-36 Sealfas adhesive and two coats of epoxy enamel. However, documentation verifying qualification of the jacketing system for a Design Basis Accident (DBA) could not be located. Therefore, asbestos and asbestos / cal-sil insulation located in the containment was re-jacketed using DBA qualified stainless steel jacketing over the original 1925 glass cloth jacketing. The stainless steel jacketing properties and installation configuration are as follows:

- Jacketing material is Type 304 or 316 stainless steel with a thickness of 0.010" or 0.016" (low traffic areas) and 0.020" (high traffic areas).
- Jacketing is applied with horizontal & vertical overlaps in order to shed water.
- Jacketing is attached with stainless steel banding located no greater than 18" on centers secured with mechanical tightening devices with the ends secured with mechanical fasteners that permit a flat joint.
- Stainless steel banding dimensions are 0.5" x 0.02" for piping less than 12" in diameter and 0.75" x 0.02" for piping 12" in diameter and greater.
- As an alternative to banding, spring loaded positive locking stainless steel buckles (Transco or approved equal) are also used.

ZOI Values for Asbestos/Cal-Sil and Asbestos

1. Asbestos/Cal-Sil:

The design calculations utilized the attributes of cal-sil insulation when evaluating the effects of the insulation category asbestos / cal-sil. In accordance with NEI 04-07 and its associated NRC SER, Table 3-2, the ZOI value for cal-sil of 5.45D is utilized for asbestos/cal-sil insulation.

- Jacketing Properties and Configuration

  The industry has performed several tests with cal-sil to establish a ZOI. Industry testing was reviewed and compared based on the similarities in the jacketing materials and configuration to those used on cal-sil insulation at Surry Power Station. This evaluation determined an appropriate ZOI based on the jacketing materials and configuration.

- Air Jet Impact Testing

  The Air Jet Impact Tests (AJITs), CDI Report No. 96-06, tested cal-sil with aluminum jacketing secured with 0.75" stainless steel bands with fold over closures placed approximately 10" apart on centers. The target pipes for the testing were 12" NPS.

  The banding used in the AJIT is similar to the installation configuration at Surry Power Station. The tests results documented that at a surface pressure of approximately 160 psig, the left banding strap on the jacketing was removed and the jacketing facing the jet nozzle was damaged, but the jacketing remained on the piping. The 160 psig recommended destruction pressure, adjusted for a two-phase PWR jet instead of an air jet (40% reduction per NEI 04-07, NRC SER), results in a ZOI of approximately 2D (NEI 04-07, Table I-3 of Appendix I).

- Two Phase Jet Testing

  Ontario Power Generation (OPG), Document No. N-REP-34320-10000, performed two phase jet tests on cal-sil insulation with aluminum cladding. The aluminum cladding was 0.016" thick and secured with 0.02" thick stainless steel bands placed 6.5" to 8" apart on centers. The test results demonstrated destruction at a pressure of 24 psig (5.45D ZOI) compared to the AJIT results at 160 psig. The significant difference in destruction pressures was attributed to: 1) a two phase jet vs. an air jet, 2) the seam orientation of the metal jacketing, 3) banding strength and, 4) jacketing thickness. OPG testing determined that the primary failure mode was tearing of the aluminum cladding due to the high stresses induced along the banding interface. The aluminum cladding used was Aluminum Alloy 1100, and has a tensile strength of 13 ksi. The stainless steel jacketing used at Surry (type 304 and 316) has a tensile strength of 85 ksi. Based on a higher tensile strength, a larger destructive pressure would be required to achieve similar results. Therefore, a 5.45D ZOI would be conservative for the destruction of the stainless steel jacketing.

  Initial OPG testing determined that seam orientation of the metal jacketing influenced the destructive pressures. OPG performed additional testing with two layers of jacketing, offsetting the horizontal seam locations. The results of the OPG testing showed a two layer jacketing system with offset seams resulted in a significant decrease in the ZOI radius. Surry has a similar two jacket configuration. The insulation jacketing seams for both systems are not aligned. The outer stainless steel jacketing system has a linear horizontal seam. The 1925 glass cloth jacketing system is wrapped around the piping and does not expose a linear seam to any jet.

  Therefore, based on the OPG testing, a ZOI less than 5.45D could be justified based on the stainless steel jacketing and crediting a double jacketed system.

Conclusion:

The review and comparison of insulation material and jacketing properties and configuration established a range of ZOIs from 2D to 5.45D. The majority of industry testing supports a ZOI of 5.45D or less. A ZOI of 5.45D was selected for the design of the strainer because this provides a reasonable degree of assurance that the cal-sil insulation and jacketing systems have been categorized properly.

2. Asbestos:

At Surry Power Station, the initial debris generation evaluation utilized 5.45D ZOI for asbestos insulation. This was reported in the February 2008 supplemental response letter. Since then, the debris generation and transport calculations have been revised to increase the ZOI to 7D. The following provides a basis for utilizing a ZOI of 7D for asbestos insulation.

Basis for ZOI Values for Asbestos

The industry has not performed ZOI testing for asbestos insulation. In the absence of testing, NEI 04-07 states that it would be conservative to use the same destruction pressure as low density fiberglass (LDFG). Using the correction factor (40%) for materials characterized with air jet testing identified in Staff Evaluation of §3.4.2.2 of the NRC's SER to NEI 04-07, the destruction pressure of LDFG is 6 psig which results in a ZOI of 17D. A reduced ZOI is justified by evaluating: 1) asbestos material properties and 2) jacketing properties and configuration.

- Material Property Comparison:

  Per NEI 04-07, LDFG has a density of 2.4 lb/ft3 and a ZOI of 17D. High Density Fiber Glass such as TempMat has a density of 11.8 lb/ft3 and a ZOI of 11.7D. Asbestos has a density of 7 to 10 lb/ft3. The comparison of materials based on densities implies that asbestos is a more durable material than LDFG and would tend to have a similar ZOI to HDFG. This is further justified per the comparisons provided below. The original insulation specification for Surry Power Station lists several asbestos types, including Pittsburgh-Corning's Unibestos, for use within containment. Pittsburgh-Corning's Unibestos is used for comparison in this review. Unibestos has the following material properties:

  - Tensile strength of 67 psi
  - Modulus of rupture (force required to break a specimen) ranges from 73.2 – 94.9 psi
  - Compressive strength of 1800 psf (12.5 psi) at 5% deformation

  Depending on the postulated failure mechanism (tensile, compressive, or flexural) the destruction pressure ranges between 12.5 psi to 94.9 psi. Based on this pressure range, a ZOI between approximately 2D and 10D per Table I-3 of Appendix

I of the NRC's SER to NEI 04-07 is determined to be appropriate. This confirms that asbestos would tend to have a smaller ZOI compared to LDFG.

- Jacketing Properties and Configuration

  The industry has not performed any testing with asbestos to establish a ZOI for this material. Industry testing was reviewed and compared based on the similarities in the jacketing materials and configuration to those used on asbestos insulation at Surry Power Station. This evaluation determined an appropriate ZOI based on the jacketing materials and configuration.

- Air Jet Impact Testing

  The Air Jet Impact Tests (AJITs), CDI Report No. 96-06, tested cal-sil with aluminum jacketing secured with 0.75" stainless steel bands with fold over closures placed approximately 10" apart on centers. The target pipes for the testing were 12" NPS. The banding used in the AJIT is similar to the installation configuration at Surry Power Station. The tests results documented that at a surface pressure of approximately 160 psig, the left banding strap on the jacketing was removed and the jacketing facing the jet nozzle was damaged, but the jacketing remained on the piping. The 160 psig recommended destruction pressure, adjusted for a two-phase PWR jet instead of an air jet (40% reduction per NEI 04-07, NRC SER), results in a ZOI of approximately 2D (NEI 04-07, Table I-3 of Appendix I).

- Two Phase Jet Testing

  Ontario Power Generation (OPG), Document No. N-REP-34320-10000, performed two phase jet tests on cal-sil insulation with aluminum cladding. The aluminum cladding was 0.016" thick and secured with 0.02" thick stainless steel bands placed 6.5" to 8" apart on centers. The test results demonstrated destruction at a pressure of 24 psig (5.45D ZOI) compared to the AJIT results at 160 psig. The significant difference in destruction pressures was attributed to: 1) a two phase jet vs. an air jet, 2) the seam orientation of the metal jacketing, 3) banding strength and, 4) jacketing thickness. OPG testing determined that the primary failure mode was tearing of the aluminum cladding due to the high stresses induced along the banding interface. The aluminum cladding used was Aluminum Alloy 1100, and has a tensile strength of 13 ksi. The stainless steel jacketing used at Surry (type 304 and 316) has a tensile strength of 85 ksi. Based on a higher tensile strength, a larger destructive pressure would be required to achieve similar results. Therefore, a 5.45D ZOI would be conservative for the destruction of the stainless steel jacketing.

  Initial OPG testing determined that seam orientation of the metal jacketing influenced the destructive pressures. OPG performed additional testing with two layers of jacketing, offsetting the horizontal seam locations. The results of the OPG testing showed a two layer jacketing system with offset seams resulted in a significant decrease in the ZOI radius. Surry has a similar two jacket configuration.

The insulation jacketing seams for both systems are not aligned. The outer stainless steel jacketing system has a linear horizontal seam. The 1925 glass cloth jacketing system is wrapped around the piping and does not expose a linear seam to any jet. Therefore, based on the OPG testing, a ZOI less than 5.45D could be justified based on the stainless steel jacketing and crediting a double jacketed system.

Conclusion:

The review and comparison of insulation material and jacketing properties and configuration established a range of ZOIs from 2D to 10D. The majority of industry testing supports a ZOI of 5.45D or less. A ZOI of 7D was selected for the design of the strainer because this provides a reasonable degree of assurance that the asbestos insulation and jacketing systems have been categorized properly.

NRC Question 3

Please provide additional information that justifies the temperature/viscosity extrapolation of data from test temperatures to predicted loss-of-coolant accident (LOCA) temperatures. Based on recent review of Rig 33 head loss traces for North Anna during the chemical effects audit of that plant, the staff believes that there may not have been "sudden" decreases in measured head loss, but there were anomalous observations of fairly large and relatively fast head loss decreases for qualification tests and other non-qualification tests for North Anna. Flow sweeps were done for some of the tests that seemed to indicate that boreholes did not have a significant influence on the temperature scaling. However, the staff does not consider this information sufficient to conclude that there were no signs of potential bed degradation. Please provide results of evaluation of the cause of the decreases in head loss that occurred during testing.

Dominion Response

It should be noted that while this response primarily addresses Rig 33 test results in response to the NRC's question, the Rig 89 test results for Surry Units 1 and 2 provide the design basis for the Dominion corrective actions that were implemented to address GL 2004-02. See response to Question 4 below.

Temperature/Viscosity Extrapolation (Rig 33)

The peak measured debris bed head loss in the reduced-scale test occurred four days after the first debris introduction. Using the peak measured debris bed head loss developed in many days in a thin-bed test to qualify short-term pump NPSH criterion has significant conservatism. In addition, this peak head loss occurred while the debris bed was still forming, prior to the time when any potential degradation might possibly occur. Another conservatism exists while scaling from test temperature to higher sump temperature. The debris bed will be less compact and more porous when the head loss is lower. The viscosity correction of head loss assuming the same compact debris bed is therefore conservative.

Recirculation Spray - In the reduced-scale test, the flow approach velocity to the strainer surface was calculated to be 0.0047 ft/s. With the test temperature (104°F) and flow condition, the test flow Reynolds number was approximately 3[1]. Hence, it was considered as laminar flow, where the NUREG/CR-6224 correlation shows that debris bed head loss is proportional to fluid viscosity.

A piece of debris bed removed from the strainer surface after the RS test is shown in Figure 2. No debris bed cracking, boreholes or degradation were observed.

An important conservatism in the temperature/viscosity extrapolation is that the peak head loss was used rather than a lower stabilized value.

Low Head Safety Injection - The SPS LHSI strainer Rig 33 reduced-scale thin bed test head loss curve is shown in Figure 3. No sudden head loss decrease was observed; hence, for this reason along with those mentioned above for the RS strainer, the viscosity correction method was applied for the LHSI strainer qualification.

Decreases in Head Loss (Rig 33)

As shown in Figure 1, the peak RS head loss occurred after the third fiber addition. After that, the head loss was in a slowly decreasing trend for a full day, with no sudden head loss decrease. The fourth fiber addition increased the head loss to 1.2 psi. Again, about 4 hours after the fourth fiber addition, the head loss decreased slowly again. The decreasing trends after the third and the fourth fiber additions were almost parallel, which indicated that the debris bed structure was consistent after the fourth addition.

A similar slow decrease in head loss was observed near the end of the Surry Rig 33 LHSI test, as shown in Figure 3. In the Surry Rig 33 reduced-scale testing, head loss increased until debris was removed from circulation. The gradual head loss decreases were assumed to have occurred after there was no more debris in circulation and the newly-formed debris bed was slowly settling into its final configuration.

As noted in the previous section, the head loss value taken from a test was the peak value, which occurred once all the debris had deposited onto the strainer.

---

[1] $\mathrm{Re} \equiv \rho VD / \mu$. The appropriate length, D, is the width of the flow passages between fibers. This has been taken as 1 mm, but could be significantly smaller. Velocity, V, is taken as the approach velocity to the debris bed, which is defined as the volumetric flow rate divided by the screen area. Assumed values are therefore: $\rho = 10^3$ kg/m^3, $V \sim 1.5\times10^{-3}$ m/s, $D \sim 10^{-3}$ m, $\mu \sim 5\times10^{-4}$ N.s/m^2, yielding Re ~ 3. This flow is fully laminar, and nowhere near the turbulent transition zone, which occurs around Re = 10^3.

Rig 89 Chemical Effects Tests

For long-term head loss, since the Rig 89 test temperature was the same as the long-term sump temperature, no viscosity correction was performed. No "sudden" head loss decreases were observed in Rig 89 testing before chemicals were added, as shown in Figure 4.

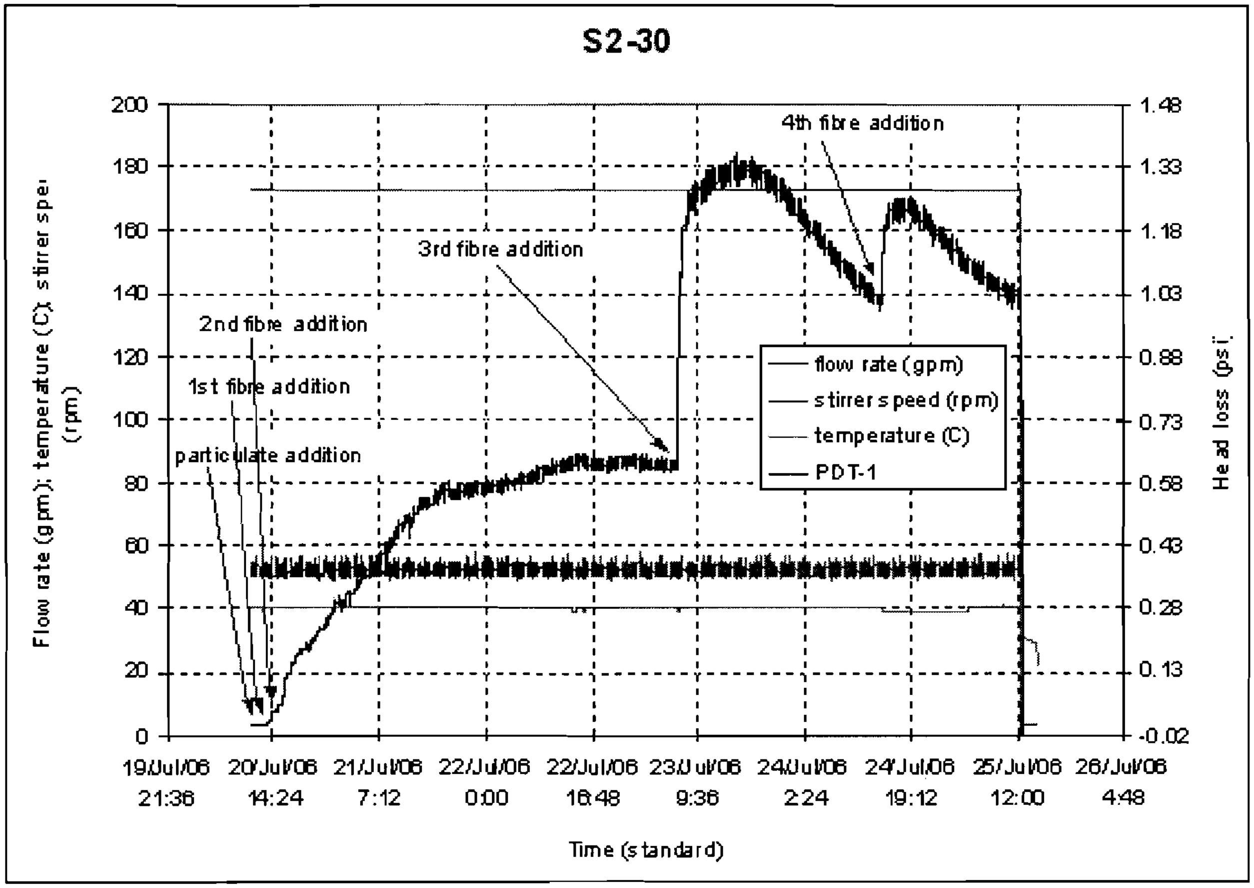

Figure 1 - Test Parameters vs. Time for SPS RS Strainer Test

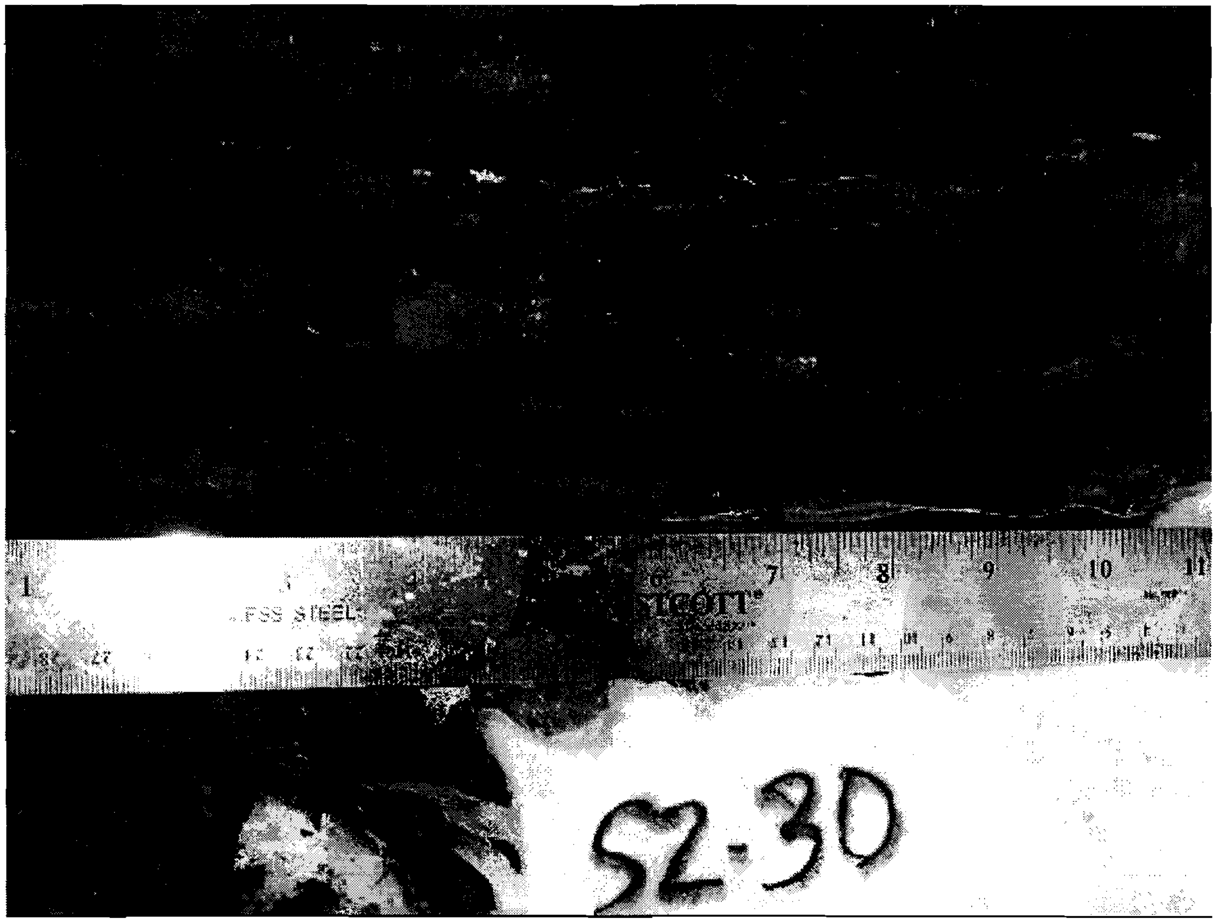

Figure 2 - Debris bed Sample after SPS RS Strainer Test

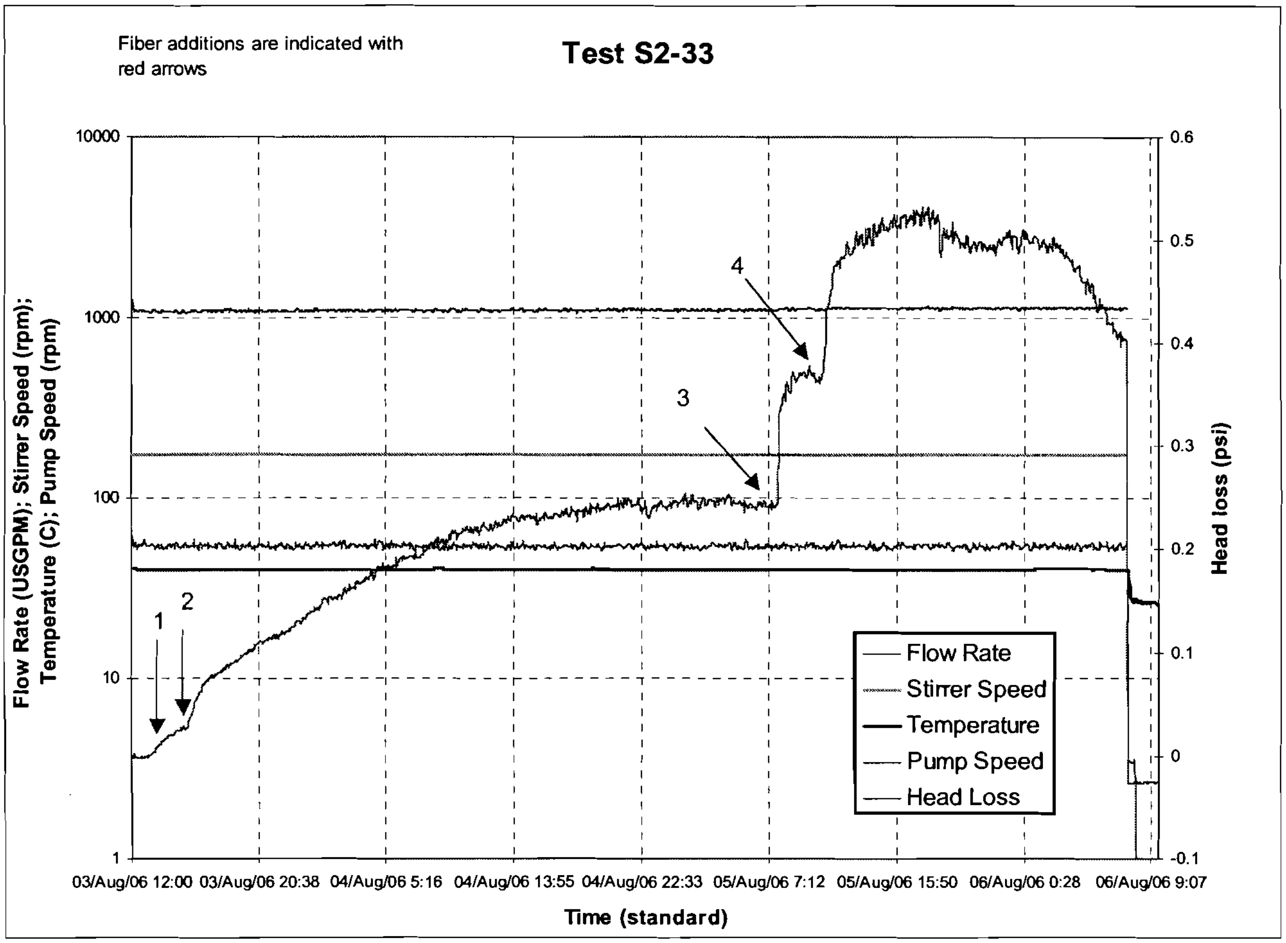

Figure 3 - Test Parameters vs. Time for SPS LHSI Test

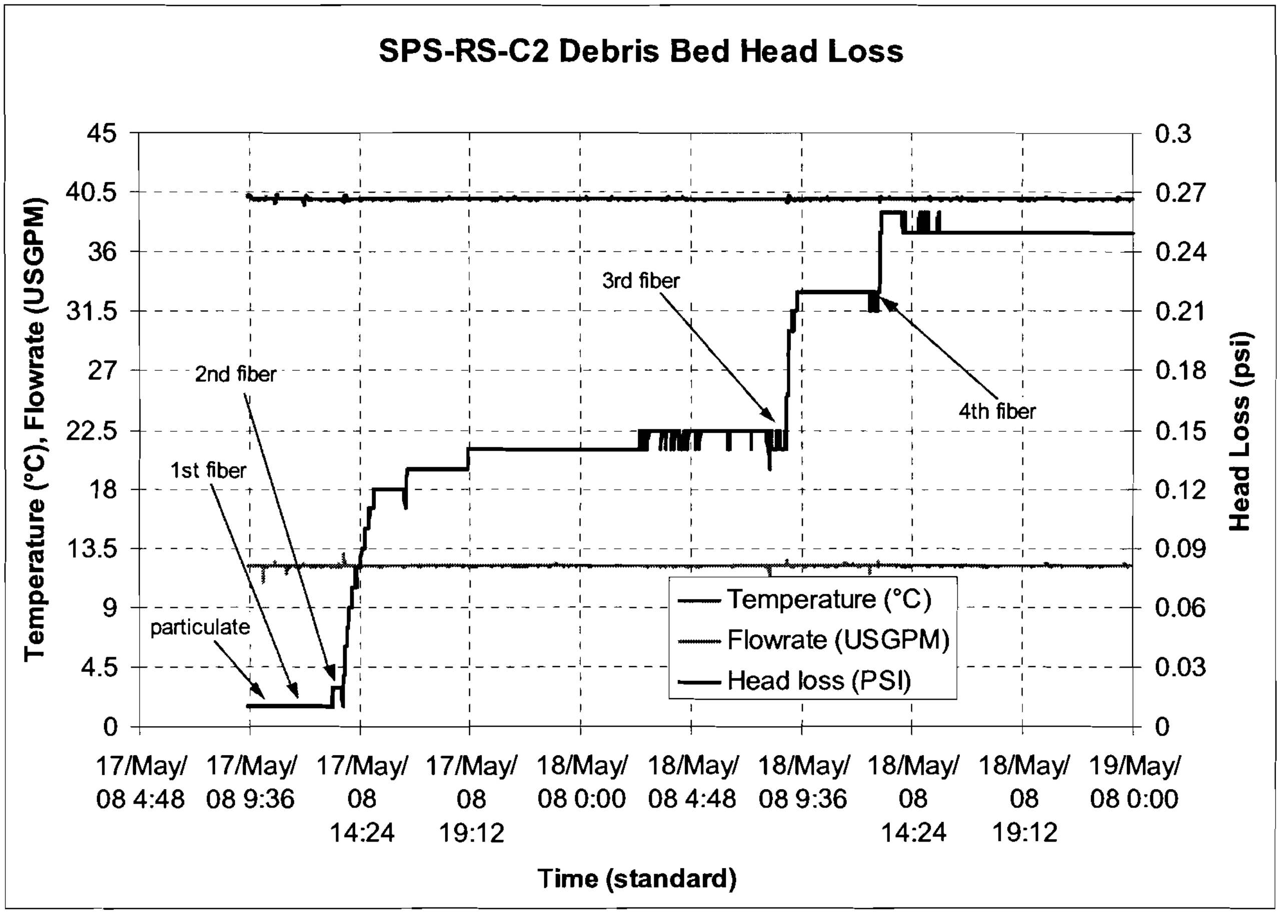

Figure 4 - Surry RS Rig 89 Short-term Debris Bed Head Loss

NRC Question 4

Please provide an evaluation similar to that provided for North Anna to show that the results of both Rig 33 and Rig 89 tests, and the magnitude of plant-specific conservatisms for Surry, ensure that the strainers will function under design conditions.

Dominion Response

Sections 1.a and 1.b of the Surry 2009 updated supplemental response dated February 27, 2009 (ADAMS ML090641018) describe the extensive plant conservatisms associated with the design of the containment sump strainer for each unit. Additional margins are discussed at the end of Section 3f in the Surry 2008 supplemental response dated February 29, 2008 (ADAMS ML080650562). The overall magnitude of these conservatisms cannot be quantified; however, they are viewed to be significant, particularly for the factors listed below:

- 5% margin was added to the debris quantities generated from the ZOI.
- A sacrificial strainer area of 150 ft^2 was assigned for both RS and LHSI strainer for each unit.
- The actual installed strainer area (effective) is larger than the test modeled strainer area as indicated in the following table:

Station	Rig 33 Test Modeled Strainer Area (ft^2)	Rig 89 Test Modeled Strainer Area (ft^2)	Actual Installed Strainer Area (Effective) [a] (ft^2)
Surry 1 RS	5584	5310	5597
Surry 1 LHSI	2040	1814	2044
Surry 2 RS	5584	5310	5640
Surry 2 LHSI	2040	1814	2091

Note: a) The actual installed strainer area (effective) equals the total installed strainer area minus the required sacrificial area of 150 ft^2.

- 100% debris transport was assumed for coating and latent debris.
- In both Rig 33 and Rig 89 testing, fibrous debris was conservatively prepared as "single fine".

Additionally, the strainer supplier, Atomic Energy of Canada Limited (AECL), has prepared a detailed analysis report to evaluate the different results observed for the head loss tests performed in Rigs 33 and 89. The evaluation focused on the test rig configurations, flow patterns, debris compositions and quantities, debris preparation, air bubble generation, chemical environment, and debris bed formation.

Sump strainer reduced-scale thin bed tests were initially conducted in Rig 33 to determine the total strainer surface area for each station unit. Rig 89 test loops were used to investigate the influence of chemical precipitates on the debris bed head loss. There were several significant test conditions that were identified to have contributed to discrepancies in the maximum head loss differences observed in the two test rigs:

- Ottawa River water was used in the Rig 33 thin bed tests whereas deionized water was used in the Rig 89 tests. Water samples from each rig's pre-tests revealed that the number of suspended particles in Rig 33 water was 60 times greater than in Rig 89, while the strainer area was only 5.2 times greater. AECL noted from one of the North Anna Rig 33 tests that small particle sizes (< 1 μm) could greatly increase the existing debris bed head loss by blocking the debris bed pores.

- Debris bed samples at the end of selected Rig 33 tests indicated that bacteria were present. The effects of the bacteria were also observed in test results where head loss continued to slowly increase after having stabilized for a period of time after the final fiber addition. No biological effects were observed in the Rig 89 tests in that the head loss did not increase further after the final fiber addition stabilization. To better simulate containment environmental conditions following a DBA, Rig 89 was designed as a closed system to limit access to open air, and deionized water with boric acid and sodium hydroxide was used, which all contributed to mitigate biological growth.

- One Rig 33 test with chemicals was performed for the Surry RS strainer. Test water was deionized and boric acid and sodium hydroxide was added before debris addition. The difference in head loss, prior to chemical effects, for Rig 33 as compared to Rig 89 testing (0.39 psi – Rig 33 & 0.26 psi – Rig 89) was much closer than for previous Rig 33 tests that used Ottawa River water. Both tests however produced head losses that were conservatively higher than the NUREG/CR-6224 predicted losses. After the aluminum was added for both Rig 89 and Rig 33, Rig 89 produced a higher peak head loss than Rig 33 (1.7 psi vs. 1.3 psi).

Based on the above discussions, AECL and Dominion believe that the Rig 89 test results provide conservative evidence to verify that the installed strainer for each unit will function under short-term and long-term design conditions. Rig 89 tests incorporate lessons learned from the earlier Rig 33 testing, such as biological growth and testing fluid impurity, and consequently provide more accurate results. The AECL/Dominion testing program has concluded that the Rig 89 head loss test results are bounding and, furthermore, that test results from both rigs are conservative in that they produced higher head losses than predicted by NUREG/CR-6224.

It should be noted certain conservatisms provided by Rig 33 over Rig 89 for the North Anna strainer cannot be accommodated for the Surry Low Head Safety Injection (LHSI) strainer. The LHSI pumps are vertical, two-stage pumps that are located inside pump "cans" outside of the containment that are connected to the sump strainer by partially buried piping. In order for the existing available NPSH determination to remain valid, the water level inside each pump "can" must be maintained above the piping nozzle inlet to the "can" from the containment sump. Recent evaluations determined that the total LHSI strainer allowable head loss provided in Table 3.f-2 of the Surry February 27, 2009 supplemental response cannot be exceeded to ensure that the water level in the pump "can" remains above the suction pipe nozzle. This limitation does not apply to the North Anna LHSI strainer as its associated pumps have air ejectors installed inside the pump "cans" to maintain a minimum water level in the event air comes out of solution.

NRC Question 5

The minimum strainer submergence was the same for both large-break and small-break loss-of-coolant LOCAs. It was not clear what sources were credited for the minimum level calculation. Please state whether the accumulators are credited for small break LOCA sump level calculations. If the accumulators are credited for small breaks, provide justification for this assumption, or provide the minimum water level if no accumulator volume is credited. Please state whether any RCS volume is credited for the minimum water level calculation. If RCS volume is credited, please provide the volume credited and the assumptions and bases for the credited volume.

Dominion Response

A single submergence value was reported for each strainer based on the more limiting minimum water level from small break LOCA (SBLOCA) and large break LOCA (LBLOCA) analyses. The basis for the minimum strainer submergence for both LBLOCA and SBLOCA is provided below. The available water sources include the refueling water storage tank (RWST), the chemical addition tank (CAT), the safety injection accumulators, and reactor coolant system (RCS) inventory released via the LOCA.

The LBLOCA minimum submergence values are 4.1" for the RS strainer and 8.2" for the LHSI strainer. These values are based on minimum water level calculations from GOTHIC NPSH transient analyses that include the holdup volumes discussed in the response to Question 7e. The LBLOCA analysis assumes that RS and LHSI recirculation begins with a +2.5% RWST wide range level bias (equivalent to 9738 gallons) on the plant setpoint, an initial RWST volume 3100 gallons below the Technical Specifications minimum, no contribution from the CAT, and initial empty containment sump. The accumulators inject fully before RS system actuation at 60% RWST level. The following table compares the LBLOCA containment sump water level to the strainer height.

	Sump Level, inches	Strainer Height above floor, inches
IRS pump start at 62.5% RWST WR level	22.6	18.5
ORS pump start at 62.5% RWST WR level + 108 second timer delay	23.6	18.5
LHSI recirculation mode at 16% RWST WR level	49.2	41.0

The approach for determining the SBLOCA minimum water level was to identify differences from the LBLOCA response for SBLOCA scenarios that actuate the Consequence Limiting Safeguards (CLS), which initiates containment spray and recirculation spray on High High Containment Pressure. An accumulator volume of 2925 ft^3 (975 ft^3 each) is included in the LBLOCA response. Breaks smaller than 2" could reach RS actuation and LHSI switchover to recirculation before any accumulator injection occurs. Therefore, the accumulator volume is assumed unavailable for SBLOCAs. However, the accumulator volume is offset by sources of water that are not credited from the LBLOCA NPSH analysis but are credible sources for SBLOCA scenarios that have no accumulator injection.

- The LBLOCA analysis assumes 1720 ft^3 of water holdup in the refueling canal volume below the spillover elevation into the reactor cavity. Valves in the drain pipe from the refueling transfer canal to the containment basement are open during power operations. The only mechanism for holdup would be LOCA-induced debris clogging. This holdup was a conservative assumption for LBLOCA analysis. For SBLOCA, there would be no debris blockage at the canal drain. All insulation in the spray region is jacketed with stainless steel, steam generator reflective metal insulation would not have a transport force from a small break, and the only path for RCS loop piping insulation to reach the refueling canal is through the recirculation spray system, which would limit the debris size to 1/16" (RS strainer hole size). It was concluded that the refueling canal drain would not clog during a SBLOCA.

- The LBLOCA analysis assumed 600 ft^3 of condensate films with 0.016-inch thickness on 450,000 ft^2 (11% above maximum design surface area) of containment heat structures as a constant throughout the NPSH analysis. Condensate films on heat sinks would not remain after containment spray actuates and the containment pressure decreases such that the passive heat structures become heat sources to the containment atmosphere. During small LOCAs with low steaming rates, the containment spray system rapidly depressurizes the containment before RS starts and condensate layers evaporate as the vapor temperature decreases below the heat sink surface temperature. The SBLOCA analysis does not include this penalty.

- The LBLOCA analysis assumes 200 ft^3 of water holdup in fibrous insulation in the sprayed regions. This insulation was jacketed with a design basis accident qualified jacketing system after the LBLOCA calculation was performed. The SBLOCA analysis does not include this penalty.

- The LBLOCA analysis ignores the contribution from the CAT (Technical Specification minimum volume of 3930 gallons), which is pumped by the containment spray system with RWST water such that the same relative water height is maintained in the tanks. At 60% RWST level, 40% CAT injection adds 1500 gallons (200 ft^3) to the RS strainer submergence. At 13.5% RWST level, 83% CAT injection adds 3300 gallons (440 ft^3) to the LHSI strainer submergence.

The above sources correspond to 2720 ft^3 of additional sump water before RS start and 2960 ft^3 before LHSI recirculation for SBLOCA scenarios. The volume for the LHSI strainer exceeds the accumulator volume of 2925 ft^3, and a minimum submergence of 8 inches is bounding for SBLOCA and LBLOCA. The volume for the RS strainer was 205 ft^3 (0.2 inch sump level) less than the accumulator volume. Accounting for this difference, the SBLOCA submergence is 3.9 inches versus 4.1 inches for LBLOCA. The minimum submergence was rounded down to 3 inches in Dominion letter Serial No. 08-0018, dated February 29, 2008.

If none of the above volumes were credited for SBLOCA, the LBLOCA submergence values would be reduced by 3.2 inches for the accumulators. There would be approximately 1 inch submergence for the RS strainer and 5 inches for the LHSI strainer. Strainer testing with no submergence and very conservative flow rates identified no air ingestion or vortexing.

The RCS contribution to the sump inventory was evaluated in terms of liquid mass rather than volume. The initial RCS liquid mass is 419,330 lbm. The hot leg double-ended guillotine break releases 283,230 lbm of RCS liquid to the containment through the end of the vessel reflood phase. At the end of reflood, the RCS contains 136,100 lbm of liquid. The RCS mass at the initiation of recirculation spray (RS) and ECCS recirculation is larger due to lower fluid temperatures in the vessel. The GOTHIC containment analysis model accounts for the temperature reduction as the containment and RCS are depressurized.

The treatment of the RCS as a SBLOCA source to the containment sump is consistent with the design basis for the RS and safety injection systems. Any break large enough to increase the containment pressure to the CLS actuation setpoint (High High Containment Pressure) and require recirculation for long-term cooling would flash the upper head and drop the RCS water level to the elevation of the hot legs, providing an RCS mass release to the containment that is comparable to a LBLOCA. The high head safety injection flow rate eventually reaches equilibrium with the break flow, but the pump flow is insufficient to recover inventory in the upper head, pressurizer, and steam generator tubes. The total RCS liquid mass remains less than 125,000 lbm until after the RWST is empty and long-term operator action is taken to depressurize the RCS below the accumulator actuation pressure and below the low head safety injection pump shutoff head.

NRC Question 6

Please provide an evaluation of the head loss fluctuations that occurred during the low-head safety injection (LHSI) Rig 89 testing between the 7th and 10th aluminum additions. Also, please explain why these fluctuations do not invalidate any viscosity corrections imposed on the test data.

Dominion Response

The head loss fluctuation between the 7th and the 10th aluminum additions during the Surry LHSI chemical effects testing is shown in Figure 5. As observed in the chemical effects tests, aluminum precipitate tended to deposit on the fiber surface and block the pores of the debris bed. At the time the 7th aluminum addition was added, the head loss was only 0.24 psi. Since the head loss was low, the debris bed was not tightly compact and it was fragile. As more aluminum precipitates deposited on the fiber surface, a dynamic process of debris bed cracking and self-repairing was initiated, which resulted in the head loss fluctuation. As more aluminum was added to the test tank, the head loss became higher and the debris bed was more densely compact and there was no fluctuation between the 11th and the 15th additions.

The peak measured head loss in the Surry LHSI strainer chemical effects test is 0.5 psi at 104°F, which occurred after the 15th aluminum addition. The long-term acceptance criterion for debris bed plus chemical effects (after subtracting allowance for analytically determined clean strainer head loss) is 1.41 feet of water at 104°F, which is equivalent to 0.61 psi at 104°F. Since the test temperature and the long-term sump temperature is the same, viscosity correction is not performed.

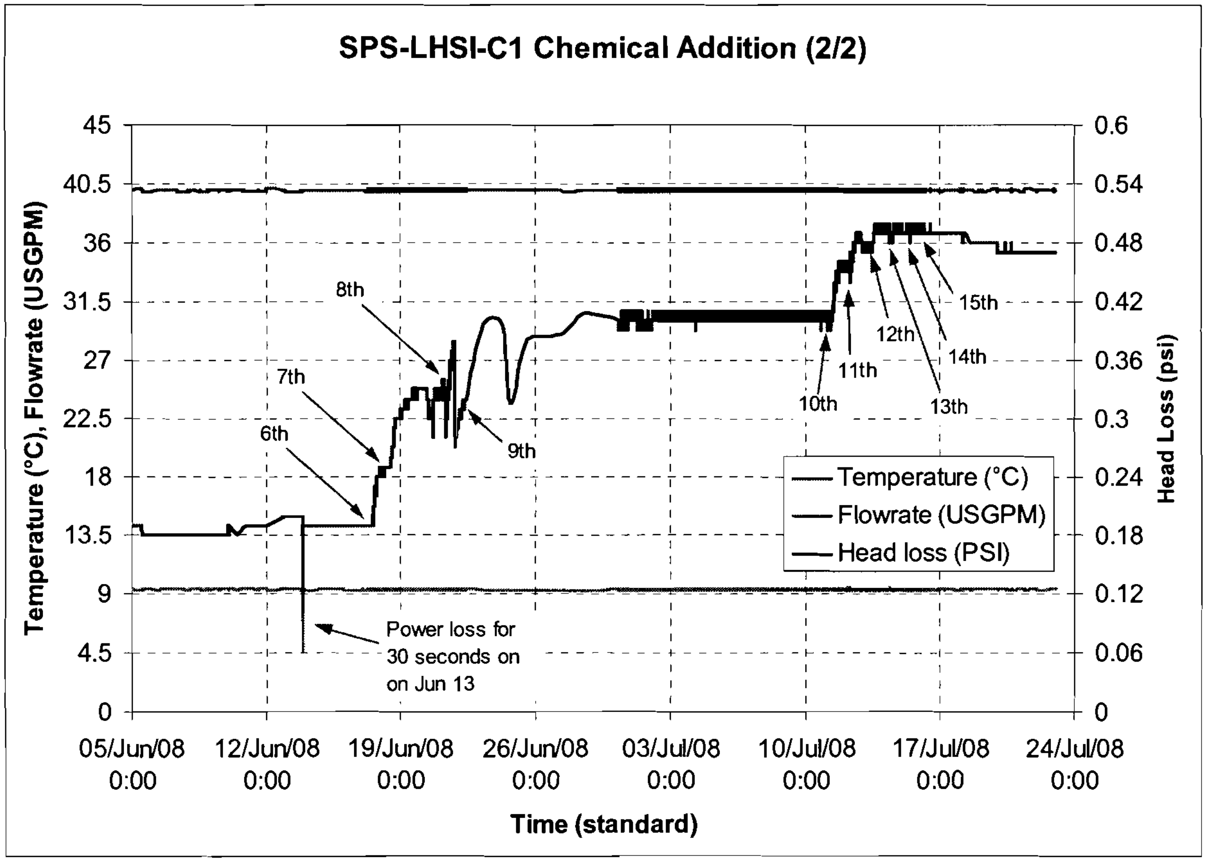

Figure 5 - Head Loss vs. Time during SPS LHSI Chemical Effects Test

NRC Question 7

The licensee's February 29, 2008, supplemental response indicated that the methodology for the Surry NPSH calculation was similar to that reviewed for North Anna during the GSI-191 audit for that plant. However, plant-specific differences and results for Surry were not provided in the supplemental response as requested in the NRC staff's content guide. Please provide the following information requested in the content guide. The responses may be in terms of stating that the same approach was used as for North Anna, or of describing any differences from the North Anna approach, which the NRC staff has already reviewed.

a. *a description of the methodology for computing the maximum flows for the LHSI and RS pumps*
b. *the basis for the required NPSH values, e.g., three percent head drop or other criterion.*
c. *a description of how friction and other flow losses are accounted for.*
d. *a description of the single failure assumptions relevant to pump operation and sump performance that were considered in the NPSH calculation*
e. *assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin*
f. *a description of whether and how the following volumes have been accounted for in pool level calculations: empty spray pipe, water droplets, condensation and holdup on horizontal and vertical surfaces. If any are not accounted for, explain why.*
g. *assumptions (and their bases) as to what equipment will displace water resulting in higher pool level*

Dominion Response

a. *a description of the methodology for computing the maximum flows for the LHSI and RS pumps.*

The maximum pump flow rates for the low head safety injection (LHSI), inside recirculation spray (IRS), and outside recirculation spray (ORS) pumps are calculated using hydraulic models of the system flow networks with the pump manufacturer's strongest pump curves and no debris on the strainers. The system hydraulic models account for the flow paths from the containment sump to the final injection point. For the RS system, the flow is discharged from the spray nozzles. For the LHSI system, the flow is discharged to the reactor coolant system cold legs during cold leg recirculation or the hot legs during hot leg recirculation. Conservative flow rates that bound the calculated flow rates from the hydraulic model are input to the GOTHIC analyses that determine minimum NPSH available (NPSHa). This same methodology was used to calculate the maximum LHSI and RS pump flow rates for North Anna.

b. *the basis for the required NPSH values, e.g., three percent head drop or other criterion.*

The pump required NPSH (NPSHr) values were reported in Table 3.g-1 of Dominion letter serial number 09-002, dated February 27, 2009. For the RS pumps, the manufacturer's pump curve includes a profile of NPSHr versus pump flow. The NPSHr curve from the manufacturer's original pump data sheet was superseded, because it was not based on a three percent head drop. Instead, it was based on lowering suction head until the NPSH was reduced to a minimum value provided in the original procurement specification. A review of the original test data revealed that the percent head drop was approximately one percent. To obtain additional margin, in 1977 Virginia Power conducted an NPSHr test at the North Anna job site with a pump with essentially identical hydraulic characteristics to the Surry RS pumps. The test results and the applicability for Surry are documented in an attachment to letter serial number 366 that was transmitted to the NRC on August 24, 1977.

For the LHSI pumps, the NPSHr curve from the manufacturer's pump data sheet was adjusted because the pump can and entrance losses were accounted for in both the NPSHr testing and in the system hydraulic model to determine NPSHa at the pump centerline impeller. Dominion documented the technical basis for the LHSI pump NPSHr value of 13.82 ft at 3330 gpm in a response to an NRC Request for Additional Information for the license amendments supporting the resolution of GSI-191. Refer to Question #2 in Attachment 2 of Dominion letter Serial No. 06-545 dated July 28, 2006.

The basis for the NPSHr values reported in Table 3.g-1 of Dominion letter Serial No. 09-002 dated February 27, 2009 is a three percent drop in pump head observed during testing, which is consistent with the method used to determine the NPSHr values at the maximum pump flow rates for North Anna.

c. *a description of how friction and other flow losses are accounted for.*

The suction head losses were calculated for the LHSI, ORS and IRS pumps using the same hydraulic network analyses that determined the maximum pump flow rate. The head loss is converted to a loss coefficient for input to the GOTHIC containment model, such that the use of a bounding maximum flow rate in GOTHIC will scale up the head loss. The modeling of the suction hydraulic head losses in the GOTHIC containment model is described in Section 3.8.2 of Topical Report DOM-NAF-3, Rev. 0.0-P-A. The hydraulic network analysis that is used to determine the maximum friction and form losses and the application in the GOTHIC containment analyses are the same methodology as that applied for North Anna.

d. *a description of the single failure assumptions relevant to pump operation and sump performance that were considered in the NPSH calculation.*

The minimum NPSHa for the LHSI pump occurs for the single failure of an emergency diesel generator (EDG) that leaves one emergency bus powered to supply one LHSI pump and a train of RS (one IRS pump and one ORS pump) for containment heat removal. This scenario produces the maximum flow demand and NPSHr on a single LHSI pump and the largest suction piping friction loss to the pump, while providing only one train of containment heat removal that limits the sump temperature reduction before ECCS recirculation mode transfer. This single failure was confirmed to produce the minimum pump NPSHa by sensitivity studies using the GOTHIC analysis methodology. Dominion also evaluated the single failure of a LHSI pump. In this configuration, all four RS pumps and heat exchangers are available for sump cooling before recirculation mode transfer. The sump temperature is colder and the LHSI pump NPSHa is greater than the EDG failure case.

Dominion also evaluated scenarios with two LHSI pumps operating. The LHSI pumps have the same discharge header and the maximum system flow rate at cold leg recirculation is limited to 4100 gpm or about 2050 gpm per LHSI pump, which is 38% less than the single-pump flow rate of 3330 gpm. At 2050 gpm, the NPSHr is 10.0 ft, which is 3.82 ft lower than the single LHSI pump case (13.82 ft @ 3330 gpm). In addition, the individual pump suction piping head loss decreases from 6.66 ft at 3330 gpm to 2.52 ft at 2050 gpm. The reduction in NPSHr and suction piping head loss with two-pump operation provides 8 ft of NPSH margin that more than offsets the increase in strainer debris head loss from one-pump (3330 gpm) to two-pump operation (4100 gpm). In the LHSI strainer system, more than 75% of pressure losses occur in the branch line leading to the LHSI pumps and although the total strainer flow for the two-pump case is 23% greater (4100 gpm vs. 3330 gpm), the branch line flow for each pump is 38% less than the flow for a single-pump case. The single-pump case produces the maximum strainer branch line flow rate and head loss, the maximum total strainer head loss (debris plus internals), the maximum suction piping head loss, and the maximum pump NPSHr. Therefore, NPSH analyses with a single LHSI pump operating bound analyses for two-pump operation.

The analyses to determine minimum RS pump NPSHa included explicit analysis of single failures that can affect the containment response, including loss of one EDG, loss of an IRS pump, loss of an ORS pump, loss of a containment spray pump, and loss of a LHSI pump. In addition, a case with full engineered safeguards (no single failure) was analyzed. Section 3.6 in Attachment 1 of Dominion letter Serial No. 06-545 dated July 28, 2006, compared the results from the most limiting scenarios of no single failure, an EDG failure, and a LHSI pump failure. The loss of a single LHSI pump was limiting for the ORS pumps. The no failure case was the limiting NPSH scenario for the IRS pumps. Table 3.g-1 in Dominion letter Serial No. 09-002, dated February 27, 2009 documents the minimum RS pump NPSH margins based on the

GOTHIC NPSH analysis with the most limiting single failure. NPSH results are compared to the RS strainer head loss with four RS pumps at maximum flow in the short-term and two RS pumps at maximum flow in the long-term.

e. *assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin.*

Section 3.8 in Topical Report DOM-NAF-3, Rev. 0.0-P-A, describes the GOTHIC analysis methodology for calculating NPSHa for the Surry LHSI and RS pumps. The use of this methodology for NPSHa analysis at Surry was approved by the NRC in a license amendment dated October 12, 2006. Section 3.8.3 in the topical report describes the water holdup terms that are included in the NPSHa analysis. These mechanisms include water added to containment spray (CS) and recirculation spray (RS) system piping, water trapped from transport to the containment sump in volumes (e.g., the refueling canal and reactor cavity), condensation films on heat structures, films on platforms and equipment that form after spray is initiated, and other losses (e.g., water absorbed in insulation). The GOTHIC containment liquid volume fraction is reduced by the total water holdup and then entered into a table of containment water level versus volume to determine the sump level that is used in the NPSHa calculation. GOTHIC explicitly models spray water droplets suspended in the atmosphere as a separate field that is not included in the containment liquid volume fraction that is used to determine the containment water level.

In addition, the Surry NPSHa analysis has other conservatisms that ensure a minimum water level is used: no contribution from the chemical addition tank; initial RWST volume of 384,000 gallons (versus Technical Specification minimum of 387,100 gallons); the containment sump is empty at the start of the LOCA (normal operation maintains approximately 500 gallons in the pit); and, +2.5% RWST wide range level uncertainty (9738 gallons) is applied in determining the initiation of RS and LHSI recirculation. Because the minimum NPSHa for the LHSI pump occurs right after recirculation mode transfer (RMT) to the sump, the assumption of 16% wide range RWST level versus the plant setpoint of 13.5% provides additional conservatism in the minimum water level calculation at RMT.

The same methodology was applied for the calculation of NPSHa for North Anna, but the Surry-specific holdup volumes are different due to plant geometry differences. The following table summarizes the holdup volumes in the Surry NPSHa analysis. The table footnotes describe conservatisms in the treatment of water holdup in insulation, as condensate films, and in the refueling canal.

Summary of Holdup Volumes in NPSHa Calculation

Item	Volume, ft^3	Application
Refueling canal	1720	Fills after containment spray starts (note 1)
Reactor cavity	2480	Fills immediately to the elevation of the incore sump room drain (-25'7"); above -25'7" the water level versus volume table accounts for the open area inside the cavity wall
Films on heat sinks	600	Assumed from time zero (note 2)
Insulation	200	Assumed from time zero (note 3)
CS Piping	157 (A train) 220 (B train)	Assumed from time zero
RS Piping	815 (each IRS + ORS train)	GOTHIC volumes fill after RS pumps start
CS spray holdup	100	Platforms wetted by CS are assumed to be covered at time zero. This value is conservative compared to 68 ft^3 that was calculated.
RS spray holdup	400	Additional platforms are wetted when RS spray is delivered from nozzles; This value is conservative compared to 361 ft^3 that was calculated.

1) Valves in the drain pipe from the refueling transfer canal to the containment basement are open during power operations. The only mechanism for holdup would be LOCA-induced debris clogging, such that the volume below the spillover elevation into the reactor cavity is unavailable to the containment sump. This was a conservative assumption at the start of the GSI-191 project. Subsequent evaluation determined that there should be no debris blockage at the canal drain. All insulation in the spray region is jacketed with a qualified system, steam generator reflective metal insulation that would be destroyed by the RCS pipe break would not transport up through the SG cubicle to the canal, and the only path for RCS loop piping insulation to reach the refueling canal is through the recirculation spray system, which would limit the debris size to 1/16" (strainer hole size).
2) This holdup assumes a 0.016-inch thick film on 450,000 ft^2 (11% above maximum design surface area) of containment condensing heat structures throughout the analysis. Condensate films on heat sinks would not remain after containment spray actuates and containment pressure decreases such that the passive heat structures become heat sources to the containment atmosphere. Also, some condensing surfaces are double counted as spray holdup horizontal surfaces.
3) This value accounted for fibrous insulation in the sprayed regions that was jacketed with a design basis accident qualified jacketing system after the NPSH calculation was performed.

f. *a description of whether and how the following volumes have been accounted for in pool level calculations: empty spray pipe, water droplets, condensation and holdup on horizontal and vertical surfaces. If any are not accounted for, explain why.*

   The water level calculation includes all of these terms. The response to Part e above describes how the volumes are accounted for in the NPSH analysis.

g. *assumptions (and their bases) as to what equipment will displace water resulting in higher pool level.*

   The relationship of containment sump water level versus volume of water accounts for the slope of the containment floor, the geometry inside the sump pit, equipment on the basement floor (iodine filters, containment air cooling units, containment instrument air compressors and receivers, and the safety injection accumulators), structures (structural columns and the reactor head storage stand), and the location of the incore sump room drain (see next paragraph). The minimum displacement volume of 174 ft^3 (between 6" and 35" above the containment floor) for the containment sump strainers was ignored in the NPSH calculation.

   Once the water level reaches -25'7" elevation, the water level versus volume table is adjusted to account for the presence of the incore sump room drain that connects the reactor cavity to the outer containment basement. The additional surface area inside the reactor cavity is 620 ft^2. The incore sump room volume below -25'7" elevation is treated as a holdup volume that fills completely at the beginning of the LOCA (see Part e above).

NRC Question 8

Please provide a description of how permanent plant changes inside containment are programmatically controlled so as to not change the analytical assumptions and numerical inputs of the licensee analyses supporting the conclusion that the reactor plant remains in compliance with Title 10 of the Code of Federal Regulations *(10 CFR) 50.46 and related regulatory requirements.*

Dominion Response

Dominion has implemented a fleet GSI-191 Program. The fleet program designates a GSI-191 Fleet Lead and Site Program Owners, and delineates staff and management responsibilities to ensure the GSI-191 design and licensing bases and technical documents established for each site are maintained.

GSI-191 procedural controls have been developed and implemented for the engineering modification process. This process applies to both permanent and temporary modifications. A fleet administrative procedure establishes the process for managing the preparation, processing, implementation, and organizational interfaces for Design

Changes (DCs) to nuclear plant Structures, Systems, and Components (SSCs). A fleet plant modification engineering standard provides guidance for performing required program reviews to: 1) verify compliance with regulatory programs, and 2) evaluate design and operational considerations to determine the acceptability of the activity being considered, including its effects on existing margins. The plant modification engineering standard includes a screening table to determine if the proposed change could affect the GSI-191 design basis. Specifically, the responsible engineer must answer a series of design effects questions. The GSI-191 design effects screening questions address the potential impact of the following:

- Changes in fibrous materials,
- Addition of labels, stickers, or signs,
- Changes that impact a containment SSC design basis,
- Addition of significant horizontal or vertical surface area,
- Change in unqualified or qualified coating inventories,
- Change in chemical effects,
- Change in downstream effects,
- Change in post-LOCA water levels or recirculation flow paths, and
- Change that modifies free volume or heat sink.

If the responsible engineer determines that the change could potentially affect the GSI-191 design basis, the potential impact must be evaluated by the GSI-191 Program Site Owner.

In addition to controlling the engineering modification process, procedural controls have been implemented for banned/restricted materials (e. g., aluminum), coatings, and insulation changes in containment. A fleet procedure has been implemented that outlines the requirements and methods for controlling the use of aluminum inside containment in support of the GSI-191 design basis. This procedure provides requirements and establishes a mechanism for tracking all aluminum installed inside of containment for the purpose of maintaining an aluminum inventory. The inventory, which is maintained by the GSI-191 Program Site Owner, provides the location and quantity of aluminum in containment and identifies whether the aluminum is subject to immersion or containment spray during DBA/LOCA accidents. The procedure requires the GSI-191 Program Site Owner to be notified of the changes.

In addition, the Surry installation specification for thermal insulation has been updated to meet the requirements of GSI-191. Also, a site administrative procedure provides guidance for applying and replacing thermal insulation in containment. The procedure requires that the GSI-191 Program Site Owner be notified of the changes. The GSI-191 Program Site Owner maintains the insulation inventory.

The site installation coating specification for inside containment has been updated to be in alignment with the GSI-191 design basis for qualified coatings. A fleet engineering coating standard has also been implemented and provides criteria for selecting qualified coatings for inside containment. Level 1 coating requirements for procured equipment with protective coating to be installed inside containment are provided in a separate fleet engineering standard. If a vendor component with an unqualified coating is considered for installation, the unqualified coating must be evaluated for GSI-191 design basis impact by the GSI Program Site Owner.

In summary, the programmatic controls stated above ensure the GSI-191 design basis is being maintained effectively with respect to the plant modification process. To strengthen personnel awareness and understanding of the programmatic controls, training has been provided in the form of computer based training, engineering continued training, and GSI-191 related information bulletins.

NRC Question 9

Please provide a description of how maintenance activities, including associated temporary changes, that could affect the licensee's analytical assumptions and numerical inputs of the licensee's analyses relating to its resolution of sump performance issues, are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65.

Dominion Response

Dominion has implemented a fleet procedure for the performance of 10 CFR 50.65, Maintenance Rule (MRule), activities that require the licensee to assess and manage the risk associated with maintenance. The MRule Program implementing procedure provides interface arrangements with other programs, such as the plant modification and preventive maintenance programs.

Changes to the design of an SSC are reviewed by the Design and System Engineers for potential impact on existing MRule functions, performance criteria, and unavailability limits. This review is part of the program and design review for a permanent or temporary change. Associated design basis criteria are reviewed for impact from the proposed change.

Compliance with the MRule also includes the assessment of daily Condition Reports by the Maintenance Rule Site Owner, Engineering supervisors, and the Condition Report review team. The reviews ensure that reported issues are compared to the functions and performance criteria listed in the Maintenance Rule Function Scoping Matrix.

Conditions that are potentially functional failures, or that challenge performance criteria or unavailability limits, are assigned to the System Engineer to perform a formal MRule evaluation.

As part of GSI-191 Program development, Dominion performed reviews of containment work orders for each of the Dominion nuclear plants. In all cases, the bulk of work activities that may have had an impact on the GSI-191 design basis were covered under the plant modification process. Only a small percentage of maintenance work order activities were identified to have potential GSI-191 design basis impact. Dominion has implemented a fleet procedure that establishes the requirements for the work management process. Instructions are provided for complying with the requirements of the MRule Program. The Work Coordination Team (WCT) is required to review Work Orders on permanent plant SSCs for license renewal reliability concerns and potential operability or MRule concerns. The review considers engineering programs, including the GSI-191 Program. The WCT also reviews emergent work issues. The work order review process also covers specific program process controls established for coatings, insulation, and banned/restricted materials including aluminum.

In addition to the process controls discussed above, controls are in place for specific maintenance activities that could impact the GSI-191 design basis.

1. Dominion has established a fleet procedure to perform coating condition assessments of coatings inside containment. An unqualified coating inventory is maintained and updated each refueling outage. The inventoried quantity of qualified coatings in the worst case postulated LOCA pipe break location is also maintained. Changes to the qualified or unqualified coating inventories are evaluated to ensure the quantity of coatings assumed to fail post accident remains below the quantity of coatings analyzed for potential impact on the recirculation sump strainer.

2. Coating activities inside containment are controlled by a site administrative procedure. Qualified coatings are applied by qualified applicators in accordance with a fleet Level 1 application procedure. For procured equipment with a protective coating that is to be installed inside containment, the coating must either be a qualified coating or evaluated for impact on the GSI-191 design basis.

3. Dominion has a fleet procedure for labeling plant equipment that includes labeling equipment in containment. The procedure ensures that equipment labels placed in the reactor containment building are appropriate for the environment and will not adversely affect the recirculation sump strainer.

4. Surry has an administrative procedure that provides guidance for applying and replacing thermal insulation in containment. The procedure ensures the materials are appropriate for the containment environment and in compliance with the insulation specification. The GSI-191 Program Site Owner is required to

evaluate insulation changes and the potential impact on the containment sump recirculation system.

5. Any material to be placed or remain in containment, that is not normally left in containment, must be evaluated by Engineering as part of an engineering process (i.e., Engineering Transmittal, Design Change Package, Limited Scope Modification, etc.) or by the work order process by request to the engineering representative on the WCT. If any equipment, supplies or materials are being considered for staging inside containment prior to cold shutdown or between outages (at power), approval must be obtained from the GSI-191 Program Site Owner.

6. Dominion has established a fleet procedure to perform periodic latent debris sampling in containment and to quantify the total latent debris in containment to ensure the quantity remains below the analyzed limit. During refueling outages, the Radiation Protection staff routinely performs cleaning of various areas in containment. Periodic wash down of containment also reduces the amount of latent debris in containment.

In summary, the procedural controls discussed above provide processes that allow Dominion to assess and manage maintenance activities inside containment that could impact the plant's GSI-191 design basis in accordance with the MRule Program.

NRC Question 10

Page 56 of 64 of the February 29, 2008 supplemental response indicates that the numerical data relating to the structural qualification of the replacement strainers is contained in two AECL Seismic Analysis Reports for Surry Power Station. In accordance with the second bullet in Section 3.k of the Revised Content Guide for Generic Letter 2004-02 Supplemental Responses, please provide and summarize, in tabular form, the design margins for the strainer components analyzed for structural adequacy.

Dominion Response

The structural design margins for SPS 1 and 2 strainer components are summarized in Tables 1 and 2 below:

For components that could fail due to stress, the design margin is defined as:

Margin of safety = (Stress limit / Calculated stress) – 1

For components that could fail because of buckling, the design margin is defined as:

Margin of safety = (Calculated permissible pressure / Actual pressure) - 1

For both cases, as long as design margin is larger than zero, the component is structurally qualified.

Table 1
Margin of Safety – SPS 1 and 2 Strainer Headers

	Margin of Safety		
Component	**LHSI-RS Header**	**RS Header**	**RS Header with Single Sided Fins**
Header Bottom Plate	6.37	5.53	7.53
Header Top Plate	2.19	2.11	3.37
Vertical Deflector	2.54	2.33	5.64
Vertical Baffle	2.87	6.02	6.02
Horizontal Baffle	3.92	-	-
Channel	1.67	4.26	3.57
Fin Tab	2.51	2.1	24.4
Frame Bracket	0.85	2.07	5.15
Saddle Support	3.54	5.27	18.6
Top & Bottom Frames	9.98	17.1	40.8
Bolts in bottom plate/header support plate	0.44	1.36	-
Bolts in saddle vertical plate/anchor vertical plate	0.19	0.71	-
Bolts in frames and fins	5.73	20.8	12.6
Bolts in fin tabs	4.81	12.6	9.0
Bolts in frame brackets	9.67	3.2	13.4
End plate	1.87	2.32	-

Table 2
Margin of Safety – SPS 1 and 2 Pump Suction Headers

	Margin of Safety		
Component	**41-2-N**	**41-2-M**	**41-2-L**
Top plate	1.65	0.98	0.73
Bottom plate	1.18	0.55	1.68
Horizontal baffle plate	3.54	5.42	3.3
Side wall plate	1.13	1.77	1.91
Flange plate	5.62	-	-
Opening flange	1.55	-	-
Transition piece	-	3.99	3.92
Saddle support	-	3.62	-
Pipe	3.26	5.4	2.2

NRC Question 11

The NRC staff considers in-vessel downstream effects to not be fully addressed at Surry as well as at other PWRs. The licensee's submittal refers to draft WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The NRC staff has not issued a final safety evaluation (SE) for WCAP-16793-NP. The licensee may demonstrate that in-vessel downstream effects issues are resolved for Surry by showing that the licensee's plant conditions are bounded by the final WCAP-16793-NP 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 Surry. 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 GSI-191.

Dominion Response

Dominion intends to address the in-vessel downstream effects issues by showing that SPS 1 and 2 are bounded by the final WCAP-16793-NP and the corresponding final NRC staff Safety Evaluation Report (SER) and that SPS 1 and 2 satisfy the conditions and limitations in the final NRC SER. Preliminary calculations and evaluations based upon Revision 0 of WCAP-16793-NP indicated that SPS 1 and 2 are bounded by the initial version of the WCAP-16793-NP and meet the draft conditions and limitations transmitted by the NRC to NEI. These preliminary calculations and evaluations where not finalized because of the subsequent Request for Additional Information by the NRC for completion of the review of WCAP-16793-NP. Preliminary evaluations have also shown that the Surry specific debris combination potentially reaching the core inlet is bounded by the fuel testing documented in Revision 1 of WCAP-16793-NP. Thus, Dominion expects to be able to finalize the calculations and evaluations and demonstrate the Surry is bounded by Revision 1 of WCAP-16793-NP and the corresponding final NRC staff Safety Evaluation and the conditions and limitations of the SER once the final NRC SER is issued. This will be confirmed and reported to the NRC within 90 days of issuance of the final NRC staff SE on WCAP-16793.

NRC Question 12

The licensee's letter dated February 27, 2009 states (page 39 of 43) that "a review of ICET results indicated minimal transport of aluminum surfaces sprayed for four hours, therefore it can be concluded that the aluminum released to the sump in the short term originates solely from submerged aluminum." On that basis, the licensee concluded that potential chemical effects during the first four hours after a LOCA would be insignificant. The NRC staff agrees that some corrosion product was retained on the sprayed aluminum samples in the relevant ICET tests. The staff, however, does not understand how this observation leads to the conclusion that the aluminum originated solely from the submerged aluminum coupons since the staff is not aware of how the measured dissolved aluminum concentrations could be apportioned into contributions from submerged and sprayed samples. Please provide the basis for this conclusion or provide alternate reasons (e.g., aluminum is more soluble at the higher pool temperatures present in the short-term following a LOCA) why the potential chemical effects are initially expected to be insignificant.

Dominion Response

The conclusion that the aluminum measured in the test solution in ICET Test 1 was released almost exclusively from the submerged coupons was based on the observation that the unsubmerged coupons gained a small amount of weight, while the submerged coupons lost a substantial amount of weight (see Table below). On the basis of the small weight gain, it was concluded that little of the corrosion film formed on the aluminum surfaces had dissolved in the spray water and transported to the test solution. If substantial corrosion of the unsubmerged coupons had occurred, a weight loss should have been detected because the aluminum hydroxide film formed by corrosion is quite soluble at the spray pH. The Scanning Electron Microscope (SEM) images of the aluminum coupons from Test 1 are consistent with this hypothesis; the submerged aluminum coupons (Figure 4-138 in Reference 1) shows a thick crust of corrosion products on the surface that has clearly dried and cracked during preparation for imaging and suggesting a substantial corrosion rate, whereas the surface of the unsubmerged coupon (Figure 4-141 in Reference 1) shows a finer-grained film that appears to be thinner, suggesting a much lower corrosion rate.

Percentage of Weight Loss (-) or Gain of Submerged Aluminum Coupons after 30 Days

Coupon Location	Test Number				
	Fiberglass			Cal-sil/Fiberglass	
	1	2	5	3	4
	(pH 10, no TSP)	(pH 7, TSP)	(pH 8.5, borax)	(pH 7, TSP)	(pH 10, no TSP)
submerged	-25.2%	-0.2%	-2.9%	0.15%	0%
unsubmerged	0.48%	0.1%	0.1%	0.1%	0.15%

While a rigorous apportioning of the contributions from the submerged and unsubmerged coupons cannot be carried out, a reasonably accurate estimate can be made as follows. Note that all data for these calculations were taken from Reference 1.

The corrosion coupons used in the ICET tests were 12" x 12" x 1/16" (30.5 cm × 30.5 cm × 0.159 cm), for a total volume per coupon of 147.7 cm^3. Fifty-nine aluminum coupons were used in the tests. Most (95%) of the aluminum surface area was unsubmerged. The coupons were suspended on seven coupon racks: the submerged rack had the following arrangement of coupons in Tests 1 and 2: eight Cu, one Al, one IOZ, two GS, eight Cu, one Al, one IOZ, two GS, one US, nine Cu, one Al, one IOZ, three GS, eight empty slots, concrete, and then eight empty slots. The locations of the aluminum coupons were changed in Tests 3 to 5, but the number of coupons did not change. Therefore, there were three submerged coupons in Test 1.

The total mass of submerged aluminum was therefore:

$$3 \times 147.7 \times 2.70 \text{ g/cm}^3 = 1196.4 \text{ g}$$

The total mass loss of the submerged coupons was 25.2%, so the mass of aluminum released to solution was 301.5 g. The test rig volume was 949 L, and therefore the concentration of aluminum in solution due to the dissolution of the submerged coupons was 318 mg/L.

The highest concentration of aluminum measured in the test solution in Test 1 was around 350 mg/L, so that only 32 g of aluminum was likely released from a combination of the unsubmerged aluminum coupons plus the fiberglass. Assuming release only from the 56 unsubmerged coupons (i.e., no aluminum release from fiberglass), each coupon released a maximum of 0.6 g of aluminum. As each coupon weighed 399 g initially, the total weight loss was 0.15%, two orders of magnitude less than that of the submerged coupons. This is consistent with the measured weight gain for the unsubmerged coupons and the limited corrosion suggested by the SEM images.

It should be noted that some aluminum may have precipitated on various surfaces in the test tank during the tests, and therefore the total aluminum release may have been higher than that inferred from the solution concentration of aluminum. However, even if the aluminum release rate from the unsubmerged coupons was underestimated by a factor of ten, release from the unsubmerged coupons would represent less than 10% of the total aluminum release.

Reference 1: J. Dallman, B. Letellier, J. Garcia, J. Madrid, W. Roesch, D. Chen, K. Howe, L. Archuleta, F. Sciacca, NUREG/CR-6914, Vol. 1, LA-UR-06-3673, Integrated Chemical Effects Test Project: Consolidated Data Report, 2006.

NRC Question 13

Please describe how transported debris was assumed to be apportioned between the recirculation spray and LHSI strainers, and provide the basis for considering dual-train operation of the LHSI system to be bounded by single-train operation. With two LHSI pumps running, the total debris accumulating on the LHSI strainer would be greater, which in turn could result in an increased head loss that exceeds the conservatism associated with the NPSH evaluation for the single-train case under clean strainer conditions.

Dominion Response

RS Strainer:

The RS pumps take suction through the RS strainer prior to the LHSI pumps switching to recirculation mode. Therefore, the RS strainer could be exposed to 100% of the debris inventory. The RS strainer is assumed to be exposed to 100% of the LOCA debris load, as no time dependence is credited in the transport analysis.

LHSI Strainer:

The LHSI pumps transfer to cold leg recirculation mode after the RS pumps are already in operation. The conservative approach is to assume the debris transport to the LHSI and RS strainers is delayed until the LHSI pumps are switched to the recirculation mode. The transported debris is assumed to be homogeneously dispersed in the containment sump pool per NEI 04-07. Therefore, the debris will split between the LHSI and RS strainers based on the flow distribution to each strainer.

The LHSI strainer was tested with 40% of the full debris load. This is conservative for the limiting NPSH configuration of a single-train LHSI pump at maximum flow and two

RS pumps at minimum flow with consideration of the RS pump suction injection flow rates. The minimum two-pump RS strainer flow rate is 5600 gpm based on two IRS pumps at a minimum flow rate of 3100 gpm each and 300 gpm recirculation flow from the discharge of the RS heat exchanger to the IRS pump suction. This is a continuous source of subcooling for IRS pump operation and results in a strainer flow of 2800 gpm per pump. During cold leg recirculation, the maximum single-pump LHSI strainer flow rate is 3330 gpm, which produces an LHSI strainer flow split of 37%. During hot leg recirculation (initiated 8.5 hours after the LOCA), the maximum flow rate increases to 3600 gpm with a LHSI strainer flow split of 39%. If two LHSI pumps are assumed to operate at 4100 gpm, the maximum flow split is 42% to the LHSI strainer. It was concluded that the small increase in LHSI strainer debris head loss for a 2% increase in the flow split (versus the 40% debris that was tested) would be well bounded by the NPSH analysis for one-pump operation. The basis demonstrating single-train LHSI operation significantly bounds two-train operation for determination of NPSH margin is provided in the response to Question 7d above.

To maintain the plant configuration consistent with the above design assumptions, the Emergency Operating Procedures maintain at least two RS pumps in service during the long-term recovery following a LOCA.