10 CFR 50.54(f)

Progress Energy

Serial: RNP-RA/08-0026

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United States Nuclear Regulatory Commission
ATTN: Document Control Desk
11555 Rockville Pike
Rockville, Maryland 20852

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261/LICENSE NO. DPR-23

SUPPLEMENTAL RESPONSE TO NRC GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS"

Ladies and Gentlemen:

On September 13, 2004, NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," was issued requesting that licensees provide the requested information pertaining to emergency core cooling system (ECCS) sump performance. Carolina Power and Light Company, also known as Progress Energy Carolinas, Inc. (PEC), is hereby providing the information requested by GL 2004-02, for H. B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2, in Attachment II to this letter.

Attachment I provides an Affirmation in accordance with the provisions of Section 182a of the Atomic Energy Act of 1954, as amended, and 10 CFR 50.54(f).

No new commitments are included with this letter. If you have any questions concerning this matter, please contact Mr. Curt Castell at (843) 857-1626.

Sincerely,

C. T. Baucom
Manager – Support Services – Nuclear

CTB/cac

Progress Energy Carolinas, Inc.
Robinson Nuclear Plant
3581 West Entrance Road
Hartsville, SC 29550

A116
NRR

Attachments:

I. Affirmation

II. Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"

c: V. M. McCree, NRC, Region II
M. G. Vaaler, NRC Project Manager, NRR
NRC Resident Inspector, HBRSEP

AFFIRMATION

The information contained in letter RNP-RA/08-0026 is true and correct to the best of my information, knowledge, and belief; and the sources of my information are officers, employees, contractors, and agents of Carolina Power and Light Company, also known as Progress Energy Carolinas, Inc. I declare under penalty of perjury that the foregoing is true and correct.

Executed On: 3/7/08

E. A. McCartney
Director – Site Operations, HBRSEP, Unit No. 2

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2

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The following information is provided based on the Nuclear Energy Institute (NEI) Revised Content Guide for Generic Letter 2004-02 Supplemental Response, dated November 2007. This information is intended to supplement and revise previously provided information associated with GL 2004-02 for HBRSEP, Unit No. 2.

1. Overall Compliance

Requested information:

Provide information requested in GL 2004-02, "Requested Information," Item 2(a), regarding compliance with regulations. Provide confirmation that the ECCS and CSS recirculation functions under debris loading conditions are, or will be, in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter. This submittal should address the configuration of the plant that will exist once all modifications required for regulatory compliance have been made and this licensing basis has been updated to reflect the results of the analysis.

HBRSEP, Unit No. 2, response:

The General Design Criteria (GDC) in existence at the time HBRSEP, Unit No. 2, was licensed for operation (July 1970) were contained in the proposed Appendix A to 10 CFR 50, "General Design Criteria for Nuclear Power Plants," published in the Federal Register on July 11, 1967. HBRSEP, Unit No. 2, conformance with the Proposed GDC is described within Updated Final Safety Analysis Report (UFSAR) Section 3.1, "Conformance with General Design Criteria."

Generic Letter (GL) 2004-02 lists the applicable GDCs as follows: GDC 35, Emergency Core Cooling; GDC 38, Containment Heat Removal System; and GDC 41, Containment Atmosphere Cleanup. The comparable GDCs for HBRSEP, Unit No. 2, include GDC 41, GDC 44, and GDC 52, which state:

GDC 41, Engineered Safety Features Performance Capability: Engineered safety features, such as the emergency core cooling system and the containment heat removal system, shall provide sufficient performance capability to accommodate the failure of any single active component without resulting in undue risk to the health and safety of the public.

GDC 44, Emergency Core Cooling System Capability: An Emergency Core Cooling System with the capability for accomplishing adequate emergency core cooling shall be provided. This core cooling system and the core shall be designed to prevent fuel and clad damage that would interfere with the emergency core cooling function and to limit the clad metal-water reaction to acceptable amounts for all sizes of breaks in the reactor coolant piping up to the equivalent of a double-ended rupture of the largest pipe. The performance of such emergency core cooling system shall be evaluated conservatively in each area of uncertainty.

GDC 52, Containment Heat Removal System: Where an active heat removal system is needed under accident conditions to prevent exceeding containment design pressure, this system shall perform its required function, assuming failure of any single active component.

Additionally, the Title 10 Code of Federal Regulations (10 CFR) listed in GL 2004-02, which include 50.46, 50.67, and Part 100, are also applicable to HBRSEP, Unit No. 2, as described in the UFSAR.

The containment sump recirculation functions under debris loading conditions are in compliance with the applicable regulatory requirements based on the improved analyses and completion of the modifications for the containment sump at HBRSEP, Unit No. 2.

Design and programmatic changes have been utilized to resolve Generic Safety Issue (GSI)-191 and GL 2004-02 head loss issues.

The strategy for resolution of GSI-191 and GL 2004-02 head loss issues included the following basic features:

- Ensuring sufficient water supply reaches the containment sump during long term recirculation. This design constraint is accomplished by ensuring credited flow paths to the sump remain clear and by utilizing the minimum credible water level at the initiation of recirculation for design of the maximum height of the new sump screens.
- Minimizing head loss due to debris accumulation at the sump screens and improving the available net positive suction head by increasing surface area utilizing complex strainer geometry, providing adequate debris mass capture (interstitial volume) without impacting effective strainer surface area, and revising the containment insulation program to ensure that insulation changes do not degrade the material characteristics from a head loss perspective.

- Minimizing latent debris by maintaining containment close-out cleanliness, foreign material exclusion standards, and an effective coatings program.

2. General Description of Corrective Actions

Requested information:

Provide a general description of actions taken or planned, and dates for each. For actions planned beyond December 31, 2007, reference approved extension requests or explain how regulatory requirements will be met as per "Requested Information" Item 2(b). Provide a general description of and implementation schedule for all corrective actions, including any plant modifications that you identified while responding to this generic letter. Efforts to implement the identified actions should be initiated no later than the first refueling outage starting after April 1, 2006. All actions should be completed by December 31, 2007. Provide justification for not implementing the identified actions during the first refueling outage starting after April 1, 2006. If all corrective actions will not be completed by December 31, 2007, describe how the regulatory requirements discussed in the Applicable Regulatory Requirements section will be met until the corrective actions are completed.

HBRSEP, Unit No. 2, response:

Analyses of debris generation, debris transport, and head loss for the new sump strainer design were completed for HBRSEP, Unit No. 2, based on the methodology presented in Nuclear Energy Institute (NEI) guidance report NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, and the associated report titled, "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,'" dated December 6, 2004. The analyses were utilized to generate a design that accommodates a new design basis for post-LOCA debris generation and accumulation condition, including chemical effects debris.

The original containment sump (also called the ECCS sump), which had an approximate overall area of 116 square feet (ft^2), was replaced during Refueling Outage (RO)-24, which ended in May 2007, with a new sump strainer with a surface area of 4178 ft^2 (of which 4000 ft^2 is credited in the design analyses). Installation involved removal of the original sump screens at the sump, removal of the coarse screens at the reactor coolant pump bay drain openings, installation of a jet impingement shield near the letdown line, and relocation of some interfering equipment adjacent to the new strainer.

To limit the amount of plastic debris in containment, an inspection was conducted in RO-24 and plant labeling procedure PLP-050, "Plant Labeling, Stenciling, and Signs," was revised to prohibit the installation of new, or replacement of existing, plastic tags or labels in containment and requires stainless steel or porcelain coated stainless steel signs.

Procedure EGR-NGGC-0005, "Engineering Change," which is used for development of plant modifications, was revised to add screening questions regarding insulation, aluminum-containing material in containment, and flow paths during the recirculation phase of an accident.

Procedure PLP-006, "Containment Vessel Inspection/Closeout," was revised to emphasize inspection for latent debris to ensure latent debris is maintained within the inputs and assumptions that support the GSI-191 issue resolution. PLP-006 is also used for identifying additions, deletions, and locations of aluminum in containment. The strainer design analysis is based on 400 lbs of latent debris in the containment, as compared to an estimated 202.5 lbs of latent debris in containment. The latent debris in containment was estimated in accordance with the NEI 04-07 methodology.

Specification L2-M-039, "Piping and Equipment Thermal Insulation," was revised to provide guidance to control insulation materials used in containment in order to maintain the debris source term in accordance with the analysis. Procedure MMM-003, "Maintenance Planning," was revised to include guidance for maintenance planners to use the new specification for activities inside containment involving insulation.

Head loss testing of the screen with design basis debris loading and chemical loading showed that the total head loss will be sufficiently limited to ensure the NPSH requirements of the ECCS pumps will be satisfied in both cases.

Downstream effects evaluations have been completed that show the effects of wear caused by the predicted quantities of debris in the fluid will be acceptable for the pumps and other components and the analyzed amount of flow blockage does not prevent the required functions.

3. Specific Information Regarding Methodology for Demonstrating Compliance

3a. Break Selection

Requested information:

The objective of the break selection process is to identify the break size and location that presents the greatest challenge to post-accident sump performance.

- Describe and provide the basis for the break selection criteria used in the evaluation.
- State whether secondary line breaks were considered in the evaluation (e.g., main steam and feedwater lines) and briefly explain why or why not.
- Discuss the basis for reaching the conclusion that the break size(s) and locations chosen present the greatest challenge to post-accident sump performance.

HBRSEP, Unit No. 2, response:

The NRC Safety Evaluation Report (SER), dated December 6, 2004, for the NEI Guidance Report (GR) NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," provides guidance for analytical techniques pertaining to compliance with Generic Letter 2004-02. The following summary table provides a description of the NRC SER section, the requirement, and how the requirement was incorporated into the design. Significant differences, if any, between the NRC SER methodology and the approach used within the associated evaluations are also discussed.

NRC SER Section	Topic	Requirement	Compliance
3	**Baseline Evaluation**		
3.3	**Break Selection**		
3.3.3	Break Size	Double-Ended Guillotine Break (DEGB) shall be used for debris generation for primary system piping or applicable plant specific break requirements for secondary side piping.	Large break, including DEGB, and small break loss of coolant accidents (LOCAs) were evaluated. Secondary system breaks (Feedwater and Main Steam) would not lead to Emergency Core Cooling System (ECCS) recirculation mode. Therefore, secondary system breaks were not evaluated.
3.3.4	Break Locations	Pipe breaks shall be postulated with the goal of creating the largest quantity of debris and/or the worst-case combination of debris types at the sump screen.	The maximum debris quantity and worst combination debris quantity were evaluated.
3.3.5	Evaluation of Break Consequences	The break consequences should be evaluated by determining the head loss across the sump screen.	The break consequences have been evaluated by determining head loss across the sump screen.
4	**Analytical Refinements**		
4.2.1	Break Selection	The NRC staff concludes it is inappropriate to cite Standard Review Plan (SRP) 3.6.2 Branch Technical Position (BTP) MEB 3-1 as the methodology to be applied when determining break locations for the purpose of PWR sump analyses.	SRP 3.6.2 has not been utilized. The break selection utilized an approach consistent with Section 3.3 of the NRC SER. Numerous pipe break locations were evaluated with the most limiting break locations identified.

The HBRSEP, Unit No. 2, accident analyses were reviewed to identify the accidents that would require ECCS sump recirculation operation. Large-break LOCAs (LBLOCAs) and some small break LOCAs (SBLOCAs) would require sump operation. Other line-break events were considered and it was determined that sump operation was not required. The results of these reviews are described as follows:

Large Break LOCA

The HBRSEP, Unit No. 2, Updated Final Safety Analysis Report (UFSAR) classifies LBLOCA as a cross-sectional break area greater than 1.0 ft^2.

A review of flow diagrams was performed to identify those lines that are part of, or directly attached to, the Reactor Coolant System (RCS) up to the first isolation valve. The lines that could potentially result in a LBLOCA are:

- 29 inch RCS Hot Leg
- 27 1/2 inch RCS Cold Leg
- 31 inch RCS Crossover Leg (This is also known as the Intermediate Leg)

Small Break LOCA

The UFSAR classifies SBLOCA as a rupture of the RCS pressure boundary in excess of charging pump capacity but less than 1.0 ft^2 in total cross sectional area. SBLOCA lines 2 inches and larger are included in this evaluation – no instrument lines or taps are addressed. This is consistent with Section 3.3.4.1 of the NRC SER, which states that breaks less than 2 inches in diameter need not be considered. The lines that could potentially result in a SBLOCA are:

- 12 inch Pressurizer Surge
- 12 inch Residual Heat Removal
- 4 inch Pressurizer Relief
- 4 inch Pressurizer Spray
- 3 inch Charging
- 2 inch Letdown
- 2 inch Auxiliary Spray
- 2 inch Reactor Coolant Pump Seal Injection / Return
- 2 inch Safety Injection

Non-LOCA High Energy Line Break (HELB) Scenarios

In non-LOCA events the RCS remains intact, thus decay heat removal via the steam generators can continue until the plant can be cooled down, depressurized, and the Residual Heat Removal system can be used. Therefore, analysis of the effects of debris generation is not necessary for these situations.

UFSAR Section 15.1.5 analyzes the Main Steam Line Break (MSLB) Accident. This section states, "Steam Generator pressures and Steam Generator masses for the affected Steam Generator and the unaffected Steam Generators are plotted in Figures 15.1.5-4 and 15.1.5-5, respectively. The pressures in the intact Steam Generators recovered as the intact Steam Generators equilibrated with the primary system and then experienced a slow decrease as the intact Steam Generators began to act as heat sinks for the primary system." The containment pressurization analysis for MSLB, described in Section 6.2 of the UFSAR, states that there is no "recirculation phase" for the MSLB accident.

Based on this information, it can be concluded that decay heat removal is established via the intact Steam Generators and the affected Steam Generator is isolated. Therefore, ECCS recirculation is not necessary to maintain long-term decay heat removal in the MSLB event.

UFSAR Section 15.2.8 analyzes the Feedwater Line Break (FWLB) Accident. A short discussion is provided that states, "In the case of H. B. Robinson, however, this event will be a cool down event and will be bounded by the Steam Line Break results..." Therefore, it is concluded that ECCS containment sump recirculation is not necessary to maintain long-term decay heat removal in the FWLB event.

Based on guidance from NRC Regulatory Guide 1.82, Position 2.3.1.5, the following break locations were considered:

Break No. 1 – Largest potential for debris:

> The break with the largest potential for debris generation is the largest break in an area with the greatest concentration of fibrous and particulate debris source material. The greatest concentration of insulation is within the reactor coolant pump (RCP) bays. Inside the RCP bays, the majority of insulation is on the steam generator.
>
> The RCS Intermediate Leg is considered to have the largest potential for debris generation as it has the largest pipe diameter of the high-energy lines. The zone of influence (ZOI) was evaluated at various locations on the Intermediate Leg and it was determined that the outlet of the steam generators leading to the RCP is the break with the largest potential for debris generation. This location produces a zone of influence that encompasses both the RCP bowl and the maximum quantity of steam generator insulation. Both of these pieces of equipment have large quantities of insulation.
>
> The RCP "C" Bay has been determined to contain the largest amount of debris potentially generated by a LBLOCA.

Break No. 2 – Large breaks with two or more different types of debris:

> The RCS Intermediate Leg Break appropriately bounds this type of break because multiple types of debris are present in each pump bay.

Break No. 3 – Most direct path to the sump:

> Small Break LOCAs could occur in the area where the strainer is installed. Isometric drawings of the lines around the pressurizer and other areas with large quantities of insulation were examined, and it was determined that there are no small lines where a potential break could cause a greater amount of debris generation than a large break in the RCS loop piping.

Break No. 4 – Largest potential particulate debris-to-insulation ratio:

> The worst-case RCP Bay pipe break is considered to be the limiting case LBLOCA, thus Break No. 4 is bounded by the LBLOCA case. RCP "C" Bay has the largest total quantity of insulation, the RCP "B" Bay has the greatest quantity of particulate-based insulation, and the RCP "A" Bay has the largest particulate-to-fiber ratio. The RCP "B"

Bay break location results in larger head loss, even though the ratio of particulate-to-fiber is slightly lower, because the RCP "B" Bay has a greater quantity of particulate than the RCP "A" Bay. Therefore, RCP "B" Bay has been analyzed as the limiting case for Break No. 4, and the RCP "C" Bay has been analyzed as the limiting case for Break No. 2.

Break No. 5 – Breaks that generate a Thin-Bed effect:

This break is intended to evaluate an amount of fibrous debris that could form a uniform thin bed that could subsequently hold sufficient particulate debris to create a relatively high head loss, referred to as the thin-bed effect. The minimum thickness of fibrous debris needed to form a thin bed has been typically estimated at 1/8 inch thick for a flat plate configuration. For complex strainer designs, a 3/8 inch bed thickness has been shown to form before any appreciable additional head loss attributable to the thin-bed effect is noted.

It can be postulated that fibrous debris is generated and transported to the sump, followed by washdown of particulate latent debris, which potentially results in the thin-bed effect. Rather than analyzing specific LOCA scenarios, the thin-bed effect has been incorporated into the head loss calculation.

Based on the information summarized above, it is concluded that a Large Break LOCA in the Intermediate Leg at the Steam Generator outlet within RCP "C" Bay generates the maximum possible quantity of debris, while the same LBLOCA in RCP "B" Bay generates the largest particulate debris load. SBLOCAs and other potential HELBs are bounded by these LBLOCAs.

3b. Debris Generation/Zone of Influence (Excluding Coatings)

Requested information:

The objective of the debris generation/ZOI process is to determine, for each postulated break location: (1) The zone within which the break jet forces would be sufficient to damage materials and create debris; and, (2) the amount of debris generated by the break jet forces.

- Describe the methodology used to determine the ZOIs for generating debris. Identify which debris analyses used approved methodology default values. For debris with ZOIs not defined in the guidance report (GR)/safety evaluation (SE), or if using other than default values, discuss method(s) used to determine ZOI and the basis for each.

- Provide destruction ZOIs and the basis for the ZOIs for each applicable debris constituent.

- Identify if destruction testing was conducted to determine ZOIs. If such testing has not been previously submitted to the NRC for review or information, describe the test procedure and results with reference to the test report(s).

- Provide the quantity of each debris type generated for each break location evaluated. If more than four break locations were evaluated, provide data only for the four most limiting locations.

- Provide total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment.

HBRSEP, Unit No. 2, response:

NRC SER Section	Topic	Requirement	Compliance
3.4	**Debris Generation**		
3.4.2	**Zone of Influence (ZOI)**		
3.4.2.2	Insulation	The minimum destruction pressure (Pd) shall define the ZOI.	The Method 1 refined analysis, "Debris Specific Spherical ZOI," described in Section 4.2.2.1.1 of the NRC SER was used. The ZOIs from Table 3-2 of the NRC SER were used in as described in Table 2.1. No destruction pressure data is available for Kaowool, low-density fiberglass, Asbestos, Unibestos, or Kaylo. Therefore, the largest ZOI of 28.6D from Table 3-2 of the NRC SER was conservatively applied to these insulation types.
3.4.2.3	ZOI and Robust Barriers	The ZOI from a break may be truncated by robust barriers (walls, steam generators, etc). The requirements also state that the shadow surfaces of components should be included in the analysis and not truncated.	If a robust barrier is encountered by a break jet, the ZOI created is assumed to have a spherical boundary with the exception of the volume beyond the robust barrier. This is consistent with the requirements of the NRC SER. The concrete walls, floors, and ceilings enclosing the individual pump bays are credited as robust barriers. Insulation encompassed within the ZOI for a specific insulation type is assumed to generate debris. Shadow surfaces are included in the analysis and not truncated. In addition, even though the Cal-Sil and Reflective Metal Insulation (RMI) ZOIs encompass only a small portion of the steam generator insulation on one side, the entire circumference of the insulation is assumed to generate debris.
4	**Analytical Refinements**		
4.2.2	**Debris Generation Zone of Influence**		

NRC SER Section	Topic	Requirement	Compliance
4.2.2.1	Debris Specific ZOIs	Specific ZOIs may be used for each material type.	Insulation debris-specific ZOIs were utilized, as documented in the insulation table provided below and described later in this section. The ZOIs are based on Table 3-1 of the NEI Sump Evaluation Methodology.
4.2.2.1.2	Direct Jet Impingement	The ZOI may be defined by modeling two freely-expanding jets emanating from each broken pipe section as opposed to using the spherical ZOI approach.	This allowance for assuming direct jet impingement when determining the ZOI is not utilized. As stated in response to 3.4.2.3, a spherical ZOI approach is used.

Insulation Types	Destruction Pressure (psi)	ZOI Radius (Radius/Break Diameter†) Value
RMI	114	2.0
Cal-Sil	24	5.5
Temp-Mat™	10.2	11.7
Nukon®	6	17.0

†Inside Diameter is used

There are three debris categories at HBRSEP, Unit No. 2, that did not have destruction pressure data available. Therefore, the largest ZOI of 28.6D from Table 3-2 of the NRC SER was conservatively applied to the following insulation categories:

- Kaowool
- Fiberglass
- Asbestos, Unibestos, and Kaylo

The following tables summarize the debris generated for the two limiting break locations as identified in the preceding Section 3a. As previously discussed, it was concluded that a LBLOCA in the Intermediate Leg at the Steam Generator outlet within RCP "C" Bay generates the maximum possible quantity of debris, while a Large Break LOCA in RCP "B" Bay generates the largest particulate debris load. SBLOCAs and other potential HELBs are bounded by the LBLOCAs.

Fibrous Insulation Debris Source Term – Break No. 2 LBLOCA (RCP "C" Bay)

Insulation Type	Quantity Destroyed (ft^3)	Size Distribution Large Pieces/Small Fines	Large Pieces (ft^3)	Small Fines		
				Amount (ft^3)	Density (lbs/ft^3)	Characteristic Size (micron)
Particulate Insulation						
Cal-Sil / Asbestos	89.0	0%/100%	0.0	89.0	144	5
Cal-Sil	43.3	0%/100%	0.0	43.3	144	5
Kaylo	5.7	0%/100%	0.0	5.7	144	5
Sum Total	**138.0**		**0.0**	**138.0**		
Fibrous Insulation						
Nukon®	245.1	40%/60%	98.0	147.1	175	7
Temp Mat™	7.0	40%/60%	2.8	4.2	162	9
Nukon or Temp Mat™	0.0	40%/60%	0.0	0.0	175	7
Temp Mat™ or Kaowool	2.9	0%/100%	0.0	2.9	162	9
Unibestos	29.3	0%/100%	0.0	29.3	153	2
Fiberglass - assume low density	17.9	0%/100%	0.0	17.9	175	7
Sum Total	**302.2**		**100.8**	**201.4**		

Limiting Particulate-to-Fiber Insulation Debris Source Term – Break No. 4 LBLOCA (RCP "B" Bay)

Insulation Type	Quantity Destroyed (ft^3)	Size Distribution Large Pieces/Small Fines	Large Pieces (ft^3)	Small Fines		
				Amount (ft^3)	Density (lbs/ft^3)	Characteristic Size (micron)
Particulate Insulation						
Cal-Sil / Asbestos	59.5	0%/100%	0.0	59.5	144	5
Cal-Sil	43.3	0%/100%	0.0	43.3	144	5
Kaylo	88.7	0%/100%	0.0	88.7	144	5
Sum Total	**191.5**		**0.0**	**191.5**		
Fibrous Insulation						
Nukon®	164.8	40%/60%	65.92	98.9	175	7
Temp Mat™	16.3	40%/60%	6.52	9.8	162	9
Nukon or Temp Mat™	0.8	40%/60%	0.32	0.5	175	7
Temp Mat™ or Kaowool	4.6	0%/100%	0.0	4.6	162	9
Unibestos	32.2	0%/100%	0.0	32.23	153	2
Fiberglass - assume low density	11.8	0%/100%	0.0	11.8	175	7
Sum Total	**230.5**		**72.8**	**157.8**		

Reflective Metal Insulation Debris Source Term – LBLOCA

Total Amount Destroyed (ft^2)	**Size Distribution Small Fines/Large Pieces**	**Amount Destroyed by Size Distribution**	
		Small Fines (0 – 2")	**Large Pieces (2 – 4")**
1066.8	75% / 25%	800.1 ft^2	266.7 ft^2

Latent Debris Source Term

Debris Type	**Density (lb/ft^3)**	**Weight (lbs)**
Latent Dirt / Dust	169	340.0
Latent Fiber	175	60.0

The requirements for labeling inside the Containment are provided in procedure PLP-050, "Plant Labeling, Stenciling, and Signs." PLP-050 requires new or replacement tags in Containment to be stainless steel or porcelain/ceramic-clad stainless steel. An inspection of the Containment was made to determine the quantity of plastic labels installed. Based on the inspection, there is

17.4 ft^2 of plastic labels, tags, and Mylar stickers identified inside the Containment. Allowing approximately 15% margin, a 20 ft^2 total area is assumed. The NRC SER states that it can be assumed that labels and tags overlap such that the potentially blocked screen area is 75% of the individual tag area. Therefore, the potentially blocked screen area is approximately 15 ft^2. Plastic cable ties were also identified in the inspection. The estimated total number of cable ties is 9,583 (including 15% margin). The area is estimated at 17,525 in^2 (approximate size of 0.19 inches x 9.625 inches per tie) or 121.7 ft^2 total, or 91 ft^2 allowing for overlap. The total potential screen blockage of plastic signs, stickers, labels, and cable ties is 106 ft^2. There is approximately 178 ft^2 of screen area reserved in the debris head loss calculation, which can be used to account for this type of debris.

3c. Debris Characteristics

Requested information:

The objective of the debris characteristics determination process is to establish a conservative debris characteristics profile for use in determining the transportability of debris and its contribution to head loss.

- Provide the assumed size distribution for each type of debris.
- Provide bulk densities (i.e., including voids between the fibers/particles) and material densities (i.e., the density of the microscopic fibers/particles themselves) for fibrous and particulate debris.
- Provide assumed specific surface areas for fibrous and particulate debris.
- Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance.

HBRSEP, Unit No. 2, response:

NRC SER Section	Topic	Requirement	Compliance
3.4.3	**Quantification of Debris Characteristics**		
3.4.3.2	Size Distribution in ZOI (insulation)	NRC SER Table 3-3 provides the percentage of small fines versus large pieces for several types of insulation.	The size distribution of insulation debris generated inside the ZOI is classified into two primary categories: (1) fines and small pieces, and (2) large pieces. The tables provided below describe the initial size distributions. The size distributions for Cal-Sil, Nukon, Temp-Mat, low-density fiberglass, unjacketed insulation, and RMI are consistent with NRC SER Table 3-3. There is no destruction data available for Unibestos, Asbestos, Kaylo, or Kaowool.

NRC SER Section	Topic	Requirement	Compliance
			Therefore, these insulation types are conservatively assumed to generate debris as 100% fines.
3.4.3.3	Outside ZOI	Material outside of the ZOI which may be subject to LOCA conditions shall be considered debris in accordance with NRC SER Table 3-3. These are considered uncovered fire barrier material, unjacketed insulation, and unqualified coatings.	Unjacketed Cal-Sil (14.2 ft^3) on the Main Steam Line outside of the ZOI was considered to be 100% destroyed into small fines. Unjacketed fiberglass (0.67 ft^3) on the containment ventilation unit, HVH-1, service water return line outside of the ZOI was considered to be 100% destroyed into small fines as well. No other materials outside the ZOI (other than unqualified coatings and latent debris) were identified that would contribute to debris (i.e., foam type insulation that floats is not considered debris since it will not drop below the water surface and adhere to the strainer). Note that subsequent inspections identified that the Cal-Sil insulation on the Main Steam Lines was all jacketed. Therefore, this quantity will be removed from the debris generation calculation in a future revision. The revised quantity was taken into account in the most recent head loss testing.
3.4.3.6	Debris Characteristics for Use in Debris Transport and Head Loss	The staff recommends that when using Guidance Report (GR) Tables 3-2 and 3-3, that these values be verified by plant specific data / vendor information due to variances in material properties.	Table 4.1 provides the debris characteristics necessary for the head loss evaluation of the debris bed. The properties of these materials are from GR Tables 3-2 and 3-3, with the exception of NUKON, which is taken from NUREG/CR-6224. The material properties are supported from plant-specific material test reports from ALION Science & Technology.
4	**Analytical Refinements**		
4.2.2.2	Debris Characteristics	Use of debris-specific characteristics is an acceptable refinement.	Debris-specific characteristics were used when available, either from industry or vendor literature, or through testing. See the tables below and the response to NRC SER Section 3.4.3.6 above for details on "Debris Characteristics for Use in Debris Transport and Head Loss."

Debris Material	Macroscopic Density (lbs/ft^3)	Microscopic Density (lbs/ft^3)	Characteristic Size (μm)
NUKON® Fiber	2.4	175	7*
Temp-Mat™	11.8	162	9*
Cal-Sil, Kaylo, and Asbestos/Cal-Sil	18.6	144	5**
Unibestos	10.0	153	2.0*
Latent Debris (Dirt/Dust)	N/A	169	17.3**
Latent Debris (Fiber)	2.4	175	7*

* - fiber diameter
** - spherical particle diameter

Note: The fiber constituent of the latent debris load is treated as NUKON fiber (fiberglass) per Section 3.5.2.3 of the NRC SER; therefore, the microscopic density and characteristic size of the NUKON fiber is used.

Debris	**Initial Destruction Size Distributions**
Unibestos	100% Fines
Cal-Sil /Asbestos	100% Fines
Cal-Sil	100% Fines
Kaylo	100% Fines
Nukon®	60% Fines / 40% Large Pieces
Temp-Mat™	60% Fines / 40% Large Pieces
Nukon® or Temp-Mat™	60% Fines / 40% Large Pieces
Temp-Mat™ or Kaowool	100% Fines
Fiberglass (low density fiberglass [LDFG])	100% Fines
Unjacketed Insulation	100% Fines
RMI	75% Fines / 25% Large Pieces

An important assumption within the debris generation calculation is the equivalency of certain insulation types. A complete data set for ZOI and destruction pressures does not exist for all insulation types. As such, approximations need to be made, and these approximations are presented below in more detail.

Asbestos

The lowest destruction pressure corresponding to the largest ZOI radius will be assumed for Asbestos. Additionally, this material is assumed to be destroyed as 100% fines. There is no available destruction test data on this material. Use of the largest ZOI radius and 100% fines provides bounding results.

Unibestos

The lowest destruction pressure corresponding to the largest ZOI radius will be assumed for Unibestos. Additionally, this material is assumed to be destroyed as 100% fines. Unibestos is a fibrous insulation. There is no available destruction test data on this material at this time. Use of the largest ZOI radius and 100% fines provides bounding results.

Kaylo

The lowest destruction pressure corresponding to the largest ZOI radius will be assumed for Kaylo. Additionally, this material is assumed to be destroyed as 100% fines. There is no available destruction test data on this material at this time. Use of the largest ZOI radius and 100% fines provides bounding results.

Cal-Sil/Asbestos

Cal-Sil/Asbestos is a combination of the two, and as such is assumed to have the same destruction pressure and ZOI size as that of Cal-Sil. This assumption is based on the Scanning Electron Microscopy that was performed on this material.

Temp-Mat™ or Kaowool

The walkdown report used as input to the debris generation calculation identified some insulation as Temp-Mat™ or Kaowool, as they could not differentiate between the two. The destruction pressure and debris size characteristics for Kaowool are not known, and are therefore conservatively assumed as the smallest destruction pressure (2.4 psi) and failure to 100% fines, respectively. Therefore, this insulation group will conservatively assume the destruction pressure and debris size characteristics of Kaowool.

Unspecified Fiberglass

The walkdown report used as input to the debris generation calculation lists some insulation as only "fiberglass." The destruction pressure for these materials is assumed to have the smallest destruction pressure identified in the NRC SER, 2.4 psig, which is equivalent to a ZOI of 28.6D. This destruction pressure is the lowest value identified in the SER, and the associated ZOI involves the entire RCP bay; therefore, the entire estimate for this type of insulation is included in the debris load. Additionally, this unspecified fiberglass is assumed to fail as 100% fines, which is in agreement with the NRC SER.

Marinite Board

Marinite Board is neglected from the debris generation calculation. This insulation is outside the secondary shield wall and is therefore outside the ZOIs considered in the debris generation calculation.

Rubber Foam / Semco PR-855 Silicone Foam / Urethane Foam

The rubber foam, Semco PR-855 Silicone Foam, and Urethane Foam are neglected from the debris generation calculation. Their respective total volumes in containment are 2.15 ft^3, 0.04 ft^3, and 0.52 ft^3, which are relatively small quantities. Furthermore, all Urethane Foam is outside the ZOIs considered in the debris generation calculation. Lastly, all of these materials float in water and will therefore not interfere with sump operation. The data sheet for Semco PR-855 gives a density of 15 to 20 lbm/ft^3. This is considered representative for the group.

3d. Latent Debris

Requested information:

The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris existing within the containment and its potential impact on sump screen head loss.

- Provide the methodology used to estimate quantity and composition of latent debris.
- Provide the basis for assumptions used in the evaluation.
- Provide results of the latent debris evaluation, including amount of latent debris types and physical data for latent debris as requested for other debris under 3c above.
- Provide amount of sacrificial strainer surface area allotted to miscellaneous latent debris.

HBRSEP, Unit No. 2, response:

NRC SER Section	Topic	Requirement	Compliance
3.5	**Latent Debris**		
3.5.2.1	Estimate Horizontal and Vertical Surface Area Inside Containment	The horizontal and vertical surface areas that could accumulate latent debris shall be calculated. These areas include floors, walls, cable trays, major ductwork, CRDM coolers, air handlers, top of RCPs, valve operators, piping surfaces, etc. In addition, consideration should be made for adhesive factors, such as oil spray or solutions or detergent films.	The horizontal surface area of floors, cable trays, air handling ducts, and other miscellaneous equipment (e.g., pipes) is conservatively calculated and documented in the latent debris survey report. The default vertical surface debris inventory of 30 lbs is used, as recommended by the NRC SER.

NRC SER Section	Topic	Requirement	Compliance
3.5.2.2	Evaluate Resident Debris Buildup	Utilize a default vertical surface debris inventory of 30 lbs to be characterized by the smallest size fraction found in the horizontal surface inventory and document a simplified, but realistic calculation of vertical surface area.	The latent debris survey report utilized the default vertical surface debris inventory of 30 lbs, as recommended by the NRC SER.
3.5.2.2.1	Evaluate Resident Debris Buildup on Surfaces	The staff considers the recommendation in the GR for direct measurement of dust thickness to be impractical. This NRC SER offers a revised approach for the assessment that is based on generic characterization of actual PWR debris samples. This revised approach also addresses the question of particulate-to-fiber ratio as it relates to the thin-bed effect. If desired, a limited plant-specific characterization can also be pursued as a refinement using this guidance.	As recommended by the NRC SER, the latent debris buildup in containment was estimated by sampling representative areas in 34 locations throughout containment using pre-weighed media. The sampling media was then weighed after sampling to determine the mass of latent debris in the sampled area. Samples with maslin cloth and contamination swipes were conducted.
3.5.2.2.2	Evaluate the Quantity of other Miscellaneous Debris	Surveys of containment shall be performed to identify miscellaneous debris, such as equipment tags, tape, and sticker or placards affixed by adhesive.	Labeling inside containment is controlled by Procedure PLP-050, "Plant Labeling, Stenciling, and Signs." PLP-050 requires new or replacement tags in containment to be stainless steel or porcelain/ceramic-clad steel. An inspection of containment was made to determine the quantity of plastic labels installed inside containment. Based on the inspection, there is 17.4 ft^2 of plastic labels, tags, and Mylar stickers identified inside containment. Allowing 15% margin, a 20 ft^2 total area is assumed. The NRC SER states that it can be assumed labels and tags overlap such that the potentially blocked screen area is 75% of the individual tag area. Therefore, the potentially blocked screen area is approximately 15 ft^2. Plastic cable ties

NRC SER Section	Topic	Requirement	Compliance
			were also identified in the inspection. The estimated total number of cable ties is 9,583 (including 15% margin). The area is estimated at 17,525 in^2 (approximate size of 0.19 inches x 9.625 inches per tie) or 121.7 ft^2 total, or 91 ft^2 allowing for overlap. The total potential screen blockage of plastic signs, stickers, labels, and cable ties is 106 ft^2. There is approximately 178 ft^2 of screen area reserved in the debris head loss calculation, which can be used to account for this type of debris.
3.5.2.2.2	Evaluate the Quantity of other Miscellaneous Debris	As a result of equipment tags, the wetted sump screen flow area should be reduced by an area equivalent to 75% of the total of the original single-sided surface area of the tags.	See response in 3.5.2.2.2 above.
3.5.2.3	(Latent) Debris Characteristics	Two methods are provided for determining the latent debris characteristics. One method is testing and the second method requires the following:	Method 2 is utilized.
3.5.2.3	(Latent) Debris Characteristics	15% of latent debris mass be classified as fiber.	The debris generation calculation specifies 15% of total latent debris mass as fiber.
3.5.2.3	(Latent) Debris Characteristics	Assume the latent fiber mean density is 1.5 g/cm^3.	The debris generation calculation specifies a higher latent fiber microscopic density of 175 lbs/ft^3 (equivalent to 2.8 g/cm^3). Section 3.5.2.3 of the NRC SER provides an additional provision that recommends assuming the head loss properties of latent fiber are the same as reported in NUREG/CR-6224 for commercial fiberglass (i.e., NUKON). Therefore, the microscopic density and characteristic size of the NUKON fiber are specified for the fiber constituent of the latent debris, since these values are used in the head loss calculation. Using a higher density than the SER recommended value of 1.5 g/cm^3 for latent fiber does not affect the transport analysis, because 100% of the latent

NRC SER Section	Topic	Requirement	Compliance
			debris is assumed to transport to the sump strainer.
3.5.2.3	(Latent) Debris Characteristics	The latent particle density is assumed to be 2.7 g/cm^3.	The debris generation calculation specifies a dirt/dust density of 169 lb/ft^3 (equivalent to 2.7 g/cm^3).
3.5.2.3	(Latent) Debris Characteristics	The particulate mass is composed of 10 μm diameter grains.	The debris generation calculation specifies a latent particulate debris characteristic size of 17.3 microns. Section 3.5.2.3 of the NRC SER provides a more refined set of assumptions that include assuming typical mixtures of latent particulate debris have a specific surface area (surface area-to-volume ratio) of 106,000 ft^{-1}. The particulates are assumed to be spherically shaped. The surface area-to-volume ratio of a sphere is 6/Diameter. Therefore, the diameter of a sphere with a specific surface area of 106,000 ft^{-1} is 5.66x10^{-5} ft, or 17.3 microns.
3.5.2.3	(Latent) Debris Characteristics	The dry-bed bulk density for latent fiber is equal to that of fiberglass insulation (2.4 lbm/ ft^3).	The debris generation calculation utilizes a latent fiber macroscopic density of 2.4 lbm/ft^3.
3.5.2.3	(Latent) Debris Characteristics	The head loss properties of latent fiber are the same as reported in NUREG/CR-6224 for commercial fiberglass.	The fiber constituent of the latent debris load is treated as NUKON fiber (fiberglass), which is the commercial fiberglass that was used in the NUREG/CR-6624 head loss correlation.
3.5.2.4	Determine Fraction of Surface Area Susceptible to Debris Accumulation	Assume that 100% of the surface area is susceptible to debris accumulation or perform an evaluation that consists of estimating the fractional surface areas susceptible to debris accumulation.	100% of the surface area is assumed susceptible to debris accumulation.

NRC SER Section	Topic	Requirement	Compliance
3.5.2.5	Calculation Total Quantity and Composition of Debris	Determine the total quantity of latent debris inside of containment	The amount of latent debris inside containment was estimated to be 202.5 lbs. The method of determining the quantity of latent debris was in accordance with NEI 04-07, as approved by the NRC SER. Refer to the responses to NRC SER requirements 3.5.2.1, 3.5.2.2 and 3.5.2.2.1 above for further details. A total of 400 lbs was assumed for the purpose of strainer design and evaluation.

Debris Material	Macroscopic Density (lbs/ft^3)	Microscopic Density (lbs/ft^3)	Characteristic Size (μm)
Latent Debris (Dirt/Dust)	N/A	169	17.3**
Latent Debris (Fiber)	2.4	175	7*

* - fiber diameter

** - spherical particle diameter

Note: The fiber constituent of the latent debris load is treated as NUKON fiber (fiberglass) per Section 3.5.2.3 of the NRC SER; therefore, the microscopic density and characteristic size of the NUKON fiber is used.

A latent debris distribution of 85% dirt/dust and 15% latent fibers is consistent with Section 3.5.2.3 of the NRC SER. Therefore, the total latent debris load of 400 lbs is broken down into 340 lbs of dirt/dust and 60 lbs of latent fibers, as shown in the table below.

Debris Type	Density (lb/ft^3)	Weight (lbs)
Latent Dirt / Dust	169	340.0
Latent Fiber	175	60.0

3e. Debris Transport

Requested information:

The objective of the debris transport evaluation process is to estimate the fraction of debris that would be transported from debris sources within containment to the sump suction strainers.

- Describe the methodology used to analyze debris transport during the blowdown, washdown, pool-fill-up, and recirculation phases of an accident.

- Provide the technical basis for assumptions and methods used in the analysis that deviate from the approved guidance.

- Identify any computational fluid dynamics codes used to compute debris transport fractions during recirculation and summarize the methodology, modeling assumptions, and results.

- Provide a summary of, and supporting basis for, any credit taken for debris interceptors.

- State whether fine debris was assumed to settle and provide basis for any settling credited.

- Provide the calculated debris transport fractions and the total quantities of each type of debris transported to the strainers.

HBRSEP, Unit No. 2, response:

NRC SER Section	Topic	Requirement	Compliance
3.6.3	Debris Transport	Define the type of containment compartmentalization for the plant being evaluated	The debris transport fractions used in the HBRSEP, Unit No. 2, debris transport calculation are based on the NEI Sump Evaluation Methodology, Section 3.6.3.1. This section of the NEI guidance deals with highly compartmentalized containments. This is considered appropriate for the HBRSEP, Unit No. 2, design.
3.6.3 - fibrous	Transport Assumptions from Table 3-4 – *Small Fines – Fibrous Debris*		
3.6.3 - fibrous	Fraction of debris generated	0.6	A debris generation factor of 60% for Temp-Mat and NUKON fibrous insulation was used. A debris generation factor of 100% for Unibestos, Kaowool, and fiberglass fibrous insulation was used. There is no available destruction test data for Unibestos, Kaowool, and fiberglass. Therefore, it was conservatively assumed that these materials were destroyed into 100% small fines.

NRC SER Section	Topic	Requirement	Compliance
3.6.3 - fibrous	Fraction of debris generated that transports into upward levels by blowdown	0.25	A transport factor of 10% for fibrous insulation debris that is postulated to transport into upward levels by blowdown was used. This conservative value (as compared to the NRC SER recommendation of 25%) was chosen because of the multiple levels of grating above the break location and the small flow area around the steam generator at Elevation 275 ft.
3.6.3 - fibrous	Fraction of debris generated that transports directly to sump pool floor by blowdown	0.75	As stated above, the fraction of debris transported to upward levels was conservatively estimated.
3.6.3 - fibrous	Fraction of Debris Generated that blows into upper levels and washes down into sump pool	1	A washdown transport factor of 50% was used. NUREG/CR-6762, Volume 4, Section 5.2, provides a 75% washdown transport fraction considering flow rates exceeding 8000 gallons per minute (gpm). The NEI Sump Evaluation Methodology assumes 100% of the fines to be transported to the containment floor, but does not take into account debris blown into areas shielded by equipment and structures or debris lodged into areas and trapped. The 50% transport fraction was used because the containment spray flow rate is considerably less than the 8000 gpm cited in the NUREG and there is a significant amount of surface area in the upper portion of the containment for the collection of fines. In addition, an evaluation was performed based on the results of the testing described in NUREG/CR-6369, Volume 2, which determined a washdown factor of 38.8%. Thus, this analysis shows that a 50% washdown factor is conservative.
3.6.3 - fibrous	Fraction of Debris Generated that enters into Inactive Sump Pools	Volume Ratio with a maximum of 15% of total debris	The 15% factor recommended by the NRC SER for determining the amount of debris trapped in inactive pools was used.
3.6.3 - fibrous	Fraction of debris that enters sump pool that transports to sump screens	1	A recirculation transport factor of 100%, as recommended by the NRC SER, was used.

NRC SER Section	Topic	Requirement	Compliance
3.6.3 - RMI	Transport Assumptions from Table 3-4 – *Small Fines – RMI*		
3.6.3 - RMI	Fraction of debris generated	0.75	A debris generation factor of 75% for generation of RMI small fines, as recommended by the NRC SER, was used.
3.6.3 - RMI	Fraction of debris generated that transports into upward levels by blowdown	0.25	A transport factor of 10% was used for RMI debris that is postulated to transport into upward levels by blowdown. This is a conservative value (as compared to the NRC SER recommended 25%), which was chosen because of the multiple levels of grating above the break location and the small flow area around the steam generator at Elevation 275 ft.
3.6.3 - RMI	Fraction of debris generated that transports directly to sump pool floor by blowdown	0.75	As stated above, the fraction of debris transported to upward levels was conservatively estimated.
3.6.3 - RMI	Fraction of Debris Generated that blows into upper levels and washes down into sump pool	0	A washdown factor of 0%, as recommended by the NRC SER, was used.
3.6.3 - RMI	Fraction of Debris Generated that enters into Inactive Sump Pools	Volume Ratio with a maximum of 15% of total debris	A factor of 15% for the proportion of RMI that is postulated to enter inactive sump pools was used, as recommended by the NRC SER.
3.6.3 - RMI	Fraction of debris that enters sump pool that transports to sump screens	1	A recirculation factor of 100%, as recommended by the NRC SER, was used.
3.6.3 – other debris	Transport Assumptions from Table 3-4 – *Small Fines – Other Debris*		
3.6.3 – other debris	Fraction of debris generated	1	100% of the particulate insulation was assumed to become small fines, and 100% of the latent debris was assumed to transport to the sump screen.

NRC SER Section	Topic	Requirement	Compliance
3.6.3 – other debris	Fraction of debris generated that transports into upward levels by blowdown	0.25	A transport factor of 10% was used for particulate insulation debris that is postulated to transport into upward levels by blowdown was used. This conservative value was chosen because of the multiple levels of grating above the break location and the small flow area around the steam generator at Elevation 275 ft. 100% of the latent debris was assumed to transport to the sump screen.
3.6.3 – other debris	Fraction of debris generated that transports directly to sump pool floor by blowdown	0.75	Based on 10% of particulate insulation assumed to be blown to the upper levels, the remainder (i.e., 90%) is left to fall to the pool floor. See the response directly above for the reason less debris than recommended by the NRC SER is postulated to transport to the upward levels.
3.6.3 – other debris	Fraction of Debris Generated that blows into upper levels and washes down into sump pool	1	A washdown transport factor of 50% for particulate insulation was used. NUREG/CR-6762, Volume 4, Section 5.2, provides a 75% washdown transport fraction considering flow rates exceeding 8000 gpm. The NEI Sump Evaluation Methodology assumes 100% of the fines to be transported to the containment floor, but does not take into account debris blown into areas shielded by equipment and structures or debris lodged into trapped areas. A 50% transport fraction was used because the containment spray flow rate is considerably less than the 8000 gpm cited in the NUREG, and there is a significant amount of surface area in the upper portion of the containment for the collection of fines. Also, an evaluation based on the results of the testing described in NUREG/CR-6369, Volume 2, was completed and determined a washdown factor of 38.8%. Thus, this analysis shows that a 50% washdown factor for particulate insulation is conservative.

NRC SER Section	Topic	Requirement	Compliance
3.6.3 – other debris	Fraction of Debris Generated that enters into Inactive Sump Pools	Volume Ratio with a maximum of 15% of total debris	The 15% factor recommended by the NRC SER for determining the amount of particulate insulation debris trapped in inactive pools was used.
3.6.3 – other debris	Fraction of debris that enters sump pool that transports to sump screens	1	The 100% factor recommended by the NRC SER for determining the amount of particulate insulation debris that transports to the sump screens after entering the sump pool was used.
4	**Analytical Refinements**		
4.2.4	Debris Transport	The NRC staff accepts the CFD method and nodal network method as alternatives for calculating debris transport.	No alternate transport methodologies are being proposed.

The following table presents the calculated debris transport fractions of each type of debris:

Load Case	Debris Transport Fraction (DTF)
LBLOCA for Nukon® and Temp-Mat™ Fibrous Debris (small fines)	49%
LBLOCA Particulate (Cal-Sil, Cal-Sil/Asbestos, and Kaylo) Debris (small fines)	81%
LBLOCA for Unibestos, Kaowool, and Fiberglass Fibrous Debris (small fines)	81%
LBLOCA Reflective Metallic Debris	57%
Coatings Particulate Debris	100%
Latent Debris (Fibers and Particulate)	100%

The following tables were derived from the results of the debris generation calculation and the debris transport calculation, and are also documented in the strainer design modification designated Engineering Change (EC) 63481:

Debris Quantities at Sump for LBLOCA in RCP "C" Bay

Insulation Type	Debris Quantity	Transport Ratio	Quantity at Strainer
Cal-Sil/Asbestos	89.0 ft^3	0.81	72.1 ft^3
Cal-Sil	43.3 ft^3	0.81	35.1 ft^3
Kaylo	5.7 ft^3	0.81	4.6 ft^3
Particulate Sub-Total	**138.0 ft^3**		**111.8 ft^3**
Nukon	245.1 ft^3	0.49	120.1 ft^3

Debris Quantities at Sump for LBLOCA in RCP "C" Bay

Insulation Type	Debris Quantity	Transport Ratio	Quantity at Strainer
Temp Mat	7.0 ft^3	0.49	3.4 ft^3
Nukon or Temp Mat	0.0 ft^3	0.49	0.0 ft^3
Temp Mat or Kaowool	2.9 ft^3	0.81	2.3 ft^3
Unibestos	29.3 ft^3	0.81	23.7 ft^3
Low-Density Fiberglass	17.9 ft^3	0.81	14.5 ft^3
Fiber Sub-Total	**302.2 ft^3**		**164.0 ft^3**
RMI	1066.8 ft^2	0.57	**608.1 ft^2**
Latent Dirt/Dust	340.0 lbs	1.00	**340.0 lbs**
Latent Fiber	60.0 lbs	1.00	**60.0 lbs**

Debris Quantities at Sump for LBLOCA in RCP "B" Bay

Insulation Type	Debris Quantity	Transport Ratio	Quantity at Strainer
Cal-Sil/Asbestos	59.5 ft^3	0.81	48.2 ft^3
Cal-Sil	43.3 ft^3	0.81	35.1 ft^3
Kaylo	88.7 ft^3	0.81	71.8 ft^3
Particulate Sub-Total	**191.5 ft^3**		**155.1 ft^3**
Nukon	164.8 ft^3	0.49	80.8 ft^3
Temp Mat	16.3 ft^3	0.49	8.0 ft^3
Nukon or Temp Mat	0.8 ft^3	0.49	0.4 ft^3
Temp Mat or Kaowool	4.6 ft^3	0.81	3.7 ft^3
Unibestos	32.2 ft^3	0.81	26.1 ft^3
Low-Density Fiberglass	11.8 ft^3	0.81	9.6 ft^3
Fiber Sub-Total	**230.5 ft^3**		**128.6 ft^3**
RMI	1066.8 ft^2	0.57	**608.1 ft^2**
Latent Dirt/Dust	340.0 lbs	1.00	**340.0 lbs**
Latent Fiber	60.0 lbs	1.00	**60.0 lbs**

3f. Head Loss and Vortexing

Requested information:

The objectives of the head loss and vortexing evaluations are to calculate head loss across the sump strainer and to evaluate the susceptibility of the strainer to vortex formation.

- Provide a schematic diagram of the emergency core cooling system (ECCS) and containment spray systems (CSS).
- Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.

- Provide a summary of the methodology, assumptions and results of the vortexing evaluation. Provide bases for key assumptions.

- Provide a summary of the methodology, assumptions, and results of prototypical head loss testing for the strainer, including chemical effects. Provide bases for key assumptions.

- Address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen.

- Address the ability of the screen to resist the formation of a "thin bed" or to accommodate partial thin bed formation.

- Provide the basis for the strainer design maximum head loss.

- Describe significant margins and conservatisms used in the head loss and vortexing calculations.

- Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the clean strainer head loss calculation.

- Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the debris head loss analysis.

- State whether the sump is partially submerged or vented (i.e., lacks a complete water seal over its entire surface) for any accident scenarios and describe what failure criteria in addition to loss of net positive suction head (NPSH) margin were applied to address potential inability to pass the required flow through the strainer.

- State whether near-field settling was credited for the head-loss testing and, if so, provide a description of the scaling analysis used to justify near-field credit.

- State whether temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. If scaling was used, provide the basis for concluding that boreholes or other differential-pressure induced effects did not affect the morphology of the test debris bed.

- State whether containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface, and if so, summarize the methodology used to determine the available containment pressure.

HBRSEP, Unit No. 2, response:

NRC SER Section	Topic	Requirement	Compliance
3.7	**Head Loss**		
3.7.2.2.1	Recirculation Pool Water Level	The minimum water level of the reactor building recirculation pool shall be used to estimate head loss.	The minimum water level (Elevation 229.5 ft) following a LBLOCA is at least 3.5 inches above the strainer top hats (i.e., the strainer is fully submerged under all postulated accident conditions requiring recirculation). The initial water level was set at 3.5 inches above the top of the top hats during prototypical testing. In addition, the NPSH margin takes into account the minimum water level of Elevation 229.5 ft.
3.7.2.2.2	ECCS Flowrate	The maximum ECCS pump flowrates shall be utilized in the head loss calculations.	The maximum strainer flow rate of 3820 gpm, as established in the NPSH calculation, was used in the base-case head loss analyses.
3.7.2.3.1.1	Fibrous Debris Beds with Particulate	Head loss parameters for materials that have not been previously characterized are recommended to have testing performed. This section also discusses several debris bed characteristics related to the solidity, compaction, and surface area of the debris types.	Plant-specific debris testing was performed and provides validation to the input parameters used in the Alion HLOSS code. The following surrogate materials were used in the testing: NUKON was used as the surrogate material for Temp Mat and Kaowool fibrous insulation. Given that the fiber diameter for NUKON is 7 microns, and the fiber diameter for Temp Mat and Kaowool is 9 microns, use of NUKON as the surrogate material for Temp Mat and Kaowool is appropriate and conservative with respect to fiber diameter. The low density fiberglass (LDFG), such as Microlok, Owens Corning, and Johns-Manville fibrous insulations, are similar to NUKON, and therefore, debris properties of NUKON can be used. The latent fiber is assumed to be equivalent to NUKON. Section 3.5.2.3 of the SER includes a provision that recommends the head loss properties of latent fiber be

NRC SER Section	Topic	Requirement	Compliance
			assumed to be the same as reported in NUREG/CR-6224 for commercial fiberglass (i.e., NUKON). Therefore, the microscopic density and characteristic size of the NUKON fiber are specified for the fiber constituent of the latent debris for use in the head loss calculation. Wollastonite 520H was used as the surrogate material for Unibestos insulation. Based on Scanning Electron Microscope comparison, Wollastonite 520H has similar fiber constituents and characteristics to the Unibestos sample. SIL-CO-SIL 53 Ground Silica was used as a surrogate for the coatings. This material has a density of 165 lb/ft^3. Non-inorganic zinc coatings density is typically on the order of 94 lb/ft^3. An adjustment was made to compensate for the difference in the volume of the material, such that an equivalent volume of the surrogate material is used. Inorganic zinc (IOZ) coatings at HBRSEP, Unit No. 2, are substantially denser than the surrogate material. No adjustment is made to the amount of surrogate material for the density difference to IOZ. This is conservative with respect to head loss, since a larger volume of the surrogate material will be used. The majority of the coatings are on the order of 10 μm in size or greater. Since a significant portion of the ground silica is less than 10 μm, the ground silica would tend to produce a debris bed with a lower porosity and higher surface-to-volume ratio than a debris bed comprised of coating material. Thus, the use of ground silica as a surrogate for coatings is conservative. Silica Sand was used as a surrogate material for latent dirt and dust debris. The size distribution was prepared to be consistent with the latent dirt/dust size

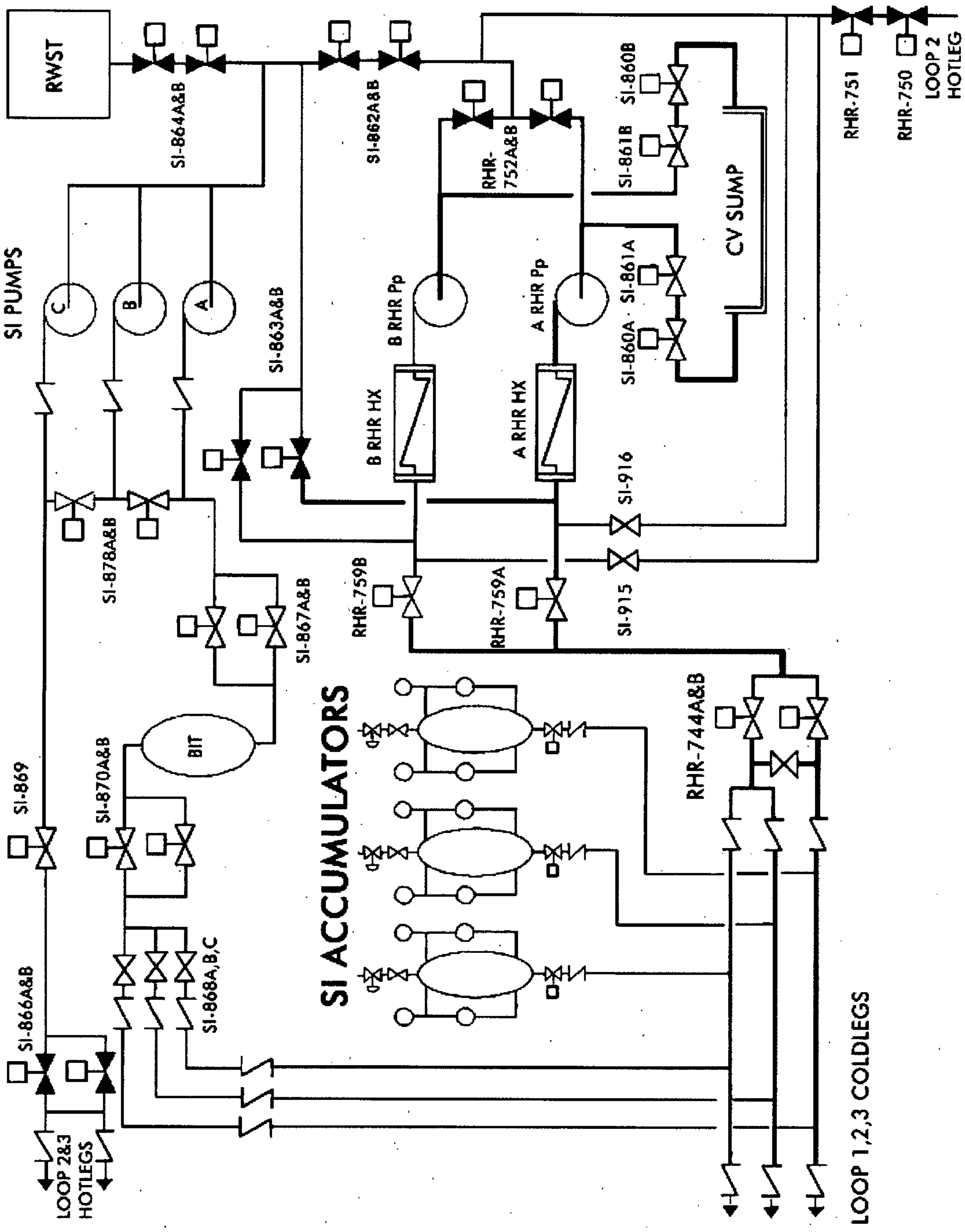
NRC SER Section	Topic	Requirement	Compliance
			distribution provided in the NRC SER. Calcium Silicate material used is IIG Thermo Gold, which is used as a surrogate for Kaylo, Calsilite, and Thermo 12 insulation. The IIG Thermo Gold has been evaluated by Scanning Electron Microscope (SEM) analysis to be an appropriate surrogate for Calsilite and Thermo 12 insulation. A sample of the Kaylo insulation was not provided for SEM analysis. However, Kaylo insulation is a calcium-type insulation and is similar to the IIG Thermo Gold insulation. In order to verify that the NUREG/CR-6224 correlation will conservatively predict head loss for the prototype array, an analysis based on the NUREG/CR-6224 correlation was performed using parameters determined in vertical loop testing. The parameters determined in the vertical loop testing were the specific surface area (S_v) and microscopic densities for Wollastonite 520H and Cal-Sil, as well as the maximum solidity. The NUREG/CR-6224 correlation predicted a head loss of 7.58 ft of water for Test #2B (test array full debris load at 85°F). The prototype test result was 6.02 ft of water for Test #2B, which indicates that the NUREG/CR-6224 correlation developed in the HBRSEP, Unit No. 2, head loss calculation is conservative with respect to the prototype test configuration.
3.7.2.3.1.2	RMI Debris Beds	The NRC SER endorses the use of the NUREG/CR-6808 head loss correlation for RMI. This correlation is reiterated in NEI 04-07.	RMI contributes negligible head loss for the HBRSEP, Unit No. 2, strainer. Utilizing the correlation reiterated in NEI 04-07, the head loss attributed to RMI is on the order of 1×10^{-8} ft of water. Therefore, RMI was not included in the debris head loss calculation.
3.7.2.3.1.3	Mixed Debris Bed	Mixed debris beds (RMI, fiber, and particulates) shall be evaluated as the algebraic sum of the head loss of the	As discussed above, the RMI contributes negligible head loss. Therefore, it was not added to the head loss attributed to the fiber/particulates bed. Testing of the

NRC SER Section	Topic	Requirement	Compliance
		fiber/particulates and the RMI.	HBRSEP, Unit No. 2, strainer design shows that the complex geometry of the top-hat-style strainer will prevent larger head loss due to thin-bed effect.
3.7.2.3.1.4	Calcium Silicate	Use the debris characteristics for Cal-Sil listed in Table 3-5 unless plant-specific data is available.	Parameters for Cal-Sil were determined in vertical loop testing for S_v, microscopic densities, as well as maximum solidity. Prototypical testing validated that the parameters utilized in the NUREG/CR-6224 correlation are conservative with respect to the prototype testing results.
3.7.2.3.1.4	Calcium Silicate	Thin-bed effect shall be shown not to occur in order to use mixed debris configuration recommendations.	The thin-bed effect is not predicted to occur based on the advanced strainer design (i.e., top hats) and the very low approach velocities (0.002 ft/sec). Prototypical strainer testing was performed using plant-specific debris mixtures to verify this assumption.
3.7.2.3.1.5	Microporous Insulation	HBRSEP, Unit No. 2, does not use any Microporous Insulation.	
3.7.2.3.2.1	Total Sump Screen Head Loss	The clean strainer head loss shall be added to the debris head loss to determine the total head loss across the screen.	The debris head loss is combined with the clean strainer head loss. This is consistent with the NRC SER. The total strainer head loss is then compared to the limiting NPSH margin of 5.2 ft to determine that the strainer meets the performance requirement.
3.7.2.3.2.2	Evaluation of Breaks with Different Combinations of Debris	A spectrum of breaks shall be analyzed to determine the worst case (head loss) break location.	A spectrum of breaks was evaluated in the debris generation calculation. The two bounding cases from that calculation were input into the debris head loss calculation to determine the worst case scenario.
3.7.2.3.2.3	Thin Beds	The head loss associated with thin-bed effect shall be evaluated.	The thin-bed effect is predicted to not occur, based on the advanced strainer design (i.e., top hats) and the very low approach velocities (0.002 ft/sec). Prototypical strainer testing was performed using plant-specific debris mixtures to verify this prediction.
3.7.2.3.2.4	Sump-Screen Submergence	The limiting condition for submerged sump screens is when the combined clean screen and debris bed head loss exceeds the NPSH margin.	The sump strainer design, as installed by EC 63481, is fully submerged in all post-accident recirculation modes of operation. The limiting NPSH margin for the RHR pumps is 5.2 ft. The clean strainer head loss (1.56 ft, not including head loss through the top hat) plus the

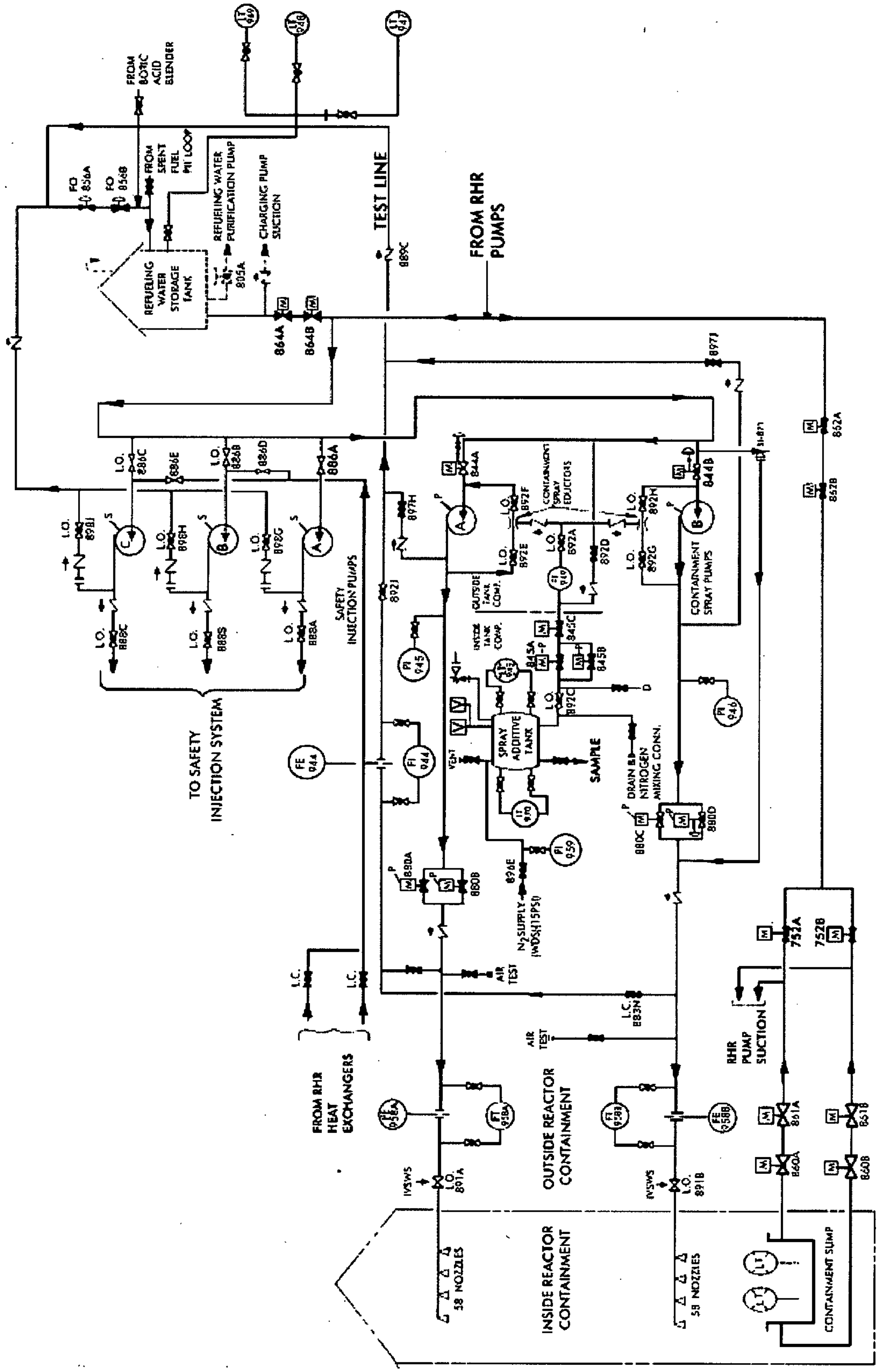
NRC SER Section	Topic	Requirement	Compliance
			debris bed head loss (2.57 ft) is less than the limiting NPSH margin (4.13 ft < 5.2 ft). Therefore, the strainer design is acceptable.
3.7.2.3.2.5	Buoyant Debris	Buoyant debris should be considered for partially submerged strainer assemblies.	The sump strainer design, as installed by EC 63481, is totally submerged in all post-accident recirculation modes of operation. Therefore, buoyant debris is not a consideration for debris head loss. Another potential concern with buoyant debris is whether the debris, if allowed to accumulate on top of the strainer, would cause the formation of an air flow path directly through the strainer surface. Evaluation of the HBRSEP, Unit No. 2, design has determined that buoyant debris will not result in air ingestion through the strainer.
3.7.2.3.3.1	Flat Screen Assumption	The evaluation of complex geometry strainer designs as flat plates is acceptable.	The NUREG/CR-6224 correlation was used to predict the debris bed head loss. Prototypical testing was performed using the plant-specific debris mix to validate the application of NUREG/CR-6224 for head loss through the debris-laden top hats. The flat screen assumption was not used.
3.7.2.3.3.2	Non-uniform Deposition on Sump Screen Surfaces	It is considered conservative to assume a uniform debris accumulation on the strainer surface.	Debris quantities were scaled for prototypical testing assuming the full debris load will load uniformly on the strainer.
3.7.2.3.3.3	Very Thin Fiber Beds	It is considered appropriate to neglect the head loss from very thin (< 1/8 inch) fiber beds.	The thin-bed effect is predicted to not occur, based on the advanced strainer design (i.e., top hats) and the very low approach velocities (0.002 ft/sec). Prototypical strainer testing was performed using plant-specific debris mixtures to verify this prediction. The Thin Bed Threshold Tests were performed at equivalent bed thicknesses of 1/8 inch and 3/8 inch.

During post-LOCA recirculation, the low pressure safety injection pumps, also referred to as the residual heat removal (RHR) pumps, take suction from a common ECCS sump in the containment. The high pressure safety injection (SI) and containment spray (CS) pumps take suction from the discharge of the RHR pumps (referred to as "piggyback" operation). When operating in piggyback mode, sump fluid is recirculated from the Containment ECCS Sump

(Containment Vessel [CV] sump), through the RHR pumps and heat exchangers, and then to a suction header that provides water to both the SI pumps and the CS pumps. This can be seen in the following simplified system diagrams.



Safety Injection System



Containment Spray System

Testing was conducted to determine the maximum head loss associated with the worst-case post-LOCA debris accumulation at the containment recirculation sump screen. The objective of the testing was to measure the head loss of a prototype ECCS recirculation strainer in a test tank at various debris quantities for a variety of flow rates through the debris bed. This testing demonstrated that the thin-bed effect does not occur for the complex geometry strainer installed at HBRSEP, Unit No. 2.

The testing was developed, implemented, and maintained in accordance with the Alion Science and Technology Innovative Technology Solutions Operation (ITSO) Quality Assurance Program for nuclear safety-related services. Those processes that affect the quality of the output were identified and controlled in accordance with project-specific procedures.

The strainer array hydraulic tank testing was performed according to Test Plans ALION-PLN-ENER-2426-07 and ALION-PLN-ENER-4534-02. The test array consisted of four horizontal top hat assemblies with a screen area of 122.72 ft^2. Test debris volumes and flowrates were scaled for the tested screen area. The data was analyzed for thin beds of fibrous debris and for thick debris beds. Head loss curves were developed from the analysis.

The strainer array testing successfully collected differential pressure, flow rate, turbidity, and temperature data for two types of tests: 1) Tests with debris beds containing high particulate-to-fiber mass ratios, and 2) tests that sought to determine full debris load head loss for a top hat strainer array. The pressure loss was a second order polynomial with debris quantity.

Tests #1B, #1C, and #1D were a series of thin bed threshold tests, at equivalent bed thicknesses of 1/8 inch and 3/8 inch.

- Test #1B – 1/8 inch Thin Bed Test with particulate debris added followed by fiber debris added
- Test #1C – 3/8 inch Thin Bed Test with simultaneous debris added (fiber and particulate)
- Test #1D – 1/8 inch Thin Bed Test with simultaneous debris added (fiber and particulate)

Test #1C produced a stabilized head loss of 3.42 ft of water at approximately 80°F. This head loss indicates there was sufficient fibrous debris available to cover the strainer, but no thin-bed effect of a high head loss at this debris load was observed. The full scale array in the plant would be expected to load more non-uniformly and would also exhibit low head loss at low fiber loads. Tests #1B and #1D produced lower head loss results and are thus considered to be bounded by Test #1C. Review of the debris head loss calculation indicates there were no anomalies observed during testing that would have affected the head loss result non-conservatively.

Tests #2B, #2C, #3B, and #3C were performed for the purpose of determining the head loss associated with the maximum debris loading on the strainer.

- Test #2B – Maximum Debris Load Test with simultaneous debris added (fiber and particulate)

- Test #2C – Maximum Debris Load Test performed at the end of Test #2B and added 20% more particulate and fibrous debris
- Test #3B – Confirmatory Test of Test #2B
- Test #3C – Confirmatory Test of Test #2C

In Test #2B, fibrous and particulate debris were added simultaneously to the tank. This debris load represented the plant's maximum debris load, which would form a fibrous debris bed of 0.52 inch, based on uniform distribution on the screen. Once a stable head loss was achieved, Test #2C added an additional debris load that amounted to 20% more particulate and fibrous debris. Test #2B produced a stabilized head loss of 6.02 ft of water at an approach velocity of 0.00213 ft/sec. The full scale array would be expected to load more non-uniformly and would exhibit lower head loss at these debris loads. Prior to the addition of the extra 20% particulate debris quantity for Test #2C, a flow sweep was performed at an approach velocity of 0.005 ft/s. This increased the head loss to a value of 10.3 ft of water due to the debris bed and strainer. After adding the extra 20% particulate debris quantity, the approach velocity indication started to become unstable and no further testing was performed. Tests #3B and #3C were performed as a confirmatory test of Tests #2B and #2C. The Test #3B stabilized head loss results (3.94 ft of water) were lower than that of Test #2B and are thus bounded. Test #3C was performed with the additional 20% debris load and resulted in a stabilized head loss of 10.3 ft of water. Review of the debris head loss calculation indicates there were no anomalies observed during testing that could have affected the head loss result non-conservatively.

Based on the conservative results of the analysis using the NUREG/CR-6224 correlation as compared to the test results, the NUREG/CR-6224 correlation was utilized to establish the maximum head loss under design conditions and debris bed head loss parameters with changes to temperature, screen area, flow rate, and debris loads. The maximum head loss for a maximum debris bed under design conditions (RCP "B" Bay Base Case, 212°F, 3820 gpm, 4000 ft^2 strainer) is 2.57 ft of water. The debris load from the RCP "B" Bay base case was selected for testing because the RCP "B" Bay has the greatest quantity of particulate-based insulation and would create the highest head loss based on the NUREG/CR-6224 correlation.

Near-Field Settling

Near-field settling was not credited for the debris head loss testing. The debris addition point in the test tank was selected to maximize the transport of the debris to the strainers, thus ensuring the results obtained are conservative. The debris was added with the test tank pump and mechanical mixer in operation. Manual stirring of the tank with a paddle along with the mechanical mixer was required at times to suspend the particulate debris and a portion of the fibrous debris.

Cavitation/Flashing/Void Fraction

It has been determined that the minimum pressure head downstream of the strainer remains above saturation pressure, provided the head loss through the strainer is 26 ft of water or less. Additionally, the strainer head loss value is significantly below 26 ft of water, based on the design for maximum strainer differential pressure of 6.5 psid (approximately 15 ft of water).

Therefore, it has been determined that cavitation will not occur under the applicable design conditions.

Dissolved air can also come out of solution as a result of the pressure drop across the strainer. Based on Figure 3 of the NRC SER, ensuring 11°F or more of subcooling downstream of the strainer will ensure the void fraction is less than 3%. The sump will be subcooled by at least 16°F when credit is given for the partial pressure of air in containment prior to the accident. This result is based on the following:

- At the time of switchover to recirculation, the containment pressure is the sum of the partial pressure of steam, which is equal to the sump fluid saturation pressure, plus an air partial pressure equal to the containment dry air pressure prior to the event.

- The containment dry air pressure prior to the event was calculated assuming 100% relative humidity and minimum normal containment pressure at a containment temperature corresponding to the maximum normal temperature experienced at the plant.

Temperature/Viscosity Adjustment

Steady-state head loss data for Test #2B during the prototypical head loss testing was performed at a temperature of approximately 82°F. Parametric evaluations were performed for a range of temperatures from 60°F to 212°F using the NUREG/CR-6224 correlation.

When scaling the head loss results to account for a higher water temperature, the head loss decreases due to decreasing viscosity at higher temperature. The NUREG/CR-6224 correlation adjusts the results to account for less compaction in the debris bed. The reduced differential pressure would reduce the likelihood of forming bore holes or impacting the bed morphology significantly. Subsequent testing at reduced flows indicated the head loss correlation with flow was linear, which indicates laminar flow. Bore holes would be expected to indicate turbulent flow. Bore holes were not observed in the debris bed during the test, so they are not expected under a less compacted (i.e., lower head loss) condition. If boreholes develop, the head loss curve tends to flatten out and become ragged as the differential pressure exceeds the shear strength of the particulate debris bed, and the boreholes form and collapse. This was not seen during the tests.

When scaling the head loss results to account for a lower water temperature, the head loss increases. The NUREG/CR-6224 correlation adjusts the results to account for more compaction in the debris bed. If bore holes were to occur under increased differential pressure, they would serve to decrease the head loss across the screen. Therefore, the results are conservative.

Vortexing Evaluation

The ECCS containment sump strainer assembly was evaluated for air ingestion. Air ingestion could theoretically occur at the top hats or through the fully submerged vents on the top of the sump box, because the suction inlets will be enclosed in the fully submerged sump box. Proprietary testing has shown that the presence of one inch thick grating located just above the top hats and negligible submergence (i.e., the top of the grating is at approximately the same elevation as the top of the water), prevents the formation of vortices at the top hats. Also, observations made during proprietary testing showed that vortices outside the area of the grating are not sustainable if required to bend to enter the top hat. In addition, Regulatory Guide (RG) 1.82, Revision 3, provides guidelines for vortex suppressor design and specifies the use of 1½ inch thick standard floor grating spanned above the inlet (Design #2 in Table A-6 of RG 1.82). It is recognized that the strainer design at HBRSEP, Unit No. 2, does not resemble the screened open pit design shown in Regulatory Guide 1.82, Revision 3.

Vortex suppressors reduce the circulation of the fluid near the intake, thus preventing vortex formation. Grids, grating, and/or vanes can be used to inhibit fluid rotation. The vortex suppressors are constructed of 1½ inch thick stainless steel grating above the top hat strainer assemblies that were determined to be potentially susceptible to vortexing. The sump box vents include vortex suppressors that are constructed of 1½ inch thick stainless steel bars. These vortex suppressors provide assurance that the ECCS sumps will not be susceptible to air ingestion caused by air core vortex formation.

The addition of the vortex suppressor does not adversely impact debris distribution and head loss. The new ECCS containment sump strainer contains 530 ft^3 of interstitial volume. The quantity of debris that is postulated to transport to the strainer screen and form a debris bed is 198.1 ft^3. This debris constitutes only 37% of the available interstitial volume. The theoretical mixed debris bed thickness (i.e., without considering compression effects) on the approximately 4,200 ft^2 strainer is 0.566 inch. The limiting clearance between the top of the top hats and the vortex suppressor grating is 1 inch. Therefore, the vortex suppressor grating will not interfere with the formation of the postulated debris bed.

The results for the top hat tests show that air entraining vortexing will not occur for specific limiting values of flow velocity through the top hat base plates and Froude number. Relationships were then developed to compare top hats that differ from those tested and evaluate the likelihood of vortexing. The following relationships were used to calculate the maximum approach velocity that can be sustained without vortexing. Two approach velocities were calculated and the minimum was conservatively used for comparison.

$$v_{limit} = 2.09 \text{ ft/s} * (A/SA)$$

$$v_{limit} = (A/SA) *(17.47 \text{ ft/s}^2 * L_{design})^{1/2}$$

where,

limit = Maximum approach velocity (ft/s)
A = Cross-sectional flow area through the base plate (ft^2)
SA = Effective top hat surface area (ft^2)
L_{design} = Submergence depth (ft)

The minimum water level is at Elevation 229.5 ft or 18 inches above the floor. The maximum local drawdown is 0.25 inch, which occurs inside the crane wall. The top of the strainer flow plenum is a maximum of 16 inches above the floor. The outside surface of the top hat outer perforated plate is located 1.5 inches below the top of the plenum. Therefore, the minimum submergence (L_{design}) of the top hat is 3.25 inches (18 inches – 0.25 inch – 16 inches + 1.5

inches). The cross-sectional flow area through the base plate must be limited to only the flow area of the outside flow annulus for double top hats. The effective top hat surface area was limited to only the surface area of the outside annulus perforated tubes for double top hats (10 inch and 12 inch outside diameter tubes); however, using the entire top hat effective area is conservative in this calculation because it provides a lower limiting approach velocity. There are two different sized top hats, and the largest effective surface area was used to minimize the limiting approach velocity. The effective surface area of the 4.5-foot top hat is 34.45 ft^2. Finally, the two limiting approach velocities were calculated and the minimum was conservatively used for comparison.

$$v_{limit} = 2.09 * (0.1897 / 34.45) = 0.0115 \text{ ft/s}$$

$$v_{limit} = (0.1897 / 34.45) * (17.47 * 3.25 / 12)^{1/2} = 0.0120 \text{ ft/s}$$

The limiting maximum approach velocity is 0.0115 ft/s. Two cases were examined. The first compared the limiting maximum approach velocity to the maximum normalized approach velocity as calculated for the clean strainer head loss. This case evaluated vortexing when the strainer is fully loaded with debris. The second case is based on the maximum expected approach velocity. This case evaluates the strainer early in the event before debris has accumulated and most of the flow comes from the top hats nearest to the location where the ECCS sump piping penetrates the containment.

As debris loads, the approach velocities for all top hats will approach the normalized approach velocities; therefore, these are the two bounding cases. The maximum normalized approach velocity is 0.002 ft/s. This is well below the limiting maximum approach velocity of 0.0115 ft/s. Therefore, air entrainment due to vortexing is not expected once the strainer is fully loaded and the approach velocities are predicted to move toward normalized approach velocities based on comparisons with test data. The maximum expected approach velocity calculated was 0.017 ft/s at the first set of top hats nearest the sump located inside the crane wall. The maximum expected approach velocity is greater than the limiting value; therefore, air entrainment due to vortexing could occur.

However, the approach velocities drop off very quickly and the third set of top hats has an approach velocity of 0.009 ft/s, which is approximately 21% below the limiting approach velocity of 0.0115 ft/s. The first set of top hats outside the crane wall are below the limiting approach velocity by approximately 10%. The remaining top hats inside and outside the crane wall are well below the limiting value. In the locations potentially susceptible to vortexing, vortex suppressors are installed over the top hats.

<u>Clean Strainer Head Loss Analysis</u>

The clean strainer head loss (CSHL) was determined using the following steps:

- The strainer effective surface area was determined considering the water level at the start of recirculation and the corresponding effective height of the top hats. The containment sump strainer design is based on the strainer being fully submerged; thus, the entire effective surface area of the strainer was considered.

- The flow distribution per square foot of effective area was calculated. This is refered to as "normalized flow."

- The head loss through each top hat was calculated using the normalized flow. The calculation is based on correlations developed through testing.

- The head loss through the flow path connecting the top hats to the containment sump (hereafter referred to as the plenum) was calculated. Flow entering the plenum from the individual top hats was modeled as a 90 degree mitre bend for the first top hats on the plenum, and as wye intersections for the remaining top hats.

- The maximum sump flow is based on one RHR pump operating, and the piping connection at the farthest end of the plenum box was used for modeling flow losses.

- The plenum head loss was calculated separately for the strainer flow path originating at the top hats outside the crane wall and the strainer flow path originating at the top hats inside the crane wall.

- The largest head loss experienced by a top hat and plenum flow path was summed to produce the most conservative head loss.

Key assumptions included:

- For the CSHL, flow through the strainer was assumed to be uniform and normalized over each of the top hats. This is a conservative assumption because in reality the flow would balance with the path of least resistance, i.e., more flow would be experienced by those top hats that were closer to the RHR pump suction lines.

- The lowest sump water temperature was assumed to be constant at 60°F. For the dynamic head losses, this is slightly conservative because water at higher temperatures (characteristic of post-accident sump temperatures) would exhibit lower viscosity. A conservatively low water temperature results in lower Reynolds numbers, and consequently higher friction factors.

3g. Net Positive Suction Head (NPSH)

Requested information:

The objective of the NPSH section is to calculate the NPSH margin for the ECCS and CSS pumps that would exist during a loss-of-coolant accident (LOCA) considering a spectrum of break sizes.

- Provide applicable pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level.

- Describe the assumptions used in the calculations for the above parameters and the sources/bases of the assumptions.

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

- Describe how friction and other flow losses are accounted for.

- Describe the system response scenarios for LBLOCA and SBLOCAs.

- Describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation.

- Describe the single failure assumptions relevant to pump operation and sump performance.

- Describe how the containment sump water level is determined.

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

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

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

- Provide assumptions (and their bases) as to what water sources provide pool volume and how much volume is from each source.

- If credit is taken for containment accident pressure in determining available NPSH, provide a description of the calculation of containment accident pressure used in determining the available NPSH.

- Provide assumptions made which minimize the containment accident pressure and maximize the sump water temperature.

- Specify whether the containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature.

- Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode.

<u>HBRSEP, Unit No. 2, response:</u>

The ECCS and CSS include two trains of emergency cooling pumps. Each train consists of one high pressure SI pump, one RHR pump, and one CS pump. Both trains are normally aligned to take suction from the refueling water storage tank (RWST), and can be aligned to the ECCS sump by manual operator actions once a pre-determined minimum water level in the RWST is reached.

System response is determined by break size and resulting RCS and containment pressure. The SI, RHR, and CS pumps are automatically actuated on decreasing RCS pressure, increasing containment pressure, or steam line break conditions. Once actuated, flow is dependent on the RCS and containment pressures. Depending on break size, CS pump actuation may occur. NPSH calculations are based on atmospheric pressure in containment and the RCS to maximize flow and minimize NPSH margins.

For a small break LOCA, the rate of RCS depressurization will be slow and therefore create a delay between SI and RHR actuations. Due to the relatively low shutoff head of the RHR pumps, RHR flow to the RCS will not begin until the RCS depressurizes to below the shutoff head. For a large break LOCA, rapid RCS depressurization and concurrent containment pressurization will cause SI, RHR, and CS actuation early in the event. For the bounding large break LOCA, RCS pressure will be sufficiently low to allow full SI and RHR flow, resulting in the most rapid depletion of the RWST and therefore earliest switchover to ECCS sump recirculation. After switchover to ECCS sump recirculation, the SI and CS pumps are aligned to take suction from the discharge of the RHR pumps (also called "piggyback" operation). Transfer to ECCS sump recirculation is accomplished by changing the suction source for the RHR pumps from the RWST to the ECCS sump. Both RHR pumps can take suction from the common ECCS sump.

Calculations were performed to establish the RHR pump NPSH margins in the absence of the ECCS strainers and collected debris. Specifically, RHR pump NPSH margins were calculated by subtracting the NPSH available (NPSHA) from the NPSH required (NPSHR), without including head loss through the ECCS strainer and collected debris.

NPSHA calculations were based on hydraulic models of the systems aligned for ECCS sump recirculation in accordance with the applicable emergency operating procedures. NPSHR was based on the pump manufacturer NPSHR curve based on the 3% head drop criterion. Different configurations were modeled and the system configuration resulting in the highest sump flow rate and minimum NPSH margin was used to determine acceptable screen head loss and sizing of the ECCS sump strainers, i.e., 5.2 ft at 3820 gpm.

The NPSH calculations are based on a large break LOCA that results in complete depressurization of the RCS, which maximizes injection flowrates and NPSHR, and minimizes NPSHA. Smaller breaks will result in an RCS pressure increase that will in turn decrease injection flowrates and increase NPSH margins. Prior to aligning the system for recirculation from the sump, the RHR pumps are stopped. Shutdown of pumps during recirculation is not credited for reducing flowrates and head loss to increase NPSH margins. Therefore, failure of a pump to stop does not adversely affect recirculation NPSH margins. Once aligned to the sump, one RHR pump is re-started. NPSH margins were determined for the various system alignments and are tabulated below. A single failure of SI or CS pumps will decrease RHR pump flow and improve NPSH margin. The RHR pump NPSH values are reported because only the RHR pumps draw suction from the ECCS sump in the containment. After alignment for recirculation from the sump, the SI and CS pumps are supplied by the RHR pump. NPSH is not a concern for these pumps when aligned in this configuration. The minimum NPSH margin occurs when aligned for a single RHR pump recirculating from the sump into a depressurized RCS. Operation of more than one RHR pump improves the NPSH margin because though total flow increases, the individual pump flow and pump suction piping flow decreases leading to decreased NPSHR and increased NPSHA. Similarly, when in piggyback alignment, total system flow is reduced, NPSHR decreases, and NPSHA increases. No credit for containment pressure above atmospheric pressure was taken in the determination of the head loss margin.

Total Recirc Flow (gpm)	CV press (psig)	RHR Pump(s)	RHR Pump Flow (gpm)	SI Pumps	CS Pumps	Sump Temp (°F)	NPSHA (ft)	NPSHR (ft)	Margin (ft)
3759	0	A	3759	-	-	212	19.5	14.3	5.2
3819	0	B	3819	-	-	212	19.8	14.6	5.2
2466	42	A	2466	A & B	A	289	17.6	9.8	7.8
2473	42	B	2473	A & B	A	289	17.7	9.8	7.9
3143	0	A & B	1555	A & B	-	212	A: 21.9	9.2	12.7
			1588				B: 22.0	9.2	12.8

These margins were used to determine the acceptability of the head loss across the debris-laden ECCS strainer during the recirculation mode of emergency core cooling following a postulated LOCA.

The water level above the sump screens is less than the head loss through the screens. Therefore, in examining the potential for release of gas from the fluid as it passes through the ECCS strainer, it was assumed that the containment dry air pressure remained constant and the partial pressure of water vapor in containment was equal to the sump saturation pressure. No credit was taken for an elevated containment pressure resulting from post-LOCA heating of the air. This approach is consistent with the guidance in Section 6.4.7.1 of NEI 04-07. The analysis concluded that voiding at the screens with the expected screen head loss is not a concern.

NPSH available calculations were performed for saturated sump water at an atmospheric pressure of 14.7 psia and a temperature of 212°F. Containment pressure can be as low as -0.8 psig (13.9 psia) or as high as 1 psig (15.7 psia). Changes to the sump temperature and associated containment pressure have a negligible net effect on NPSH, because the NPSHA calculation subtracts the vapor pressure from atmospheric pressure, and atmospheric pressure is conservatively assumed to be equal the vapor pressure

As sump pool temperature increases above 212°F, water viscosity decreases. This results in decreased head loss due to piping friction losses and flow through the debris bed based on a constant volumetric flowrate. Therefore, the effect of increased sump pool temperature is an increase in NPSHA due to the decrease in head loss.

As sump pool temperature decreases, the corresponding saturation pressure (i.e., vapor pressure) decreases below the initial containment pressure, resulting in a subcooled sump pool, which increases NPSHA. However, as sump pool temperature decreases below the limiting value, water viscosity increases. This results in an increase in head loss due to piping friction losses and increasing head loss through the debris bed, which decreases NPSHA. A parametric evaluation was performed to determine the impact of decreasing sump pool temperature on head loss. This evaluation demonstrated that the relatively small increase in head loss was overwhelmed by the sump pool subcooling effect (i.e., sump pool saturation pressure decreasing below the minimum post-accident containment pressure). For example, as the sump pool temperature decreases from 212°F to 60°F, the debris head loss increases by less than 10.4 ft of water, but NPSHA increases by approximately 33 ft of water due to subcooling of the sump pool. The net effect of decreased sump pool temperature is also an increase in NPSHA. Therefore, the limiting NPSH available occurs at the saturation temperature associated with the minimum pre-accident containment pressure.

Clean screen head loss associated with flow in the strainer assembly, including top hats and plenums, was calculated using information from Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe," Fried, Erwin, and Idelchik, "Flow Resistance: A Design Guide for Engineers," and Churchill, "Friction-Factor Equation Spans All Fluid-Flow Regimes." This head loss assumes a clean screen head loss for a top hat of 0.021 ft of water based on testing. The lowest sump water temperature is assumed constant at 60°F, as lower temperatures yield higher viscosities, resulting in lower Reynolds numbers and higher friction factors. The flow across the strainer is assumed to be uniform and normalized over the total strainer area, which is conservative because the flow will balance with the path of least resistance, i.e., more flow will be experienced by the top hats that are closer to the recirculation lines for the initial, clean condition. The head loss through the strainer was calculated as 1.585 feet of water, which includes 0.021 ft of water for the head loss through a top hat.

Head loss testing of the screen with design basis debris loading and chemical loading was conducted. Measured head loss with the design debris load and chemical precipitate load at the design flowrate was approximately 5.4 ft of water at 80°F with debris only, and 10.1 ft at 80°F with debris and chemical precipitant loading. When adjusted for viscosity at 212°F (saturation temperature at 0 psig), the head loss is approximately 1.8 ft of water for debris only, and 3.5 ft of water for debris and chemical loading. The head loss from the ECCS sump through the strainer plenums and clean top hat strainers is calculated as 1.56 ft of water at design flow conditions. The results indicate the total head loss of 5.1 ft of water (1.56 ft of water in the strainer plenum and 3.51 ft of water through the strainer debris and chemical bed) is less than 5.2 ft of water and will be sufficient to ensure the NPSH requirements of the ECCS sumps will be satisfied in chemical debris loading cases.

The minimum water level in containment at the start of transition to recirculation is site Elevation 229.5 ft above mean sea level (MSL) for a small or large break LOCA. The floor of containment is at Elevation 228 ft MSL; thus, the minimum pool depth is 1.5 ft. The transition to recirculation begins when the RWST is at 27%. Transition to ECCS recirculation is complete when the RWST is drained to approximately 9%. Therefore, during recirculation, the water level will increase above the assumed 229.5 ft level. However, as a conservatism, no credit is taken for the water injected from the RWST during the transition to recirculation.

The water level calculation first determines the mass of water injected into containment, then subtracts out the mass of water that is diverted away from the sump. The remaining mass of water is converted to a pool level. The water level calculation conservatively accounts for the sources of water on the containment floor and for the water holdup mechanisms and associated volumes. Determination of the minimum water level accounted for water holdup in the following locations:

- Steam holdup in the containment atmosphere.
- Water volume required to fill the RHR and CS piping that is empty prior to the LOCA.
- Additional mass of water that must be added due to the increase in the water density at the lower sump water temperatures (versus the RCS temperature prior to the LOCA).
- Condensation on surfaces.
- Water volume required to fill the pressurizer steam space.
- Water in transit from the CS nozzles and the break to the containment sump.
- Water holdup in the refueling canal.
- Water holdup within the curbs in the RCP platform.
- Water lost through ECCS leakage from containment.
- A miscellaneous holdup volume is included in the calculation. Some of the contributions to the miscellaneous holdup include:
    - Small quantity of leakage into the Seal Table Room,
    - Small quantity of water that leaks past the water repellant mastic or metal jacketing covering piping and component insulation,
    - Small quantity of water that might holdup in the containment building elevator, and
    - Holdup in the containment drainage piping.
- Water holdup in the floor drain cavities beneath the RCPs.

The inputs to the water level calculation are biased toward minimizing the containment water level. The calculation uses the RWST and the accumulators as water sources. The RWST is assumed to initially be at the Technical Specifications minimum water level. As injection proceeds, the level is assumed to drop to the low alarm setpoint, at which point the transition to recirculation begins. The total volume of water injected from the RWST is 34,527 ft^3. Each of the three accumulators is assumed to be at the Technical Specifications minimum level, and the total volume of water added to the containment floor from the accumulators is 2,475 ft^3. Each water source is assumed to be at its respective maximum temperature to minimize the mass of water injected into containment. Water level is based in part on an RCS leak in 1975 that raised the water level to Elevation 229 ft, or 0.5 feet below the minimum water level. Equipment that might displace water is incorporated into the correlation of water volume spilled and actual water level. It was conservatively assumed in the minimum containment water level calculation that none of the components between the Elevations 228 ft and 229.5 ft will displace the water volume.

3h. Coatings Evaluation

Requested information:

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.

- 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.
- Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.
- 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.
- Provide bases for the choice of surrogates.
- 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.
- Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.
- Describe any ongoing containment coating condition assessment program.

HBRSEP, Unit No. 2, response:

NRC SER Section	Topic	Requirement	Compliance
3.4	**Debris Generation**		
3.4.2.1	Coatings	All coatings (qualified and unqualified) shall be assumed to fail within 10D (diameters) of the pipe break (using a spherical model) or plant-specific coatings ZOI should be determined.	The quantity of qualified coatings assumed to fail was calculated for both a 10D ZOI and a 5D ZOI. The quantity of qualified coatings generated within a 10D ZOI was used for the base case head loss calculation. A parametric analysis based on a 5D ZOI for qualified coatings resulted in an approximate 1.5% decrease in head loss across the debris bed. Unqualified coatings inside the containment, as identified in the exempt coatings log, are assumed to fail.
3.4.2.1	Coatings	All degraded qualified coatings outside the ZOI are assumed to fail.	Quantities of unqualified coatings inside containment are provided in a table below. This table was derived from the exempt coatings log, which includes degraded qualified coatings along with unqualified coatings. Unqualified coatings inside the containment are assumed to fail wherever they exist, as identified in the exempt coatings log.
3.4.2.1	Coatings	All unqualified coatings outside the ZOI are assumed to fail.	Unqualified coatings inside the containment are assumed to fail.
3.4.3.3	Outside ZOI	Material outside of the ZOI which may be subject to LOCA conditions shall be considered debris in accordance with NRC SER Table 3-3. These are considered uncovered fire barrier material, unjacketed insulation, and unqualified coatings.	Unqualified coatings inside the containment are assumed to fail.
3.4.3.4	Protective Coating Quantification	If a thin bed will not occur, then the coating debris (qualified and unqualified) should be sized based on plant-specific analyses.	Thin-bed effect was not ruled out as a possibility prior to testing. Thin bed threshold testing was performed and as discussed in the preceding Section 3f, the thin-bed effect was not observed.

NRC SER Section	Topic	Requirement	Compliance
3.4.3.4	Protective Coating Quantification	Degraded "Qualified" coatings that have not been remediated shall be treated as "Unqualified" coatings.	Degraded "Qualified" coatings are treated as "Unqualified."
3.4.3.6	Debris Characteristics for Use in Debris Transport and Head Loss	The staff recommends that when using GR Tables 3-2 and 3-3, that these values be verified by plant-specific data/vendor information due to variances in material properties.	The debris characteristics necessary for the head loss evaluation of the debris bed are provided in a table below. The properties of these materials are from NEI 04-07, Tables 3-2 and 3-3. The material properties are further supported by material characteristic reports. The observed coatings debris sizes are in the range of 10 microns to 50 microns. The coatings debris generated within the ZOI is treated as fine particulate debris 10 microns in size, consistent with the NEI methodology. Unqualified coatings outside the ZOI are conservatively assumed to also fail as 10 micron fines. Other coating characteristics were obtained from material data sheets for specific coatings, if available (i.e., Carboline 890, Carbozinc-11 Primer, and Phenoline 305 Finisher). Otherwise, coating dry film density was obtained from NEI 04-07.
3.4.3.6	Debris Characteristics for Use in Debris Transport and Head Loss	Degraded "Qualified" coatings that have not been remediated shall be treated as "Unqualified" coatings.	Degraded "Qualified" coatings are treated as "Unqualified."
3.6.3 – other debris	Fraction of debris generated	1	100% of the coatings debris source term is assumed to be destroyed as small particles.
3.6.3 – other debris	Fraction of debris generated that transports into upward levels by blowdown	0.25	100% of the coatings debris source term is assumed to transport to the sump strainer.
3.6.3 – other debris	Fraction of debris generated that transports directly to sump pool floor by blowdown	0.75	100% of the coatings debris source term is assumed to transport to the sump strainer.

NRC SER Section	Topic	Requirement	Compliance
3.6.3 – other debris	Fraction of Debris Generated that blows into upper levels and washes down into sump pool	1	100% of the coatings debris source is assumed to transport to the sump strainer.
3.6.3 – other debris	Fraction of Debris Generated that enters into Inactive Sump Pools	Volume Ratio with a maximum of 15% of total debris.	100% of the coatings debris source term is assumed to transport to the sump strainer.
3.6.3 – other debris	Fraction of debris that enters sump pool that transports to sump screens	1	100% of the coatings debris source term is assumed to transport to the sump strainer.
3.7.2.3.1.1	Fibrous Debris Beds with Particulate	Head loss parameters for materials that have not been previously characterized are recommended to have testing performed.	Plant-specific debris testing was performed and provides validation to the input parameters used in the NUREG/CR-6224 analysis.

Summary of Types of Coatings

The primary original field-applied acceptable coatings systems in containment for HBRSEP, Unit No. 2, were Carbozinc 11 (CZ-11) and Phenoline 305 for steel, and Carboline 195, Phenoline 305 Primer, or Phenoline 305 for concrete. These coatings are design basis accident (DBA) resistant, as required by the plant licensing basis requirements, which pre-date ANSI 101.2 and ANSI 101.4 requirements, and were originally evaluated for HBRSEP, Unit No. 2, in report WCAP-7198-L. The coatings described include coatings in containment subject to direct jet impingement of DBA spray and transport in recirculation.

In addition, the following coatings systems have been used for concrete and steel maintenance coating work: Carboline 801 and Carboline/Carboguard 890. Some applications on concrete were primed with Starglaze 2011S.

A corporate specification, which invokes ANSI 101.2 and 101.4 requirements for DBA-qualified coatings, was made effective for HBRSEP, Unit No. 2, in November of 1992. A corporate procedure was made effective in June 2004 to replace the site procedure for controlling application of maintenance coating in accordance with the ANSI standards invoked by the specification. Non-qualified coatings are evaluated as an acceptable coating, or are evaluated and tracked as an unqualified coating in accordance with HBRSEP, Unit No. 2, procedures.

Post-LOCA Paint Debris Generation and Transport Analysis Bases

The post-DBA debris evaluations of coatings subject to DBA-jet impingent and transportation were based on NEI 04-07 or testing, as discussed below.

The debris generation assumption for "DBA-qualified" and "Acceptable" coatings in the zone of influence of the LOCA is based on testing performed on representative coating systems.

In the analysis 5D and 10D ZOI for containment coatings were used. For debris generation and transport analysis, 10 micron particles were assumed for "DBA qualified" and "Acceptable" coatings within the ZOI. In addition, 100% of the DBA-unqualified and degraded coatings were assumed to fail as 10 micron particles.

For original equipment manufacturer (OEM) coatings that are not "DBA-qualified" or "Acceptable," 10 microns was assumed for particle sizes. EPRI 1011753, "Design Basis Accident Testing of Pressurized Water Reactor Unqualified Original Equipment Manufacturer Coatings," dated September 2005, shows that, on average, much less than half of OEM coatings detached and failed during testing. Based on the EPRI test results, 100% failure of OEM coatings is conservative.

No debris was included in transport and head loss analysis for unqualified coatings outside the ZOI that are covered by intact insulation or otherwise isolated from spray and transported to the sump.

For the postulated break, a ZOI sphere was placed in the model centered at the break location. The painted surface area within the sphere was then determined using various features of AUTOCAD. Credit was taken in a conservative manner for some areas shielded by robust barriers. The CAD model includes walls, floors, major equipment, and structural supports. Coated items not included in the CAD model (e.g., grating, minor equipment, valves, etc.) were accounted for by incorporating a safety factor into the overall coated steel surface area.

Head Loss Testing

For head loss testing, representative surrogates with similar density, size, and shape to the debris generation characteristics were selected.

Ongoing Containment Coating Condition Assessment Program

Monitoring of containment coatings is conducted, at a minimum, once each fuel cycle in accordance with procedures and preventative maintenance (PM) requirements. Monitoring involves conducting a general visual examination of assessable coated surfaces within the containment, followed by additional nondestructive and destructive examinations of degraded coating areas as directed by the plant Coatings Program Manager. Examinations of degraded coating areas are conducted by qualified personnel. Detailed instructions on conducting coating examinations, including deficiency reporting criteria and documentation requirements, are delineated in procedures.

Unqualified Coatings

Zone	Surface Area (ft^2)	Volume (ft^3)	Mass (lbs)
Primary (inside primary shield wall)	109.7	0.09	8.8
Secondary (between primary and secondary shield wall)	360.1	0.37	36.3
Outside (outside secondary shield wall)	3179.3	2.46	241.1
Containment Total	3649.1	2.92	286.2

Debris Characteristics

Debris Material	Macroscopic Density (lbs/ft^3)	Microscopic Density (lbs/ft^3)	Characteristic Size (μm)
Inorganic Zinc (within ZOI)	N/A	457	10**
Topcoats (within ZOI)	N/A	94	10**
Unqualified Paint (Alkyds)	N/A	98	10**

**spherical particle diameter

Coating Characteristics

Coating Type	Liquid Density (lb/gal)	Percent Solids by Weight (%)	Spread Rate (ft^2/gal/mil)	Dry Film Density (lb/ft^3)
Carboline 195 Surfacer	Not Available	Not Available	Not Available	94
Carboline 890	14.5	77	1,203	112
Carboline 801	Not Available	Not Available	Not Available	94
Carbozinc-11 Primer	23	81	1,000	223.6
Phenoline 305 Finisher	11.68	66	1,040	103.8
Starglaze 2011S	Not Available	Not Available	Not Available	94

The following table provides a summary of the quantity of coating debris generated:

Failed Coating Debris Source Term

Coating Description	Failed Surface Area (ft^2)	Applied Thickness (mils)	Volume (ft^3)	Density (lb/ft^3)	Weight (lbs)
10D ZOI Qualified Coatings	16,974	6 to 35	8.8	94 to 223.6	1040.2
5D ZOI Qualified Coatings	4,250	6	2.12	94 to 223.6	293.9
Unqualified Coatings (Alkyd)	n/a	n/a	6	98	588.0

3i. Debris Source Term

Requested information:

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.

- 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, "A 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.

In responding to GL 2004-02 Requested Information Item 2(f), provide the following:

- 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.

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

- 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.

- 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 NRC SER (Section 5.1) were used, summarize the application of the refinements.

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

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

- Modifications to equipment or systems conducted to reduce the debris burden at the sump strainers.

- Actions taken to modify or improve the containment coatings program.

<u>HBRSEP, Unit No. 2, response:</u>

Procedure PLP-006, "Containment Vessel Inspection/Closeout," provides the housekeeping programmatic requirements that control the latent debris burden. PLP-006 includes a definition of latent debris, which states, "Latent debris is defined as unintended dirt, dust, (including miscellaneous particles), paint chips, fibers, pieces of paper (shredded or intact), plastic, tape, adhesive labels, fines or shards of thermal insulation, fireproof barrier, or other materials that are already present in the containment prior to a postulated break in a high-energy line inside containment. Potential origins for this material include activities performed during outages and foreign particulates brought into containment during outages." This procedure also includes the latent debris acceptance criteria, which is invoked in the steps pertaining to the pre-job briefing and physical inspection of the containment prior to entering Mode 4. Accumulation of debris during operation in Modes 1 through 4 is prevented by control of containment access and inspection requirements for each containment entry in accordance with PLP-006.

There is substantial margin in the analysis of latent debris and the programmatic controls in PLP-006 are utilized to prevent a substantial increase in the latent debris in containment. Therefore, an on-going latent debris sampling program has not been established for the containment.

As described in Section 2 of this response, procedure EGR-NGGC-0005, "Engineering Change," the procedure used for the development of plant modifications, was revised to add screening questions regarding coatings, insulation, aluminum-containing material in containment, and flow paths during the recirculation phase of an accident. These changes were intended to ensure that permanent plant changes inside containment are programmatically controlled to not change the analytical assumptions and numerical inputs of the analyses supporting the conclusion that compliance is maintained with 10 CFR 50.46 and related regulatory requirements.

As defined in procedure ADM-NGGC-0101, "Maintenance Rule," 10 CFR 50.65(a)(4) requires that an ongoing assessment of total plant equipment that is out-of-service for maintenance is performed to determine the overall effect on performance of needed safety functions, during on-line and shutdown conditions, and that actions under 10 CFR 50.65(a)(4) assess and manage the risk of activities, including but not limited to surveillance, testing and corrective and preventative maintenance, which may need consideration during risk assessment. Procedure OMM-048, "Work Coordination and Risk Assessment," provides guidance for managing the risk of maintenance.

No specific insulation change-out was performed, although as stated in Section 2 of this response, Specification L2-M-039, "Piping and Equipment Thermal Insulation," was revised to provide guidance for the control of insulation materials used in containment in order to maintain the debris source term in accordance with the analysis. Procedure MMM-003, "Maintenance Planning," was revised to include guidance for maintenance planners to use the new specification for activities inside containment involving insulation.

A recent improvement to the coatings program included the development of procedure EGR-NGGC-0023, "Primary Containment Coatings Condition Assessment," which replaced a site procedure previously utilized to conduct assessments. The purpose of this procedure is to perform a condition assessment of protective coatings inside the containment during each refueling outage, and that primary coatings inside containment are assessed to identify and quantify coatings degradation and unqualified coatings. The purpose of EGR-NGGC-0023 further states that the condition assessment is consistent with ASTM D5163, NUREG-1801 XI.S8, and the applicable specification for protective coatings (CPL-XXXX-W-005).

Additional improvements were made to the containment coatings exempt log, as documented in Calculation RNP-C/CONT-1003, and site procedure MMM-039, "Containment Building Coatings Exemption Requests." These improvements included incorporation of GSI-191 bases and requirements for evaluating and tracking unqualified coatings in the containment.

3j. Screen Modification Package

Requested information:

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

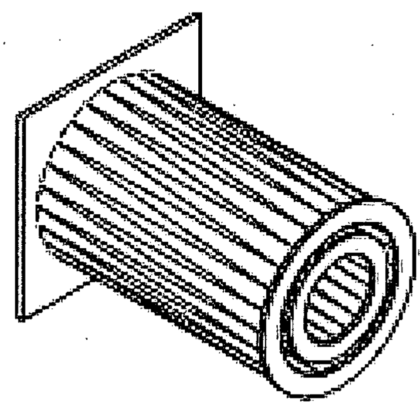
- Provide a description of the major features of the sump screen design modification.

- 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.

HBRSEP, Unit No. 2, response:

The design and installation of the HBRSEP, Unit No. 2, ECCS sump strainer was conducted under Engineering Change (EC) 63481. In the following description of the modification package, the term "strainer" refers to the top hat strainer assemblies, plenum boxes, and vortex suppressors, unless specified otherwise.

The replacement strainer assembly consists of 128 high-performance top-hat-style assemblies, which provide a net effective surface area of approximately 4,200 ft^2 (see drawing below for a depiction of a top hat). The strainer section that is located outside of the crane wall consists of 88 top hat assemblies and the strainer section inside the crane wall consists of 40 top hat assemblies. The majority of the strainer assembly inside the crane wall is physically located under the refueling canal.



Top Hat Sketch

The strainer design incorporates two top hat lengths depending upon the available space. Each top hat is either 48 inches long or 54 inches long with a square flange on one end. The high-performance top hat assemblies consist of four tubes (12-inch, 10-inch, 7-inch, and 5-inch diameter) fabricated from perforated plate. The annular areas where water flows horizontally through the top hats (after passing through the perforated plate) contains a bypass eliminator material consisting of knitted wire mesh. The top hats with the "debris bypass eliminator" design have been shown through testing to minimize the total fibrous debris bypass quantity, which is material that due to its size or shape passes through the strainer perforated plate. The top hat modules are bolted horizontally to the vertical sides of 15-inch square plenum boxes. In this design, water enters through the perforated plate surfaces of the strainers and travels through the two annuli created between the two outer cylinders and the two inner cylinders. The flow then travels through the plenum to a sump box covering the two existing ECCS suction inlet pipes.

The sump box, which is essentially an extension of the plenum, was installed over the two existing ECCS suction inlet pipes in the floor depression of the ECCS containment sump.

The strainer that is outside the crane wall is physically located from the northern side of the equipment hatch in a clockwise direction in an approximately 45° arc around the containment. The design includes a personnel walkway constructed of floor grating installed above the strainer plenum and top hats, to allow personnel access. The personnel walkway floor grating is expected to not be submerged at the initiation of containment recirculation. Suspended from the personnel walkway floor grating support structure will be additional grating that is expected to be submerged at the initiation of containment recirculation and acts as a vortex suppressor. The personnel walkway and vortex suppressor are safety-related and Seismic Class I design.

For the strainer assembly that is inside the crane wall, grating will be installed over the top hat assemblies to act as a vortex suppressor. The vortex suppressor is safety-related and Seismic I design.

Trash racks were determined to be not required for the new HBRSEP, Unit No. 2, sump design.

Interferences were modified, as required, to ensure that the replacement strainer could be installed and maintained.

The Chemical and Volume Control System (CVCS) excess letdown line that was routed through the existing ECCS sump and across the containment annulus between the crane wall and the containment wall on the east side of the refueling cavity was re-routed due to the piping and its supports interfering with the layout of the strainer. The interfering portion of the excess letdown line was moved higher up the crane wall so that the pipe and associated supports no longer interfere with the strainer.

Three letdown line supports interfered with the layout of the strainer assembly: CH-7-44, CH-7-147, and CH-7-167. Support CH-7-44 was redesigned in order to allow passage of the plenum box. Support CH-7-167 was redesigned in order to avoid interfering with the structural frame for the personnel walkway and vortex suppressor. Support CH-7-147 was redesigned under Engineering Change (EC) 61244.

During installation of the jet impingement shield structure (EC 61244) at the letdown isolation valves LCV-460A and B, it was found that the location of CH-7-167 needed to shift south from its original installation.

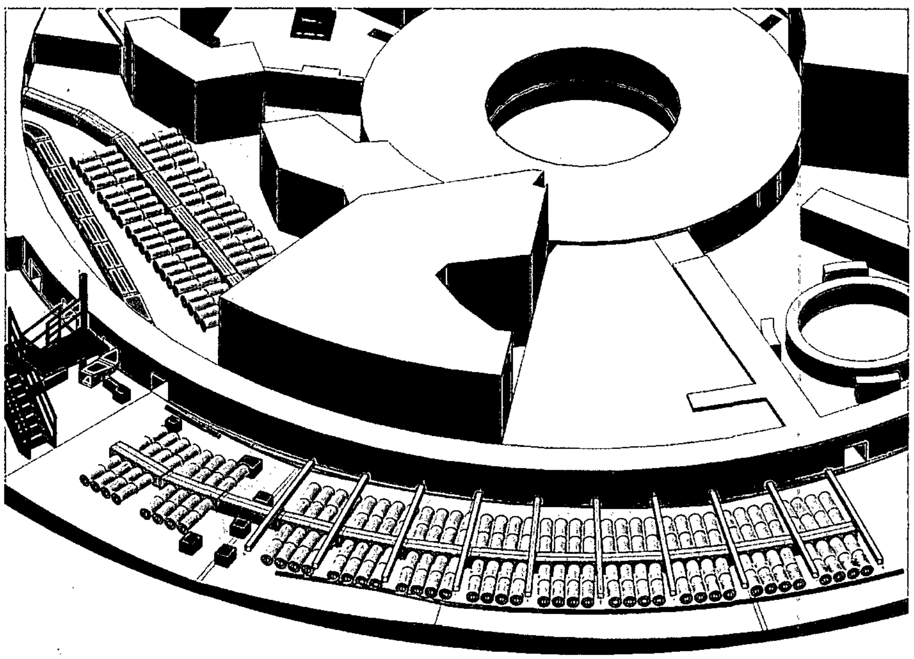
The 2-CH-17 letdown line was temporarily removed to save radiation dose during strainer/plenum installation and replaced with new pipe in the same location. Letdown line support CH-7-N2 (1027) was temporarily removed to facilitate weldout of piping joints, and the upper anchor bolt would not torque up when reinstalled. Due to extensive rebar interferences in the crane wall, the support was redesigned as a floor-mounted support.

The coarse filtration screens located inside the crane wall covering the square openings (approximately 2 ft across) were removed and replaced with a new structure constructed of stainless steel bars that will allow water to freely pass through the crane wall without becoming clogged with debris. The new structure is also sized to prevent personnel from entering the High Radiation Areas inside the crane wall at Elevation 228 ft.

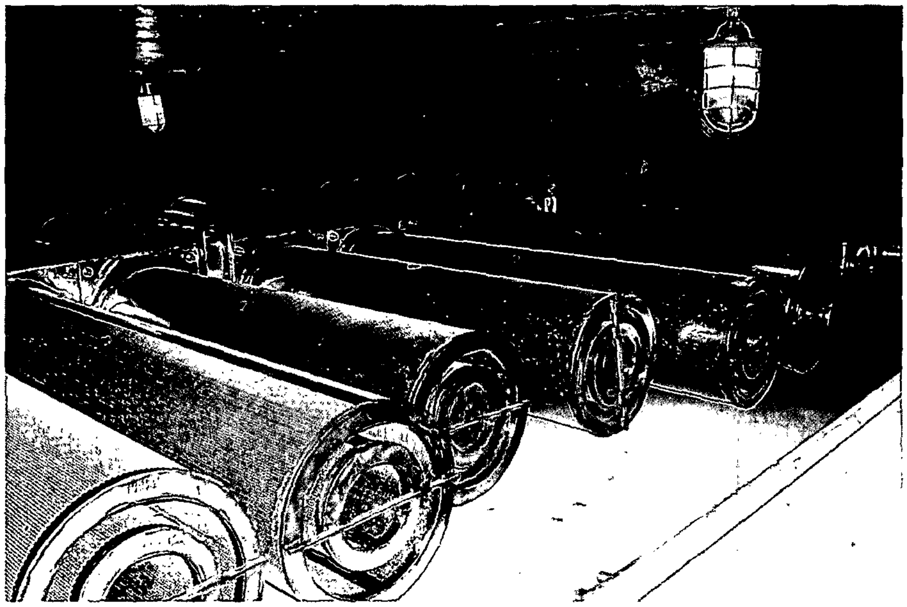
The layout of the strainer assembly (including personnel walkway and vortex suppressor) outside the crane wall was designed so that it does not interfere with the following structures and their supports: Conduit that runs along both the outer containment wall and the crane wall, accumulator supports, a fire hose station located underneath the accumulator, the stairway at the 330° azimuth, and a 6.5-inch diameter (including insulation) vertical pipe located in the annulus just outside the east-side edge of the crane wall penetration that the plenum travels through.

The 4 ft 6 inch baffle wall surrounding the ECCS containment sump and the 9-inch curb surrounding the ECCS sump were modified for installation of the flow plenum.

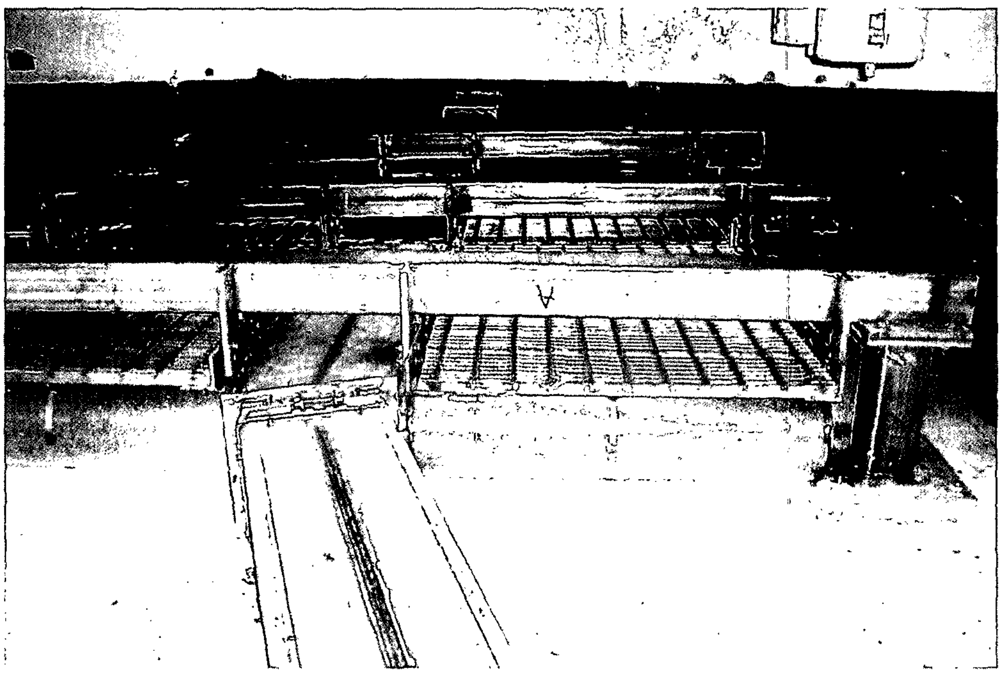
The following diagrams and pictures are provided to show aspects of the new sump strainer design.



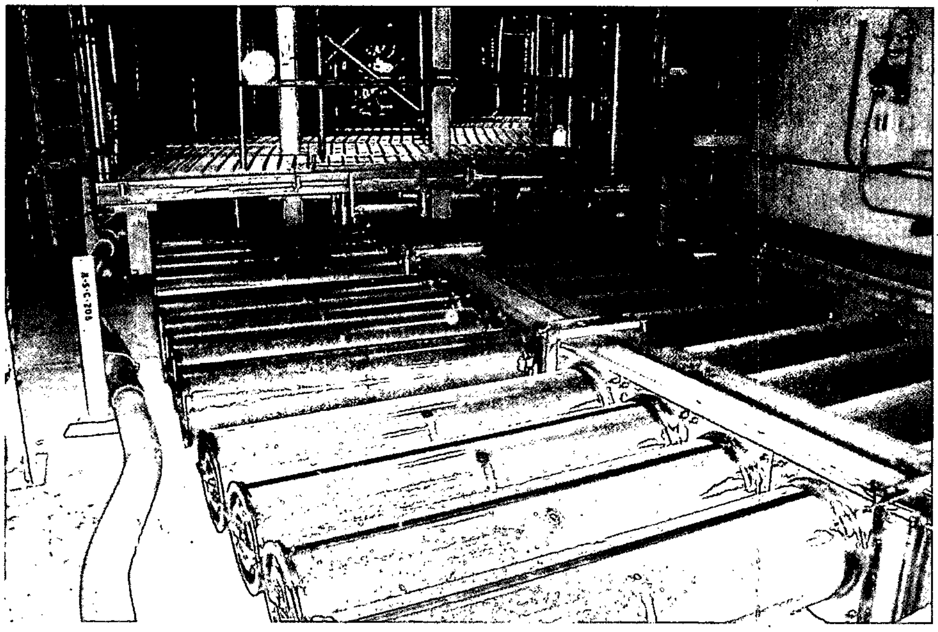
Locations of New Strainers



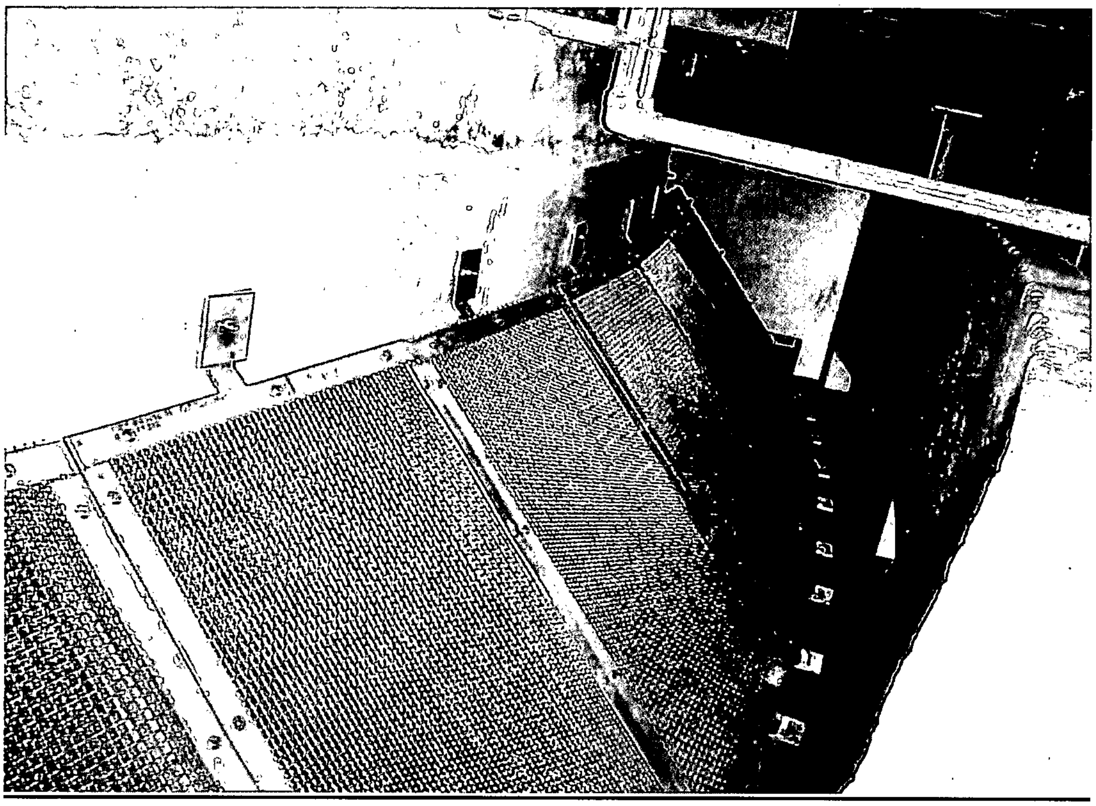
Straineris Inside the Crane Wall (No Vortex Suppressors)



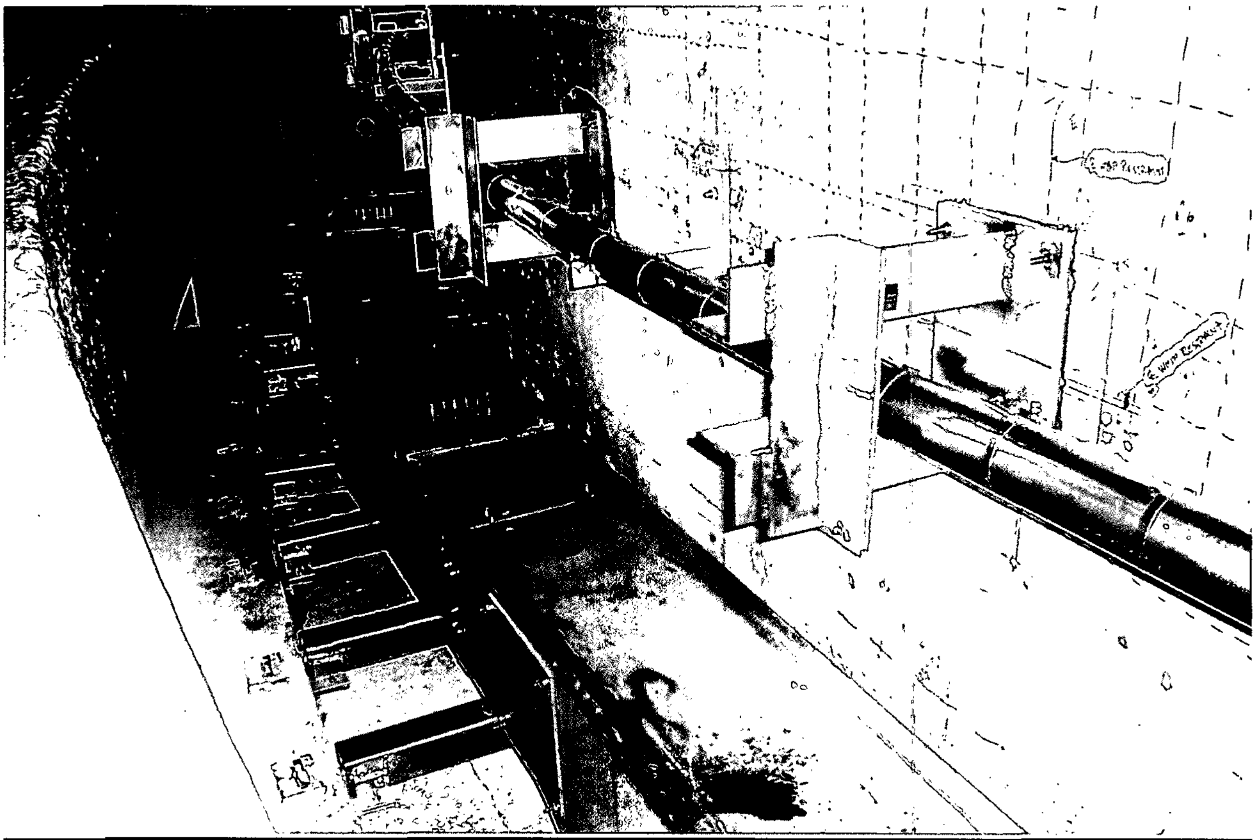
Strainer Assemblies with Plenum Inside the Crane Wall (With Vortex Suppressors)



Strainer Assembly with Plenums Outside Crane Wall (View is North from the Equipment Hatch Area)



Previously Existing Sump Screen (Removed)



Sump Plenum and Sump Box Area (Location of Previously Existing Sump Screens)

<u>3k. Sump Structural Analysis</u>

<u>Requested information:</u>

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. Provide the information requested in GL 2004-02, "Requested Information," Item 2(d)(vii), that is, provide 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.

- Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.
- Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.

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

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

<u>HBRSEP, Unit No. 2, response:</u>

The strainer structural analyses included the maximum design temperature and pressure for the containment. In addition, the strainer design (including personnel walkway and vortex suppressor) is stainless steel to minimize corrosion in the harsh post-accident environment. The stainless steel components and structures were constructed utilizing NRC-approved techniques (i.e., Regulatory Guides 1.31 and 1.44) and good construction practices to minimize the risk for stress corrosion cracking.

The new ECCS containment sump strainer and structures associated with the strainer assembly are designed in accordance with the American Institute of Steel Constructions (AISC) Specification for Design, Fabrication, and Erection of Structural Steel for Buildings, contained in the AISC Manual of Steel Construction, Eighth and Ninth Editions.

The top hat assemblies of the ECCS containment sump strainer are constructed of perforated steel and are qualified by calculations using conventional engineering approaches. Combinations of dead weight, seismic (including hydrodynamic loads), and differential pressure loads are considered. The perforated cylinders are considered as solid cylinders and the physical properties are adjusted to account for the effects of the perforations. This is accomplished by applying reduction factors for allowable stresses and modulus of elasticity.

The ECCS containment sump strainer plenum and sump box were analyzed utilizing the GTSTRUDL computer program. Combinations of dead weight, seismic (including hydrodynamic loads), and differential pressure loads are considered. The sump strainer plenum and sump box are conservatively analyzed for faulted loads using the lower normal allowables. Conservative damping factors are used. The structural design is based on the following seismic combination methods:

- Modal responses: The strainer structure is evaluated using dynamic modal analysis. Modal responses are combined using the square root of the sum of the squares method.

- Directional responses: The envelope of the results from one horizontal combined absolutely with vertical loading (conservative approach).

The ECCS containment sump strainer assembly is subjected to various temperatures during normal operating and accident conditions. In order to accommodate the thermal expansion of the structure, bolted connections with slotted holes are designed for the plenum boxes. This allows thermal growth of each plenum box without imposing significant additional stresses in the structure. In order to reduce the conservatism in GTSTRUDL analysis, dynamic analysis of the sump strainer plenum and sump boxes is performed.

A backflushing strategy is not utilized.

Missile Protection

The strainer sections outside the crane wall are protected from missiles by the crane wall and outer containment wall. The majority of the strainer sections located inside the crane wall are located under the refueling canal. The remaining strainer sections located inside the crane wall are not in the direct line of sight of potential missile hazards inside the surrounding RCP bays. The personnel walkway (outside the crane wall only) and vortex suppressor provide additional protection to the strainer sections. Therefore, the strainer assembly is adequately protected from the hazardous effects of missiles.

HELB Requirements in the Vicinity of the New Strainer Hardware

The new strainer components were installed in the vicinity of the 2-inch normal letdown line, a 3-inch charging line, accumulators lines, and SI lines. These lines are connected to the RCS such that their rupture would result in a LOCA.

The 3-inch charging line branches off to three separate lines that connect to the RCS, and incorporates check valves (CVC-312A, CV-312B, CVC-313) at the connection to the RCS loop to prevent loss of reactor coolant in the event of an upstream charging line rupture, which precludes the need for containment recirculation. A charging line rupture downstream of these check valves would result in uncontrolled loss of reactor coolant that would require containment recirculation through the strainer, but the break locations (at the nozzle connection to the RCS loop) are remote from the strainer hardware and do not have the potential to result in pipe whip or jet impingement on strainer components.

A break in the 2-inch normal letdown line would be isolable by letdown isolation valves LCV-460A and B that automatically close on a pressurizer low level alarm. If these air-operated valves lose instrument air, they are designed to fail in the closed position. Should a break occur in the CVCS at any point beyond the first check valve or remotely operated isolation valve (i.e., valves LCV-460A and B), actuation of the valve(s) would limit the release of coolant and assure continued functioning of the normal means of heat dissipation from the core. Therefore, a break in the normal letdown line downstream of isolation valves LCV-460A and B would not lead to ECCS recirculation. Thus, it is necessary to protect the strainer only from damage that could occur due to a high energy line break in the normal letdown line upstream of valves LCV-460A and B.

The majority of the normal letdown line running along the crane wall is located 6 inches from the wall. The end of the top hats are approximately 42 inches from the crane wall. A circumferential break in the normal letdown line was calculated to impact the top hats at approximately 1.58 psi due to the layout of the letdown line along the crane wall. This pressure is well within the 6.5 psi design criteria for the top hats. Therefore, the only area of concern is where the normal letdown line is routed an additional 20 inches from the crane wall to where the

LCV-460A and B isolation valves are located. A break at the elbows in this portion of the normal letdown line would result in a 6443 lb_f (lbs force) jet pointed directly at the top hats. Therefore, a jet impingement shield was built to protect the strainer from a high energy jet emanating from a break at this location. The jet shield is designed to encompass jets from the downstream elbow as well as the upstream elbow (in relation to the LCV-460A and B valves), because there is concern that a break in the downstream elbow could result in a combination of limited pipe whip and jet force that could incapacitate the LCV-460B valve, resulting in only the LCV-460A valve being available to isolate the break. Considering single failure criteria, if valve LCV-460A was to fail, then a break in the elbow downstream of the isolation valves could result in a LOCA requiring ECCS recirculation through the sump.

The lines from Accumulators "A" and "C" are located near the strainer that has been installed inside and outside of the crane wall. Check valves SI-875A and SI-875C in these lines are located very close to the RCS Loop 1 and 3 cold legs, and would prevent the discharge of RCS inventory for breaks upstream. These check valves are normally closed and are periodically leak tested. In addition, during plant heatup these valves are verified closed prior to opening the accumulator discharge valves. Breaks upstream of these valves will not result in depressurization of the RCS that require ECCS operation, because these valves are verified closed during normal plant operation. A rupture downstream of these check valves would result in uncontrolled loss of reactor coolant that would require containment recirculation through the strainer, but the break locations (at the nozzle connection to the RCS loop) are remote from the strainer hardware and do not have the potential to result in pipe whip or jet impingement on strainer components.

The SI lines connected to the hot leg for RCS Loops 2 and 3 were evaluated. Check valves SI-874A and SI-874B in these lines are located very close to RCS Loop 2 and 3 and would prevent the discharge of RCS inventory for breaks upstream of these check valves. These check valves are normally closed and are periodically leak tested. Breaks upstream of these valves will not result in depressurization of the RCS that require ECCS operation, because these valves are verified to be closed during normal plant operation. A rupture downstream of these check valves would result in uncontrolled loss of reactor coolant that would require containment recirculation through the strainer, but the break locations (at the nozzle connection to the RCS loop) are remote from the strainer hardware and do not have the potential to result in pipe whip or jet impingement on strainer components.

ECCS Containment Sump Strainer Personnel Walkway and Vortex Suppressor Structural Design

The ECCS containment sump strainer personnel walkway and vortex suppressor is a space frame that is qualified utilizing the GTSTRUDL computer program. The personnel walkway is designed for a live load of 100 pounds per square foot (psf). The combinations of dead weight, seismic (including hydrodynamic loads), and live loads are considered. The structure is conservatively qualified for faulted loads using the lower normal allowables. Conservative damping factors are used. The structural design is based on the following seismic combination methods:

- Modal responses: The personnel walkway and vortex suppressor structure is evaluated using dynamic modal analysis. Modal responses are combined using the square root of the sum of the squares method.

- Directional responses: The envelope of the results from one horizontal combined absolutely with vertical loading (conservative approach).

The ECCS containment sump strainer personnel walkway is designed for a live loading of 100 psf. This is satisfactory for nominal personnel and equipment movement. The vortex suppressor grating was not designed to be used as a platform for personnel. However, it is reasonable to assume that personnel will choose to utilize the vortex suppressor grating as a platform on occasion. Therefore, the vortex suppressor grating has been qualified for a live load of 100 psf to ensure that mistaken use of the vortex suppressor grating as a temporary platform will not result in failure of the grating or possible personnel injury.

The personnel walkway and vortex suppressor is subjected to various temperatures during normal and accident operating conditions. In order to accommodate the thermal expansion of the personnel walkway and vortex suppressor structure (North-South direction), support guides are provided, which allow unrestrained thermal growth. Also, bolted connections with slotted holes are designed for the long tube steel members (East-West direction). This allows thermal growth of the supporting structure without imposing any additional loads or stresses in the structural members. To reduce the conservatism in the GTSTRUDL analysis, the dynamic analysis of the personnel walkway and vortex suppressor structure was performed.

Strainer Differential Pressure

The clean strainer head loss is 1.56 ft of water (not including head loss attributed to the top hat) at a sump temperature of 60°F and the maximum sump flow of 3,820 gpm. Based on the head loss analysis, a strainer with an active surface area of 4,000 ft^2 will exhibit a debris head loss across the sump screen of 3.5 ft of water at a sump temperature of 212°F. A parametric evaluation shows that when the long-term temperature of the sump pool decreases to 60°F, the debris-bed head loss increases to 13.9 ft of water. The assumption of a 4,000 ft^2 strainer is conservative, because the sump strainer has a total active surface area of approximately 4,178 ft^2. Increasing the total strainer surface area reduces the average approach velocity of water entering the top hat screen modules, thus decreasing head loss.

As temperature decreases, viscosity increases, which results in higher head loss. The sump temperature decreases slightly from 175°F at one day post-accident to 168°F approximately 11.5 days post-accident. Therefore, the 60°F is conservatively low as compared to the actual sump temperature 30 days post-accident.

When determining the maximum differential pressure for which the strainer is designed, it is conservative to use the debris-bed head loss values predicted to occur at the lowest reasonable sump temperature. Adding the debris head loss of 13.9 ft of water to the clean strainer head loss of 1.56 ft of water (clean strainer head loss value, not including head loss attributed to the top hat) and converting to pressure drop (assuming water density of 62.31 lbm/ft^3), the total pressure drop across the strainer is 6.7 psi. The strainer was designed to withstand a maximum differential pressure of 7 psi.

3l. Upstream Effects

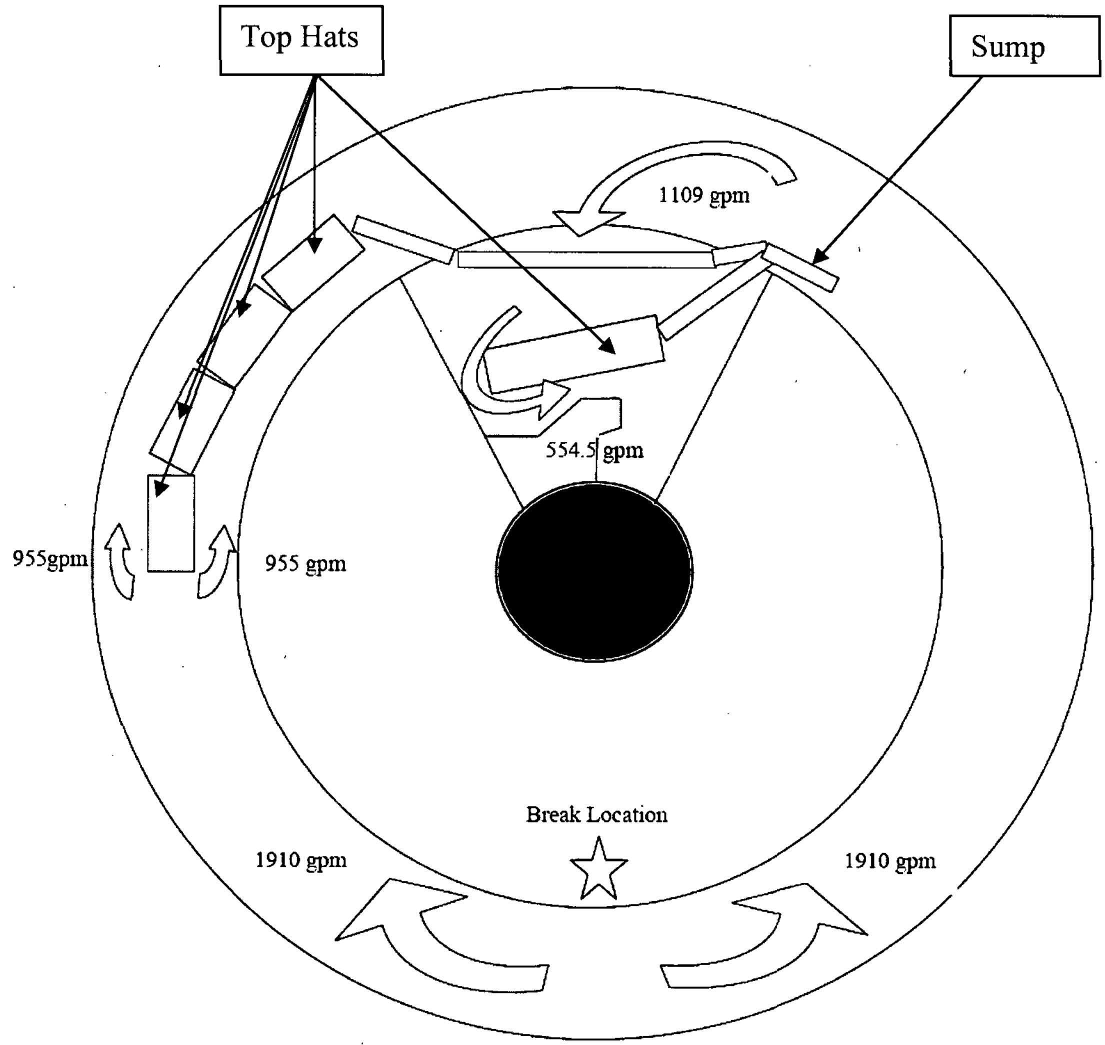
Requested information:

The objective of the upstream effects assessment is to evaluate the flow paths upstream of the containment sump for holdup of inventory which could reduce flow to and possibly starve the sump. Provide a summary of the upstream effects evaluation including the information requested in GL 2004-02, "Requested Information," Item 2(d)(iv), including 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.

- 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.
- Summarize measures taken to mitigate potential choke points.
- Summarize the evaluation of water holdup at installed curbs and/or debris interceptors.
- Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.

HBRSEP, Unit No. 2, response:

The NRC SER, Section 7.2, addresses upstream effects and requires that licensees estimate the potential for water inventory holdup. The post-LOCA containment water level calculation has been prepared to address inactive pools and the minimum containment flooding levels during small break and large break LOCAs. In addition, the containment water level calculation includes an evaluation showing that clogging of the 3 inch drain line at the north end of the refueling canal does not adversely impact the ability to go into containment recirculation mode. The containment was evaluated for areas where there is draw-down of the containment water surface due to flow restrictions, velocity increases, or frictional head loss as water travels to the sump strainer. It was confirmed there will be no hydraulic back flow (i.e., there are no choke points where the flow of water to the strainer cannot keep up with the suction demands of the sump). Refer to the sketch below which shows the general flow path of the water as it travels from the break location to the new strainer.



Refer to preceding Section 3e for further details regarding the debris transport analysis. Note that debris interceptors and trash racks were not included or required for the HBRSEP, Unit No. 2, ECCS sump strainer design.

It was determined that trash racks did not need to be installed around the floor drain near the excess letdown heat exchanger and the floor drain near the existing ECCS sump screen. These floor drains are credited for positive flow (i.e., flow coming out of the drains as opposed to flowing into the drains) in the containment water level calculation. Also, drains must be verified clear of obstructions prior to containment closeout. Therefore, it is highly unlikely these drains will become clogged with debris. Should the drains become clogged, they are part of a system of floor drains that will enable water to be diverted from these drain openings to other drain openings on the containment floor during containment flooding.

Trash racks did not need to be installed around the floor drains at the bottom of the Elevation 229.2 ft depressions below the steam generator platforms. Due to the close proximity of these drains to the RCS loop piping (site of the postulated large break LOCA), it is judged that even if these drains were not to become clogged, the 3 inch drain could not keep up with the flow emitting from the RCS break. Therefore, the containment water level calculation assumes one floor drain cavity below the steam generator platform as a water holdup volume. The other two floor drains are expected to allow flow to the containment sump.

A trash rack will not need to be installed around the 3 inch refueling canal drain. As described in the water level calculation, the water level on the containment floor will have reached Elevation 229.5 ft following a large break LOCA as the RWST drains to the 27% level. This will allow the operators to switch to containment recirculation mode. The water level calculation does not credit drainage through the 3 inch refueling canal drain following a large break LOCA. Therefore, even in the unlikely situation that a large break LOCA would generate debris causing the 3 inch refueling canal drain to be blocked, sufficient water will still be available to the containment floor when the RWST reaches the 27% level switchover point. A small break LOCA is not expected to block the 3 inch refueling canal drain. A small break LOCA would result in limited debris generation and would not produce the forces necessary to transport debris to the refueling canal.

Note there is no potential for adverse effects of smaller debris downstream of the 3 inch refueling canal drain. This drain is not hard-piped into other drains at Elevation 228 ft. Instead, the pipe drains into a funnel that can overflow if the floor drains are clogged. Therefore, even if the drains on Elevation 228 ft were to clog with debris, the water would spill onto Elevation 228 ft where it would be available for containment recirculation.

The expanded mesh screen (used as a personnel barrier) at the west side of the sump trench (outside the crane wall) was modified for passage of the plenum while continuing to prevent unauthorized access to high radiation areas beneath the refueling canal outside the crane wall.

The coarse filtration screens located inside the crane wall covering the square openings were removed and replaced with a new structure constructed of stainless steel bars that allows water to freely pass through the crane wall without becoming clogged with debris. The new structure is also sized to provide a personnel barrier to the high radiation areas inside the crane wall at Elevation 228 ft.

The personnel barrier fences that prevent unauthorized access to the high radiation areas underneath the refueling canal, inside the crane wall (Elevation 228 ft), were modified. The barriers were modified in accordance with the following requirements:

- Provide openings to allow the strainer assembly to penetrate the barriers as required by its designed layout.

- Continue to prevent unauthorized access to high radiation areas.

- Provide a means for water to flow through the barrier without potentially clogging with debris.

3m. Downstream Effects – Components and Systems

Requested information:

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. 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.

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

Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptable to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

- If approved methods were used (e.g., WCAP-16406- P with accompanying NRC SER), 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.
- Provide a summary and conclusions of downstream evaluations.
- Provide a summary of design or operational changes made as a result of downstream evaluations.

HBRSEP, Unit No. 2, response:

Evaluations of downstream effects on components and systems were developed based on guidance provided in Revision 1 of WCAP-16406-P, "Evaluation of the Downstream Sump Debris Effects in Support of GSI-191," the NRC SER for WCAP-16406-P, NEI 04-07, and the NRC SER for NEI 04-07.

The evaluations confirm that ECCS components will not be subjected to excessive wear or blockage. The applicable components, except the CS educators, were evaluated for 30 days of continuous operation. The spray eductors were evaluated for more than 24 hours. Actual spray operation is expected to be 11 hours.

One departure from the methodology of WCAP-16406-P was utilized in the evaluation of pump wear. The size distribution for depletable and non-depletable coating particulates was calculated in lieu of the size specified in WCAP-16406-P. The analysis determined the plant-specific depletable and non-depletable particle sizes based on HBRSEP, Unit No. 2, specific velocities. The average approach velocity at the screens of 0.002 ft/sec is credited for depletion of particulates at the screens. As the fluid enters the screens it will slow to an average of 0.002 ft/sec allowing some particles over time to sink at the screens.

WCAP-16406-P concludes unqualified coatings that are 100 μm to 400 μm are not considered to deplete in the core inlet plenum where velocities are on the order of 0.1 to 0.2 ft/sec, because the settling velocity of 400 μm paint chips is 0.15 ft/sec. The core inlet plenum flow velocity is 75 times the average screen approach velocity. Adjusting for the velocity difference, the evaluation found coatings greater than 50 μm would tend to settle at the screens. It is recognized that some of the particles will pass through the screens and contribute to downstream wear, but the overall concentration will deplete over time.

A depletion coefficient was selected based on the measured turbidity of the fluid downstream of the screens during prototypical head loss testing. The coefficient was conservatively determined, because it did not account for multiple manual agitations of the debris in the tank that slowed the overall depletion rate. When hot leg injection begins at approximately 11 hours after recirculation, the flowrate will reduce and the approach velocity will be much less than 0.002 ft/sec. No credit is taken for the additional settling and depletion that would coincide with the lower flow.

The evaluations confirm that there is no significant air entrainment with the ECCS that would either impact ECCS pump operation or cause air pockets in ECCS piping.

The evaluations of the downstream effects of debris ingestion on equipment, including valves, pumps, heat exchangers, orifices, spray nozzles, and instrumentation tubing, are based on the WCAP-16409-P methodology. The effect of debris ingested through the containment sump strainers during recirculation mode of the ECCS and CS systems include erosive wear, abrasion, and potential blockage of equipment and flow paths. The calculations also assess changes in system or equipment operation caused by wear, including an evaluation of degraded pump hydraulic performance due to internal wear. Based on the evaluation, excessive wear or plugging of the system valves, pipes, orifices, nozzles, or heat exchangers is not expected. Excessive pump wear from free-flowing abrasive/erosive wear or asymmetric packing is not expected. The seal on the CS pump "B" was noted to have a graphite bushing. This seal was replaced with a seal using a metallic bushing.

The evaluations conclude that the consequences of pump seal leakage into the auxiliary building are not increased by the presence of debris in the fluid.

3n. Downstream Effects – Fuel and Vessel

Requested information:

The objective of the downstream effects, fuel and vessel section, is to evaluate the effects that debris carried downstream of the containment sump screen and into the reactor vessel has on core cooling.

- 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.

HBRSEP, Unit No. 2, response:

WCAP-16406-P methodology was used for the evaluation of potential core blockage following a hot leg or a cold leg break. With the low flow velocity calculated in the reactor vessel lower plenum and sump screens, particulate debris with a density that is heavier than water will settle and not be passed into the core. Fibrous debris with a density approximately the same as water would be carried along with the recirculated sump water, but would be filtered by the sump strainers and by screens located at the inlet to the fuel bundles.

The evaluation determined the amount of particulate debris that flows into the reactor vessel with the ECCS water. The total volume of particulate and coatings debris that migrates to the vessel is calculated as approximately 187 ft^3. Only a portion of the total debris is expected to settle. The volume of the reactor vessel lower plenum below the core is larger than the calculated debris volume (approximately 232 ft^3 as compare to 187 ft^3). Therefore, particulate and coating debris does not impact flow in the lower plenum.

The evaluation shows that approximately 200 ft^3 of fibrous insulation and latent fibrous debris will be formed in containment following a large break LOCA and be transported to the screens. The strainers include a bypass-eliminator feature, which is essentially stainless steel wool inside the top hat assemblies. The bypass-eliminator traps the majority of the fibers that pass through the orifices of the strainer assemblies. The fiber that makes it downstream is primarily small particle sizes. Based on full scale testing of bypass-eliminator performance, the majority of the fibrous debris will be retained on the strainers and bypass-eliminators. It is estimated that 4.97 ft^3 could reach the core. It has been determined that only a small fraction of the 4.97 ft^3 will be more than 1000 microns in length (approximately 0.12 ft^3 of the 4.97 ft^3).

A fibrous debris bed thickness of less than 1/8 inch thick is not expected to have the structure to bridge the gaps and filter particulates based on pressure drop studies for BWR strainer blockage concerns in NUREG/CR-6224. This acceptance criterion is conservative because it is expected that low, non-uniform flow rates would likely exist at the core inlet during the post-LOCA long-term cooling period, making the formation of a uniform compact fiber bed at the core inlet unlikely.

The downstream effects evaluation determined that a 1/8 inch thick fibrous debris bed could be created by approximately 0.6 ft^3 of fibrous debris. As mentioned previously, 0.12 ft^3 of fibrous debris that could build up a debris bed is expected at the core. This has been determined to be less than the volume required to cover the bottom of the core. Therefore, a fiber bed is not expected to form at the core inlet.

Cal-Sil is a particulate insulation with fiber content, such that it can accumulate on structures without a fiber bed. Testing of the Cal-Sil that passed through the screens or bypass-eliminators shows that the fibers contained in the Cal-Sil are small and are not expected to be capable of forming a debris bed in the absence of a fiber bed.

To prevent an excessive concentration of boric acid within the core following a large cold leg break, the existing emergency operating procedures instruct operators to alternate between cold leg and hot leg injection. Procedure steps establish hot leg injection approximately 11 hours after the accident regardless of the break location.

There is the opportunity for a considerable amount of the debris to be filtered out or to settle from the water that flows to the top of the core, because hot leg injection will not begin until approximately 11 hours after the pipe break occurs. Analysis based on the methodology of WCAP-16406-P indicates that after approximately 11 hours the particulate debris concentration in the recirculating fluid will be about one half of the initial value. Fibrous debris will deplete at a faster rate because the screens are more efficient at filtering long fibers than small particles.

In addition to locations at the core inlet and exit, other possible locations for blockage within the reactor vessel internals that could affect core cooling were assessed. The smallest clearance was found to be 5/8 inches. This dimension is approximately a factor of 6.7 greater than the dimension of the strainer holes in the containment sump strainer. In addition, the bypass eliminator material inside the screens makes the effective strainer mesh size even smaller.

The potential to locally block flow at the fuel spacer grids was also considered. A one-inch solid plug around the hot spot on the peak power rod was considered. It was shown that the cladding temperature remains below 913°F, which is well below the 10 CFR 50.46 acceptance criterion of 2200°F.

An additional detailed evaluation of long-term cooling considering particulate and chemical debris in the recirculation fluid was also performed by reviewing the differences between the conditions analyzed by WCAP-16793-P, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid," Revision 0, and plant-specific design and postulated post-accident conditions. The evaluation considers the scenarios of clad temperature in a grid location, mid-span clad temperatures, the effect of time and chemistry on clad temperature with the LOCADM model, and blockage at the fuel assembly inlet.

For the clad temperature in a grid location, the evaluation determines that the WCAP-16793-P analyzed values are very similar to the HBRSEP, Unit No. 2, values. HBRSEP, Unit No. 2, has a lower heat flux than that used in the WCAP-16793-P analysis, and the plant-specific grid geometry is considered sufficiently similar to that analyzed in WCAP-16793-P. The plant-specific value of cladding thickness is slightly larger than that used in WCAP-16793-P. The cladding thickness difference is evaluated as having a very small impact on cladding temperatures. The HBRSEP, Unit No. 2, evaluation concludes that the plant-specific cladding temperature is not substantially different from the value of 474°F provided in WCAP-16793-P.

For the mid-span clad temperatures, the evaluation states that the differences between the fuel design evaluated in WCAP-16793-P and the plant-specific fuel design are not expected to alter the applicability of Table 4-4 of WCAP-16793-P. It is concluded that the estimated peak temperature for the mid-span case would result in temperatures below 800°F for HBRSEP, Unit No. 2.

A plant-specific analysis was performed using plant data for input parameters such as sump pH, spray pH, sump temperature, containment temperature, rated reactor power, pellet stack length, and fuel rod outer diameter. The analysis used the LOCADM model to predict the time-varying peak clad temperature as boiling in the reactor vessel increases the concentrations of materials in the vessel and increases the plate-out of scale from heat transfer from the clad surface. Four inputs that had a large impact on clad temperature are: Sump pH, containment temperature, and upper plenum pressure. Higher sump pH, higher containment temperature, and lower upper plenum pressure result in higher clad temperature. The inputs for HBRSEP, Unit No. 2, were biased such that these quantities were set conservatively. A LOCA deposit thermal conductivity of 0.2 W/m-K was used, which is consistent with WCAP-16793-NP. A crud thickness of 140 microns was used. No plant-specific refinements were made to the WCAP-16530-NP base model. The values of aluminum release from the WCAP-16530-NP spreadsheet were adjusted in accordance with the guidance contained in draft Westinghouse letter, "LOCADM Guidance for Modification to Aluminum Release," to account for higher aluminum corrosion rate at the beginning of the accident.

LOCADM was run with increased quantities of debris in accordance with the "bump-up factor" methodology. The results of this LOCADM run show the highest cladding temperature is approximately 400°F, which is well below the acceptance criterion of 800°F in Appendix A of WCAP-16793-P; this peak temperature occurs at the onset of recirculation. The cladding temperature decreases to approximately 175°F over 720 hours.

For blockage at the fuel assembly inlet, the plant-specific evaluation states that the power level for the condition analyzed in WCAP-16793-P is significantly higher than power level for HBRSEP, Unit No. 2. The differences in power distribution are small.

In the fuel assembly inlet blockage evaluation, two cases were considered: (1) Twenty-eight peripheral fuel assembly inlets are debris-free (82% blockage), and (2) only the inlet to one high-power assembly is debris-free (99.4% blockage). The plant-specific evaluation concludes that HBRSEP, Unit No. 2, is bounded by the results of WCAP-16793-P. No design or operational changes were identified as a result of this part of the downstream-effects evaluation.

3o. Chemical Effects

Requested information:

The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on head loss and core cooling.

- 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.

- 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. ML072600372).

    - 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, how it was determined, and any additional information that is needed to show why a more detailed chemical effects analysis is not needed.

    - Licensees should discuss why the debris from the break location selected for plant-specific head-loss 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 was based on break location 2.

    - 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.

    - Licensees should identify the vendor who performed plant-specific chemical effects testing.

    - Since the NRC staff is not currently aware 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.

    - Licensees should provide the chemical identities and amounts of predicted plant-specific precipitates.

- For licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart, 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.

- List the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.

- Licensees should clearly identify any refinements (plant-specific inputs) to the base WCAP-16530 model and justify why the plant-specific refinement is valid.

- 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.

- 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 a small amount of chemical precipitate can produce significant increases in head loss.

- Licensees should list the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.

- 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.

- 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.

- 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).

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

- Licensees should provide the one-hour or two-hour precipitate settlement values measured within 24 hours of head loss testing.

- Licensees should provide a best estimate of the amount of surrogate chemical debris that settles away from the strainer during the test.

- 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.

- 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).

- Provide the test termination criteria.

- Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.

- Licensees should explain any extrapolation methods used for data analysis.

- 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.

<u>HBRSEP, Unit No. 2, response:</u>

The tasks performed that are applicable to resolution of the chemical effects issue included prototypical hydraulic strainer array testing with plant debris including chemical effects. This testing is complete and the test results indicate that replacement strainer head loss is sufficiently low such that NPSH requirements are met at full plant debris/chemical loading.

Prototypical hydraulic strainer array testing was conducted by Alion Science and Technology in a test tank at the Alion facility in Warrenville, Illinois. This testing used tap water maintained between 80°F and 90°F. With the recirculation pump running, a plant-specific debris mixture was added to the test tank. This mixture represented insulation debris, coatings debris, and latent debris. Section 3f of this supplemental response discusses the head-loss testing in additional detail. Spargers on the recirculation pump discharge, agitators, and manual stirring were used to ensure insulation was transported to the prototype screens. Following the debris addition, chemical precipitates were added to the tank in increments.

The species and quantities of chemical precipitates were predicted using the spreadsheet developed by Westinghouse as part of WCAP-16530-NP. The version of the spreadsheet used was Version 1.1, which was transmitted to the industry in letter OG-06-378. Plant-specific inputs to the WCAP-16530-NP methodology include the following:

- Post-LOCA containment recirculation pool temperature profile from the containment analysis for the maximum-temperature case. Temperatures were increased 1°F for conservatism.

- Post-LOCA containment atmosphere temperature profile from the containment analysis for the maximum-temperature case. Temperatures were increased 1°F for conservatism.
- pH profile of the containment spray from the plant pH transient calculation. The maximum calculated pH of the spray is 12.2.
- pH profile of the sump pool from the plant pH calculation. The maximum calculated pH of the sump is 9.4.
- Submerged aluminum of 725 lb/376 ft^2 and un-submerged aluminum of 234 lb/638 ft^2.
- Debris quantities in the recirculation pool are from the debris generation calculation.
- Exposed area of concrete of 10,000 ft^2, which bounds the break ZOI area plus non-DBA qualified coatings.
- The maximum calculated recirculation pool volume is used, as it leads to the largest quantities of chemical precipitates.

Some key assumptions used during the calculation of chemical precipitates include:

- Exposed aluminum components that are not submerged are wetted by containment spray. This is a conservative assumption, as it maximizes the quantity of precipitates that are formed.
- The sump pool is assumed to be unmixed until two pool turnovers are completed.
- Once the maximum sump pool pH values are reached, it is assumed that the pH values do not decrease over time. This is conservative, as it maximizes the quantity of precipitates that are formed.
- Containment spray is assumed to run for 11 hours, after which it is secured.
- Silicate inhibition of aluminum corrosion was credited in the determination of chemical precipitate quantities as described in WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16785-NP Chemical Model," and the following:
    - o The silicon threshold value, above which silicate inhibition will occur, was conservatively assumed to be 100 ppm rather than the inhibition threshold reported in WCAP-16785-NP of 75 ppm.
    - o The aluminum release reduction factor for 50 to 75 ppm silicon was assumed to be two (2), based on aluminum release reported in WCAP-16785-NP.
    - o No inhibition was credited for un-submerged aluminum.
    - o No credit was taken for the silicon released due to fiberglass dissolution.
    - o The limiting debris quantity was determined to be approximately 40% of the design basis Cal-Sil debris load (i.e., when credit is taken for silicon inhibition, chemical precipitate load is maximized when Cal-Sil debris input is reduced to 40% of that predicted to reach the screens). It should be noted that the actual quantity of Cal-Sil debris used to develop the tested debris bed was based on 100% of the quantity predicted to reach the screens.
- The solubility of aluminum oxyhydroxide was credited in the determination of precipitate quantities as described in WCAP-16785-NP.
    - o Section 5.4.2 of WCAP-16785-NP discusses the testing of the solubility of aluminum oxyhydroxide (AlOOH) under a variety of conditions. Testing was conducted at 200°F and 140°F at a variety of aluminum concentrations. Based on these results, the solubility limit of aluminum oxyhydroxide solutions at 140°F to 200°F is 40 ppm aluminum, and at 200°F or above is 98 ppm aluminum. This

was confirmed for a pH range of 7.0 to 9.0 and for all buffering agents currently in use, as well as the alternative buffering agents identified in WCAP-16596. While the pH of interest, 9.4, falls outside of the range of the testing, it is reasonable to extrapolate this small amount when the pH range examined showed no influence on the AlOOH solubility.

- o Not crediting solubility of AlOOH would increase the debris load slightly over the tested chemical debris load (approximately 13%). Chemical debris was added in increments during the prototype testing. The AlOOH debris load would represent less than 2.5 of the test debris load increments. The head loss testing showed the head loss was relatively insensitive to changes in the chemical debris load at elevated loads. The last three chemical debris adds did not increase the overall head loss. Therefore, the overall chemical effects evaluation remains conservative.

- Alloy-specific aluminum corrosion rates (i.e., Alloy 3003, 5005, and 6061) were not credited.

HBRSEP, Unit No. 2, has some zinc-coated items in containment, including scaffolding and grating. Section 6.2.2 of WCAP-16530-NP states that zinc releases are relatively small and can be ignored in chemical effects precipitation modeling.

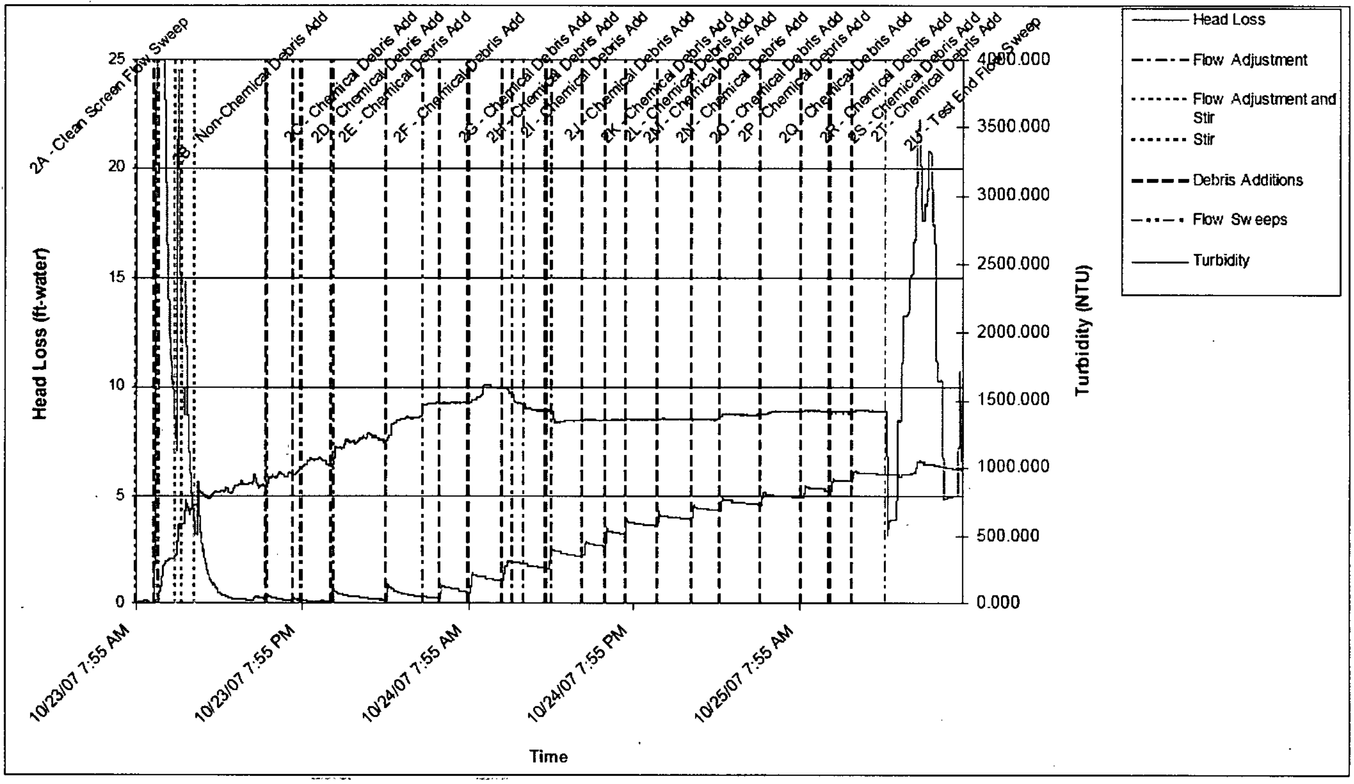
The results of the spreadsheet modeling indicate a maximum chemical debris load of 1,475 lb of sodium aluminum silicate.

The chemical precipitates used in the testing were prepared in accordance with the methodology of WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," Revision 0. The chemical model developed in WCAP-16530-NP considers only the release rates of aluminum, calcium, and silicate, and provides justification for not including zinc, ferrous materials, copper, and nickel. The quantity of zinc in containment is described in the hydrogen generation calculation and is not an input to the model. As described above, a conservative value of uncoated concrete was used as an input to the model.

The one-hour settling volume for each batch of chemical precipitates was determined at the time that the batch was produced. The sodium aluminum silicate (NAS) batches had initial one-hour settling volumes greater than or equal to 6.7 ml, which met the revised acceptance criteria. These batches were either prepared or re-tested within three weeks of being used.

Although settling volumes were not determined within 24 hours of use of the precipitates, the observations from testing performed by Pacific Gas and Electric indicates that the chemicals were acceptable.

Head loss was tested at chemical debris loads up to 1,500 lb (1,475 lb calculated design load) sodium aluminum silicate equivalent; the measured head loss was 10.1 ft of water at test conditions. When adjusted for accident conditions, this head loss is 3.51 ft of water. A plot of the test result is provided, as follows:



The termination criteria for the head loss testing were:

- At least five pool turnovers have occurred, and
- The differential pressure across the debris bed changes by less than or equal to 1% over a one-hour period.

The test tank included a sparger, mixers, and manual stirring of the tank was done during testing to preclude debris and precipitates from accumulating in low-flow areas of the tank. Based on visual observation during testing and during tank clean-out, the amount of debris and precipitates that did not transport to the screens was minimal. The screens filled the majority of the tank floor. The space between the sides of the screen and the tank wall are typical of the spacing between screen sections in the field. The sparger was approximately one top hat diameter from the front of the screens and precluded significant accumulation of debris on the tank bottom between it and the tank wall. The agitator swept the tank floor behind the screen plenum and precluded significant accumulation of debris on the tank bottom behind the screens. The testing is representative of expected transport during a LOCA.

The tank testing is a conservative representation because containment spray will be secured in accordance with plant procedures once the pressure in containment is below the reset point for containment spray. This will reduce the velocity of water in the sump pool, as well as reduce the turbulent kinetic energy in the pool resulting from the spray falling into the pool. Both of these effects will result in more settling of debris in the pool before it reaches the sumps. Scaling is discussed in Section 3f of this supplemental response.

3p. Licensing Basis

Requested information:

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. That is, provide a general description of and 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. 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.

HBRSEP, Unit No. 2, response:

The HBRSEP, Unit No. 2, UFSAR has been updated in Revision 21 to show the modified containment sump configuration. The other licensing basis changes associated with ECCS and CSS analyses are incorporated into the plant licensing basis by this letter and any correspondence associated with GL 2004-02. A license amendment to change the Technical Specifications to account for the new sump strainer design was approved by the NRC in License Amendment No. 213, dated April 4, 2007.

The docketed correspondence associated with GL 2004-02 provides and describes the new licensing basis associated with the containment sump debris issue. Additional UFSAR updating for the most recent analyses conducted for GL 2004-02 is required to be conducted in accordance with 10 CFR 50.71(e).