Figure 2: Strainer Head Loss and Structural Margin
Unit 1 Cold Leg Recirculation - Single Pump Operation

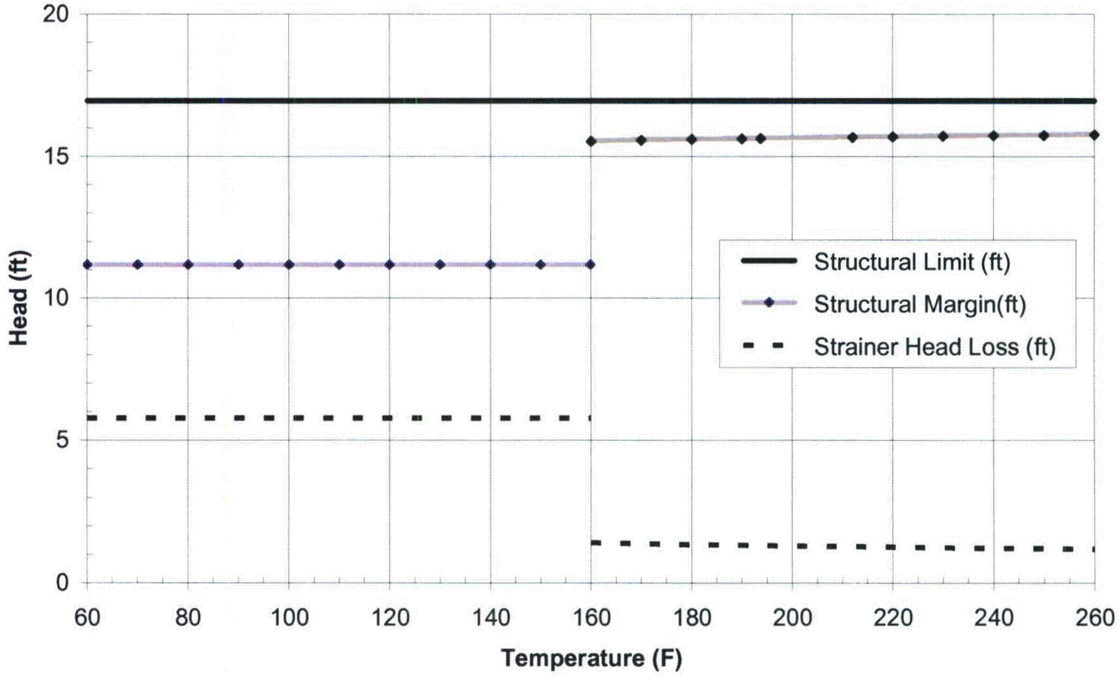


Figure 3: Limiting Margin
Unit 1 Cold Leg Recirculation - Single Pump Operation

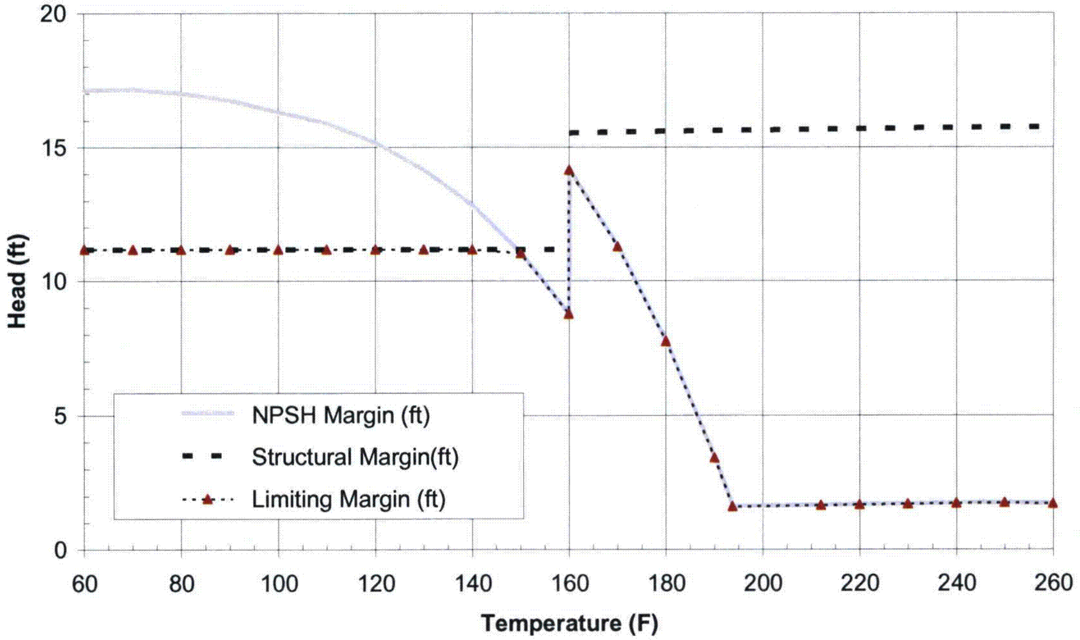


Figure 4: NPSH Available and Margin
Unit 2 Hot Leg Recirculation - Single Pump Operation

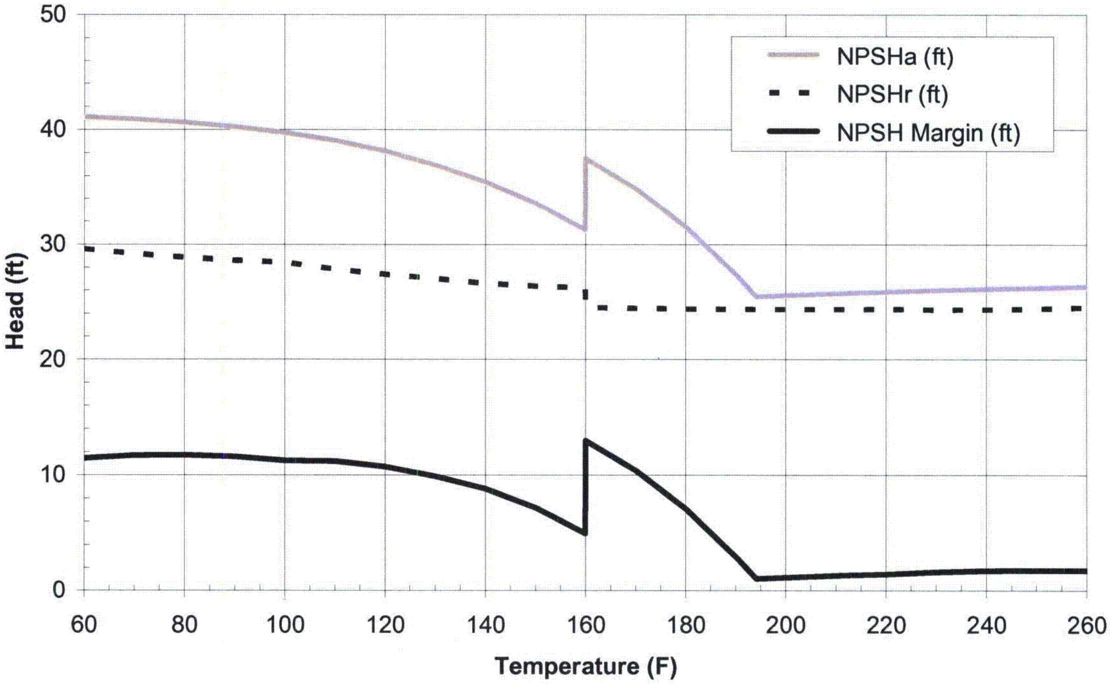


Figure 5: Strainer Head Loss and Structural Margin
Unit 2 Hot Leg Recirculation - Single Pump Operation

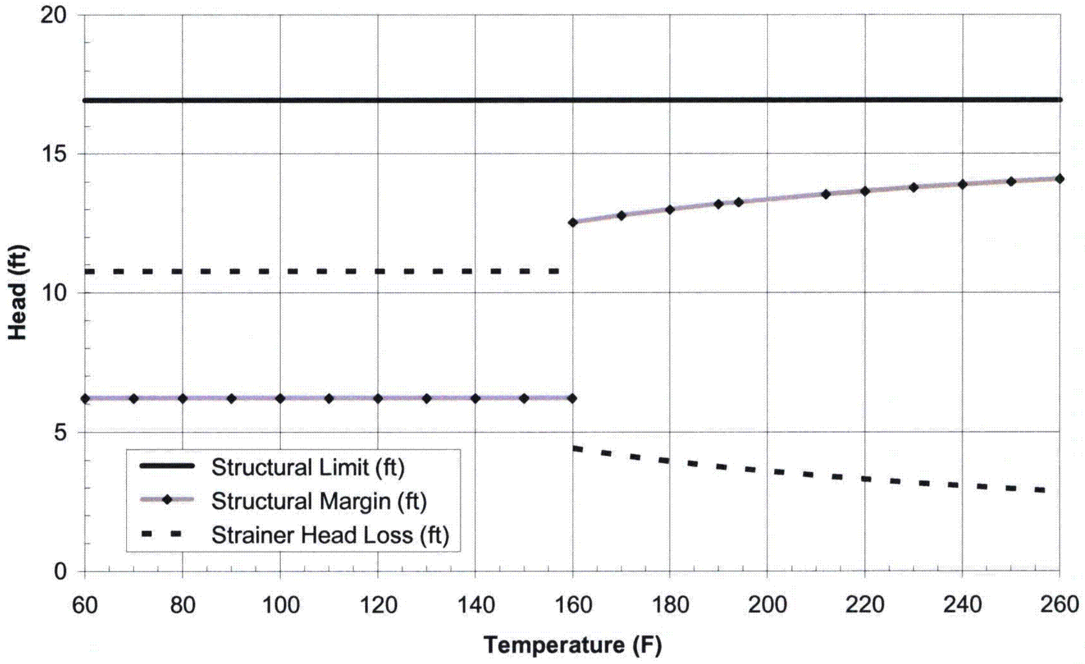


Figure 6: Limiting Margin
Unit 2 Hot Leg Recirculation - Single Pump Operation

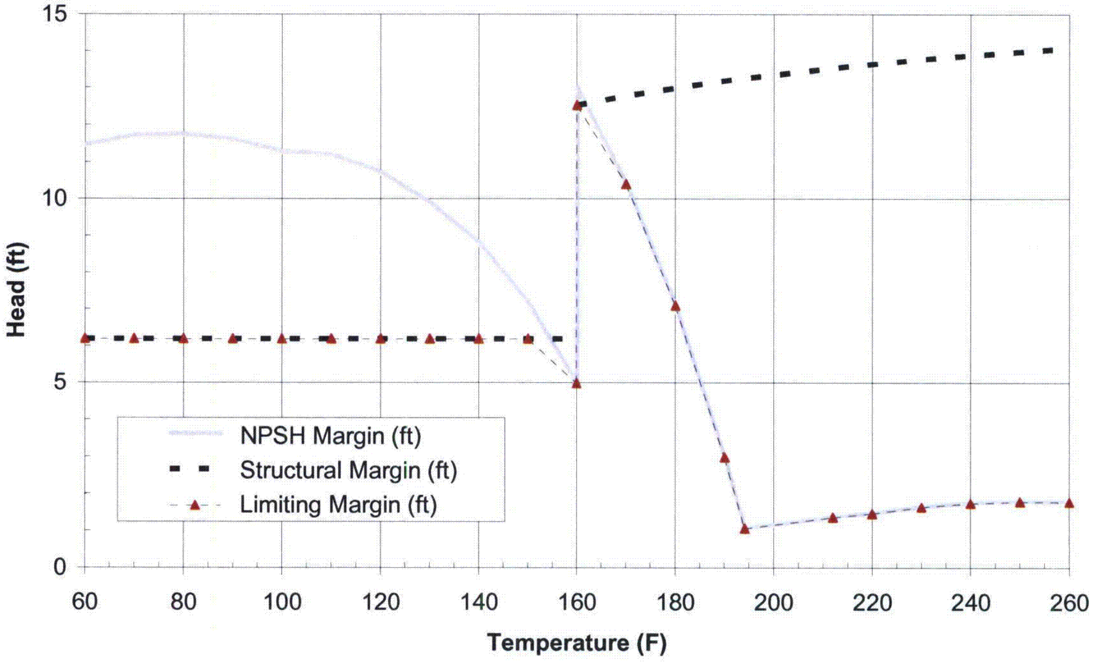


Figure 7: NPSH Available and Margin
Unit 1 Containment Spray Recirculation - Two Pump Operation

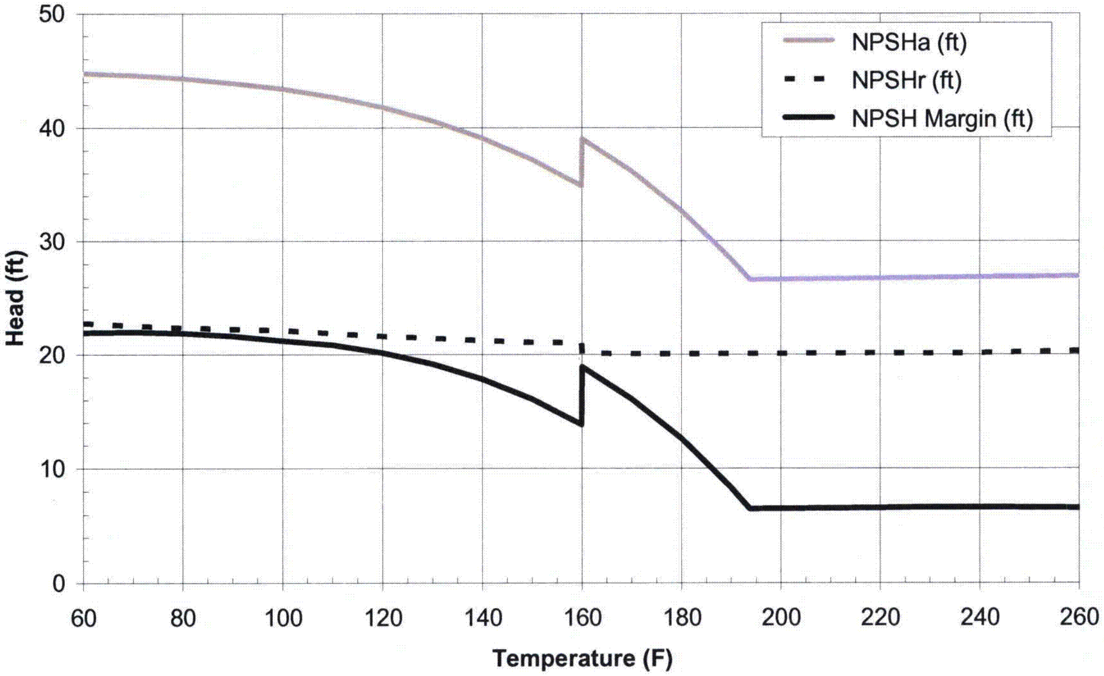


**Figure 8: Strainer Head Loss and Structural Margin
Unit 1 Containment Spray Recirculation - Two Pump Operation**

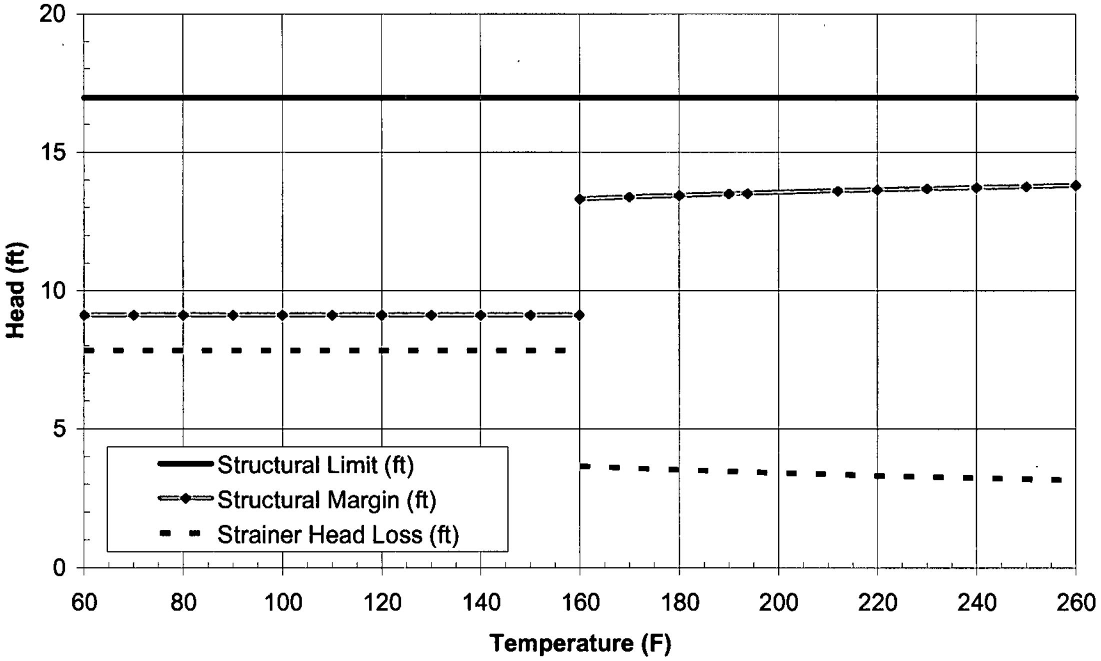


Figure 9: Limiting Margin
Unit 1 Containment Spray Recirculation - Two Pump Operation

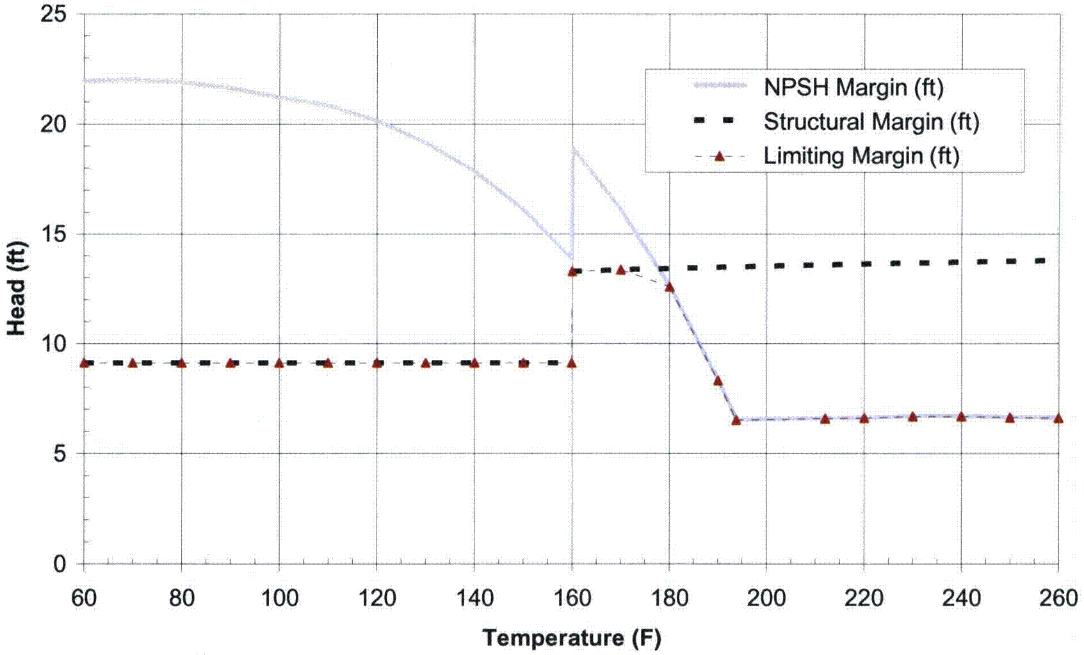


Figure 10: NPSH Available and Margin
Unit 2 Containment Spray Recirculation - Two Pump Operation

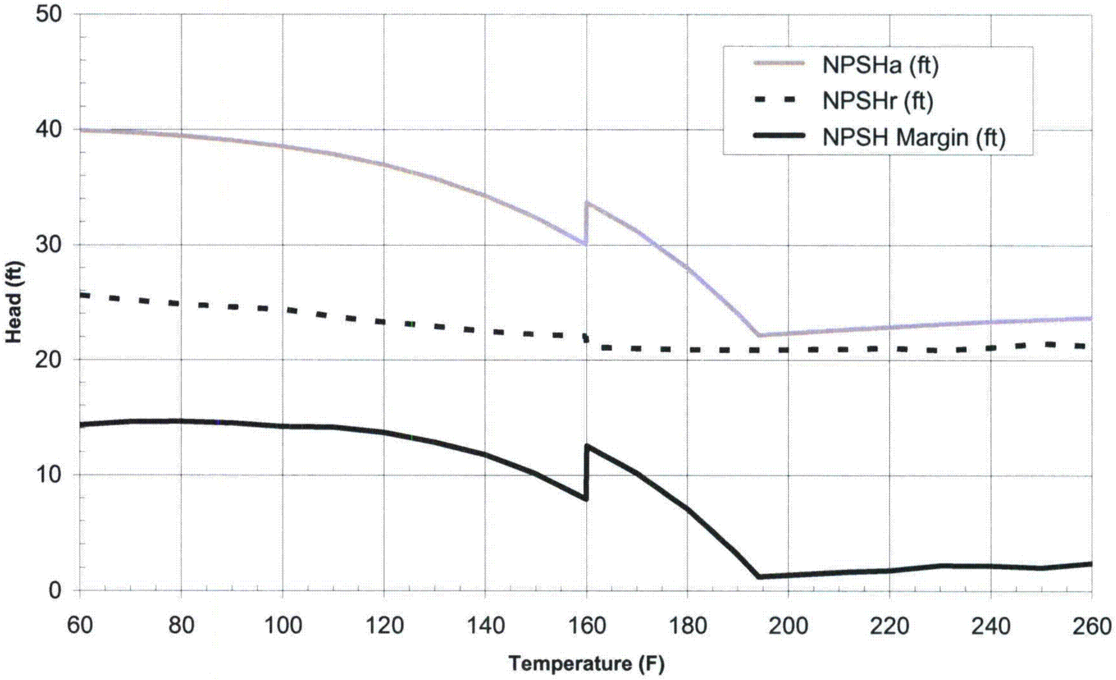


Figure 11: Strainer Head Loss and Structural Margin
Unit 2 Containment Spray Recirculation - Two Pump Operation

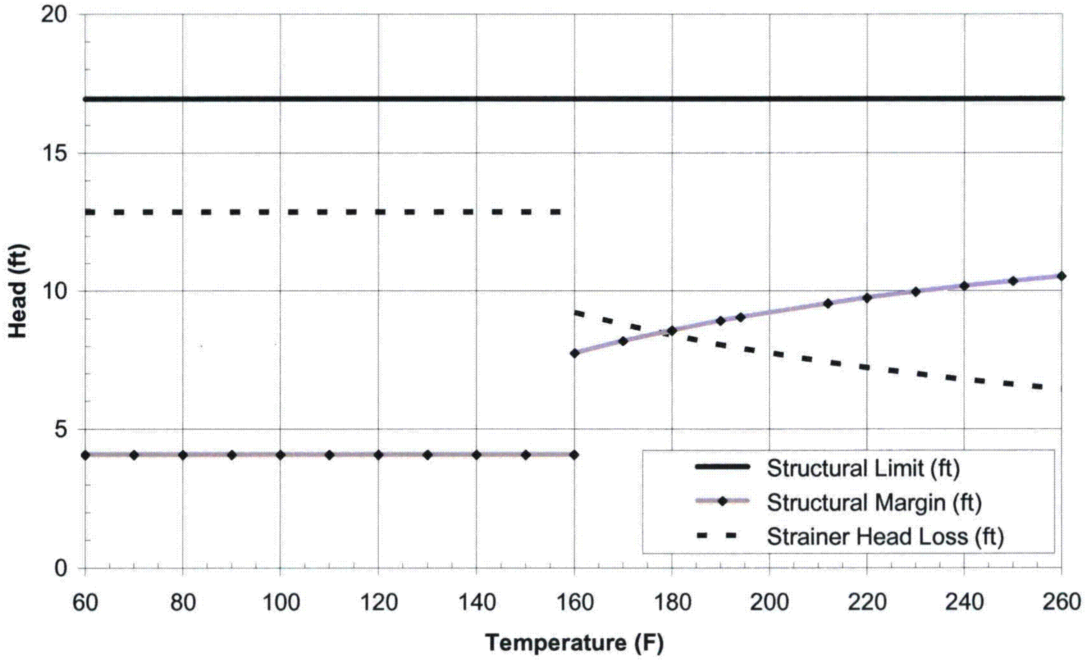
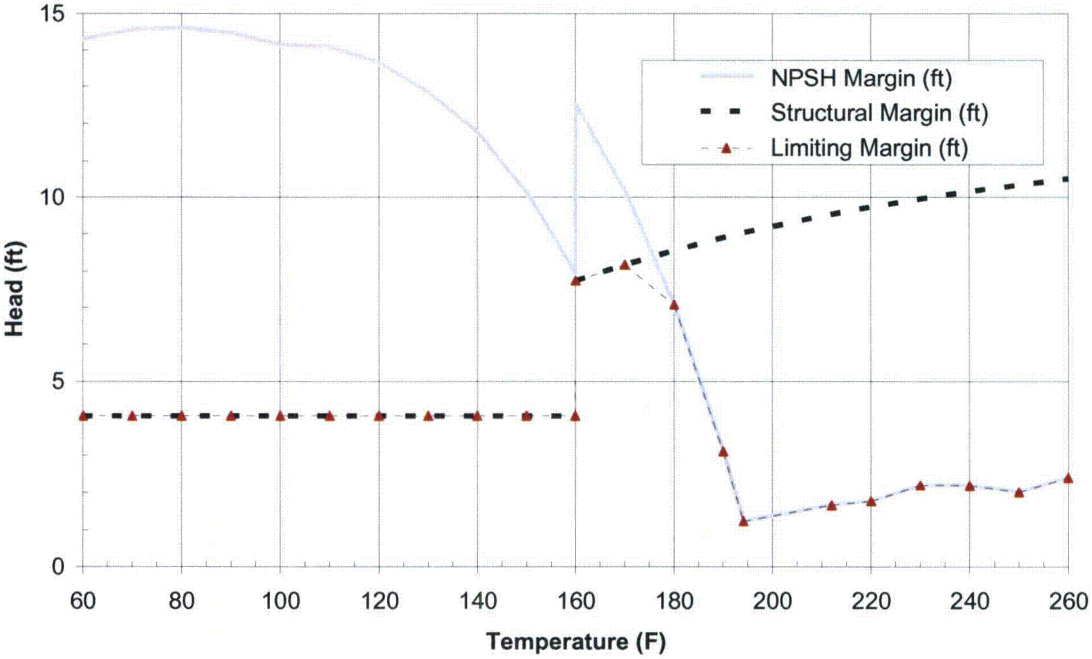


Figure 12: Limiting Margin
Unit 2 Containment Spray Recirculation - Two Pump Operation



The limiting margin results presented in Figures 3, 6, 9, and 12 above are summarized in Tables 3g-4 and 3g-5 (References A.41 and A.77) for the sump temperatures at which the minimum limiting margin occurs. Margin exists for all scenarios. The limiting margin prior to chemical precipitate formation occurs at the temperature at which the vapor pressure of the sump water is equal to the minimum initial air pressure in containment (193.7°F for Unit 1, 194.1°F for Unit 2). The limiting margin once chemical precipitates form occurs at the precipitate formation temperature 160°F; however, the limiting margin at 160°F is the same for lower sump temperatures (T<160°F) if the limiting margin is the structural margin since the structural limit is constant. The total strainer head loss includes both the component and debris bed head loss.

For Unit 1, more than 8 feet of margin exists for all temperatures at which chemical precipitates may be present for both 1 and 2 pump operation. This corresponds to approximately twice the existing debris bed (bore hole) head loss.

For Unit 2, more than 4 feet of margin exists for all temperatures at which chemical precipitates may be present for both 1 and 2 pump operation.

Table 3g-4: Unit 1 Available Margin Summary

Parameter	1-Pump Operation Cold Leg Recirculation		2-Pump Operation Containment Spray Recirculation	
	T =193.7°F (prior to chemical effects)	T < 160°F (onset of chemical effects)	T =193.7°F (prior to chemical effects)	T < 160°F (onset of chemical effects)
Total Strainer Head Loss (ft)	1.3	5.8	3.4	7.8
Debris Bed Head Loss (ft)	0.3	4.8 (Bore Holes)	0.6	4.8 (Bore Holes)
Limiting Margin (ft)	1.6 (NPSH)	8.8 (NPSH)	6.5 (NPSH)	9.1 (Structural)

* Values based on spreadsheet computations are rounded.

Table 3g-5: Unit 2 Available Margin Summary

Parameter	1-Pump Operation Hot Leg Recirculation		2-Pump Operation Containment Spray Recirculation	
	T =194.1°F (prior to chemical effects)	T ≤ 160°F (onset of chemical effects)	T =194.1°F (prior to chemical effects)	T ≤ 160°F (onset of chemical effects)
Total Strainer Head Loss (ft)	3.7	10.8	7.9	12.9
Debris Bed Head Loss (ft)	2.7	9.8 (Bore Holes)	4.8	9.8 (Bore Holes)
Limiting Margin (ft)	1.1 (NPSH)	5.0 (NPSH)	1.2 (NPSH)	4.1 (Structural)

* Values based on spreadsheet computations are rounded.

3h. Coatings Evaluation

The objective of the coatings evaluation section is to determine the plant-specific ZOI and debris characteristics for coatings for use in determining the eventual contribution of coatings to overall head loss at the sump screen.

3h.1) Provide a summary of type(s) of coating systems used in containment, e.g., Carboline CZ 11 Inorganic Zinc primer, Ameron 90 epoxy finish coat.

Table 3h-1 summarizes the type(s) of qualified coating systems installed in the Salem Unit 1 and 2 containments. Qualified epoxy coatings are used in containment; qualified inorganic zinc (IOZ) coatings are not used in containment. The coating information is from Technical Standard NC.DE-TS.ZZ-6006 (Reference A.28).

Table 3h-1: Containment Coating Systems

Substrate	Salem System Specification
Carbon Steel Elevation Below 130 feet (original coating system)	Keeler and Long Epoxy Primer 6548/7107 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Intermediate Coat E-1-8591 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Topcoat E-1-7844 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Topcoat E-1-1105 (Fire Protection only) DFT: 2.0 to 4.0 mils
Carbon Steel Elevation Below 130 feet (alternative and maintenance coating systems)	Keeler and Long Epoxy Primer 6548/7107 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Intermediate Coat D-1-8591 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Topcoat D-1-7844 DFT: 2.5 to 3.5 mils
Carbon Steel Elevation 130 feet and above (original coating system)	Keeler and Long Epoxy Primer 6548/7107 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Intermediate Coat E-1-7475 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Topcoat E-1-7475 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Topcoat E-1-1105 (Fire Protection only) DFT: 2.0 to 4.0 mils
Carbon Steel Elevation 130 feet and above (alternative and maintenance coating systems)	Keeler and Long Epoxy Primer 6548/7107 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Intermediate Coat D-1-8591 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Topcoat D-1-9140 DFT: 2.5 to 3.5 mils
Containment Liner Plate (original coating system)	Keeler and Long Epoxy Primer 6548/7107 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Topcoat E-1-7475 DFT: 2.5 to 3.5 mils
Containment Liner Plate (alternative and maintenance coating systems)	Keeler and Long Epoxy Primer 6548/7107 DFT: 2.5 to 3.5 mils
	Keeler and Long Epoxy Topcoat D-1-9140 DFT: 2.5 to 3.5 mils

Substrate	Salem System Specification
Concrete Floors Elevation 130 feet and below (original coating)	Carboline Epoxy Surfacer 195 or 300 DFT: 8 to 12 mils
	Carboline Epoxy Topcoat Phenoline 300 DFT: 8 to 12 mils
Concrete Floors Elevation 130 feet and below (alternative and maintenance coating systems)	Carboline Epoxy Surfacer 2011S DFT: 20 to 24 mils
	Carboline Epoxy Topcoat 890 DFT: 4 to 6 mils
Concrete Walls and Ceilings Elevation 130 feet and below (original coating system)	Carboline Epoxy Surfacer 195 DFT: 8 to 12 mils
	Carboline Epoxy Intermediate and Topcoat Phenoline 305 DFT: 4 to 6 mils per coat (8-12 mils total)
Concrete Walls and Ceilings Elevation 130 feet and below (alternative and maintenance coating systems)	Carboline Epoxy Surfacer 2011S DFT: 12 to 20 mils
	Carboline Epoxy Intermediate and Topcoat 890 DFT: 4 to 6 mils per coat (8-12 mils total)

3h.2) Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.

In accordance with the guidance provided in NEI 04-07 and its associated SER (References 2 and 3), all coating debris is considered particulate. All coating debris (qualified and unqualified) in the active sump pool is modeled as transporting to the sump strainer. As described in Section 3e.1 of this response, some qualified coating does not transport to the strainer since the coating particulate is either retained on walls (inertial capture) during blowdown or sequestered in inactive volumes during pool fill-up.

3h.3) Discuss suction strainer head loss testing performed as it relates to both qualified and unqualified coatings and what surrogate material was used to simulate coatings debris.

During design basis head loss testing (see section 3.f.4.1.5 of this response), the qualified/unqualified coating quantity that transports to the screen was modeled as stone flour. Coatings were modeled as particulate and not chips due to particulate being more conservative (see section 3h.4 of this response).

While Salem has never performed testing with paint chips, it is CCI's experience through numerous tests of different clients that head loss tests with stone flour in lieu of paint chips create higher head losses and as such are more conservative

(Reference A.67). Further explanation for not testing coatings as chips is provided in Section 3f.4.1.5.9.2 of this response.

3h.4) Provide bases for the choice of surrogates.

CCI uses a stone flour product manufactured by COOP (a Swiss Corporation) for strainer performance testing. The stone flour product demonstrates characteristics very similar to the latent debris and coating particulate. The size spectrum analysis (Figure 3h-3) measured its S_v value as 0.776 m^2/cm^3, which corresponds to a sphere diameter of 7.7 μm (Reference A.74). This is a measured value, which is bounded by the 10 μm particulate constituent size given in NEI 04-07. Epoxy coating particulates are characterized by a sphere diameter of 10 μm (Reference 2). Since this is a theoretical value and available particulates always have a size distribution spectrum, CCI chooses to use a surrogate particulate product with a similar S_v value to the theoretical product with the spheres of 10 μm.

The quantity of particulates generated is defined by volume. However, CCI measures the particulate quantity for the tests by weight. The volume quantity has been converted to weight by the density of the surrogate particulates. The surrogate particle material density was measured to be 2680 kg/m^3 (167.4 lb/ft^3). In previous testing (Reference A.63) it was determined that stone flour transportation to the strainer module is comparable to that of paint particulate/small chips. For the testing, paint chips were ground down to various sizes from 0 – 4 mm. The graphs below show the sedimentation of paint particle sizes from 0 – 0.075 mm and stone flour. It can be seen that the transport of stone flour is comparable to that of the actual paint particulate. The stone flour settles at a slightly higher rate than the paint particulates. However, the trends are comparable and the stone flour settlement rate for Salem's case is typically within approximately 8% to13% of the paint particulate rate. During head loss testing, if excessive sedimentation occurs in the test loop, the sedimentation is agitated back into suspension as described in Section 3f.4.1.5.12 of this Response.

Figures 3h-1 and 3h-2 below present the sedimented debris percentage as a function of the specifical time t'=l/(v*h) where l= distance from debris introduction to the front of the strainer (0.5 m for test 2, 1.5 m for Tests 3-repeat, 5 and 6), v= water velocity and h= water flume height (0.741 m). Table 3h-2 shows the specifical time and sedimentation for the conditions of CCI thin bed Test 2. Table 3h-3 shows the specifical time and sedimentation for the conditions of CCI thin bed Test 3-repeat. Table 3h-4 shows the specifical time and sedimentation for the conditions of CCI design basis head loss Tests 5 and 6.

Tables 3h-2 through 3h-4 present information for both 1-pump and 2-pump flow strainer rates. The 2-pump flow rate assessed for Tests 2 and 3-repeat (Tables 3h-2 and 3h-3) included margin above the design basis 2-pump flow rate (Reference A.14).

Table 3h-2: Specifical Time and Sedimentation for Salem Thin Bed Test 2 (Reference A.89)

	Plant Flow Rate (gpm)	Loop Flow Rate (m^3/hr)	Upstream Flume Velocity (m/s)	Specifical Time (s/m)	% Sedimented Debris per Fig 3h-1	% Sedimented Stone Flour per Fig 3h-2
Salem Unit 2, 2-Pump Flow Rate	9000	29.33	0.0275	24.55	1	10
Salem Unit 2, 1-Pump Flow Rate	4980	16.23	0.0152	44.36	5	18

Table 3h-3: Specifical Time and Sedimentation for Salem Thin Bed Test 3-Repeat (Reference A.89)

	Plant Flow Rate (gpm)	Loop Flow Rate (m^3/hr)	Upstream Flume Velocity (m/s)	Specifical Time (s/m)	% Sedimented Debris per Fig 3h-1	% Sedimented Stone Flour per Fig 3h-2
Salem Unit 1, 2-Pump Flow Rate	9000	28	0.0262	77.26	12	25
Salem Unit 1, 1-Pump Flow Rate	5110	15.9	0.0149	135.86	25	33

Table 3h-4: Specifical Time and Sedimentation for Salem Head Loss Tests 5 and 6 (Reference A.74)

	Plant Flow Rate (gpm)	Loop Flow Rate (m^3/hr)	Upstream Flume Velocity (m/s)	Specifical Time (s/m)	% Sedimented Debris per Fig 3h-1	% Sedimented Stone Flour per Fig 3h-2
Salem Unit 1, 2-Pump Flow Rate	8850	27.53	0.0258	78.46	12	25
Salem Unit 2, 2-Pump Flow Rate	8850	28.84	0.0270	74.89	12	25
Salem Unit 1, 1-Pump Flow Rate	5110	15.9	0.0149	135.85	25	33
Salem Unit 2, 1-Pump Flow Rate	4980	16.23	0.0152	133.09	25	33

Figure 3h-1: Paint Chip Sedimentation

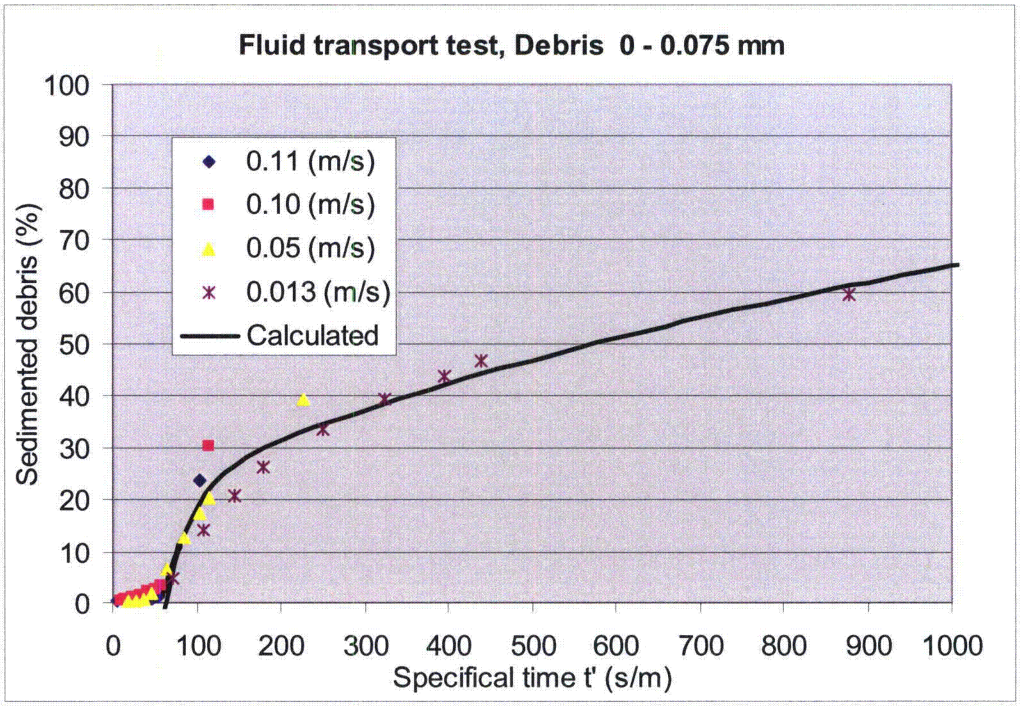


Figure 3h-2: Stone Flour Sedimentation

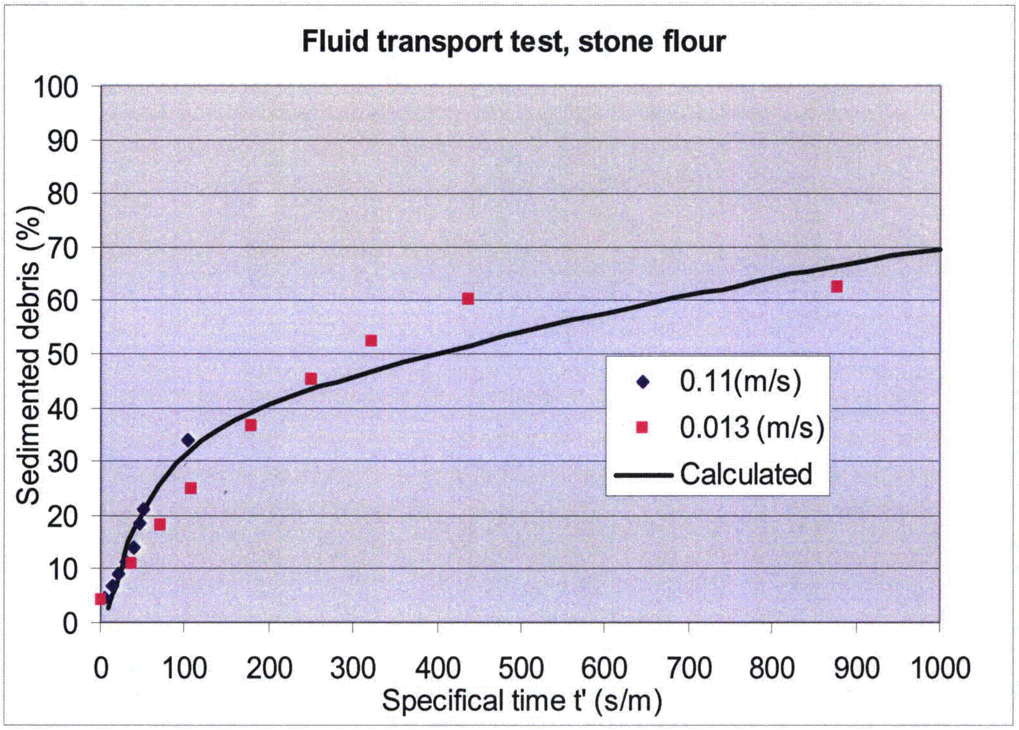


Figure 3h-3: Stone Flour Particle Size Analysis

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            Sulzer Innotec AG, Werkstoffanalysen 1501, 8404 Winterthur

SYMPATEC    HELOS  Partikelgrößenanalyse        30.05.05 / 09:35:54.000

 DISPERGIERSYSTEM Suspensionszelle (SUCELL)         Ultraschall Dauer  0       s
 Flüssigkeit      wasser                                        Pause          s
 Zusatz                                            Rührerdrehzahl  50          %
                                         Referenzmessung        -999h00,    0.0%
 MESSBEDINGUNG     Brennweite  100mm     Messzeit / Wartezeit   maximal    25.0s
                   Zykluszeit 1000ms     Start / Stop  bei    %  auf Kanal
 PROBE Steinmehl                         Dichte       g/ccm  Formfakt.

 Kommentar1     SWATM05 0534
 Kommentar2
 Bearbeiter     MM                       Datei                          C:\300506
 LD-Auswertemodus (V.4.7.0)

    xo/ µm       Q3/% |  xo/ µm      Q3/% |  xo/ µm      Q3/% |  xo/ µm      Q3/%
 ---------------------------------------------------------------------------------
                      |    3.10     10.35 |   12.50     31.52 |   51.00     69.55
      0.90       1.90 |    3.70     12.38 |   15.00     35.20 |   61.00     76.96
      1.10       2.78 |    4.30     14.29 |   18.00     38.87 |   73.00     85.63
      1.30       3.63 |    5.00     16.36 |   21.00     42.32 |   87.00     94.29
      1.50       4.44 |    6.00     18.98 |   25.00     46.77 |  103.00    100.00
      1.80       5.62 |    7.50     22.31 |   30.00     51.99 |  123.00    100.00
      2.20       7.13 |    9.00     25.23 |   36.00     57.62 |  147.00    100.00
      2.60       8.59 |   10.50     28.02 |   43.00     63.44 |  175.00    100.00

 x10      =    3.00  µm        x50    =   28.09  µm       x90     =    80.06  µm
 x16      =    4.88  µm        x84    =   70.75  µm       x99     =   100.20  µm
 Sv =     0.776 m2/cm3                                     c_opt  =    12.5 %
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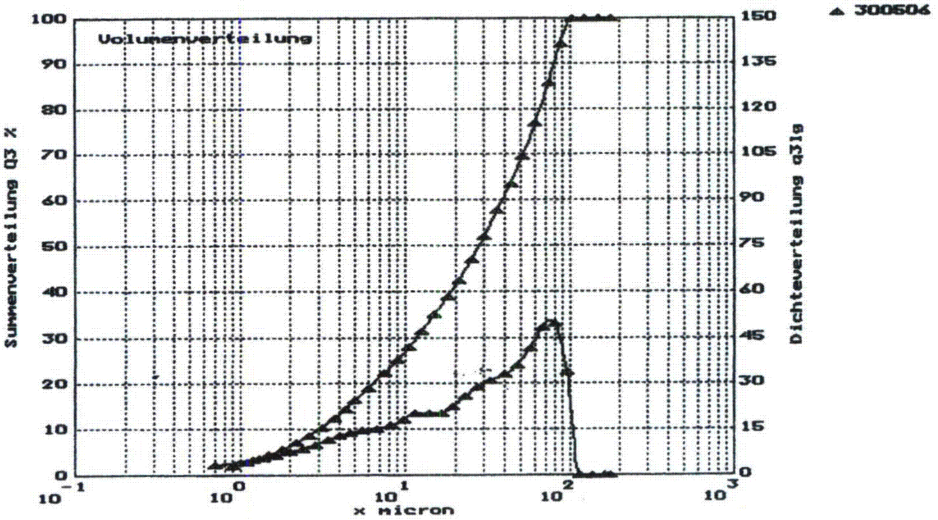


3h.5) Describe and provide bases for coatings debris generation assumptions. For example, describe how the quantity of paint debris was determined based on ZOI size for qualified and unqualified coatings.

All qualified coatings at Salem are epoxy coatings evaluated with a 4D ZOI. Based upon the results of testing presented in WCAP-16568-P (Reference 22) a 4D ZOI is acceptable. Use of the reduced ZOI for epoxy coatings was accepted by the NRC in 2010 (Reference 39). All unqualified coatings are considered to be debris consistent with NEI 04-07 and its associated SER (References 2 and 3).

Based on the comparisons summarized in Table 3h-5 below (Reference A.14), the test results in WCAP-16568-P are applicable to the qualified Salem epoxy coatings.

Table 3h-5: Coating Systems Comparison

Substrate	Salem System Specification (Refs. A.101 & A.28)	WCAP Coupon Specification (Reference 22)	Applicability
Steel Elevation 130 feet and below	K&L 6548/7101	K&L 6548/7101	Same material
	K&L E-1-8591	K&L D-1-9140	The K&L 1-D-9140 epoxy has the same chemical structure (polyamide) as the E-1 series epoxies. Therefore, testing is applicable.
	K&L E-1-7844		
Concrete Elevation 130 feet and below	Carboline Phenoline 300S	Carboline Carboguard 2011S	The Carboguard 2011S epoxy surfacer has the same performance as the Phenoline 300S epoxy surfacer since they are of similar chemical family.
	Carboline Phenoline 300	Carboline Carboguard 890N	The Carboguard 890N has the same performance as the Phenoline 305 epoxy, which also has the same performance of Phenoline 300, since they are all of similar chemical family.

To determine the amount of qualified coating debris generated at Salem, structural and civil drawings were consulted. Bounding break locations are determined from inspection of these drawings, then the total surface area of coated steel and concrete within a 4D ZOI of the break locations is calculated. The quantity of qualified coatings generated by the bounding breaks is presented in Table 3h-6.

A conservative coating thickness, determined from specifications and plant walkdowns performed by KTA-Tator, is applied to this surface area to determine the total coating debris volume. A 10% margin is added to the steel coating total to account for miscellaneous surfaces that were not otherwise accounted for, such as handrails, kick plates, ladders and small supports.

Table 3h-6: Qualified Coating Debris

Break	Steel Coatings [ft^3]	Concrete Floors [ft^3]	Concrete Walls [ft^3]	Total Qualified Coatings [ft^3]
S1	3.5	0.0	0.9	4.4
S7	5.3	0.0	0.0	5.3
S8	4.0	0.0	0.5	4.5
S10	5.3	0.8	0.0	6.1

The area of unqualified coatings in both units is known and reported in the debris generation calculation (Reference A.1). All unqualified coatings are included in the design debris load except a portion of the coatings on Limitorque valve actuators. Testing performed by EPRI (Reference 49) has shown that not all unqualified coatings on Limitorque valve actuators fail in a post-LOCA environment. The total unqualified coating amount is provided in Tables 3h-7a and 3h-7b. Unqualified coatings in containment are tracked under a coating deviation form in procedure NC.DE-TS.ZZ-6006 (Reference A.28).

The RPV, RCP motors, and pressurizers at Salem Units 1 and 2 are all considered to be coated with aluminum paint. The Unit 1 steam generators are coated with black Carboline 4674, while the Unit 2 steam generators are not coated. The coating debris load due to the coated NSSS components is discussed below.

The area of the aluminum paint is based on the area of the pressurizer which becomes exposed (e.g. insulation is removed due to the break jet) during the limiting break and one-half of the area of aluminum coatings on the miscellaneous NSSS equipment. Break S7 results in the largest exposed pressurizer area for Unit 1, while Break S10 is limiting for Unit 2. One half of the total from the miscellaneous NSSS equipment is included since only the NSSS equipment on one half of containment is impacted by any given break. Furthermore, the aluminum paint is approximately evenly distributed among the four RCS loops. The area of the unimpacted portions of the pressurizer or other NSSS components is not included since the aluminum coating underneath unimpacted insulation is not expected to fail as it is not exposed to spray or jet forces. However, if it were to fail, it would be retained by the insulation or its associated retaining rings on the component. The pressurizer shell is insulated with MRI at Unit 2 and jacketed

NUKON at Unit 1. Since MRI has a larger ZOI than jacketed NUKON, more aluminum coating transports to the pool in Unit 2.

The Unit 1 steam generators are coated with black Carboline 4674. The area of the Carboline 4674 paint which could fail during an accident is based on the limiting area of the steam generators exposed (e.g. insulation is removed due to the break jet) due to a pipe break (Break S1). The area of the unimpacted portions of the steam generators is not included since the coating underneath unimpacted insulation is not expected to fail during an accident. However, if it were to fail, it would be retained by the insulation or its associated retaining rings on the component.

Table 3h-7a: Unit 1 Unqualified Coating Debris

Description	**Area**	**Thickness**	**Volume**
	[ft^2]	**[mils]**	**[ft^3]**
Polar Crane Upgrade Stencil	2	10.5	0.002
Valve Coatings[1]	various	various	0.48
Aluminum Paint	2750	3	0.688
Steam Generator Coatings	2900	3	0.725
Total			**1.89**

1) Valve coatings consist of both IOZ and epoxy coatings.

Table 3h-7b: Unit 2 Unqualified Coating Debris

Description	**Area**	**Thickness**	**Volume**
	[ft^2]	**[mils]**	**[ft^3]**
Polar Crane Upgrade Stencil	2	10.5	0.002
Valve Coatings[1]	various	various	0.48
Aluminum Paint	2900	3	0.725
Total			**1.21**

1) Valve coatings consist of both IOZ and epoxy coatings.

3h.6) Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.

For discussion of coating surrogate characteristics see Sections 3h.3, 3h.4 and 3f.4.1.5.9.2 of this response.

3h.7) Describe any ongoing containment coating condition assessment program.

Salem Units 1 and 2 has implemented a coating condition monitoring program (Reference A.66). It provides guidance for the engineering department to conduct assessments of the conditions of the containment coatings during refueling outages. It incorporates the practices of ASTM D5163 (Reference A.39) and includes the adhesion test procedure outlined in EPRI Report 1014883 Section 4 (Reference A.61).

PSEG follows the guidance of ASTM D5163 (Reference A.39). During each refueling outage, engineering personnel walk through accessible areas of the containment, including Elevations 78ft, 100ft, and 130ft, and the bioshield elevations. The condition of protective coatings installed on concrete and steel substrates is observed and corrective actions are taken if required.

The walkdowns consist of close visual observations (all up to about 10 feet in height) of the following structures and components: floors, walls, piping, structural steel, components (tanks, accumulators, fan units, panels, etc.), hatches, polar crane, and containment liner.

Other structures and components greater than approximately 10 feet in height are visually observed from floor elevation for delaminations and cracks. This includes walls, ceilings, piping, structural steel, components (tanks, accumulators, fan units, etc.), hatches, the polar crane, and the containment liner. The polar crane is used for personnel to gain higher access to visually inspect the containment liner coatings, as well as the upper portions of the polar crane.

The individuals responsible for conducting and coordinating the service level I coating performance monitoring have a minimum of 2 years experience in assessing the condition of service level I coatings. This experience includes oversight of coating applications, visual assessment of coating defects and the repair of the defects, or industry coursework in coatings.

Qualified coatings requiring maintenance are documented in accordance with the PSEG Corrective Action Program. Deficiencies are reviewed by engineering and supervisory personnel to recommend the proper level of attention. Work orders are generated and prioritized by Station management.

The person observing the coating conditions specifies whether the observed degraded condition should be immediately repaired, tracked for future repairs, or visually monitored. Typical repairs are performed by removing the delamination and scraping back to a sound coating.

PSEG considers operating experience feedback and input from industry experts for program updates, e.g., by interacting with EPRI and the Nuclear Utilities Coatings Council (NUCC).

3i. Debris Source Term

The objective of the debris source term section is to identify any significant design and operational measures taken to control or reduce the plant debris source term to prevent potential adverse effects on the ECCS and CSS recirculation functions.

3i.1) Provide the information requested in GL 04-02 Requested Information Item 2.(f) regarding programmatic controls taken to limit debris sources in containment.

GL 2004-02 Requested Information Item 2(f)
A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduced into containment (e.g., insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions. Addressees may reference their responses to GL 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment," to the extent that their responses address these specific foreign material control issues.

PSEG has existing programmatic controls to ensure that potential sources of debris are not introduced into containment. This includes Salem Procedure SC.SA-ST.ZZ-0001(Q), "Salem Containment Entries in Modes 1 through 4" (Reference A.33) that requires all personnel entering containment during Modes 1 through 4 to complete a Foreign Material Exclusion (FME) Area Accountability Log of all loose materials carried into containment. This procedure provides guidance to personnel conducting the containment visual inspection and maintaining compliance with Technical Specifications for ECCS (Reference A.45).

S1(2).OP-ST.SJ-0010(Q) (Reference A.24) are the TS surveillance containment inspections required for MODE 4 entry and include verification that various containment elevations do not have loose debris or loose coatings that may be transported to the sump.

PSEG has implemented a FME Program (Reference A.40) that provides specific guidance to personnel performing work in the containment building.

PSEG has already implemented controls (Reference A.28) for the procurement, application, and maintenance of Service Level I protective coatings used in containment that is consistent with the licensing basis and regulatory requirements applicable to the Salem Station as stated in PSEG Letter dated November 12, 1998, Response to Generic Letter 98-04 (Reference A.100).

All the plant modifications are controlled through design change process procedures CC-AA-102 (Reference A.36) and CC-AA-102-1001 (Reference A.37). These procedures ensure that the plant modifications do not create a negative impact on the existing plant components.

Salem Units 1 and 2 have provided additional programmatic controls through revision to procedures CC-AA-102 (Reference A.36) and CC-AA-102-1001 (Reference A.37) to ensure that potential sources of debris are assessed for adverse effects on the ECCS and CS System recirculation functions. These programmatic controls include requirements related to coatings, insulation, containment housekeeping, material condition, and modifications.

In responding to GL 2004 Requested Information Item 2(f), provide the following:

3i.2) A summary of the containment housekeeping programmatic controls in place to control or reduce the latent debris burden. Specifically for RMI/low-fiber plants, provide a description of programmatic controls to maintain the latent debris fiber source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fibrous debris remain valid.

Prior to entering Mode 4 from a refueling outage, a formal containment closeout procedure S1(2).OP-PT.CAN-0001 (Q) (Reference A.34) is performed to ensure that loose materials are removed. The closeout procedure requires a check for foreign materials such as tape, equipment labels, construction and maintenance debris (for example, rags, plastic bags, packaging, sawdust, etc.), and temporary equipment (for example, scaffolding, ladders, insulation material, etc). Additionally, the walkdown requires operations personnel to check for dirt, dust, lint, paint chip buildup, and loose paint/coatings on surfaces such as walls or floors in containment.

As part of containment closeout, the ECCS containment sump and sump screens are inspected utilizing procedures S1(2).OP-ST.SJ-0010(Q) and S1(2).OP-ST.SJ-0011(Q) (Reference A.24) for damage and debris.

Procedure S1(2).OP-SO.SF-0004 (Reference A.24) is used for draining the refueling canal and cavity. Although there is no specific step to ensure refueling canal drains are free of debris, these lines are used to support draining of the cavity. Subsequently, procedure S1(2).OP-IO.ZZ-0001 (Reference A.24) directs the Refueling Canal Drain Flange Drain Valve (WL221) to be unbolted and swung out of position. Since this line is used for draining the refueling canal, the actual draining of the canal proves the lines are not clogged.

In support of the Generic Letter 2004-02 evaluation, a containment walkdown of Salem Unit 2 was performed to evaluate the build-up of latent debris (Reference A.15). The walkdown was performed using guidance provided in NEI 02-01. The results of the walkdown showed the amount of latent debris in containment to be 33 lbm (Reference A.15). For conservatism, 200 lbm of latent debris was used for Salem Unit 1 and 2 Debris Generation Calculation.

The periodic containment close-out inspections described herein, foreign material exclusion controls and design change process described in Section 3i.1, combined with the conservative value for latent debris in the debris generation calculation (Reference A.1) provide reasonable assurance that the amount of latent debris in containment will remain less than the amount evaluated.

3i.3) A summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the containment.

Salem has procedures in place to control the introduction of foreign material inside containment.

Procedure MA-AA-716-008 (Reference A.40) provides overall requirements and guidance to prevent and control introduction of foreign materials into structures, systems, and components. This procedure also controls investigation and recovery actions when FME integrity is lost or unexpected foreign material is discovered.

All containment entries during Modes 1 through 4 are done in accordance with the procedure SC.SA-ST.ZZ-0001(Q) (Reference A.33). This procedure requires that all material taken into containment is either installed or removed upon exit. The final disposition of the material is documented in the FME area accountability log. The procedure addresses minimizing the material left unsecured and unattended while working in the containment building.

A containment walkdown is performed at the beginning and end of each refueling outage in accordance with procedure S1(2).OP-PT.CAN-0001 (Q) (Reference A.34). One of the requirements of the procedure is to check the areas for foreign material, large accumulation of dirt, dust, lint and paint chips, and loose paint/coatings.

Procedures S1(2).OP-ST.SJ-0010(Q) and S1(2).OP-ST.SJ-0011(Q) (Reference A.24) are performed every refueling outage to visually inspect the containment sump to verify that no FME exists in the sump and that sump components (trash racks, screens, etc.) show no evidence of structural distress or corrosion. The front and back strainer pockets are visually inspected to ensure they are clean, have no visible gaps greater than the criteria specified, and are in good material condition. Also, refueling canal drains are verified to be unobstructed and that there is no potential debris sources in the refueling canal area that could obstruct the drains.

All the plant modifications are controlled through the design change process procedures CC-AA-102 (Reference A.36) and CC-AA-102-1001 (Reference A.37). These procedures ensure that the plant modifications do not have a negative impact on the existing plant components.

As part of the containment sump strainer replacement project, additional programmatic controls were established through these modification control procedures to ensure that potential sources of debris that may be introduced into containment are assessed for adverse effects on the ECCS and Containment Spray System recirculation functions. These programmatic controls include requirements related to coatings, containment housekeeping, and material condition.

3i.4) A description of how permanent plant changes inside containment are programmatically controlled so as to not change the analytical assumptions and numerical inputs of the licensee analyses supporting the conclusion that the reactor plant remains in compliance with 10 CFR 50.46 and related regulatory requirements.

Salem Unit 1 and 2 have configuration control procedures CC-AA-102 (Reference A.36) and CC-AA-102-1001 (Reference A.37) in place that require a review of all modifications to ensure that they do not have a negative impact on the plant design basis.

As part of the containment sump strainer replacement project, these design procedures have been revised to enhance the controls for introducing material in the containment. These procedures require that engineering changes be evaluated for system interactions. As part of the evaluation, there is a requirement to consider any potential adverse effect with regard to debris sources and/or debris transport paths associated with the containment sump. Specifically, it requires the review of the following:

- Insulation inside containment
- Coatings inside containment
- Structural changes (i.e., choke points) in containment
- Inactive volumes in containment
- Labels inside containment
- Addition of materials inside containment that may produce chemical effects in the post-LOCA flood pool/environment. It specifically prohibits the introduction of aluminum inside containment unless an evaluation is performed to assess the impact on the containment sump strainer head loss.

3i.5) A description of how maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65.

If any of the following suggested design and operational refinements given in the guidance report (guidance report, Section 5) and SE (SE, Section 5.1) were used, summarize the application of the refinements.

All temporary changes are performed in accordance with procedure CC-AA-112 (Reference A.42). This procedure requires a review of the temporary modification impact on the plant systems in accordance with procedures CC-AA-102 (References A.36) and CC-AA-102-1001 (Reference A.37) to ensure that potential sources of debris that may be introduced into containment are assessed for adverse effects on the ECCS and CSS recirculation functions. These programmatic controls include requirements related to coatings, containment housekeeping, material condition, and modifications.

10CFR50.65 (a)(4) requires that licensee assess and manage the increase in risk that may result from proposed maintenance activities. The potential increase in risk is assessed in accordance with OU-SA-105 (Reference A.52) and OP-AA-101-

112-1002 (Reference A.53). Critical to managing the increase in risk is to ensure that maintenance is performed in accordance with approved procedures.

NEI 04-07 Section 5 states the following:

> "In addition to analytical refinements, licensees may choose to consider administrative control refinements, design refinements, or a combination of administrative control and design refinements, to enhance post-accident sump performance. This section describes some of these refinements that are generically applicable to all PWRs. Licensees may identify additional design or operational refinements that are applicable to their specific plant."

The following sections provide information associated with the items discussed in NEI 04-07 Section 5 as they pertain to the Salem Units 1 and 2.

A. Housekeeping and FME Programs:

Salem has procedures in place to control the introduction of foreign material inside containment.

Procedure MA-AA-716-008 (Reference A.40) provides overall necessary requirements and guidance to prevent and control introduction of foreign materials into structures, systems, and components. This procedure also controls investigation and recovery actions when FME integrity is lost or unexpected foreign material is discovered.

All containment entries during Modes 1 through 4 are done in accordance with the procedure SC.SA-ST.ZZ-0001(Q) (Reference A.33). This procedure requires that all material taken into containment is either installed or removed upon exit. The final disposition of the material is documented in the FME area accountability log. Due to the possibility of an emergency exit, the procedure requires minimizing the material left unsecured and unattended while working in the containment building.

A containment walkdown is performed at the beginning and end of each refueling outage in accordance with procedure S1(2).OP-PT.CAN-0001 (Q) (Reference A.34). One of the requirements of the procedure is to check the areas for foreign material, large accumulation of dirt, dust, lint and paint chips, loose paint/coatings.

Procedures S1(2).OP-ST.SJ-0010(Q) and S1(2).OP-ST.SJ-0011(Q) (Reference A.24) are performed every refueling outage to conduct a visual inspection of the containment sump to verify that the subsystem suction inlets are not restricted by debris and that sump components (trash racks, screens, etc.) show no evidence of structural distress or corrosion. This inspection includes review of the ECCS containment sump and sump screens for damage and debris. The front and back strainer pockets are visually inspected to ensure they are clean, no visible gaps greater than the criteria specified, and are in good material condition. Also, refueling canal drains are verified to be unobstructed and that there is no potential debris sources in the refueling canal area that could obstruct the drains.

At Salem Units 1 and 2, all the plant modifications are controlled through the design change process procedures CC-AA-102 (Reference A.36) and CC-AA-102-1001 (Reference A.37). These procedures ensure that the plant modifications do not have a negative impact on the existing plant components.

Salem Units 1 and 2 have provided additional programmatic controls through procedures CC-AA-102 (Reference A.36) and CC-AA-102-1001 (Reference A.37) to ensure that potential sources of debris that may be introduced into containment will be assessed for adverse effects on the ECCS and Containment Spray System recirculation functions. These programmatic controls include requirements related to coatings, containment housekeeping, material condition, and modifications.

B. Change-out of insulation

At Salem Unit 1 and 2, all the calcium silicate insulation within the ZOI has been replaced and Min-K insulation was replaced wherever possible (Reference A.29 and A.30). Reflective metallic insulation was used at most of the locations. However, in some cases NUKON was used due to accessibility concerns. In all cases, the added reflective metallic insulation, NUKON and the remaining Min-K insulation were accounted for in the Debris Generation Calculation (Reference A.1).

C. Modify or improve coatings program

The majority of coatings at Salem Units 1 and 2 are qualified coatings. The amount of unqualified coatings is contained in Section 3h.5 of this response.

During every refueling outage, PSEG performs a containment walkdown to observe the conditions of protective coatings installed on concrete and steel substrates. PSEG follows the guidance of ASTM D5163 (Reference A.39).

Salem procedures CC-AA-102 (Reference A.36) and CC-AA-102-1001 (Reference A.37) have been enhanced to provide additional programmatic controls to ensure that coatings are assessed for adverse effects on the ECCS and CSS recirculation functions.

Salem has issued a coating condition monitoring program (Reference A.66). It provides guidance for the engineering department to conduct assessments of the conditions of the containment coatings during refueling outages. It incorporates the practices of ASTM D5163 (Reference A.39) and includes the adhesion test procedure outlined in EPRI Report 1014883 Section 4 (Reference A.61).

D. Floor Obstruction Design Considerations

Debris interceptors have been installed in front of the strainer modules to help reduce total debris movement toward the containment sump. The debris interceptors are approximately 9 inches tall and are made of grating with bearing bars on 15/16 inch centers and cross bars on 4 inch centers (References A.116 and A.117). Attached to the back of the grating is perforated plate with 1/8 inch diameter perforations. In addition, perforated plate with 1/12 inch diameter perforations was installed between the containment floor and the bottom of the strainer modules to prevent debris from transporting from the front to the back of the strainer.

E. Screen Modifications

Passive strainers have been installed at the Salem Units 1 and 2. The original containment sump strainer area for each Salem Unit was approximately 85 ft^2. The new ECCS containment sump strainer modules installed at Salem Unit 1 and 2 have a surface area of 4,854 ft^2 and 4,656 ft^2 respectively. The new surface area was based on debris load and chemicals precipitates, as well as plant layout. In addition to providing a significant increase in strainer surface area, the new design incorporates a reduction in strainer hole size from 1/8 inch nominal (original strainer) to 1/12 inch nominal (new strainer).

F. Bioshield Door Modifications

PSEG modified three of four wire mesh doors and folding gates in the stairwell near the accumulators for both Salem Units. The modifications replaced wire mesh with bars spaced at least 9 inches apart in the bottom 3 feet of the doors/gates. The wire mesh was removed to prevent water hold-up in the inner annulus. The bars were added to the bottom of the doors/gates to meet the radiation protection personnel safety requirements. However, the door/gate nearest to the strainer module was not modified in either Salem Unit because blockage of these doorways would result in a more tortuous path for debris, thus potentially reducing the overall debris transport.

3i.6) Recent or planned insulation change-outs in the containment which will reduce the debris burden at the sump strainers

At Salem Unit 1 and 2, all the calcium silicate insulation within the ZOI has been replaced and Min-K insulation was replaced wherever possible (Reference A.29 and A.30). Reflective metallic insulation was used at most of the locations. However, in some cases NUKON was used due to accessibility concerns. In all cases, the added Reflective metallic insulation, NUKON and the remaining Min-K insulation were accounted for in the Debris Generation Calculation (Reference A.1).

During the Salem Unit 2 Spring 2008 refueling outage, the SGs were replaced. The old SGs were insulated with NUKON insulation. The replacement SGs are insulated with Transco RMI.

3i.7) Any actions taken to modify existing insulation (e.g., jacketing or banding) to reduce the debris burden at the sump strainers

As stated in Response 3i.6, all calcium silicate insulation within ZOI and Min-K insulation wherever possible has been replaced. Reflective metallic insulation was used at most of the locations. However, in some cases NUKON was used due to accessibility concerns. In all cases, the added Reflective metallic, insulation NUKON and the remaining Min-K insulation were accounted for in the Debris Generation Calculation.

Also, the Salem Unit 2 replacement steam generators are insulated with Transco RMI, while the original Unit 2 steam generators were insulated with NUKON. Other than these replacements, PSEG has determined that no additional modification to the existing insulation is necessary to reduce debris burden at the sump strainers.

3i.8) Modifications to equipment or systems conducted to reduce the debris burden at the sump strainers

PSEG has not made any modifications to equipment or systems to reduce the debris burden at the sump strainers other than those described in Section 3i.5.

3i.9) Actions taken to modify or improve the containment coatings program

The existing Salem containment coatings program (Reference A.28) includes the specification of materials, surface preparation, application, and inspection procedures.

During every refueling outage, PSEG performs containment walkdown to observe the conditions of protective coatings installed on concrete and steel substrates. PSEG follows the guidance of ASTM D5163 (Reference A.39).

Salem Units 1 and 2 have issued a new coating condition monitoring program (Reference A.66). It provides guidance for the engineering department to conduct assessments of the conditions of the containment coatings during refueling outages. It incorporates the practices of ASTM D5163 (Reference A.39) and includes the adhesion test procedure outlined in EPRI Report 1014883 Section 4 (Reference A.61).

3j. Screen Modification Package

The objective of the screen modification package section is to provide a basic description of the sump screen modification.

3j.1) Provide a description of the major features of the sump screen design modification.

3j.2) Provide a list of any modifications, such as reroute of piping and other components, relocation of supports, addition of whip restraints and missile shields, etc., necessitated by the sump strainer modifications.

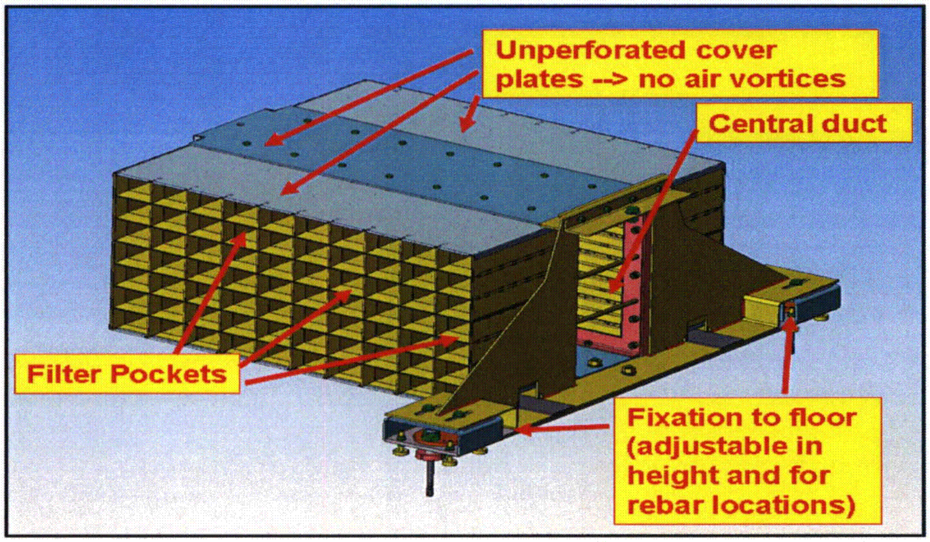
PSEG completed the physical changes necessary to bring Salem Unit 1 and 2 into full resolution with Generic Letter 2004-02. This involved removing the ECCS containment sump outer cage and inner screen and installing new ECCS containment sump strainer modules in each unit.

The sumps are located in the outer annulus area on elevation 78 feet of the Salem Unit 1 and Salem Unit 2 containment buildings. Each sump is surrounded by a concrete curb with the top of the curb at elevation 78 feet 9 inches. The inside of the sump is partitioned into two sides: the non-safety side that collects water from the trenches around the bioshield wall, and the ECCS side that takes water from the floor at elevation 78 feet to supply the RHR pumps during recirculation following a LOCA.

The pre-Generic Letter 2004-02 design consisted of an outer cage made of 1 ¼ inch x 3/16 inch vertical grid bars on 1 3/16 inch centers for the walls and solid 3/16 inch plate for the top. The outer cage prevented large debris from blocking or damaging the inner screen. The inner screen covered the ECCS side of the sump. It was structured as a box frame that was covered with stainless steel mesh with 1/8 inch by 1/8 inch openings. The inner screen had a screen surface area of approximately 85 ft^2. In addition to the outer cage and inner screen, the top of the sump also had a 1/8 inch mesh partition between the non-safety side of the sump and the ECCS side.

To accommodate the debris generated by a LOCA and transported to the sump, the surface area of the screen had to be significantly increased. A series of strainer modules were installed along the outer containment wall between the existing containment sump and the Pressurizer Relief Tank (PRT) to achieve the required total screen surface area.

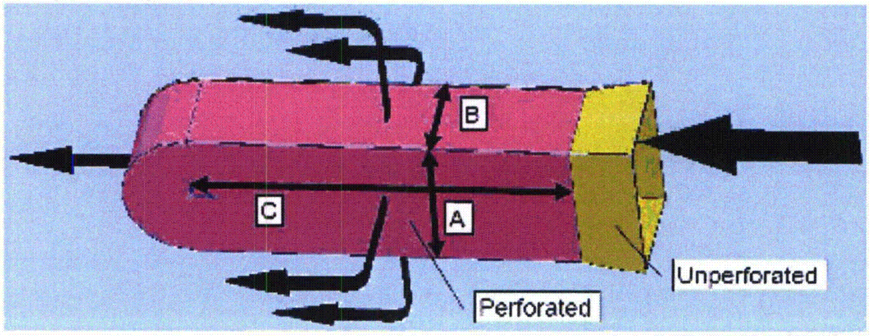
Figure 3j-1: Layout of a Standard Strainer Module



The strainer modules are passive strainers that were engineered, qualified, and manufactured by CCI. In order to maximize the surface area in a small footprint, each strainer module has pockets attached to the front and back of the module with a flow channel in the center.

The modules are either 10-pocket modules or 15-pocket modules. The 10-pocket modules are 10 pockets wide and 7 pockets high, whereas the 15-pocket modules are 15 pockets wide and 7 pockets high. The pockets (see sketch below) are made of stainless steel plate with 1/12 inch diameter holes and are nominally 400 mm deep. The smaller diameter holes are required to reduce bypass and prevent potential damage/blockage of downstream components such as valves and pumps.

Figure 3j-2: Layout of a Typical Strainer Pocket



The ECCS side of the sump is covered with a stainless steel enclosure made of 6 mm thick solid plate. The enclosure has an access panel that allows entry into the sump for maintenance and inspection. Inside the sump enclosure is a diffuser at the water inlet to help reduce turbulence.

There are two level transmitters located in each sump with a span of 204 inches. These level transmitters are three-stage transmitters such that the bottom and middle stage is fully submerged in the sump and the top stage is completely outside the sump (Reference A.120).

Therefore, the top of the sump enclosure has sealing plates that fit around the level transmitters and/or conduit. The 1/8 inch mesh partition between the two sides of the sump was sealed with a solid plate to prevent communication between the two sides. This forces water from the non-safety side of the sump back up through the trenches, onto the floor at elevation 78 feet and through the new strainer modules. This tortuous path helps to allow debris to settle, limiting the amount transported to the sump.

The strainer modules are connected end-to-end and attached to the sump enclosure via a connection duct. The connection duct has internal vanes to reduce turbulence through the duct. The final result is a train of strainer modules that extends approximately a quarter of the way around the outer annulus and allows flow of water to the sump and the RHR pumps.

A 9 inch tall debris interceptor is bolted to the front feet of the strainer modules to prevent large debris from reaching the strainer pockets. The debris interceptor is made of grating with bearing bars on 15/16 inch centers and cross bars on 4 inch centers. Attached to the back of the grating is perforated plate with 1/8 inch diameter perforations. The top of the debris interceptor has an overhanging lip that keeps larger debris from lifting off the floor and flowing over the debris interceptor. At the end of the strainer train, the debris interceptor wraps around the side and extends to the containment liner to limit debris transport to the back of the strainers.

A perforated plate with 1/12 inch holes is also installed between the bottom of the back face of each strainer module and the containment floor. The purpose of this plate is to prevent debris from transporting from the floor in front of the strainer to the area in back of the strainer, effectively creating a space for trapping debris underneath the strainer modules. This space was not credited in the debris transport analysis described in Section 3e of this response although it was included in the design basis head loss tests described in Section 3f.4.1.5.1 of this response.

PSEG modified three of four wire mesh doors and folding gates in the stairwell near the accumulators for both Salem Units. The modifications replaced wire mesh with bars spaced at least 9 inches apart in the bottom 3 feet of the doors/gates. The wire mesh was removed to prevent water hold-up in the inner annulus. The bars were added to the bottom of the doors/gates to meet the radiation protection personnel safety requirements. However, the door/gate nearest to the strainer module was not modified in either Salem Unit because blockage of these doorways would result in a more tortuous path for debris, thus potentially reducing the overall debris transport.

To support resolution of Generic Letter 2004-02, insulation was replaced inside the bioshield area and three out of the four bioshield doors were modified. By replacing the Calcium Silicate, Min-K and most of the NUKON insulation with RMI, the head loss across the screen and the chemical effects are greatly reduced. To prevent holdup of water in the bioshield area, the bottom portion of three of the four bioshield doors were modified. The modifications replaced wire mesh with bars spaced at least 9 inches apart in the bottom 3 feet of the doors/gates so that large pieces of insulation would not block the flow of water to the sump.

Other modifications required to support the strainer installation included modification of cable tray supports, radiant energy heat shielding and tube tray supports; relocation of the containment atmospheric pressure transmitter; stair modifications between Elevation 78 feet and 100 feet; and modification of instrument cabinet doors.

3k. Sump Structural Analysis

The objective of the sump structural analysis section is to verify the structural adequacy of the sump strainer including seismic loads and loads due to differential pressure, missiles, and jet forces.

3k.1) Provide the information requested in GL 2004-02 Requested Information Item 2(d)(vii).

GL 2004-02 Requested Information Item 2(d)(vii)

Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under flow conditions.

As discussed in section 3k.4, the strainers are not subjected to missiles or dynamic effects of high energy line breaks (HELB). The design of the new strainers accounted for the full post-LOCA debris load. The debris interceptors were installed in front of the strainers to reduce the debris load on the strainer, not for structural purposes, but for head loss purposes.

The 9 inch tall debris interceptor is bolted to the front feet of the strainer modules to minimize the transport of large debris to the strainer pockets. The debris interceptor is made of standard floor grating with bearing bars on 15/16 inch centers and cross bars on 4 inch centers. Attached to the back of the grating is perforated plate with 1/8 inch diameter perforations.

The top of the debris interceptor has an overhanging lip that keeps larger debris from lifting off the floor and flowing over the debris interceptor. At the end of the strainer train, the debris interceptor wraps around the side and extends to the containment liner to limit debris transport to the back of the strainers.

The grating bearing bars are 1 ½ inch x 3/16 inch. With the longest span of approximately 6 feet 3 inch, the allowable load on the grating is 202 lb_f/ft^2, which is considerably higher than the loads imposed by the debris. During containment flooding, the resultant static pressure from 9 inches of water on the debris interceptor grating is well below the allowable loads in the extremely unlikely event that the entire length of the debris interceptor is completely blocked by debris until such time as the water level exceeds the grating height.

Since the debris interceptors are only 9 inches high and the strainers are fully submerged during recirculation operation (water level is at least 1 foot-10 inches above the debris interceptor for a water level elevation of 80 feet 11 inches), the pressure differential across the debris interceptor is negligible. The attached perforated plate is bolted to the grating in three places. The perforated plate has been analyzed for deflection based on the maximum water velocity experienced at the debris interceptor. The maximum deflection was determined to be less than 1/8 inch, which is acceptable.

The debris interceptor is securely fastened to the base of the strainer frame by bolts. The analysis of the bolts is documented in VTD 900501 "Structural Analysis of Strainer and Support Structure" (Reference A.55). According to the calculation, there are no additional loads due to the attached curb to the strainer feet. Since both sides of the debris interceptor are flooded at recirculation operation, there is negligible pressure difference acting on the grating.

Any additional load caused by debris is encompassed in the strainer module analysis. The dead weight, seismic and hydrodynamic influence are also addressed in the strainer module analysis. Further discussion regarding the analysis of loads on the strainers is provided in item 3k.2.

3k.2) Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.

Design Conditions

Minimum sump water temperature during recirculation	50 °F = 10.0 °C
Maximum sump water temperature during recirculation	263 °F = 128.3 °C
Maximum containment air temperature	263 °F = 128.3 °C

The maximum pressure difference across the strainers used in the static analysis is based on the allowable head loss at 190°F (87.8 °C). This pressure difference is converted to the minimum sump water temperature of 50 °F (10.0 °C) based on the viscosity change.

The pressure difference at the high temperature is much lower; see 3 SA-096.020, Revision 9, chapter 3.1 which is documented in PSEG VTD 900501 (Reference A.55).

Allowable head loss at 190°F (87.8 °C)		3.15 ft
Kinematic viscosity of water	at 87.8 °C	$\upsilon_1 = 3.322*10^{-7}\ m^2/s$
	at 10.0 °C	$\upsilon_2 = 1.307*10^{-6}\ m^2/s$

Maximum head loss dH = 3.15 ft υ_2/υ_1= 12.39 ft = 3.776 m

A pressure difference of 13.12 ft (4 m) is used for the mechanical design.

Maximum pressure difference dP = 5.802 psi = 0.04 MPa

Design life 40 years stand-by life
2880 hours operating life time after LOCA

Weight of Structure

Weight of modules (10 pockets long):

Type	Number of Pockets	Mass [kg]	Mass [lb]
Modules without cartridges	10	160	353
1 cassette	10	17.5	39
14 cassettes @ 17.5 kg each	10	245	540
Total module	10	405	893

Weight of modules (15 pockets long):

Type	Number of Pockets	Mass [kg]	Mass [lb]
Modules without cartridges	15	200	441
1 cassette	15	24	53
14 cassettes @ 24 kg each	15	336	741
Total module	15	536	1182

Weight of supporting structure

The density 7900 kg/m^3 (493.2 lb/ft^3) is used to calculate the weight of the supporting structure. An allowance of 5% is added to the weight of modules to account for the weight of bolts, sealing plates, etc.

536 kg x 1.05 = 563 kg

Weight of Debris

The following was used as design input based on the original debris load.

Debris Unit 2	Volume [ft^3]	Density [kg/m^3]	Mass	
			[kg]	[lb]
NUKON Fiber	600	38.4	652.4	1438
Kaowool Fiber	600	48.1	817.2	1802
Reflective Metal Insulation	0.2502	7850	55.6	123
Qualified Coatings	25.5	1506	1087.5	2397
Unqualified Coatings	0.5	1506	21.3	47
Latent Particulates	1.01	2701	77.2	170
Latent Fiber	0.33	1500	14.0	31
Total Mass			2725.3	6008
per Module (23)			118.5	261
per Cassette			16.9	37

The tables below represent the tested debris loads for Units 1 and 2 based on Reference A.74. The tested debris loads bound the analytically determined debris loads at the Unit 1 and 2 strainers (Section 3f.4.1.5.8 of this response). The debris weight for both units is bounded by the original weight calculation; thus, the original calculation is conservative. Although MRI and RMI were not tested, the transported quantities (converted to volume using a conservative foil thickness of 6 mils) are included in the weight of debris on the strainer. Also, the coatings and latent particulate weight is based on the density from NEI 04-07 (Reference 2) instead of the density of the tested coatings surrogate.

Debris Unit 1	Volume [ft^3]	Density [lbm/ft^3]	Density [kg/m^3]	Mass [kg]	Mass [lbm]
NUKON Fiber	236.4	2.4	38.4	257.4	567.4
Kaowool Fiber	33.1	8	128.1	120.1	264.8
Fiberglas (formerly Generic Fiberglass)	45	3.9	62.5	79.6	175.5
Min-K	5.3	16	256.3	38.5	84.8
MRI	1.20*	490	7850	266.7	588.0
Qualified Coatings	11.5	94	1506	490.3	1081.0
Unqualified Coatings	0.5	94	1506	21.3	47.0
Latent Particulate	1	168.6	2701	76.5	168.6
Latent Fiber	12.5	2.4	38.4	0.0	30.0
Total Mass				1350.4	3007.1
per Module (24.5)				55.1	122.7
per Cassette (7)				7.9	17.5

* *Volume due to 2400 ft^2 of MRI (rounded up from value in Section 3e.6 of this response)*

Debris Unit 2	Volume [ft^3]	Density [lbm/ft^3]	Density [kg/m^3]	Mass [kg]	Mass [lbm]
NUKON Fiber	20.9	2.4	38.4	22.8	50.2
Kaowool Fiber	29.2	8	128.1	106.0	233.6
Fiberglas (formerly Generic Fiberglass)	47	3.9	62.5	83.1	183.3
Min-K	24.5	16	256.3	177.8	392
MRI	1.45*	490	7850	322.3	710.5
Transco RMI	0.20*	490	7850	44.5	98.0
Qualified Coatings	11.5	94	1506	490.3	1081
Unqualified Coatings	0.5	94	1506	21.3	47
Latent Particulate	1.0	168.6	2701	76.5	169
Latent Fiber	12.5	2.4	38.4	13.6	30
Total Mass				1358.2	2994.6
per Module (23.5)				57.8	127.4
per Cassette (7)				8.3	18.2

* *Volume due to 2900 ft^2 of MRI and 400 ft^2 of Transco RMI (rounded up from values in Section 3e.6 of this response).*

Pressure

The strainer is not a pressure retaining part and is therefore not subjected to any pressure transients or hydrostatic pressure during normal operation of the plant. If the strainer areas are covered with debris and the pumps are in use, then the following external pressures will act on the strainer.

$\Delta P=0.04$ MPa at 15°C
$\Delta P=0.01$ MPa at 87.8 °C and above

Hydrodynamic Water Masses

The calculation model represents two halves of a long strainer. The dimensions of one strainer are used to determine the hydrodynamic water masses. In the first step, the effects of the wall and the perforated sheets are minimal.

Coordinate directions:
X- horizontal, longitudinal direction
Y- horizontal, transverse direction
Z- vertical

Module height $h_m := 0.603m$ Module width $w_m := 1.122m$ Module length $l_m := 1.804m$

Duct height $h_d := 0.603m$ Duct width $w_d := 0.30m$

Density of steel $\rho_s := 7900 \frac{kg}{m^3}$ Density of water $\rho_w := 996 \frac{kg}{m^3}$

Steel mass of module $m_{Steel} := 536kg$ (used to calculate the volume displaced by the steel)

Included Water Mass

$$mi_y := \left(h_m \cdot w_m \cdot l_m - \frac{m_{Steel}}{\rho_s} \right) \cdot \rho_w \qquad mi_y = 1148kg$$

$$mi_x := \left[\left(h_m \cdot w_m \cdot l_m \right) - \left(h_d \cdot w_d \cdot l_m \right) - \frac{m_{Steel}}{\rho_s} \right] \cdot \rho_w \qquad mi_x = 823kg$$

(In x-direction the water included in the duct is not considered, because the duct has open ends at both sides)

$$mi_z := mi_y \qquad mi_z = 1148kg$$

Hydrodynamic Water Mass

See Reference 8 of this section. The factor f1 versus ratio a/b is given in this reference.

Hydrodynamic mass is given per Salem Unit length for long bodies with rectangular cross section.

Y-direction $a := \frac{h_m}{2}$ $b := \frac{w_m}{2}$ $\frac{a}{b} = 0.537$

$f_1 = 1.686$ for $\frac{a}{b} = 0.537$ $f_2 := 1.0$

$mh_y := f_1 \cdot \pi \cdot \rho_w \cdot a^2 \cdot l_m \cdot f_2$ $mh_y = 865\text{kg}$

X-direction $a := \sqrt{w_m \cdot h_m}$ $b := l_m \cdot 11$ $\frac{b}{a} = 24.125$

$f_1 := 0.1$ (for b/a=10) $f_2 := 1.0$

$mh_x := f_1 \cdot \rho_w \cdot a^2 \cdot l_m \cdot f_2$ $mh_x = 122\text{kg}$

Z-direction $a := \frac{w_m}{2}$ $b := \frac{h_m}{2}$ $\frac{a}{b} = 1.861$

$f_1 = 1.381$ for $\frac{a}{b} = 1.861$ $f_2 := 1.0$

$mh_z := f_1 \cdot \pi \cdot \rho_w \cdot a^2 \cdot l_m \cdot f_2$ $mh_z = 2453\text{kg}$

Total Water Mass

$m_x := mi_x + mh_x$ $m_x = 945\text{kg}$

$m_y := mi_y + mh_y$ $m_y = 2013\text{kg}$

$m_z := mi_z + mh_z$ $m_z = 3601\text{kg}$

Applied Water Mass

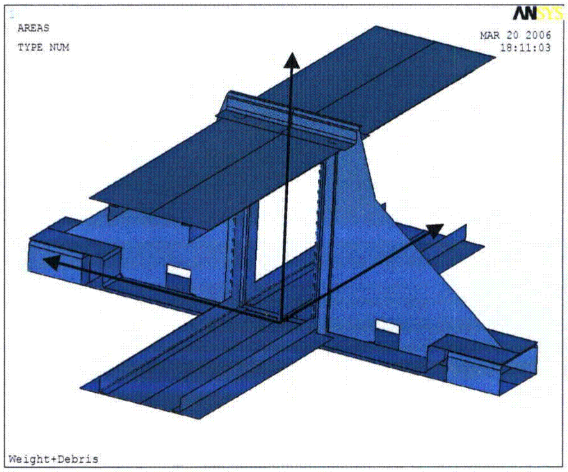
The value of the water mass is strongly affected by two influencing variables:

- Nearness to a wall / gap to the floor
- Perforated sheet

The strainer modules are located close to the floor and next to the wall. The water mass is accelerated by the wall and the floor. The inertia forces acting on the water are transferred directly through the water into the ground / wall and, therefore, no forces are exerted on the structure of the strainer. The strainers are not compact bodies, but mainly made of perforated plates. Therefore, for horizontal movements, only a portion of the surrounding water is accelerated, the rest "slips" through the perforation.

Direction	Wall / Basement f1	Perforated sheet f2
x	1	1
y	0.6	0.6
z	0	0.6

Applied Water Mass:
$mx = f_1 \cdot f_2 \cdot m_x = 950$ kg
$my = f_1 \cdot f_2 \cdot m_y = 725$ kg
$mz = f_1 \cdot f_2 \cdot m_z = 0$ kg



Faceplate at the end of the row

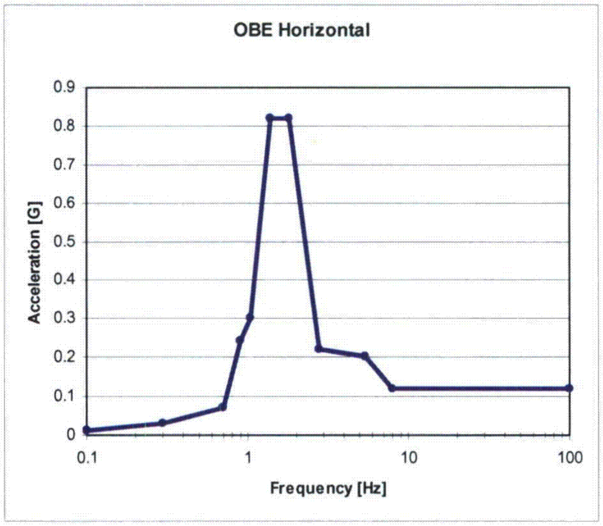
The hydrodynamic mass calculated above is applied in the spectrum analysis for Operating Basis Earthquake (OBE) and Design Basis Earthquake (DBE) of the strainer module. The mass causes lower natural frequencies and higher spectral accelerations. Because the hydrodynamic mass is large compared to the steel mass, the inertia loads acting on the strainer are higher.

Temperature
Due to the design of the strainers, there are no significant temperature stresses. The specified temperatures are used only for evaluating the material properties.

Earthquake
The strainers are Seismic Class 1 structures.

The response spectra are given in Attachment C of PSEG Specification No. S-C-CAN-MDS-0445 (Reference A.22). The damping values are 0.5% for OBE and 1% for DBE. For the spectrum analysis a simplified response spectra is used:

Figure 3k-1: Seismic Accelerations OBE



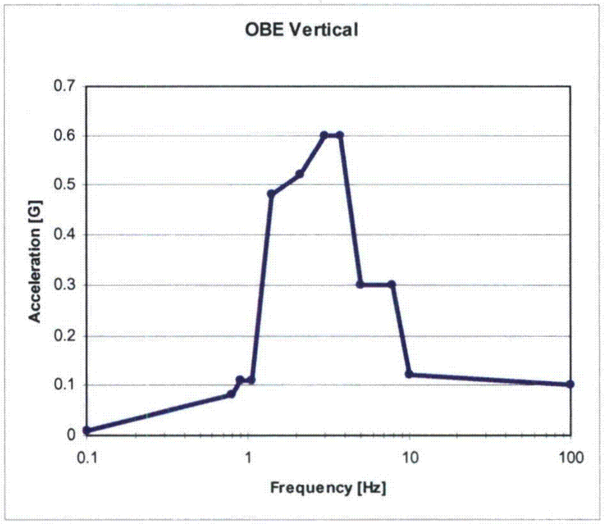
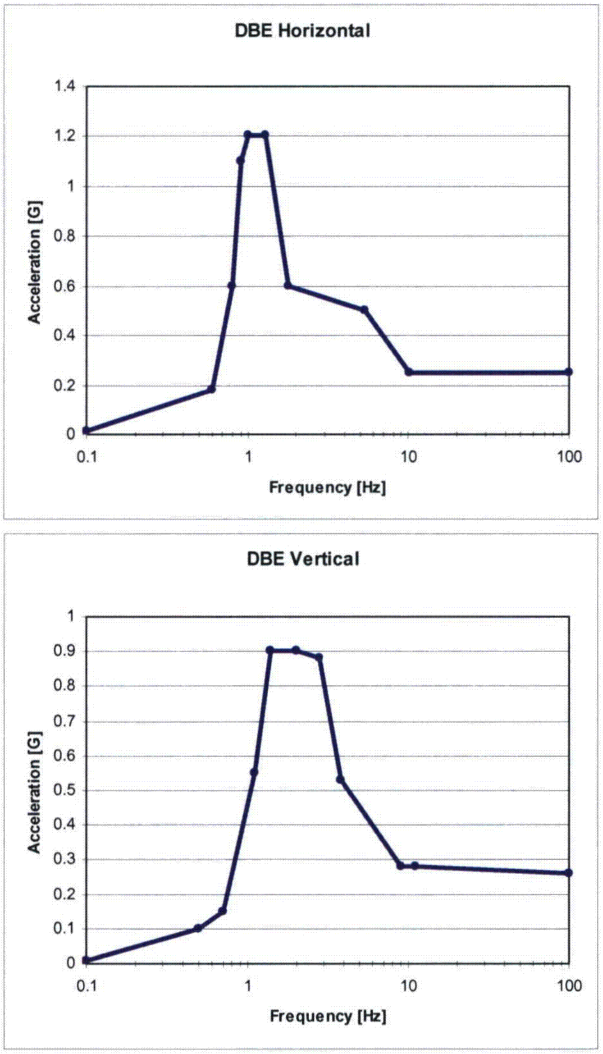


Figure 3k-2: Seismic Accelerations DBE



The resultant effects for both horizontal and vertical earthquake loads are determined by combining the individual effects by the square root of the sum of the squares method.

Load Combinations

The following table shows the event combinations that are considered.

Table 3k-1: Load Combinations

Load comb No.	Temperature (°F)	Temperature (°C)	Load Combination	Loading Category
1	263	128.3	W (pool dry)	Design/Service Limit A
2	263	128.3	W + OBE (pool dry)	Service Limit B
3	263	128.3	W + DBE (pool dry)	Service Limit C
4	263	128.3	W + W_D + W_W + OBE (pool filled)	Service Limit B
5	50	10.0	W + W_D + W_W + ΔP (0.04 MPa) + DBE (pool filled)	Service Limit C
6	263	128.3	W + W_D + W_W + ΔP (0.01 MPa) + DBE (pool filled)	Service Limit C

The pressure difference at the high temperature is much lower; see 3 SA-096.020, Revision 9, chapter 3.1 which is documented in PSEG VTD 900501 (Reference A.55).

Loads:

W	Weight of strainers, supporting structure, channels
W_D	Weight of Debris
W_W	Hydrodynamic Water Mass and Included Water Mass (occurs only with OBE and DBE)
ΔP	Pressure difference across strainers
OBE	Operating Basis Earthquake
DBE	Design Basis Earthquake

Thermal expansion does not cause significant stresses, for two reasons:

- There are no temperature differences within the steel structure
- Sliding joints are provided between ducts and supports, so that different expansion of steel structure and concrete floor are compensated.

The temperatures are considered for the stress limits.

For the load combinations 4, 5 and 6, hydrodynamic masses are considered. The pockets are assumed to be full of water. Additional mass is conservatively considered for the debris weight (W_D).

OBE and DBE loads are much higher if the pool is filled as if it is dry.

<u>Design Codes and other references utilized in the structural evaluation are as follows</u>

1. PSEG Nuclear LLC, Spec. No. S-C-CAN-MDS-0445, Salem Generating Station Containment Sump Strainers, Detailed Technical and Procurement Specification

2. PSEG Nuclear, "Parameters for Strainer Design" dated July 18, 2005
3. 2004 ASME Boiler and Pressure Vessel Code, Section NF; Supports
4. 2004 ASME Boiler and Pressure Vessel Code, Section II; Part D – Properties (Metric)
5. ASME B31.1-2004, Power Piping
6. HILTI, Kwik Bolt 3, 2005 Product Technical Guide Supplement.
7. AISC, Manual of Steel Construction, Sixth Edition
8. T. Kirk Patton, Tables for Hydrodynamic Mass Factors for Translational Motion
9. Program ANSYS, Rev. 10.0
   Computer: PC, Windows XP Professional
   Author(s): ANSYS Inc., Houston, PA, USA
   Documentations: 4 Vol. User's Manuals
10. Effective Mass and Damping of Submerged Structures, NTIS Document UCRL52342, issued 01 Apr. 1978

3k.3) Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.

In CCI calculation 3 SA-096.020, Revision 9 (Reference A.55) the stress evaluations were sometimes too conservative since even the local stresses were below material allowable limits. This calculation assumed a concurrent loss of coolant accident (LOCA) and seismic event. A more realistic analysis has been performed in calculation 3 SA-096.078, Revision 0 by reducing the conservatism on stresses, since a design basis LOCA and a seismic event are not postulated to occur at the same time. The values in the following tables summarize the limits given in 3 SA-096.078, Revision 0 (Reference A.103), which is Attachment F to PSEG VTD 900501. To identify the design margin, subtract the value in the Stress Ratio columns from 100%.

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Table 3k-2: Summary of Loads and Stresses

Component	Stress Type	Part	Chapter	Loads and Stresses									Material	Stress Ratio				Used pressure	max pressure	Δh
				σ_m		P_m	$\sigma_m + \sigma_b$		$P_m + P_b$					mem	bend	shear				
Module Structure	Plate and Shell	Base Plate Bottom	5.3.7.1	111.0 MPa 16099 psi	<	172.5 MPa 25019 psi	137.0 MPa 19870 psi	<	258.8 MPa 37536 psi				304L	64.3%	52.9%	-		0.040 MPa 5.802 psi	0.062 MPa 9.016 psi	6.36 m 20.88 ft
		Base Plate Top	5.3.7.2	**103.0** MPa 14939 psi	<	172.5 MPa 25019 psi	**201.0** MPa 29153 psi	<	258.8 MPa 37536 psi				304L	59.7%	77.7%	-		0.040 MPa 5.802 psi	0.052 MPa 7.470 psi	5.27 m 17.30 ft
		Duct Plate "Bottom"	5.3.7.3	39.0 MPa 5656 psi	<	172.5 MPa 25019 psi	144.0 MPa 20885 psi	<	258.8 MPa 37536 psi				304L	22.6%	55.6%	-		0.040 MPa 5.802 psi	0.072 MPa 10.427 psi	7.36 m 24.15 ft
		Duct Plate "Top"	5.3.7.4	68.0 MPa 9863 psi	<	172.5 MPa 25019 psi	97.0 MPa 14069 psi	<	258.8 MPa 37536 psi				304L	39.4%	37.5%	-		0.040 MPa 5.802 psi	0.101 MPa 14.717 psi	10.39 m 34.08 ft
		Frame	5.3.7.5	**117.0** MPa 16969 psi	<	172.5 MPa 25019 psi	**201.0** MPa 29153 psi	<	258.8 MPa 37536 psi				304L	67.8%	77.7%	-		0.040 MPa 5.802 psi	0.052 MPa 7.470 psi	5.27 m 17.30 ft
		L-Holder / Flange	5.3.7.6	30.0 MPa 4351 psi	<	172.5 MPa 25019 psi	83.0 MPa 12038 psi	<	258.8 MPa 37536 psi				304L	17.4%	32.1%	-		0.040 MPa 5.802 psi	0.125 MPa 18.090 psi	12.77 m 41.89 ft
		L-Profile	5.3.7.7	**106.0** MPa 15374 psi	<	172.5 MPa 25019 psi	**159.0** MPa 23061 psi	<	258.8 MPa 37536 psi				304L	61.4%	61.4%	-		0.040 MPa 5.802 psi	0.065 MPa 9.441 psi	6.66 m 21.86 ft
		Socket	5.3.7.8	**105.0** MPa 15229 psi	<	172.5 MPa 25019 psi	**201.0** MPa 29153 psi	<	258.8 MPa 37536 psi				304L	60.9%	77.7%	-		0.040 MPa 5.802 psi	0.052 MPa 7.470 psi	5.27 m 17.30 ft
		Trapezoid	5.3.7.9	**95.0** MPa 13779 psi	<	172.5 MPa 25019 psi	**173.0** MPa 25092 psi	<	258.8 MPa 37536 psi				304L	55.1%	66.8%	-		0.040 MPa 5.802 psi	0.060 MPa 8.679 psi	6.13 m 20.10 ft
	Bolts			f_t		F_{tb}	f_v		F_{vb}					tension	shear	combined				
		Frame and duct plate top	5.3.7.11	9.4 MPa 1370 psi	<	194.1 MPa 28152 psi	58.4 MPa 8470 psi	<	80.1 MPa 11618 psi				B8 Class 1	4.9%	72.9%	53.4%		0.040 MPa 5.802 psi	0.055 MPa 7.957 psi	5.62 m 18.43 ft
		Frame and duct plate bottom	5.3.7.11	7.1 MPa 1023 psi	<	194.1 MPa 28152 psi	62.0 MPa 8998 psi	<	80.1 MPa 11618 psi				B8 Class 1	3.6%	77.5%	60.1%		0.040 MPa 5.802 psi	0.052 MPa 7.490 psi	5.29 m 17.35 ft
		Duct plate top and l-holder	5.3.7.11	1.0 MPa 142 psi	<	194.1 MPa 28152 psi	4.9 MPa 711 psi	<	80.1 MPa 11618 psi				B8 Class 1	0.5%	6.1%	0.4%		0.040 MPa 5.802 psi	0.654 MPa 94.837 psi	66.94 m 219.63 ft
		Duct plate bottom and base plate top	5.3.7.11	0.2 MPa 32 psi	<	194.1 MPa 28152 psi	50.0 MPa 7245 psi	<	80.1 MPa 11618 psi				B8 Class 1	0.1%	62.4%	38.9%		0.040 MPa 5.802 psi	0.064 MPa 9.303 psi	6.57 m 21.55 ft
		L-holder and trapez	5.3.7.11	7.2 MPa 1046 psi	<	194.1 MPa 28152 psi	33.5 MPa 4859 psi	<	80.1 MPa 11618 psi				B8 Class 1	3.7%	41.8%	17.6%		0.040 MPa 5.802 psi	0.096 MPa 13.872 psi	9.79 m 32.12 ft
		L-profile and frame	5.3.7.11	15.7 MPa 2274 psi	<	194.1 MPa 28152 psi	56.0 MPa 8115 psi	<	80.1 MPa 11618 psi				B8 Class 1	8.1%	69.9%	49.4%		0.040 MPa 5.802 psi	0.057 MPa 8.306 psi	5.86 m 19.23 ft
		Socket and base plate top	5.3.7.11	5.0 MPa 722 psi	<	284.5 MPa 41263 psi	94.1 MPa 13648 psi	<	117.5 MPa 17042 psi				B8M Class 2	1.8%	80.1%	64.2%		0.040 MPa 5.802 psi	0.050 MPa 7.244 psi	5.11 m 16.78 ft
	Anchor Bolts			T		T_A	S		S_A					tension	shear	combined				
		5/8-in KB III	5.3.7.12	4.1 kN 922 lbf	<	7.3 kN 1641 lbf	8.8 kN 1978 lbf	<	14.5 kN 3260 lbf					56.2%	60.7%	81.7%		0.040 MPa 5.802 psi	0.049 MPa 7.098 psi	5.01 m 16.44 ft
	Buckling			f_a		F_a								f_a/F_a						
		Support Rod	5.3.7.10	22.6 MPa 3283 psi	<	89.8 MPa 13024 psi							304L	25.2%				0.040 MPa 5.802 psi	0.159 MPa 23.016 psi	16.25 m 53.30 ft
		Leveling Screws	5.3.7.11	79.5 MPa 11528 psi	<	127.9 MPa 18557 psi							B8 Class 1	62.1%				0.040 MPa 5.802 psi	0.064 MPa 9.339 psi	6.59 m 21.63 ft
	Linear Type Supports			f_a		F_a	f_{bx}		F_{bx}	f_{by}		F_{by}		axial	bending 1	bending 2	combined			
		Support Rod	5.3.7.10	22.6 MPa 3283 psi	<	89.8 MPa 13024 psi	25.7 MPa 3721 psi	<	170.1 MPa 24673 psi	10.3 MPa 1488 psi	<	170.1 MPa 24673 psi	304L	25.2%	15.1%	6.0%	46.3%	0.040 MPa 5.802 psi	0.086 MPa 12.525 psi	8.84 m 29.01 ft

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Table 3k-2: Summary of Loads and Stresses (cont)

Component	Stress Type	Part	Chapter	Loads and Stresses									Material	Stress Ratio				Used pressure	max pressure	Δh
				σ_m		P_m	$\sigma_m + \sigma_b$		$P_m + P_b$	τ		Shear		mem	bend	shear				
Standard Cartridges	Plate and Shell	Perforated Sheets	6.1.4	120.0 MPa 17405 psi	<	207.0 MPa 30023 psi	180.0 MPa 26107 psi	<	310.5 MPa 45034 psi				304	58.0%	58.0%	-		0.045 MPa 6.527 psi	0.078 MPa 11.259 psi	7.95 m 26.07 ft
		Unperforated Sheets	6.1.4	40.0 MPa 5802 psi	<	207.0 MPa 30023 psi	110.0 MPa 15954 psi	<	310.5 MPa 45034 psi				304	19.3%	35.4%	-		0.045 MPa 6.527 psi	0.127 MPa 18.423 psi	13.00 m 42.66 ft
		Perforated Sheets Pockets	6.2.2.1			207.0 MPa 30023 psi	144.0 MPa 20885 psi	<	310.5 MPa 45034 psi				304	-	46.4%	-		0.045 MPa 6.527 psi	0.097 MPa 14.073 psi	9.93 m 32.59 ft
		Unperforated Sheets Pockets	6.2.2.1			207.0 MPa 30023 psi	110.0 MPa 15954 psi	<	310.5 MPa 45034 psi				304	-	35.4%	-		0.045 MPa 6.527 psi	0.127 MPa 18.423 psi	13.00 m 42.66 ft
		Locking Tabs	6.3	83.3 MPa 12082 psi	<	207.0 MPa 30023 psi				10.0 MPa 1450 psi	<	124.2 MPa 18014 psi	304	40.2%	-	8.1%		0.045 MPa 6.527 psi	0.112 MPa 16.219 psi	11.45 m 37.56 ft
Connection Duct Link	Plate and Shell			σ_m		P_m	$\sigma_m + \sigma_b$		$P_m + P_b$					mem	bend	shear				
		Wall	7.	2.1 MPa 305 psi	<	172.5 MPa 25019 psi	177.0 MPa 25672 psi	<	258.8 MPa 37536 psi				304L	1.2%	68.4%	-		0.042 MPa 6.092 psi	0.061 MPa 8.907 psi	6.29 m 20.63 ft
		Bottom / cover	7.			172.5 MPa 25019 psi	106.0 MPa 15374 psi	<	258.8 MPa 37536 psi				304L	-	41.0%	-		0.042 MPa 6.092 psi	0.103 MPa 14.873 psi	10.50 m 34.44 ft
		Connection duct link support	Attachment C			172.5 MPa 25019 psi	170.0 MPa 24656 psi	<	258.8 MPa 37536 psi				304L	-	65.7%	-		0.042 MPa 6.092 psi	0.064 MPa 9.274 psi	6.55 m 21.48 ft
	Bolts			f_t		F_{tb}	f_v		F_{vb}					tension	shear	combined				
		Wall and bottom / cover	7.	16.6 MPa 2408 psi	<	194.1 MPa 28152 psi	23.0 MPa 3336 psi	<	80.1 MPa 11618 psi				B8 Class 1	8.6%	28.7%	9.0%		0.042 MPa 6.092 psi	0.146 MPa 21.215 psi	14.97 m 49.13 ft
		Wall Parts	7.			194.1 MPa 28152 psi	16.7 MPa 2422 psi	<	80.1 MPa 11618 psi				B8 Class 1	-	20.8%	4.3%		0.042 MPa 6.092 psi	0.201 MPa 29.218 psi	20.62 m 67.66 ft
		Support and Duct	Attachment C	3.0 MPa 435 psi	<	284.5 MPa 41263 psi	99.4 MPa 14417 psi	<	117.5 MPa 17042 psi				B8M Class 2	1.1%	84.6%	71.6%		0.042 MPa 6.092 psi	0.050 MPa 7.201 psi	5.08 m 16.68 ft
	Anchor Bolts			T		T_A	S		S_A					tension	shear	combined				
		5/8-in KB III	Attachment C	0.0 kN 0 lbf	<	7.3 kN 1641 lbf	7.4 kN 1668 lbf	<	14.5 kN 3260 lbf					-	51.2%	32.7%		0.042 MPa 6.092 psi	0.082 MPa 11.904 psi	8.40 m 27.57 ft
Guide Plates	Plate and Shell			σ_m		P_m	$\sigma_m + \sigma_b$		$P_m + P_b$					mem	bend	shear		* The guide plates are not directly affected by the pressure difference. No further considerations.		
		Plates conditions number 1	8.	32.0 MPa 4641 psi	<	172.5 MPa 25019 psi	90.0 MPa 13053 psi	<	258.8 MPa 37536 psi				304L	18.6%	34.8%	-				
		Plates conditions number 2	8.	32.0 MPa 4641 psi	<	172.5 MPa 25019 psi	60.0 MPa 8702 psi	<	258.8 MPa 37536 psi				304L	18.6%	23.2%	-				
	Bolts			f_t		F_{tb}	f_v		F_{vb}					tension	shear	combined				
		Plates conditions number 1	8.	0.0 MPa 0 psi	<	175.7 MPa 25483 psi	10.1 MPa 1465 psi	<	72.5 MPa 10515 psi				B8 Class 1	-	13.9%	1.9%				
		Plates conditions number 2	8.	6.8 MPa 986 psi	<	175.7 MPa 25483 psi	8.5 MPa 1227 psi	<	72.5 MPa 10515 psi				B8 Class 1	3.9%	11.7%	1.5%				
End Plate and Angle Plate	Plate and Shell			σ_m		P_m	$\sigma_m + \sigma_b$		$P_m + P_b$					mem	bend	shear				
		Plates	9	85.9 MPa 12459 psi	<	172.5 MPa 25019 psi	245.0 MPa 35534 psi	<	258.8 MPa 37536 psi				304L	49.8%	94.7%	-		0.050 MPa 7.252 psi	0.053 MPa 7.660 psi	5.41 m 17.74 ft
Sealing Plates	Plate and Shell			σ_m		P_m	$\sigma_m + \sigma_b$		$P_m + P_b$					mem	bend	shear				
		Plates	10	0.0 MPa 0 psi	<	172.5 MPa 25019 psi	202.0 MPa 29298 psi	<	258.8 MPa 37536 psi				304L	-	78.1%	-		0.050 MPa 7.252 psi	0.064 MPa 9.291 psi	6.56 m 21.52 ft

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Table 3k-2: Summary of Loads and Stresses (cont)

Component	Stress Type	Part	Chapter	Loads and Stresses									Material	Stress Ratio				Used pressure	max pressure	Δh
				σ_m		P_m	$\sigma_m + \sigma_b$		$P_m + P_b$					mem	bend	shear				
Suction Box	Plate and Shell	U-Profile	11.3	60.0 MPa 8702 psi	<	207.0 MPa 30023 psi	220.0 MPa 31908 psi	<	310.5 MPa 45034 psi				304	29.0%	70.9%	-		0.060 MPa 8.702 psi	0.085 MPa 12.282 psi	8.67 m 28.44 ft
		L-Profile	11.4	45.0 MPa 6527 psi	<	207.0 MPa 30023 psi	127.0 MPa 18420 psi	<	310.5 MPa 45034 psi				304	21.7%	40.9%	-		0.050 MPa 7.252 psi	0.122 MPa 17.730 psi	12.52 m 41.06 ft
		Steel Sheet	11.5	36.4 MPa 5279 psi	<	207.0 MPa 30023 psi	162.0 MPa 23496 psi	<	310.5 MPa 45034 psi				304	17.6%	52.2%	-		0.060 MPa 8.702 psi	0.115 MPa 16.679 psi	11.77 m 38.63 ft
		Door	11.6	148.5 MPa 21538 psi	<	207.0 MPa 30023 psi	250.0 MPa 36259 psi	<	310.5 MPa 45034 psi				304	71.7%	80.5%	-		0.060 MPa 8.702 psi	0.075 MPa 10.808 psi	7.63 m 25.03 ft
		Diffuser	11.8	0.0 MPa 0 psi	<	207.0 MPa 30023 psi	58.7 MPa 8508 psi	<	310.5 MPa 45034 psi				304	-	18.9%	-		* The diffuser is not directly affected by the pressure difference. No further considerations.		
		Gauge Cover (perforated)	11.9.1.3	48.0 MPa 6962 psi	<	207.0 MPa 30023 psi	74.4 MPa 10791 psi	<	310.5 MPa 45034 psi				304	23.2%	24.0%	-		0.040 MPa 5.802 psi	0.167 MPa 24.212 psi	17.09 m 56.07 ft
		Gauge Cover (non perforated)	11.9.1.3	32.0 MPa 4641 psi	<	207.0 MPa 30023 psi	40.0 MPa 5802 psi	<	310.5 MPa 45034 psi				304	15.5%	12.9%	-		0.040 MPa 5.802 psi	0.259 MPa 37.529 psi	26.49 m 86.91 ft
		Upper Lateral Support	11.9.2.3	31.0 MPa 4496 psi	<	207.0 MPa 30023 psi	31.0 MPa 4496 psi	<	310.5 MPa 45034 psi				304	15.0%	10.0%	-		* This part is not directly affected by the pressure difference. No further considerations.		
		Lower Vertical Support	11.9.3.1	56.0 MPa 8122 psi	<	207.0 MPa 30023 psi	56.0 MPa 8122 psi	<	310.5 MPa 45034 psi				304	27.1%	18.0%	-		* This part is not directly affected by the pressure difference. No further considerations.		
		Level Instrument Bracket	11.10			207.0 MPa 30023 psi	182.0 MPa 26397 psi	<	310.5 MPa 45034 psi				304	-	58.6%	-		0.050 MPa 7.252 psi	0.085 MPa 12.372 psi	8.73 m 28.65 ft
	Bolts			f_t		F_{tb}	f_v		F_{vb}					tension	shear	combined				
		U-Profile	11.3.1	7.9 MPa 1150 psi	<	284.5 MPa 41263 psi	106.0 MPa 15374 psi	<	117.5 MPa 17042 psi				B8M Class 2	2.8%	90.2%	81.5%		0.060 MPa 8.702 psi	0.067 MPa 9.646 psi	6.81 m 22.34 ft
		L-Profile	11.4.1	43.7 MPa 6344 psi	<	284.5 MPa 41263 psi	57.5 MPa 8340 psi	<	117.5 MPa 17042 psi				B8M Class 2	15.4%	48.9%	26.3%		0.050 MPa 7.252 psi	0.102 MPa 14.819 psi	10.46 m 34.32 ft
		Steel Sheet	11.5.1	61.8 MPa 8959 psi	<	284.5 MPa 41263 psi	12.6 MPa 1833 psi	<	117.5 MPa 17042 psi				B8M Class 2	21.7%	10.8%	5.9%		0.060 MPa 8.702 psi	0.276 MPa 40.081 psi	28.29 m 92.82 ft
		Door	11.6.1	77.1 MPa 11187 psi	<	284.5 MPa 41263 psi	69.5 MPa 10080 psi	<	117.5 MPa 17042 psi				B8M Class 2	27.1%	59.1%	42.3%		0.060 MPa 8.702 psi	0.101 MPa 14.712 psi	10.39 m 34.07 ft
		Beam Supports B)	11.7.2	0.0 MPa 0 psi	<	284.5 MPa 41263 psi	93.2 MPa 13518 psi	<	117.5 MPa 17042 psi				B8M Class 2	-	79.3%	62.9%		0.040 MPa 5.802 psi	0.050 MPa 7.314 psi	5.16 m 16.94 ft
		Diffuser	11.8	0.0 MPa 0 psi	<	194.1 MPa 28152 psi	28.1 MPa 4076 psi	<	80.1 MPa 11618 psi				B8 Class 1	-	35.1%	12.3%		* The diffuser is not directly affected by the pressure difference. No further considerations.		
		Gauge Cover	11.9.1.3	4.2 MPa 609 psi	<	194.1 MPa 28152 psi	24.2 MPa 3510 psi	<	80.1 MPa 11618 psi				B8 Class 1	2.2%	30.2%	9.2%		0.040 MPa 5.802 psi	0.132 MPa 19.203 psi	13.55 m 44.47 ft
	Anchor Bolts			T		T_A	S		S_A					tension	shear	combined				
		5/8-in KB III	11.2.1	1.3 kN 299 lbf	<	7.3 kN 1641 lbf	6.1 kN 1371 lbf	<	14.5 kN 3260 lbf					18.2%	42.1%	29.5%		0.040 MPa 5.802 psi	0.095 MPa 13.790 psi	9.73 m 31.94 ft
	Buckling			f_a		F_a								f_a/F_a						
		Beam Support	11.7.1.3.5	27.4 MPa 3974 psi	<	112.5 MPa 16317 psi								24.4%				0.040 MPa 5.802 psi	0.164 MPa 23.820 psi	16.81 m 55.16 ft
	Linear Type Supports			f_a		F_a	f_b		F_b	τ		Shear		axial	bending	shear				
		Beam Supports (+Earthquake)	11.7.1.3.4	21.3 MPa 3089 psi	<	112.5 MPa 16317 psi	**134.0** MPa 19435 psi	<	204.9 MPa 29718 psi	17.3 MPa 2509 psi	<	124.2 MPa 18014 psi		18.9%	65.4%	13.9%		0.040 MPa 5.802 psi	0.061 MPa 8.871 psi	6.26 m 20.54 ft
		Beam Supports (-Earthquake)	11.7.1.3.5	27.4 MPa 3980 psi	<	112.5 MPa 16317 psi	**152.0** MPa 22046 psi	<	204.9 MPa 29718 psi	18.6 MPa 2698 psi	<	124.2 MPa 18014 psi		24.4%	74.2%	15.0%		0.040 MPa 5.802 psi	0.054 MPa 7.821 psi	5.52 m 18.11 ft

The calculations show, that the allowable pressure difference over the parts are:

Component	Maximum Allowable Pressure	Pressure Difference
Module Structure	0.049 MPa / 7.098 psi	**[5.01 m / 16.44 ft]**
Standard Cartridge	0.078 MPa / 11.259 psi	[7.95 m / 26.07 ft]
Connection Duct Link	0.050 MPa / 7.201 psi	[5.08 m / 16.68 ft]
End Plate and Angle Plate	0.053 MPa / 7.660 psi	[5.41 m / 17.74 ft]
Sealing Plates	0.064 MPa / 9.291 psi	[6.56 m / 21.52 ft]
Suction Box	0.051 MPa / 7.333 psi	[5.16 m / 16.94 ft]

The weakest part is the module (anchor bolt) and it defines the maximum allowable pressure of the strainer parts.

Calculation S-C-RHR-MDC-2296 (Reference A.77), uses the above information to determine the structural limit of the strainer assembly.

Since the suction box is downstream of the modules, the minimum head loss of the z-shaped duct (0.554 ft at 4980 gpm) is subtracted from the structural limit of the suction box (16.94 ft) for a direct comparison with the module (16.44 ft) for the same flow condition. The suction box structural limit less the z-shaped duct head loss is 16.39 ft.

Thus, if the total head loss of the sump strainer (up to the suction box) is below the structural limit of the suction box, the structural limit of the module structure will not be exceeded.

Therefore, the structural limit for the evaluation of the sump strainer head losses is that of the suction box, i.e. 16.94 ft.

3k.4) Summarize the evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high-energy line breaks (as applicable).

The new strainer configuration is not exposed to dynamic effects such as pipe whip, jet impingement, and missiles associated with high-energy line breaks. As described in the Salem UFSAR, the bioshield wall and refueling floor serve as barriers between the reactor coolant loops and the containment liner. The UFSAR Section 3.6.5.1.1 states the following:

> "The 3 foot thick wall, which extends from Elevation 81 feet to 130 feet, acts as a barrier between the containment liner and the sources of jet forces, pipe whip, and missiles associated with a failure of the RCS. All "essential components" (safety-related components in the containment which are required for operation during an accident) are located behind these missile barriers and therefore, are not subject to damage resulting from the dynamic effects associated with a LOCA."

The strainer modules are located between the bioshield wall and the containment liner and, therefore, are not exposed to a direct impact of an RCS failure. However, the effect of a high energy line break (HELB) on the strainer modules was re-examined for the RHR injection lines, safety injection lines and the charging lines, which pass through the outer annulus before penetrating the bioshield wall and have one isolation valve outside the bioshield wall. The assessment is based on a review of plant drawings and calculations (Reference A.1).

In order to assess the impact of a HELB on the strainer, a ZOI of 28.6D is selected for the strainer. This is the requirement for MRI with standard bands and is based on Air Jet Impact Tests (AJIT) performed by BWROG. The tested MRI is made of a 0.024 to 0.062 inch stainless steel sheath with stainless steel reflective foils. The AJIT tests that were performed on MRI indicated that the air jet did not directly penetrate the stainless-steel sheaths; rather, the sheaths disassembled at the seams, similar to rivet failures. The results showed that the failure of the MRI was due to the seams being in direct alignment with the jet. Compared to the MRI, the strainer modules and sump enclosure are significantly more robust. The strainer modules have pockets that are 1.5 mm thick or approximately 0.059 inch, which is similar to the tested MRI sheaths. The stainless steel sump enclosure is made of 3 to 4 mm thick solid plate, which is several times the thickness of the MRI that was tested. The support structures for the modules and the enclosure are 6 mm thick and the entire configuration is a bolted assembly. Therefore, the strainers are far sturdier than MRI and the use of a 28.6D ZOI is conservative.

Each RHR cold leg injection line, accumulator injection line, and charging line located in containment contains two check valves inside the bioshield wall. This double isolation reduces the possibility that a HELB would occur outside the bioshield wall since the Reactor Coolant pressure boundary is inside the bioshield.

Each RHR hot leg injection line located in containment contains two check valves; one inside and one outside the bioshield wall. In the case that the check valve inside the bioshield should fail, it is possible to have a HELB outside the bioshield. The largest potential HELB in these lines could occur in an 8 inch line. A 28.6D ZOI would be a sphere with a radius of 19 feet. However, these lines are located near Accumulators 13/23 and 14/24 (which are in a different quadrant than the strainer). Therefore, the new strainer modules and sump enclosure are not located within the ZOI of the RHR hot leg injection lines. Because the strainer modules are not within the ZOI, they would not be affected by a HELB in the RHR hot leg injection lines.

Each cold leg safety injection line contains two check valves; one inside and one outside the bioshield wall. In the case that the check valve inside the bioshield should fail, it is possible to have a HELB outside the bioshield. At this location, the safety injection lines are 2 inches in diameter. A 28.6D ZOI would be a sphere with a radius of 4.8 feet. Although a portion of these lines is located in the same quadrant as the strainer, the new strainer modules and sump enclosure are not located within the ZOI of the cold leg safety injection lines. Because the strainer modules are not within the ZOI, they would not be affected by a HELB in the cold leg safety injection lines.

Each hot leg safety injection line contains two check valves; one inside and one outside the bioshield wall. In the case that the check valve inside the bioshield should fail, it is possible to have a HELB outside the bioshield. At this location, the safety injection lines are 2 inches to 8 inches in diameter. A 28.6D ZOI would be a sphere with a radius of 4.8 feet to 19 feet. However, these lines are either on the opposite side of containment from the strainer or enter the bioshield near Accumulator 13/23 (which is in a different quadrant than the strainer) which is also near the check valve outside the bioshield. Therefore, the new strainer modules and sump enclosure are not located within the ZOI of the hot leg safety injection lines. Because the strainer modules are not within the ZOI, they would not be affected by a HELB in the hot leg safety injection lines.

The charging/safety injection lines contain a single check valve outside the bioshield and a single check valve in each of four branch lines inside the bioshield. In the case where one of the four check valves inside the bioshield should fail, it is possible to have a HELB outside the bioshield. Most of the charging/safety injection lines are located on the other side of the elevator shaft from the strainer modules and therefore a break at this location would not affect the strainer modules. Of the lines that are closer to the strainer modules, the maximum diameter is 1 ½ inch. Using the methodology above, the strainer modules would have to be within 42.9 inches of the break. Since the strainer modules are not within this ZOI, a HELB in the charging/safety injection lines will not affect the integrity of the strainer modules.

The auxiliary pressurizer spray from the charging line contains two isolation valves; one inside the bioshield (CV76) and one outside the bioshield (CV75). For both units, CV75 is right next to the bioshield near the 14/24 quadrant (not near the strainer) and the piping is routed straight from the valve through the bioshield. Therefore a HELB in the auxiliary pressurizer spray from the charging line would not adversely impact the strainers.

The check valves in the RHR, safety injection, and charging lines are located as close as possible to the reactor coolant loop connections, thereby shortening the reactor coolant pressure boundary and minimizing pipe whip. All RHR lines penetrating the bioshield have been anchored to the bioshield wall to prevent reactor coolant pipe rupture forces from being transferred to the containment through the RHR branches.

3k.5) If a backflushing strategy is credited, provide a summary statement regarding the sump strainer structural analysis considering reverse flow.

PSEG did not credit a back flushing strategy in the containment strainer design.

3l. Upstream Effects

The objective of the upstream effects assessment is to evaluate the flowpaths upstream of the containment sump for holdup of inventory which could reduce flow to and possibly starve the sump.

3l.1) Provide a summary of the upstream effects evaluation including the information requested in GL 2004-02 Requested Information Item 2(d)(iv).

GL 2004-02 Requested Information Item 2(d)(iv)
The basis for concluding that the water inventory required to ensure adequate ECCS or CSS recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths.

3l.2) Summarize the evaluation of the flow paths from the postulated break locations and containment spray washdown to identify potential choke points in the flow field upstream of the sump.

3l.3) Summarize measures taken to mitigate potential choke points.

3l.4) Summarize the evaluation of water holdup at installed curbs and/or debris interceptors.

3l.5) Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.

Following is response to Items 3l.1, 3l.2, 3l.3, 3l.4, and 3l.5.

As part of the minimum flood level and debris transport calculations performed in accordance with the NEI Guidance and its associated NRC SER documents (References 2 and 3), flowpaths were identified for returning water to the containment sump strainer, and possible holdup locations were considered. Flowpaths within the containment sump pool were also modeled in a CFD analysis performed as part of the debris transport calculation (Reference A.2).

There is one primary flowpath from the postulated break locations to the strainers. The primary flowpath has water flowing from the break inside the bioshield, out through the bioshield doors and down the stairwells to the outer annulus at elevation 78 feet. A possible choke point for this flowpath is blockage of the bioshield doors.

A secondary flowpath to the strainers includes containment spray washdown flow through openings outside the bioshield area such as stairways, and gratings. A possible choke point for this flowpath is the lower portion of the refueling cavity drain.

The minimum containment flood level calculation (Reference A.21), conservatively accounts for holdup volumes (Refer to section 3g.8 of this response for further details).

Note that in the minimum containment flood level calculation for the refueling cavity only the upper cavity was assumed to be a holdup volume as the lower cavity has a 6 inch opening that allows the water to drain.

The total (upper and lower) Salem refueling cavity volume is approximately 6,550 ft^3 (Reference A.21). The refueling cavity is only filled by containment spray (no break flow fills the refueling cavity).

The Salem reactor cavity volume is approximately 10,400 ft^3 (Reference A.10). The reactor cavity can be filled directly by a break at the reactor vessel nozzle or by overflow from the containment sump volume once the level in the containment reaches the 81 feet 9 inches level (which is 11 inches above the minimum level required for recirculation operation of 80 feet 10 inches).

A break in the RCS piping at the steam generators could potentially block the refueling cavity drain. However, this break will not result in immediate filling of the reactor cavity. For this type of break, it is possible for a piece of debris to be blown up between the steam generators and the enclosure wall and land on the refueling cavity drain on elevation 130 feet. With the drain blocked, any of the containment spray discharge falling into the refueling cavity would be lost to the recirculation pool inventory.

Conversely, a break at the reactor nozzle that leads to direct filling of the reactor cavity will not generate the amount of debris needed to block the refueling cavity drain.

Therefore, the concurrent use of both of these hold up volumes for determining minimum flood level for switchover to recirculation operation is not credible at Salem Unit 1 and 2. Because the reactor cavity has the largest volume, the reactor cavity is considered the limiting case for ECCS inventory hold up for both Salem Unit 1 and 2.

With the above entrapped water, the minimum flood level is determined to be adequate to support ECCS switchover to recirculation.

To prevent personnel access during plant operation and reduce exposure to high radiation areas, the entrance to the Salem inner annulus (bioshield) is restricted. This is accomplished with locked closed wire mesh and folding gates located at the stairwells leading up from the outer annulus to the inner annulus (each Salem Unit has four stairwells). Following a LOCA, water from the break will flow from the inner annulus through these stairwells into the outer annulus area of the containment, where the containment sump is located.

To ensure that water does not get trapped inside the inner annulus in the event of a LOCA, gates in three of the four-bioshield stairwells in each Unit have been modified. The folding gates at three of the four bioshield stairwells have been removed at Units 1 and Unit 2. The door/gate nearest to the strainer module was not modified in either Salem Unit because blockage of these doorways would result in a more tortuous path for debris, thus potentially reducing the overall debris transport to the strainer. An evaluation (Reference A.92) was performed to show that the doors nearest to the strainer that were not modified are structurally adequate to withstand the debris and hydrodynamic loads during a LOCA.

The new strainer configuration includes a debris interceptor that is attached to the front feet of each strainer module. The debris interceptor consists of grating with perforated plate bolted to the back of the grating. This debris interceptor is modeled in the debris transport calculation as a piece of solid plate that is approximately 9 inch high.

Additionally, the sump pit is surrounded by a 9 inch high curb. Neither the debris interceptor nor the sump curb creates holdup volumes as they are located in the outer annulus area. At switchover to recirculation operation all curbs and debris interceptors in the annulus area are fully flooded by the sump pool.

As previously discussed, the curb at the reactor cavity is at elevation 81 feet 9 inch, which is above the minimum water level required for switchover to recirculation operation. Therefore, water already on the containment floor will not flow into the reactor pit prior to switchover. The minimum flood level calculation, however, conservatively assumes that the reactor cavity fills at the start of the LOCA before water begins spilling on the containment floor. With this holdup volume, there is still adequate water to support switchover to recirculation operation.

3m. Downstream Effects – Components and Systems

The objective of the downstream effects, components and systems section is to evaluate the effects of debris carried downstream of the containment sump screen on the function of the ECCS and CSS in terms of potential wear of components and blockage of flow streams.

3m.1) Provide the information requested in GL 04-02 Requested Information Item 2(d)(v) and 2(d)(vi) regarding blockage, plugging, and wear at restrictions and close tolerance locations in the ECCS and CSS downstream of the sump.

GL 2004-02 Requested Information Item 2(d)(v)
The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen, or containment spray nozzles). The discussion should consider the adequacy of the sump screen's mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.

As a result of GL 2004-02 new containment sump screens are installed at Salem. The screens have round holes with nominal diameters of 1/12 inch (2.1 mm) per CCI report 680/41273 (Reference A.23). After installation, these screens were inspected using site procedures S1(2).OP-ST.SJ-0010(Q) and S1(2).OP-ST.SJ-0011(Q) (Reference A.24).

The susceptibility of the ECCS equipment required to pass debris-laden fluid during the recirculation phase after a postulated accident was evaluated to ensure the equipment would function as required. This evaluation was performed in Calculation S-C-RHR-MEE-1883 (Reference A.25). This evaluation determined the ECCS equipment that would be in the post-accident recirculation flow path and compared the dimensions of close-tolerances in this ECCS equipment against a screening criteria up to two (2) times the screen hole size.

The gaps in the bushings and wear rings of the ECCS pumps were determined to have clearances less than 1.1 times the screen hole size, and are classified as close tolerance components, which are discussed in Section 3m.2 of this response.

SI throttling valves, RHR pump mechanical seal heat exchangers and SI stop valves were determined to have a minimum opening of between 1.7 and 2 times the screen openings. These components were reviewed for the effect of wear on their performance using the methodology described in section 3m.3. Since these openings are greater than 1.7 times the screen opening, blockage is not a concern.

3m.2) *GL2004-02 Requested Information Item 2(d)(vi)*
Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

Blockage of components is addressed previously in section 3m.1. Long-term wear calculation S-C-RHR-MDC-2089 (Reference A.18) addresses wear in close tolerance components. It also includes instrument lines, relief valves, piston check valves and post accident sampling system components for the potential for blockage due to debris.

Based on the calculations performed in Calculation S-C-RHR-MDC-2089 (Reference A.18), the pumps, valves and other ECCS and CSS components are not subject to excessive wear due to extended post-accident operation with debris laden fluids.

The In-Service Testing (IST) data for the RHR pumps indicated negligible pump degradation due to normal operations and the calculations for pump wear due to long term operation with debris-laden fluids showed negligible wear on the pump components using the required mission time of 30 days. Therefore, the RHR pumps are not adversely affected by the debris passing downstream of the containment sump screen.

The IST data for the SI pumps indicated some wear due to normal operation. During every refueling outage, the safety injection pumps are tested (Reference A.122) to ensure that they provide the required flow rate. This information is used in Reference A.18 to ensure that the safety injection pumps will perform their intended function during a postulated LOCA for the two day mission time when the debris laden fluid passes through them. The results from this calculation show that the safety injection pumps will perform their intended function during the recirculation phase of a LOCA. In the future, any degrading trends that could potentially impact the availability of the safety injection pumps for the remaining life of the plant will be entered into PSEG's corrective action program to evaluate and resolve the concern.

The C/SI pumps are not required to operate during the recirculation mode.

Calculations showed that the tube thicknesses for the ECCS heat exchangers in the recirculation path remain greater than the minimum required thickness. In addition, it was shown that the amount of wear on the orifices, containment spray nozzles and throttle valves is less than the acceptance criterion for these components.

3m.3) If NRC-approved methods were used (e.g., WCAP-16406-P with accompanying NRC SE), briefly summarize the application of the methods. Indicate where the approved methods were not used or exceptions were taken, and summarize the evaluation of those areas.

The methods of WCAP-16406-P (Reference 27) were used with the guidance of the SER to the WCAP and clarifications described in letters OG-07-510 (Reference 27.1) and LTR-SEE-IV-10-73 (Reference 27.3) and during the October 2007 training teleconference (OG-07-412, Reference 27.2). Calculation S-C-RHR-MDC-2089 (Reference A.18) used more detailed methods where additional quantification was required. Additional debris beyond the amount calculated by recommended transport models was included in the wear evaluation to allow margins for unforeseen plant changes. Noteworthy differences between S-C-RHR-MDC-2089, and WCAP-16406-P (References A.18 and 27, respectively) are described below.

Section 5 of WCAP-16406-P (Reference 27) describes a methodology for calculating debris depletion over time. The WCAP also provides values of depletion coefficients by way of example. The WCAP does not provide specific depletion coefficients. Based on flow rates, volumes and settling velocities at Salem, plant specific depletion coefficients were calculated. These depletion coefficients also credited filtration of particulates as well as fibers on the sump screen where such filtration is supported by plant specific testing. Based on data presented in CCI bypass and head loss test reports (Reference A.83 and A.75) and described in Section 3f.4 for this response submittal, Appendix B of the Salem downstream wear calculation (Reference A.18) calculated a fiber bypass fraction of 1.4%, resulting in an initial fiber removal efficiency of 98%. For conservatism, a value of 97% was used in the calculations in Reference A.18.

The bypass factor calculated in the downstream wear evaluation is 1.4%. This is conservative and overestimates the amount of debris which would bypass the strainer, thereby providing margin to the downstream wear and downstream fuel evaluations.

WCAP-16406-P (Reference 27) provides information on size distribution and settling fraction of coatings. It states that qualified coatings fail as 10 micron particles. This is conservative for pressure drop calculations, but not for downstream calculations. The Salem Unit 1 and 2 specific evaluation used a larger size particle based on vendor information about size of pigments in the coatings, resulting in a more conservative higher calculated wear.

WCAP-16406-P (Reference 27) assumes that unqualified coatings larger than 100 microns will settle. The Salem Unit 1 and 2 calculation uses an empirical correlation for friction factor that does not assume a constantly decreasing laminar friction factor and benchmarks the resulting settling size against NRC-sponsored settling tests documented in NUREG/CR-6916 (Reference 19). Because the paint chips were all assumed to settle with the widest cross section perpendicular to the direction of settling, the calculation showed a larger settling size for a given paint chip and settling velocity. This results in a conservative, benchmarked, plant-specific settling size for particulates.

A pump curve (after wear) is calculated for each Salem ECCS pump rather than utilizing WCAP-16406-P (Reference 27) Figure 8.1-3, which is based on a single stage pump with a particular specific speed. The WCAP pump curve does not bound the calculated wear effect for multi-stage high head, low flow pumps like the High Pressure Safety Injection pump. A more conservative method is used in S-C-RHR-MDC-2089 (Reference A.18). The worn pump curve is evaluated against system requirements to assure that adequate core cooling will be maintained in the recirculation phase after a postulated LOCA.

The WCAP-16406-P (Reference 27) recommendation for support stiffness calculations for pumps not previously analyzed in WCAP-16406-P is not utilized in Reference A.18. For pumps that are not analyzed in WCAP-16406-P, the WCAP suggests using Table R-2 for the centering loads and support stiffness for suction and discharge running clearances. However, this WCAP table was not used in Reference A.18 since individual pump designs may be significantly different from those whose results are reported in Tables R-2 and R-3 of WCAP-16406-P. Instead, the reference support stiffnesses with 2X clearances were calculated and compared to the stiffness calculated with worn out gaps at the end of mission time.

WCAP-16406-P (Reference 27), Appendix O, Section 2.3 recommends an assumed friction factor of 0.01 to maximize wear. During the performance of the calculation, it was found that the rate of wear, measured as gap increase, would be maximum when the combination of parameters, friction factor times bearing length divided by clearance, was set equal to 2/3. Since this can be demonstrated mathematically it is no longer necessary to make an assumption about the friction factor in order to maximize the wear.

WCAP-16406-P (Reference 27) does not explicitly address seal leakage. PSEG interprets Sections 7.2 and 8.1.3 of WCAP-16406-P and its associated SER to state that if debris laden fluid is piped from the recirculation stream to flush a pump's seal then the primary seal would fail as a direct consequence of the postulated LOCA. This would constitute a common mode failure mechanism. Conversely, if fluid from the recirculation stream is not piped to a pump's seal then there is no credible source of debris to fill the seal chamber and the primary pump seal is not assumed to fail as a direct consequence of the postulated LOCA. Such seals would still be subject to a postulated random failure of the pressure boundary as a moderate or high-energy line break. The leakage rate through a pump seal for one-half hour after a postulated primary seal failure was calculated. This calculation included the effects of wear on the components in the seals that would remain intact after a primary seal failure.

Rounding the inlet to an orifice in conjunction with increasing the orifice diameter decreases the flow resistance more than just increasing the diameter. In order to account for the effects of rounding the inlet of an orifice by debris Section 8.4 of WCAP-16406-P (Reference 27) recommends a formula taken from the first edition of Idelchik's "Handbook of Hydraulic Resistance". The first edition, translated from Russian in the 1960's has been updated and the corresponding formula from the third edition of Idelchik's "Handbook of Hydraulic Resistance" (Reference 30) was used.

Chemical precipitates that may form in a PWR post-LOCA environment do not pose a significant threat to the safety-related functions of ECCS and CSS components located downstream of the ECCS sump strainer (Reference 48). Therefore, the impact of chemical precipitates on ECCS and CSS components located downstream of the ECCS sump strainer has not been evaluated.

3m.4) Provide a summary and conclusions of downstream evaluations.

The ECCS components and systems that are required to operate and pass debris-laden fluid during the recirculation phase of recovery from a postulated LOCA have been identified. These ECCS components have been evaluated for blockage and wear from debris that would pass through the new containment sump screens. It has been shown that the ECCS equipment at Salem will remain capable of passing sufficient flow to the reactor to adequately cool the core during the recirculation phase of a postulated LOCA.

The in-vessel evaluations are addressed in Section 3n.

3m.5) Provide a summary of design or operational changes made as a result of downstream evaluations.

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

3n. Downstream Effects - Fuel and Vessel

3n.1) Show that the in-vessel effects evaluation is consistent with, or bounded by, the industry generic guidance (WCAP-16793), as modified by NRC staff comments on that document. Briefly summarize the application of the methods. Indicate where the WCAP methods were not used or exceptions were taken, and summarize the evaluation of those areas.

The in-vessel downstream effects analysis for Salem is documented in Calculation S-C-RHR-MDC-2295 (Reference A.13). This calculation utilizes the WCAP-16793-NP methodology (Reference 28) and addresses both material deposition on the fuel rods and core blockage due to fibrous debris which could bypass the containment sump strainer.

The NRC has not yet issued a Safety Evaluation for WCAP-16793-NP (Reference 28). Consequently, the in-vessel downstream effects evaluation may require revision after the SER is issued.

Calculation S-C-RHR-MDC-2295 (Reference A.13) first addresses material deposition on the fuel rods which may interfere with the transfer of heat to the coolant and result in excessive fuel cladding temperatures. The calculation uses plant specific conditions as input and the methodology recommended in WCAP-16793-NP (Reference 28), the second option from the Additional Guidance for Modeling Post-LOCA Core Deposition which is contained in the enclosure to PWROG letter OG-07-534 (Reference 31), and the modified methodology to determine aluminum release contained in PWROG letter OG-08-64 (Reference 35). The insulation debris volumes and the aluminum surface areas and masses used in the fuel deposition analysis were taken from the chemical effects analysis (Reference A.4) and conservatively increased by 20%.

The primary mode of deposition is boiling in the core. The plate-out of the chemicals that are introduced into the containment sump as a result of a LOCA was analyzed. These chemicals are from materials that are in the reactor coolant and containment (i.e., aluminum, insulation, and concrete) that dissolve, and are added to the recirculating water in the sump. The calculation also addresses the potential for fiber which bypasses the sump strainer to deposit on the fuel rods.

Calculation S-C-RHR-MDC-2295 (Reference A.13) determines the thickness of the material deposited on the fuel cladding to be 28.4 mils. This is below the recommended limit of 50 mils provided in WCAP-16793-NP (Reference 28). The maximum temperature of the fuel cladding over the 30 days following the LOCA is calculated to be 390 °F. This is below the recommended limit of 800°F provided in WCAP-16793-NP (Reference 28).

The second issue addressed in Calculation S-C-RHR-MDC-2295 (Reference A.13) is blockage of the core due to fibrous debris which could bypass the containment sump strainer. Revision 2 of WCAP-16793-NP (Reference 28) concludes that plants with less than 15 grams of fiber bypass per fuel assembly in the core will have acceptable long term core cooling. The potential fiber bypass quantity for Salem is calculated based on the results of strainer bypass testing conducted by CCI and described in Section 3f.4.1.6 of this response.

The preparation of the fibrous debris used in the bypass tests is described in Section 3f.4.1.5.7.1 of this response and is consistent with the fibrous debris preparation guidelines issued by NEI (Reference 50). Specifically the NUKON and Kaowool fibrous debris was baked in an oven and separated using a high pressure water jet to obtain readily suspendible, prototypical debris for use in the test. The anti-sweat fiberglass (Fiberglas) was prepared in the same manner, except that it was not baked since it is not installed on hot piping in the plant.

The prototypical approach or penetration velocity (volumetric flow rate divided by screen area) that was used in the Salem fiber bypass tests was 0.0569 in/s (Reference A.75). This is more than a factor of forty lower than the penetration velocities documented in NUREG/CR-6885 (Reference 51) due to the large screen area installed at Salem.

Calculation S-C-RHR-MDC-2295 (Reference A.13) concludes that the potential fiber debris bypass quantity is 9.7 grams per fuel assembly. This compares favorably to the acceptance criteria of 15 grams per fuel assembly from WCAP-16793-NP (Reference 28). The favorable results are in part due to the prototypical preparation of the fibrous debris and the low, prototypical approach velocity of the containment sump strainer described above.

3o. Chemical Effects

3o.1) Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.

In June of 2008, a strainer module representative of the strainer modules at Salem was tested by CCI under flow and debris conditions that were scaled to the conditions at Salem at the time (Reference A.75). Chemical effects were also included in these tests. CCI head loss Test 5 for Salem Unit 1 was performed from June 4 through June 12. CCI head loss Test 6 for Salem Unit 2 was performed from June 16 to June 24. The results of these tests were used to determine the maximum expected strainer head loss as a function of containment sump temperature in Reference A.77. The testing and head loss calculation are described in detail in Sections 3f.4.1.5, 3f.4.2.3, 3f.9 and 3f.10 of this response.

Reference A.77 also determines the maximum allowable strainer head loss based on the structural considerations of the strainer modules and the suction box. For all sump temperatures, it is shown in Reference A.77 that the expected strainer head loss is less than the allowable structural limit.

The Net Positive Suction Head Available (NPSHa) for the ECCS pumps is determined as a function of containment sump temperature using the strainer head loss results in Reference A.41. The NPSHa is determined for one and two pump operation during cold leg recirculation, hot leg recirculation, and containment spray recirculation for both Salem Units. By subtracting the required NPSH from the

NPSHa, the NPSH margin is found for each scenario. Similarly, the structural limit on the strainer is determined (Reference A.103). The structural margin is the difference between the structural limit and the strainer head loss. The strainer head loss margin is the limiting margin between the NPSH margin and the strainer structural margin. The limiting strainer head loss margin for Unit 1 is approximately 1.6 feet, which occurs for single pump operation during cold leg recirculation prior to the formation of chemical precipitates. The limiting strainer head loss margin for Unit 2 is approximately 1.1 feet, which occurs for single pump operation during hot leg recirculation prior to the formation of chemical precipitates. The limiting strainer head loss margins following chemical precipitate formation are 8.8 feet for Unit 1 (for single pump operation during cold leg recirculation) and 4.1 feet for Unit 2 (for two pump operation during containment spray recirculation).

Therefore, the strainer head loss with debris and chemical effects is acceptable considering both the structural limits and the NPSH requirements.

The in-vessel chemical effects analysis which addresses long-term cooling is described in the response to Item 3n of this response.

3o.2) Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425). This document was revised by Enclosure 3 to a letter from the NRC to NEI dated March 28, 2008 (ADAMS Accession No. ML080380214).

Responses to the content guidance in Enclosure 3 in the letters from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425) and March 28, 2008 (ADAMS Accession No. ML080380214) are provided in the following subsections (3o.1.x).

3o.1.1d(i) <u>Sufficient 'Clean' Strainer Area</u>: Those licensees performing a simplified chemical effects analysis should justify the use of this simplified approach by providing the amount of debris determined to reach the strainer, the amount of bare strainer area and how it was determined, and any additional information that is needed to show why a more detailed chemical effects analysis is not needed.

Salem is not performing a simplified chemical effects analysis.

The quantity of chemicals (aluminum, calcium, and silicon) dissolved in the post-LOCA sump pool and precipitates generated were determined using the methodology from WCAP-16530-NP (Reference 24). The chemical precipitate quantities were then provided to the screen vendor, CCI, so that prototypical chemical effects head loss tests could be performed.

3o.1.2d(i) Debris Bed Formation: Licensees should discuss why the debris from the break location selected for plant-specific head loss testing with chemical precipitate yields the maximum head loss. For example, plant X has break location 1 that would produce maximum head loss without consideration of chemical effects. However, break location 2, with chemical effects considered, produces greater head loss than break location 1. Therefore, the debris for head loss testing with chemical effects should be based on break location 2.

The equivalent debris quantities used by the screen vendor in the head loss tests (Reference A.74) are shown to be greater than the maximum debris quantities that transport to the strainer modules in Section 3f.4.1.5.8 of this response and Section 5.6 of Reference A.2. The use of the maximum debris load ensures the maximum head loss in the tests. Break selection criteria are discussed in detail in Section 3a of this response. Debris transport is discussed in detail in Section 3e of this response.

The maximum 30-day chemical precipitate quantities (aluminum, calcium, and silicon) for Salem Unit 1 (based on a jacketed NUKON ZOI of 7D) and Unit 2 were also provided to the screen vendor for head loss testing. The chemical precipitate quantities are based on the breaks that generate the most debris (NUKON, Kaowool, anti-sweat fiberglass, and Min-K) which is expected to dissolve when submerged in the containment sump pool or exposed to containment spray. Inputs to the chemical effects analysis are described in more detail in the response to Item 3o.1.3d(i).

The total equivalent chemical precipitate quantities used by the screen vendor in the head loss tests (Reference A.74) for Unit 2 are shown to be greater than the maximum 30-day precipitate chemical quantities in Section 6.0 of the chemical effects analysis (Reference A.4), which uses the WCAP-16530-NP (Reference 24) methodology. This comparison is repeated in Section 3o.1.21d(i) of this response. The tested precipitate quantity used for Unit 1, which does not bound the maximum 30-day precipitate chemical quantity, is discussed in detail in Section 3o.1.17d(ii) of this response. Due to the nature of the debris bed at Salem Units 1 and 2, the maximum head loss with chemical precipitates is observed prior to addition of the total 30-day chemical precipitate quantity. Thus, the tested chemical precipitate debris load resulted in the worst-case head loss for both Units 1 and 2.

Thus, the debris load and chemical precipitate quantities used in the screen vendor chemical effects head loss testing resulted in the worst-case head loss. Note that testing was performed individually for each Salem Unit and therefore debris loads and dissolved chemical quantities were provided individually for each Salem Unit.

3o.1.3d(i) ***Plant Specific Materials and Buffers:*** **Licensees should provide their assumptions (and basis for the assumptions) used to determine chemical effects loading: pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects.**

The chemical effects analysis for Salem Unit 1 and 2 is documented in calculation S-C-RHR-MDC-2298 (Reference A.4). This calculation determined both the quantity of chemicals which are dissolved in the post-LOCA sump as well as the predicted quantity of precipitate present in the post-LOCA sump using the methodology (and spreadsheet) outlined in WCAP-16530-NP (Reference 24).

Descriptions of the primary inputs to the chemical effects analysis are provided in the following paragraphs. Salem Unit 1 and 2 are similar, and therefore all inputs apply to both Salem Units unless otherwise specified.

The materials in containment which are exposed to the sump pool and containment spray in the post-LOCA environment and which, when dissolved, may lead to precipitates in the post-LOCA sump pool are: NUKON, Kaowool, anti-sweat fiberglass, Min-K, latent debris, exposed aluminum metal, aluminum paint, and exposed concrete. This is consistent with the guidance in WCAP-16530-NP (Reference 24).

All LOCA generated debris (NUKON, Kaowool, anti-sweat fiberglass, Min-K, and latent debris) is modeled as being submerged in the sump pool except intact NUKON debris generated in upper containment. Intact NUKON debris in upper containment does not contribute to chemical effects since its cover shields the insulation from containment spray. NUKON and anti-sweat fiberglass release significant amounts of calcium and silicon, and a smaller amount of aluminum. Kaowool releases a significant amount of silicon and aluminum while Min-K releases only silicon. Latent debris is modeled as 85% particulate concrete and 15% fiberglass, and it releases calcium, silicon, and aluminum.

Margin is added to the debris quantities taken from the debris generation calculation (Reference A.1) for use in the chemical effects analysis. The limiting breaks for both Salem Unit 1 and Salem Unit 2 have the largest quantity of each debris type and therefore the maximum debris quantities are used in the chemical effects analysis. This results in conservative calcium, silicon, and aluminum releases in the post-LOCA sump pool.

The following equipment in containment contains exposed aluminum metal: source, intermediate, and power neutron flux monitoring system detectors, control rod drive mechanism connectors, NSSS (Nuclear Steam Supply System), flux mapping drive system, miscellaneous valves, aluminum carabiners, loose material, and tri-band antennas. In the chemical effects analysis, aluminum metal is modeled as submerged or non-submerged. The submerged aluminum metal in containment has a surface area of 12.6 ft^2 and a mass of 25 lbm, which is conservatively increased to 13 ft^2 and 25.75 lbm for the chemical effects analysis. The non-submerged aluminum metal (excluding paint) subject to containment spray in containment has a surface area of 542 ft^2 and a mass of 1194 lbm which is conservatively increased to 558 ft^2 and 1230 lbm for the chemical effects analysis.

Aluminum paint in containment is accounted for separate from aluminum metal in the chemical effects analysis. Submerged exposed aluminum paint in containment has a surface area of 290 ft^2 and a mass of 2.3 lbm, which is conservatively increased to 298.7 ft^2 and 2.4 lbm in the chemical effects analysis. Non-submerged exposed aluminum paint subject to containment spray in containment has a surface area of 2610 ft^2 and a mass of 20.4 lbm, which is conservatively increased to 2688 ft^2 and 21.0 lbm in the chemical effects analysis.

Exposed concrete is concrete which is uncoated, coated with unqualified coating, or coated with qualified coating within the break ZOI. This concrete is subject to dissolution in the post-LOCA environment. The total quantity with margin of exposed concrete in containment used in the chemical effects analysis is 3592 ft^2, of which 983 ft^2 is submerged and 2609 ft^2 is non-submerged and subject to containment spray.

The quantity of debris, aluminum, and concrete which dissolves is dependent upon the characteristics of both the post-LOCA sump pool and the containment spray. The sump pool properties are used to determine dissolution of submerged materials and the spray properties are used to determine dissolution of non-submerged materials. The properties of the sump pool and spray which are most important are: the sump pool volume, the sump water and containment atmosphere temperature profiles, the sump and spray pH profiles and the spray duration.

The maximum sump pool volume is conservatively used in the chemical effects analysis. This results in the greatest quantity of dissolved material since the material dissolution rate is dependent on the concentration of material already dissolved in the sump pool per the WCAP-16530-NP methodology; i.e., the lower the material concentration in the containment sump pool, the higher the dissolution rate, the more material dissolves. The maximum sump pool volume in Calculation S-C-A900-MDC-0082 (Reference A.10) is 463,807 gallons for Unit 1 and 470,838 gallons for Unit 2.

The sump water and the containment atmosphere temperature profiles are taken from WCAP-16503-NP (Reference A.5). The analyses in WCAP-16503-NP are performed using assumptions which maximize the global containment pressure and temperature response to design-basis mass and energy release events. The sump water temperature response for all Salem Unit 1 and 2 scenarios modeled in WCAP-16503-NP were compared to determine the most limiting scenario. The most limiting (highest sump water temperature) scenario identified is for the case with the Salem Unit 2 RSG and a DEPS break with minimum safeguards and no recirculation containment spray. This scenario also results in the most limiting containment atmosphere temperature profile. The containment atmosphere and sump water temperature profiles are provided in Table A.6.3-6 and Figures A.6.3-5 and A.6.3-6 of the WCAP, respectively. The figures are repeated below.

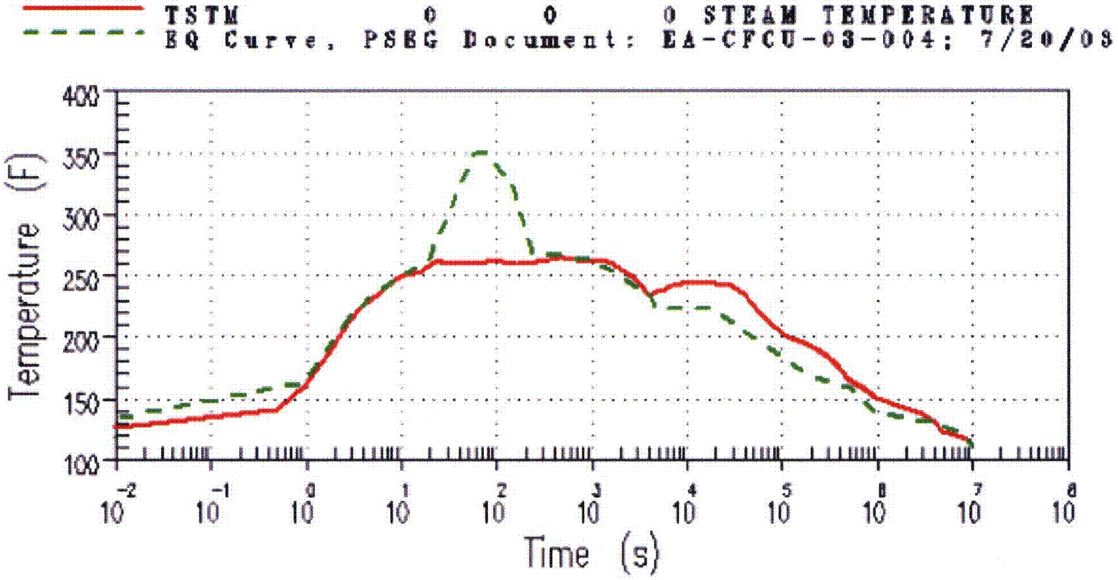


Figure A.6.3-5 Containment Temperature – Double-ended Pump Suction Break with Minimum Safeguards for Salem Unit 2 without Recirculation Spray

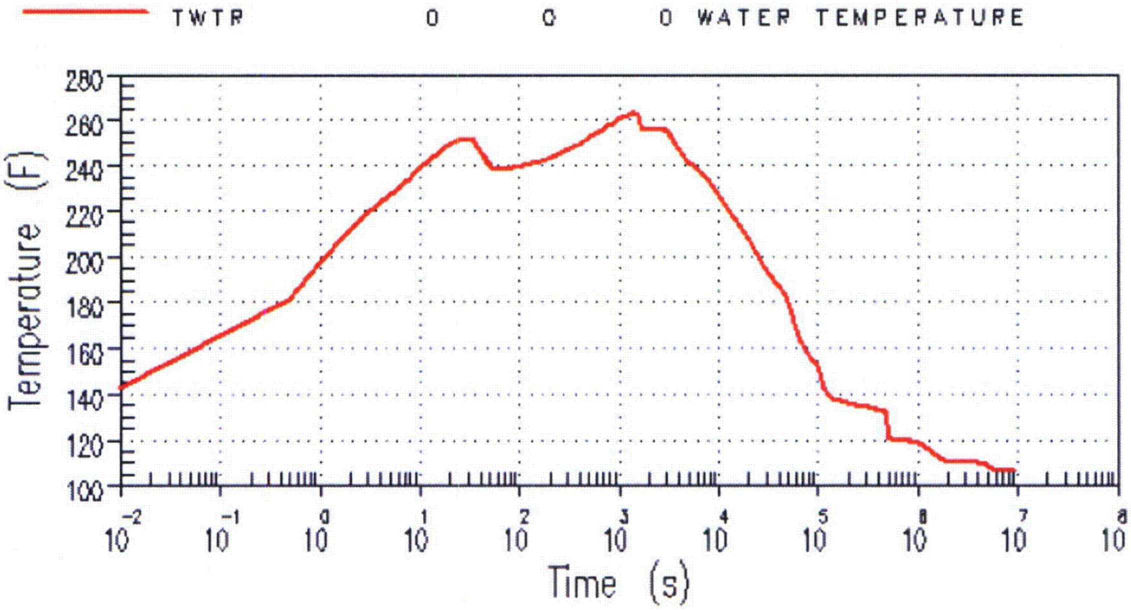


Figure A.6.3-6 Containment Sump Temperature – Double-ended Pump Suction Break with Minimum Safeguards for Salem Unit 2 without Recirculation Spray

The sump and spray pH profiles used in the chemical effects analysis are based on calculation S-C-SJ-MDC-2092 (Reference A.11) and §6.2.3.4.1 of the UFSAR. Per calculation S-C-SJ-MDC-2092 (Reference A.11), the sump pH is 8.4 or greater from 1 hr to 30 days post-LOCA. This pH is applicable to both the sump and spray following the injection phase. Per §6.2.3.4.1 of the UFSAR, the duration of safety injection is 48 minutes, and the spray pH during this time is between 8.5 and 10.0.

The buffer, which is sodium hydroxide (NaOH), is introduced to the containment via the containment spray system. Since higher pH values result in greater aluminum dissolution, both the sump and the spray are modeled with a pH of 10.0 for the first 48 minutes post-LOCA. Following the injection phase (t > 48 minutes), the sump and spray pH are both 8.4.

The event mission time also impacts the quantity of material which dissolves. Per Calculation S-C-SJ-MEE-1978 (Reference A.12), the post-LOCA mission time is 30 days. Therefore, the chemical quantities dissolved in the sump and the predicted precipitate quantities are based on 30-day event duration. Containment spray is conservatively modeled as remaining on for 30 days post-LOCA, which maximizes dissolution of non-submerged materials.

3o.1.4c(i) *Approach to Determine Chemical Source Term (Decision Point)*: Licensees should identify the vendor who performed plant-specific chemical effects testing.

Salem chemical effects testing was performed by CCI with chemical precipitates generated in a separate tank prior to being added to the test loop.

3o.1.5 *Separate Effects Decision (Decision Point)*: State which method of addressing plant-specific chemical effects is used.

The WCAP-16530-NP (Reference 24) methodology is used to determine the quantity of chemical precipitates in the post-LOCA sump for Salem Unit 1 and 2.

3o.1.6d(i) *AECL Model*: Since the NRC staff is not currently aware of the complete details of the testing approach, the NRC staff expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results.

The AECL method is not used by PSEG.

3o.1.6d(ii) *AECL Model*: Licensees should provide the chemical identities and amounts of predicted plant-specific precipitates.

The AECL method is not used by PSEG.

3o.1.7d(i) *WCAP Base Model*: Licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart [in ADAMS Accession No. ML080380214], should justify any deviations from the WCAP base model spreadsheet (i.e., any plant specific refinements) and describe how any exceptions to the base model spreadsheet affected the amount of chemical precipitate predicted.

The base model spreadsheet was originally issued in February 2006, as part of WCAP-16530-NP (Reference 24). Following the initial issuance, errors were discovered in the spreadsheet as described in letter WOG-06-102 (Reference 24.3) and a revised spreadsheet was issued on March 17, 2006, via letter WOG-06-103 (Reference 24.4). Additional errors in the spreadsheet were discovered and were described in letter OG-06-232 (Reference 24.5).

These errors were corrected, and a revised spreadsheet was issued on August 7, 2006, via letter OG-06-255 (Reference 24.6). Following this issuance of the spreadsheet, one additional error in the spreadsheet was discovered as described in letter OG-06-273 (Reference 24.7), dated August 28, 2006. However, no revision to the WCAP spreadsheet was issued following the issuance of letter OG-06-273.

The spreadsheet used in Calculation S-C-RHR-MDC-2298 (Reference A.4) is based on that issued via letter OG-06-255 (Reference 24.6); however, the spreadsheet was modified to address the error described in Letter OG-06-273 (Reference 24.7). The error correction involved changing a cell reference in several worksheets as is described in letter OG-06-273. Letter OG-06-273 states that this error only impacts plants which use TSP for a buffer. Since Salem Unit 1 and 2 utilize a sodium hydroxide buffer, this error and its associated correction do not impact the Salem Unit 1 and 2 results.

In addition, sheets were added to the WCAP-16530-NP (Reference 24) spreadsheet to explicitly address aluminum paint and particulate concrete separately from aluminum metal and exposed concrete. These sheets were added since the WCAP-16530-NP spreadsheet modeled the dissolution of aluminum metal and exposed concrete as a function of surface area, not thickness.

Hence, dissolution of aluminum metal and exposed concrete continues throughout the duration of the event based on the implicit assumption that there is an unlimited quantity of each material. Given the limited thickness/quantity of aluminum paint and limited mass of particulate concrete, the assumption of indefinite dissolution was not appropriate for these two materials.

Therefore, separate sheets were added such that dissolution of aluminum paint and particulate concrete continued only to the point at which all aluminum paint and particulate concrete was dissolved.

Other than the modifications mentioned above, no other changes to the WCAP base model spreadsheet were made in the Salem Unit 1 and 2 chemical effects analysis. Also, no plant-specific refinements presented in WCAP-16785-NP (Reference 25) were incorporated into the WCAP-16530 base model spreadsheet.

The PWROG responses to the relevant NRC RAIs (References 24.1, 24.2 and 24.8) and the NRC SE (Reference 24.9) were considered in the Salem chemical effects analysis, and were found to not affect the results.

OG-06-387 (Reference 24.1) RAI #24 discusses the aluminum corrosion rate from ICET Test 1 and OG-07-129 (Reference 24.2) (RAI #6) includes a set of correlation coefficients that was developed by the NRC based on ICET Test 1 data (which has a relatively high initial dissolution rate). The NRC correlation coefficients result in a higher mass of precipitate. OG-07-408 (Reference 24.8, top of page 6) and the NRC SE (Reference 24.9, page 14) note that the aluminum corrosion rates in WCAP-16530-NP are not conservative over the first 15 days but the cumulative 30-day integrated aluminum corrosion product release rate is appropriate. This information along with some editorial changes was included in the approved version of the chemical model documentation, WCAP-16530-NP-A (Reference 24.10), by attaching the NRC SE to the original document. Therefore, the release rates and integrated aluminum corrosion products for intermediate times (i.e., less than 30 days) found in the spreadsheets in Calculation S-C-RHR-MDC-2298 (Reference A.4, Attachments 1A, 1B, 1C, and 8) are not conservative and were not used. Therefore, only the resulting 30-day precipitate masses were conservatively used in the CCI chemical effects head loss tests.

3o.1.7d(ii) *<u>WCAP Base Model</u>*: Licensees should list the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.

The maximum quantities of dissolved chemicals and generated precipitates in the post-LOCA sump are determined in Calculation S-C-RHR-MDC-2298 (Reference A.4) and are repeated below. The values presented in the table below are the quantities of chemicals which dissolve in the post-LOCA sump over 30 days following a LOCA.

Table 3o-1: Maximum Dissolved Chemicals

Chemical	Salem Unit 1	Salem Unit 2
Aluminum (g)	43,741	41,962
Silicon (g)	112,698	57,743
Calcium (g)	24,863	13,890

In addition to the dissolved chemical quantities, the chemical effects analysis also predicts the quantity of precipitate which will form over 30 days following a LOCA due to the dissolved chemicals.

Table 3o-2: Maximum Precipitates

Chemical	Salem Unit 1	Salem Unit 2
Sodium Aluminum Silicate, $NaAlSi_3O_8$ (g)	350,491	180,065
Aluminum Oxyhydroxide, AlOOH (g)	17,045	51,691
Calcium Phosphate, $Ca_3(PO_4)_2$ (g)	0.0	0.0
Total (g)	367,536	231,756

3o.1.8 *WCAP Refinements*: State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

The Salem Unit 1 and 2 chemical effects analysis, Calculation S-C-RHR-MDC-2298 (Reference A.4), did not utilize any of the refinements described in WCAP-16785-NP (Reference 25).

3o.1.9d(i) *Solubility of Phosphates, Silicates and Al Alloys*: Licensees should clearly identify any refinements (plant-specific inputs) to the base WCAP-16530 model and justify why the plant-specific refinement is valid.

The Salem Unit 1 and 2 chemical effects analysis, Calculation S-C-RHR-MDC-2298 (Reference A.4), did not utilize any of the refinements described in WCAP-16785-NP (Reference 25).

3o.1.9d(ii) *Solubility of Phosphates, Silicates and Al Alloys*: For crediting inhibition of aluminum that is not submerged, licensees should provide the substantiation for the following: (1) the threshold concentration of silica or phosphate needed to passivate aluminum, (2) the time needed to reach a phosphate or silicate level in the pool that would result in aluminum passivation, and (3) the amount of containment spray time (following the

achieved threshold of chemicals) before aluminum that is sprayed is assumed to be passivated.

The Salem Unit 1 and 2 chemical effects analysis, Calculation S-C-RHR-MDC-2298 (Reference A.4), did not utilize any of the refinements described in WCAP-16785-NP (Reference 25). Specifically, the analysis does not model aluminum passivation.

3o.1.9d(iii) *Solubility of Phosphates, Silicates and Al Alloys*: For any attempts to credit solubility (including performing integrated testing), licensees should provide the technical basis that supports extrapolating solubility test data to plant-specific conditions. In addition, licensees should indicate why the overall chemical effects evaluation remains conservative when crediting solubility given that small amount of chemical precipitate can produce significant increases in head loss.

The Salem Unit 1 and 2 chemical effects analysis, Calculation S-C-RHR-MDC-2298 (Reference A.4), did not utilize any of the refinements described in WCAP-16785-NP (Reference 25). Specifically, the analysis does not credit solubility of phosphates, silicates, or aluminum alloys.

3o.1.9d(iv) *Solubility of Phosphates, Silicates and Al Alloys*: Licensees should list the type (e.g., AlOOH) and amount of predicted plant specific precipitates.

The Salem Unit 1 and 2 chemical effects analysis, Calculation S-C-RHR-MDC-2298 (Reference A.4), did not utilize any of the refinements described in WCAP-16785-NP (Reference 25). The type and amount of predicted plant precipitates based on WCAP-16530-NP analysis are provided in the response to Item 3o.1.7d(ii).

3o.1.10 *Precipitate Generation (Decision Point)*:
State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.

In previous testing, precipitates were formed by chemical injection. However, for the design basis chemical effects head loss testing performed in 2008, precipitate generation was performed in a separate mixing tank per the methodology in WCAP-16530-NP (Reference 24). The precipitates were added to the test flume in four portions after the non-chemical debris. Between each of the four chemical additions there was a wait of at least four hours to allow the water to clear. Any settled debris was agitated to put it back in suspension. The chemical head loss test procedure is presented in detail in Section 3f.4.1.5 of this response.

3o.1.11d(i) ***Chemical Injection into the Loop*:**
Licensees should provide the one-hour settled volume (e.g., 80 ml of 100 ml solution remained cloudy) for precipitate prepared with the same sequence as with the plant-specific, in-situ chemical injection.

The design basis Salem testing used precipitate generation outside the loop in accordance with Westinghouse WCAP-16530-NP. The precipitates were transferred to the test loop via pump. No dissolved chemicals were injected into the test loop.

3o.1.11d(ii) ***Chemical Injection into the Loop*:**
For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminum), the percentage that precipitates, and the percentage that remains dissolved during testing.

The design basis Salem testing used precipitate generation outside the loop in accordance with Westinghouse WCAP-16530-NP. The precipitates were transferred to the test loop via pump. No dissolved chemicals were injected into the test loop.

3o.1.11d(iii) ***Chemical Injection into the Loop*:**
Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100 percent, 140 percent of the amount calculated for the plant).

The design basis Salem testing used precipitate generation outside the loop in accordance with Westinghouse WCAP-16530-NP. The precipitates were transferred to the test loop via pump. No dissolved chemicals were injected into the test loop. The mass of precipitates added to the test loop was equivalent to 100 percent of the calculated 30 day precipitate mass in the post-LOCA environment for Unit 2 and 71% of the calculated 30 day precipitate mass in the post-LOCA environment for Unit 1. Justification for the Unit 1 chemical effects head loss tests is provided in Section 3o.1.17d(ii) of this response.

3o.1.12d(i) *Pre-Mix in Tank*:

Licensees should discuss any exceptions taken to the procedure recommended for surrogate precipitate formation in WCAP-16530.

No exceptions were taken to the procedure recommended for surrogate precipitate formation in WCAP-16530. The precipitate generation procedure is based on a procedure written by Westinghouse for the Salem chemical effects head loss tests (Reference A.96).

The guidance of WCAP-16530-NP was used for preparing the precipitates. This includes the use by CCI of the updated 1 hour settled volumes (6.0 ml or greater for Aluminum Oxyhydroxide and Sodium Aluminum Silicate) found in WCAP-16530-NP-A (Reference 24.10) for tests in which the objective is to keep chemical precipitate suspended.

The sodium silicate used by CCI was manufactured by Chemira GmbH while the sodium silicate used in the development of the WCAP-16530-NP methodology was manufactured by EMD Chemicals Inc. Westinghouse verified that the two products were equivalent for the purposes of preparing the sodium aluminum silicate precipitates (Reference A.93).

The amount of precipitate that was prepared was based on the predicted precipitate loading reduced by the scaling factor. The quantity of chemicals used to generate the precipitates added to the test loop is provided in Table 3o-3 (Reference A.74). For Unit 1, the tested precipitate quantity was based on a jacketed NUKON ZOI of 7D while the current design basis is based on a ZOI of 17D. The acceptability of the tests based on the 7D precipitate load is discussed in Section 3o.1.17d(ii) of this response.

Table 3o-3: Quantity of Chemicals Used to Generate Precipitates

		Unit 1 (Test 5, Ref. A.74)	Unit 2 (Test 6, Ref. A.74)
Portions 1-3 (values provided for a single portion)			
Mass of $NaAlSi_3O_8$ Desired	g	987	859
Minimum Initial Water Volume	L	86	74
$Al(NO_3)_3 \cdot 9H_2O$	g	1412	1229
40% $Na_2O{*}3SiO_2$ Solution	g	6983	6122
Minimum Final Water Volume	L	91	78.5
Portion 4			
Mass of AlOOH Desired	g	599	749
Minimum Initial Water Volume	L	52	65
$Al(NO_3)_3 \cdot 9H_2O$	g	3741	4680
30% NaOH Solution	g	3990	5003
Minimum Final Water Volume	L	55	69

For Unit 1, each of the first 3 portions was ~28% and the last portion was ~17% of the total precipitate added during the test. For Unit 2, each of the first 3 portions was ~26% and the last portion was ~23% of the total precipitate added during the test.

The following is a description of the precipitate generation process (Reference A.74). It is based on a precipitate generation procedure written by Westinghouse for the Salem chemical effects head loss tests (Reference A.96).

Preparation of Sodium Aluminum Silicate ($NaAlSi_3O_8$)

- Verify the mixing tank has been rinsed with water and is visibly clean of particulate matter.
- Add the required volume of potable water to the tank.
- Initiate mixing.
- Slowly add the required quantity of aluminum nitrate nonahydrate ($Al(NO_3)_3 \cdot 9H_2O$) and allow to dissolve.
- After aluminum nitrate dissolution is complete (allow at least 15 minutes), slowly add the required quantity of sodium silicate solution ($Na_2O{*}3SiO_2$). A precipitate slurry will form on addition of sodium silicate.
- Continue mixing for a minimum of 60 minutes and then secure mixing.

- Verify that the pH is greater than 6.5 to show that the reaction is complete. Use a 200 mL sample of the precipitate slurry for the one-hour settling volume determination. Dilute the sample to obtain a sodium aluminum silicate concentration of 9.6 to 9.8 grams per liter.

- Obtain and dilute the sample directly after mixing is secured. Mix the sample following dilution in order to homogenize the solution.

- Once the settling criterion is met (see section 3o.1.15d(ii) of this response), transfer the contents of the mixing tank to suitably sized storage container(s) or directly to the strainer test loop.

- Re-suspend solids via mixing before transfer to the test loop. If the mixture is stored for greater than 24 hours before introduction into the test loop, remix to homogenize and re-verify the settling criterion is met.

Preparation of Aluminum Oxyhydroxide (AlOOH)

- Verify mixing tank has been rinsed with water and is visibly clean of particulate matter.

- Add the required volume of potable water to the tank.

- Initiate mixing.

- Slowly add the required quantity of aluminum nitrate nonahydrate ($Al(NO_3)_3 \cdot 9H_2O$) and allow to dissolve.

- After aluminum nitrate dissolution is complete (allow at least 15 minutes), slowly add the required quantity of sodium hydroxide solution (NaOH). A precipitate slurry will form on addition of sodium hydroxide.

- Continue mixing for a minimum of 60 minutes, then secure mixing.

- Verify that the pH is greater than 6.5 to show that the reaction is complete. Use a 200 mL sample of the precipitate slurry for one-hour settling volume determination. Dilute the sample to obtain an AlOOH concentration of 2.1 to 2.3 grams per liter.

- Obtain and dilute the sample directly after mixing is secured. Mix the sample following dilution in order to homogenize the solution.

- Once the settling criterion is met (see section 3o.1.15d(ii) of this response), transfer the contents to a storage container or directly to the strainer test loop.

- Re-suspend the solids via mixing before transfer to the test loop. If the mixture is stored for greater than 24 hours before introduction into the test loop, remix to homogenize and re-verify the settling criteria.

3o.1.13 *Technical Approach to Debris Transport (Decision Point)*: State whether near-field settlement is credited or not.

CCI does not credit near-field settlement in the head loss testing. Although some limited amount of debris cannot be prevented from settling directly in front of the strainer (especially if not all debris fits into the pockets), there is no strategy to credit near-field settling. Additionally, any debris which did settle during the design basis head loss testing was re-suspended using agitation in the test loop. The agitation methodology is described in detail in Section 3f.4.1.5.12 of this response.

3o.1.14d(i) *Integrated Head Loss Test with Near-Field Settlement Credit*: Licensees should provide the one-hour or two-hour precipitate settlement values measured within 24 hours of head loss testing.

Near-field settlement is not credited for Salem. Debris was agitated in the flow loop as described in Section 3f.4.1.5.12 of this response. See Section 3o.1.15d(ii) of this response for precipitate settlement values.

3o.1.14d(ii) *Integrated Head Loss Test with Near-Field Settlement Credit*: Licensees should provide a best estimate of the amount of surrogate chemical debris that settles away from the strainer during the test.

Near-field settlement is not credited for Salem. Debris was agitated in the flow loop as described in Section 3f.4.1.5.12 of this response. See Section 3f.4.2.3 of this response for the debris settlement fractions for the chemical effects head loss tests.

3o.1.15d(i) *Head Loss Testing Without Near Field Settlement Credit*: Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable.

The debris settlement fractions for the design basis chemical effects head loss tests are presented in Section 3f.4.2.3 of this response and a detailed discussion of debris agitation is described in Section 3f.4.1.5.12 of this response.

3o.1.15d(ii) *Head Loss Testing Without Near Field Settlement Credit*: Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).

The one hour settled volumes for design basis chemical effects head loss Tests 5 and 6 performed by the strainer vendor, CCI, are in Table 3o-4 (Reference A.75). All settled volumes were measured within 24 hours of the addition of the precipitates to the test flume.

Table 3o-4: One Hour Precipitate Settled Volumes

	Test 5	Test 6
$NaAlSi_3O_8$ Portion 1 (ml)	9.0	9.1
$NaAlSi_3O_8$ Portion 2 (ml)	9.0	9.1
$NaAlSi_3O_8$ Portion 3 (ml)	9.0	8.6
AlOOH (ml)	8.0	8.0

The settled volume for $NaAlSi_3O_8$ and AlOOH must be greater than 6.0 mL when near field settlement is not credited (Reference 24.10). These criteria were met in Tests 5 and 6.

Although near field settlement is not credited, a comparison of the 1 hour settled volume values for $NaAlSi_3O_8$ and AlOOH to the 1 hour settled volume values for the 2.2 g/l concentration line on Figure 7.6-1 in Reference 24 was performed. This comparison is requested in Reference 24.9 for plants which do credit near field settlement. The 1 hour settled volume measurement for the 2.2 g/l concentration line in Figure 7.6-1 is approximately 9.1 ml. The settled volumes of $NaAlSi_3O_8$ and AlOOH in Tests 5 and 6 are equal to or just below this criterion. However, as discussed above, near field settlement is not credited since debris was agitated to ensure maximum transport to the strainer. The total quantity of debris that settled on the floor upstream of the debris interceptor was less than 1% for Test 5 and Test 6 as documented in Section 3f.4.2.3.

3o.1.16d(i) *Test Termination Criteria*: Licensees should provide the test termination criteria.

A change within a +1% to -1% range in strainer pressure drop for 60 continuous minutes was specified as the test termination criterion for design basis head loss Tests 5 and 6 (Reference A.74). The same criterion was used for the debris only portion of the tests as well as the portion of the tests that included chemical effects. If the termination criteria were not met, the test engineer waited at least four hours after the final debris addition before continuing to the next step in the test.

In the debris only portion of Test 5, the most stable head loss observed was a 1.3% change for 60 continuous minutes (Reference A.75). After waiting several days for a more stable observation, the chemical effects portion of the test was started. The most stable head loss observed during the chemical effects portion of Test 5 was 0.9% change for 60 continuous minutes.

In the debris only portion of Test 6, the most stable head loss observed was a 0.7% change for 60 continuous minutes (Reference A.75). The most stable head loss observed during the chemical effects portion of Test 6 was 0.3% change for 60 continuous minutes. Therefore, the test termination criterion was met for both the debris only and the chemical effects head loss portions of CCI Test 6.

3o.1.17d(i) *Data Analysis*:
Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.

The pressure drop curves as a function of time for design basis chemical effects head loss Tests 5 and 6 can be found in Section 3f.4.2.3 of this response.

3o.1.17d(ii) *Data Analysis*:
Licensees should explain any extrapolation methods used for data analysis.

Test Data Extrapolation to 30 Days for Design Basis Tests 5 (Unit 1) and 6 (Unit 2)

The design basis Test 5 (Unit 1) and 6 (Unit 2) strainer head loss tests are based on the total amount of transported debris (including 30 days of fiber erosion) and a 30-day chemical precipitate quantity (References A.2, A.4, and A.74). Therefore, stable head loss measurements during the tests (as documented in Section 3f.4.2.3 of this response) are indicative of the head loss which would be experienced in the plant both prior to chemical precipitate formation and after 30 days (once precipitates have formed). Also, for the head loss during the chemical effects portions of design basis Tests 5 and 6, the maximum head loss prior to channeling is used for the design basis. Test 5 was run for more than 2 days and Test 6 was run for more than 5 days after the peak head loss occurred. The peak head loss with chemical precipitates occurred during the first of four chemical additions during design basis Tests 5 and 6 and neither additional chemical additions nor test duration resulted in a greater head loss than the initial peak value. The first chemical addition was approximately 25% of the total tested 30-day chemical precipitate quantity (Reference A.74). Once channeling was experienced with the full debris load, the head loss did not increase beyond the initial peak. Therefore, extrapolation of the test data to 30 days is not required (Reference A.77).

Applicability of Chemical Effects Head Loss Testing Based on 7D NUKON ZOI

Unit 2 has no jacketed or unjacketed NUKON and design basis Test 6 for Unit 2 used a bounding 30-day chemical precipitate quantity; therefore, the Unit 2 design basis testing was not impacted by the increase in NUKON ZOI from 7D to 17D. However, the trends observed during the Unit 2 design basis testing (Test 6) are used to explain why the Unit 1 design basis testing continues to be applicable, as described below.

Design basis Test 5 for Unit 1 of the 2-Sided MFTL Test Series (described in Sections 3f.4.1.5 and 3f.4.2.3 of this response) was performed using the 30-day chemical precipitate quantity determined using the debris generated based on a jacketed NUKON ZOI of 7D, not 17D. However, the head loss determined during the testing based on a "7D" chemical precipitate load is acceptable for a "17D" chemical precipitate load due to the channeling which was observed since the channeling limits the maximum head loss.

The justification for using the head loss determined during the testing based on a "7D" chemical precipitate load for the head loss expected with a "17D" chemical precipitate load is based on four strainer head loss tests. The four strainer head loss tests considered are design basis Tests 5 and 6 (References A.74 and A.75) and non-design basis Tests 5 and 6 (References A.87 and A.88). The design basis tests were performed with the 2-sided MFTL and are described in Sections 3f.4.1.5 and 3f.4.2.3 of this response, while the non-design basis tests were performed in the 1-sided MFTL and are described in Sections 3f.4.1.4 and 3f.4.2.4 of this response. To compare the design basis and non-design basis non-chemical and chemical debris loads, see Sections 3f.4.1.4.3 and 3f.4.1.5.6 and Sections 3f.4.1.4.4 and 3o.1.7d(ii) of this response, respectively.

In the design basis tests, the chemical precipitates were formed outside of the test loop using the WCAP-16530 method and were added to the test loop in batches.

In the non-design basis tests, the chemical precipitates were formed in situ in the test loop using the CCI chemical injection method. The non-design basis tests are not part of the design basis due to concerns pertaining to debris preparation and observed settling in the tests.

Even though each of the four strainer head loss tests were performed with different chemical and non-chemical debris loads, all four tests resulted in the formation of bore holes, or channeling, through the debris bed before the final batch of chemical debris was added to the test loop. A bore hole occurs when the differential pressure across the debris bed causes the debris that has built up on the strainer to collapse. Once the bore hole forms, the differential pressure that can be supported by the debris bed decreases and the total strainer head loss is reduced. The pressure versus time histories recorded during each of these four tests can be found in Figures 3f.4.2.3.4-1, 3f.4.2.3.5-1, 3f.4.2.4.1-1, and 3f.4.2.4.2-1 of this response. The formation of bore holes is indicated by sudden decrease in differential pressure.

For design basis Test 5 (for Unit 1), the peak debris bed head loss of 142 mbar (4.8 ft) occurred after the addition of 28% (72 kg equivalent) of the tested chemical precipitate load. After the chemical precipitate addition, a bore hole formed and the head loss dropped significantly as can be seen in Figure 3f.4.2.3.4-1 of this response. The debris bed head loss for this same test after the addition of all chemical precipitate (100% of the tested total, 259.7 kg equivalent) was ~100 mbar (~3.4 ft). Thus, the final debris bed head loss was 30% less than the peak head loss.

For design basis Test 6 (for Unit 2), the peak debris bed head loss of 292.5 mbar (9.8 ft) occurred after the addition of 26% (59.9 kg equivalent) of the tested chemical precipitate load. After the chemical precipitate addition, a bore hole formed and the head loss dropped significantly as can be seen in Figure 3f.4.2.3.5-1 of this response. The debris bed head loss for this same test after the addition of all chemical precipitate (100% of the tested total, 231.8 kg equivalent) was ~220 mbar (~7.4 ft). Thus, the final debris bed head loss was 21% less than the peak head loss.

Non-design basis Tests 5 and 6 (both based on Unit 1 debris loads) utilized the same non-chemical and chemical debris loads, both of which were greater than the design basis non-chemical and chemical debris loads. Non-design basis Tests 5 and 6 simulated a total analytical chemical precipitate debris load of 388 kg. However, up to 140% (543 kg equivalent) of the 100% quantity was generated in the test loop to provide margin.

For non-design basis Test 5, bore holes formed after the first chemical addition of 40%. For non-design basis Test 6, bore holes formed after the first chemical addition of 100% (the entire amount was added at once). After the bore holes formed, the head loss increased slightly with further chemical additions, but then reached a limit. The head loss traces for non-design basis Tests 5 and 6 are provided as Figures 3f.4.2.4.1-1 and 3f.4.2.4.2-1 of this response. The phenomenon of experiencing bore holes prior to the maximum head loss is most likely due to the CCI injection method generating precipitates over time versus the WCAP chemical precipitate method in which all precipitates are added to the test loop intact (pre-generated outside the test loop).

For non-design basis Test 5, the stabilized head loss increased from 75.1 to 77 mbar (2.5% increase) when the chemical debris load was increased from 100% to 140%. For non-design basis Test 6, the stabilized head loss increased from 75.5 to 80 mbar (6% increase) when the chemical debris load was increased from 100% to 120%. Based on Figures 3f.4.2.4.1-1 and 3f.4.2.4.2-1 of this response, it is concluded that although additional chemicals may increase the debris bed head loss, the percentage increase would be minimal.

The peak head loss prior to bore hole formation is used for the Salem Unit 1 design basis head loss with chemical effects. As explained in Table 3g-4 of this response, use of the peak Unit 1 debris bed head loss of 142 mbar (4.8 feet) (without temperature or velocity scaling) results in a minimum head loss margin of 8.8 feet (at 159.9°F) for 1-pump operation at low sump temperatures when chemical precipitates are present. At sump temperatures of 150°F and lower, the strainer head loss margin is at least 11.0 feet. The strainer head loss margins when chemical precipitates are present are non-limiting and are much greater than the limiting margin of 1.6 feet for 1-pump operation at high sump temperatures when chemical precipitates are not present.

For the NPSH margin at low sump temperatures to become limiting, the increase in peak debris bed head loss due to increased quantities of chemical precipitates would have to be at least 7.2 feet [=8.8-1.6] or 150% [=7.2/4.8] for 1-pump operation.

The trend demonstrated by each design basis test is that the head loss exhibits an initial increase prior to bore hole formation. The head loss after bore hole formation is relatively stable as the remainder of chemical precipitates are added; any head loss increase experienced is minimal and does not result in a head loss near the peak head loss prior to bore hole formation.

The trend demonstrated by each non-design basis test is that the stabilized head loss continues to increase as more chemicals were added to the test loop. However, the rate of increase of head loss decreases with each chemical addition. The maximum head loss increase was 6% in non-design basis Test 6 when the chemical quantity was increased from 100% to 120%, as explained above.

Therefore, the Unit 1 design basis head loss test (Test 5 of the 2-Sided MFTL test series) is considered valid even with a design basis chemical precipitate debris load greater than the tested chemical precipitate debris load. The bases for this conclusion are summarized below.

- bore holes that limit the peak debris bed strainer head loss form in both design basis and non-design basis strainer head loss tests,
- in the design basis strainer head loss tests the head loss measured after bore hole formation is never higher than the peak head loss measured prior to bore hole formation,
- in the non-design basis strainer head loss tests in which the chemical precipitates were continually forming in the test tank, the greatest increase in head loss after the injection of the total chemical load was 6% when an additional 20% (for a total of 120%) chemical load was added,
- The head loss due to chemical effects would have to increase at least 150% for the low containment sump temperature NPSH margin to become limiting.

3o.1.18d *Integral Generation of Chemical Products In-Situ (Alion)*:

Salem does not utilize the Alion methodology. Therefore, this question is not applicable to Salem.

3o.1.19c(i) *Tank Scaling / Bed Formation*:

Explain how scaling factors for the test facilities are representative or conservative relative to plant-specific values.

The scaling factor is derived as the ratio of the plant screen surface, reduced conservatively by the sacrificial area (500 ft^2) due to stickers, etc., to the test screen surface. This scaling ratio is used for reducing the flow rate and the amounts of debris and chemical precipitates. Together with the geometric similarity (see Section 3f.4.1.5.1 of this response), the testing is prototypical.

Table 3o-5 from Reference A.74 shows the screen area of the ECCS sump strainer and the screen area of the test module used in the test loop. The scaling factor is the result of the division of the two areas.

Table 3o-5: ECCS Strainer and Test Model Screen Areas

Screen Area Plant	Net Screen Area Plant	Screen Area Test Loop	Scaling Factor
Unit 1, 4854 ft^2 (-500 ft^2)	404.5 m^2	5.54 m^2	73.0
Unit 2, 4656 ft^2 (-500 ft^2)	386.1 m^2	5.54 m^2	69.7

The test configuration for Salem is a representative slice of the whole train of modules with proper representation of the two-sided cartridges, the space in front of the module, the flow space above the module, and the space behind the module including the simulation of the containment wall. Together with the scaled flow rate and debris amounts, the debris bed formation is representative of the plant.

3o.1.19c(ii) *Tank Scaling / Bed Formation*:
Explain how bed formation is representative of that expected for the size of materials and debris that is formed in the plant specific evaluation.

The preparation of the debris used in design basis chemical effects head loss Tests 5 and 6 results in a prototypical or conservative debris size distribution. The debris preparation for these tests is described in detail in Section 3f.4.1.5.7 of this response. All debris was added to the test loop as fines, which is consistent with the transport analysis (see Section 3e of this response) in which the majority of debris transported to the strainer is fines. The build-up of the debris bed during a test is presented in Figure 3f.4.1.5.11-1. This figure shows that a relatively uniform debris bed was formed on the strainer during the tests.

The test configuration for Salem is a prototypical slice of the whole train of modules, with proper representation of the two-sided strainer, the space in front of the module, the flow space above the module, and the space behind the module including the simulation of the containment wall. Together with the scaled flow rate and debris amounts, the debris bed formation is representative of the plant (see Section 3f.4.1.5 of this response).

3o.1.20c *Tank Transport*:
Explain how the transport of chemicals and debris in the testing facility is representative or conservative with regard to the expected flow and transport in the plant-specific conditions.

The spaces in front of, above and behind the strainer module and the flow rate in the test loop were representative of the plant. The debris interceptor in front of the strainer and the perforated plate under the strainer were representative of the plant as well (see Section 3f.4.1.5.1 of this response). The debris was added to the to the test flume slowly, with alternating portions of fiber and particulate. Additionally, debris which settled in the test flume was agitated into suspension again as described in Section 3f.4.1.5.12 of this response. Test loop agitation ensured that all debris transported to the immediate vicinity of the strainer. Therefore, the transport of chemicals and debris in the test was representative.

A comparison of the analytically determined transported non-chemical debris to the quantity of tested non-chemical debris is provided in Section 3.f.4.1.5.8 of this response.

3o.1.21d(i) *30-Day Integrated Head Loss Test*:
Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.

The mass of precipitates used in design basis chemical effects head loss Tests 5 and 6 from Reference A.74 are compared to the precipitate masses analytically determined in the chemical effects analysis (Reference A.4) in Table 3o-6.

Table 3o-6: Comparison of Maximum Calculated and Tested Precipitate Masses

	Calculated (Reference A.4)	Tested (Reference A.74)
Test 5 (Unit 1) – $NaAlSi_3O_8$ (g)	350,491	216,000
Test 5 (Unit 1) – AlOOH (g)	17,045	43,700
Unit 1 Total (g)	367,536	259,700
Test 6 (Unit 2) – $NaAlSi_3O_8$ (g)	180,065	179,606
Test 6 (Unit 2) – AlOOH (g)	51,691	52,190
Unit 2 Total (g)	231,756	231,796

The total equivalent precipitate load used in the Unit 2 CCI tests is greater than the total precipitate load calculated for all Salem breaks. For Unit 1, the tested precipitate quantity is based on a jacketed NUKON ZOI of 7D while the current design basis is based on a ZOI of 17D. The acceptability of the Unit 1 tests (based on the 7D precipitate load) is discussed in Section 3o.1.17d(ii) of this response.

It has been determined that the NPSH critical point occurs when the sump temperature is high and the initial partial pressure of air in containment is not credited (see Sections 3g.13 and 3g.15 of this response). The formation of chemical precipitates is also temperature dependent. At higher temperatures, aluminum is more soluble and less likely to precipitate. At lower temperatures, aluminum precipitates are more likely to form.

Benchtop chemical effects testing was performed by Enercon to determine the temperature above which no precipitates form at Salem (Reference A.95). The benchtop testing consisted of a series of temperature controlled beakers each containing borated water and scaled amounts of insulation, aluminum, and concrete debris.

Five separate tests (1-5) were performed each with three replicate beakers (A, B, C). The tests are delineated in Table 3o-7. The debris loads in Enercon Tests 1 and 2 correspond to the debris loads used in CCI design basis head loss Tests 5 and 6. Enercon Tests 3-5 were used to find the sensitivity of the precipitate formation to varying insulation debris loads. Test 3 was performed in case Tests 1 and 2 resulted in excessive precipitate formation. The debris amounts in Test 3 represent a minimal debris load that could be reached with insulation removal if needed. Tests 4 and 5 utilized the bounding Test 1 and 2 debris values from Unit 1 and 2 (with the exception of Min-K) and were performed to provide margin for potential insulation additions or discoveries in the event that Tests 1 and 2 resulted in no precipitates.

Table 3o-7: List of Enercon Benchtop Tests

Test 1	Unit 1 Debris Load used in CCI Head Loss Test 5
Test 2	Unit 2 Debris Load used in CCI Head Loss Test 6
Test 3	Minimum Debris Load with Decrease in Insulation Quantity
Test 4	Composite Debris Load with 5% Increase in Insulation Quantity
Test 5	Composite Debris Load with 10% Increase in Insulation Quantity

The temperature in the beakers was controlled to mimic the first 72 hours of the Salem post-LOCA sump water temperature profile used in the chemical effects calculation (shown in Section 3o.1.3d(i) of this response). Because the test equipment was limited to a maximum temperature of 190 °F, additional aluminum, NUKON, Min-K, and Kaowool were added to the beakers for the first 12 hours. The amounts of additional insulation needed to compensate for the limited maximum temperature in the lab were calculated using the WCAP-16530-NP spreadsheet. First, the scaled debris loads and the sump water temperature profile were input into the spreadsheet to determine prototypical dissolved chemical amounts. Then, the temperature profile in the spreadsheet was limited to 190 °F as it would be in the experiment. Lastly, the debris amounts input into the spreadsheet were increased until the dissolved chemical amounts calculated with the limited temperature profile matched the prototypical dissolved chemical amounts.

The beakers were monitored for three days for precipitate formation. Also samples were periodically taken for ion concentration analysis. Figures 3o-1 through 3o-5 show the Replicate A beakers at 190.0 °F, 166.5 °F, 130.0 °F, 105.0 °F, and 90.0 °F.

Figure 3o-1: 190.0 °F

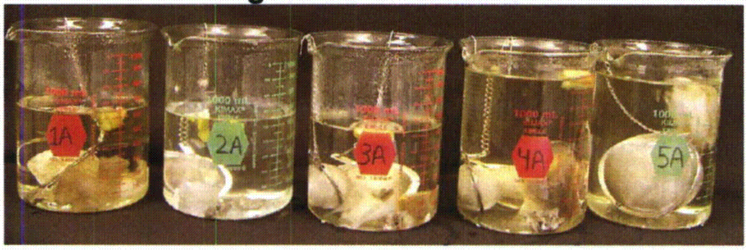


Figure 3o-2: 166.5 °F

Figure 3o-3: 130.0 °F

Figure 3o-4: 105.0 °F

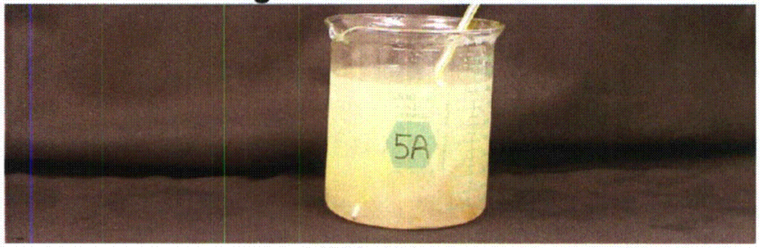
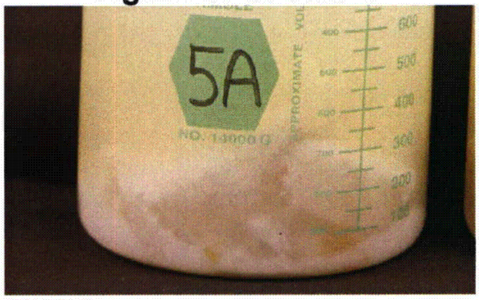


Figure 3o-5: 90.0 °F



Figures 3o-1 through 3o-3 show that the beakers remain clear and precipitate free at elevated temperatures (≥130°F). The first indication of precipitate occurred in the Test 5 beakers at a temperature of 105 °F as shown in Figure 3o-4. When the temperature of the beakers had reached 90 °F, the Test 5 beakers contained significant amounts of settled precipitate. The Test 4 beakers had initial signs of precipitate formation at 94 °F. Similar results were found in the B and C replicate beaker series. No precipitates were observed for Tests 1-3 at temperatures as low as 94°F (the end of the test) (Reference A.95).

The aluminum, silicon, and calcium ion concentrations measured during the benchtop tests were in substantial agreement with predictions made using the WCAP-16530-NP spreadsheet. In Tests 4 and 5, the aluminum and silicon concentrations decreased at the end of the test period. This is consistent with the visual observations that precipitation occurred in Tests 4 and 5 as the solutions cooled (Reference A.95).

The benchtop tests concluded that chemical precipitates will not form in the Salem post-LOCA sump water until it cools to a temperature of 110 °F which conservatively bounds the temperature of 105 °F at which the first indications of precipitation occurred (Reference A.95). However, the temperature at which chemical precipitates form has been conservatively increased to 160 °F in the head loss and NPSH calculations (References A.77 and A.41).

With the increase of the jacketed NUKON ZOI from 7D to 17D, the Unit 1 debris loads used in the Enercon testing no longer bound the analytically determined Unit 1 debris load. The Unit 2 debris load used in the Enercon testing no longer bounds the Unit 2 debris load used in the chemical effects analysis since the chemical effects analysis included margin above the analytically determined debris load. An alternate evaluation was performed to determine the temperature at which chemical precipitates are expected to form. In this evaluation, the concentration of aluminum determined using the WCAP-16530-NP spreadsheet with the increased Unit 1 and Unit 2 debris loads (Reference A.4) is compared to the aluminum solubility functions determined at Argonne National Laboratory (Reference 47).

The most conservative aluminum solubility functions from Reference 47 give aluminum concentration at the point of precipitation as a function of pH and temperature.

$$\left[Al_{ppm}\right] = 26980 * 10^{pH-14.4+0.0243T} \qquad (T \leq 175\ ^\circ F)$$

$$\left[Al_{ppm}\right] = 26980 * 10^{pH-10.41+0.00148T} \qquad (T > 175\ ^\circ F)$$

The 30 day aluminum concentration for Unit 1 with the increased NUKON debris load is 25 ppm with a pH of 8.4 (Reference A.4). The 30 day aluminum concentration for Unit 2 is 23 ppm with a pH of 8.4 (Reference A.4). With a pH of 8.4 and an aluminum concentration of 25 ppm, the solubility functions show that precipitation is expected to occur at temperatures less than 122°F. This result is comparable to the results of the Enercon bench tests. However, the temperature at which chemical precipitates form has been conservatively increased to 160 °F in the head loss and NPSH calculations.

3o.1.21d(ii) ***30-Day Integrated Head Loss Test*:**
Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.

The pressure drop curves as a function of time for design basis chemical effects head loss Tests 5 and 6 can be found in Section 3f.4.2.3 of this response.

3o.1.22d(i) ***Data Analysis Bump Up Factor*:**
Licensees should provide the details and the technical basis that show why the bump-up factor from the particular debris bed in the test is appropriate for application to other debris beds.

PSEG does not use bump-up factors to determine strainer debris bed head losses.

3p. Licensing Basis

The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the sump evaluation or plant modifications.

Provide the information requested in GL 04-02 Requested Information Item 2.(e) regarding changes to the plant licensing basis. The effective date for changes to the licensing basis should be specified. This date should correspond to that specified in the 10 CFR 50.59 evaluation for the change to the licensing basis.

GL 2004-02 Requested Information Item 2(e)
A general description of planned schedule for any changes to the plant licensing bases resulting from any analysis or plant modifications made to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter. Any licensing actions or exemption requests needed to support changes to the plant licensing basis should be included.

PSEG submitted a Licensing Basis Change on August 15, 2007 to revise the licensing basis for the Net Positive Suction Head available (NPSHa) methodology for the ECCS pumps and containment spray recirculation using RHR pumps, as described in Appendix 3A of the Salem Updated Final Safety Analysis Report (UFSAR). The NRC approved the request on November 15, 2007 (Reference A.9), for implementation no later than December 31, 2007. The methodology for crediting the pre-accident partial pressure of air in containment, consistent with these license amendments (Reference A.9), is summarized in Section 3g.13. In support of amendment implementation, PSEG approved changes to the UFSAR description of the NPSHa calculation methodology in November, 2007, and incorporated the changes in Revision 24 of the Salem UFSAR, Appendix 3A, dated May 11, 2009.

PSEG approved and incorporated changes to the Salem UFSAR in support of implementation of the physical plant modifications associated with the containment sump upgrades (References A.31 and A.32). These changes included:

- a revised description of containment sump strainer and debris interceptor design
- revised NPSHa values for ECCS pumps and recirculation containment spray using RHR pumps
- changes for consistency with the debris generation and debris transport calculations (References A.1 and A.2, respectively)
- changes related to the containment sump level instrumentation.

The UFSAR changes associated with these modifications were evaluated in accordance with PSEG's 10CFR50.59 and UFSAR change processes, and did not involve any licensing actions or exemptions from NRC regulations. PSEG completed the incorporation of the UFSAR changes resulting from the containment sump upgrades (References A.31 and A.32) in UFSAR Revision 24, dated May 11, 2009.

In November 2011, PSEG approved changes to the NPSH required (NPSHr) values in UFSAR Table 6.3-13. These changes are consistent with Revision 6 of the NPSH calculation (Reference A.41), which addresses the effect of void fractions at the RHR pump inlet due to deaeration, by applying correction factors for NPSHr as summarized in Section 3g.16. UFSAR Table 6.3-13 is revised to change NPSHr for the Salem Unit 2 cold leg recirculation case with single pump operation, from 22.8 feet to 23.1 feet, and the NPSHr for the Unit 2 hot leg recirculation case with single pump operation, from 24 feet to 24.4 feet. The revised values are consistent with Table 3g-3 of this response. PSEG has evaluated these changes in accordance with our 10CFR50.59 and UFSAR change processes and determined that no licensing actions or exemptions from NRC regulations are needed.

Salem Nuclear Generating Station Units 1 and 2
Docket Nos. 50-272 and 50-311
Generic Letter 2004-02
Updated Response to February 9, 2006 RAIs

GL 2004-02 RAI Response

On February 9, 2006, the Commission issued a Request for Additional Information (RAI) to the Salem site to be answered within 60 days (Reference A.70).

On January 4, 2007, the Commission issued a letter stating that it would allow licensees to include the RAI response in the final GL response for closure of all of the GSI-191 issues no later than December 31, 2007 (Reference 33).

On November 30, 2007, the Commission issued a letter extending the submission of GL response for closure of all of the GSI-191 issues no later than February 29, 2008 (Reference 34).

On February 29, 2008, PSEG submitted RAI responses in Reference A.80. Following are the original RAI responses with updates after each response.

1. **(Not applicable).**

   Updated response: No change.

2. **Identify the amounts (i.e., surface area) of the following materials that are:**

   (a) submerged in the containment pool following a loss-of-coolant accident (LOCA),

   (b) in the containment spray zone following a LOCA:

   - **aluminum**
   - **zinc (from galvanized steel and from inorganic zinc coatings)**
   - **copper**
   - **carbon steel not coated**
   - **uncoated concrete**

   Compare the amounts of these materials in the submerged and spray zones at your plant relative to the scaled amounts of these materials used in the Nuclear Regulatory Commission (NRC) nuclear industry jointly-sponsored Integrated Chemical Effects Tests (ICET) (e.g., 5x the amount of uncoated carbon steel assumed for the ICETs).

   The surface area of submerged and sprayed aluminum (both paint and metal) as well as the surface area of submerged and sprayed exposed concrete is provided below. In addition, the quantity of particulate concrete (i.e. latent particulate debris) is included.

	Submerged Quantity	Sprayed Quantity
Aluminum Metal	9.5 ft^2	489.2 ft^2
Aluminum Paint	500 ft^2	4500 ft^2
Exposed Concrete	983 ft^2	2609 ft^2
Particulate Concrete	170 lbm	0 lbm

Zinc, copper, and uncoated carbon steel are not addressed in the Salem Generating Station chemical effects analysis (Reference A.4) since they would not significantly contribute to precipitate formation in the post-LOCA environment, consistent with WCAP-16530-NP (Reference 24).

The dissolution tests documented in WCAP-16530-NP demonstrated that very little zinc and iron dissolved when exposed to conditions similar to those, which could be expected in a post-LOCA containment. Investigations with copper were not performed by Westinghouse since copper has a very similar corrosion resistance to uncoated carbon steel and galvanized steel per Section 5.1.2 of WCAP-16530-NP (Reference 24).

Calculation VTD 900984, Revision 2 (Reference A.4) contains a comparison of the amount of material submerged versus sprayed (non-submerged) at Salem Generating Station to that used in ICET #1, which is the ICET most representative of Salem Generating Station. This comparison is included in the table below.

Material	ICET #1		Salem		Ratio of Salem to ICET #1	
	Submerged	Sprayed	Submerged	Sprayed	Submerged	Sprayed
Aluminum Metal	5%	95%	1.9%	98.1%	0.38	1.03
Aluminum Paint	N/A	N/A	10.0%	90.0%	N/A	N/A
Exposed Concrete	34%	64%	27.4%	72.6%	0.81	1.13
Particulate Concrete	100%	0%	100%	0%	1.0	1.0

Updated response: The revised aluminum and concrete amounts used in the final chemical effects analysis can be found in Attachment 1, Section 3o.1.3d(i). Chemical effects head loss testing is now based on the WCAP-16530-NP (Reference 24) methodology. Therefore, while ICET #1 still remains representative of Salem, the current design documentation does not perform a comparison to ICET parameters.

3 **Identify the amount (surface area) and material (e.g., aluminum) for any scaffolding stored in containment. Indicate the amount, if any that would be submerged in the containment pool following a LOCA. Clarify if scaffolding material was included in the response to Question 2.**

There is no aluminum scaffolding permanently stored inside Containment.

The scaffold inside the Containment is made of steel material. All the permanent scaffolding stored inside the Salem Unit 1 and 2 Containment is specified on Drawing 605772 (Reference A.38). The drawing has a note that states "The aluminum planks may be stored only during outages and shall be removed prior to containment closures."

Updated response: No change.

4 **Provide the type and amount of any metallic paints or non-stainless steel insulation jacketing (not included in the response to Question 2) that would be either submerged or subjected to containment spray.**

There is no non-stainless steel insulation jacketing in the Salem Unit 1 and 2 containments. The quantity of metallic paint in the Salem Unit 1 and 2 containments is provided in the response to RAI #2.

Updated response: No change. The aluminum paint amounts used in the final chemical effects analysis can be found in Attachment 1, Section 3o.1.3d(i).

5 **Provide the expected containment pool pH during the emergency core cooling system (ECCS) recirculation mission time following a LOCA at the beginning of the fuel cycle and at the end of the fuel cycle. Identify any key assumptions.**

The sump water pH following the ECCS recirculation phase is as follows during the mission time (up to 30 days):

The containment sump pH is much higher at end of cycle (Reference A.58) than the 8.4 value documented in Calculation S-C-SJ-MDC-2092, Rev. 0 for the beginning of Fuel Cycle

Key Assumptions/Inputs are as shown below (S-C-SJ-MDC-2092, Rev. 0, Methodology and Assumptions Sections). These predict lower sump water pH.

A. No credit for CsOH production from the fission product is taken.
B. Hydrogen ion (H^+) production from radiolysis of water and cable is included in the analysis. Beta shielding factor of 10 was assumed.
C. Aerosol source term fraction in sump water is assumed to be 0.8.

Updated response: No change. The pH used in the chemical effects analysis is discussed in Attachment 1, Section 3o.1.3d(i).

6 **For the ICET environment that is the most similar to your plant conditions, compare the expected containment pool conditions to the ICET conditions for the following items: boron concentration, buffering agent concentration, and pH. Identify any other significant differences between the ICET environment and the expected plant-specific environment.**

A comparison of the ICET number 1 conditions to the conditions expected in the post-LOCA Salem Unit 1 and 2 sump pool is provided in calculation VTD 900984, Revision 2 (Reference A.4) and is repeated below. The Salem parameters presented result in the maximum mass of precipitate.

Parameter	Test #1 Data Report	Salem Unit 1 and 2	Units
Duration of Test	30	30	Days
Temperature	140	111 to 265	°F
Boron Concentration	2800	2440	mg/L
Spray Duration	4	720	hours
Maximum spray pH	12	10	
Target solution pH	10	8.4	
Buffer	NaOH	NaOH	
Buffer Concentration	As needed	30	Wt%
NaOH Injection with spray	30	48	minutes
pH Range at 25°C	9.4 to 10.0	8.4	

Updated response: No change.

7 **For a large-break LOCA (LBLOCA), provide the time until ECCS external recirculation initiation and the associated pool temperature and pool volume. Provide estimated pool temperature and pool volume 24 hours after a LBLOCA. Identify the assumptions used for these estimates.**

The LBLOCA (pump suction line double-ended break with minimum safeguards (failure of a complete train) data are shown below:

The ECCS recirculation initiation time:

• Salem Unit 1	1,748 seconds (WCAP-16503-NP, Rev. 3 (Reference A.5), Table 6.3-1)
• Salem Unit 2	1,748 seconds (WCAP-16503-NP, Rev. 3, Table 6.3-2)
• Salem Unit 2 (RSG)	1,748 seconds (WCAP-16503-NP, Rev. 3, Table A.6.3-2)

Sump temperature:

• Salem Unit 1	249°F @ 1,748 seconds (WCAP-16503-NP, Rev. 3, Table 6.3-4)
• Salem Unit 2	252°F @ 1,748 seconds (WCAP-16503-NP, Rev. 3, Table 6.3-6)
• Salem Unit 2 (RSG)	258°F @ 1,748 seconds (WCAP-16503-NP, Rev. 3, Table A6.3-6)
• Salem Unit 1	136°F @ 24 hours (WCAP-16503-NP, Rev. 3, Table 6.3-4)
• Salem Unit 2	136°F @ 24 hours (WCAP-16503-NP, Rev. 3, Table 6.3-6)
• Salem Unit 2 (RSG)	156°F @ 24 hours (WCAP-16503-NP, Rev. 3, Table A6.3-6)

Sump Volume after recirculation (i.e., after 1,748 seconds):

• Salem Unit 1 and 2	456,000 gal (basis provided below)
• Salem Unit 2 (RSG)	459,000 gal (basis provided below)

Note: RSG = Replacement Steam Generator.

During the Salem Unit 2 refueling outage in Spring 2008 the SG will be replaced. The values shown above with (RSG) are for Salem Unit 2 after the steam generator replacement.

The above data are based on the following assumptions:

a) Loss of one ECCS train is assumed.
b) The cooling water temperature for the duration of accident remains at the maximum value, 93°F.
c) Recirculation sprays are not used.
d) Containment fan coolers are used.
e) One RHR and one CCW heat exchanger are used.
f) The total sump volume after the initiation of the recirculation phase is estimated based on minimum usable volumes in accumulators (6,200 gallons per accumulator per UFSAR Table 6.3-2), minimum usable volume in RWST (364,500 gallons per UFSAR Table 6.3-4), nominal volume in Boron Injection Tank (900 gallons per UFSAR Table 6.3-3), and RCS liquid volume (11,892 ft^3 per page 8 of S-C-A900-MDC-0082, Rev. 4A) reduced by water retained in vessel and piping (3,036 ft^3 per page 8 of S-C-A900-MDC-0082, Rev. 4A). It should be noted that the Boron Injection Tank is not utilized for storing boron and is assumed to be filled with water acting just like a pipe. The replacement steam generator volume is 3,000 gallons more than the existing Salem Unit 2 steam generator volume, thus, Salem Unit 2 with RSG sump volume is 3,000 gallons more than Salem Unit 2 with existing steam generators. This estimate neglects less significant terms such as steam in the containment atmosphere, water film on heat sinks, etc.
g) RWST water temperature is 100°F.

Updated response:

The steam generators have been replaced for Unit 2; therefore the initial responses are clarified as follows.

The LBLOCA (pump suction line double-ended break with minimum safeguards (failure of a complete train) data are shown below:

The ECCS recirculation initiation time:

Salem Unit 1	1,748 seconds (WCAP-16503-NP, Rev. 3, Table 6.3-1)
Salem Unit 2	1,748 seconds (WCAP-16503-NP, Rev. 3, Table A.6.3-2)

Sump temperature:

• Salem Unit 1	249°F @ 1,748 seconds (WCAP-16503-NP, Rev. 3, Table 6.3-4)
• Salem Unit 2	258°F @ 1,748 seconds (WCAP-16503-NP, Rev. 3, Table A6.3-6)
• Salem Unit 1	136°F @ 24 hours (WCAP-16503-NP, Rev. 3, Table 6.3-4)
• Salem Unit 2	156°F @ 24 hours (WCAP-16503-NP, Rev. 3, Table A6.3-6)

Sump Volume after recirculation (i.e., after 1,748 seconds):

• Salem Unit 1	452,400 gal (basis provided below)
• Salem Unit 2	459,400 gal (basis provided below)

The above data are based on the following assumptions:

a) Loss of one ECCS train is assumed.
b) The cooling water temperature for the duration of accident remains at the maximum value, 93°F.
c) Recirculation sprays are not used.
d) Containment fan coolers are used.
e) One RHR and one CCW heat exchanger are used.
f) The total sump volume after the initiation of the recirculation phase is estimated based on minimum usable volumes in accumulators (6,200 gallons per accumulator per UFSAR Table 6.3-2), minimum usable volume in RWST (364,500 gallons per UFSAR Table 6.3-4), nominal volume in Boron Injection Tank (900 gallons per UFSAR Table 6.3-3), and RCS liquid volume (11,351 ft^3 for Unit 1 and 12,291 ft^3 for Unit 2 per page 8 of S-C-A900-MDC-0082, Rev. 7, Reference A.10) reduced by water retained in vessel and piping (3,035 ft^3 per Attachment 6 of S-C-A900-MDC-0082, Rev. 7). It should be noted that the Boron Injection Tank is not utilized for storing boron and is assumed to be filled with water acting just like a pipe. This estimate neglects less significant terms such as steam in the containment atmosphere, water film on heat sinks, etc.
g) RWST water temperature is 100°F.

The sump volume in the above discussion is different than the maximum sump volume described in the maximum containment flood level analysis and used within the chemical effects analysis. The maximum water volume from sources that enter containment is 463,807 gallons for Unit 1 and 470,838 gallons for Unit 2 (Reference A.10). The minimum sump volume used for the NPSH and vortexing analyses corresponds to a minimum flood level of 80 feet 11 inches. The minimum sump volume during recirculation of 18,352 ft^3 or 137,282 gallons is determined in Reference A.21.

8 **Discuss your overall strategy to evaluate potential chemical effects including demonstrating that, with chemical effects considered, there is sufficient net positive suction head (NPSH) margin available during the ECCS mission time. Provide an estimated date with milestones for the completion of all chemical effects evaluations.**

Salem has performed a detailed analysis in accordance with WCAP 16530-NP as discussed in detail in Attachment 1 Section 3o of this response.

Salem has previously performed some chemical testing in the MFTL at the vendor facility. These tests showed that the head loss was within the acceptable limits. These tests are being repeated to use a more prototypical test configuration and to resolve some concerns from the NRC regarding testing methodology. This configuration is designed to provide a highly representative post-accident sump environment and sump strainer challenge for Salem Unit 1 and 2.

Salem Unit 1 and 2 testing will be performed at the vendor facility (CCI) in a MFTL using Salem representative precipitates postulated strainer debris loading, and chemicals. The testing is not completed. PSEG has submitted and received an approval for an extension request until June 30, 2008 (Reference A.27). Upon completion of testing and associated calculations, the information will be submitted to NRC.

Updated response: Salem has successfully completed final head loss testing including chemical effects. The results of these tests were used to determine the total head loss across the screen under post-LOCA conditions. This information was used to demonstrate that there is sufficient NPSH margin available during the entire ECCS mission time. These tests and the NPSH analysis are discussed in detail in Attachment 1, Sections 3f.4.1.5, 3f.4.2.3, and 3g.

9 **Identify, if applicable, any plans to remove certain materials from the containment building and/or to make a change from the existing chemicals that buffer containment pool pH following a LOCA.**

At Salem Unit 1 and 2, the calcium silicate insulation has been removed from the zone of influence. Also, Min-K insulation was replaced with Transco RMI wherever possible. Based on the analyses performed, PSEG does not plan to change the existing sodium hydroxide buffer solution.

Updated response: No change.

10 **If bench-top testing is being used to inform plant-specific head loss testing, indicate how the bench-top test parameters (e.g., buffering agent concentrations, pH, materials, etc.) compare to your plant conditions. Describe your plans for addressing uncertainties related to head loss from chemical effects including, but not limited to, use of chemical surrogates, scaling of sample size and test durations. Discuss how it will be determined that allowances made for chemical effects are conservative.**

In previous testing, CCI used bench-top test results to identify the quantity and quality of chemical precipitate generated during actual testing. The future tests will use the full WCAP 16530-NP methodology for external loop precipitate generation. Bench-top testing is not necessary during this testing other than to establish the precipitate settling rate.

Updated response: Additional bench top testing was performed by Enercon to determine the sump temperature at which precipitates can form. These tests are described in Attachment 1, Section 3o.1.21d(i).

11 **Provide a detailed description of any testing that has been or will be performed as part of a plant-specific chemical effects assessment. Identify the vendor, if applicable, that will be performing the testing. Identify the environment (e.g., borated water at pH 9, deionized water, tap water) and test temperature for any plant-specific head loss or transport tests. Discuss how any differences between these test environments and your plant containment pool conditions could affect the behavior of chemical surrogates. Discuss the criteria that will be used to demonstrate that chemical surrogates produced for testing (e.g., head loss, flume) behave in a similar manner physically and chemically as in the ICET environment and plant containment pool environment.**

Previous Testing:
In December 2006, CCI performed its first chemical effects assessment of Salem's replacement ECCS strainers. CCI tested three different debris loads during the tests: Case 1a, Case 1b, and Case 2.

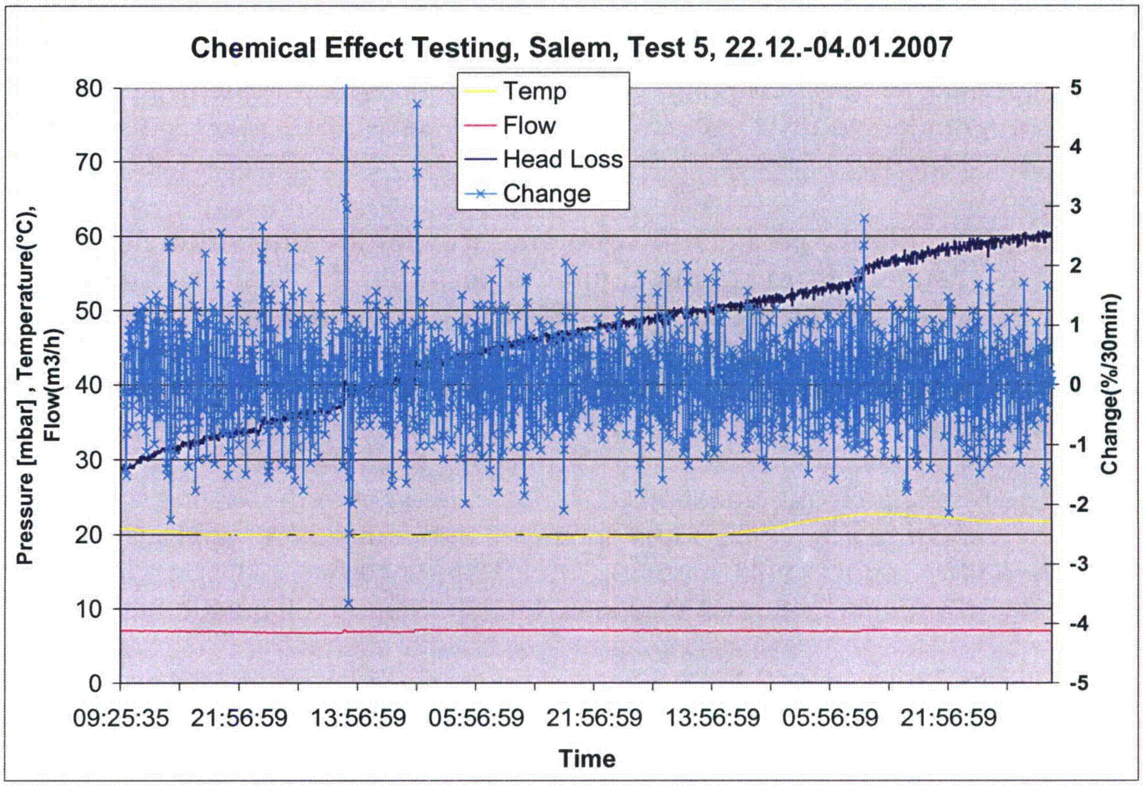
Case 1a was for Salem Unit 1 with NUKON on SG s. Case 1b was for Salem Unit 1 with the NUKON on SG replaced with RMI. Case 2 was for Salem Unit 2. First, chemical bench tests were performed to identify the quantity and quality, including particle size, filterability and settling rates of the precipitate, which would be generated in the actual tests. Chemical assays of the injected chemicals were also performed.

The head loss tests were performed by first filling the MFTL with tap water and borating the loop water. The pH was then checked to be in the 4.5 to 5.5 range and then the debris bed was built. The chemical constituents were then added to generate precipitates in steps of 40%, +30%, +30%, +20%, +20% resulting in ~140% of the total amount of chemical precipitates present in the loop. The loop pH and water temperature are measured throughout the chemical addition process. The pH was maintained at or below 8.4 for 100% or more chemicals. A grab sample was then taken to measure for suspended solids as well as dissolved boron, aluminium, calcium and silica. The extremes for observed water temperature during all testing were: low (12 °C) and high (24°C).

The scaling factors for these tests were 162.5 and 155.1 for Salem Unit 1 and 2 respectively. The flow rates for the tests were scaled from 9000 gpm (two trains) and 5110 gpm (one train) for both Salem Unit 1 and Salem Unit 2.

Test 5 in particular was based on the Case 2 debris load. The test ran for 2 days at 9000 gpm equivalent and demonstrated a peak of 78 mbar. Starting on the 3rd day, the flow was adjusted to the 5110 gpm equivalent and head loss was measured at 28.3 mbar. The loop was left running for the next 13 days and it demonstrated a continuous increase in head loss. The stabilization criterion of 2 periods with 1% per 30 min was fulfilled after planned test duration; however, the head loss rose up and doubled in value over the extended time period. Additionally, the head loss value of 28.3 mbar after reducing the flow rate (to 5110 gpm equivalent) is greater than would be expected if the debris had accumulated at 5110 gpm since the debris accumulation was made with higher flow rate.

The results are plotted here:



Planned Testing:

In head loss testing planned to be performed during March 2008, the tests will be performed using the precipitate generation process described in WCAP 16530-NP and subsequent enclosures, and the associated NRC SER. Precipitates will be formed in an external precipitate generator and their settling rates will be evaluated prior to addition into the test loop. The testing will review head loss in both thin-bed and full load debris scenarios as well as chemical effects on head loss.

For the planned testing, the scaling factors will be 73 and 69.7 for Salem Unit 1 and 2 respectively. The flow rates are the same as previously conducted tests: scaled from 9,000 and 5,110 gpm for Salem Unit 1 and scaled from 9,000 gpm and 4,980 gpm for Salem Unit 2.

For the tests, both the coatings and latent debris particulate is planned to be modelled using stone flour (see Section 3h.4). Additionally, generic fiberglass fines (individual glass fibers which transport to the strainer surface) were modelled as NUKON fines. During the testing any debris, which does settle on the loop floor away from the strainer will be re-suspended via agitation.

Updated response: The final head loss testing including chemical effects was performed in 2008. These tests are described in Attachment 1, Sections 3f.4.1.5 and 3f.4.2.3.

12 **For your plant-specific environment, provide the maximum projected head loss resulting from chemical effects (a) within the first day following a LOCA, and (b) during the entire ECCS recirculation mission time. If the response to this question will be based on testing that is either planned or in progress, provide an estimated date for providing this information to the NRC.**

The response to the question will be completed after the testing is completed at the vendor facility. PSEG has submitted and received an approval for an extension request until June 30, 2008 (Reference A.27). Upon completion of testing and associated calculations, the information will be submitted to NRC.

Updated response: PSEG submitted and received approval for an additional extension request until December 31, 2008 (Reference A.73). The final head loss tests with chemical effects were successfully completed in 2008 and are described in Attachment 1, Sections 3f.4.1.5 and 3f.4.2.3. The strainer head loss as a function of sump temperature is provided in Attachment 1, Section 3f.10. The strainer head loss as a function of sump temperature is plotted in Figures 2, 5, 8, and 11 of Attachment 1, Section 3g.16.

13 **Results from the ICET #1 environment and the ICET #5 environment showed chemical products appeared to form as the test solution cooled from the constant 140 °F test temperature. Discuss how these results are being considered in your evaluation of chemical effects and downstream effects.**

CCI will use the method described in the Westinghouse WCAP 16530-NP to generate chemical precipitates and provide head loss results for the plant.

However, CCI uses the results of viscosity measurements of the ICET tests to assess the influence of the chemicals onto the viscosity of pure water. The difference between viscosity of the ICET #1 solution and pure water is accounted for in the strainer head loss. In-vessel downstream effects are addressed using WCAP 16793-NP (Reference 28).

Updated response: Bench top testing performed by Enercon and the aluminum solubility functions determined by Argonne (Reference 47) are used to determine the temperature at which chemical precipitates form. The results of these tests are described in Attachment 1, Section 3o.1.21d(i).

14 to 24 Not Applicable

Updated response: No change.

25 Describe how your coatings assessment was used to identify degraded qualified/acceptable coatings and determine the amount of debris that will result from these coatings. This should include how the assessment technique(s) demonstrates that qualified/acceptable coatings remain in compliance with plant licensing requirements for design basis accident (DBA) performance. If current examination techniques cannot demonstrate the coatings' ability to meet plant licensing requirements for DBA performance, licensees should describe an augmented testing and inspection program that provides assurance that the qualified/acceptable coatings continue to meet DBA performance requirements. Alternately, assume all containment coatings fail and describe the potential for this debris to transport to the sump.

PSEG conducted walkdowns for evaluating debris sources inside the Salem Unit 1 and 2 containments during 2004 and 2005 as part of the resolution of GL 2004-02 (References A.16 and A.17). The walkdowns provided visual observation of the general condition of the qualified coatings applied to equipment, piping, and structures, and confirmed that the coating locations were in accordance with the design documents.

In addition, during each refueling outage engineering personnel walk through accessible areas of the containment, to observe the conditions of protective coatings installed on concrete and steel substrates. Degraded coatings are initially documented via the Notification process. Notifications are reviewed by engineering and plant branch managers and recommended for the proper level of attention. Work orders are generated from the notifications and prioritized by Station management. The person observing the coating conditions categorizes in the notification text whether the observed degraded condition should be immediately repaired in the current refueling outage, or tracked for future repairs or visual monitoring. Delaminating coatings are typically repaired by removing the delamination, and scraping back to a sound coating.

As part of the newly installed containment sump strainers, PSEG has issued a new coating condition monitoring program (Reference A.66). It provides guidance for the engineering department to conduct assessments of the conditions of the containment coatings during refueling outages. It incorporates the practices of ASTM D5163 (Reference A.39) and includes the adhesion test procedure outlined in EPRI Report 1014883 Section 4 (Reference A.61). It is supplemented with examination techniques to provide assurance that the coatings continue to meet DBA performance requirements.

The calculations for the sizing of the recently installed sump strainers incorporated the assumptions that all non-qualified coatings in containment failed and were transported to the strainers.

Updated response: No change.

26 to 29 **Not applicable**

Updated response: No change.

30 **The NRC staff's safety evaluation (SE) on the NEI guidance report, NEI 04-07 addresses two distinct scenarios for formation of a fiber bed on the sump screen surface. For a thin bed case, the SE states that all coatings debris should be treated as particulate and assumes 100% transport to the sump screen. For the case in which no thin bed is formed, the staff's SE states that the coatings debris should be sized based on plant-specific analyses for debris generated from within the zone of influence (ZOI) and from outside the ZOI, or that a default chip size equivalent to the area of the sump screen openings should be used (Section 3.4.3.6). Describe how your coatings debris characteristics are modeled to account for your plant-specific fiber bed (i.e. thin bed or no thin bed). If your analysis considers both a thin bed and a non-thin bed case, discuss the coatings debris characteristics assumed for each case. If your analysis deviates from the coatings debris characteristics described in the staff-approved methodology, provide justification to support your assumptions.**

Both the previously performed testing as well as upcoming tests include head loss verification for both thin bed and full debris load cases. In both cases CCI has selected a conservative approach and modelled coating debris as particulate (reference response 3h.4). As previously described, smaller particulate has a greater impact on S_v so coating chips can be conservatively modelled using the stone flour described in section 3h.4. While the stone flour does have a higher density than coating debris, the stone flour remains acceptable because the test

loop is agitated and particulate, which has settled, is put back into suspension. Additionally, Salem has adequate amounts of fiber to prevent chips from blocking significant amounts of holes. The Salem Unit 2 full fiber load results in approximately 0.5 inch uncompressed fiber debris bed and the Salem Unit 1 full fiber load results in an uncompressed fiber bed well over 1 inch.
Also, PSEG has not performed testing with paint chips, however, it is CCI's experience through numerous tests for different clients that head loss tests with stone flour in lieu of paint chips create higher head losses and as such is more conservative (Reference A.67).

Updated response: For the debris load used in design basis head loss tests (5 and 6) documented in Reference A.75, the Salem Unit 1 uncompressed fiber debris load is approximately 0.9 inches (Test 5 in Reference A.74) and the Salem Unit 2 uncompressed fiber debris load is approximately 0.3 inches (Test 6 in Reference A.74). In thin bed tests (2 and 3-repeat) documented in Reference A.75, it is shown that no thin bed is formed. The thin bed tests are described in more detail in Attachment 1, Sections 3f.4.1.5, 3f.4.2.3.2, and 3f.4.2.3.3.

31 **Your submittal did not provide details regarding the characterization of latent debris found in your containment as outlined in the NRC SE. Please provide these details.**

The latent debris present at Salem Generating Station is discussed in detail in Attachment 1 Section 3d.

Updated response: No change.

32 **How will your containment cleanliness and foreign material exclusion (FME) programs assure that latent debris in containment will be controlled and monitored to be maintained below the amounts and characterization assumed in the ECCS strainer design? In particular, what is planned for areas/components that are normally inaccessible or not normally cleaned (containment crane rails, cable trays, main steam/feedwater piping, tops of steam generators, etc.)?**

At the end of an outage, a formal containment closeout procedure S1(2).OP-PT.CAN-0001 (Q) (Reference A.34) is performed. The closeout is performed to ensure that loose materials are removed. The procedure specifically requires checking for foreign material such as tape, equipment labels, construction and maintenance debris (example rags, plastic bags, packaging, sawdust, etc.), temporary equipment (example scaffolding, ladders, insulation material, etc).

Also, the walkdown requires checking for dirt, dust, lint, paint chip buildup, and loose paint/coatings on surfaces such as walls or floors in containment.

As part of containment closeout, each ECCS train containment sump and sump screens are inspected utilizing procedure S1(2).OP-ST.SJ-0011(Q) (Reference A.24) for damage and debris. Also, refueling canal drains are verified to be unobstructed and that there is no potential debris sources in the refueling canal area that could obstruct the drains.

In support of the Generic Letter 2004-02 evaluation, a Salem Unit 2 containment walkdown was performed to determine the amount of latent debris. The results showed that the amount to be 33 lbm (Reference A.15). For conservatism, 200 lbm latent debris was used for Salem Unit 1 and 2 Debris Generation Calculation and head loss testing.

Based on the information that there is a substantial margin between the assumed and as found latent debris and programmatic controls, PSEG does not plan to perform future walkdowns to determine the amount of latent debris.

Updated response: No change.

33 **Will latent debris sampling become an ongoing program?**

See response to RAI question 32

Updated response: No change.

34 **You indicated that you would be evaluating downstream effects in accordance with WCAP 16406-P. The NRC is currently involved in discussions with the Westinghouse Owner's Group (WOG) to address questions/concerns regarding this WCAP on a generic basis, and some of these discussions may resolve issues related to your particular station. The following issues have the potential for generic resolution; however, if a generic resolution cannot be obtained, plant-specific resolution will be required. As such, formal RAIs will not be issued on these topics at this time, but may be needed in the future. It is expected that your final evaluation response will specifically address those portions of the WCAP used, their applicability, and exceptions taken to the WCAP. For your information, topics under ongoing discussion include:**

a) **Wear rates of pump-wetted materials and the effect of wear on component operation**

b) Settling of debris in low flow areas downstream of the strainer or credit for filtering leading to a change in fluid composition
c) Volume of debris injected into the reactor vessel and core region
d) Debris types and properties
e) Contribution of in-vessel velocity profile to the formation of a debris bed or clog
f) Fluid and metal component temperature impact
g) Gravitational and temperature gradients
h) Debris and boron precipitation effects
i) ECCS injection paths
j) Core bypass design features
k) Radiation and chemical considerations
l) Debris adhesion to solid surfaces
m) Thermodynamic properties of coolant

Since there is no specific NRC question here, no response is provided.

Updated response: See Attachment 1, Section 3m for a discussion of downstream effects on components and systems. See Attachment 1, Section 3n, for a discussion of in-vessel downstream effects.

35 **Your response to GL 2004-02 question (d) (viii) indicated that an active strainer design will not be used, but does not mention any consideration of any other active approaches (i.e., backflushing). Was an active approach considered as a potential strategy or backup for addressing any issues?**

PSEG did not utilize an active strainer approach to resolve the Generic Letter 2004-02 concerns. PSEG has not utilized the active strainer or back flushing approach in the resolution strategy.

Updated response: No change.

36 **The NRC staff's SE discusses a "systematic approach" to the break selection process where an initial break location is selected at a convenient location (such as the terminal end of the piping) and break locations would be evaluated at 5-feet intervals in order to evaluate all break locations. For each break location, all phases of the accident scenario are evaluated. It is not clear that you have applied such an approach. Please discuss the limiting break locations evaluated and how they were selected.**

While the SE discusses a "systematic approach" of investigating breaks at 5-feet increments, it also states that the "concept of equal increments is only a reminder to be systematic and thorough." For this calculation PSEG has selected breaks near large insulation targets, i.e. major equipment and walls, and have placed the breaks on the largest pipes in order to maximize the ZOI. Further discussion is provided in Attachment 1 section 3a of this response.

Updated response: No change.

37 **You stated that SE values for destruction pressure and ZOI were applied for each debris type in their evaluations, except for Kaowool and Transco fiber. For Kaowool and Transco fiber, ZOI values were acquired from Table 4-1 of the Nuclear Energy Institute guidance report and a ZOI equivalent to that of unjacketed NUKON (17 D) was applied. Please discuss the evaluations that were performed to justify that the applied value is applicable for the Salem-specific insulation type.**

NUKON and Kaowool insulation are similar material types, with similar installations and have similar densities and it is therefore considered reasonable that they would have similar ZOIs.

However, due to the relatively large ZOI and postulated break diameters, the debris generation calculation conservatively considers damage to all Kaowool in the area of containment where the break occurs. This is discussed in greater detail in Attachment 1 Section 3b of this response. Transco fiber is not part of the Salem Unit 1 and 2 debris load.

Updated response: Discussion of the ZOI's for NUKON, Kaowool, and anti-sweat fiberglass insulation can be found in Attachment 1, Sections 3b.1 and 3b.2.

38 **You stated that fibrous debris was characterized into four debris size categories based on the interpretation of the Boiling Water Reactor Owner's Group (BWROG) Air-Jet Impact Testing (AJIT) data. Please discuss the technical evaluations performed to conclude that this data is applicable for the Salem specific insulation types.**

For unjacketed NUKON and Kaowool fibrous debris generated from a 17D ZOI, the 4 category size distribution is no longer utilized, instead the SE recommended debris size distribution be used. For jacketed NUKON debris generated by an 8D ZOI, the AJIT data is used because the insulation/jacketing combination tested by the AJIT evaluation is representative of the jacketed NUKON present at Salem. A 4 size category size distribution is not used with an 8D ZOI. Further discussion of debris size distributions is contained in Attachment 1 section 3c of this response.

Updated response: A 17D ZOI is now used for jacketed and unjacketed NUKON debris. This is discussed in more detail in Attachment 1, Sections 3b.1 and 3b.2. Size distributions for all generated fiber types are discussed in Attachment 1, Section 3c.1.

39 **Has debris settling upstream of the sump strainer (i.e., the near-field effect) been credited or will it be credited in testing used to support the sizing or analytical design basis of the proposed replacement strainers? In the case that settling was credited for either of these purposes, estimate the fraction of debris that settled and describe the analyses that were performed to correlate the scaled flow conditions and any surrogate debris in the test flume with the actual flow conditions and debris types in the plant's containment pool.**

CCI introduces debris close to the strainer module. Additionally, debris, which does settle on the test loop floor, is re-suspended via loop agitation. Therefore, CCI does not credit near-field settlement integrally in the head loss testing. Although some limited amounts of debris cannot be prevented from settling directly in front of the strainer (especially in cases where more debris than strainer pocket volume exists) there is no CCI strategy to credit near-field settling.

Updated response: The design basis head loss testing does not credit near-field settling, as discussed in Attachment 1, Section 3f.12. However, during the design basis head loss tests, some debris settled adjacent to the strainer modules. The settlement locations and fractions are discussed in Attachment 1, Sections 3f.4.1.5.14, 3f.4.2.3, and 3f.12. Scale factors, flow rates, and debris surrogates for the design basis head loss testing are discussed in Attachment 1, Sections 3f.4.1.5.4, 3f.4.1.5.5, and 3f.4.15.7, respectively.

40 **Are there any vents or other penetrations through the strainer control surface, which connect the volume internal to the strainer to the containment atmosphere above the containment minimum water level? In this case, dependent upon the containment pool height and strainer and sump geometries, the presence of the vent line or penetration could prevent a water seal over the entire strainer surface from ever forming; or else this seal could be lost once the head loss across the debris bed exceeds a certain criterion, such as the submergence depth of the vent line or penetration. According to Appendix A to Regulatory Guide 1.82, Revision 3, without a water seal across the entire strainer surface, the strainer should not be considered to be "fully submerged." Therefore, if**

applicable, explain what sump strainer failure criteria are being applied for the "vented sump" scenario described above.

See response to Attachment 1 section 3f.11.

Updated response: No change.

41 **What is the basis for concluding that the refueling cavity drain(s) would not become blocked with debris? What are the potential types and characteristics of debris that could reach these drains? In particular, could large pieces of debris be blown into the upper containment by pipe breaks occurring in the lower containment, and subsequently drop into the cavity? In the case that large pieces of debris could reach the cavity, are trash racks or interceptors present to prevent drain blockage? In the case that partial/total blockage of the drains might occur, do water hold-up calculations used in the computation of NPSH margin account for the lost or held-up water resulting from debris blockage?**

Each Salem Unit has a 6 inch drain line from the lower refueling cavity. During normal operation the refueling canal drain flanges on the bottom of these drain lines are unbolted and swung out of position. These lines drain directly to the containment floor. Blockage of these drain lines would create a holdup volume, however, this blockage is not considered credible based on the following:

- Pipe breaks that result in sump recirculation are located either under the operating floor or within the pressurizer enclosure.
- No additional debris is generated due to exposure to containment spray.
- Any debris that would make it to the refueling cavity would have to be blown up by the break effluence through either grating or through narrow openings around the steam generators.
- Large pieces (4 inch and larger) do not easily pass through gratings. In addition, large pieces that enter the upper containment through openings around the SG would have to be blown over the 10' high shield wall around the steam generators.

Therefore, large insulation debris pieces are not expected to end up in the refueling canal. As small debris pieces (such as small insulation pieces, latent debris, foreign materials, etc.) are not likely to be capable of blocking a 6 inch drain line, blockage of the 6 inch refueling canal drain line in the lower refueling cavity is not expected.

Further examination showed that for the purposes of minimum containment flood level, it is more conservative and realistic to assume the reactor cavity is a holdup volume rather than the refueling cavity. For Salem Unit 1 and 2, the refueling cavity volume is approximately 6,550 ft3 (Reference A.10).
The reactor cavity volume is approximately 10,400 ft3 (Reference A.10). The refueling cavity is only filled by containment spray (no LOCA fills the refueling cavity). The reactor cavity can be filled directly by a break at the reactor vessel nozzle, or by overflow from the containment sump volume once the water level in the containment reaches the 81 feet 9 inch level (which is above the minimum water level required for recirculation operation of 80 feet 10 inch).

If there is a break in the RCS piping at the steam generators, in order to block the refuel cavity drain, a piece of debris would have to be blown up between the SG and the enclosure wall and land on the refueling cavity drain on the 130 feet elevation. With the drain blocked, any of the containment spray discharge falling into the refueling cavity would be lost to the recirculation pool inventory. However, this break will not result in immediate filling of the reactor cavity. Conversely, the break at the reactor nozzle that leads to direct filling of the reactor cavity will not generate the debris that could block the refueling cavity drain.

Therefore, at Salem Unit 1 and 2, concurrent use of both of these hold up volumes for determining minimum flood level for switchover to recirculation operation is not credible. Since the reactor pit has the largest volume, then it is considered the limiting case for ECCS inventory hold up for both Salem Units at Salem Generating Station.

Updated response: Use of a 17D ZOI for jacketed NUKON results in debris generation above the grating around the steam generators. Therefore, not all debris in upper containment is transported to upper containment from lower containment by being blown through grating around the steam generators (see Attachment 1, Sections 3b.1, 3b.2, and 3e.1.1); some debris is generated in upper containment (above the grating). However, this does not change the conclusion of the response above. See also Attachment 3, Section 7.

42 **What is the minimum strainer submergence during the postulated LOCA? At the time that the re-circulation starts, most of the strainer surface is expected to be clean, and the strainer surface close to the pump suction line may experience higher fluid flow than the rest of the strainer. Has any analysis been done to evaluate the possibility of vortex formation close to the pump suction line and possible air ingestion into the ECCS pumps? In addition, has any analysis or test been performed to evaluate the possible**

accumulation of buoyant debris on top of the strainer, which may cause the formation of an air flow path directly through the strainer surface and reduce the effectiveness of the strainer?

In accordance with PSEG TODI 80080788-06 (Reference A.6) Minimum Water Submergence, the minimum expected water submergence after a LOCA is 3 inches.

The proof that no vortices occur for clean strainers, including the effects of non-uniformity of flow rates into individual modules along the train of modules, is provided in the CCI vortexing report 3SA-096.071 which is documented in PSEG VTD 901380 (Reference A.72). For more details see Attachment 1 section 3f.3. The tests that are the basis for this proof, have shown that buoyant debris disrupts air vortices and does not enhance them.

Updated response: The details of the final vortex analysis are provided in Attachment 1, Section 3f.3. The clean strainer vortex analysis utilized the as-built minimum submergence of 3.78 inches for Unit 1 and 3.85 inches for Unit 2.

43 **The September 2005 GL response indicated that your debris transport analysis included modeling of fibrous debris erosion. Please explain how you modeled erosion of debris.**

Erosion of fibrous debris is described in Attachment 1 section 3e.1and 3e.2 of this response.

Updated response: The debris transport analysis uses a conservative erosion fraction over a 30-day period of 20% for NUKON and 15% for Kaowool. Erosion of fibrous debris is described in detail in Section 3e.1and 3e.2 of Attachment 1 of this submittal.

Salem Nuclear Generating Station Units 1 and 2
Docket Nos. 50-272 and 50-311
Generic Letter 2004-02
Updated Response to Draft Audit Open Items

Draft Audit Open Items

During the week of October 1, 2007 the NRC conducted a detailed audit of the Salem Unit 1 and 2 new containment sump design and its associated analyses, testing, modifications and evaluations. The draft audit open items are documented in Reference A.71. Final audit open items were transmitted to Salem in Reference A.78. Responses to the final audit open items can be found in Attachment 4.

Following are the original responses to the draft audit open items submitted on February 29, 2008 (Reference A.80) with updates after each response.

1. **Aluminum Paint**
   The licensee's chemical effects analysis does not address the presence of large amounts of aluminum paint on the Salem Unit 2 steam generators. The licensee should address this material in its evaluations and/or testing.

   The initial Salem chemical effects evaluation TODI 80080788-007 (Reference A.44) did not account for aluminum (Al) paint on the existing Salem Unit 2 steam generators, as they are scheduled for replacement during the Spring 2008 outage. The new SGs have no aluminum paint. However, this evaluation (Reference A.44) was revised to consider the aluminum in paint on the existing SG for a period of time until they are replaced. The evaluation concludes that the aluminum paint on the existing Salem Unit 2 SG is acceptable until their replacement during the 2R16 (spring 2008) refueling outage.

   Updated response: The Unit 2 Steam Generators were replaced during the 2R16 (spring 2008) refueling outage per Reference A.79.

2. **Chemical Effects Resolution**
   Because plant-specific chemical effects evaluations were in progress at the time of the onsite audit, chemical effects resolution in general was designated as an open item. The licensee needs to complete plant-specific chemical effects evaluations and integrated head loss tests.

   The final chemical and non-chemical head loss testing has not been completed. PSEG has submitted and received an approval for an extension request until June 30, 2008 (Reference A.27). Upon completion of testing and associated calculations, the information will be submitted to NRC.

   Updated response: Salem has successfully completed the plant specific chemical effects evaluation and the final head loss testing that included chemical effects.

These tests and evaluations are discussed in detail in Attachment 1, Sections 3f.4.1.5, 3f.4.2.3, and 3o.

3. **Downstream Effects for Components and Systems Incomplete**
The downstream effects analysis for components and systems was in progress but incomplete. Examples of specific items which were incomplete were evaluation of the charging pump start/stop operations and charging system evaluation, validation of safety injection pump and charging pump mission times, and general validation of critical inputs to the downstream effects analyses. The licensee needs to complete the analysis for downstream effects for components and systems.

The downstream effects and in-vessel evaluations have not been completed. PSEG has submitted and received an approval for an extension request for this item until June 30, 2008 (Reference A.27). Upon completion of the evaluations, the information will be submitted to the NRC.

Updated response: Salem has completed is the downstream effects analysis for components and systems. This analysis is discussed in detail in Attachment 1, Section 3m.

4. **Downstream Effects for Fuel and Vessel**
The licensee analysis of downstream effects for the fuel and vessel was in draft and will be re-evaluated in accordance with WCAP 16793 "Evaluation of Long-term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid, Revision 0." The licensee needs to complete the analysis for downstream effects for the fuel and vessel.

The downstream effects and in-vessel evaluations have not been completed. PSEG has submitted and received an approval for an extension request for this item until June 30, 2008 (Reference A.27). Upon completion of the evaluations, the information will be submitted to NRC.

Updated response: Salem has completed a downstream effects analysis for the fuel and vessel based on WCAP-16793-NP, Revision 2 (Reference 28). This analysis is discussed in detail in Attachment 1, Section 3n. However, a NRC Safety Evaluation for WCAP-16793-NP, Revision 2, has not yet been issued. Salem will provide a response within 90 days of the issuance of the final NRC Safety Evaluation on WCAP-16793-NP.

5. **Use of an 8 Pipe Diameter (8D) Zone of Influence (ZOI) for Steel Jacketed NUKON**
The licensee used an 8D ZOI for steel jacketed NUKON fibrous insulation based on a Westinghouse (WCAP) test report which the licensee did not possess and therefore was unavailable for audit team review. The licensee needs to provide the NRC an opportunity to review this test report.

The design at Salem Unit 2 utilized WCAP 16710-P "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON® Insulation for Wolf Creek and Callaway Nuclear Operating Plants" thus reducing the ZOI to 8D instead of 17D.

Updated response: WCAP-16710-P is not used for NUKON at Salem. Jacketed and unjacketed NUKON use a ZOI of 17D as discussed in Sections 3b.1/3b.2 of Attachment 1 to this submittal.

6 **Preparation of Fibrous Debris for Head Loss Tests Not Prototypical**
In the head loss tests conducted by the licensee before the onsite audit week, the fibrous debris was prepared in such a significantly coarse manner that a major fraction of it settled in front of the test strainers and loaded the strainer test pockets in a gravitationally-skewed manner. However, licensee documentation showed that the fibrous debris accumulating on the sump strainer would consist mainly of readily transported suspended and generally independent fibers. Therefore, the preparation of fibrous debris for the head loss tests was not prototypical and, as a result, tended to preclude the formation of a fibrous debris "thin bed" in the test strainers. The licensee's conclusion that a thin bed would not form on the sump strainer may therefore be in error. The licensee should evaluate this issue for its impact on plant testing.

PSEG had telecon on October 17, 2007, with the NRC to discuss the concern and received clarifications. Debris samples similar to the debris used in MFTL testing prepared by CCI were provided to NRC for review. The following is a comparison of the CCI fibrous debris preparation with the NUREG CR-6917 METHOD.

A. Objective

To separate NUKON fiber insulation blankets into a homogenous, single-fiber slurry for use in bypass and thin bed effect testing on ECCS strainers.

B. Methods Explained

NUREG CR-6917 describes preparing NUKON by first subjecting the NUKON to a 12 to 14 hour heat treating process on a 600°F hot plate. The blanket is then shredded through a wood chipper. Next either 25 or 12.5 grams NUKON are then weighed out and added to 1000 mL or 500 mL water, respectively, and shredded in a commercial blender for a range of 3 to 10 minutes.

CCI Method per Salem Test Specification Q.003.84805:

- The fibers will be freed from the jacketing (if jacketed). Then the fibers will be baked by placing them in an oven with a regulated temperature of 250°C (482°F) for 24 hours prior to testing. The baking is meant to simulate the exposure of fiber insulation in the plant to hot surfaces such as the steam generator, pressurizer, and piping.
- The fibers will be hand cut in pieces of approx. 50 x 50 mm.
- The dry material gets weighed
- The fibers get split in batches of 3 to 4 dm^3 (0.1 to 0.14 ft^3)
- Each batch gets soaked in 2 l of water (½ gal) until saturated
- Their adherence will be decomposed by a high pressure water jet with a capacity of 100 bar and with the jet at a distance of ± 0.05 m to the water surface for a duration of approximately 4 min for each batch.
- It will be ensured by visual means that the insulation is decomposed in the water in fine pieces with no clumps of fibers remaining intact and individual fiber pieces smaller than 8 mm.
- Several batches can be mixed together to a main batch (portion) according to the test description.

In the past, CCI has also separated NUKON by using the same high-pressure water jet to force the NUKON through a 12mm x 12mm mesh screen. The resulting slurry had the same characteristics as the slurry prepared in the bucket only.

Figure 1. Baked Blankets and Strips

Figure 2. 5 cm x 5 cm Pieces

C. Results Comparison:

Figure 3-2 from NUREG CR-6885, shows the prepared NUKON characteristics. This NUREG document describes preparing the NUKON slurry by first using a leaf shredder to shred the NUKON blankets. The NUKON is then heated to >90°C and stirred for 5 minutes using a kitchen blender (slurry concentration is unknown).

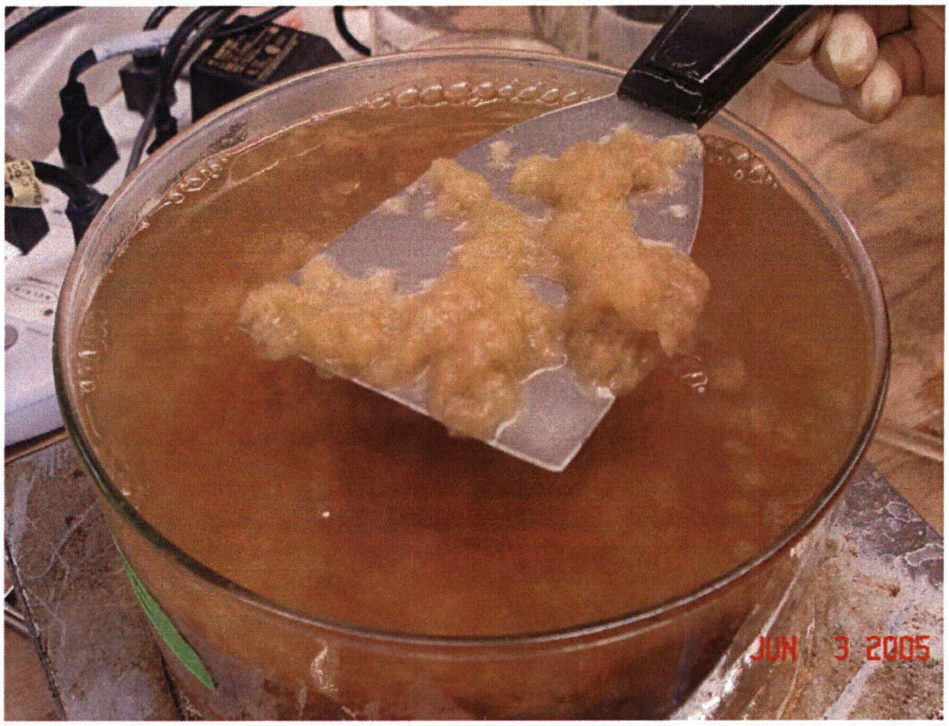


Figure 3-2. BP NUKON™.

Figure 3. Blender Processed NUKON

The figure below displays the NUKON properties of a slurry prepared per the CCI preparation method.

Figure 4. CCI Method Prepared Debris

Below, Figure 5 and Figure 6 are from the thin bed testing performed in October 2005 for Salem. The photos were taken after the test conclusion and all water had been drained from the test loop. As can be seen in Figure 6 the drain down process causes some small areas in the debris bed to fall off the top and side strainer surfaces. These open areas do not exist during testing.

Additionally, to confirm the small open areas were not present during testing we can refer to the thin bed test results detailed in VTD 901000 (Reference A.65). The results show a rise in head loss as the flow rate is increased and then a slow reduction in head loss as the flow rate decreases. The test results are outlined in Table 1 and Diagram 1 below:

Test step #	**Time [hh.mm]**	**Flow Temp [°C]**	**Pool Temp [°C]**	**Flow rate [m³/h]**	**Δp [mbar]**	**Δp U-tube [mmWC]**	**Remarks**
16	11:14	12.3	12.4	47.6	78.4	-	
17	11:38	12.4	12.5	56.9	81.7	-	
18	12:11	12.7	12.8	66.7	82.9	-	
19	12:48	12.8	12.9	47.6	71.1	-	
20	13:20	12.9	13.0	33.4	57.8	-	

Table 1

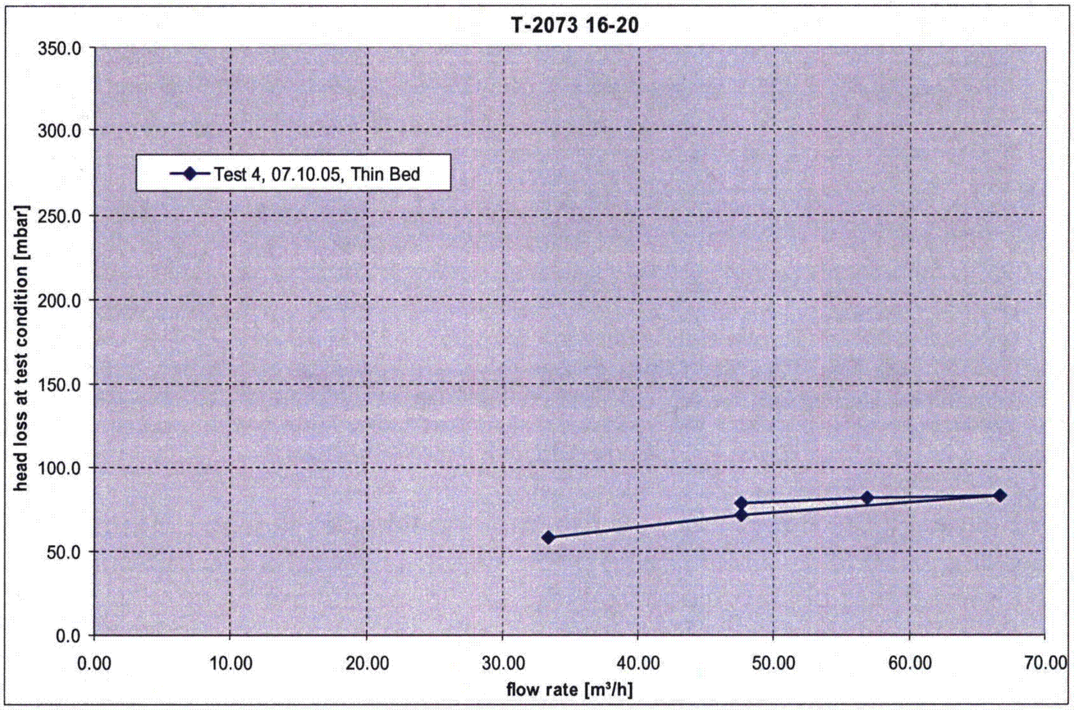


Diagram 1

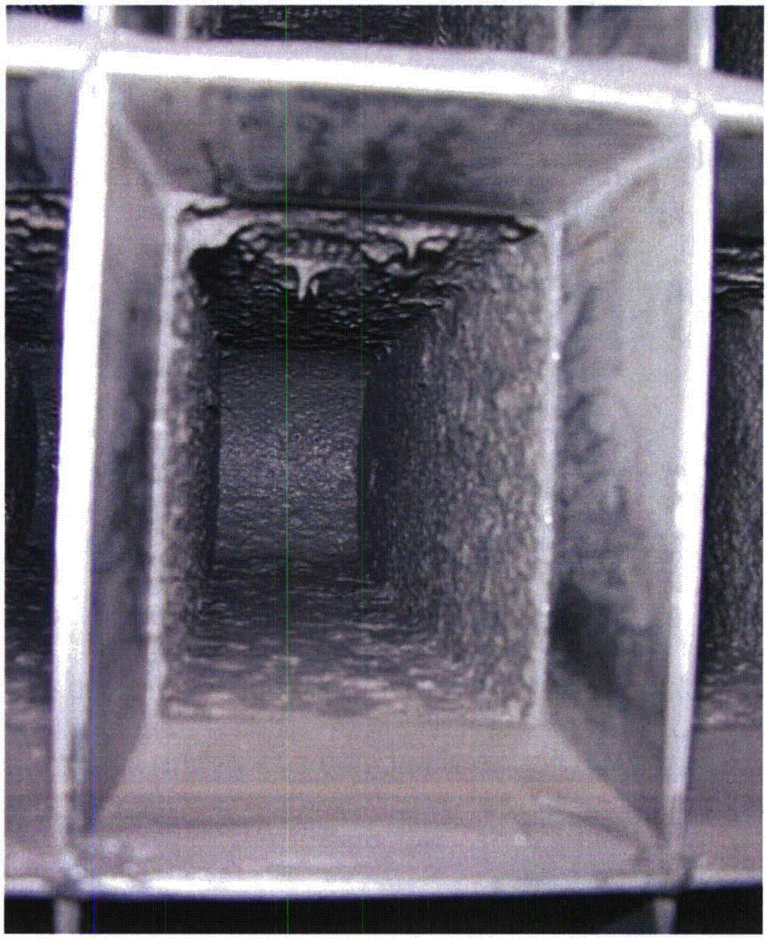
These results show that the screen does not exhibit thin bed behavior.

Figures 5 and 6, when combined with the test results demonstrate adherence to Criterion 1 through 5 (in particular Criterion 2) in section 3.1.1 of NUREG CR-6917. The Criterion are listed here:

- Material should form a complete debris bed on the specified metal screen or perforated plate.

- Debris beds should be uniformly thick and internally as homogeneous as possible in the radial direction.
- Uniform debris beds should be formed over the range of debris loadings specified by the NRC proposed test matrix provided as part of NUREG CR-6917.
- The debris beds generated for a given composition and target debris loading should yield repeatable physical and performance characteristics.
- The debris beds should meet NRC specifications for debris bed composition and criteria for head loss measurements (e.g., formed at specified bed formation velocity and temperature).

Figure 5



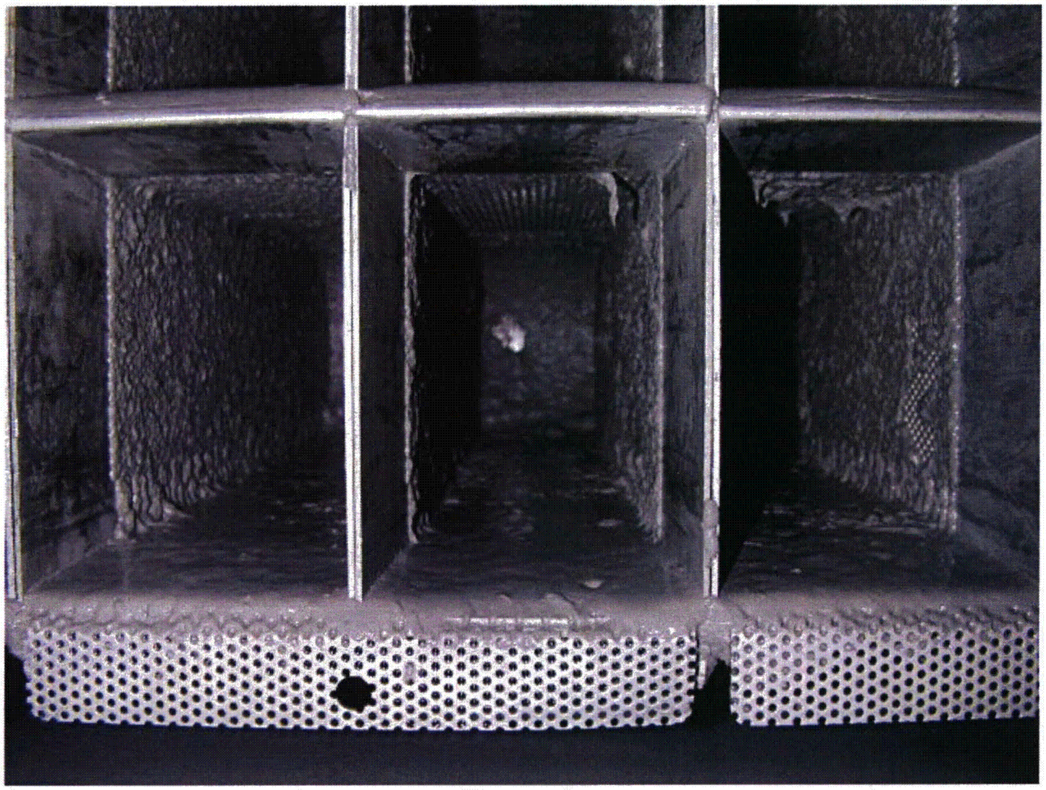


Figure 6.

D. CCI's Findings

Our testing has determined the following:

1) All NUKON fibers will eventually settle in a zero turbulence environment as described in Figure 7 below. Figure 7 shows a sample 12.5 gram NUKON/500 mL water slurry prepared using the method described in NUREG CR-6917. The slurry in the photo has been undisturbed for approximately 36 hours and no fibers remain in suspension.

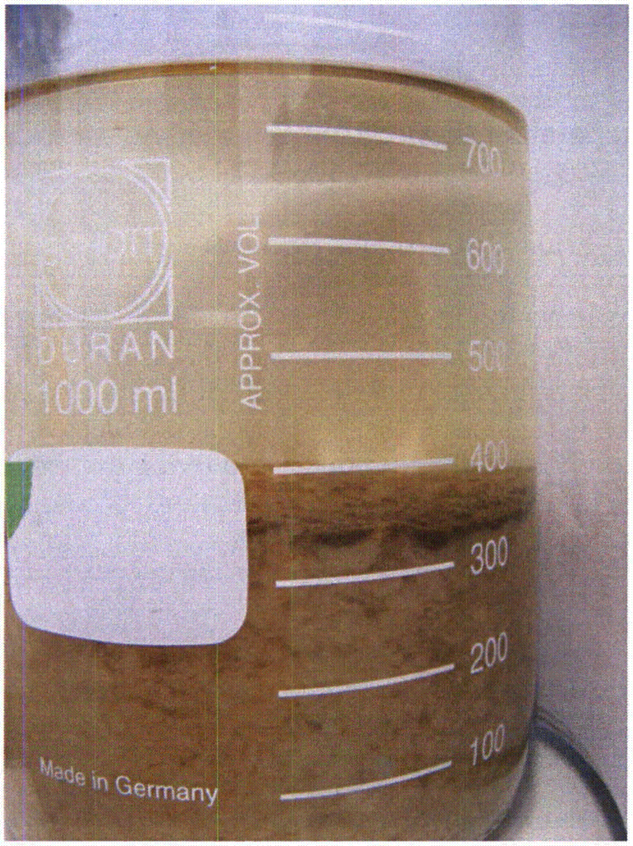


Figure 7.

2) There are 2 methods for improving likeliness of a true single fiber NUKON slurry when introducing fibers into the test loop
    a. Agitate the fibers prior to adding. CCI does this by operating a propeller style blade powered by a drill in each bucket prior to adding to the test loop.
    b. The most influential variable – a low NUKON concentration in the NUKON/water slurry. We have found that no matter how small or finely separated the fibers are if the NUKON concentration in the water is too high clumps will form. To achieve as close to single fiber slurries as possible in thin bed tests, CCI typically uses approximately 110g NUKON per between 10 to 30 L water.

E. Conclusion

Based on the behaviors of the NUKON slurry in both the NUREG and CCI described preparation methods the CCI method satisfies the criterion described in Section 3.1.1 of NUREG CR-6917.

F. Additional In-Loop Underwater Photos:

These photos were made during non-QA testing performed December 11 and 12, 2007. The photos were taken after 900 grams of NUKON (approximately 0.166 inch thick bed) and 1 kg of stone flour were added to the loop. Sufficient time was allowed for the particulate to filter from the water for photo clarity. The photos clearly demonstrated that a thin bed would not form.

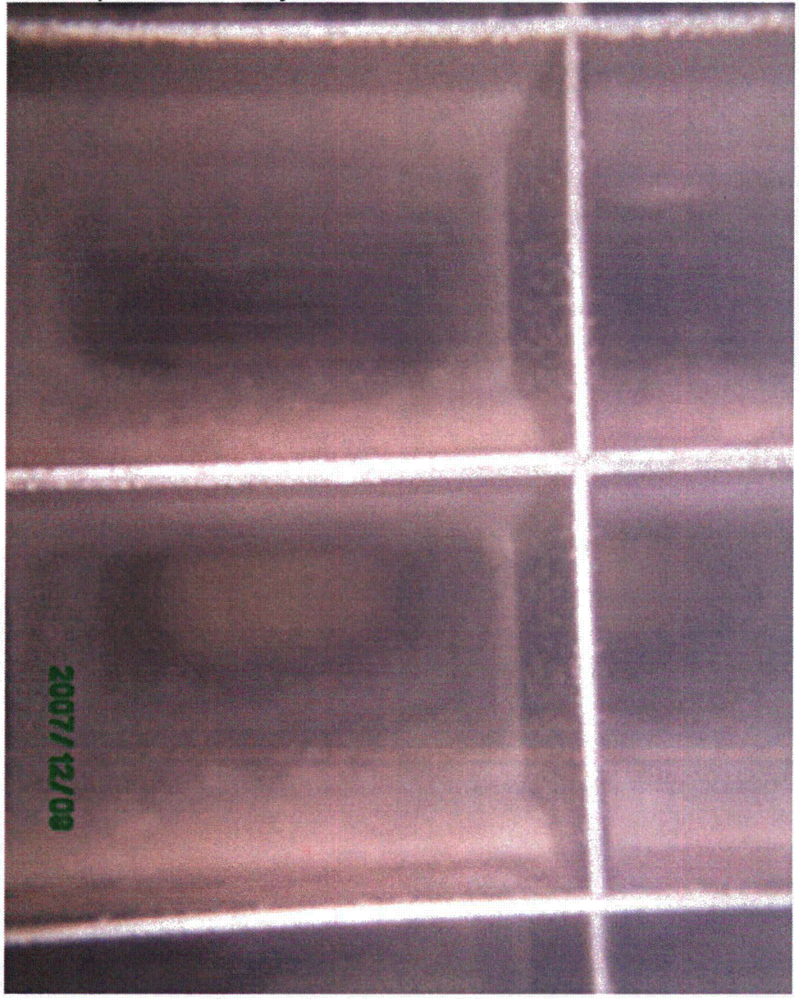


Figure 8 - Front-mid strainer

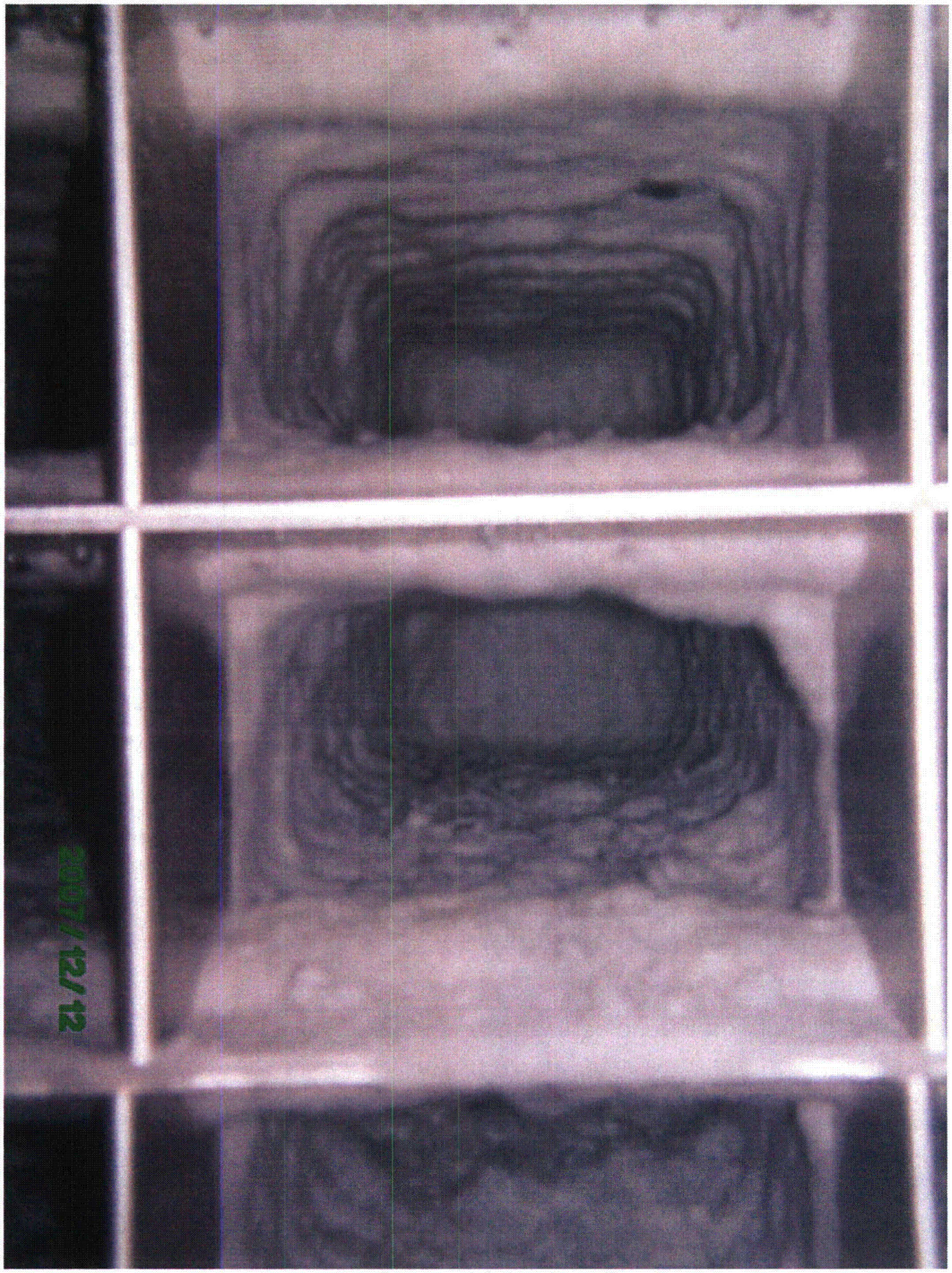


Figure 9 - Rear-mid Strainer Pockets

Updated response: In October of 2007 a sample of insulation debris prepared using the CCI methodology was given to members of the NRC staff.

Between April 20 and 25, 2008, the members of the NRC staff visited the CCI test facilities in Winterthur, Switzerland (Reference A.81). While there the staff observed the CCI methodology for the preparation of fiber insulation debris and found it to be satisfactory. The resulting fibrous debris transported in a prototypical manner and formed prototypical debris beds.

Additional thin bed tests were performed in February, March, and April of 2008 and documented in Reference A.75. Tests 2 and 3-repeat show that no thin bed was formed. The thin bed tests are described in more detail in Attachment 1, Sections 3f.4.1.5, 3f.4.2.3.2, and 3f.4.2.3.3.

7. **Certain Water Holdup Calculation Omitted from Latest Revision to the Minimum Sump Water Level Calculation**
The technical evaluation for steam generator nozzle break loss-of-coolant accidents (LOCAs) capable of filling the lower refueling cavity by blocking the drain line with debris and preventing the lower refueling cavity from draining (and thereby decreasing sump water volume) was omitted from the licensee's latest revision to the minimum sump water level calculation. This evaluation explained that although significant from a holdup perspective, LOCAs from this set of breaks are mutually exclusive from, and less severe than, reactor vessel nozzle breaks that directly fill the reactor pit but have no potential to block the lower refueling cavity drain line nor fill the lower refueling cavity. The licensee should revise the latest minimum sump water level calculation to include the previous technical evaluation from an earlier version of the minimum sump water level calculation.

The minimum flood level calculation was revised to include the analysis documented in the previous revision (0IR0) of the calculation that considered the entire refuel cavity as a holdup volume.

This analysis was not used in revision 0 of the calculation since it was determined that it was not credible to assume both the refuel cavity and the reactor cavity volumes were lost to the sump pool from a LOCA. The reactor cavity was determined to be the limiting case ECCS inventory holdup as described below.

For Salem, the refuel cavity volume is approximately 6,550 ft^3 (Reference A.10). The reactor cavity volume is approximately 10,400 ft^3 (Reference A.10). The refuel cavity is only filled by containment spray (no break flow fills the refuel cavity). The reactor cavity can be filled directly by a break at the reactor vessel nozzle, or by overflow from the containment sump volume once the level in the containment reaches the 81 feet 9 inch level which is above the minimum level required for recirculation operation of 80 feet 10 inch.

If there is a break in the RCS piping at the steam generators, in order to block the refuel cavity drain, a piece of debris would have to be blown up between the SG and the enclosure wall then land on the refuel cavity drain on the 130 foot elevation.

With the drain blocked, any of the containment spray discharge falling into the refuel cavity would be lost to the recirculation pool inventory. However, this break will not result in immediate filling of the reactor cavity. Conversely, the break at the reactor nozzle that leads to direct filling of the reactor cavity will not generate the debris that could block the refuel cavity drain.

Therefore, at Salem concurrent use of both of these hold up volumes for determining minimum flood level for switchover to recirculation operation is not credible. Since the reactor cavity has the largest volume, it is considered the limiting case for ECCS inventory hold up at Salem Unit 1 and 2.

For historical purposes, revision 0IR0 is now included as Attachment J to calculation S-C-CAN-MDC-2061 (Reference A.21), Minimum Containment Flood Level, Revision 1.

Updated response: Use of a 17D ZOI for jacketed NUKON results in debris generation above the grating around the steam generators; i.e. some debris is generated in upper containment rather than being transported to upper containment from lower containment by being blown through grating around the steam generators (see Attachment 1, Sections 3b.1, 3b.2, and 3e.1.1). However, this does not change the conclusion of the response above.

8 Final Chemical and Non-chemical Integrated Head Loss Testing not Performed

The licensee needs to perform the final chemical and non-chemical head loss testing and then calculate strainer head loss. Net-positive suction head (NPSH) margin for the emergency core cooling systems (ECCS) pumps can then be calculated.

The final chemical and non-chemical head loss testing has not been completed. PSEG has submitted and received an approval for an extension request until June 30, 2008 (Reference A.27). Upon completion of testing and associated calculations, the information will be submitted to NRC.

Updated response: PSEG submitted and received approval for an additional extension request until December 31, 2008 (Reference A.73). The final head loss tests with chemical effects were successfully completed in 2008 and are described in Attachment 1, Section 3f.4.1.5 and 3f.4.2.3. The NPSH margin for the ECCS pumps is described in Attachment 1, Section 3g.16.

9 **Licensee NPSH Calculations Credit Containment Partial Air Pressure Without an Approved License Amendment Request (LAR)**
Licensee calculations include credit for the contribution of partial containment air pressure to NPSH, but the NRC has not yet approved the licensee's LAR requesting approval for this credit. The licensee needs to receive the NRC-approved LAR or remove the credit for air pressure-difference contribution to NPSH.

PSEG submitted a LAR to revise the licensing basis for the NPSHa for ECCS and Containment Heat Removal System pumps as described in the Appendix 3A of the Salem UFSAR. The NRC approved the LAR on November 15, 2007 (Reference A.9).

Updated response: No change.

10 **Spray Droplet Water Holdup Calculation Omitted from Latest Revision to the Minimum Sump Water Level Calculation**
The technical evaluation for the spray droplet holdup mechanism was omitted from the licensee's latest revision to the minimum sump water level calculation. The licensee needs to revise the minimum sump water level calculation to include the technical evaluation of spray droplet holdup in the containment atmosphere.

The minimum flood level calculation was revised to include containment spray water droplets that would not contribute to the water level until the droplets fell to the sump pool. This analysis utilized the terminal velocities of droplets and the falling distance from the highest spray ring elevation to the containment floor.

During the time it takes for the water droplets to fall (approximately 15 seconds, worst case), the volume of water suspended in the atmosphere is about 175 ft^3. This translates to a reduction in the sump level of approximately 0.31 inches.

This analysis is included as Attachment K to calculation S-C-CAN-MDC-2061 (Reference A.21), Minimum Containment Flood Level, Revision 1.

Updated response: No change.

11 Inadequate Technical Basis for Maximum Flow Rates for RHR Pumps The licensee needs to develop an adequate technical basis for the maximum flow rates for the RHR pumps for cold leg and hot leg injection, and spray operation in limiting single-pump operation.

Calculation S-C-RHR-MDC-1711 (Reference A.41) provides the ECCS sump performance based on the following maximum RHR pump flow rate (single pump in operation) in the recirculation mode.

Mode	Salem Unit 1	Salem Unit 2	Basis
Cold Leg Recirculation (w/o Sprays)	5,110 gpm	4,900 gpm	Salem Unit 1 – Note 1 Salem Unit 2 – Note 2
Hot Leg Recirculation	4,980 gpm	4,980 gpm	Note 3
Cold Leg Recirculation with Sprays	4,850 gpm	4,850 gpm	Note 4

Notes:

1. The calculated flow is for one RHR pump line-up that feeds all four cold legs (two by normal paths and also through loop path and all four charging/SI pumps). This condition is explained further with an example below. The hydraulic analysis (Calculation number FSE/SS-PSE/PNJ-2017) was performed by Westinghouse.

   During normal LOCA recirculation lineup (without sprays) the 11 RHR pump feeds 11 and 13 Cold legs and 2 SI pumps and 12 RHR pump feeds 12 and 14 Cold leg and 2 charging pumps.

   Following loss of one operating RHR pump (example #11 RHR pump) the 12 RHR pump would supply to 12 and 14 cold legs and charging pumps (as previously discussed). In addition a loop around would occur due to the failed

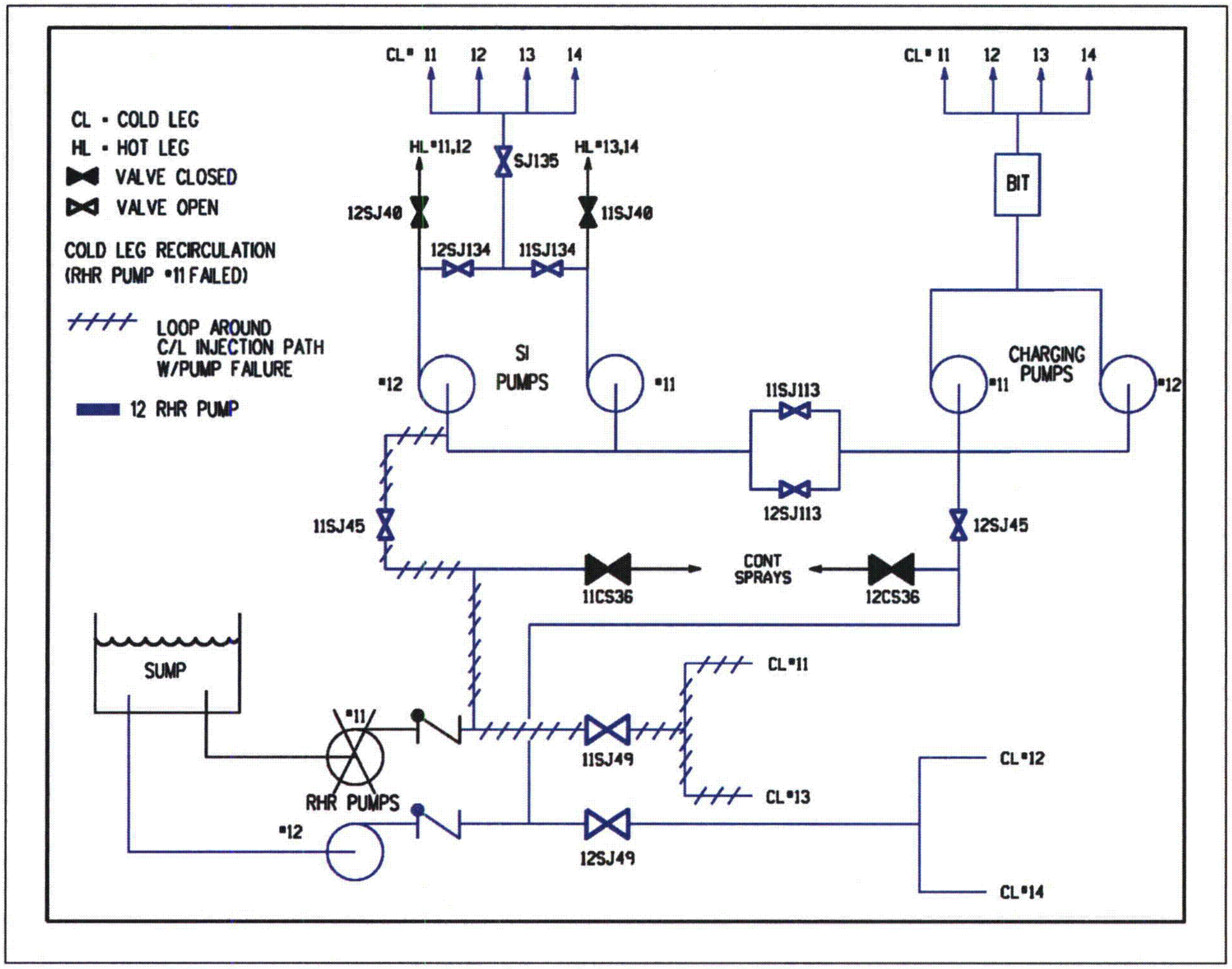
RHR pump. The loop around flow path would be, as shown in Figure 1 (below). This configuration results in maximum flow per pump.

2. The calculated flow path for Salem Unit 2 is similar to Salem Unit 1 (as discussed above in Note 1). The hydraulic analysis (Calculation number FSE/SS-PSE-1828 and FSE/SS-PSE/PNJ-2017) was performed by Westinghouse.

3. 4,300 gpm per pump is the maximum estimated RHR pump flow with four ECCS pumps (two Charging and two SI) in hot leg recirculation alignment (Westinghouse letter PSE-06-24 dated March 2, 2006, (Reference A.56), and calculation FSE/SS-PSE/PNJ-2056. A conservative value of 4980 gpm is used in the NPSH analysis that exceeds the value computed in the hydraulic analysis.

4. In this mode one RHR pump is aligned to two RCS cold legs and two SI pumps. The other pump is aligned to containment sprays and two charging pumps. Assuming failure of the RHR pump aligned to containment sprays, the calculated flow through the operating RHR pump is <=4,850 gpm (FSE/SS-PSE/PNJ-2017, page 14). The failure of the RHR pump aligned to RCS cold legs is bounded by the above failure (FSE/SS-PSE/PNJ-2017, page 13).

Figure 1 Salem Unit 1 Cold Leg Recirculation (w/o Containment Spray)



<u>Updated response</u>: No change however, the response is revised to indicate the revised referenced documents.

Calculation S-C-RHR-MDC-1711 (Reference A.41) provides the ECCS sump performance based on the following maximum RHR pump flow rate (single pump in operation) in the recirculation mode.

Mode	Salem Unit 1	Salem Unit 2	Notes
Cold Leg Recirculation (w/o Sprays)	5,110 gpm	4,900 gpm	1
Hot Leg Recirculation	4,980 gpm	4,980 gpm	2
Cold Leg Recirculation with Sprays	4,850 gpm	4,850 gpm	3

Notes:

1 The calculated flow is for the RHR pump in cold leg recirculation alignment and includes loop around flow. The loop around flow provides the maximum flow condition. The hydraulic analysis was performed by Westinghouse. The Unit 1 evaluation is documented in VTD 901694 (Reference A.118) and the Unit 2 evaluation is documented in VTD 901695 (Reference A.119). The loop around flow evaluation for both Units is documented in VTD 901696 (Reference A.120). The loop around condition occurs when one RHR pump fails and the flow from the operating pump loops around and provides additional flow.

2. The calculated flow is for the RHR pump in hot leg recirculation alignment. The hydraulic analysis was performed by Westinghouse. The Units 1 and 2 evaluation is documented in VTD 901697 (Reference A.121).

3. The calculated flow is for the RHR pump in cold leg recirculation with containment spray alignment. The hydraulic analysis was performed by Westinghouse. The Units 1 and 2 evaluation is documented in VTD 901697 (Reference A.121).

12 Salem has water in its sumps during the operating cycle. This condition has a potential for biological growth, necessitating clean-up during each outage. This item needs to be addressed by PSEG in its sump analysis. Provide with documentation, which describes the PSEG analysis of this issue?

The ECCS containment sump at Salem Unit 1 and 2 is filled with water during the normal operating mode. The concern is that stagnant water in the containment sump would result in biological growth, which has a potential to impact the operation of containment sump during recirculation phase of the LOCA.

A containment sump inspection was performed at Salem Unit 2 in 2003 to determine if there is any biological growth. This inspection showed substantial amount of algae in the sump. At that time the sump was thoroughly cleaned.

Subsequently at Salem Unit 1 and 2 work orders were created for thorough inspection of the containment sump during every refueling outage and the cleaning of any algae growth. These subsequent inspections show a very thin film of algae. Salem Unit 1 inspections were performed on June 4, 2004, November 9, 2005, and April 15, 2007 and the next inspection is scheduled for upcoming 1R19 refueling outage (Fall 2008).

Salem Unit 2 inspections were performed on November 11, 2003, May 6, 2005, and November 11, 2006, and the next inspection is scheduled for upcoming 2R16 refueling outage (Spring 2008).

This thin film of algae on the water surface will breakdown during a LOCA condition. The small mass of algae will be negligible relative to the other debris generated. Therefore, the algae are not expected to cause downstream concerns or reduction in sump performance.

Updated response: No change.

The first containment sump inspection was performed at Salem Unit 2 in 2003 during 2R13 refueling outage and at Unit 1 in 2004 during 1R16 refueling outage. The inspection showed approximately ¼ inch thick rust colored algae inside the sump pit. The sump pit was cleaned to remove the algae. Subsequently, the containment sump is inspected at every Salem refueling outage. A review of the associated work orders shows that the sump pit has remained clean.

Salem Nuclear Generating Station Units 1 and 2
Docket Nos. 50-272 and 50-311
Generic Letter 2004-02
Response to Final Audit Open Items

Final Audit Open Items

During the week of October 1, 2007, the NRC conducted a detailed audit of the Salem Unit 1 and 2 new containment sump design and its associated analyses, testing, modifications and evaluations. Draft audit open items were transmitted to Salem from the NRC in Reference A.71 on October 24, 2007. The update responses to the draft audit open items can be found in Attachment 3 of this submittal. The final audit open items were transmitted to Salem from the NRC in Appendix 1 of Reference A.78 on August 12, 2008. Following are the responses to the final audit open items with updates after each response.

Open Item 3.2-1: Use of an 8 Pipe Diameter (8D) Zone of Influence (ZOI) for Steel Jacketed Nukon

The licensee used an 8D ZOI for steel jacketed Nukon fibrous insulation based on a Westinghouse (WCAP) test report which the licensee did not possess and, therefore, the report was not available for audit team review. The licensee needs to justify use of an 8D ZOI for this material.

WCAP-16710-P has now been used to support a 7D ZOI for Steel Jacketed Nukon at Salem. Applicability of WCAP-16710-P to Salem is discussed in Section 3b.3 of Attachment 1 to this submittal.

Updated response: Jacketed and unjacketed NUKON now use a ZOI of 17D as discussed in Sections 3b.1/3b.2 of Attachment 1 to this submittal.

Open Item 3.5-1: Structural Capability of Crane-Wall Bioshield Door

The licensee needs to demonstrate the capability of the unmodified mesh gate located near the ECCS strainers to withstand the potential post-LOCA structural loadings (e.g., jet impingement, subcompartment depressurization, and containment pool flows when obstructed with debris and provide a summary of results to the NRC staff.

The structural analysis of the mesh gates is discussed in the response to RAI 3 in Attachment 5 of this submittal.

Updated response: No change.

Open Item 3.6-1: Final Chemical and Non-chemical Integrated Head Loss Testing Not Performed to support NPSH margin calculations for ECCS pumps.

The licensee needs to perform the final chemical and non-chemical head loss testing and then calculate strainer head loss. Net-positive suction head (NPSH) margin for the emergency core cooling systems (ECCS) pumps can then be calculated. The licensee should summarize for the NRC staff how the eight aspects of this issue discussed in Section 3.6.6 of this audit report have been addressed

Salem has successfully completed final head loss testing including chemical effects. The results of these tests were used to determine the total head loss on the screen under post-LOCA conditions. This information was used to demonstrate that there is sufficient NPSH margin available during the entire ECCS mission time. These tests and the NPSH analysis are discussed in detail in Attachment 1, Sections 3f.4.1.5, 3f.4.2.3, and 3g (see 3g.16 for NPSH margin discussion). The eight aspects of this issue discussed in Section 3.6.6 of the audit report (Reference A.78) are responded to below.

1) ***The preparation of fibrous debris combined with the transport of the fiber to the test strainer may not have been prototypical of the plant. Based on the licensee transport calculation, a significant portion of very fine, suspended fibrous debris is expected to arrive at the strainer. A small amount of small fibrous debris is also predicted to transport. Testing should include appropriate fiber preparation and transport to ensure prototypical bed formation. Testing should identify whether a thin-bed forms.***

   The preparation of fibrous debris is discussed in detail in the response to Draft Audit Open Item 6 in Attachment 3 of this submittal and in Section 3f.4.1.5.7.1 of Attachment 1 of this submittal. Debris agitation was used to ensure transport as described in Section 3f.4.1.5.12 of Attachment 1 of this submittal. Thin bed tests were performed in February, March, and April of 2008 and documented in Reference A.75. Tests 2 and 3-repeat show that no thin bed was formed. The thin bed tests are described in more detail in Sections 3f.4.1.5, 3f.4.2.3.2, and 3f.4.2.3.3 of Attachment 1 of this submittal.

2) ***The preliminary testing and head loss calculation showed that the design head loss could be exceeded during the most limiting LOCA conditions. The future testing and head loss evaluations should verify whether NPSH margin exists for the ECCS pumps.***

Salem has successfully completed the final head loss testing, head loss calculation, and NPSH calculation. These tests and calculations are discussed in detail in Attachment 1, Sections 3f.4.1.5, 3f.4.2.3 and 3g of this submittal. The NPSH margin available for all analyzed scenarios can be found in Table 3g-3 in Section 3g.16 of Attachment 1 of this submittal. The limiting NPSH margin is 1.4 feet with single pump operation during hot leg recirculation.

3) Strainer head loss exceeds the strainer submergence. This condition should be evaluated for flashing, if applicable, based on future testing.

Salem has successfully completed the final head loss testing. Using these results, the risk of flashing in the debris bed, behind the screen and at the inlet of the pump has been analyzed. This analysis shows that no flashing occurs in the debris bed or downstream of the strainer. Details of the flashing analysis can be found in Section 3f.14 of Attachment 1 of this submittal.

4) Bounding amounts of particulate debris should be used for testing on a given unit. The amount of Min-K® that the licensee included in its testing intended to be applicable to both units was based on Unit 1, though Unit 2 contained a significantly larger amount of this insulation.

Separate head loss tests have been performed for Units 1 and 2. Both tests used debris loads that bounded the amount of debris that is expected to transport to the strainers. The debris amounts transported to the strainer for each unit can be found in Section 3e.6 of Attachment 1 of this submittal. The debris amounts used in the unit specific head loss tests are given in Section 3f.4.1.5.6 of Attachment 1 of this submittal. A comparison of the analytically determined debris load to the tested debris load is provided in Section 3f.4.1.5.8 of Attachment 1 of this submittal.

5) Future testing should be conducted with prototypical water levels to allow for valid observations for vortex formation.

The vortex analysis is presented in Section 3f.3 of Attachment 1 of this submittal. No vortices were observed during the chemical effects head loss tests performed with the minimum submergence, as discussed in Section 3f.4.2.3 in Attachment 1 of this submittal.

6) If testing shows that a thin-bed forms and that head loss is not proportional to debris loading, the clean strainer head loss calculation should be re-evaluated.

Tests 2 and 3-repeat performed during the final head loss tests by the strainer vendor, CCI, show that no thin-bed forms on the Salem strainers under prototypical debris loading. The thin-bed tests are described in detail in Sections 3f.4.1.5, 3f.4.2.3.2, and 3f.4.2.3.3 of Attachment 1 of this submittal. The clean strainer head loss calculation is described in Section 3f.9 of Attachment 1.

7) The void fraction downstream of the strainer should be evaluated as part of the final strainer calculation.

The void fraction downstream of the strainer has been evaluated. Using the results of the final head loss tests, it has been shown that the no voids form downstream of the strainer or at the pump inlet due to vortexing or flashing. Voids can form immediately downstream of the strainer debris bed pressure drop due to a decrease in the solubility of air. The air voids formed by this de-aeration effect are re-absorbed due to the increase in solubility from increasing static head before they are ingested by the pumps. The details of this evaluation are presented in Sections 3f.3 and 3f.14 of Attachment 1 of this submittal.

8) After the results of the testing have been analyzed, the licensee should verify whether the single-pump operating case is more limiting than the two-pump operating case.

The final head loss testing and the final NPSH calculation have been completed. The NPSH margin available for all analyzed scenarios can be found in Table 3g-3 in Section 3g.16 of Attachment 1 of this submittal. The limiting NPSH margin is 1.4 feet with single pump operation during hot leg recirculation.

Updated responses:
Items 2 and 8: The limiting NPSH margin (1.4 feet) has changed since the analysis now accounts for void fraction at the pump. The revised limiting NPSH margins are presented in Table 3g-3 of Attachment 1 of this submittal.

Item 7: Air which evolves due to the pressure drop through the debris bed and strainer is no longer modeled as being reabsorbed prior to reaching the pump. A deaeration analysis was performed to determine how much air evolves due to the pressure drop based on Henry's Law. The quantity of evolved air is then used to compute the void fraction at the pump inlet (without credit for reabsorption of the evolved air). The impact of the void fraction on the NPSH required by the pumps is assessed using Appendix A of Regulatory Guide 1.82, Revision 3. The evolved air will not accumulate at the top of the strainer based on the bubble size as well as the velocities in the suction box which were determined via CFD analysis.

The details of the deaeration and air accumulation analysis are presented in Section 3f.3.2 of Attachment 1 of this response. The impact of the void fraction at the pump inlet on NPSH required is presented in Section 3g.16 of Attachment 1 of this response.

Open item 3.6-2: Preparation of Fibrous Debris for Head Loss Tests Not Prototypical

The preparation of fibrous debris for the head loss tests was not prototypical and, as a result, tended to preclude the formation of a fibrous debris "thin bed" in the test strainers. The licensee's conclusion that a thin bed would not form on the sump strainer may therefore be in error. The licensee should evaluate this issue for its impact on plant testing and summarize the results for NRC staff.

The preparation of fibrous debris is discussed at length in response to draft open item 6 in Attachment 3 of this submittal and in Section 3f.4.15.7.1 of Attachment 1 of this submittal. It has been determined that the preparation of fibrous debris for the 2008 thin-bed tests performed by CCI, the strainer vendor would lead to prototypical fiber transport and debris bed formation. CCI Tests 2 and 3-repeat show that no thin bed is formed. The thin bed tests are described in more detail in Attachment 1, Sections 3f.4.1.5, 3f.4.2.3.2, and 3f.4.2.3.3.

Updated response: No change.

Open Item 5.1-1: Strainer Structural evaluation

Based on strainer head loss and chemical effects testing, confirm that the head-loss values used in the strainer module structural evaluation are conservative or revise the strainer module structural evaluation to reflect the maximum expected pressure drop across the strainer. Provide a summary of the results to NRC staff for review.

The maximum allowable head loss when considering the structural loading on both the strainer modules and the sump suction box has been calculated. The total strainer head loss, which includes chemical effects, is below the structural limits as shown in Section 3g.16 of Attachment 1 of this submittal. The details of this structural analysis are presented in Section 3k of Attachment 1 of this submittal.

Updated response: No change.

Salem Nuclear Generating Station Units 1 and 2
Docket Nos. 50-272 and 50-311
Generic Letter 2004-02
Response to Final Audit Open Items

Open Item 5.3-1: ***Downstream Effects for Fuel and Vessel***

The licensee analysis of downstream effects for the fuel and vessel was in draft and will be re-evaluated in accordance with WCAP 16793 "Evaluation of Long-term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Revision 0 [84]. The licensee needs to complete the analysis for downstream effects for the fuel and vessel and provide a summary of the results to NRC staff.

The issue of in-vessel downstream effects will be addressed in its entirety within 90 days of the issuance of the final SE on WCAP-16793 by the NRC. The methodology and results of the existing fuel deposition calculation are presented in Section 3.n of Attachment 1 of this submittal.

Updated response: Salem will provide a response within 90 days of the issuance of the final NRC Safety Evaluation on WCAP-16793-NP.

Open Item 5.3-2: Downstream Effects for Components and Systems Incomplete

The downstream effects analysis for components and systems was in progress but incomplete. Examples of specific items which were incomplete were evaluation of the charging pump start/stop operations and charging system evaluation, validation of safety injection pump and charging pump mission times, and general validation of critical inputs to the downstream effects analyses. The details of the open items are listed in Section 5.3.3 of this report. The licensee needs to complete the analysis for downstream effects for components and systems addressing the issues noted in Section 5.3.3 and provide a summary of the results to NRC staff.

The downstream effects analysis for components and systems has been completed. Details of the analysis can be found in Section 3m of Attachment 1 of this submittal. Answers to the open items listed in Section 5.3.3 of the Final Audit Report (Reference A.78) follow.

1) ***The licensee must validate the critical inputs and assumptions used in the ECCS pump analysis.***

   During the audit, a draft calculation was provided to the NRC. Since the audit, calculation S-C-RHR-MDC-2089 (Reference A.18) has been completed. Critical inputs and assumptions are validated or otherwise shown to be conservative.

2) ***The licensee must use pump curves which consider actual operating characteristics in the evaluation of the ECCS pump degradation.***

This question was later formulated in limitation #16 of the Safety Evaluation for WCAP-16406-P (Reference 37). The method for meeting this limitation is described in Section 5.16 of Calculation S-C-RHR-MDC-2089 (Reference A.18). The use of plant IST data is further described in Section 3m.2 of this submittal.

3) ***The licensee must evaluate Stop/Start operation of the ECCS pumps.***

This question was later formulated in limitation #14 of the Safety Evaluation for WCAP-16406-P (Reference 37). The method for meeting this limitation is described in Section 5.16 of Calculation S-C-RHR-MDC-2089 (Reference A.18). Intermittent operation is not credited for reducing the mission time of the pumps.

4) ***The licensee must evaluate changes in pump rotor dynamics and the long-term effects of vibration caused by wear.***

This question was asked in context of commenting on a draft calculation revision. Calculation S-C-RHR-MDC-2089 (Reference A.18) has been completed and pump vibration is addressed.

5) ***The licensee must complete evaluations of potential blockage of system piping, containment spray nozzles, and instrumentation tubing by bypass debris.***

This question was asked in context of commenting on a draft calculation revision. Calculation S-C-RHR-MDC-2089 (Reference A.18) has been completed. Sections 3m.1 and 3m.2 of Attachment 1 of this submittal provide the results of the blockage evaluation as requested.

6) ***The licensee must evaluate the extent and effect of air entrainment downstream of the sump screens (apart from vortexing).***

The void fraction downstream of the strainer has been evaluated. Using the results of the final head loss tests, it has been shown that the no voids form downstream of the strainer or at the pump inlet due to flashing. Voids can form immediately downstream of the strainer debris bed pressure drop due to a decrease in the solubility of air. The air voids formed by this de-aeration effect are re-absorbed due to the increase in solubility from increasing static head before they are ingested by the pumps. The details of this evaluation are presented in Sections 3f.3.2 and 3f.14 of Attachment 1 of this submittal.

7) ***The licensee must conduct an overall system evaluation, integrating limiting conditions and including the potential for reduced pump/system capacity resulting from internal bypass leakage or through external leakage.***

This question was asked in context of commenting on a draft calculation revision. Calculation S-C-RHR-MDC-2089 (Reference A.18) has been completed and includes the effects of wear on the system performance. The pumps that were required to operate during the recirculation mode were shown to meet the IST acceptance curve after 25 more years of operation and the post-LOCA mission time. Since system performance is based on the IST limits, no further system level evaluations were required.

8) ***The licensee must evaluate the environmental and dose consequences outside containment due to leakage past ECCS pump seals.***

Seal leakage was calculated in Calculation S-C-RHR-MDC-2089 (Reference A.18) and evaluated in context of the plant licensing bases. Section 3m.3 of Attachment 1 of this submittal provides further discussion on this subject.

9) ***The licensee must resolve the characteristics of the strainer bypass debris and factor that information into the ECCS pump component analysis.***

Plant debris and strainer specific test data was used to determine the amount and characteristics of the debris bypassing the strainer. This is described in Section 3m.3 of Attachment 1 of this submittal. Calculation S-C-RHR-MDC-2089 (Reference A.18) documents the detailed evaluation of the test results to determine the amount of debris that bypasses the screen.

Updated response:
Item 6: Air which evolves due to the pressure drop through the debris bed and strainer is no longer modeled as being reabsorbed prior to reaching the pump, which is different than the approach outlined in the initial response to Item 6. A deaeration analysis was performed to determine how much air evolves due to the pressure drop based on Henry's Law. The quantity of evolved air is then used to compute the void fraction at the pump inlet (without credit for reabsorption of the evolved air). The impact of the void fraction on the NPSH required by the pumps is assessed using Appendix A of Regulatory Guide 1.82, Revision 3. The evolved air will not accumulate at the top of the strainer based on the bubble size as well as the velocities in the suction box which were determined via CFD analysis.

The details of the deaeration and air accumulation analysis are presented in Section 3f.3.2 of Attachment 1 of this response. The impact of the void fraction at the pump inlet on NPSH required is presented in Section 3g.16 of Attachment 1 of this response.

Item 7: See Attachment 1, Section 3m.2 for a discussion of downstream effects on components and systems.

Open Item 5.4-1: Chemical Effects Resolution

Because plant-specific chemical effects evaluations were in progress at the time of the onsite audit, chemical effects resolution in general was designated as an open item. The licensee needs to complete plant-specific chemical effects evaluations and integrated head loss tests and provide a summary of the results to NRC staff.

The Chemical Effects analysis and testing have been completed. The methodology and results of the analysis are presented in Section 3.o of Attachment 1 of this submittal. The strainer head loss testing which included chemical effects is described in Sections 3.f.4.1.5, 3f.4.2.3, and 3.o of Attachment 1 of this submittal.

Updated response: No change.

Open Item 5.4-2: Chemical Effects Resolution

There is a general open item across the PWR reactor fleet related to the potential for coatings to contribute to chemical effects by changes to the paint due to the pool environment (i.e., the potential for some of the coatings chips to turn into a product that causes high head loss). For Salem, this is designated as Open Item 5.4-2. The nuclear industry recently submitted a coatings test report that evaluates the effects of a representative post-LOCA environment on various plant coatings. The staff will determine whether the generic industry supplied information demonstrates that the potential interaction between coatings and chemical effects is insignificant. The licensee will need to address this issue once the staff has notified the licensee regarding the adequacy of the nuclear industry test report, either by declaring the issue resolved or by providing further technical information. Should further information be needed, it should be provided to the staff along with descriptions of how the plant-specific open items have been addressed.

On March 9, 2009, the NRC staff informed PSEG via email that, based on staff review of industry test data, licensees responding to GSI-191 audit open items do not need to provide additional information regarding coatings-environment interactions.

Updated response: No change.

Salem Nuclear Generating Station Units 1 and 2
Docket Nos. 50-272 and 50-311
Generic Letter 2004-02
Response to December 17, 2008 RAI

GL 2004-02 RAI Response

On December 17, 2008, the Commission issued a Request for Additional Information (RAI) to the Salem site to be answered March 31, 2009 (Reference A.82).

Following are the responses to the RAIs issued to PSEG for Salem Units, with updates after each response.

1 **Please describe what effect that the test jet size, used for acquiring test report WCAP-16710-P data, would have on applying the conclusions of that report to insulation systems at Salem, where potentially much larger jets could be experienced from reactor coolant system loop piping breaks.**

For the NUKON jet impingement tests documented in WCAP-16710-P (Reference 26), the test articles were placed at a distance from the 3.5 inch nozzle based on the calculated stagnation pressures (Section 11 of Reference 26) that relate to a specific zone of influence (ZOI). The ZOI was based on the distance to the test article and the 3.5 inch nozzle (L/D). For a LOCA in an operating nuclear power plant like the Salem units, the jet associated with the break will have the same stagnation pressure impinging on the SSCs as experienced by the test article. The equivalent ZOI in the operating plant will be based on the actual pipe diameter. In the case of a cold leg break at Salem, the cold leg diameter is 27.5" inches. For a typical component located at 5D from the break, the jet would impact at approximately 11.4 feet as opposed to the 3.6 feet (43 inches) used in the test. In either case, the fluid conditions are such that the stagnation pressure, the maximum pressure experienced by the fluid at the point where the fluid is brought to rest (impingement), is the same. Hence, the use of the jet impingement testing and resulting ZOIs calculated with a 3.5 inch jet are directly applicable to the much larger jets that could be experienced in a LOCA since it is not the size of the jet but the "damage pressure" based on the local conditions, that impinges on the SSC that is of importance when determining debris generation within a ZOI.

<u>Updated response</u>: WCAP-16710-P is no longer used to determine the ZOI for NUKON at Salem. Jacketed and unjacketed NUKON now use a ZOI of 17D as discussed in Sections 3b.1/3b.2 of Attachment 1 to this submittal.

2 **Please summarize the test report WCAP-16727-NP methodology and describe how its conclusions were determined to be applicable to the lead blankets installed in the Salem containments, especially with respect to materials, construction, blanket quantity, proximity to the analyzed breaks, and mounting details.**

The high temperature lead blankets tested at Wyle laboratory and specified in WCAP 16727-NP (Reference 32) were made with Alpha Maritex (silicon impregnated fiberglass) inner fabric covering style 3259-2 SS and outer fabric covering style 8459-2-SS. The specifications for Alpha Maritex 3259-2 SS are 17.5 oz /square yard, specific gravity of 2.4 with 0.018 in thick (18 mils) inner cover and for Alpha Maritex style 8459-2-SS are 34 oz / square yard, specific gravity 2.4.with 0.037 in thick (37 mils) outer cover.

The lead blankets at Salem Units 1 and 2 are specified and installed per Reference A.97. They contain Alpha Maritex style 3259-2-SS inner fabric covering and 8459-2-SS outer covering with the same material specification as used in the Wyle test. Therefore, the lead blankets used at Salem Units 1 and 2 are same as the lead blankets used at the Wyle test and specified in WCAP 16727-NP.

Following is the information regarding the lead blankets installed at Salem Units 1 and 2 (Reference A.98)

- Lead blankets are installed at 15 locations at Salem Unit 1 and 14 locations at Salem Unit 2, inside the Reactor Containment.
- The total volume of the 15 permanent lead shielding applications is calculated to be 250 ft^3. The number of lead blankets used at Salem Unit 1 is 840 and for Unit 2 is 758. These blankets vary in length between 2 feet and 6 feet and the width varies between 8 inches and 12 inches. The sizes vary based on the location and type of radiation source that needs protection.

- All lead blankets are secured on the top by hooks in regularly spaced grommets on seismically restrained scaffold structures. The hooks are either aluminum carabiners and/or U-bolts. The added aluminum quantity is included in the Post LOCA Chemical Effects Analysis. The bottom of the blankets remains unrestrained.

Following are the locations of the lead blankets installed at Salem Unit 1 (Reference A.59) and Salem Unit 2 (Reference A.60).

No	Lead Blanket Location	Reactor Cont. Elevation (feet)	Break (Note 1)	Distance from break location (feet)	Back Frame (Open Back /Close Back)
1	11(21) RCS Intermediate Loop piping	81	S6	0.5	Open Back
2	12(22) RCS Intermediate Loop piping	81	S6	0.5	Open Back
3	13(23) RCS Intermediate Loop piping	81	S6	0.5	Open Back
4	14(24) RCS Intermediate Loop piping	81	S6	0.5	Open Back
5	11(21) vertical SJ piping @ 21 RCP platform	103	S2	11	Open Back
6	12(22) vertical SJ piping @ 22 RCP platform	103	S2	11	Open Back
7	13(23) vertical SJ piping @ 23 RCP platform	103	S2	11	Open Back
8	14(24) vertical SJ piping @ 24 RCP platform	103	S2	11	Open Back
9	11(21) horizontal SJ piping @ 21 RCP platform	111	S6 (Note 3)	16	Open Back
10	12(22) horizontal SJ piping @ 22RCP platform	111	S6 (Note 3)	16	Open Back
11	13(23) horizontal SJ piping @ 23RCP platform	111	S6 (Note 3)	16	Some Close Back
12	14(24) horizontal SJ piping @ 24 RCP platform	111	S6 (Note 3)	16	Open Back
13	Pressurizer spray line between 11-13 (21-23) RCP	107	S1	11.7	Open Back
14	Lead shielding @ 2RH2 valve El. 78'	78	Note 2	N/A	Open Back
15	Pressurizer Enclosure	159	Note 2 & 6	N/A	Open Back

Note 1: The breaks noted above are discussed in Section 3b.4 of this response.

Note 2 The lead blankets installed at 2RH2 valve and Pressurizer Enclosure (El. 159') are outside the bioshield wall and are not subjected to jet impingement.

Note 3: The distance from a postulated break S6 location is 16'. Per WCAP 16727-NP, all blankets installed at an equivalent spherical ZOI ≥ 5D may be excluded from debris generation consideration. The ZOI for S6 break is 13 feet (pipe diameter 31"). Therefore, the lead shielding will be outside the ZOI and damage to the blankets is not considered.

Note 4: SJ = Safety Injection

Note 5: RCS Intermediate Loop piping is between the steam generator and reactor coolant pump.

Note 6: The lead blankets at Pressurizer Enclosure are installed at Salem Unit 1 only.

Note 7: The numbers is parenthesis denote Unit 2. For example on the first row 11 RCS Intermediate Loop piping is for Unit 1 and 21 RCS Intermediate Loop piping (Unit 2) is for Unit 2.

All the lead blanket installations at Salem Units 1 and 2, were reviewed against the WCAP 16727-NP. Six locations at Unit 1 and 5 locations at Unit 2 were determined to be outside the 5D ZOI. WCAP 16727 states that all blankets installed at an equivalent spherical ZOI ≥ 5D may be excluded from debris generation consideration. Therefore, for these locations that are outside the 5D ZOI, no blanket damage is postulated.

The lead blankets at the remaining nine locations were categorized as open back and they fall within the 5D ZOI. The following evaluation reviews the blankets installed at these nine locations against the WCAP test methodology.

In the test specimen, the lead blankets were secured top and bottom by hooks in the regularly spaced grommets. At Salem Units 1 and 2 the lead blankets are secured at the top by hooks in regularly spaced grommets. In some Salem configurations, one layer of blanket is used and in other configurations two layers of blankets are used. In the two layer configuration, the blankets have their own grommets and hooks. The following pictures show the test configuration and blankets installed at Salem.

Figure 1: Lead Blanket #4 mounted prior to Jet Impingement Test
Lead blanket specimen #4 secured at the top and bottom by hooks in the regularly spaced grommets to an open frame (open back).

Figure 2: Lead Blanket Installed at Salem

In the Wyle test, six specimens were tested with varying configurations. Test #1 was done with lead blankets secured at the top and bottom by hooks in the regularly spaced grommets to an open frame (open back). The test specimen was positioned 8.25 inches (1.25D) in front of the nozzle. The test results showed that all grommets were torn from the blanket. The cover material was torn in several places but appeared intact. There were four torn pieces of the blanket approximately 23 inches in length located at the top and bottom center of the blanket. Both ends of the blanket were torn open with some loss of threading. There were abrasion marks on both sides of the blanket. All of the lead wool shielding remained intact. Based on the above results, the WCAP concluded, for high temperature lead blankets that hang free at an equivalent spherical ZOI ≥ 1.25D, no debris is generated that would interfere with the emergency sump

As stated above, all lead blanket installed at Salem have open back configuration (except one which is outside the 5D ZOI). Therefore, Wyle Test #1 would be applicable. The testing showed that the grommets were the weakest link and that no debris was generated. A failure resulting in debris generation only occurred in a strong back configuration.

At Salem one or two layers of lead blankets are installed with hooks through regularly spaced grommets from top only as against Wyle test where the lead blanket was secured at top and bottom with hooks through grommets. In the two layer configuration, each blanket is installed with its own grommet and hook. Therefore, the second layer will not act as a strong back and will fail similar to the one layer configuration.

As stated above, the WCAP 16727-NP concluded that free hanging lead blankets at ZOI ≥ 1.25D do not generate debris that would interfere with the containment sump. At Salem Units there are some locations where the lead blanket are installed (open back) with less that 1.25D ZOI. It should be noted that although the testing performed is for distance at 1.25D, the failure modes for distances less than 1.25D should not change. The grommets are the weakest link and would fail first and the cover material should not separate from the lead wool to generate any debris impacting the sump.

Based on the above information, it is concluded that the open back test documented in WCAP 16727-NP is applicable to Salem configurations. Therefore, the conclusion that no debris will be generated with this configuration is applicable to Salem Units.

<u>Updated response</u>: WCAP-16727-NP is no longer used to determine the ZOI for lead blankets at Salem. Details of the lead blanket ZOI and size distribution are provided in Sections 3b.4 and 3c.1, respectively, of Attachment 1 of this submittal.

3 **Please provide a response to Open Item 3.5-1 in the NRC's GL 2004-02 audit report for Salem which stated:**

> **The licensee needs to demonstrate the capability of the unmodified mesh gate located near the ECCS [emergency core cooling system] strainers to withstand the potential post-LOCA [loss of coolant accident] structural loadings (e.g., jet impingement, subcompartment depressurization, and containment pool flows when obstructed with debris and provide a summary of results to the NRC staff.**

At Salem Units 1 and 2, there are four wire mesh gates at the entrance of the bioshield to restrict personnel entry. Debris generated during a postulated LOCA could block the wire mesh gates and impede water flow to the containment sump strainers. In order to prevent this concern, three of the four inner bioshield gates were modified. However, the gate closest to the containment sump was not modified. This condition would result in a tortuous path to the sump and allow large debris to settle prior to reaching the sump.

Calculation 6S0-1703 (Reference A.92) was created to evaluate the capacity of the unmodified door for debris load and jet impingement. Any pipe break that results in ECCS sump recirculation was reviewed to determine the jet impingement impact. Since small break LOCAs do not result in ECCS recirculation, they were not considered. The evaluation showed that there are no postulated large bore pipe breaks in the vicinity of the unmodified bioshield door. Therefore, jet impingement is not a concern for the unmodified bioshield door.

The evaluation also showed that the door is capable of withstanding the load from the debris that would strike the door combined with the hydrodynamic load from water flowing during a postulated LOCA. Also, there is no subcompartment depressurization concerns because the wire mesh will not be fully filled with debris. Based on the results of the evaluation it was verified that the unmodified door is capable of accommodating the expected structural loading and no modifications were required for the door.

Updated response: No change.

4 **Please provide verification that the fibrous size distribution used during testing was prototypical or conservative compared to the size distribution predicted by the transport evaluation.**

The fiber size distribution utilized in the transport analysis is given in Section 3c.1 of Attachment 1 of this response.

The fiber size distribution utilized during testing is given in Section 3f.4.1.5.7.1 of Attachment 1 of this response. This section verifies that the tested fibrous size distribution is either prototypical or conservative.

Updated response: No change.

5 **Please provide details of the debris addition procedures used. Please include a description of fibrous concentration during debris addition, the debris addition location, and the method of adding fibrous debris to the test tank. Please provide verification that the debris introduction processes did not result in non-prototypical settling, agglomeration, or deposition of debris prior to addition or as the material was added.**

The details of the debris addition procedure used during testing are given in Section 3f.4.1.5.11 of Attachment 1 of this response.

Updated response: No change. Debris agitation following debris addition is described in Section 3f.4.1.5.12 of Attachment 1 of this response.

6 **Provide the amounts of various debris types added during each test and describe the debris characteristics.**

The quantity of debris used during testing is given in Section 3f.4.1.5.6 of Attachment 1 of this response. The characteristics of the tested debris are described in Section 3f.4.1.5.7 of Attachment 1 of this response.

Updated response: No change.

7 **Please provide scaling values used for testing.**

Test scaling is described in Sections 3f.4.1.5.4 and 3o.1.19c(i) of Attachment 1 of this response.

Updated response: No change.

8 **If the strainer head loss test(s) allowed near-field settling, please provide a comparison of the flows predicted around the strainer in the plant and the flows present in the test flume during the testing. Please show that the test velocities and turbulence levels were prototypical or conservative compared to the plant.**

Near-field settling was not credited in the strainer head loss tests. Instead, the test flume was agitated to minimize debris settling. Debris agitation methods used during testing are described in Section 3f.4.1.5.12 of Attachment 1 of this response. The amount of debris that did accumulate on the floor of the test flume in the strainer head loss tests can be found in Section 3f.4.2.3 of

Attachment 1 of this response. The test flume flow rates are provided in Section 3f.4.1.5.5 of Attachment 1 of this response.

Updated response: No change.

9 **If the strainer head loss test(s) allowed near-field settling, please provide the amount of debris that settled in the test tank.**

Near-field settling was not credited in the strainer head loss tests. Instead, the test flume was agitated to minimize debris settling. Debris agitation methods used during testing are described in Section 3f.4.1.5.12 of Attachment 1 of this response. The amount of debris that did accumulate on the floor of the test flume in the strainer head loss tests can be found in Section 3f.4.2.3 of Attachment 1 of this response.

Updated response: No change.

10 **If agitation was utilized to prevent debris settling, please verify that the debris bed was not non-conservatively disturbed by the agitation and that non-prototypical transport did not result.**

Debris agitation methods used during testing are described in Section 3f.4.1.5.12 of Attachment 1 of this response. The debris bed was not disturbed by the agitation of the settled debris.

Updated response: No change.

11 **Please provide an overview of the test procedures used during testing (thin-bed and full-load tests).**

An overview of the test procedures used during thin-bed and full-load head loss testing is provided in Section 3f.4.1.5 of Attachment 1 of this response.

Updated response: No change.

12 **Please provide any extrapolation performed on the test data to account for flow rates or temperatures different from those present during testing, but actually expected during the ECCS mission time. If temperature scaling is used, please discuss considerations made to identify and account for bore holes or channeling that may have occurred during testing. Alternatively, please discuss how it was verified that these phenomena did not occur.**

Flow rate and temperature/viscosity scaling of the strainer head loss with no chemical effects is discussed in Sections 3f.10 and 3f.13 of Attachment 1 of this response. Verification that bore holes did not form in the debris bed prior to the addition of chemical precipitates is provided in Section 3f.4.2.3 of Attachment 1 of this response. Since bore holes were formed in the debris bed with chemical effects, no scaling of these results was performed. Temporal extrapolation of the test results to the 30-day ECCS mission time is not required as described in Section 3o.1.17d(ii) of Attachment 1 of this response.

Updated response: No change.

13 **Please provide the methodology used for calculation of clean strainer head loss (CSHL) and provide the CSHL value.**

The clean strainer (no debris) head loss is nominally 2.9 feet for two pump operation for Units 1 and 2. The component (non-debris) head loss for a debris laden strainer is nominally 1.0 ft for single pump operation and 3.1 ft for two pump operation for Units 1 and 2. The methodology used for the calculation of the clean strainer head loss and the CSHL values are presented in Section 3f.9 of Attachment 1 of this response.

Updated response: No change.

14 **Please provide the void fraction downstream of the strainer.**

The void fraction due to vortexing, flashing, and deaeration is 0.0% at the ECCS pump inlets as documented in Sections 3f.3 and 3f.14 of Attachment 1 of this response.

Updated response: The void fraction at the ECCS pump inlets due to deaeration is no longer 0.0%. Details of the deaeration analysis are provided in Section 3f.3.2 of Attachment 1 of this submittal.

15 **Please verify that the limiting net positive suction head (NPSH) margin scenario has been considered for both single train and dual train ECCS operation.**

The methodology used for the calculation of the limiting net positive suction head margin is presented in Section 3g.16 of Attachment 1 of this response. The case with the most limiting NPSH margin is single train operation during Cold Leg recirculation for Unit 1 and during Hot Leg recirculation for Unit 2.

Updated response: No change.

16 **Please evaluate the potential for flashing within the debris bed or strainer based on the head loss values obtained during final head loss testing considering one and two train operation.**

The flashing analysis is described in detail in Section 3f.14 of Attachment 1 of this response. This analysis shows that flashing does not occur in the debris bed or strainer.

Updated response: No change.

17 **Please provide the vortexing evaluation. Please consider the higher flow rates associated with the module closest to the pump suction and the non-uniformity in the flow pattern contributed by the upstream flow in containment.**

The vortexing analysis is described in detail in Section 3f.3 of Attachment 1 of this response.

Updated response: No change.

18 **Please provide description of any changes made to the NPSH calculation and minimum NPSH margins as a result of completion of strainer head loss testing.**

The strainer head loss margin is the limiting margin between the NPSH margin and the strainer structural margin. The minimum strainer head loss margin for single train operation is 1.6 feet for Unit 1 (during Cold Leg recirculation) and 1.4 feet for Unit 2 (during Hot Leg recirculation). The minimum strainer head loss margin for two train operation is 6.8 feet for Unit 1 and 2.3 feet for Unit 2 (both occur during Containment Spray recirculation). The methodology and results of the calculation of the limiting net positive suction head margin based on the final strainer head loss testing are presented in Section 3g of Attachment 1 of this response.

Updated response: Revised limiting margins are presented in Table 3g-3 of Attachment 1 of this submittal.

19 **Please address Open Item 5.1-1 in the NRC's GL 2004-02 audit report for Salem which stated:**

> **Based on strainer head loss and chemical effects testing, confirm that the head-loss values used in the strainer module structural evaluation are conservative or revise the strainer module structural evaluation to reflect the maximum expected pressure drop across the strainer. Provide a summary of the results to NRC staff for review.**

The methodology and results from the strainer module structural evaluation are presented in Section 3k of Attachment 1 to this submittal.

Updated response: No change.

20 **Please provide the information requested under item m, "Downstream effects Components and Systems" in the "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses" (ADAMS Accession No. ML073110389).**

The Downstream Effects analysis for components and systems has been completed. The methodology and results of this analysis are presented in Section 3m of Attachment 1 of this response.

Updated response: No change.

21 **The NRC staff considers in-vessel downstream effects to not be fully addressed at Salem, as well as at other pressurized-water reactors. PSEG's submittal refers to Revision 0 of the Pressurized-Water Reactor Owners Group (PWROG) topical report WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." At this time, the NRC staff has not issued a final safety evaluation (SE) for this topical report since the PWROG intends to submit Revision 1 to address several issues identified by the Advisory Committee on Reactor Safeguards and the NRC staff. The licensee may demonstrate that in-vessel downstream effects issues are resolved for Salem by showing that the Salem plant conditions are bounded by the revised version of WCAP-16793 and the corresponding final NRC staff SE, and by addressing the conditions and limitations in the final SE. The licensee may also resolve this item by demonstrating, without reference to WCAP-16793 or the staff SE, that in-vessel downstream effects have been addressed at Salem. In any event, the licensee should report how it has**

addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on WCAP-16793. The NRC staff is developing a Regulatory Issue Summary to inform the industry of the staff's expectations and plans regarding resolution of this remaining aspect of Generic Safety Issue 191.

The methodology and results of the existing fuel deposition calculation are presented in Section 3n of Attachment 1 of this response. PSEG will provide the requested information within 90 days of issuance of the final NRC staff Safety Evaluation for WCAP-16793-NP.

Updated response: Salem will provide a response within 90 days of the issuance of the final NRC Safety Evaluation on WCAP-16793-NP.

22 **At the time of the supplemental response, the Salem chemical effects testing was not yet complete. Please provide the updated results from chemical effects testing that demonstrate the Salem plant-specific chemical effects have been evaluated in a conservative manner. Please provide this information using a similar format to that in your February 29, 2008, letter (ADAMS Accession No. ML080800469).**

The Chemical Effects analysis and testing have been completed. The methodology and results of the analysis are presented in Section 3o of Attachment 1 of this response. The strainer head loss testing which included chemical effects is described in Sections 3f.4.1.5, 3f.4.2.3, and 3o of Attachment 1 of this response.

Updated response: No change.

23 **On page 40 of 124 of Attachment 1 of the PSEG supplemental response, it is noted that some of the debris is added downstream of the strainers:**

a. **How much (in kilograms) and what percentage is added downstream?**

b. **How is this consistent with the transport analysis for this plant?**

c. **Please describe how this material is introduced downstream of the pocket strainer in the multi-functional test loop.**

The results of the transport analysis including the amounts of debris transported to both the upstream and the downstream sides of the strainer are presented in Section 3e.6 of Attachment 1 of this response. The Test 5 and Test 6 amounts of debris added both upstream and downstream of the strainers in the final head loss tests are greater than or equal to the amounts determined in the transport analysis as shown in Section 3f.4.1.5.8 of Attachment 1 of this response. The details of the debris addition procedure including the amounts added both upstream and downstream of the strainer during testing are given in Sections 3f.4.1.5.11 and 3f.4.1.5.6, respectively, of Attachment 1 of this response.

Updated response: The total Test 5 and Test 6 amounts of debris added in the final head loss tests are greater than or equal to the amounts determined in the transport analysis as shown in Section 3f.4.1.5.8 of Attachment 1 of this submittal. However, several tested upstream and downstream quantities are slightly less than the analytically determined transport quantities. This is acceptable as documented in Section 3f.4.1.5.8 of Attachment 1 of this submittal.

24 Please confirm that the debris used for Salem Unit No.2 chemical effects testing represented the bounding break location for Unit 2.

The break locations that resulted in the largest possible debris load were analyzed in the debris generation analysis as discussed in Section 3a.3 of Attachment 1 of this response. The results of the debris transport analysis of the bounding debris loads are presented in Section 3e.6 of Attachment 1 of this response. The debris amounts used in the final strainer head loss tests bound those determined in the transport analysis as shown in Section 3f.4.1.5.8 of Attachment 1 of this response.

The precipitate amounts used in the strainer head loss tests which included chemical effects were greater than precipitate amounts determined for all of the bounding breaks analyzed in the chemical effects analysis as shown in Section 3o.1.21d(i) of Attachment 1 of this response.

Updated response: No change for Unit 2. However, the precipitate debris load utilized in the final Unit 1 strainer head loss test (Test 5) was based on a NUKON ZOI of 7D. Since a NUKON ZOI of 17D is now utilized, the Unit 1 chemical precipitate quantity used in the final strainer head loss test is less than the precipitate quantity determined in the chemical effects analysis. However, the final Unit 1 strainer head loss test (Test 5) is still valid for design as explained in Section 3o.1.17d(ii) of Attachment 1 of this submittal.

Salem Nuclear Generating Station Units 1 and 2
Docket Nos. 50-272 and 50-311
Generic Letter 2004-02
References

General References

1. NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents for Pressurized-Water Reactors," dated September 13, 2004.

2. Nuclear Energy Institute (NEI) document NEI 04-07 Revision 0, December 2004, "Pressurized Water Reactor Sump Performance Evaluation Methodology."

3. Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), "Pressurized Water Reactor Sump Performance Evaluation Methodology," Issued December 6, 2004.

4. Regulatory Guide 1.82, "Water Sources for Long Term Recirculation Cooling Following a Loss of Coolant Accident," Revision 3, November 2003.

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A.88 VTD 901218, "Salem MFTL Chemical Test Report – Containment Sump Project," Revision 1, Dated April 17, 2008. (CCI Document No. 680/41352, Revision 1, "Chemical Effect Test Filter Performance Report").

A.89 VTD 901382, "Salem Multi Functional Loop Thin Bed & Bypass Test Specification for Containment Sump Strainers," Revision 5, Dated August 17, 2009. (CCI Document No. Q.003.84 808, "Containment Sump Strainer Replacement: Salem MFT Thin Bed and Bypass Test Specification").

a. CCI Document No. Q.003.84 808, Revision 0, Dated February 22, 2008.
b. CCI Document No. Q.003.84 808, Revision 5, Dated November 18, 2008.
c. CCI Document No. Q.003.84 808, Revision 6, Dated November 21, 2008.
d. CCI Document No. Q.003.84 808, Revision 3, Dated March 31, 2008.

A.90 Omitted

A.91 CCI Drawings
  a. VTD 901020, Sheet 31, "Salem Containment Sump – Support Structure Flex," Revision 1, Dated May 8, 2007. (CCI Document No. 103.132.241.500, Revision H, Dated June 12, 2006).
  b. VTD 900504, Sheet 26, "Salem Containment Sump – Support Structure Flex," Revision 1, Dated March 3, 2008. (CCI Document No. 103.132.241.500, Revision D, Dated September 19, 2006).

A.92 Calculation 6S0-1703, "Salem Units 1 and 2 Reactor Containment - Equipment Access Platforms and Barriers," Revision 2, Dated August 29, 1996.

A.93 VTD 902524, Westinghouse Document LTR-CDME-08-58, "Evaluation of Sodium Silicate Solution Procured by CCI for Use in the Preparation of Chemical Surrogates for Salem Units 1 and 2," Revision 0, Dated March 12, 2008.

A.94 CCI report 680/41042, "CCI Test Report Justifying the Absence of Vortex," Dated March 17, 2005. This report is proprietary to CCI.

A.95 VTD 901587, Revision 1, "Chemical Effects Bench Top Test Report – Containment Sump Project," Dated December 23, 2008 (Enercon Report No. PSE-027-PR-001, Revision 0).

A.96 VTD 901396, Revision 1, Dated March 14, 2008, Westinghouse Document TP-120270-1, Revision 0, "Procedure For Generation of Chemical Surrogates For Salem Units 1 & 2."

A.97 PSEG Specification S-C-CAN-SDS-0462, Revision 1, "Procurement Specification for High Temperature Lead Blankets to be used for Permanent Shielding inside Containment Salem Unit 1 & 2," Dated November 28, 2006.

A.98 Lead Shielding Design Change Package
  A.98.1 DCP 80088609, Revision 0, "Salem Unit 1 Permanent Lead Shielding Inside Containment."
  A.98.2 DCP 80087096, Revision 2, "Salem Unit 2 Permanent Lead Shielding Inside Containment."

A.99 S-TODI-2009-0015, "Minimum Flood Level for Vortex Evaluation," Dated March 18, 2009.

A.100 Letter from PSEG to United States Nuclear Regulatory Commission, LR-N98530, "RESPONSE TO GENERIC LETTER 98-04 DATED JULY 14 1998, HOPE

CREEK GENERATION STATION SALEM STATIONS UNITS 1 & 2," Dated November 2, 1998.

A.101 PSEG Specification S-C-X400-SDS-0148, Revision 0, "Structural Paint Specification Reactor Containments, Fuel Handling and Auxiliary Buildings," Dated June 2, 1988.

A.102 VTD 901735, Revision 1, Westinghouse Document LTR-SEE-I-09-44, "Westinghouse Response to NRC RAI on Jet Impingement in Support of Containment Sump Project," Dated March 30, 2009.

A.103 CCI Document No. 3 SA-096.078, Revision 0, Dated December 1, 2008, "Structural Limit Calculation." (Included in VTD 900501)

A.104 Calculation S-C-RHR-MDC-2297, Revision 0, Dated June 14, 2011, "Deaeration of Sump Water Due to the Pressure Drop Across the Containment Sump Strainers." (S&L Calculation 2010-05410, Revision 0)

A.105 VTD 323585, Revision 1, "Salem Unit 1 RWST Draindown & Cold Leg Recirculation Engineering Report," Dated January 5, 1998.

A.106 VTD 323001, Revision 1, "Salem Unit 2 RWST Draindown & Cold Leg Recirculation Engineering Report," Dated May 22, 1997.

A.107 1-EOP-LOCA-1, Revision 25, "Loss of Reactor Coolant," Dated December 14, 2006.

A.108 2-EOP-LOCA-1, Revision 28, "Loss of Reactor Coolant," Dated April 28, 2008.

A.109 1-EOP-LOCA-3, Revision 28, "Transfer to Cold Leg Recirculation," Dated October 14, 2010.

A.110 2-EOP-LOCA-3, Revision 29, "Transfer to Cold Leg Recirculation," Dated October 14, 2010.

A.111 1-EOP-LOCA-5, Revision 24, "Loss of Emergency Recirculation," Dated April 11, 2007.

A.112 2-EOP-LOCA-5, Revision 25, "Loss of Emergency Recirculation," Dated October 28, 2006.

A.113 VTD 901688, Revision 1, Dated March 5, 2009, (CCI Report 680/41434, Revision 0, "Vortexing Test Report for Clean Strainers").

Salem Nuclear Generating Station Units 1 and 2
Docket Nos. 50-272 and 50-311
Generic Letter 2004-02
References

A.114 1-EOP-LOCA-2, Unit 1 "Post LOCA Cooldown and Depressurization," Revision 23, Dated July 21, 2005.

A.115 2-EOP-LOCA-2, Unit 2 "Post LOCA Cooldown and Depressurization," Revision 25, Dated July 21, 2005.

A.116 Dwg. 606086, Sheet 10, Revision 0, Dated March 27, 2008, "Salem 1 Containment Sump Upgrades - 9" High Galv. Grtg. Curb at El. 78'-0"."

A.117 Dwg. 606067, Sheet 12, Revision 0, Dated February 22, 2010, "Salem 2 Containment Sump Upgrades - 9" High Galv. Grtg. Curb at El. 78'-0"."

A.118 Work Order 60066109, "Outage-S1 Containment Sump Upgrades," Operation 1190.

A.119 Work Order 60078991, "S2 CTMT Sump Strainers Perf Plates."

A.120 Unit 1 Drawing 239086, Revision 5, Dated March 11, 1982, "Containment Sump Level Transmitter Installation Details."
Unit 2 Drawing 239087, Revision 4, Dated July 27, 1995, "Containment Sump Level Transmitter Installation Details."

A.121 Calculation SC-SJ006-01, Revision 0, Dated June 8, 1998, "Salem Unit 1 RWST Level Uncertainty Calculation."
Calculation SC-SJ007-01, Revision 2, Dated January 17, 2000, "Salem Unit 2 RWST Level Uncertainty Calculation."

A.122 Procedure S1.OP-ST.SJ-0014 (Q), "Intermediate Head Cold Leg Throttling Valve Flow Balance Verification," Revision 23, Dated January 20, 2011.
Procedure S2.OP-ST.SJ-0014 (Q), "Intermediate Had Cold Leg Throttling Valve Flow Balance Verification," Revision 26, Dated April 19, 2011.

Salem Nuclear Generating Station Units 1 and 2
Docket Nos 50-272 and 50-311
Generic Letter GL 2004-02

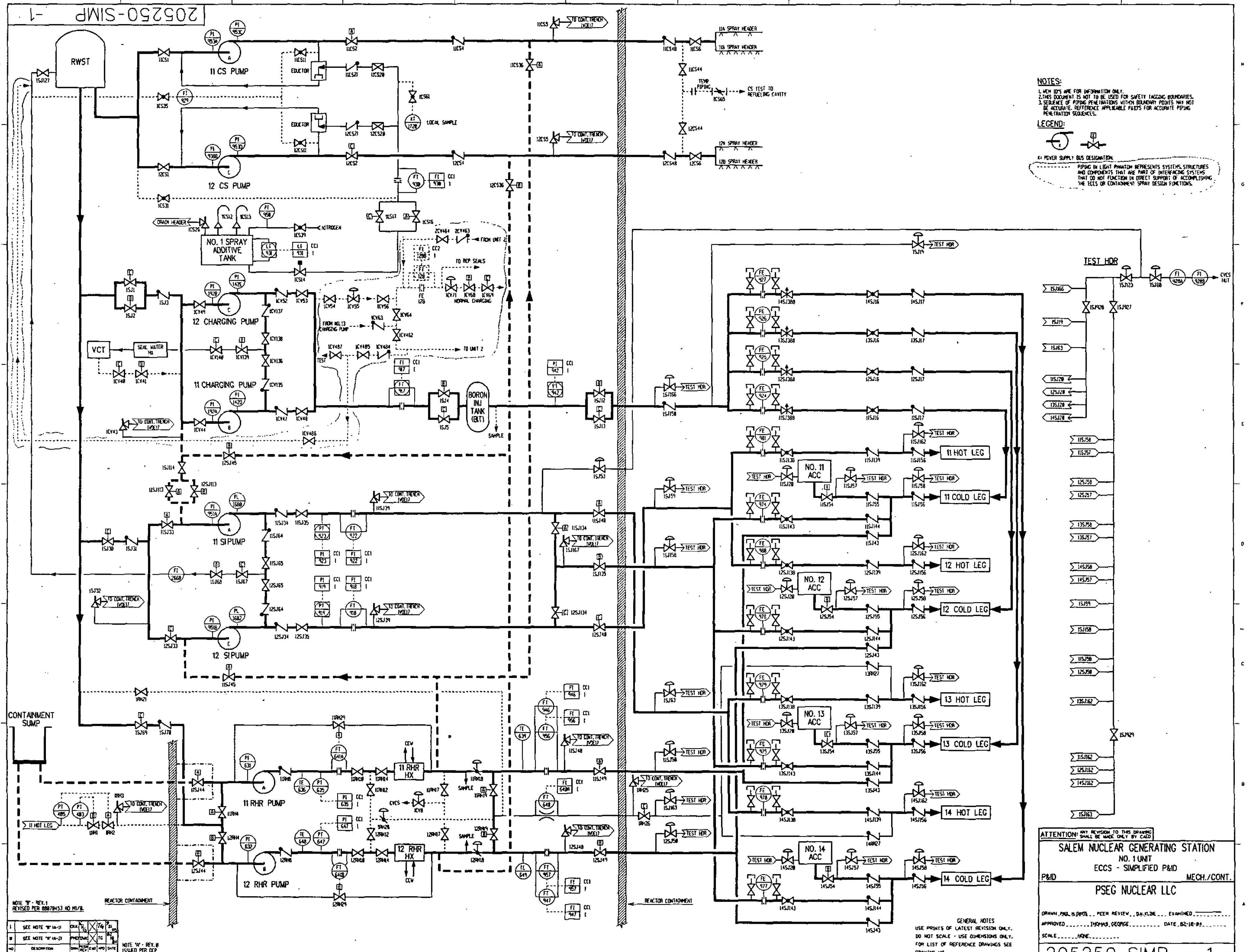
The following are simplified P&ID drawings associated with the ECCS and CSS. Copies are included in this Enclosure:

1. Drawing 205250-Simp No 1 Salem Unit ECCS Simplified P&ID, Revision 1 Dated September 21, 2005
2. Drawing 205350-Simp No 2 Salem Unit ECCS Simplified P&ID, Revision 4 Dated September 21, 2005
3. Drawing 205234-Simp No 1 Salem Unit Safety Injection Simplified P&ID, Revision 0 Dated June 16, 1999
4. Drawing 205334-Simp No 2 Salem Unit Safety Injection Simplified P&ID, Revision 1 Dated February 5, 1999
5. Drawing 205235-Simp No 1 Salem Unit Containment Spray Simplified P&ID, Revision 0 Dated June 16, 1999
6. Drawing 205335-Simp No 2 Salem Unit Containment Spray Simplified P&ID, Revision 1 Dated February 5, 1999

Updated Response:

There are no changes to the revision numbers for these drawings.

205250-SIMP -1



NOTE "B" - REV.1
REVISED PER 80070453 AD M1/0L

NO	DESCRIPTION	DWN	PEER REV	ENG	APD	DATE
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0	SEE NOTE "A" (A-2)	PMD	DWK		TG	02 10 04

REVISION

NOTE "A" - REV.0
ISSUED PER DCP
80068283 AD M1/0

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- - - - - - - - PIPING IN LIGHT PHANTOM REPRESENTS SYSTEMS, STRUCTURES AND COMPONENTS THAT ARE PART OF INTERFACING SYSTEMS THAT DO NOT FUNCTION IN DIRECT SUPPORT OF ACCOMPLISHING THE ECCS OR CONTAINMENT SPRAY DESIGN FUNCTIONS.

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NO. 1 UNIT
ECCS - SIMPLIFIED P&ID
P&ID MECH./CONT.

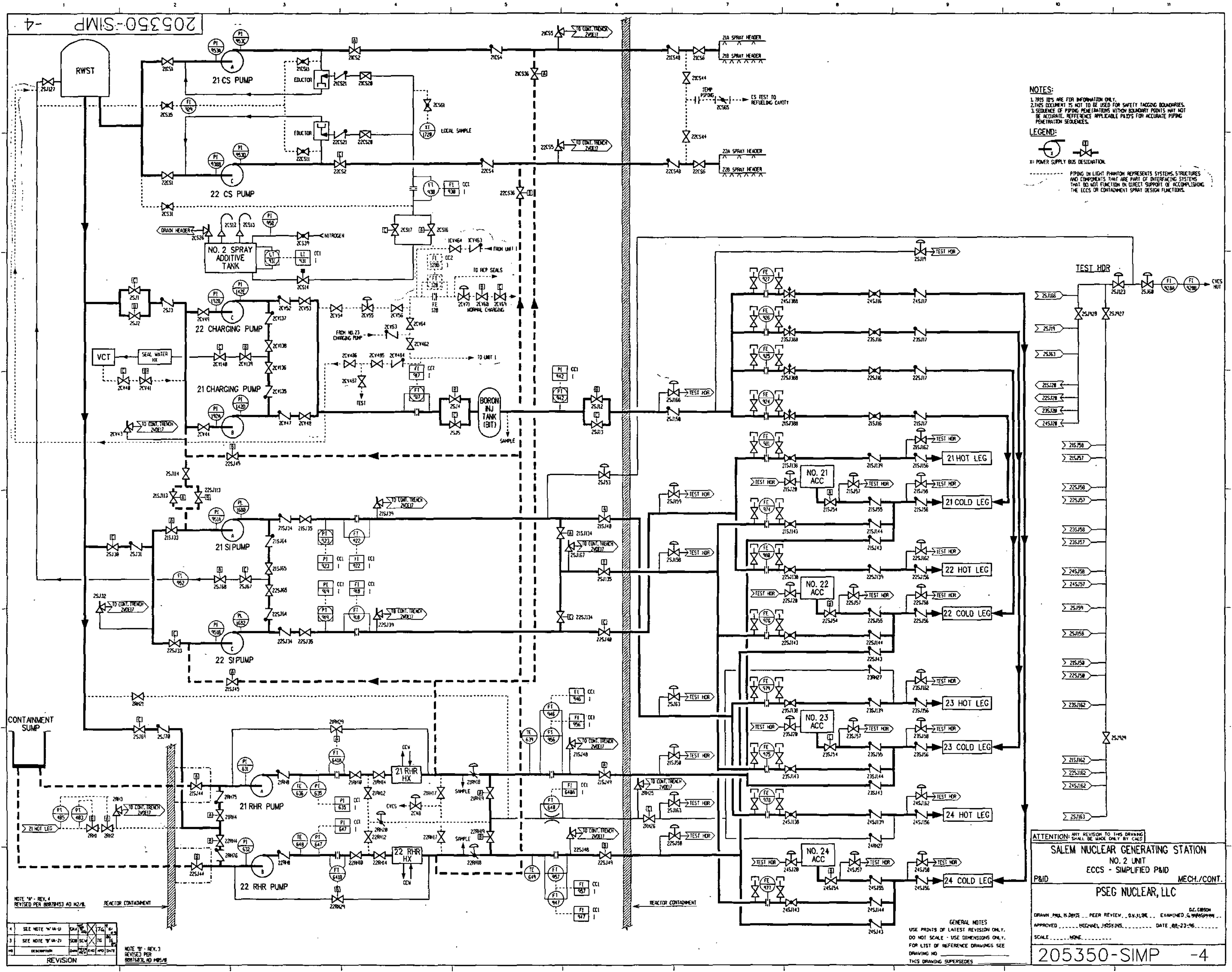
PSEG NUCLEAR LLC

DRAWN PAUL M.DAVIS PEER REVIEW D.W.KLINE EXAMINED ______
APPROVED THOMAS GEORGE DATE 02-10-04
SCALE NONE

205250-SIMP -1

205250-SIMP

205350-SIMP -4



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NOTE "A" - REV. 4
REVISED PER 80070453 AD H2/8L

NOTE "B" - REV. 3
REVISED PER 80076831 AD H05/B

NO	DESCRIPTION	DWN	PEER REV	EXD	APD	DATE
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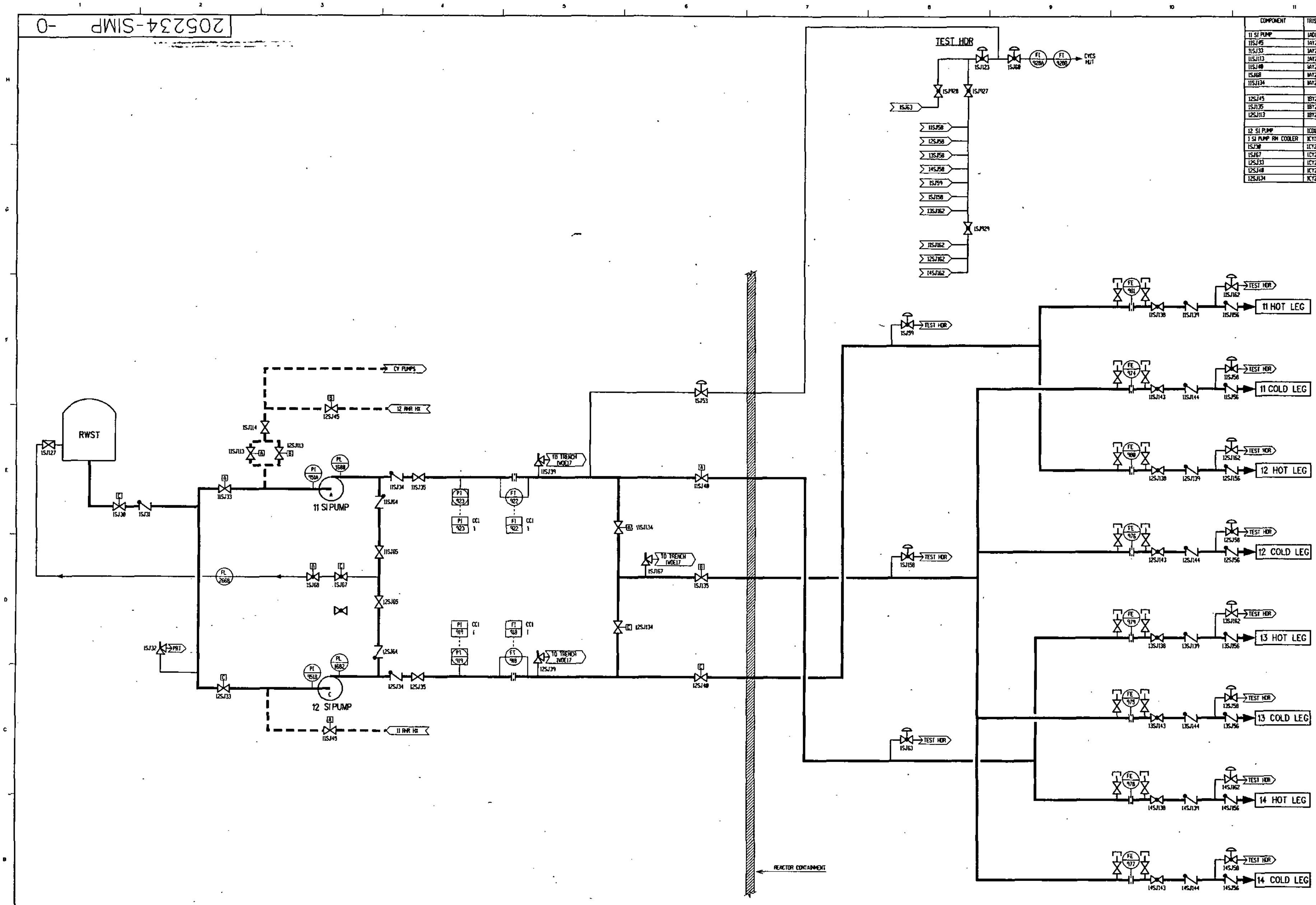
APPROVED MICHAEL HOSKINS DATE 08-23-96
SCALE NONE

205350-SIMP -4



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11SJ40	1AY2EP4E
1SJ68	1AY2AX4I
11SJ134	1AY2EP5I
12SJ45	1BY2AX1E
1SJ135	1BY2AX9I
12SJ113	1BY2AXBA
12 SI PUMP	1CD1AX50
1 SI PUMP RM COOLER	1CY1EP1D
1SJ30	1CY2AX0A
1SJ67	1CY2AX0E
12SJ33	1CY2AX3E
12SJ40	1CY2AX4E
12SJ134	1CY2AX7I

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REVISION

NOTE "A" - REV. 0
ORIGINAL ISSUE.
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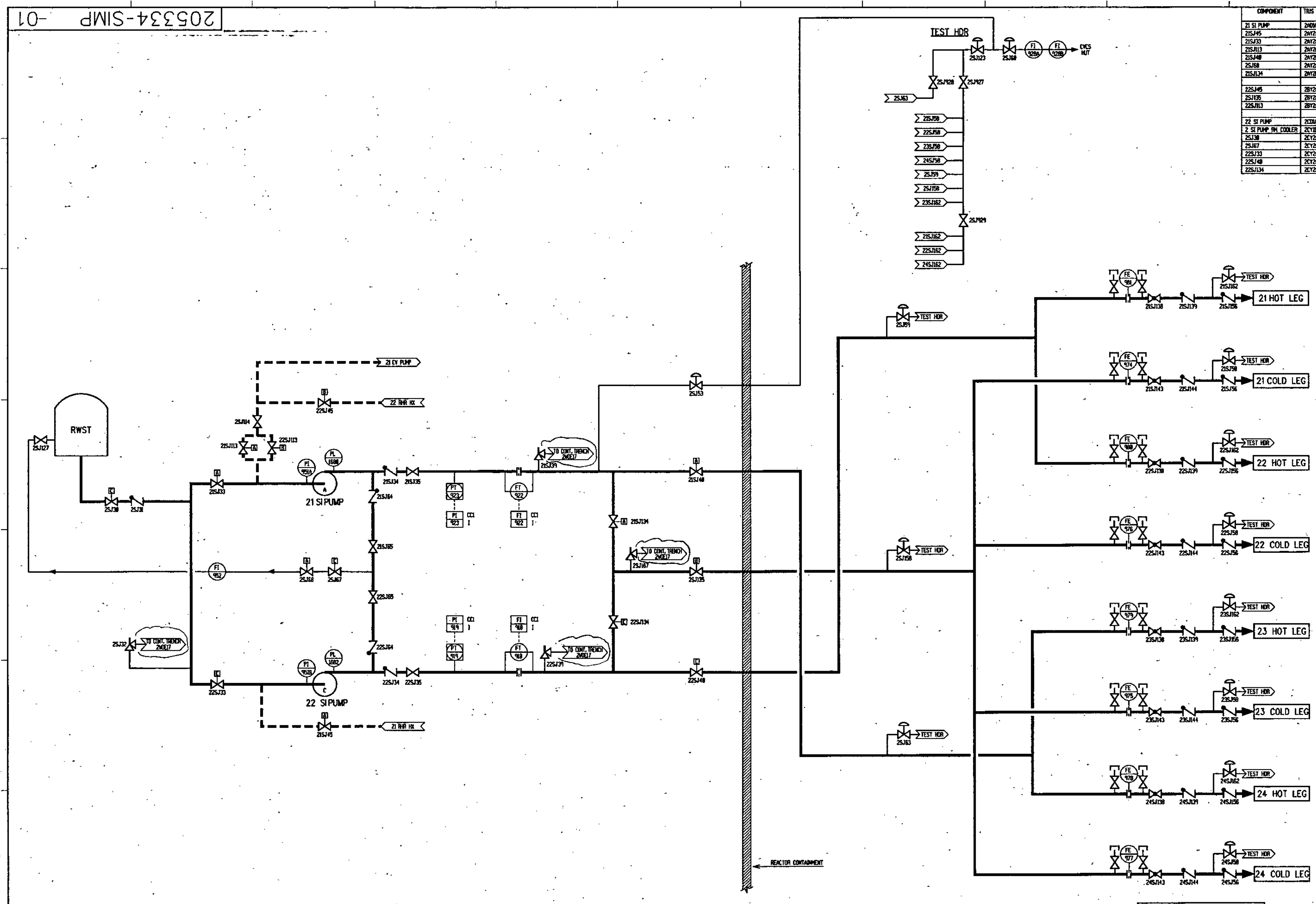
NUCLEAR DEPARTMENT
DRAWN PAUL H DAVIS PEER REVIEW J Mayer EXAMINED
APPROVED DATE 6-8-99
SCALE NONE

205234-SIMP -0

205234-SIMP -0



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21SJ33	2AY2AX3E
21SJ113	2AY2AX3I
21SJ40	2AY2EP4E
2SJ60	2AY2AX4I
21SJ134	2AY2EP5I
22SJ45	2BY2AX1E
2SJ135	2BY2AX9I
22SJ113	2BY2AX8A
22 SI PUMP	2CD1AX5D
2 SI PUMP RM. COOLER	2CY1EP1D
2SJ30	2CY2AX1A
2SJ67	2CY2AX1E
22SJ33	2CY2AX3E
22SJ40	2CY2AX4E
22SJ134	2CY2AX7I

NOTE 'B' - REV. 1
REVISED: (4) OFF-PAGE CONN'S. (VARIOUS ZONES).
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1	SEE NOTE 'B' (A-1)	GLM				
0	SEE NOTE 'A' (A-2)	PND	DWK BB	JM POD	MH	11-05-96
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REVISION

NOTE 'A' - REV. 0
ORIGINAL ISSUE.
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APPROVED MICHAEL HOSKINS DATE 11-05-96
SCALE NONE

205334-SIMP -01

205235-SIMP -0

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11 CS PUMP RM COOLER	1AY1EP2G
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1CS14	1BY2AX4A
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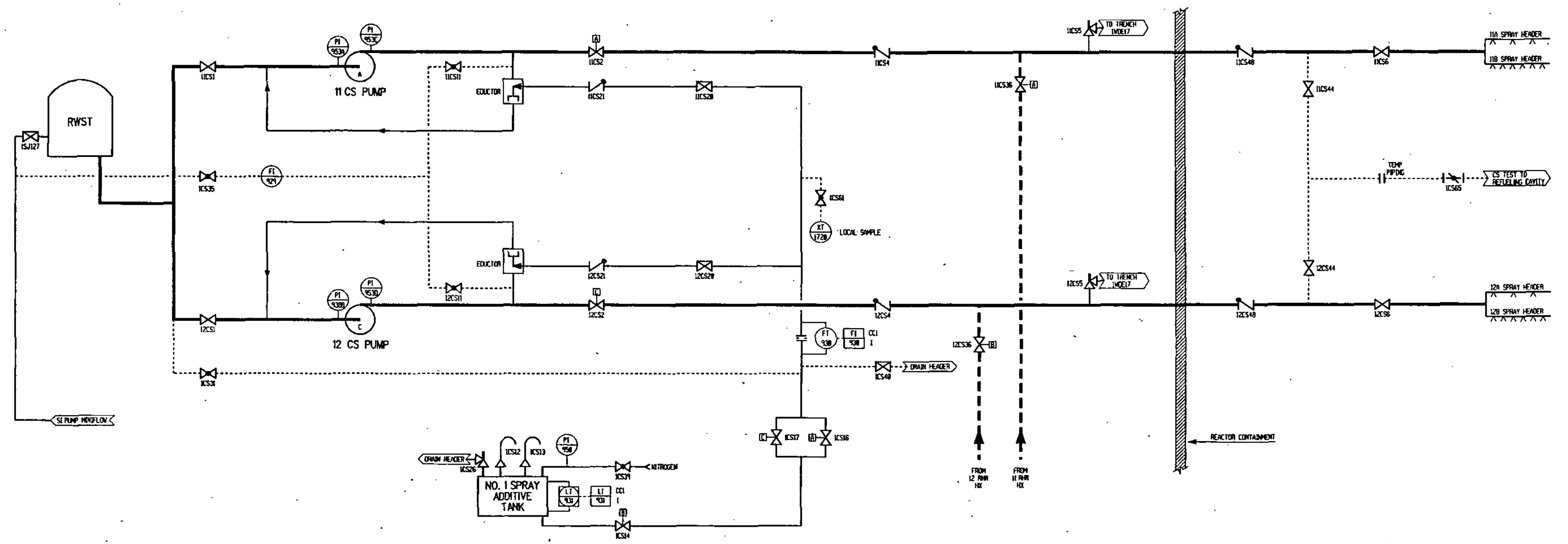

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NO	DESCRIPTION	DWN	PEER REV	EXD	APD	DATE

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DRAWN PAUL W. DAVIS PEER REVIEW EXAMINED
APPROVED DATE 6-14-99
SCALE NONE

205235-SIMP -0

205235-SIMP

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21CS2	2AY2AX3A
21CS36	2AY2EP1E
2CS14	2BY2AX4A
22CS36	2BY2AX6E
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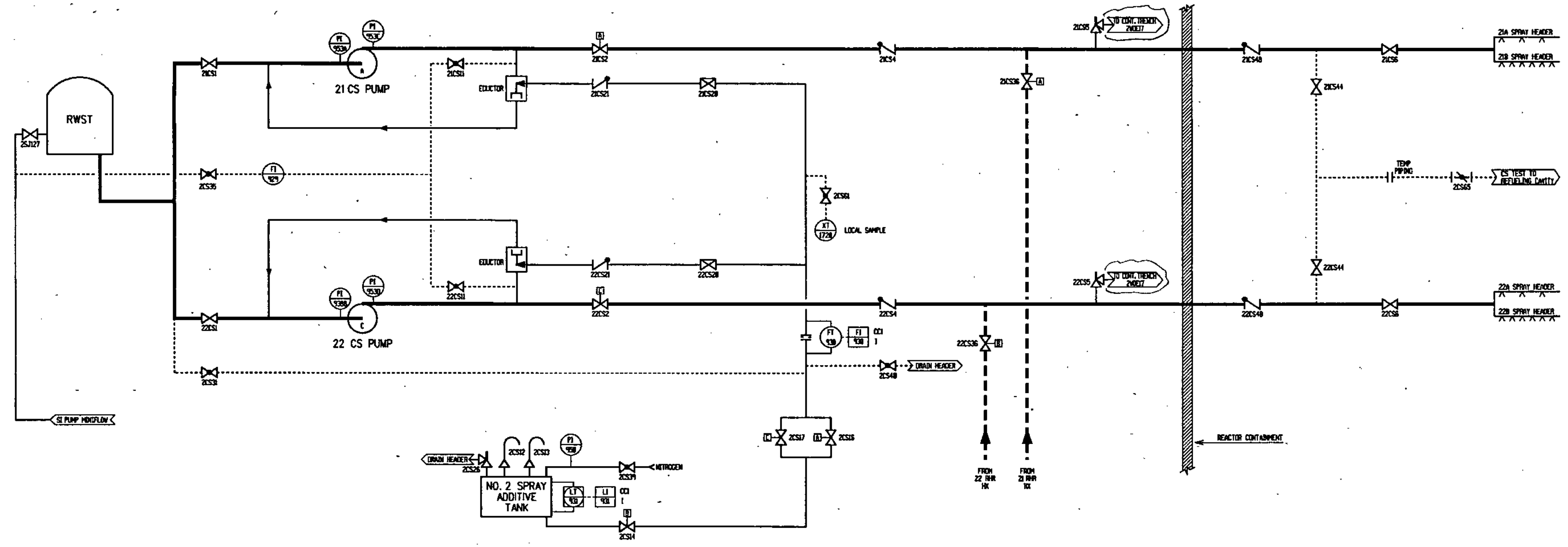

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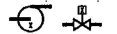

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NOTE "B" - REV.1
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NO	DESCRIPTION	DRWN	PEER REV	EXD	APPD	DATE
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NOTE "A" - REV.0
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APPROVED MICHAEL HOSKINS DATE 12-28-96
SCALE NONE

205335-SIMP -01

Salem Nuclear Generating Station Units 1 and 2
Docket Nos. 50-272 and 50-311
Generic Letter 2004-02
Response to February 4, 2010 RAI

GL 2004-02 RAI Response

On February 4, 2010, the Commission issued a Request for Additional Information (RAI) to Salem. The answers to these RAIs are presented in this attachment.

The staff's review focused on the licensee's March 31, 2009, response to the NRC's request for additional information (RAI) dated December 17, 2008 (ADAMS Accession No. ML083300079). As applicable, issues identified in the February 2010 RAIs (below) are linked directly to the December 2008 RAIs. For example, "RAI 1" below refers to the first numbered RAI in the set of RAIs dated December 17, 2008. New RAIs identified in the current review and not linked to previous RAIs are simply numbered without being preceded by "RAI."

Following are the responses to the RAIs issued to PSEG for Salem Units. Each response contains pointers to the section of Attachment 1 of this response which provides more detail pertaining to the RAI.

Debris Generation/Zone of Influence (ZOI)

RAI 1 This RAI requested that the licensee describe what effect the size of the test jet used for acquiring test report WCAP-16710-P data would have on applying the conclusions of that report to insulation systems at Salem, where potentially much larger jets could be experienced from reactor coolant system (RCS) loop piping breaks.

In its response to RAI 1 and in the updated supplemental response, the licensee provided a significant amount of information regarding the Westinghouse testing of the jacketed Nukon® insulation system and the installation of Nukon in the Salem containments. The RAI response concentrates on the fluid conditions and asserts that the size of the jet would have no effect on the determination of the ZOI as tested by Westinghouse. The staff does not agree with this position. Subsequent to requesting information from the licensee, the staff has developed a more detailed set of RAIs regarding the testing conducted and reported on in WCAP-16710-P. The set of RAIs provided below are being transmitted to provide the licensee the full range of the staff's concern regarding the testing.

For Salem Unit 2, the staff considers it likely that the overall evaluation of head loss was conservative because the additional fibrous debris that would result from a larger ZOI for jacketed Nukon is very small compared to the overall fibrous load for that unit. For this unit, the licensee may choose to provide a ratio of additional insulation not included in previous

testing because of the reduced ZOI to that actually tested, and to thereby justify that the effect of the additional insulation on head loss would be insignificant. For Salem Unit 1, the overall evaluation may not be conservative because of the large amount of jacketed Nukon installed in the Unit 1 containment. However, the debris preparation for the head loss testing resulted in all fine fibrous debris. This is a significant conservatism in head loss testing. The licensee may choose to provide an evaluation of the additional amount of fibrous debris if a 17D ZOI (safety evaluation approved spherical ZOI) were applied to jacketed Nukon for Unit 1, and to balance that change against the conservatism just discussed regarding debris preparation. This information may allow the staff to determine whether the overall evaluations were conservative, irrespective of the resolution of the below-stated concerns reflected in the new RAIs below.

Response to Previous RAI 1

Salem Unit 1 no longer utilizes a reduced ZOI based on WCAP-16710-P for jacketed NUKON insulation.

Salem Unit 2 never used a reduced ZOI for jacketed NUKON since there is no jacketed NUKON within the ZOI in the Unit 2 containment.

All NUKON (both jacketed and unjacketed) in both Salem Units 1 and 2 is currently modeled with the NRC Safety Evaluation approved ZOI of 17D, as described in Section 3b of Attachment 1 of this response.

New RAIs Regarding the Reduced ZOI for Jacketed Nukon

The Pressurized Water Reactor Owners Group is working on answers to the multi-plant issues that follow. These questions have been modified from the generic version based on staff review of information received from Salem.

1. **Although ANSI/ANS Standard 58.2-1988 predicts higher jet centerline stagnation pressures associated with higher levels of subcooling, it is not intuitive that this would necessarily correspond to a generally conservative debris generation result. Please justify the initial debris generation test temperature and pressure with respect to the plant RCS conditions, specifically the hot and cold leg operating conditions. If ZOI reductions are also being applied to lines connecting to the pressurizer, then please also discuss the temperature and pressure conditions in these lines. Were any tests conducted at alternate temperatures and pressures to assess the variance in the destructiveness of the test jet to the initial test condition specifications? If so, provide that assessment.**

2. **Please describe the jacketing/insulation systems used in the plant for which the testing was conducted and compare those systems to the jacketing/insulation systems tested. The Salem supplemental response described the jacketed Nukon on the steam generators, but did not compare it to the tested insulation system. Demonstrate that the tested jacketing/insulation system adequately represented the plant jacketing/insulation system. The description should include differences in the jacketing and banding systems used for piping and other components for which the test results are applied, potentially including steam generators, pressurizers, reactor coolant pumps, etc. At a minimum, the following areas should be addressed:**

   a. **How did the characteristic failure dimensions of the tested jacketing/insulation compare with the effective diameter of the jet at the axial placement of the target?**

      The characteristic failure dimensions are based on the primary failure mechanisms of the jacketing system, e.g., for a stainless steel jacket held in place by three latches, where all three latches must fail for the jacket to fail, then all three latches must be effectively impacted by the pressure for which the ZOI is calculated. Applying test results to a ZOI based on a centerline pressure for relatively low L/D (nozzle diameter to target spacing) tests would be non conservative with respect to impacting the entire target with the calculated pressure.

   b. **The information provided should also include an evaluation of scaling the strength of the jacketing or encapsulation systems to the tests. For example, a latching system on a 30-inch pipe within a ZOI could be stressed much more than a latching system on a 10-inch pipe in a scaled ZOI test. If the latches used in the testing and the plants are the same, the latches could be significantly understressed in the tests. If a prototypically-sized target were impacted by an undersized jet, it would similarly be under-stressed. Evaluations of banding, jacketing, rivets, screws, etc., should be made. For example, scaling the strength of the jacketing was discussed in the Ontario Power Generation report on calcium silicate debris generation testing.**

3. **There are relatively large uncertainties associated with calculating jet stagnation pressures and ZOIs for both the test and the plant conditions based on the models used in the WCAP reports. What steps were taken to**

ensure that the calculations resulted in conservative estimates of these values? Please provide the inputs for these calculations and the sources of the inputs.

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

   a. **In WCAP-16710-P, why was the analysis based on the initial condition of 530 °F, whereas the initial test temperature was specified as 550 °F?**

   b. **Was the water subcooling used in the analysis that of the initial tank temperature or was it the temperature of the water in the pipe next to the rupture disk? Test data indicated that the water in the piping had cooled below that of the test tank.**

   c. **The break mass flow rate is a key input to the ANSI/ANS-58-2-1988 standard. How was the associated debris generation test mass flow rate determined? If the experimental volumetric flow was used, then explain how the mass flow was calculated from the volumetric flow given the considerations of potential two phase flow and temperature dependent water and vapor densities? If the mass flow was analytically determined, then describe the analytical method used to calculate the mass flow rate.**

   d. **Noting the extremely rapid decrease in nozzle pressure and flow rate illustrated in the test plots in the first tenths of a second, how was the transient behavior considered in the application of the ANSI/ANS-58-2-1988 standard? Specifically, did the inputs to the standard represent the initial conditions or the conditions after the first extremely rapid transient, e.g., say at one tenth of a second?**

   e. **Given the extreme initial transient behavior of the jet, justify the use of the steady state ANSI/ANS-58-2-1988 standard jet expansion model to determine the jet centerline stagnation pressures rather than experimentally measuring the pressures.**

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

a. What were the assumed plant-specific RCS temperatures, pressures and break sizes used in the calculation? Note that the isobar volumes would be different for a hot leg break than for a cold leg break since the degrees of subcooling is a direct input to the ANSI/ANS-58-2-1988 standard which affects the diameter of the jet. Note that an under-calculated isobar volume would result in an under-calculated ZOI radius.

b. What was the calculational method used to estimate the plant-specific and break specific mass flow rates for the postulated plant loss-of-coolant accident (LOCA), which was used as input to the standard for calculating isobar volumes?

c. Given that the degree of subcooling is an input parameter to the ANSI/ANS-58-2-1988 standard and that this parameter affects the pressure isobar volumes, what steps were taken to ensure that the isobar volumes conservatively match the plant-specific postulated LOCA degree of subcooling for the plant debris generation break selections? Were multiple break conditions calculated to ensure a conservative specification of the ZOI radii?

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

a. Based on the temperature traces in the test reports it is apparent that the fluid near the nozzle was colder than the bulk test temperature. How was the fact that the fluid near the nozzle was colder than the bulk fluid accounted for in the evaluations?

b. How was the hydraulic resistance of the test piping which affected the test flow characteristics evaluated with respect to a postulated plant-specific LOCA break flow where such piping flow resistance would not be present?

c. What was the specified rupture differential pressure of the rupture disks?

7. WCAP-16710-P discusses the shock wave resulting from the instantaneous rupture of piping.

a. **Was any analysis or parametric testing conducted to get an idea of the sensitivity of the potential to form a shock wave at different thermal-hydraulic conditions?**

Were temperatures and pressures prototypical of pressurized-water reactor hot legs considered?

b. **Was the initial lower temperature of the fluid near the test nozzle considered in the evaluation? Specifically, was the damage potential assessed as a function of the degree of subcooling in the test initial conditions?**

c. **What is the basis for scaling a shock wave from the reduced-scale nozzle opening area tested to the break opening area for a limiting rupture in the actual plant piping?**

d. **How is the effect of a shock wave scaled with distance for both the test nozzle and plant condition?**

8. **Please provide the basis for concluding that a jet impact on piping insulation with a 45° seam orientation is a limiting condition for the destruction of insulation installed on steam generators, pressurizers, reactor coolant pumps, and other non-piping components in the containment. For instance, considering a break near the steam generator nozzle, once insulation panels on the steam generator directly adjacent to the break are destroyed, the LOCA jet could impact additional insulation panels on the generator from an exposed end, potentially causing damage at significantly larger distances than for the insulation configuration on piping that was tested. Furthermore, it is not clear that the banding and latching mechanisms of the insulation panels on a steam generator or other RCS components provide the same measure of protection against a LOCA jet as those of the piping insulation that was tested. Although WCAP-16710-p asserts that a jet at Wolf Creek or Callaway cannot directly impact the steam generator, but will flow parallel to it, it seems that some damage to the steam generator insulation could occur near the break, with the parallel flow then jetting under the surviving insulation, perhaps to a much greater extent than predicted by the testing. Similar damage could occur to other insulated components. Please provide a technical basis to demonstrate that the test results for piping insulation are prototypical or conservative of the degree of damage that could occur to insulation on steam generators and other non-piping components in the containment.**

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

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

<u>Response to RAIs 1-10</u>

Salem Unit 1 no longer utilizes a reduced ZOI based on WCAP-16710-P for jacketed NUKON insulation.

Salem Unit 2 never used a reduced ZOI for jacketed NUKON since there is no jacketed NUKON within the ZOI in the Unit 2 containment.

All NUKON (both jacketed and unjacketed) in both Salem Units 1 and 2 is currently modeled with the NRC Safety Evaluation approved ZOI of 17D, as described in Section 3b of Attachment 1 of this response.

11. The response noted that lead blankets were credited for shielding Min-K$^{®}$ microporous insulation on two of the intermediate RCS legs. The response did not justify this position. The licensee should justify that the lead

blankets would provide adequate protection such that the Min-K would not become debris or show that the amount of Min-K added to the testing bounds the potential for Min-K debris generation.

Response to RAI 11

Lead blankets are only credited for shielding Min-K on targets approximately 18D from the break. For further details, see Section 3b of Attachment 1 of this response.

Debris Transport

12. During the staff's audit of strainer performance calculations in October 2007, cumulative 30-day erosion percentages of 40% for Nukon and 15% for Kaowool® refractory fiber insulation were assumed to address NRC staff concerns associated with the erosion test results for Nukon and Kaowool. However, the March 31, 2009, supplemental response indicates that the currently assumed 30-day erosion percentages are 30% for Nukon and 10% for Kaowool. A basis was not provided in the supplemental response to justify the reduced erosion percentages that are currently assumed. Please provide a technical basis for the currently assumed 30-day erosion percentages for Nukon and Kaowool to address the concerns identified with the testing in the audit report and demonstrate that the percentages are prototypical or conservative for the plant condition.

Response to RAI 12

The 30-day erosion fractions used for NUKON and Kaowool are 20% and 15%, respectively. The technical basis for use of these values is provided in Section 3e.1.5 of this response.

Head Loss and Vortexing

RAI 14 Vortexing

The supplemental response stated that there is a potential for intermittent vortex formations during two pump operation at the minimum submergence level with little or no debris on the strainer. The March 31, 2009, submittal stated that video analysis of the test showed that the maximum air ingestion rate during the test was 0.05% by volume. The response further calculated that the total air entrainment would be 0.00356% if the entire strainer train was included in the calculation. The staff needs more information regarding the video analysis and the calculation to determine whether the methodology used to derive the

estimate is realistic. It is not clear how video could be used to estimate the amount of entrained air.

Response to Previous RAI 14 - Vortexing

A video of vortex formation was used to scale the size of the vortices formed at very high flow rates. The details of the video analysis are provided in Section 3f.3.1.1 of Attachment 1 of this response.

RAI 14 Degasification

The licensee determined that degasification of the fluid could occur as it passes through the debris bed. The licensee postulated that any evolved gasses would be reabsorbed by the liquid prior to reaching the pump suction due to the static head of water above the pump. It was not clear to the staff that any gasses that evolved from the sump fluid would be reabsorbed into the fluid prior to flowing into the pump suction. It was not clear that the dynamics of reabsorption were fully addressed or that all possibilities for evolved gasses were considered. For example, could the gasses collect within the strainer and be entrained in the flow as larger bubbles later in the event? This issue could be mitigated if it were shown that higher submergence would result for the large break LOCA such that degasification were reduced or eliminated and that the head loss across the strainer for a small break LOCA would be significantly lower. Please provide justification for the conclusion in the submittal that all gasses would be reabsorbed prior to the fluid entering the pump, or provide an alternative evaluation of degasification and its effects on the pump.

Response to Previous RAI 14 - Degasification

Air which evolves due to the pressure drop through the debris bed and strainer is no longer modeled as being reabsorbed prior to reaching the pump. A deaeration analysis was performed (Reference A.104) to determine how much air evolves due to the pressure drop based on Henry's Law. The quantity of evolved air is then used to compute the void fraction at the pump inlet (without credit for reabsorption of the evolved air). The impact of the void fraction on the NPSH required by the pumps is assessed using Appendix A of Regulatory Guide 1.82, Revision 3. The evolved air will not accumulate at the top of the strainer based on the bubble size as well as the velocities in the suction box which were determined via CFD analysis.

The details of the deaeration and air accumulation analysis are presented in Section 3f.3.2 of Attachment 1 of this response. The impact of the void fraction at the pump inlet on NPSH required is presented in Section 3g.16 of Attachment 1 of this response.

13. **The Salem Unit 1 chemical effects head loss test was conducted utilizing the full debris load. However, the Unit 1 thin bed test had a significantly higher head loss (78 mbar) than the non-chemical full load head loss (30 mbar). Please provide information that justifies that the chemical effects testing conducted with the full debris load bounds the head loss that could occur on a chemically laden thin bed. Alternately, a thin bed test can be conducted with chemicals to ensure that the head loss included in the evaluation is bounding for potential plant conditions.**

Response to RAI 13

The thin bed test utilized a higher debris load than the full load head loss test. In addition, the thin bed test was performed using room temperature water while the full load test was performed using heated water. Details of the justification for performing the chemical effects head loss test with the full debris load are provided in Section 3f.4.2.3.4 of Attachment 1 of this response.

Net Positive Suction Head (NPSH)

14. **The March 31,2009, supplemental response states that the calculated minimum containment flood level when the refueling water storage tank (RWST) reaches its low level alarm setpoint is greater than the required level for adequate strainer submergence and emergency core cooling system recirculation operation, except for Case 1. To address this case, the response states that Emergency Operating Procedures are currently in place to direct operators to continue injecting until the RWST low-low-level setpoint is reached.**

    a. **Please discuss whether the operation of the residual heat removal pumps has been evaluated with respect to vortex formation at the RWST suction intake with the water level at the low-low-level setpoint to ensure adequate pump performance.**

    Response to RAI 14(a)

    Operation of the residual heat removal pumps has not been evaluated with respect to vortex formation at the RWST intake with the water level at the low-low level setpoint to ensure adequate pump performance. As discussed below, a condition in which the RWST reaches its low-low level setpoint before sufficient containment sump level has been achieved to support initiation of cold leg recirculation is outside the Salem design and licensing basis.

As stated in Section 3g.5 of Attachment 1 of this response, the RHR pumps stop taking suction from the RWST after the RWST low level setpoint and the minimum required containment water level are reached. The minimum required containment water level is achieved prior to reaching the RWST low-low level setpoint.

This RAI asks a question, whether the RHR pumps are subject to vortex formation when taking suction from RWST if the water level has reached the low-low set point.

It should be noted that RHR pump operation at the RWST low-low level setpoint is a very unlikely scenario. During a LOCA, water from the RWST will be directed into the RCS through the ECCS pumps to provide core cooling or sprayed into containment for containment heat removal and pressure control. The water pumped from the RWST will collect on the containment floor and mix with that discharged from the postulated large break in the RCS piping raising the containment flood level.

The only way the RWST can reach the low-low alarm level and the containment sump level does not exceed the alarm set point level is, if a RWST pipe break occurs outside the Reactor Containment or containment flood level indication malfunctions.

The first possibility requires a break in the RCS pressure boundary and another break in the RWST piping outside the Reactor Containment during the injection phase. .This is not a credible accident; assuming two breaks is outside the Salem design and licensing basis.

There are two redundant level switches installed inside the Reactor Containment. In addition to the level switches there are two separate level transmitters that provide the containment flood level. As noted in UFSAR Section 6.3.1.4, the Salem ECCS is designed to tolerate a single active failure during the short-term immediately following an accident (injection phase) or to tolerate a single active or passive failure during the long-term (recirculation phase) following an accident. Therefore, failure of two redundant level switches is outside the design and licensing basis of Salem Units.

Based on the above information, the condition where RWST reaches the low-low level alarm and the required containment flood level is not reached is beyond the design and licensing basis of the Salem Units. Also, anti-vortex suppression devices are installed at the RWST discharge lines for the ECCS and CS pumps per VTD 147766.

When the RWST reaches the low level alarm set point and the required containment flood level is not reached, the operators transition to EOP-LOCA-5. At this point the ECCS pumps are not stopped. EOP-LOCA-5 provides appropriate recovery actions to delay depletion of RWST by adding makeup and reducing the outflow. This is accomplished by stopping the containment spray pumps and decreasing the ECCS pump flow rate. However, when the RWST reaches its low-low alarm set point, the operator stops all pumps taking suction from the RWST.

Based on the above information it is concluded that there is no concern associated with vortex formation for the RHR pumps.

b. **Please also discuss whether the minimum water level for Case 1 credits the injection of the accumulators. If credit is taken, please provide a basis to demonstrate that their injection would be expected and a basis for considering the Case 1 to be a limiting water level that bounds small-break LOCA cases for which the accumulators may not inject or may not fully inject. If a more limiting water level is possible for small-break LOCA conditions without accumulator injection, please identify this water level.**

Response to RAI 14(b)

The minimum containment flood level for Case 1 is determined assuming both injection of all accumulators as well as injection of none of the accumulators, as described in Section 3g.8 of Attachment 1 of this response. The minimum containment flood level is achieved prior to reaching the RWST low-low level both with and without the accumulators injecting.

15. **Page 2 of Attachment 1 to the licensee's submittal of March 31, 2009, indicates that level switches used for indication of containment flood levels "alert the control room operator when sufficient sump level has been achieved to support initiation of cold leg recirculation". This statement suggests that two conditions must now be satisfied before recirculation switchover is initiated: RWST low water level AND containment sump level. Please describe what action the operator would take if both of these**

conditions are not met; in particular, a case where the RWST is exhausted, but indicated containment water level is too low to have activated the level switches.

Response to RAI 15

A detailed description of the system response for LBLOCAs and SBLOCAs is provided in Section 3g.5 of Attachment 1 of this response. The description explains the steps which would be taken if the RWST were exhausted prior to the containment flood level reaching the level required for switchover.

In addition, Section 3g.7 of Attachment 1 of this response explains that the only ways in which the RWST can reach the low-low level without reaching the minimum containment sump level are: 1) A break in the line from the RWST to containment, and 2) a malfunction in the containment sump level instrumentation. Both of these scenarios are outside the Salem design and licensing basis.

See Sections 3g.5 and 3g.7 of Attachment 1of this response for more details.