VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

February 27, 2009

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

Serial No. 09-002
NLOS/GDM R1
Docket Nos. 50-280/281
License Nos. DPR-32/37

VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNITS 1 AND 2
UPDATED SUPPLEMENTAL RESPONSE TO NRC GENERIC LETTER 2004-02
POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

By letter dated February 29, 2008 (ADAMS ML080650562), Virginia Electric and Power Company (Dominion) submitted supplemental detailed information concerning corrective actions taken in response to NRC Generic Letter (GL) 2004-02 for Surry Power Station (Surry) Units 1 and 2. That letter fully detailed the corrective actions that had been performed for GL 2004-02 at that time and specified the corrective actions that were ongoing including: 1) downstream effects evaluations for Emergency Core Cooling System (ECCS) and Recirculation Spray System (RSS) pump seal performance and component wear, and 2) chemical effects testing and evaluation. The required date for completion of the outstanding corrective actions for Surry Units 1 and 2 was extended from the original due date of December 31, 2007 to November 30, 2008. [Reference NRC letter dated September 29, 2008 (ADAMS ML082730022).]

The attachment to this letter provides Dominion's updated supplemental response to GL 2004-02 for Surry Units 1 and 2 and includes the necessary information to appropriately address the analyses performed and corrective actions taken that were not complete at the time of Dominion's previous supplemental response. These corrective actions were completed for Surry Units 1 and 2 by the November 30, 2008 due date with the exception of the removal of a RS subsystem flow value from the Surry Technical Specifications Design Features section. The flow value was removed from TS by Surry Units 1 and 2 License Amendments 262/262 dated December 10, 2008 (ADAMS ML082682183). By letter dated November 4, 2008 (ADAMS ML083010126), the NRC stated that they considered and understood the relationship between the license amendment application and the Dominion GL 2004-02 extension request dated September 5, 2008 (ADAMS ML082540495).

Final resolution of potential chemical and downstream effects on the reactor core and flowpaths is pending the issuance of WCAP-16793-NP and the associated NRC Safety

A116
NRR

Evaluation Report (SER). Corrective actions will be identified, if required for resolution of this item, within 90 days of issuance of the NRC SER.

The content and level of detail provided in the attachment are consistent with the guidance included in NRC letters dated November 21, 2007 (ADAMS ML073110389) and March 28, 2008 (ADAMS ML080230112) to the Nuclear Energy Institute.

Should you have any questions or require additional information, please contact Mr. Gary D. Miller at (804) 273-2771.

Sincerely,

J. Alan Price
Vice President – Nuclear Engineering

Commitment:

1. Corrective actions for resolution of potential chemical and downstream effects on the reactor core and flowpaths will be determined and reported to the NRC within 90 days following the issuance of revised WCAP-16793-NP and the associated NRC Safety Evaluation Report (SER).

Attachment:

Updated Supplemental Response to Generic Letter 2004-02, Surry Power Station Units 1 and 2

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Mr. J. Alan Price, who is Vice President – Nuclear Engineering, of Virginia Electric and Power Company. 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 27th day of February, 2009.

My Commission Expires: 4/30/13.

Notary Public

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

cc: U.S. Nuclear Regulatory Commission
Region II
Sam Nunn Atlanta Federal Center
61 Forsyth Street, SW
Suite 23T85
Atlanta, Georgia 30303

NRC Senior Resident Inspector
Surry Power Station

Ms. D. N. Wright
NRC Project Manager
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop O-8 H4A
11555 Rockville Pike
Rockville, Maryland 20852

Mr. J. F. Stang, Jr.
NRC Project Manager
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop O-8 G9A
11555 Rockville Pike
Rockville, Maryland 20852

ATTACHMENT

UPDATED SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02

SURRY POWER STATION UNITS 1 AND 2

**VIRGINIA ELECTRIC AND POWER COMPANY
(DOMINION)**

UPDATED SUPPLEMENTAL RESPONSE TO GL 2004-02 SURRY POWER STATION UNITS 1 AND 2

1.0 Description of Approach for Overall Compliance

This information supplements the Overall Compliance information included in the supplemental response to GL 2004-02 dated February 29, 2008.

By letter dated February 29, 2008, Serial No. 08-0018, Dominion provided a supplemental response 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 (Surry) Units 1 and 2. This attachment updates the information that was previously provided. The balance of this attachment provides the following items:

1.a Conservatisms
1.b Summary
2.0 General Description of and Schedule for Corrective Actions
3.f Head Loss and Vortexing
3.g Net Positive Suction Head (NPSH)
3.i Debris Source Term
3.j Screen Modification
3.m Downstream Effects – Components and Systems
3.n Downstream Effects – Fuel and Vessel
3.o Chemical Effects
3.p Licensing Basis

1.a Conservatisms

Detailed analyses of debris generation and transport ensure that a bounding quantity and a limiting mix of debris are assumed at the containment sump strainer following a design basis accident (DBA). Using the results of the analyses, conservative evaluations were performed to determine worst-case strainer head loss and downstream effects. Chemical effects bench-top tests conservatively assessed the solubilities and behaviors of precipitates and applicability of industry data on the dissolution and precipitation tests of station-specific conditions and materials. Reduced-scale testing was performed by Atomic Energy of Canada Limited (AECL) using two separate test facilities: Test Rig 33, a single-loop test rig, and multi-loop Test Rig 89. The reduced-scale testing established the influence of chemical products on head loss across the strainer surfaces by simulating the plant-specific chemical environment present in the water of the containment sump after a Loss-of-Coolant-Accident (LOCA). These analyses included the conservatisms discussed in the balance of this section.

1. Test evaluations demonstrate that a fully formed thin-bed of debris requires significant time (hours) to form and that formation of a thin-bed is dependent upon disturbing settled debris throughout the test tank. Consequently, a worst-case thin-bed of debris would be difficult to form and would not be expected to form until several hours after sump recirculation is initiated. Significant debris settling and sump water subcooling occurs during the formation of a debris-bed so additional net positive suction head (NPSH) margin is present for chemical effects head loss. However, as a conservative measure, chemical effects testing began with an established debris thin-bed on the strainer fin and was conducted for the 30-day mission time.

2. The debris load in head loss testing was taken from the debris transport calculation, which conservatively credits no particulate settling.

3. Debris introduction procedures in chemical effects testing ensured minimum near-field settling and resulted in conservatively high debris bed head losses.

4. Debris introduction was accomplished in a carefully controlled manner to result in the highest possible head loss. Particulate was introduced initially, which was followed by discrete fiber additions after the particulate debris had fully circulated.

5. Only fines of fibrous debris were used in head loss testing as if all the fibrous debris erosion, which is expected to take a considerable amount of time, occurred at recirculation start.

6. Debris bed formation during testing included agitating (or "stirring") the settled debris to ensure maximum debris on the strainer. However, any turbulence in post-LOCA containment sump water is expected to be localized to limited areas of the strainers. Consequently, much of the sump water will be quiescent, which would promote debris settling.

7. Particulate settling in head loss testing was conservatively minimized through use of a lower density walnut shell particulate as a surrogate for the higher density epoxy coating particulate that may be present in post-LOCA sump water.

8. Downstream wear analysis used the Large Break LOCA particulate load to determine abrasive and erosive wear. This is a conservative particulate loading, in view of the following:

   - Much of the particulate included in analysis is unqualified coating that is outside the break zone of influence (ZOI). This unqualified coating is assumed to dislodge due to exposure to the containment environment. However, such dislodgement is likely only after many hours and days, if at all.

- The low velocity of the sump water column and the significant number of surfaces throughout containment promote significant settling of particulate in containment. Settled coating will not be drawn through the sump strainer since the Recirculation Spray (RS) strainer is located approximately six inches, and the Low Head Safety Injection (LHSI) strainer is approximately 19 inches, above the containment floor.

- The analysis assumes 100% strainer bypass of particulate conservatively maximizing the effects of downstream wear.

9. Chemical effects testing results were conservative based upon several conditions:

   - Aluminum corrosion amounts were calculated at high pH (pH 9), where aluminum corrosion and release rates are high. Testing was performed at neutral pH (pH 7), where aluminum solubility is low to encourage aluminum compound precipitation. Sump water pH is expected to be approximately 8 in the long-term.

   - The minimum sump water volume at specified times post-LOCA were used to maximize the calculated sump aluminum concentrations.

   - The analysis of aluminum load conservatively does not account for the possible inhibitory effect of silicate or other species on aluminum corrosion.

   - The rate of corrosion is maximized by analysis that does not assume development of passive films, i.e., no aluminum oxides remain adhered to aluminum surfaces. The formation of passive films could be credited to decrease the corrosion and release rates at long exposure times. Consequently, it is conservative to assume that all aluminum released by corrosion enters the solution.

   - All aluminum released into the solution is conservatively assumed to transport to the debris-bed instead of plating out on the multiple surfaces throughout containment. During bench-top testing, aluminum plated out on glass beakers and, during reduced-scale testing, aluminum plated out on fiber. It is reasonable to expect that a portion of the aluminum ions released into solution will plate out on some of the multiple surfaces in containment prior to arriving at the debris-bed on the strainer.

- Chemical effects test evaluations conservatively neglect the effect of the presence of oxygen in the sump water. The corrosion rate of aluminum in aerated pH 10 alkaline water can be a factor of two lower than that measured in nitrogen-deaerated water. This data is in NUREG/CR-6873, "Corrosion Rate Measurements and Chemical Speciation of Corrosion Products Using Thermodynamic Modeling of Debris Components to Support GSI [Generic Safety Issue]-191."

10. NPSH margins were determined with the following conservatisms:

- No credit was taken for additional NPSH margin in the short-term due to subcooling of the sump water combined with the several hours required to form the limiting thin-bed of debris. Our analyses conservatively assume transport to the strainer following the break occurs much sooner.

- There is conservatism in scaling from test temperatures to higher specified sump temperatures. The debris bed will expand slightly when head loss is lower, i.e., at the higher sump temperature, the bed would be expected to be slightly more porous than at the lower test temperature. The assumption of a purely linear relationship between head loss and viscosity when scaling to higher temperatures is, therefore, conservative.

- The NPSH calculations were guided by the observation that the minimum margin would likely occur for the combination of parameters that would minimize the containment pressure and maximize the sump water temperature (and, hence the vapor pressure of this fluid), thereby conservatively minimizing the contribution of containment accident pressure to the calculated NPSH margin.

1.b Summary

The corrective actions associated with GL 2004-02 to resolve NRC Generic Safety Issue (GSI) 191, "*Assessment of Debris Accumulation on PWR Sump Performance,*" have been completed for Surry Units 1 and 2.

Downstream effects analyses (components) have been completed consistent with WCAP-16406-P, Rev. 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," to identify any wear, blockage or vibration concerns with components and systems due to debris-laden fluids.

Significant conservatisms are inherent in these analyses, which provide reasonable assurance that downstream component clogging will not occur, and downstream component wear will not significantly affect component or system performance. The results of these analyses are detailed in Section 3.m below.

Downstream effects analyses for the fuel and vessel were previously performed consistent with the methodology of WCAP-16793-NP, Rev. 0, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," May 2007. However, since that time, in response to concerns raised by the Advisory Committee on Reactor Safeguards regarding WCAP-16793-NP, Rev. 0, the Pressurized Water Reactor Owners' Group (PWROG) is performing additional testing and analyses to more realistically determine the potential downstream and chemical effects on the reactor core and the vessel/components. Dominion will review the results of the staff SER when issued to determine if additional analyses and corrective actions are required. Corrective actions will be identified, if required for resolution of this item, and submitted to the NRC within 90 days following the issuance of the revised WCAP-16793-NP and the associated NRC Safety Evaluation Report (SER).

Chemical effects testing and analyses have been completed. AECL has performed various hydraulic tests that simulated the actual debris loading and chemical conditions specific to Surry Units 1 and 2 based on debris generation, debris transport, and chemical effects evaluations. Fibrous and particulate debris and chemicals were added to a test rig to simulate the plant-specific chemical environment present in the water of the containment sump following a DBA. Each test was operated for more than 30 days after the formation of the debris bed and initial chemical addition at specified temperatures and flow rates to assess chemical precipitate formation and head loss change. These tests verified that adequate NPSH is available to support the operation of the LHSI and RS pumps during the post-LOCA recirculation mode. The description of the analysis methodology, as well as the analysis and testing results, are provided in Section 3.o below.

In addition, the remaining Surry Unit 2 plant modifications that had not been completed at the time of the February 29, 2008 submittal are now complete. Specifically, the remaining Surry Unit 2 RS strainer modules have been installed, installation of debris shields over the wide range level transmitters has been completed, and insulation inside the containment (that could contribute to spray or submergence generated debris) that was found to be damaged, degraded or covered with an unqualified coating system was removed or jacketed with a jacketing system qualified for a DBA.

The completion of the evaluation of downstream effects on systems and components and chemical effects testing resulted in changes to information submitted in Dominion's previous supplemental response dated February 29, 2008. Therefore, updated information is provided in Sections 3.f, 3.g, 3.i, and 3.j below.

Based on the methodology, modifications, and conservatisms described herein, as well as the detailed information provided in Dominion's previous supplemental response dated February 29, 2008, there is reasonable assurance that long-term core cooling will successfully remove decay heat for at least 30 days following a DBA.

2.0 Description of and Schedule for Corrective Actions

This information supplements the Description of and Schedule for Corrective Actions information included in the supplemental response to GL 2004-02 dated February 29, 2008.

By letter dated February 29, 2008, Dominion indicated that the following actions were on-going, and that an update would be provided:

1. Chemical and downstream effects testing evaluation.
2. Chemical effects bench-top testing.
3. Chemical effects reduced-scale testing.
4. Downstream wear evaluation for components.
5. Downstream wear evaluation for fuel and vessel.
6. Installation of the remaining Unit 2 RS strainer modules.
7. Remediation of containment spray generated debris, calcium silicate (Cal-Sil), asbestos, and Cerafiber (Unit 2).
8. Installation of debris shields over the Unit 2 wide range level transmitters.

Previously approved extension requests for Surry Units 1 and 2 permitted the completion of these corrective actions by November 30, 2008. In addition, removal of a RS subsystem flow value from the Surry Technical Specifications Design Features section was accomplished by Surry Units 1 and 2 License Amendments 262/262 dated December 10, 2008 (ADAMS ML082682183). By letter dated November 4, 2008 (ADAMS ML083010126), the NRC stated that they considered and understood the relation of the license amendment application to the Dominion GL 2004-02 extension request dated September 5, 2008 (ADAMS ML082540495).

Component downstream effects analyses have been completed using the methodology described in WCAP-16406-P, Rev. 1, and those analyses and relevant results are discussed in Section 3.m below. Information previously provided on downstream effects for components and systems in the supplemental response letter dated February 29, 2008 remains valid.

In-vessel downstream effects have been evaluated using WCAP-16406-P, Rev. 1, and WCAP-16793-NP, Rev. 0, with acceptable results as described in Section 3.n below. The NRC SER for WCAP-16793-NP has not been issued and may contain staff conditions and limitations to be addressed. Dominion will review the results of the staff SER when issued to determine if additional analyses and corrective actions are required. If necessary, Dominion will submit its plan to address any changes to the analysis of the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SER on WCAP-16793.

Chemical effects testing and analyses have also been completed. The testing and analyses were completed using a methodology and testing protocol developed with AECL at their Chalk River facility and observed, in part, by the NRC staff. The description of the analysis methodology, as well as the testing and analysis results, are discussed in Section 3.o below. Information previously provided on chemical effects in the supplemental response letter dated February 29, 2008 remains valid.

The remaining plant modifications for Surry Unit 2 have been completed as noted above.

3.0 Additional Information for Head Loss and Vortexing (3.f), Net Positive Suction Head (NPSH) (3.g), Debris Source Term (3.i), Screen Modification (3.j), Downstream Effects – Components and Systems (3.m), Downstream Effects – Fuel and Vessel (3.n), Chemical Effects (3.o), and Licensing Basis (3.p)

The Dominion supplemental response to GL 2004-02 dated February 29, 2008 indicated in the response to Requests for Additional Information (RAIs) 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 34 from NRC letter dated February 9, 2006 (ADAMS ML060380017) that additional information related to these requests would be provided when the downstream effects and chemical effects evaluations were complete. Sections 3.m and 3.o below provide additional information relevant to these RAIs.

3.f Head Loss and Vortexing

This information supplements the Head Loss and Vortexing information included in the supplemental response to GL 2004-02 dated February 29, 2008.

The Dominion GL 2004-02 supplemental response dated February 29, 2008 provided containment sump strainer head loss information based on testing without chemical effects. Chemical effects testing has been completed (see Section 3.o) and revised allowable head loss values were determined for input to the final strainer hydraulic analyses. The hydraulic analyses are performed to identify NPSH margins for pumps taking suction from the containment sump (Section 3.g) and to evaluate the effect of any predicted sump fluid flashing or dissolved air released from solution in the strainer or at the pump suctions.

Containment sump strainer head loss is evaluated for two distinct time periods – short-term and long-term. The short-term is defined as the time period from event initiation to the point at which stable containment pressure, sump temperature, and sump water level are achieved, which occurs within 4 hours. During this initial period of the accident response, chemical effects are not required to be considered in the determination of strainer head loss since chemical debris would not have begun to influence the debris bed head loss for several hours or days. The long-term considers containment conditions from 4 hours to 30 days and conservatively includes the maximum effect of aluminum precipitation in the debris bed for the entire period.

The RS strainer flowrate for the short-term is defined by the operation of all four RS pumps. Post-LOCA containment conditions stabilize below atmospheric pressure within 4 hours and emergency operating procedures direct operators to stop two of the four RS pumps. Therefore, for the long-term period, the RS strainer flowrate is defined by the limiting set of two RS pumps in operation.

Containment sump conditions and required pump flowrates were considered for each time period, and the limiting condition for strainer head loss requirements was determined for use in this evaluation. Final design and testing criteria for the containment sump strainers were determined and are provided in Table 3.f-1.

Table 3.f-1: Final Design and Testing Acceptance Criteria for Sump Strainers

	Total Strainer Allowable Head Loss (ft H_2O)	Flow Rate (gpm)	Temperature (°F)	Water Level (ft.) above floor
Recirculation Spray				
RS Short Term[a]	3.5[b] (ORS)[c] 3.7 (IRS)[c]	12,700	170	1.8
RS Long Term[a]	5.0	6700	104	4.6
Low Head Safety Injection				
LHSI RMT Initiation (No Debris)	1.0	3330	160	4.1
LHSI Short Term[a] (after 1 Sump Turnover)	1.77	3330	140	4.6
LHSI Long Term[a]	2.2	3330[d]	104	4.6

a. Short Term is defined as the time period from event initiation to the point at which stable containment pressure, sump temperature, and sump water level are achieved (less than 4 hours). Long Term considers containment conditions from 4 hours to 30 days and includes the maximum effect of aluminum precipitation in the debris bed.
b. Allowable head loss based on analysis is 3.1 ft H_20 at 188°F, which equates to 3.5 ft H_20 at 170°F, using dynamic viscosity scaling for the debris bed head loss.
c. ORS – Outside Recirculation Spray, IRS – Inside Recirculation Spray
d. Long-term strainer hydraulic analysis assumes a bounding flowrate of 3600 gpm compared to the value of 3330 gpm used in testing – see Table 3.f-2.

Strainer Flashing

The potential for sump liquid flashing into vapor in the strainer system was re-evaluated. The methods of analysis were the same as described in the Dominion GL 2004-02 supplemental response dated February 29, 2008.

The analysis revealed that the onset of flashing is predicted for the Surry Unit 1 RS strainer (the worst-case RS strainer) when the debris bed on the fins reached a pressure loss of 0.36 ft. H_2O or about 23% of the allowable debris pressure loss of 1.53 ft. H_2O at the bulk water temperature used in the flashing analysis. If the pressure loss of the debris bed increases above this level, then flashing is predicted in the strainer internal piping.

The condition for which the possibility of flashing was evaluated is a worst-case low margin scenario occurring approximately 6 minutes after the RS system is put in service. At this time a debris bed is only just beginning to form on the strainer fins. Testing performed by AECL has shown that several hours to days are required for the full debris bed to form and to reach the point where maximum debris pressure loss occurs. At the time the transient low margin condition occurs, the pressure loss due to debris will be well below 23% of the full debris pressure loss, and flashing will not occur within the strainer system.

The flashing analysis for the LHSI strainer concluded that there is significant margin to flashing considering the maximum allowable strainer head loss. Therefore, there is no concern for flashing in the LHSI strainer.

Air Ingestion

The potential for air ingestion due to voiding was also re-evaluated considering the results of chemical effects testing. (There is no change to the vortexing evaluation results provided with the Dominion GL 2004-02 supplemental response dated February 29, 2008.) The analytical evaluation for the allowable head loss limit shows either a small amount of voiding or no voiding within the strainer system, and no voiding at the inlets to the pumps. Since there is no void formation at the pump inlet due to air ingestion, no adjustment to required NPSH is necessary.

Hydraulic Analysis Results

The total allowable strainer head loss compared to the test results from chemical effects head loss testing (described in Section 3.o) is provided in Table 3.f-2.

To encompass the effects of dissolved chemicals on the viscosity of sump water, the calculations for strainer debris bed head-loss and internal head-loss include a 12% increase in water viscosity over that of clean water. This value is supported by the chemical effects testing performed by AECL and the data from NUREG/CR-6914, Vol. 1.

Table 3.f-2: Hydraulic Analysis Results

	Total Strainer Allowable Head Loss, H_{Lt} (ft H_2O)	Strainer Internal Head Loss, H_{Ls} (ft H_2O)	Debris Bed Head Loss, H_{Ld} (ft H_2O)[a]	$H_{Lt} > H_{Ls} + H_{Ld}$?
Recirculation Spray Strainer				
IRS Short Term	3.7	1.69	1.91	YES
IRS Long Term	5.0	1.14	3.37	YES
ORS Short Term	3.5	1.55	1.91	YES
ORS Long Term	5.0	1.14	3.37	YES
Low Head Safety Injection Strainer				
LHSI RMT Initiation (No Debris)	1.0	0.82	--	YES
LHSI Short Term (after 1 Sump Turnover)	1.77	0.79	0.838	YES
LHSI Long Term[b]	2.2	0.92	1.16	YES

a. These debris bed head loss results in ft H_2O are equivalent to the debris bed head loss results reported in Section 3.o in psi. The debris head loss includes fin loss.
b. The strainer internal head loss and debris bed head loss for the LHSI Long Term case is evaluated at 3600 gpm (the bounding maximum flowrate corresponding to hot-leg recirculation mode).

3.g Net Positive Suction Head (NPSH)

This information supplements the Net Positive Suction Head (NPSH) information included in the supplemental response to GL 2004-02 dated February 29, 2008.

The Dominion GL 2004-02 supplemental response dated February 29, 2008 provided NPSH information based on containment sump strainer testing without chemical effects. Chemical effects testing has been completed (see Section 3.o) and hydraulic analyses have been performed incorporating the results of chemical effects testing.

Revised NPSH margins were determined for the RS and LHSI pumps drawing from the containment sump following a LOCA. NPSH margins were determined at the time after a LOCA corresponding to lowest available NPSH for the short-term and long-term cases. The NPSH margin was determined by subtracting the total strainer allowable head loss and the required NPSH ($NPSH_r$) from the available NPSH ($NPSH_a$), which was determined from the worst-case Surry GOTHIC containment analysis result and does not include the strainer head loss. The total strainer allowable head loss establishes the design requirement for the sump strainer. In most cases, containment analysis results provided an $NPSH_a$ value at a containment sump temperature that was greater than the head loss test temperature. Conservatively, the allowable strainer head loss was specified at test temperature without temperature correction, which provides an additional unquantified margin in the head loss results.

Surry UFSAR Figures 6.2-3, 6.3-7, and 6.3-11 illustrate the trend of available NPSH (without strainer losses) over time after an accident for the LHSI, ORS, and IRS pumps, respectively.

As stated in Section 3.f, there is no void fraction at the pump inlets; therefore, there is no adjustment required to the $NPSH_r$ for the pumps. The $NPSH_r$ values in Table 3.g-1 are based on the pump manufacturers curve at the maximum design flowrate.

NPSH margin calculation results based on maximum allowable strainer head loss are provided in Table 3.g-1. Note that information in this table supersedes the information in Table 3.g-1 included in the February 29, 2008 supplemental response.

The total allowable strainer head loss was compared to the test results from chemical effects head loss testing (described in Section 3.o) in Table 3.f-2. All sump strainer test results satisfactorily met the allowable head loss criteria. The difference between the test results and the allowable head loss is not included in the Minimum Margin values identified in Table 3.g-1 as an additional conservatism.

Table 3.g-1: Summary of RS and LHSI Pump Margins

Pump	Min. $NPSH_a$ (ft H_2O)[a]	Total Strainer Allowable Head Loss, H_L (ft H_2O)[b]	$NPSH_r$ (ft H_2O) at Maximum Flowrate (gpm)	Minimum Margin (ft H_2O) = $NPSH_a$ - H_L - $NPSH_r$
ORS – Short Term[e]	12.48 @ 196.3°F	3.1 @ 188°F[c,d]	9.19 @ 3300	0.19
ORS – Long Term[e]	24.48 @ 104°F	5.0 @ 104°F	9.19 @ 3300	10.29
IRS – Short Term[e]	15.14 @ 208.4°F	3.7 @ 170°F[d]	10.5 @ 3650	0.94
IRS – Long Term[e]	28.0 @ 140.0°F	5.0 @ 104°F	10.5 @ 3650	12.5
LHSI – RMT	15.7 @ 177.9°F	1.0 @ 160°F[d]	13.82 @ 3330	0.88
LHSI – Short Term[e]	21.06 @ 164.1°F	1.77 @ 140°F[d]	13.82 @ 3330	5.47
LHSI – Long Term[e]	25.37 @ 146.6°F	2.2 @ 104°F[d]	14.6 @ 3600[f]	8.57

a. This value is from the Surry GOTHIC containment analysis and does not include strainer head loss.
b. This value includes the debris bed and strainer internals head loss at the strainer flowrate identified in Table 3.f-1.
c. Total allowable strainer head loss equates to 3.5 ft H_2O at 170°F after correction using dynamic viscosity ratio.
d. Conservatively, no temperature correction has been made from $NPSH_a$ specified temperature.
e. Short Term is defined as the time period from event initiation to the point at which stable containment pressure, sump temperature, and sump water level are achieved (less than 4 hours). Long Term considers containment conditions from 4 hours to 30 days and includes the maximum effect of aluminum precipitation in the debris bed.
f. The LHSI pump $NPSH_r$ for the LHSI - Long Term case is evaluated at 3600 gpm (the bounding maximum flowrate corresponding to hot-leg recirculation mode).

3.i Debris Source Term

This information supplements the Debris Source Term information included in the supplemental response to GL 2004-02 dated February 29, 2008.

Insulation inside the Surry Unit 2 containment that could contribute to spray or submergence generated debris that was found to be damaged, degraded or covered with an unqualified coating system was removed or jacketed with a jacketing system qualified for a DBA.

3.j Screen Modification

This information supplements the Screen Modification information included in the supplemental response to GL 2004-02 dated February 29, 2008.

The remaining Surry Unit 2 RS strainer modules have been installed.

Although the maximum opening size in the Surry Units 1 and 2 sump strainer fins is a 0.0625 inch diameter hole, the possibility exists for larger 'gaps' in the strainer assembly due to fit-up inconsistencies. The potential for gaps up to 0.125 inch wide for a total of 1% of strainer total flow area, and a limited number of 0.1875 inch wide and 1 inch long gaps, was evaluated for its affect on the downstream effects analysis described in Section 3.m.

Five areas of the downstream effects analysis that could be affected by increased debris resulting from increased gap size were evaluated: (1) bypass fraction and debris size, (2) downstream component wear, (3) downstream component blockage, (4) fuels blockage, and (5) strainer hydraulics. The evaluation concluded that the presence of 0.125 inch wide gaps for 1% of strainer flow area, and 0.1875 inch wide by 1 inch long gaps limited to four on the LHSI strainer and eight on the RS strainer, would have no significant effect on the results of the downstream effects analyses for systems and components or the fuel and vessel.

3.m Downstream Effects—Components and Systems

This information supplements the Downstream Effects – Components and Systems information included in the supplemental response to GL 2004-02 dated February 29, 2008.

The methodology used for downstream effects analysis was consistent with WCAP-16406-P, Rev. 1, and the limitations and conditions described in the accompanying NRC SER dated December 20, 2007 (ADAMS ML073520295).

No design or operational changes were required as a result of the downstream effects evaluations.

This update of the downstream effects analysis addresses:

- Wear of the High Head Safety Injection (HHSI) pumps (Charging pumps), ORS pumps, IRS pumps, LHSI pumps, manually throttled valves, motor operated valves, spring-loaded check valves, orifices, cavitating venturis, recirculation spray nozzles, and heat exchangers, and an analysis of the wear effects on the performance of these components,

- Pressure relief valves which could potentially open and piston check valves which will open during recirculation to determine if there is a possibility that the valves will not reseat properly due to debris in the fluid potentially resulting in an undesirable flow path for the recirculation fluid, and

- Blockage of downstream components, including instrumentation, due to the presence of debris.

Debris from the LOCA may pass through the containment sump LHSI and RS strainers and enter the ECCS and RSS causing abrasion and/or erosion on the surfaces of components. Wear models were developed in accordance with the methodology provided in WCAP-16406-P, Rev. 1, to assess the amount of wear in ECCS and RSS components based on the initial debris concentration in the pumped fluid, the debris concentration depletion due to settling and filtration, the hardness of the wear surfaces, and the mission time. The results for all downstream components were determined to be acceptable per the criteria set forth in WCAP-16406-P, Rev. 1.

Wear Models

- Abrasive Wear Models

  Two abrasive wear models have been considered: the "free flow" type and the "packing (or Archard's)" type. Free flow wear is the removal of material due to hard or sharp particles that flow with the fluid between two close-proximity surfaces in relative motion to each other. In the Archard's model, particles carried by the fluid adhere to the stationary surface by forming a packing that wears the moving surface.

  These types of wear affect, in particular, pump components such as wear rings, impeller hubs, bushings, and diffuser rings. The wear rate of Archard's model is constant and does not depend on the debris concentration and its depletion over time. Once packing is established in the close running clearances, debris depletion in the bulk fluid does not affect the rate of wear.

For the free flowing abrasive wear model, the rate of wear is a direct result of the debris concentration in the fluid at any time during the pump (or other component) duty cycle. Archard's wear is single sided since only the moving surface is worn out, whereas the free flow model wears both the rotating and the stationary surface individually and independently.

- Erosive Model

  Erosive wear is caused by particles impinging on a component surface or edge and removing material from that surface due to momentum effects. This type of wear can occur in components with high velocity flows such as throttling valves, orifices, heat exchanger tubes, and pump components.

The wear rate model includes the capability to calculate the initial debris concentration, the debris concentration as a function of time, and the rate of debris settlement. In addition to being captured by the sump strainer, debris heavier than the recirculation fluid tends to settle out in the low velocity regions, such as the reactor lower plenum. Therefore, the concentration of debris in the recirculation flow will diminish with time.

The time-dependent concentrations of particulate and fibrous debris were used as inputs to complete the evaluation of the effects of debris ingestion on Emergency Core Cooling System (ECCS) and RS System (RSS) pumps, safety-related valves, heat exchangers, orifices, recirculation spray nozzles, piping, and instrumentation tubing.

Pumps

The evaluation of pump hydraulic performance and mechanical dynamic performance was based on design performance characteristics as a starting point. This approach is supported by a review of approximately ten years of inservice testing data that concludes that there has been no statistically significant degradation of the performance of the HHSI, LHSI, IRS, and ORS pumps over this time period.

- Hydraulic Performance

Abrasive and erosive wear of pump internal subcomponents resulting from pumping debris-laden water can cause an increase in the flow clearances of the pump, which can result in increases in internal leakages and an overall decrease in pump performance. ECCS and RSS pump wear was conservatively calculated and the "worn" condition pump hydraulic performance was evaluated for its effect on system minimum performance requirements. This overall system performance evaluation also included a review of cumulative system resistance changes due to wear in system piping and components to determine the impact on system maximum flow to assess pump runout potential. The review of component wear concluded that all system components pass the WCAP-16406-P, Rev. 1, criteria. In addition, the system performance evaluation concluded that there is no significant effect on system resistance or flowrates.

The overall system performance evaluation concluded that the ECCS and RSS pumps meet their hydraulic performance requirements at the end of the 30 day mission time.

- Mechanical Seal Wear/Performance

The impact of abrasive debris on the performance of pump mechanical shaft seals has been evaluated for the LHSI, HHSI, and ORS pumps (IRS pumps do not utilize a mechanical seal). The conclusion of the evaluation is that the debris-laden recirculation fluid would not adversely impact the performance of the mechanical seals.

For the LHSI and ORS pumps with a tandem seal design, the inboard seal is cooled by pump discharge water. The evaluation conservatively assumed that the inboard seal failed due to wear from the debris-laden pumpage, and shaft sealing was accomplished solely by the outboard seal, which is cooled by demineralized water in a closed loop cooling subsystem. The evaluation concluded that, since there is no significant convection of fluid to bring debris into the outer seal and diffusion of debris is not credible due to the small clearances between the stationary and pumping rings of the seal, the LHSI and ORS pumps outboard seals would continue to function as required for the duration of the mission time.

The HHSI pump shafts are sealed with single stage mechanical seals at each end of the pump. The seals are cooled by pumped fluid that is circulated through an external seal cooler for heat removal. Following a LOCA, the HHSI pumps initially take suction from the Refueling Water Storage Tank (RWST) containing cooled, demineralized borated water such that the seal water is initially clean at the start of the mission time. The potential for debris-laden recirculation fluid to reach the seal cavity was evaluated to determine if seal cooling could be degraded, seal faces could be worn excessively, or the seal internal mechanism could be fouled preventing proper operation. The evaluation concluded that the HHSI pump seals would be adequately cooled and seal faces would not wear significantly from particulate debris during the mission time. In addition, the amount of debris entering the seal chamber would be insignificant such that the function of the seal internal mechanism would not be affected.

The seal analysis determined that no additional leakage is anticipated as a result of debris-laden pumped fluid. Therefore, the HHSI pump seals meet performance criteria and would continue to function as required for the duration of the mission time.

- Mechanical Dynamic Performance

The increased flow clearances resulting from the abrasive and erosive wear of pump components were evaluated to determine if ECCS and RSS pumps would operate satisfactorily, without excessive vibrations, to provide the required flow to cool the core and depressurize the containment for the required mission time post-LOCA.

The LHSI, IRS, and ORS pumps were found to satisfy the WCAP-16406-P, Rev. 1, dynamic performance requirements criteria for the required 30 day mission time. The HHSI pumps met the WCAP-16406-P, Rev. 1, criteria for a limited operating time of 75 hours, which exceeds the required HHSI pump operating time for the limiting small break LOCA. Although the HHSI pumps are not required to operate for the large break LOCA that defines the 30 day mission time, a detailed plant-specific analysis was performed by the pump manufacturer to qualify these pumps for a 30-day mission time. The additional analysis was also performed to confirm that pump wear would not lead to the potential for overpressurization of the pump outboard mechanical seal.

The pump vendor evaluation of HHSI pump mechanical dynamic stability was based on the WCAP-16406-P, Rev. 1, methodology along with a detailed analysis of Surry-specific debris constituents. Specifically, since the testing referenced in WCAP-16406-P, Rev. 1, that resulted in packing-type abrasive wear was performed with coatings particulate debris, detailed debris characterization for the Surry debris-laden recirculation fluid were determined. The Surry debris mix consists of 226 ppm particulate, of which less than 5% (11 ppm) is coatings debris. The pump vendor evaluation concluded that, since the WCAP-16406-P, Rev. 1, tests resulted in packing formation observed at 920 ppm but not at 92 ppm coatings debris concentration, the formation of packing in the Surry HHSI pump running clearances is not anticipated based on the low concentration of plant-specific coatings. Therefore, there would be no packing-type abrasive wear over the HHSI pumps mission time.

Free-flow abrasive wear and erosive wear were determined to cause wear at close clearance HHSI pump internals locations. The most critical diametral clearance enlargement determined from the vendor analysis for a 30-day mission time is 0.34 mils at the balance drum and is bounding for the other close clearances within the pump. This calculated wear is within design tolerances for the pump and will not affect pump mechanical dynamic performance or the outboard mechanical seal pressure. Therefore, the dynamic performance of the HHSI pumps is acceptable for the entire 30-day mission time following a LOCA considering debris-laden recirculation fluid.

Heat Exchangers

Tube leakage or failure could occur due to excessive wall thinning as a result of wear in heat exchangers. The heat exchangers in the recirculation flowpath have been evaluated for wear effects due to debris-laden fluid flow. The evaluation concluded that the actual wall thickness of the heat exchangers' tubes minus the tube wall thickness lost due to erosion during a 30 day period is greater than the minimum wall thickness required to withstand both the internal tube design pressure and the external shell design pressure. Therefore, the heat exchanger tubes have sufficient wall thickness to withstand the erosive effect of the debris-laden water for a period of 30 days post-LOCA.

In addition, tube blockage will not occur since the internal tube diameter is greater than the maximum debris size and the flow velocity is greater than the settling velocity.

Other Components

Manually throttled valves, spring-loaded check valves, orifices, cavitating venturis, and RS nozzles in the recirculation flow path were evaluated for the effects of wear due to the debris-laden fluid flow. These components were evaluated individually and were found to meet the criteria set forth in WCAP-16406-P, Rev. 1. A system evaluation was also performed to determine the cumulative effect of wear on system flowrates and the hydraulic performance requirements were determined to be met.

Relief valves in the recirculation flowpath have been evaluated for the ability to reseat in the event of opening considering the debris-laden fluid. None of these relief valves have the potential to lift during the recirculation phase; therefore, the potential for debris blockage in the open position does not exist.

Piston check valves were evaluated for the potential to malfunction due to debris, and it was determined that failure of the piston check valves to close would have no effect on system functions required for the recirculation phase.

Motor operated valves used for flow control in the recirculation flowpath were evaluated for the effects of wear due to debris-laden fluid flow and determined to be acceptable since the valves are remotely positioned (throttled) based on flow indication which compensates for the minimal potential wear.

Instrumentation

Instrumentation, except for the Reactor Vessel Level Instrumentation System (RVLIS), in the recirculation flow path that is required to function after a LOCA is mounted either horizontally or vertically on top of the recirculation flowpath piping, or the associated instrument sensing lines are oriented horizontally or vertically (from above) at the pipe taps. The orientation of the instrument in the pipe will allow the debris to continue flowing beyond the instrumentation.

The RVLIS measures reactor vessel water level with a differential pressure transmitter connected through instrument tubing to the top and bottom of the reactor vessel. There is no flow through the RVLIS tubing so debris would not be drawn into the RVLIS connections. Additionally, no debris is expected to accumulate in the reactor vessel upper head near the RVLIS connection. The flows in the reactor vessel lower plenum during recirculation would be minimal, so debris is expected to collect around the instrument nozzle penetrations, one of which is used for the RVLIS connection. However, since the instrument nozzle extends above the inside surface of the reactor vessel lower head and there is no flow through the RVLIS sensing tubing, debris would not collect near the tubing open end in sufficient quantity to prevent the RVLIS from sensing lower head pressure produced by vessel water level changes. The debris collecting in the lower plenum would not affect RVLIS water level measurements.

Therefore, instrumentation will not be adversely affected by debris in the recirculation flowpath.

3.n Downstream Effects – Fuel and Vessel

This information supplements the Downstream Effects – Fuel and Vessel information included in the supplemental response to GL 2004-02 dated February 29, 2008.

Dominion completed a LOCA Deposition Analysis Model (LOCADM) to quantify the maximum expected deposition of chemical precipitates on the Surry Unit 1 and 2 fuel and the resultant maximum clad temperature. The results show that the maximum clad temperature is approximately 404°F at the start of recirculation. The maximum temperature is well below the acceptance criterion limit of 800°F. The scale buildup starts at recirculation and reaches a maximum of 922 microns (36.2 mils) at the end of 30 days. This value takes into account the potential for strainer bypass and includes a factor of 2 times the expected aluminum release and is well below the acceptance criterion of 1270 microns (50 mils). The results are essentially the same as shown in Figure 5-3 of WCAP-16793-NP, Rev. 0. Thus, the conclusions of the WCAP for the fuel and vessel analysis are applicable to Surry Units 1 and 2 and demonstrate acceptable long-term core cooling in the presence of core deposits.

Although this analysis to date has incorporated conditions and limitations imposed on use of WCAP-16793-NP, Rev. 0, the initial NRC comments provided for this technical report have been withdrawn and the WCAP is currently in revision. The source of the revision is understood to be related to the fuel blockage analysis, not the fuel deposit methodology. Upon issuance of revised guidance, and the anticipated Regulatory Issue Summary to inform the industry of the NRC staff's expectations and plans regarding resolution of this remaining aspect of GSI-191, Dominion assumes that the existing analysis for Surry Units 1 and 2 will remain bounding of plant conditions and limitations on LOCADM use in a final SER for WCAP-16793-NP. This assumption will be confirmed through review of the revised WCAP-16793-NP and associated final NRC SER. The results of this review will be reported within 90 days following issuance of the final documents.

3.o Chemical Effects

This information supplements the Chemical Effects information included in the supplemental response to GL 2004-02 dated February 29, 2008.

Overview

Dominion contracted AECL to perform chemical effects head loss testing and evaluation for Surry Units 1 and 2. The methodology for chemical effects testing and evaluation used observations of the Integrated Chemical Effects Tests (ICET), the Westinghouse Owners Group document WCAP-16530-NP, Rev. 0, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," and various NRC-sponsored research presented at public meetings or posted on the NRC website. Chemical effects bench-top tests were performed and conservatively assessed the solubilities and behaviors of precipitates and the applicability of industry data on the dissolution and precipitation tests to station-specific conditions and materials. Reduced-scale testing was performed to establish the influence of chemical products on head loss across the strainer surfaces by simulating the plant-specific chemical environment present in the water of the containment sump after a LOCA. Reduced-scale testing was conducted for greater than 30 days after the formation of a debris bed and initial chemical addition at a specified temperature and flow rate to assess the possibility of precipitate formation and any subsequent change in strainer head loss. These tests verified that adequate NPSH is available to support the operation of the LHSI and RS pumps during the post-LOCA recirculation mode.

Potential for Sufficient "Clean" Strainer Surface Area

Surry Units 1 and 2 chemical effects head loss testing was conducted at the AECL Chalk River Laboratories. It is expected that, due to debris settling and very low pool velocities, much of the debris generated following a large break LOCA will not reach the strainer. For a small break LOCA, even less debris would be expected to reach the strainer. In addition, the strainer construction at Surry Units 1 and 2 spans a significant arc of the containment basement annulus and debris from any particular break will likely be drawn to a localized portion of the strainer rather than tend to cover the entire strainer surface. Despite these factors that encourage the existence of open strainer surface area, no credit is taken for open strainer surface area in the evaluation of head loss due to chemical effects.

Debris-bed Formation

The worst-case strainer head loss is obtained for Surry Units 1 and 2 with a thin-bed of fibrous and particulate debris. Extensive testing without chemical precipitants has determined that the thin-bed fiber thickness is nominally 1/4 inch. Since the fibrous and particulate debris constituent mixtures for Surry Units 1 and 2 are essentially the same for any of the limiting break locations, the break that produces the maximum particulate load produces the worst-case head loss when an approximately 1/4 inch thick fibrous bed is deliberately formed following the addition of particulate. The same break that produces the worst-case head loss in the absence of chemical effects is expected to produce the worst-case head loss with chemical precipitants added to the debris-bed. Debris-bed formation for the chemical effects testing followed the same procedure that was used for previous head loss testing to ensure the worst-case debris-bed was formed (i.e., head loss was highest). All of the particulate was added to the test loop, which contained borated water with sodium hydroxide (NaOH) at pH 7 to simulate the post-LOCA sump water. Once the particulate was well distributed throughout the test loop water, fibrous debris was added. Fibrous debris was prepared consistent with previous head loss tests to ensure individual fiber separation and maximum head loss. Fibrous debris was added in four increments, each of which had enough fiber to form a 1/16 inch thick fiber bed (except 1/32 inch for the last addition for the RS strainers, which was all of the remaining debris load), spaced to allow sufficient time for the debris to pack onto the strainer and begin collecting particulate debris. No sodium aluminate additions to the debris bed were made until after the head loss had stabilized.

Plant Specific Materials and Buffers

The sump pH buffer used at Surry Units 1 and 2 is sodium hydroxide solution that is sprayed in along with RWST water during containment spray pump operation.

As described later under the AECL Method section, potential reactive materials in containment have been evaluated and aluminum was determined to be the chemical effects contributor of concern for the Surry Units 1 and 2 sump strainer evaluation. The total quantity of aluminum in containment has been determined and categorized as either submerged, unsubmerged-sprayed, unsubmerged-unsprayed, or encapsulated based on its exposure to sump or spray water. Except for encapsulated aluminum, which does not contribute to the aluminum in post-LOCA sump water, each category of aluminum was evaluated for its contribution to aluminum in solution. Surry Unit 2 aluminum quantities, which were determined to be bounding for both units, are as follows:

Exposure Category	Surface Area (ft^2)	Mass (lbm)
Submerged	53.6	146.3
Unsubmerged – Sprayed	826.7	1826.8
Unsubmerged – Unsprayed	204.6	620.2

Containment sump water and spray temperature and pH have been evaluated at various time periods following the LOCA. The worst case or bounding values of pH and temperature were used in the analysis of aluminum corrosion (high pH, high temperature) and precipitation (low pH). Containment sprays are assumed to continue for the entire 30 days following a LOCA.

Approach to Determine Chemical Source Term

Chemical effects testing and evaluation were performed for Surry Units 1 and 2 by AECL and consisted of a chemical effects assessment, bench-top testing and reduced-scale tests.

Separate Effects

A plant-specific chemical effects assessment was performed using the AECL method, which includes single-effects bench-top testing.

AECL Method

The AECL method for assessment of chemical effects on strainer head loss was audited by the NRC (Reference North Anna Power Station Audit Report dated February 10, 2009, ADAMS ML090410626). The NRC staff visited Dominion's Innsbrook facility from November 12-14, 2008, to perform a chemical effects audit for North Anna Power Station Units 1 and 2. Prior to the on-site portion of the audit, the staff reviewed relevant documents related to chemical effects bench-top testing and integrated head loss test results for North Anna. The NRC staff also visited AECL's Chalk River Facility on May 5-9, 2008, to observe integrated chemical effects head loss testing for the Dominion plants. The NRC staff reviewed the overall chemical effects approach, including the AECL test facilities, North Anna safety systems drawing from the sump, observed systematic non-chemical head loss differences, chemical effects head loss test results, and analytical conservatisms. The audit report includes detailed descriptions and evaluations of the head loss testing facilities. The report also documents a detailed review of head loss testing results and a review of the significant conservatisms incorporated into the sump strainer performance analysis and an assessment of the post-LOCA NPSH margins. The NRC staff concluded that the chemical effects audit of North Anna is complete with no open items or requests for additional information.

The AECL testing methods described herein are identical to the North Anna testing methods. Identical test facilities were used for both plants' sump strainer testing (in fact, tests were performed concurrently for both North Anna and Surry strainers). Additionally, Surry safety systems taking suction from the containment sump are similar to North Anna systems in both function and performance. The testing results and significance of conservatisms are similar as well, such that the conclusions drawn from the North Anna chemical effects testing and analysis are equally applicable to Surry chemical effects testing and analysis.

The AECL methodology for the determination of chemical effects on sump strainer performance consisted of three elements:

1. An assessment of potential precipitates, including determination of reactive material amounts present in the containment sump pool, pH and temperature profiles in containment, and a review of existing test and scientific literature data.

2. Bench-top testing to demonstrate that the solubility behavior of potential precipitates determined from literature is reproducible under plant conditions and to confirm that precipitates can be produced, if required, for reduced-scale testing.

3. Reduced-scale testing to determine the influence of chemical products present in the containment sump pool on the head loss across the ECCS strainer.

Assessment of Potential Precipitates

AECL reviewed the published results of the ICET, the Westinghouse Owners Group document WCAP-16530-NP, and various NRC sponsored research presented at public meetings or posted on the NRC website. In addition, AECL representatives attended most of the NRC public meetings on chemical effects in 2006 and 2007 and reviewed all of the relevant presentations from these meetings. The following conclusions were drawn from the data reviewed:

1. The ICET tests clearly show that, at the pH values studied, aluminum corrosion can give rise to the formation of an aluminum-bearing precipitate. However, the tests also show that:

a) Aluminum corrosion may be inhibited by species present in the sump environment (e.g., phosphates, silicates).
b) The precipitate formed included boron. The presence of boron can affect the mass or flocculation properties of the aluminum-bearing precipitate formed.

2. For the surface areas of materials used in these tests, only low concentrations of iron, nickel, magnesium and zinc dissolved into the simulated sump water, and these species did not lead to the formation of significant amounts of precipitates.
3. Significant concentrations of silicon and calcium from dissolution of fiberglass and Cal-Sil can be present in the sump solutions. If trisodium phosphate (TSP) is present, precipitates containing calcium and phosphate, or calcium, phosphate and carbonate, can form. In the absence of TSP, the calcium and silicon do not lead to the formation of significant chemical precipitates.
4. Concrete does not appear to be a significant source of calcium in solution.
5. Thermodynamic modeling alone cannot properly predict the identity or quantities of precipitates formed under PWR sump conditions; kinetic factors are very important.
6. There is no evidence of direct chemical effects from paint debris.
7. While WCAP-16530-NP suggests that sodium aluminum silicate is a possible precipitate, a review of the literature on the thermodynamics and kinetics of aluminosilicate formation suggests that this is unlikely under PWR post-LOCA sump water conditions.

Based on these conclusions, it was further concluded that in PWR post-LOCA containment sump water, only two precipitates would be of concern: aluminum hydroxide or oxyhydroxide, and calcium phosphate (likely hydroxyapatite). Since Surry Units 1 and 2 do not use TSP as a pH buffer for the sump water, only the formation of aluminum hydroxide was further evaluated. This evaluation was based on the available experimental data including ICET tests, WCAP-16530-NP, and data from the reviewed literature.

The AECL study used the basic methodology outlined in WCAP-16530-NP to calculate the mass of aluminum released. However, rather than use the WCAP-16530-NP release equation, the data from WCAP-16530-NP and other sources were used by AECL to develop a semi-empirical release equation. To model the aluminum release rate, the pH and temperature dependencies of the corrosion rates were evaluated separately. This allowed better comparison with existing literature data on aluminum corrosion. AECL determined aluminum corrosion rate expressions based on pH and on temperature from review of literature data. The time dependence of the corrosion rate was also evaluated but no term for the time dependence was included in the final release model. Neglecting time dependence was considered to be a conservatism.

Containment aluminum inventories can be divided into exposure categories of submerged, unsubmerged-sprayed, unsubmerged-unsprayed, or encapsulated based on its exposure to sump or spray water. Except for encapsulated aluminum, which does not contribute to the aluminum in post-LOCA sump water, each category of aluminum was evaluated for its contribution to aluminum in solution. Each category has a temperature evolution profile and a worst-case scenario pH. In addition, unsprayed aluminum has a limited time period during which transport of aluminum corrosion products to the sump can occur, which limits its contribution to the sump aluminum concentration.

The aluminum released to the containment sump was calculated based on the aluminum surface areas and sump and spray water pH based on the correlation:

$$\text{ALUMINUM RELEASE OVER INTERVAL} = \text{CORROSION RATE} \times \text{INTERVAL LENGTH} \times \text{ALUMINUM SURFACE AREA}$$

where CORROSION RATE (i.e., aluminum release rate) is dependent upon pH and temperature and is determined from the following equation developed by AECL:

Release Rate (mg/m^2-s) = $55.2 \bullet \exp(1.3947 \bullet \text{pH} - 6301.1 \bullet T^{-1})$,

where T is in degrees Kelvin. The results of the application of the AECL release rate model was compared to the WCAP-16530-NP model results using Surry aluminum inventories and were found to predict a greater 30-day release of aluminum.

For unsubmerged-unsprayed aluminum, a detailed heat transfer and condensation evaluation was performed to determine the time required to equalize the temperature between the aluminum surface and the containment environment. When the temperature is equalized, no further condensation will take place resulting in no further contribution of aluminum to the sump water.

The following conservatisms were included in the calculation of aluminum release in support of chemical effects testing:

1. The maximum expected temperatures of the sump and spray water were used during the corrosion calculations for each time interval.
2. The maximum expected pH values were used during the corrosion calculations for each time interval.
3. No credit was taken for the possible inhibitory effect of silicate or other species on aluminum corrosion.

4. No credit was taken for the presence of any oxide films formed on the aluminum surfaces prior to the LOCA.
5. All the aluminum released by corrosion enters the solution, i.e., no aluminum oxides remain on the aluminum surfaces.
6. No credit was taken for the effect of the presence of oxygen in the sump water. Literature data suggest the corrosion rate of aluminum in aerated pH 10 alkaline water is a factor of two lower than that measured in nitrogen-deaerated water.
7. No credit was taken for the decrease in corrosion rate as a factor of exposure time that results from the development of a passive film.

Based on these conservatisms, it is believed that the aluminum release into the sump water is significantly overestimated.

The total aluminum mass released to the sump water was calculated using the aluminum release rate equation above along with the Surry-specific aluminum inventory based on exposure category, sump and spray water pH, and sump and spray water temperatures for specific time intervals following a LOCA. Data from the Surry LOCA analysis were evaluated to determine the maximum containment sump and spray water pH as input to the chemical effects evaluation. The sump and spray water pH values for corresponding time intervals following a LOCA are provided in Table 3.o-1.

Table 3.o-1: Summary of Post-LOCA Sump and Spray Water pH

Time Interval after LOCA (sec.)	Maximum Sump pH	Maximum Spray pH
0 – 4 hours	8.4	10.3
4 hours – 30 days	8.4	8.4

The calculation of sump aluminum mass conservatively assumed a long-term sump and spray pH of 9.0 and a short-term spray pH of 10.5 for the first 4 hours following a LOCA, along with the containment sump and water vapor (spray) temperatures tabulated in Table 3.o-2.

Table 3.o-2: Containment Sump and Water Vapor Temperature

Time Interval after LOCA (sec.)	Maximum Vapor Temperature (°F)	Maximum Sump Temperature (°F)
0-120	275	250
120-600	275	250
600-1,200	260	250
1,200-1,800	257	250
1,800-2,400	230	225
2,400-3,000	223	202
3,000-3,600	213	182
3,600-4,200	187	172
4,200-4,800	160	170
4,800-5,400	150	170
5,400-7,200	150	170
7,200-14,400	150	165
14,400-28,800	140	155
28,800-57,600	140	145
57,600-86,400	140	135
86,400-172,800	140	130
172,800-259,200	140	125
259,200-345,600	110	122
345,600-30 days	110	120

The precipitation behavior of aluminum hydroxide under representative Surry Units 1 and 2 post-LOCA sump water conditions was further evaluated in bench-top testing.

Bench-Top Testing

Bench-top testing was conducted to gain an understanding of the chemistry to be expected in reduced-scale testing. The bench-top testing consisted of the following tasks:

- Precipitation Testing of Aluminum Hydroxide
- Dependence of Walnut Shell Properties on Chemistry

Precipitation Testing of Aluminum Hydroxide

AECL conducted bench-top tests to determine aluminum solubility under the worst-case conditions expected in the post-LOCA sump water. Two series of tests were conducted: station-specific precipitation tests and aluminum solution stability tests. In the station-specific precipitation tests, the sump water chemistry conditions that are expected to exist after 30 days were used for determination of aluminum precipitation. These chemistry conditions are considered the most conservative since after 30 days, the temperature of the sump water has decreased to a stable, low value, and the dissolved aluminum concentration has reached its maximum value. For additional conservatism, a pH of 7.0 was maintained since this is the lowest expected sump pH based on accident analysis. The concentration of aluminum used for the bench-top testing was 37 mg/L, which was based on preliminary determinations of the aluminum inventory in containment and the post-LOCA containment sump water pH and temperature. The use of this high aluminum concentration provided conservative bench-top test results. In the aluminum solution stability tests, it was sought to determine pH values at which 2.5 to 100 mg/L aluminum solutions remained kinetically stable for 30 days.

The station-specific bench-top tests for aluminum precipitation were conducted in three flasks identified as Warm, RT (room temperature), and BL (blank). The flasks were maintained at 140°F and two (Warm and RT) included insulation debris. All three of the flasks contained borated water to which sodium aluminate was added. The solutions were stirred slowly with a magnetic stirrer and once the pH was adjusted to the target value, the solutions were allowed to stand for 30 days. The pH was nearly constant throughout the 30 days. Turbidity measurements were taken for the Warm and RT flasks daily (at test temperature for the Warm flask samples and at room temperature for the RT flask samples). The mass of any precipitate formed after 30 days was determined by filtering the BL solution through a 0.1-µm pore size filter, drying the filter, and then weighing the dried filter; however, very little precipitate formed in any of the tests. Samples of the BL filtrate were taken for elemental analysis using Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES).

A measurable mass of precipitate was recovered from the Surry bench-top test solution, indicating that precipitation is predicted at the 37 mg/L concentration of aluminum used in the bench-top tests. Based on correlation with a North Anna test solution precipitate analysis, the precipitate was determined to consist of mainly Al and O indicating the formation of aluminum hydroxide or oxyhydroxide species.

The aluminum solution stability tests consisted of two parts: the first, a titration of aluminum solutions starting at high pH against nitric acid, was used to establish lower limits at which precipitation would occur; the second brought aluminum solutions down to 1 pH unit above the established lower limit and monitored the turbidity over 30 days. Tests were conducted at room temperature, 104°F, and 140°F.

The results provided a stability map of Al concentration vs. pH in which the Surry station-specific conditions were predicted to be unstable with respect to aluminum precipitation.

Dependence of Walnut Shell Properties on Chemistry

Walnut shell powder is used in the debris head loss tests to simulate epoxy coating which is conservatively anticipated to be broken into very small particulate sizes (nominally 10μm) post-LOCA. Tests were carried out as part of the bench-top testing to determine if exposure to chemicals would dissolve or alter the walnut shell particulate.

Particle size and dissolution tests carried out to characterize the effects of exposure of walnut shells to borated water containing sodium aluminate showed no obvious change on particle size distribution or particle morphology. Measurements of the total organic carbon in the test solution gave inconsistent results with respect to the amount of walnut shell dissolution, while measurements of the weight change suggested a maximum weight loss of 12%. No significant effect on the results of reduced-scale testing is expected from walnut shell dissolution or weight change.

Reduced-Scale Testing

Reduced-scale testing was conducted for Surry Units 1 and 2 to determine the debris bed head loss. Two different test rigs were used to perform the testing. Test Rig 33 was used to determine total strainer size requirements, as described in Section 3.f of the previous supplemental response (Dominion letter dated February 29, 2008), but was not used for the reduced-scale chemical effects testing. To expedite reduced-scale chemical effects testing, a multi-loop test rig, Test Rig 89, was designed and constructed to facilitate the performance of concurrent testing of multiple strainer configurations and post-accident containment sump conditions for several of Dominion's nuclear units (i.e., Surry, North Anna and Millstone).

The differences in debris-only head loss testing results for the two different test rigs were evaluated during the North Anna Chemical Effects Audit performed by NRC staff in 2008 (Reference North Anna Power Station Audit Report dated February 10, 2009, ADAMS ML090410626). The NRC staff ultimately concluded that, although the reasons for differences in head loss for the two test rigs could not be definitively identified, the significant conservatisms incorporated into the sump strainer performance analysis bound the uncertainties associated with the formation of debris beds in the multi-loop Test Rig 89. As described previously, the Surry testing methodology, test rig, and significance of conservatisms are identical to North Anna strainer testing. Therefore, the audit report conclusions also apply to Surry chemical effects head loss testing.

Test Description

Reduced-scale chemical effects testing was performed to establish the influence of chemical products on the head loss across the containment sump strainer surfaces after a LOCA. Tests were carried out for Surry Units 1 and 2 RS and LHSI strainers using the multi-loop Test Rig 89. Fibrous and particulate debris and chemicals were added into the test rig to simulate the plant-specific chemical environment present in the water of the containment sump. Each test was operated for more than 30 days, after the formation of a debris bed and initial chemical addition, at a specified temperature and flow rate to assess the possibility of precipitate formation and subsequent head loss change. The following includes descriptions of the test facility, debris load, chemical environment, and the chemical addition procedure.

Test Facility

The test facility consists of six single test loops. Each test loop has the same configuration except that the strainer box orientation and fin pitch distance may be different. Each single test loop includes a 16 in. × 16 in. × 36 in. strainer box (volume approximately 40 gal) and a 12 in. diameter × 18 in. long cylindrical debris addition tank (volume approximately 9 gal). Two fins were installed inside each strainer box with a pre-determined pitch distance. The fins have perforated material on the sides facing each other, while the sides facing away from the other fin have cover plates to cover the fin holes. For Surry testing, the fins and strainer boxes were horizontally oriented to simulate the installed RS and LHSI strainer module orientation. The topside and underside of the strainer box have clear windows to enable observation of any precipitates and the debris bed on the strainer screens inside the box. Stainless steel tubes and fittings are utilized to connect the strainer box to other components of the loop. The loop is capable of producing flow rates from 1 to 20 gpm. The flow rates can be adjusted via a variable frequency drive. A magnetic flow meter is installed to provide feedback for constant flow rate control. Each loop is equipped with a 6kW in-line stainless steel heater to provide heating to a maximum temperature of 140°F (60°C). Cooling is provided by an in-line stainless steel cooler using service water. Figure 3.o-1 provides a representation of a single loop of the Test Rig 89 multi-loop test facility.

Physical debris including fiber and particulate, and chemicals including liquid solutions, can be added through the debris addition tank. The debris addition tank is equipped with a paddle-type stirrer to keep the debris suspended, and mixed debris can be slowly metered out of the tank. Each test loop is connected to a header tank located at an elevation of 15 feet above floor level. The header tank can be used to accommodate extra fluid from debris addition or thermal expansion and to control the loop pressure. Chemical solutions can also be added in small quantities via the chemical injection points.

Each loop is instrumented with a thermocouple to measure the water temperature and a flow meter to measure the flow rate through the test loop. The strainer box is instrumented with a differential pressure transmitter for measuring the debris bed head loss. Two manual pressure gauges are also connected upstream and downstream of the test screen to allow for verification of the pressure and to provide back-up measurements in case the differential pressure transmitter should fail. The pump speed, heater and cooler are controlled by a programmable logic controller (PLC). The water temperature and flow rate and the debris bed head loss are monitored and recorded by the PLC. Monitoring of pH, turbidity, and concentrations of elements in solution is via grab samples.

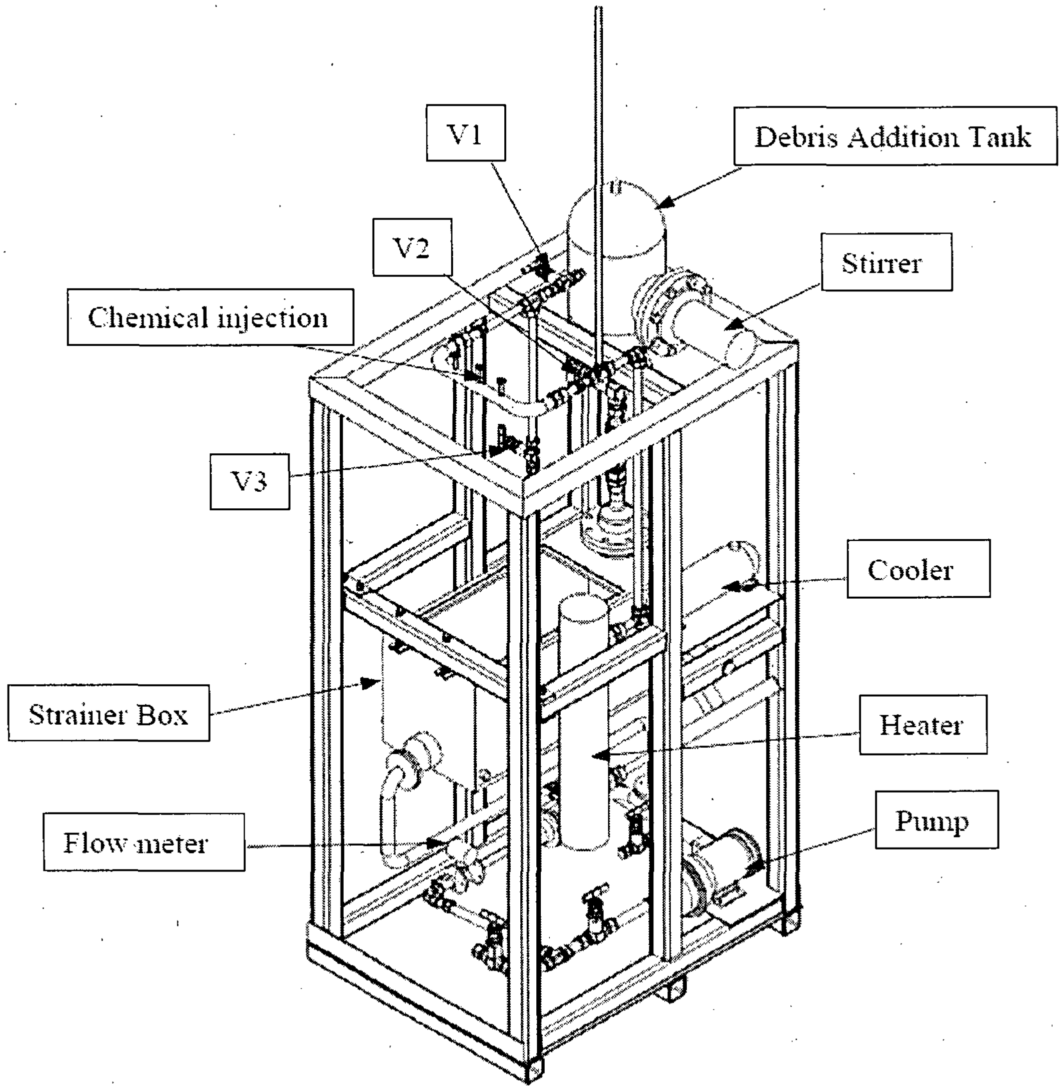


Figure 3.o-1: Test Rig 89 Single Test Loop (One of Six)

Debris Load

Debris composition for the reduced-scaled chemical effects testing for the Surry Units 1 and 2 sump strainer was the same as was used for the strainer head-loss testing as described in the previous supplemental response (Dominion letter dated February 29, 2008) for "Break S1" (the limiting debris source). Test debris quantities were directly scaled from the total debris by the ratio of the total modeled strainer area to the test section area, termed the "debris-scaling factor." The Rig 89 RS strainer test module area is 5.74 ft^2 while the total modeled area was 6000 ft^2. Therefore, the RS strainer debris-scaling factor is 1045.3. The LHSI strainer debris-scaling factor is 357.1 since the LHSI strainer test module area is 5.74 ft^2 and the modeled surface area is 2050 ft^2.

The full particulate debris load for each test was added at the start of the test, and then additions of fibrous debris were made in 1/16 in. theoretical bed thickness increments. The theoretical bed thickness is defined as the uncompressed fiber volume divided by the test module surface area. The first fiber addition (1/16 in.) was made 30 minutes after the addition of the particulate debris. The second fiber addition (an additional 1/16 in.) was made 30 minutes after the first addition. Subsequent fiber additions were only made once the pressure increase resulting from previous additions had stabilized (changed by less than 5% or 0.01 psi, whichever was greater, and exhibited no general steadily increasing trend in pressure, within 25 minutes (approximately five tank turnovers)). Fiber additions were continued until the debris bed thickness had reached the thin bed thickness as determined by previous thin bed tests (1/4 inch for the LHSI strainer, and 7/32 inch for the RS strainer since the scaled debris-load for Surry is not sufficient to form a 1/4 inch thin-bed).

Chemical Environment

Surry-specific post-LOCA sump water chemical conditions at the end of the 30-day mission time for ECCS were simulated in the reduced-scale tests. The water was maintained at the conservatively low minimum pH limit of 7.0 to enhance precipitate formation. Sodium aluminate ($NaAlO_2$) was added to the test solution, after the particulate addition and debris bed formation, to produce the desired concentration of aluminum in solution. The test fluid also included boric acid and sodium hydroxide concentrations that were equivalent to the expected post-LOCA sump water conditions.

Chemical Addition Procedure

After the debris bed was formed and the pressure drop had stabilized, sodium aluminate solutions were added into the loop through the chemical injection points. Over the course of the test, 17 sodium aluminate additions were made to the LHSI strainer test loop, for a total 56.75 g $NaAlO_2$, and 11 sodium aluminate additions were made to the RS strainer test loop, for a total of 36.09 g $NaAlO_2$.

<u>Precipitate Generation</u>

Chemical additions for the chemical effects testing were accomplished by addition of sodium aluminate solutions into the test loop through chemical injection points in the test rig. Aluminum precipitates were generated in-situ, mainly on the fibers and particles, by a heterogeneous precipitation mechanism.

Chemical Injection into the Loop

Two methods of sodium aluminate addition were employed through the course of the testing. Each method was successively developed in an attempt to approximate more closely the aluminum release rate into solution in the post-LOCA containment sump.

Method A. The first method used an injector to inject 3.6 L (or less) of 200 mg/L Al solutions over 20-30 minutes, repeated every hour as necessary. The sodium aluminate was added every 3 days to approximate the predicted aluminum release rate into solution. Solutions of sodium aluminate were made with borated loop water (water obtained from the test rig) adjusted to pH 12 to facilitate dissolution of sodium aluminate. The advantages of this addition method were that the test rig water volume was kept constant, and there were no dilution effects on other chemicals. The disadvantage was that, since sodium hydroxide was added to the loop water, it was necessary to add nitric acid to adjust the loop pH back to 7.0. It was found that the follow-up nitric acid addition caused precipitate to form in localized low pH environments around the addition point.

Method B. The second method also used an injector, as described above. In this method, deionized water was used to dissolve the sodium aluminate. To compensate for the dilution of the test loop solution caused by the addition of the deionized water, boric acid dissolved in loop water was added to the loop in a separate step. The combined effect of (basic) sodium aluminate additions and (acidic) boric acid additions was that the loop pH remained stable, and nitric acid additions were no longer required.

The amount of injected aluminum at the end of the test was 65.0 mg/L of which 2.2 mg/L remained in solution for the LHSI strainer test, and 41.3 mg/L of which 3.7 mg/L remained in solution for the RS strainer test.

Technical Approach to Debris Transport

Surry plant-specific analysis determined the amount and type of debris that could be generated and transported to the sump strainer post-LOCA. Essentially all debris (or applicable surrogate) that is analyzed to reach the containment sump strainer was included in the reduced-scale testing. RMI debris was not included in the chemical effects test, as RMI does not affect debris bed formation or the resultant head loss when present in the relatively small quantities existing in Surry Units 1 and 2.

Head-Loss Testing Without Near-Field Settlement

No specific credit was taken for near-field debris settlement in the strainer head loss analysis for chemical effects.

Debris was added during the tests by mixing in the debris addition tank and then slowly metering into the strainer test box. A mixer was used in the debris addition tank to prevent debris settling on the floor of the tank. A magnetic brush was used intermittently to sweep the strainer box floor in an attempt to keep fibrous debris from settling. At the end of the tests, the amount of debris attached to the strainer module fins was measured, with the following results:

RS Strainer Test:	69%
LHSI Strainer Test:	55%

The lower fraction of fibrous debris attached to the fins is attributed to the large fraction of Temp Mat insulation debris due to its high density. Temp Mat was difficult to re-suspend during strainer box floor sweeps. The lower fraction of fibrous debris attached to the fins is not considered significant to the chemical effects testing results because, as was determined in debris head-loss testing previously, more or less debris settled on the floor of the test rig had no significant influence on the total debris bed head loss.

Test Termination Criteria

The termination criteria used for the tests are described below.

1. Little or no precipitate forms in 30 days; aluminum concentrations in solution remain at the specified value (10.3 mg/L).

2. Precipitate forms and the head loss exceeds the allowable debris bed head loss or the available test rig NPSH margin.

3. Precipitate forms but criterion 2 is not met. Aluminum will be added to the test loop to maintain the specified concentration until the maximum mass of aluminum, scaled to the aluminum release mass based on containment aluminum inventory, is added.

Data Analysis

Test Procedure Summary

Each test loop of the reduced-scale multi-loop test rig had a volume of 200 L, and each head tank had a volume of about 30 L. Each test strainer module had a surface area of 5.74 ft^2. To begin each test, the chemical environment was established by filling each loop with a pH 7 boric acid solution (2800 mg/L B). Test solution temperature was maintained at 104°F for the tests, and, for comparison, allowable debris bed head losses were corrected for temperature using the dynamic viscosity ratio. Particulate debris was added followed by fibrous debris that established a debris thin bed. Once the head loss had stabilized, chemical additions began.

Throughout the tests, daily water samples were taken for ICP-AES analysis to determine the concentrations of Al, B, Ca, Fe, K, Na, P, and Si. Sample analysis results consistently showed much lower concentration of aluminum in the test solution than was calculated based on sodium aluminate additions, indicating that the aluminum had either precipitated or deposited (plated out) on surfaces such as the debris bed.

Aluminum additions were made to the test loops in an attempt to reach a test strainer aluminum load equivalent to the containment strainer aluminum load resulting from a 10.3 mg/L Al concentration in the containment sump. The strainer aluminum load was determined by calculating the total expected aluminum mass in the proportioned sump volume for the individual strainer (either LHSI or RS strainer) and dividing by the individual strainer surface area. The proportioned sump volume is the total sump volume proportioned by the individual strainer flowrate relative to the total strainer flowrate.

After chemical additions were completed, the test temperature was reduced to 70°F to evaluate the effect of temperature on head loss. A flow sweep was performed by reducing flow to 90%, then 80%, then back to 100% to evaluate the response of head loss to flow velocity changes.

Test Results

In the Surry LHSI test (identified as test SPS-LHSI-C1), there were 17 additions of aluminum over the duration of the test (in the form of sodium aluminate solutions) resulting in reaching a 2.53 g/ft^2 strainer aluminum load. The resulting head loss was 0.50 psi and did not exceed the short-term allowable debris bed head loss limit of 3.5 psi[1] during the course of the test.

In the Surry RS test (identified as test SPS-RS-C2), the first 9 additions of aluminum, resulting in a 1.05 g/ft^2 strainer aluminum load, produced a peak head loss of 1.44 psi, which exceeded the allowable debris bed head loss limit of 1.4 psi[1]. Data analysis determined that the 8th Al addition resulted in 0.85 g/ft^2 strainer aluminum load and produced an acceptable head loss of 1.17 psi. The

[1] The head loss limits determined previously for debris bed head loss testing (see the previous supplemental response in Dominion letter dated February 29, 2008) were established as the test criteria for the LHSI and RS strainer chemical effects testing. Subsequently, final head loss criteria were developed and are compared to debris bed test results in Section 3.f, Table 3.f-2 of this attachment.

test rig flowrate was based on RS strainer flowrate with all four RS pumps in operation. This strainer flowrate is only expected for a limited time following a LOCA based on emergency operating procedure requirements to reduce RS system flowrate to two-pump operation after containment conditions have stabilized below atmospheric pressure (see Section 3.f). Accordingly, the test rig flowrate was reduced to the equivalent of two-pump operation, reducing the strainer debris-bed head loss, and two more aluminum additions were made resulting in a 1.56 g/ft^2 aluminum strainer load. This aluminum load produced a peak head loss of 1.43 psi at the lower flowrate, which did not exceed the revised allowable debris bed head loss limit of 2.15 psi[2].

A summary of the test head loss results are presented in Table 3.o-3.

The pressure drop curves (head loss across the strainer section vs. time) for the LHSI and RS strainer tests are provided in Figures 3.o-2 and 3.o-3, respectively. The curves indicate debris addition, aluminum addition, temperature changes, and flowrate changes during the test and the corresponding effect on strainer head loss.

Evaluation of Results

In the Surry LHSI strainer test, the allowable debris bed head loss was not exceeded. A maximum aluminum load of 2.53 g/ft^2 was achieved after 17 aluminum additions, giving a maximum head loss of 0.50 psi, which is lower than the 3.5 psi allowable head loss.

In the Surry RS strainer test, the allowable debris bed head loss of 1.4 psi was exceeded before the target aluminum load of 1.56 g/ft^2 was attained. As described above, the test flowrate at that time was equivalent to RS strainer flowrate with four RS pumps in operation. This is considered a short-term operating condition post-LOCA since the operators would reduce to two RS pump operation after stable sub-atmospheric containment conditions were reached in accordance with emergency operating procedures, which is expected within four hours. When the test flowrate was reduced to the equivalent of two RS pump operation, an acceptable head loss was attained at the target aluminum load of 1.56 g/ft^2. Since an acceptable debris-bed head loss was obtained during the full flow test at a strainer aluminum load of 0.85 g/ft^2, the flow reduction must be shown to occur prior to reaching this strainer aluminum load. This strainer aluminum load is equivalent to 6,440 g total sump aluminum load.

Since the RS strainer flowrate is expected to be reduced within four hours after a LOCA, the amount of aluminum release to the sump expected within the first four

---

[2] This revised head loss limit was determined by reducing the strainer internal head loss contribution based on the lower two-pump operation flowrate.

hours was determined. A review of ICET test results indicated minimal transport of aluminum corrosion products from 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. The aluminum corrosion model predicts that less than 35 g of aluminum would be released from the submerged aluminum surface area of 53.6 ft^2 within the first four hours, which is significantly less than the allowable two-train sump aluminum load of 6,440 g. Therefore, based on the small sump aluminum load expected in the first four hours, it was concluded that the chemical effect on the debris-bed head loss would be insignificant such that the RS strainer head loss criterion would be met for the short-term.

Based on the reduced-scale chemical effects testing, the limiting long-term containment sump aluminum load is 13,800 g, limited by 2.53 g/ft^2 strainer aluminum load on the LHSI strainer.

Sump Chemical Load Calculation

Calculation of the sump aluminum load, based on the aluminum inventory in containment that is subject to corrosion post-LOCA, results in approximately 13,611 g expected to be released within 30 days of event initiation, conservatively assuming a maximum long-term sump pH of 9.0. The expected aluminum release post-LOCA is less than the limiting sump aluminum load of 13,800 g. Therefore, conservatively assuming all aluminum released to the containment sump water results in increased head loss across the strainer debris bed, the resulting head loss would be acceptable.

Programmatic controls have been established as part of the design control process and containment close-out verification following maintenance or refueling operations to limit the amount of aluminum bearing materials inside containment during operation such that the calculated aluminum release limit will not be exceeded.

Table 3.o-3: Summary of Test Rig 89 Chemical Effects Test Results

Rig 89 Test Loop	Test Loop Temperature (°F)	Test Loop Flowrate (gpm)	Strainer Aluminum Load (g/ft²)	Head Loss Test/Limit (psi)
LHSI Strainer Test				
SPS-LHSI-C1 (prior to Al addition)	104	9.3	0	0.11 / 3.5
SPS-LHSI-C1 (end of Al addition)	104	9.3	2.53	0.50 / 3.5
SPS-LHSI-C1 (temperature reduction)	70	9.3	2.53	0.48[a] / 3.5
SPS-LHSI-C1 (flow sweep – 90%)	70	8.37	2.53	0.35[b] / NA
SPS-LHSI-C1 (flow sweep – 80%)	70	7.44	2.53	0.28[b] / NA
SPS-LHSI-C1 (flow sweep – 100%)	70	9.3	2.53	0.42[b] / 3.5
RS Strainer Test				
SPS-RS-C2 (prior to Al addition)	104	12.1	0	0.25 / 1.4
SPS-RS-C2 (Al addition at head loss limit)	104	12.1	1.05	1.44 / 1.4
SPS-RS-C2 (flow reduction to one-train flowrate)	104	6.41	1.05	0.49 / 2.15
SPS-RS-C2 (end of Al addition)	104	6.41	1.56	1.43 / 2.15
SPS-RS-C2 (temperature reduction)	70	6.41	1.56	1.69 / 2.15
SPS-RS-C2 (flow sweep – 90%)	70	5.77	1.56	1.23[c] / NA
SPS-RS-C2 (flow sweep – 80%)	70	5.13	1.56	1.02[c] / NA
SPS-RS-C2 (flow sweep – 100%)	70	6.41	1.56	1.46[c] / 2.15

a. Head loss had stabilized at 0.46 psi before test loop temperature reduction.
b. Head loss was 0.42 psi prior to the start of the flow sweep.
c. Head loss was 1.45 psi prior to the start of the flow sweep.

Figure 3.o-2: Test SPS-LHSI-C1 Chemical Effects Test - Head Loss vs. Time

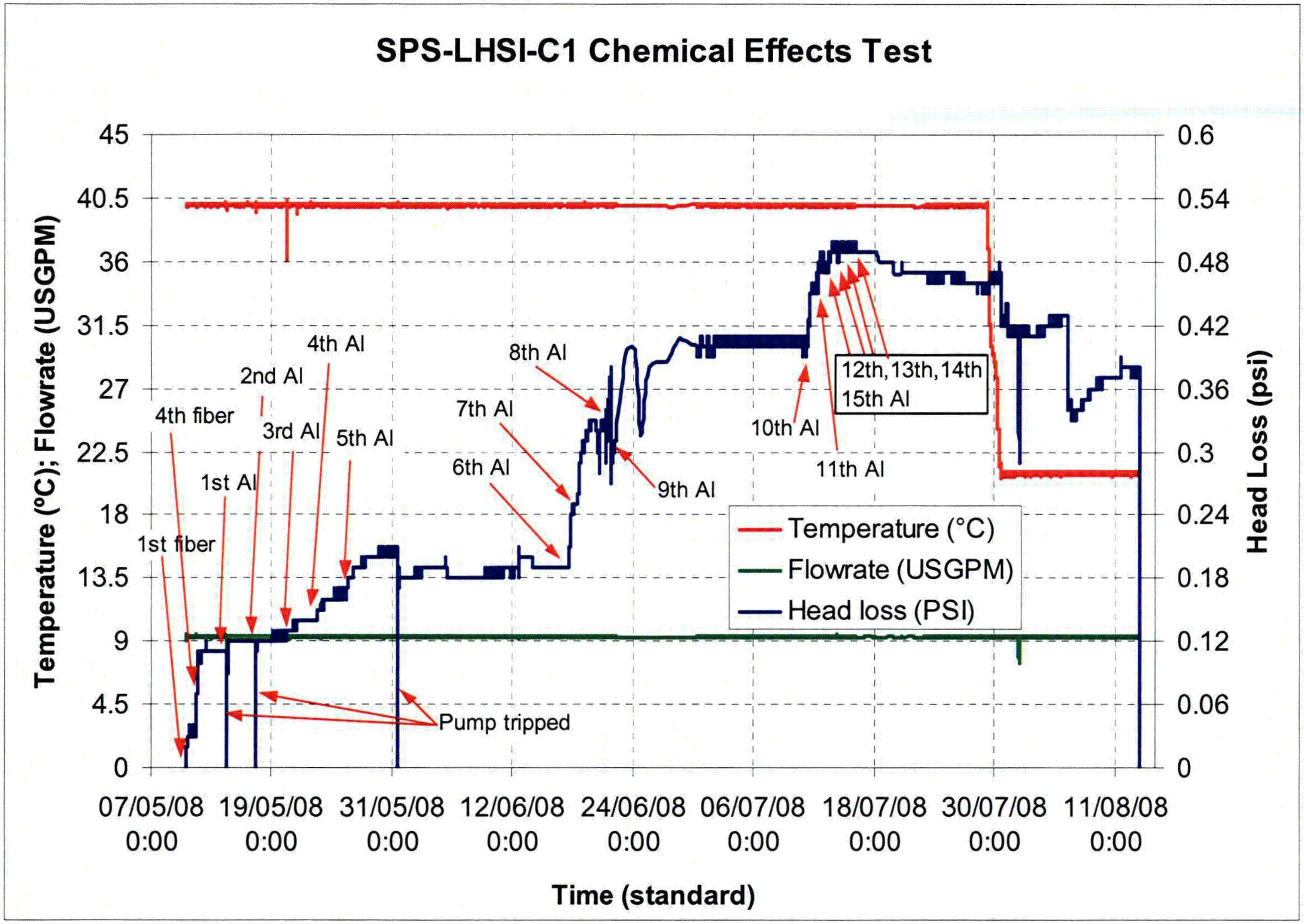
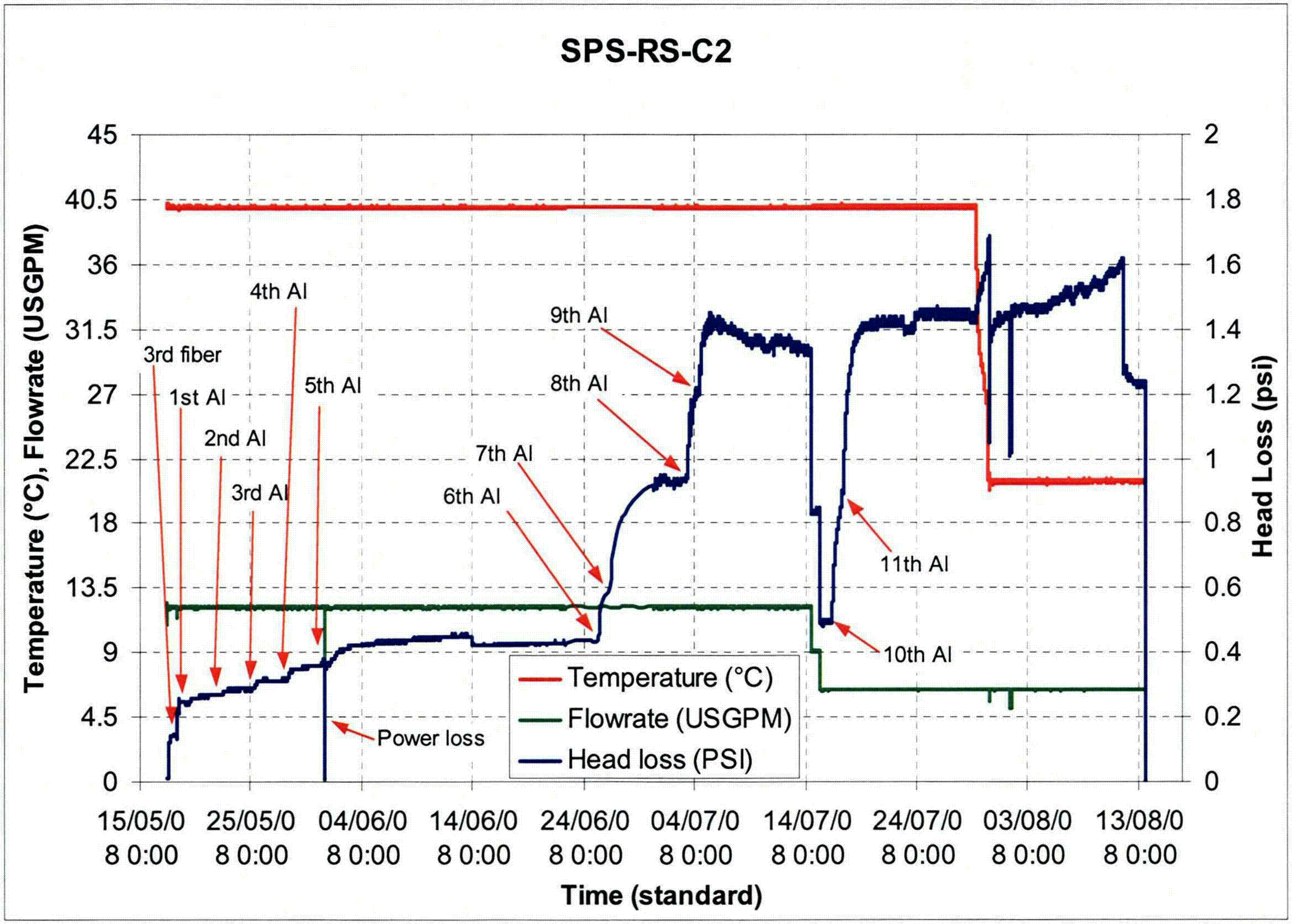


Figure 3.o-3: Test SPS-RS-C2 Chemical Effects Test - Head Loss vs. Time



3.p Licensing Basis

Dominion's February 29, 2008 supplemental response discussed the licensing bases changes that had been implemented for Surry Units 1 and 2 associated with the resolution of the sump issues considered in GSI-191 and GL 2004-02 in the form of Updated Final Safety Analysis Report (UFSAR) Revisions, analysis methodology changes and license amendment requests.

Since that time, one additional license amendment request was submitted and approved by the NRC. Specifically, License Amendment 262/262 for Surry Units 1 and 2 deleted the Containment Spray (CS) and RS subsystem minimum flow values from the Design Features section of the Surry Technical Specifications (TS). These values are not required to be contained in the TS and were revised based on the containment analysis methodology changes that were implemented to resolve GSI-191 sump performance issues. The minimum flow requirements for the CS and RS systems are contained in the UFSAR.

An additional UFSAR change was made to establish the limit for the long-term containment sump pH to 9.0 from 9.5 to be consistent with the calculation of sump aluminum load discussed in Section 3.o.