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June 30,2009

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

SUBJECT: Follow-up Supplemental Response to NRC Generic Letter 2004-02

Palisades Nuclear Plant
Docket 50-255
License No. DPR-20

References:

1. Entergy Nuclear Operations, Inc. letter, "Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated February 27, 2008 (ADAMS Accession No. ML080630253)
2. Entergy Nuclear Operations, Inc. letter, "Request for Extension of Completion Date for Corrective Actions Required by Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated June 17, 2008 (ML081690612)
3. NRC letter, "Palisades Nuclear Plant – Issuance of Request for Additional Information Regarding Supplemental Responses to GL 2004-02 (TAC No. MC4701)," dated December 24,2008 (ML083450689)
4. Entergy Nuclear Operations, Inc. letter, "Response to Request for Additional Information Regarding Supplemental Responses to NRC Generic Letter 2004-02 (TAC No. MC4701)," dated March 20, 2009 (ML090790844)
5. NRC letter, "Palisades Plant – Report on Results of Staff Audit of Chemical Effects Related Actions to Address Generic Letter 2004-02 (TAC No. MC4701)," dated May 13,2009 (ML091070664)

Dear Sir or Madam:

Entergy Nuclear Operations, Inc. (ENO) provided a supplemental response for Palisades Nuclear Plant (PNP) to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," in Reference 1. In Reference 2, ENO committed to submit a follow-up to the GL 2004-02 supplemental response 60-days following restart

from the 2009 refueling outage if modifications were required during the outage to resolve GSI-191 issues. This letter provides the follow-up supplemental response following modifications that were completed in the 2009 refueling outage. The refueling outage ended on May 2, 2009. This follow-up supplemental response also contains the additional responses to the NRC request for additional information items 2, 3, 9, 13, 14, 15, and 17 in Reference 3 that were committed to in Reference 4. Additionally, this letter addresses the two open items resulting from the NRC chemical effects audit discussed in Reference 5.

Enclosure 1 is in the same format as the February 2008 ENO supplemental response for PNP. The format follows both the revised NRC content guide for GL 2004-02 supplemental responses provided in a November 21, 2007, letter to the Nuclear Energy Institute, and the NRC staff review guidance dated March 2008. Enclosure 2 provides the attachment drawings that are referenced in Enclosure 1.

This letter includes a new commitment, repeats a previous commitment, and closes two commitments, as described in Enclosure 3.

By a separate letter on this date ENO is providing vendor proprietary information related to Reference 5, Section 5.4.1, item 1, on the containment sump strainer hole size.

I declare under penalty of perjury that the foregoing is true and correct. Executed on June 30,2009.

Sincerely,

cjs/jlk

Enclosure: 1. Follow-up Supplemental Response to NRC Generic Letter 2004-02
2. Attachment Drawings
3. List of Regulatory Commitments

cc: Administrator, Region III, USNRC
Project Manager, Palisades, USNRC
Resident Inspector, Palisades, USNRC

ENCLOSURE 1

FOLLOW-UP SUPPLEMENTAL RESPONSE

TO

NRC GENERIC LETTER 2004-02

"Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"

General Guidance

Nuclear Regulatory Commission (NRC) Request

The GL [Generic Letter 2004-02] *supplemental response should begin with a summary-level description of the approach chosen. This summary should identify key aspects of design modifications, process changes, and supporting analyses that the licensee believes are relevant or important to the NRC staff's verification that corrective actions to address the GL are adequate. The summary should address significant conservatisms and margins that are used to provide high confidence the issue has been addressed even with uncertainties remaining.*

In general, the follow-up supplemental responses in each area should, as appropriate:
1. state that the information previously provided continues to apply
2. supplement previous information
3. revise previous information

Entergy Nuclear Operations, Inc. (ENO) Response

This follow-up supplemental response section is new and revises previous information provided by ENO for the Palisades Nuclear Plant (PNP), in the supplemental response to Generic Letter (GL) 2004-02, on February 27, 2008 (Reference G.1).

Passive strainer assemblies have been installed that are sized for acceptable head loss based on bounding post loss-of-coolant-accident (LOCA) debris loads, which has been confirmed by PNP specific strainer testing. To reduce the amount of chemical debris that might exist in post-LOCA conditions, the containment sump buffer was changed from trisodium phosphate (TSP) to sodium tetraborate (STB). To achieve increased margin for pump net positive suction head (NPSH), the containment spray valves were modified to move to a throttled position on a recirculation actuation signal (RAS). Evaluations of upstream effects were completed and two choke points that could hold up the post-LOCA sump volume were eliminated. Evaluation of downstream components for blockage and wear has been completed. All components were determined to be acceptable for the required mission time, with the possible exception of the mechanical seals and seal cooling for the high pressure safety injection (HPSI) pumps. As the acceptability of these items for the HPSI pumps could not be confirmed at that time, ENO completed modifications to the HPSI pumps mechanical seal and seal cooling to assure acceptability for the required mission time. An evaluation of in-vessel effects has been completed and the results were determined to be acceptable. It is recognized that an NRC safety evaluation (SE) has not yet been issued on this item and ENO has a commitment (Reference G.2) to report how it has addressed the in-vessel downstream effects issue within 90 days following the issuance of the NRC SE for WCAP-16793 (Reference G.5). Section 2 provides more details on these items.

NRC letter dated December 24, 2008 (Reference G.3), provided a request for additional information (RAI) on the ENO February 27, 2008, supplemental response (Reference G.1). ENO RAI responses that were provided in a letter dated March 20, 2009 (Reference G.2), have been added to the associated section of this follow-up supplemental response, as appropriate. Additionally, responses to RAI items 2, 3, 9, 13, 14, 15, and 17 in the NRC RAI letter of December 24, 2008, are provided in the associated section of this follow-up supplemental response.

The results of an NRC chemical effects audit at PNP are documented in NRC letter dated May 13, 2009 (Reference G.4). Open Items identified are addressed in Section 3.f of this follow-up supplemental response.

Provided below are some of the conservatisms, detailed within this response, that were applied in the supporting analysis and testing for meeting GL 2004-02 for PNP.

1. Conservative zone-of-Influence (ZOI) values provided by in Nuclear Energy Institute report NEI 04-07 were used for qualified coatings, mineral wool, and jacketed calcium silicate. A large 28.6 diameters (D) ZOI was used for conservatism for the cloth covered calcium silicate.

2. The debris transport analysis conservatively assumes 100% transport of fine particulate and fiber.

3. The debris transport analysis used incipient tumbling velocities corresponding to the lowest applicable values cited in the documents referenced in NEI 04-07 Table 4-2 for each of the debris types.

4. November 2008 strainer testing used bounding debris values as inputs, including the worst case break for fiber (break S5) and the worst case break for calcium silicate (break S6). This is highest fiber and highest particulate combined.

5. The November 2008 strainer testing added chemical precipitate well beyond the design basis amount.

6. The November 2008 testing used WCAP-16530 (Reference G.7) and aluminum oxy-hydroxide (AlOOH) as the chemical surrogate. The use of AlOOH is considered conservative as a surrogate for the various aluminum precipitates that may form.

References

G.l ENO letter dated February 27, 2008, "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accident at Pressurized Water Reactors'"

G.2 ENO letter dated March 20, 2009, "Response to Request for Additional Information Regarding Supplemental Responses to NRC Generic Letter 2004-02 (TAC No. MC4701)"

G.3 NRC letter dated December 24, 2008, "Palisades Nuclear Plant – Issuance of Request for Additional Information Regarding Supplemental Responses to GL 2004-02 (TAC NO. MC4701)"

G.4 NRC letter dated May 13, 2009, "Palisades Plant – Report on Results of Staff Audit of Chemical Effects Related Actions to Address Generic Letter 2004-02 (TAC No. MC4701)"

G.5 WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculation Fluid," Revision 1, April 2009

G.6 NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, December 2004

G.7 WCAP-16530-NP, "Evaluation of Post Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," Revision 0, February 2006

1. Overall Compliance:

NRC Request

Provide information requested in GL 2004-02 <u>*Requested Information*</u> *Item 2(a) regarding compliance with regulations.*

> <u>*GL* 2004-02 *Requested Information Item 2(a)*</u>
> *Confirmation that* the [emergency core cooling system] *ECCS and* [containment spray system] 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 GL. 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 described above.*

ENO Response

This section of the follow-up supplemental response is revised from previous information provided in the PNP supplemental response dated February 27, 2008 (Reference 1.3).

By letter dated June 27, 2008 (Reference 1.1), the NRC approved a request for extension of the completion date of actions required by GL 2004-02 prior to restart from the 2009 refueling outage, for the PNP. The approved extension request actions have been completed. With the completed modifications and supporting analyses described in this follow-up supplemental response, ENO has completed all the required actions to confirm that the ECCS and CSS recirculation functions under debris loading conditions at PNP are in compliance with all applicable regulatory requirements listed in the GL.

As stated in the General Guidance Section above, an evaluation of in-vessel effects has been completed and the results were determined to be acceptable. It is recognized that an NRC SE has not yet been issued on this item and ENO has a commitment to report how it has addressed the in-vessel downstream effects issue for PNP within 90 days following the issuance of the NRC staff safety evaluation for WCAP-16793-NP (Reference 1.2). Currently, no further modifications to the plant are anticipated to address this open commitment.

PNP design basis debris values for addressing GL 2004-02 is based on using jet impingement testing as documented in WCAP-16836-P, WCAP-16710-P, and WCAP-16727-NP (References 1.4, 1.5, and 1.6). Use of specific testing instead of conservative values stated in NEI 04-07 is an allowance provided by NEI 04-07, provided appropriate justification is given. Use of these WCAPs has been evaluated as appropriate for PNP by the comparison of material tested to that installed in the plant. This is described in more detail in Section 3.b. Some generic open questions exist regarding the jet impingement WCAP testing that are being responded to by the Pressurized Water Reactor Owners Group (PWROG). ENO will follow resolution of generic questions to assure currently assumed ZOIs remain supported.

The configuration of the plant that exists for the noted compliance statement is summarized below.

ENO has installed two passive strainer assemblies on the base slab (590 foot elevation) of the containment. The passive strainer assemblies connect to the containment sump via two containment sump downcomer pipes. These two containment sump downcomer pipes provide the post-LOCA credited flow pathway from the passive strainer assemblies to the containment sump to provide a suction source of water to the ECCS and CSS pumps.

In addition to the passive strainer assemblies, debris screens are installed on the remaining open containment sump entrance pathways, which include the four remaining downcomer pipes, the seven containment floor drains, and the two containment sump vent lines. The existing reactor cavity corium plugs, located in the reactor cavity drain lines, contain pellets within the corium plug tube, tube end cap, and tube bottom cup support assembly, which form a debris interceptor similar to the debris screens. These debris screens and corium plugs are intended to intercept and segregate debris outside of the containment sump envelope to ensure that post-LOCA-generated debris does not enter the containment sump envelope, through these non-credited post-LOCA flow pathways. Attachment 2 depicts the sump strainer modification installed at PNP.

Section 2 below also provides details of some other configuration changes made to the plant as part of the GL resolution.

<u>References</u>

1.1 NRC Letter dated June 27, 2008, "Palisades Nuclear Plant - Generic Letter 2004-02 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors" Extension Request Approval (TAC No. MC4701)'"

1.2 WCAP-16793-NP, "Evaluation of Long Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Revision 1, April 2009

1.3 ENO letter dated February 27, 2008, "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accident at Pressurized Water Reactors'"

1.4 WCAP-16836-P, Revision 0, dated October 2007, "Arkansas Nuclear One - Jet Impingement Testing of Insulation Materials"

1.5 WCAP-16710-P, Revision 0, dated October 2007, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON Insulation for Wolf Creek and Callaway Nuclear Operating Plants"

1.6 WCAP-16727-NP, Revision 0, dated November 2007, "Evaluation of Jet Impingement and High Temperature Soak Test of Lead Blankets for Use Inside Containment of Westinghouse Pressurized Water Reactors"

2. General Description of and Schedule for Corrective Actions:

NRC Request

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).

> *GL 2004-02 Requested Information Item 2(b)*
> *A general description of and implementation schedule for all corrective actions, including any plant modifications, that you identified while responding to this GL. 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.*

ENO Response

This section of the follow-up supplemental response is revised from previous information provided in the PNP supplemental response of February 27, 2008 (Reference 2.6). Specifically, the status of previously uncompleted activities is updated to reflect completion.

The following corrective action activities in association with Generic Safety Issue (GSI).-191, "Assessment of Debris Accumulation on [Pressurized Water Reactor] PWR Sump Performance," resolutions have been completed:

> Containment walkdown and debris generation and transport analysis was completed. Detailed containment walkdowns to identify and quantify the types and locations of debris sources were completed during the spring 2003 refueling outage. The walkdowns were conducted in accordance with the guidance in NEI 02-01 (Reference 2.1). The walkdowns focused on obtaining information on the sources, types, and location of potential debris that could be transported to the containment sump screen following a small, medium or large break LOCA. The information gathered was necessary to proceed with the analyses described in NEI 04-07 (Reference 2.7).
>
> Walkdowns were performed to identify and quantify the types and locations of debris sources, which consisted of:

1. Gathering containment building configuration data that would be used to plan three subsequent walkdowns

2. Identifying insulation quantity

3. Identifying coatings

4. Identifying foreign material

Piping walkdowns were performed to confirm, to the extent practical, that the data obtained from controlled source documents was correct. The types and quantities of insulation installed on piping in containment had been previously determined using plant as-built drawings and specifications. The walkdowns were typically conducted on an area by area basis. Insulation on piping without associated isometric drawings (typically small bore piping) was also quantified.

Similarly, walkdowns of major pieces of insulated equipment (steam generators, reactor coolant pumps, reactor, and pressurizer) were performed to confirm information obtained using as-built drawings and specifications.

General areas of the containment, including the reactor coolant loop compartments, were surveyed to collect information regarding miscellaneous debris sources that could potentially restrict flow of water through the containment sump screens. In each area (or zone), the surveys quantified items that could potentially become debris following a LOCA, e.g., fire resistant barrier materials, tape, tags, labels, dirt, dust, lint, paper, pipe banding, tie-wraps, maintenance materials, tygon tubing, gates, and filters. Significant transport paths between cubicles were also noted during the walkdowns.

Latent debris walkdowns were completed. A "Calculation for Latent Debris (Dust & Lint) for Palisades Containment for Resolution of GSI-191," (Reference 2.2) documents the results of the Spring 2006 refueling outage containment latent debris sampling walkdown, which confirmed, based on 46 sample locations within containment, that the latent debris quantity in containment is approximately 156 pounds. Therefore, the 200 pounds of latent debris quantity assumption previously used in the debris generation and transportation calculation was conservative.

Downstream (ex-core) effects analyses have been performed on mechanical components. The downstream effects evaluation of ECCS and CSS components was performed using guidance provided to the industry by the PWROG WCAP-16406-P (earlier version of Reference

2.3) as a framework. The analysis led to the decision of the replacement of the HPSl pumps mechanical seals and cyclone separators during the 2007 refueling outage.

- Replacement of HPSI pumps mechanical seals and cyclone separators were completed during the fall 2007 refueling outage. The HPSl pumps employed a cyclone separator in the seal flush path to remove particulate debris in order to extend the life of the pump seals. The HPSl pump mechanical seal cooling cyclone separator was determined to be susceptible to fouling with the postulated fibrous material passing through the HPSl pump, potentially resulting in a loss of pump seal cooling water and premature seal failure. Also identified was the potential for fibrous debris to become lodged in the mechanical seal small linear loading springs, potentially resulting in non-uniform pressure applied to the seal faces, resulting in premature seal failure. Therefore, in order to ensure that the HPSl pumps are capable of performing their safety related design function during their required mission time of 30 days under post-LOCA conditions, the HPSl pump mechanical seal system was replaced during the fall 2007 refueling outage, with a mechanical seal system that is not susceptible to post-LOCA debris-induced failure.

- Installation of replacement containment sump passive strainer assemblies was completed during the fall 2007 refueling outage. The configuration of the PNP containment sump, required for GL 2004-02 compliance, includes replacement of the original sump flat screens with Performance Contracting Inc. (PCI) Sure-Flow 8 passive strainer module assemblies on the 590-foot elevation of containment. The passive strainers were specifically designed for PNP in order to address and resolve the GSI-191 ECCS sump blockage issue.

- Replacement of CSS valves was completed during the fall 2007 refueling outage. In order to reduce the post-LOCA hydraulic demand, and establish adequate NPSH margin when the passive strainers are aligned to the containment sump, the openlclosed style CSS containment isolation valves, air operators, solenoid valves, valve position switches and air pressure regulators were replaced. The new Control Components, Inc (CCI) DRAG ® style replacement valves, actuators and accessories are capable of being placed in the OPEN/CLOSED or a fixed THROTTLED position.

- Replacement of containment sump buffering agent was completed during the fall 2007 refueling outage. This modification addressed an NRC Information Notice 2005-26, "Results of Chemical Effects Head Loss Tests in a Simulated PWR Sump Pool Environment," concern on the potential sump screen blockage due to the formation of the calcium phosphate precipitation in the sump fluid. The sump buffering agent of

TSP was replaced with the STB. The change from TSP to STB will have beneficial results on the post-LOCA chemical precipitation and will provide relief from chemical precipitation induced head loss across the sump strainers.

- Modifications of containment base slab configuration that were completed during the 2004 refueling outage, eliminated two choke points that could hold up the post-LOCA sump volume. A door stop was installed on the access door to the clean waste receiver tank room to ensure the flow pathway to the sump strainers is clear, and a portion of the air room partition was replaced with a new blowout panel. The new blowout panel is designed to collapse when there is a differential water level of two feet or more across the panel.

- Enhancements of programmatic control of LOCA debris sources in the containment have been implemented. Design and operational measures taken to control the plant debris source term to prevent potential adverse effects on the ECCS and CSS recirculation functions have been implemented into the procedures and specifications. The significant changes are described in section 3.1 of this document.

- Combined debris and chemical head loss strainer testing was performed in May 2008. This was a large flume test prototypical to plant specific parameters. PCI was contracted to conduct the test using the facility at Alden Research Laboratory (ARL). In support of the testing, a Computational Fluid Dynamics (CFD) analysis was performed by AREVA/Alden for refining debris transport to the sump strainer. The testing performed in May 2008 was unsuccessful.

- Following the May 2008 testing, additional debris reduction measures were pursued. Refined calculations were performed (see Section 3.a for more detail) and potential modifications were evaluated including debris interceptors, more strainers, insulation replacement, and new strainers with larger holes. The approach taken was the next strainer testing effort would "test for success" meaning upfront work was done for determining associated design inputs for testing each of the various potential modifications, if necessary.

- In November 2008, strainer testing was completed by PCI at ARL using the large flume test protocol. The initial design basis test was unsuccessful using refined design inputs, and a strainer with 0.045-inch diameter holes corresponding to the then installed strainers at PNP. The design basis test pursued next was successful with the use of a strainer having a perforated plate with 0.095 inch diameter holes.

During the spring 2009 refueling outage, all containment sump passive strainer assemblies were replaced with strainers that have 0.095 inch diameter holes.

The previously noted downstream components analysis was revised to address WCAP-16406-P, Revision 1 (Reference 2.3).

The analysis of the downstream effects on the fuel per WCAP-16793-NP, Revision 0 (Reference 2.4), was completed.

The approved extension request (Reference 2.5) identified actions have been completed. As indicated in the General Guidance Section above, ENO has a commitment to report how it has addressed the in-vessel downstream effects issue within 90 days following the issuance of the NRC staff SE for WCAP-16793-NP. Currently, no further modifications to the plant are anticipated to address this open commitment. As indicated in Section 1, ENO will follow resolution of the generic jet impingement WCAP testing questions to assure currently assumed ZOIs remain supported.

References

2.1 NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments," dated April 2002

2.2 EA-MOD-2005-004-12, "Calculation for Latent Debris (Dust & Dirt) for Palisades Containment for Resolution of GSI-191," June 20, 2006, covering Sargent & Lundy Calculation 2006-06022, Revision 0, of the same name, dated May 30,2006

2.3 WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1, August 2007

2.4 WCAP-16793-NP, "Evaluation of Long Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Revision 0, May 2007

2.5 NRC Letter dated June 27, 2008, "Palisades Nuclear Plant - Generic Letter 2004-02 "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors" Extension Request Approval (TAC No. MC4701)"

2.6 ENO letter dated February 27, 2008, "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accident at Pressurized Water Reactors'"

2.7 NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, December 2004

3.a. Break Selection

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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

- *Describe and provide the basis for the break selection criteria used in the evaluation.*

ENO Response

The original PNP August 25, 2005, response to GL 2004-02 (Reference 3.a.3) used the basic approach to the break selection and debris generation that was essentially unchanged until after the May 19, 2008, testing. The break selection process is described in Section 3.3.4 of NEI 04-07 (Reference 3.a.l). All primary coolant system (PCS) piping and attached energized piping is evaluated. Feedwater and main steam piping is not considered since the recirculation flow is not required for main steam or feedwater line breaks. The decisions were based on the concept that calcium silicate (CalSil), fiber (particularly fine fiber), and chemical precipitates were the main contributors to head loss. Since the sprayed and submerged aluminum in containment were largely break independent, the aluminum chemical effect was not considered a major break choice issue. Due to the well known thin bed effect, once a significantly large fiberglass component was identified, deference was given to those breaks that produced the most CalSil debris. After the 2007 refueling outage, the sump buffer changed from TSP to STB, which eliminated calcium phosphate precipitate from consideration. The net effect was reduction in the importance of the CalSil relative to the 2005 era analysis.

After the May 19, 2008, testing, it was apparent that additional debris reduction measures were necessary. The ZOI for fiber was reduced based on engineering analysis of the PNP specific insulation material.

1. A ZOI of 7 D was established for Nukon and Transco Thermal-Wrap
2. Debris totals for fiberglass and mineral wool were separated
3. Insulation debris totals were differentiated by separating totals by ZOI "subzones"
4. Calcium silicate jacketing assumptions and ZOIs were revised

5. Qualified concrete coatings, unqualified coatings, foreign materials, and latent debris totals are also updated

6. Using the newly available engineering information developed in 1 through 4 above, debris size distributions were made ZOI and subzonedependent

The limiting breaks were re-evaluated in light of the new ZOIs and additional breaks were considered. From this, new large breaks S5 and S6 were identified as limiting. S5 is the high fiber case and S6 is the high CalSil case.

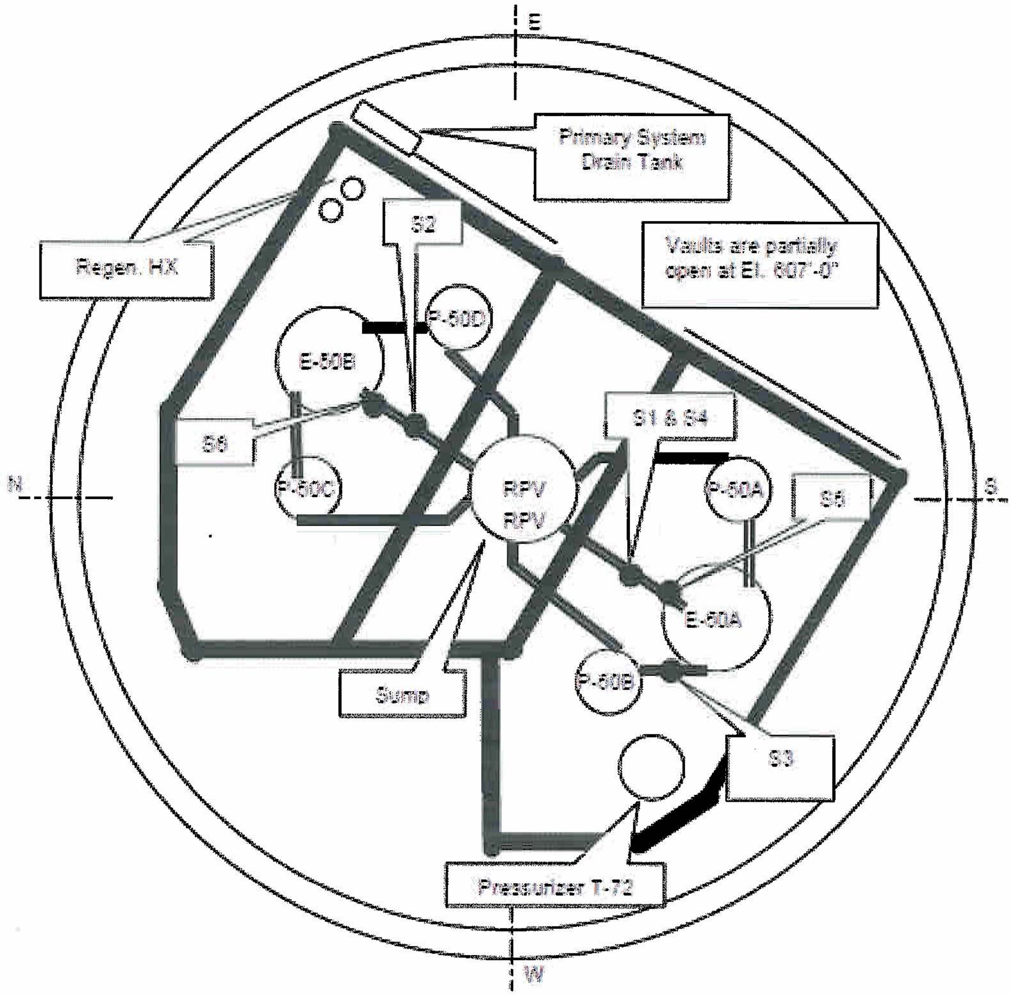
Break sizes less than large breaks (LB) and smaller piping break (SB) locations were also evaluated in the latest revision of the debris generation calculation, as suggested in the current NRC guidance documents. The debris quantities for the limiting SB are markedly less than for LB. The main issues relate to the lower sump levels that might exist for SB, which do not result in release of the safety injection tanks (SITs) contents. The main problem is identifying whether the screen head loss is low enough to accommodate the levels projected as a result of higher hold up in the PCS and ECCS equipment.

Reference 3.a.2 documents the most recent PNP debris generation calculation, which includes the analyses of debris sources in the containment, break selection, and ZOI. In selecting the break locations, the "limiting" break is identified as the break that results in the type, quantity, and mix of debris generation that is determined to produce the maximum head loss across the sump strainers, and also the maximum debris transport potential. This means that determining the maximum debris generated by any given break may not result in the maximum head loss. Therefore, the debris types and mix have to be reviewed with the possible break locations and break sizes to determine several possible limiting break locations. There were six break locations selected for debris generation evaluation. The locations are depicted in Figure 3a1.

The six LB shown on Figure 3al below were analyzed within the debris generation calculation. They are summarized as follows.

Break Name	Break ID	Piping
S1	42-inch	Hot Leg A
S2	42-inch	Hot Leg B
S3	30-inch	Cold Leg Suction 1B
S4 (14" Sch 160)	11.19-inch	Hot Leg A (Alternate)
S5	42-inch	Hot Leg A
S6	42-inch	Hot Leg B

Figure 3al



Notes: Small breaks are not shown on Figure 3al.
RPV – Reactor Pressure Vessel
E-50A – Steam Generator 'A'
E-50B – Steam Generator 'B'
P-50A, B, C, & D – Primary Coolant Pumps
Vaults are depicted by the heavy black lines

ZOI radii for insulation and coating materials were taken from the SE for NEI 04-07, Table 3-2 and Section 3.4.2. The ZOIs for jacketed Nukon and for cloth jacketed calcium silicate are specified based on other PNP analysis, which will be discussed in section 3.b of this submittal.

Insulation/Coating	ZOI Radius / Break Diameter (R/D)
Transco reflective metal insulation (RMI)	2.0
Qualified coatings	10
Calcium Silicate (Aluminum with Stainless.Steel (SS) bands)	5.45
Nukon – Jacketed, Transco Thermal-Wrap	7.0
Nukon – Unjacketed	17.0
Calcium Silicate (Cloth Jacketed)	28.6

The types of insulation present on the piping and equipment inside containment are as shown in Table 3al below. Nukon insulation was determined to represent both Transco Thermal-Wrap (Transco blankets) and the Nukon brand. Therefore, all Nukon or Thermal-Wrap is modeled as Nukon. In addition, generic mineral wool, and site-manufactured fiberglass insulation were modeled as fiberglass, and use the applicable ZOI for unjacketed Nukon. The insulation is jacketed unless noted otherwise.

Table 3aI Insulation Modeling Similarity Assumptions

Equipment/Piping	Insulation Type	Insulation Type Modeled
Steam Generator E-50A & B	Transco blankets	Nukon
Pressurizer bottom head & skirt	Unjacketed Thermal-Wrap	Nukon
Pressurizer shell	Mineral wool	Mineral wool (fiberglass)
Pressurizer top head	Nukon	Nukon
Primary Coolant Pumps	Transco RMI, Nukon	Transco RMI, Nukon
Regenerative Heat Exchangers	Cloth Jacketed Calcium Silicate, Unjacketed Nukon	Cloth Jacketed Calcium Silicate, Unjacketed Nukon
Primary System Drain Tank	Fiberglass	Fiberglass
RPV top head	Nukon	Nukon
Reactor Vessel	RMI	RMI
Reactor cavity wall/MK-R3 panels	Mineral wool	Mineral wool
Reactor cavity floor slab	Unibestos	Not modeled
Reactor cavity Access Tube	Nukon	Nukon
Hot Leg, Cold Leg Suction & Discharge	Nukon, RMI, Transco blankets	Nukon, RMI, Transco blankets
Hot Leg Injection	Nukon	Nukon
Pressurizer Surge Line	Nukon, RMI	Nukon, RMI
Letdown Line	RMI Nukon, Cal-Sil, Mineral Wool, Site Manufactured	RMI Nukon, Cal-Sil, Mineral Wool, Fiberglass
Safety Injection	Nukon, Cal-Sil, Site Manufactured	Nukon, Cal-Sil, Fiberglass
SIT Pressure Control	Nukon, Cal-Sil, Site Manufactured	Nukon, Cal-Sil, Fiberglass
Charging and Aux. Spray	Nukon, Cal-Sil, Site Manufactured	Nukon, Cal-Sil, Fiberglass
Pressurizer Spray	Nukon, Cal-Sil	Nukon, Cal-Sil
Shutdown Cooling	Nukon, Cal-Sil	Nukon, Cal-Sil
PCS Drain Lines	Nukon	Nukon
Pressurizer Safety and POR	Nukon, Cal-Sil	Nukon, Cal-Sil
Controlled Bleedoff	Fiberglass, Site Manufactured	Fiberglass
AFT to SG	Nukon	Nukon
Steam Generator Blowdown/Recirc.	Nukon	Nukon
Main Steam	Nukon, Cal-Sil, Site Manufactured	Nukon, Cal-Sil, Fiberglass
Main Feedwater	Nukon, Cal-Sil	Nukon, Cal-Sil
Service Water Supply/Return	Fiberglass (Anti-Sweat)	Fiberglass
Heating Steam and Condensate Return	Fiberglass	Fiberglass

Table 3a2 below provides the insulation totals based on a reduced ZOI of 7 D for Nukon and Transco Thermal-Wrap. The debris totals for fiberglass and mineral wool were separated. Additionally, the insulation debris totals were further differentiated by separating totals by ZOI "subzones." These ZOIs and the corresponding subzones were direct input based on other PNP analysis and is discussed in section 3.b. A new break, S6 is evaluated, and the S5 break from the previous revision is updated to include all debris sources. Qualified concrete coatings, unqualified coatings, foreign materials, and latent debris totals are also updated, based on revised design input. SBLOCA break locations were chosen and tabulated in the calculation as well. Table 3a2 summarizes the debris generation calculation results for LBLOCAs.

Table 3a2 Summary of Debris Generated

Debris Type	ZOI (D)	Units	Break S1	Break S2	Break S3	Break S4	Break S5	Break S6
			HL A	HL B	CLS 1B	Alternate Break	HL A	HL B
INSULATION								
Nukon / Thermal Wrap Jacketed	7	[ft^3]	525.85	476.30	244.58	24.34	581.95	534.70
Calcium Silicate Jacketed	5.45	[ft^3]	35.51	57.04	21.61	0	50.94	69.32
Transco RMI	2	[ft^2]	1095.48	500.76	1427.76	501.48	844.92	250.56
Low Density Fiberglass Jacketed	17	[ft^3]	10.1	41.71	9.18	0.04	10.1	41.71
Mineral Wool Jacketed	17	[ft^3]	148.44	0.51	148.44	0	148.44	0.51
Nukon Unjacketed	17	[ft^3]	0.8	0.89	0.8	0	0.8	1.79
Calcium Silicate Cloth Jacketed	28.6	[ft^3]	11.41	32.71	11.41	3.75	11.41	32.71
Low Density Fiberglass Unjacketed	17	[ft^3]	0.59	0.59	0.59	0.59	0.59	0.59
COATINGS								
Carboline - Flexxide Thinner	10	[ft^3]	1.425	0.956	1.425	0.273	1.425	0.956
Carboline – MultiBond 120	10	[ft^3]	0.475	0.319	0.475	0.091	0.475	0.319
Carboline 890	10	[ft^3]	2.403	1.834	2.403	0.273	2.403	1.834
Carboline – Carbozinc 11	10	[ft^3]	1.735	1.167	1.735	0.975	1.735	1.167
Inorganic Zinc Silicate	10	[ft^3]	1.439	1.454	1.439	0.891	1.439	1.454
Aluminum Paint	10	[ft^3]	0.008	0.008	0.008	0	0.008	0.008
Zinc Chromate	10	[ft^3]	0.006	0.006	0.006	0	0.006	0.006
Carboline 3912	10	[ft^3]	0	0.091	0	0	0	0.091
QUALIFIED COATINGS TOTAL		[ft^3]	7.491	5.835	7.491	2.503	7.491	5.835
UNQUALIFIED COATINGS		[ft^3]	20.1	20.1	20.1	20.1	20.1	20.1
LATENT DEBRIS		[lb$_m$]	200	200	200	200	200	200
Marinite Board Fiber		[ft^3]	12.8	12.8	12.8	12.8	12.8	12.8

Table 3a3 provides the foreign materials component of the LB debris generated.

Table 3a3 Summarv of Foreign Materials Debris Generated

Debris Type		Units	Break S1	Break S2	Break S3	Break S4	Break S5	Break S6
			HL A	HL B	CLD 1A	Alternate Break	HL A	HL B
FOREIGN MATERIALS								
Miscellaneous		[ft^2]	113.37	113.37	113.37	113.37	113.37	113.37
Signs (metal) (75% area)		[ft^2]	1.60	1.60	1.60	1.60	1.60	1.60
Signs (plastic) (75% area)		[ft^2]	9.89	9.89	9.89	9.89	9.89	9.89
Stickers (75% area)		[ft^2]	31.03	31.03	31.03	31.03	31.03	31.03
Tags (metal) (75% area)		[ft^2]	12.62	12.62	12.62	12.62	12.62	12.62
Tags (plastic & paper) (75% area)		[ft^2]	19.49	19.49	19.49	19.49	19.49	19.49
Tape (75% area)		[ft^2]	346.93	346.93	346.93	346.93	346.93	346.93
Lead Blankets (Alpha-Maritex cloth)		[ft^2]	2452	5020	2452	2452	2452	5020
TOTAL FOREIGN MATERIALS		[ft^2]	2986.93	5554.93	2986.93	2986.93	2986.93	5554.93

Table 3a4 Summarv of Small Break Debris Generated

Debris Type	ZOI (D)	Units	Break SB1	Break SB2	Break SB3	Break SB4
			CLD 1A	Prz. Spray	CLD 2B	Saf. Inj. [illegible]
INSULATION						
Nukon / Thermal Wrap Jacketed	7	[ft^3]	20.03	[illegible]	23.5	10.79
Calcium Silicate Jacketed	5.45	[ft^3]	0	1.42	[illegible]	2.14
Transco RMI	2	[ft^2]	0	[illegible]	0	0
Low Density Fiberglass Jacketed	17		[illegible]	[illegible]	[illegible]	[illegible]
Mineral Wool Jacketed	17	[ft^3]	0	46.2	[illegible]	[illegible]
Nukon Unjacketed	17	[illegible]	0	0	0	0.89
Calcium Silicate Cloth Jacketed	28.6	[ft^3]	1.43	0.62	[illegible]	0
Low Density Fiberglass Unjacketed	17	[ft^3]	[illegible]	0.59	0.59	0.59
QUALIFIED COATINGS TOTAL (steel coatings)		[lbm]	0.5	0.5	0.5	0.5
UNQUALIFIED COATINGS		[ft^3]	20.1	20.1	20.1	20.1
LATENT DEBRIS		[lbm]	200	200	200	200
Marinite Board Fiber		[ft^3]	12.8	12.8	[illegible]	12.8
TOTAL FOREIGN MATERIALS		[ft^2]	534.93	534.93	534.93	534.93

Table 3a4 above provides comparable debris generated by SBLOCAs. SB are defined as those less than 6-inch and greater than 2.5-inch diameter. SB, by definition, assume the water and steam phases inside the reactor vessel are separated during initial blowdown, whereas LB assume a uniform steam and water froth exists during blowdown. Because of the smaller ZOIs, SB are more position dependent than LB with ZOIs that can cover entire "vault" compartments. Breaks high in the PCS are favored since they leave more water in the PCS and hence less on the floor at the strainers. Being high in the system means the breaks rapidly come to blow only steam, which makes the assumed destructive pressure and ZOI conservative.

Most locations do not yield much insulation debris due to the small ZOI sphere. However, some break locations near large pipes or equipment can yield a large debris quantity (in relation to the break size). Per the PNP Final Safety Analysis Report (FSAR), Section 14.17.2, a 0.08 sq ft break (an approximate 4-inch single ended pipe break), will release the water in the SITs before a RAS occurs. Therefore, a 6-inch nominal pipe break was conservatively assumed in the analysis along with assuming SIT water is not released. Breaks larger than this will result in a larger total water volume and a higher flood elevation inside containment.

Lines inside the vaults were examined by calculating insulation totals at 5-foot increments along the pipes as outlined in the NRC SE for NEI 04-07 (Reference 3.a.6). The four breaks with the largest debris quantities were chosen and are presented in the calculation. The limiting case from a debris standpoint for a small break is a 4-inch break in the pressurizer spray line. This is due to the close proximity to the pressurizer shell. For conservatism, 6-inch break sizes or equivalent breaks on larger pipes were also examined to determine total debris quantities. No 6-inch cases resulted in a larger debris load than the 4-inch pressurizer spray line case.

Descriptions of the four breaks in Table 3a4 are below:

> SB1. The loop 1 cold leg discharge 1A near the outlet of the primary coolant pump, P-50A, at containment elevation (EL) 618.21' (6-inch internal diameter (ID)) (at node 3B, global coordinate (21.95, 618.21, -6.09)). This break uses a 6-inch ID for the cold leg discharge, and affects a large amount of fiber debris on the adjacent piping.
>
> SB2. The 4-inch pressurizer spray line CC-9 near the top of the pressurizer shell at EL 643.01' (at node 4, global coordinate (25.18, 643.01, 37.29)). This break, although only a 4-inch ID, will generate the largest quantity of debris for the SB due to the close proximity to the pressurizer shell insulation.

SB3. The loop 2 cold leg discharge 2B near the outlet of primary coolant pump, P-50D, at EL 618.21' (6-inch ID) (at node 3B, global coordinate (-8.70, 618.21, -19.11)). This break is similar to SB1, except it is located in vault B on the loop 2 piping.

SB4. The 6-inch safety injection CC-4 line near the cold leg at EL 618.21' (at node 1, global coordinate (-22.65, 618.21, -3.63)). This is at the connection to the 12-inch safety injection line and is chosen as another loop 2 break with a large debris quantity.

NRC Request

- *State whether secondary line breaks were considered in the evaluation (e.g., main steam and feedwater lines) and briefly explain why or why not.*

ENO Response

Feedwater and main steam piping is not considered since the recirculation flow is not required for main steam or feedwater line breaks.

NRC Request

- *Discuss the basis for reaching the conclusion that the break size(s) and locations chosen present the greatest challenge to post-accident sump performance.*

ENO Response

As it was presented in the preceding discussion, several break locations have been selected for the determination of the maximum debris laden head loss across the strainers. In selecting the break locations, the "limiting" break is identified as the break that results in the type, quantity, and mix of debris generation that is determined to produce the maximum head loss across the sump screen and also the maximum debris transport potential. This means that determining the maximum debris generated by any given break may not result in the maximum head loss. Therefore, the debris types and mix have to be reviewed with the possible break locations and break sizes to determine several possible limiting break locations.

For small breaks it was assumed the PCS refilled to water solid condition and the SITs did not activate prior to RAS. This minimized the water level in containment. Additional details on the small break LOCA are covered in sections 3.f and 3.g.

The request below is from the December 24,2008 NRC RAI.

NRC Request

Regarding the last two RAIs below, the licensee indicated in its February 27, 2008 supplemental response that additional chemical effects testing will be performed for PNP and, as a result, the NRC staff has not been able to develop a comprehensive list of chemical effects RAIs. The NRC staff expects that chemical effects information as called for in the NRC Content Guide will be forthcoming in a follow-on Generic Letter 2004-02 supplemental response. The NRC staff will review this information when the licensee submits it, and as a result of such review, the NRC staff could request additional information in this subject area if needed. Nevertheless, at this time the NRC staff has the two chemical effects questions that follow:

17. The February 27, 2008, supplemental response states that the "choice of worst breaks is applicable to the new passive strainers and the new STB [sodium tetraborate] buffer" in part because the impact of trisodium phosphate and calcium silicate was not widely understood at the time the break selection analysis was performed. Please clarify this statement and confirm that the break location determined to be the "worst case" results in the projected maximum quantity of aluminum containing precipitates being generated.

ENO Response

17. Following the submittal of the PNP GL 2004-02 supplemental response, on February 27, 2008, revised and new basis calculations have been performed in support of the PNP November 2008 strainer testing. As committed in ENO letter of March 20, 2009 (Reference 3.a.5), response to this RAI is provided using the updated design basis debris values.

The above material reflects the new calculations and responds to NRC Request RAI 17. See first page of this Section (3.a) regarding aluminum impact on limiting break choice.

Note: The response to the second NRC RAI item, referred to above under NRC Request, RAI 18, is provided in Section 3i below.

References

3.a.l NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, December 2004

3.a.2 EA-MOD-2005-04-06 Debris Generation, Revision 4, "Acceptance of Debris Generation" Calculation 2005-01340, Revision 3, February 9, 2009

3.a.3 Nuclear Management Company (NMC) letter to NRC, August 25, 2005, "Nuclear Management Company Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for Palisades Nuclear Plant"

3.a.4 ENERCON Project Report ENTP-003-PR-06, "Containment Sump Strainer SBLOCA Evaluation for Palisades," dated March 6, 2009

3.a.5 ENO letter dated March 20, 2009, "Response to Request for Additional Information Regarding Supplemental Responses to NRC Generic Letter 2004-02 (TAC No. MC4701)"

3.a.6 SE by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, NEI Guidance Report (Proposed Document Number NEI 04-07), "Pressurized Water Reactor Sump Performance Evaluation Methodology," issued December 6, 2004

3.b. Debris Generation/Zone of Influence (ZOI) (excluding coatings)

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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.*

ENO Response

The LOCA-generated debris analysis for PNP is documented in Reference 3.b.1, which defines the debris sources, break selections, and ZOI of the debris. The methodologies used in determining the LOCA-generated debris mix are described below.

<u>Piping and Equipment Insulation</u>

As listed below, the ZOI radii for insulation and coating materials were taken from the NRC SE for NEI 04-07, Table 3-2 and Section 3.4.2 (Reference 3.b.5). The ZOIs for jacketed Nukon and for cloth jacketed CalSil are based on other analyses, as described below.

Insulation/Coating	ZOI Radius/Break Diameter (WD)
Transco RMI	2.0
Qualified coatings	10
Calcium Silicate (Aluminum with SS bands)	**5.45**
Nukon – Jacketed, Transco Thermal-Wrap	7.0
Nukon – Unjacketed	17.0
Calcium Silicate (Cloth Jacketed)	28.6

The ZOI for cloth jacketed CalSil is not given in the table and the largest ZOI in the table, 28.6, was conservatively assigned. This corresponds to 2.4 psi damage pressure, which is very conservative for rigid insulation such as CalSil.

The ZOI for jacketed Nukon and Trancso Thermal Wrap is based on WCAP-16836-P (Reference 3.b.7) and the report in Reference 3.b.6, which addresses the applicability of the WCAP to PNP insulation types. It is acknowledged that the NRC has issued extensive RAIs to at least two other licensees regarding the WCAPs that form the basis for the reduced ZOIs. Because ENO does not own either the data or the technique used to generate it, ENO is supporting and relying on the PWROG generic response to address these RAIs.

The ZOI for qualified coatings is 10.0 D. All the unqualified coating inside containment is assumed to be failed under a LOCA scenario.

Insulation drawings, piping isometric drawings, and information from an inventory of insulation volumes for piping and equipment have been compiled for each insulation type. The piping layouts from the isometric drawings and area piping drawings were combined with information provided for each line from the plant insulation drawings and specifications, including insulation type and thickness. Insulation types are conservatively modeled where multiple insulation types are provided or where the order of multiple insulation types along a pipe segment is not known. This information was used to create a spreadsheet with node points for each length of pipe, elbow, etc. If not provided on piping drawings, valve locations are approximate and lengths are conservatively assumed. Each directional change and intermediate point along longer lengths of pipe were given node points. The distance between node points is approximately two feet. These node points were given incremental coordinates with respect to each other with information from each isometric drawing.

Global coordinates were then determined by locating a known starting point, with the center of containment at the (0, 0) point. The global coordinates for the lines were found from where the pipe tied in with a piece of equipment, a containment penetration, or with another pipe. Occasionally, the area piping diagrams were used to determine the starting coordinate with respect to the center of containment. Emphasis is given to the global coordinates of the piping nodes inside the vaults to reduce the effects of drawing inaccuracies. The (X, Y, Z) axis uses south as positive X, west as positive Z, and up as positive Y. This activity was performed for each vault. Piping outside the vaults (except near openings to the vault at containment elevation 607'-0") was either excluded from the model or the insulation type zeroed out such that it is not included as debris. This includes the heating steam and condensate return lines and the service water supply and return lines.

The spreadsheet uses the pipe outside diameter as input, the insulation thickness, and the insulation type, along with an insulation factor. The factor is 1.0 for pipe and elbows, and 1.5 for valves where no detailed insulation data is provided based on the typical valve diameter as compared to the associated pipe. These numbers, along with the insulation length that is calculated from the global coordinates, provides an insulation volume for a given segment of pipe. Equipment is also modeled in this fashion.

With this insulation volume and location information, a global coordinate can be chosen for a pipe break, an insulation type selected, and all of the insulation of that type that is within the applicable ZOI is summed. By using this method with the various insulation types, a total insulation volume can be determined for any break location. By narrowing the break locations down to the applicable high energy lines (the primary piping, safety injection, and pressurizer surge line), a debris total can be determined. Break locations are selected in 5-foot increments along the applicable piping to determine the maximum worst case debris mix. Each ZOI encompasses the affected piping and equipment for that particular break. Vault area(s) shielded by large equipment and/or a structure are also indicated where applicable.

Pipes and equipment are modeled as one-dimensional lines with the centerline of the pipe or equipment serving as the coordinate points. The equipment (steam generators, pressurizer, regenerative heat exchangers, and primary system drain tank) is modeled as a line at the centerline of the equipment with 1'-0 increments. The coordinates for the centerline of the equipment will be different than the outer surface of the insulation, and for this reason the equipment is also checked against plan views of piping and structural drawings to ensure that any break would not accidentally exclude some outside portions of the equipment insulation. To account for slightly different coordinates for the outer surfaces of the large lines and the equipment, a ZOI factor of 1.1 is used when determining insulation volumes. This will include any pieces of insulation that may have fallen just outside of the ZOI due to the coordinate chosen as the pipe centerline. In addition, some isometric drawings note that the actual as-built dimensions may vary slightly, and actual dimensions are found in the stress calculation. The ZOI factor of 1.1 should adequately account for any minor changes in the information found on the drawings. This factor also accounts for any portions of piping insulation that has damaged jacketing.

RMI consists of layers of thin metal foils surrounded by metal jacketing. Therefore, the insulation is not solid like fiberglass insulation. For this reason, the surface area of the metal foils contained within the jacketing is calculated, rather than a volume. The spreadsheet automatically calculates a volume for the insulation, regardless of insulation type. The RMI also has an air gap between the pipe and the insulation of ¾" according to insulation drawings for the reactor vessel and loop piping. The area of the metal foils is calculated manually by dividing the insulation volume by the insulation thickness to determine the average surface area. For the foil area, the surface area is multiplied by the number of foils to determine the total foil area. The primary loop piping, primary coolant pumps and the reactor pressure vessel have nine layers of foil on the RMI sections. The pressurizer shell is insulated with mineral wool, and also contains a layer of metal foil. This foil area was calculated separately.

Heating steam and condensate return piping lines were not modeled in the spreadsheet. These lines did not have isometric drawings associated with them, and the lines travel along the containment liner with 1-inch thick fiberglass insulation, however, the possibility that some contain calcium silicate insulation cannot be ruled out. These lines fall entirely outside of either vault. Because the largest breaks and the maximum debris potential are within the vault, the lines will not affect the debris generation calculation, as they are jacketed and will be outside of the ZOI affected area.

In addition, other lines with insulation fall outside of any break locations, and therefore the insulation is not counted in any of the tables or the attachments. The service water supply and return lines are both covered with I-inch thick anti-sweat fiberglass and are located at the 590'-0" containment elevation. These lines do not pass into the vaults or near of the openings on the east side at the 607'-0" containment elevation, and will not be in the ZOI for any postulated breaks. The lines are not shown on the detailed calculation sheets since their volume of insulation would be zero in the break ZOI. The aluminum jacketing on the portion of the service water piping that resides in the sump below the normal post-LOCA water level is, however, included as submerged metal in the aluminum corrosion analysis.

The cloth jacketed CalSil has been assigned a ZOI of 28.6 feet based upon that being the highest value in the NEI 04-07 table and hence is conservative (Reference 3.b.10). Since the CalSil has significant compressive strength to support the fiberglass cloth, and since the mastic must be water resistant to avoid deterioration during normal operation, a ZOI closer to 5.45 rather than 28.6 might be justifiable.

Coatings

Coatings are covered in the debris generation calculation in section 3.h of this document.

Latent Debris

Latent debris includes dirt, dust, lint, fibers, etc. As provided by Reference 3.b.5, NRC NEI 04-07 Safety Evaluation, a value of 200 pounds of latent debris was used in the absence of representative sample data. Therefore, 200 pounds will be used as the latent debris quantity. A later walkdown in the 2006 refueling outage took representative samples from within containment. A calculation (Reference 3.b.2) reducing the raw data from debris samples arrived at a value of 156 pounds of latent debris. This value represents the upper 90% confidence level of the collected, data. The 200 pound guidance value was retained to provide conservatism to cover future containment conditions. Additional discussion of the latent debris is included in section 3.d of this document.

Foreign Materials

Foreign materials inside containment may become debris during a LOCA or during containment spray. Examples of foreign materials are electrical tape, stickers, conduit tags, etc.

The total areas of the foreign materials are tabulated in the results summary. The foreign materials found within the containment are self-adhesive labels, stickers, placards, etc. Stickers and placards attached with adhesives, tape, and tags were accounted for in the debris generation calculation by reducing the wetted flow area of the sump screen by 75% of the total of the original single-sided area of the item per Reference 3.b.5, Section 3.5.2.2.2. A 10% multiplier is added to all of the foreign material totals. The lead blankets listed in the results table were removed from the foreign material list in that they were in containment as an approved plant modification. Reference 3.b.3 has tested prototypical blankets using identical jacket material and found that it is capable of surviving direct break jet blasts without fragmenting the jacket or the lead into pieces that would likely transport to the sump.

During the PNP prototypical flume testing conducted at Alden Research in May 2008 (Reference 3.b.8 section 6.1.3 on page 23), which was configured to model near field debris transport, samples of these kinds of miscellaneous material, including lead blanket covering fabric, were inserted in the flume. None of them transported and to avoid artificial blockage of finer debris, none were incorporated into any subsequent tests. The major disposition of this debris is that it will not transport to the strainers, however, an allowance for 100 square feet was left in the analysis to cover possible future discoveries of new types of foreign materials.

With regard to lead blankets and the NRC RAI of December 24, 2008, the below material was also provided in the ENO RAI 1 response on March 20, 2009 (Reference 3.b.9).

NRC Request

1. If lead blankets were determined to contribute to potential sump blockage debris, please identify the zone of influence (ZOI) size used. Please provide information relative to impact of differences in jet size, target size and geometry used in developing the test report WCAP-16727-P, "Evaluation of Jet Impingement and High Temperature Soak Tests of Lead Blankets For Use Inside Containment of Westinghouse Pressurized Water Reactors," dated February 2007, with that of the jet sizes and lead blankets at Palisades.

ENO Response

Lead blankets were included in the debris generation calculation done by Sargent & Lundy. Below is an excerpt from that calculation.

> 4.6 *FOREIGN MATERIALS*
> *Foreign materials inside containment may become debris during a* [Loss of Coolant Accident] *LOCA or during Containment Spray. Examples of foreign materials are electrical tape, stickers, conduit tags, etc. See Table 5.5-1 for complete listing of foreign material compiled from information in Reference 6.1.4. Foreign materials become debris regardless of their location and the location of the break as directed in Reference 6.1.3, with the exception of lead blankets (discussed below). Lead blankets are installed in containment and can become debris following a LOCA. However, the lead blankets are robust and securely held; therefore they are only considered debris when located in the same vault as the break.*

Lead blankets were reported as "Foreign Materials" in Table 5.5-1, which (according to section 4.6 above) included all of the lead blankets located in the same vault as the break.

ENO, then, relied upon the ZOIs given in WCAP-16727-P (Reference3.b.3) to eliminate almost all lead blankets from further consideration as producers of GSI -191 debris that can be transported to the sump screen. The ZOI values are listed below:

ZOIs for Lead Blankets:

- *1.25D* (D = *diameters) for free hanging & no backing, no damage*
- 5D *for attached with backing, no damage*
- *0D-2.65D for attached with backing, total destruction of lead & cover*
- 2.650-50 *for attached with backing, destruction of* 25% *cover and* 10% *of lead*

Conversion to spherical radius of influence in feet

ZOI in feet (ft)	*Hot Leg D=3.5 ft*	*Cold Leg D=2.5 ft*
1.25D	4.375 *ft*	3.125 *ft*
2.65D	9.275 *ft*	6.625 *ft*
5D	17.5 *ft*	12.5 *ft*

The exception is the blankets on frame no.1 shown on drawing C-277, sheet 2, Revision 0, "Permanent Shielding Area 1 Plan of EL 607'-0" [elevation 607 feet–zero inches] at zone C-4." Frame no.1 is a three sided wrap-around frame on the three-inch pressurizer spray line pipe installed on grating at EL 618'-7". The frame is shown on drawing C-279, sheet 1, Revision 0, "Permanent Shielding & Frames Inside Containment Details," which also specifies that the blankets be covered with two layers of Alpha-Maritex Style 8459-2-SS cloth, or equivalent. The typical six-foot long by one-foot wide blankets are laid over the frame and are bolted to the frame in four places. The frame is rated for 2880-pounds (lbs) load, which at 15-lbs per square foot (ft^2), would equal 192 ft^2 of lead with four layers of cloth. However, there is no backing plate on the frame. This frame is less than 2.65D from the 30" cold leg, which lies right below it.

Although the frame no.1 blankets may be blown apart and enter the sump, none of the constituents are transported to the screen. The lead particles sink very rapidly and do not transport. The Alpha-Maritex cloth was included in the flume testing as small cut pieces and did not transport beyond about one pool depth.

PNP was a buy-in participant in the WCAP-16727-P effort. ENO has determined that the tested blankets were sufficiently similar to the PNP permanently installed blankets to use the test results. ENO has supported the PWROG effort and has accepted the conclusion in the WCAP report that it is applicable to PWROG plants for reference under GSI-191. There is an on-going PWROG effort that ENO is supporting to answer questions on the test scaling and test methodology.

With respect to geometry, ENO would be, in effect, using the results for breaks up to and including 3 0 cold leg breaks. This would be around 10 times the diameter of the test jets. A single ten-foot long blanket wall would include around fifty blankets hung up to four deep, whereas the test targets were single blankets. Each of the single blankets in the wall would, however, scale nearly one-to-one dimensionally with the test target blankets.

With regard to foreign materials, and the NRC RAI of December 24,2008, the material below was also provided in the ENO RAI 6 response on March 20, 2009 (Reference 3.b.9):

NRC Request

6. *Please provide a description of the methodology used to count the number of tags, signs, tapes and stickers in containment and estimate their total surface area (e.g., walkdown of containment, photographs of containment areas, review of design drawings, etc.).*

ENO Response

6. These items were hand counted by the walkdown crews and were summed in a spreadsheet when the notes were transcribed. In cases such as tie wraps, the number of items was determined by informal estimates such as counting the visible tie wraps for a known length of tray, multiplying by a depth factor to cover the hidden tie wraps in the lower levels of the tray, and by a length factor representing the length of the tray. These estimate calculations were not preserved in the recorded documentation.

With regard to miscellaneous foreign materials and the NRC RAI of December 24, 2008, the material below was also provided in the ENO RAI 7 response on March 20, 2009 (Reference 3.b.9).

NRC Request

7. *Please specify the types of materials included in the miscellaneous category in the foreign materials section of the "Summary of LOCA Generated Debris" table on page 17 of the February 27, 2008, submittal.*

ENO Response

7. Below is the list of materials included in the 113.4 ft^2 value noted as Miscellaneous in the table on page 17 of the February 27, 2008, submittal.

- air dryer, green plastic
- Bakelite cap on shield cooling pump motors
- Bakelite knobs
- beige electrical ground fault circuit interrupter outlet on wall
- cable – neutron instrumentation (NI), braided sheath
- cable - NI, white splice tape, by containment air cooler, VHX-4
- cable - NI, wrapped with white tape, by containment air cooler VHX-3
- cable tie-wraps in cable trays

- fibrous I2 filter inlet filters
- filter on primary coolant pump motor connection box
- Gaitronics speaker rubber surround
- lucite dP gauges on iodine filter
- N2 dryer filter material
- plastic air line spacer
- plastic gauge faces
- plastic radiation detector source
- plastic telephone boxes
- plywood mount board for phone boxes
- red electrical penetration caps
- red rubber protective cap on instrument connector
- rope, nylon, on core support barrel lift rig
- rubber grommet on intake duct
- tygon tubing
- vinyl valve handle
- white conduit support "bumpers"

NRC Request

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).

ENO Response

Testing done for WCAP-16836-P (Reference 3.b.7), and WCAP-16710-P (Reference 3.b.11) were used to justify the 7D ZOI for Nukon and Transco Thermal Wrap fiberglass insulation. For other materials, applications of ZOIs for PNP are consistent with the guidelines provided in NEI 04-07, or are based on engineering analysis alone or similarity to the NEI guideline rated materials. Although not an insulation material, in evaluating the ZOI for lead blankets, the WCAP-16727-P (Reference 3.b.3) data is used. It is our understanding that NRC has the above mentioned reports.

ENO is aware of NRC questions on the reports, which appear to be generic rather than PNP-specific. Therefore, we are participating in the PWROG efforts to resolve the questions.

NRC Request

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.

ENO Response

Results of the Debris Generation Calculation

The following tables from Reference 3.b.l summarize the debris generation for the analyzed break scenarios by zone and sub-zone of influence. Six LB locations and four SB locations are provided. LB S5 and S6 are the most limiting locations. For convenience, the tables retain their original table numbers in the header. Sub-zones are discussed in response to Item 3.c., Debris Characteristics.

TABLE 5.2-2: S1 INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE (D)	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wrap Jacketed	[ft³]	7	0 - 5	347.96	525.85
			5 - 7	177.89	
Nukon Unjacketed	[ft³]	17	0 - 7	0	0.8
			7 - 11.9	0.8	
			11.9 - 17	0	
Low Density Fiberglass Jacketed	[ft³]	17	0 - 7	6.52	10.1
			7 - 11.9	3.58	
			11.9 - 17	0	
Mineral Wool Jacketed	[ft³]	17	0 - 7	0	148.44
			7 - 11.9	148.44	
			11.9 - 17	0	
Low Density Fiberglass Unjacketed	[ft³]	17	0 - 7	0.22	0.59
			7 - 11.9	0.37	
			11.9 - 17	0	
Calcium Silicate Jacketed	[ft³]	5.45	0 - 2.7	3.86	35.51
			2.7 - 5.45	31.65	
Calcium Silicate Cloth Jacketed	[ft³]	28.6	0 - 2.7	0	11.41
			2.7 - 28.6	11.41	
Transco RMI	[ft²]	2	NA	NA	1095.48

TABLE 5.2-3: S2 INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE (D)	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wrap Jacketed	[ft³]	7	0 - 5	327.22	476.3
			5 - 7	149.08	
Nukon Unjacketed	[ft³]	17	0 - 7	0.89	0.89
			7 - 11.9	0	
			11.9 - 17	0	
Low Density Fiberglass Jacketed	[ft³]	17	0 - 7	9.61	41.71
			7 - 11.9	32.1	
			11.9 - 17	0	
Mineral Wool Jacketed	[ft³]	17	0 - 7	0	0.51
			7 - 11.9	0.51	
			11.9 - 17	0	
Low Density Fiberglass Unjacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Calcium Silicate Jacketed	[ft³]	5.45	0 - 2.7	8.45	57.04
			2.7 - 5.45	48.59	
Calcium Silicate Cloth Jacketed	[ft³]	28.6	0 - 2.7	0	32.71
			2.7 - 28.6	32.71	
Transco RMI	[ft²]	2	NA	NA	500.76

TABLE 5.2-4: S3 INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE (D)	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wrap Jacketed	[ft³]	7	0 - 5	49.86	244.58
			5 - 7	194.72	
Nukon Unjacketed	[ft³]	17	0 - 7	0.8	0.8
			7 - 11.9	0	
			11.9 - 17	0	
Low Density Fiberglass Jacketed	[ft³]	17	0 - 7	2.5	9.18
			7 - 11.9	2.31	
			11.9 - 17	4.37	
Mineral Wool Jacketed	[ft³]	17	0 - 7	0	148.44
			7 - 11.9	82.47	
			11.9 - 17	65.97	
Low Density Fiberglass Unjacketed	[ft³]	17	0 - 7	0.3	0.59
			7 - 11.9	0	
			11.9 - 17	0.29	
Calcium Silicate Jacketed	[ft³]	5.45	0 - 2.7	0.25	21.61
			2.7 - 5.45	21.36	
Calcium Silicate Cloth Jacketed	[ft³]	28.6	0 - 2.7	0	11.41
			2.7 - 28.6	11.41	
Transco RMI	[ft²]	2	NA	NA	1427.76

TABLE 5.2-5: S4 INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE (D)	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wra Jacketed	$[ft^2]$	7	0 - 5	5.97	24.34
			5 - 7	[illegible]	
Nukon Unjacketed	$[ft^2]$	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17		
Low Density Fiberglass Jacketed	$[ft^2]$	17	0 - 7	0	0.04
			7 - 11.9	0	
			11.9 - 17	0.04	
Mineral Wool Jacketed		17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Low Density Fiberglass Unjacketed	$[ft^2]$	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Calcium Silicate Jacketed	$[ft^2]$	5.45	0 - 2.7	0	0
			2.7 - 5.45	0	
Calcium Silicate Cloth Jacketed		28.6	0 - 2.7	0	3.75
			2.7 - 28.6	3.75	
Transco RMI	$[ft^2]$	2	NA	NA	501.48

TABLE 5.2-6: S5 INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wrap Jacketed	$[ft^2]$	7	0 - 5	453.74	581.95
			5 - 7	128.21	
Nukon Unjacketed	$[ft^2]$	17	0 - 7	0	0.8
			7 - 11.9	6.8	
			a1.9 - 17	0	
Low Density Fiberglass Jacketed	$[ft^2]$	17	0 - 7	[illegible]	10.1
			7 - 11.9	2.59	
			11.9 - 17	0	
Mineral Wool Jacketed	$[ft^2]$	17	0 - 7	0	148.44
			7 - 11.9	148.44	
			11.9 - 17	0	
Low Density Fiberglass Unjacketed	$[ft^2]$	17	0 - 7	0.52	0.59
			7 - 11.9	0.07	
			11.9 - 17	0	
Calcium Silicate Jacketed	$[ft^2]$	5.45	0 - 2.7	2.97	50.94
			2.7 - 5.45	47.97	
Calcium Silicate Cloth Jacketed	$[ft^2]$	28.6	0 - 2.7	0	11.41
			2.7 - 28.6	11.41	
Transco RMI	$[ft^2]$	2	NA	NA	844.92

TABLE 5 2-7: S6 INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE (D)	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wrap Jacketed	[ft³]	[illegible]	0 - 5	404 89	[illegible]
			5 - [illegible]	[illegible]	
Nukon unjacketed	[ft³]	[illegible]	0 - [illegible]	[illegible] 70	[illegible]
			[illegible] - 11 9	[illegible]	
			11 9 - 17	[illegible]	
Low Density Fiberglass Jacketed	[ft³]	17	0 - 7	12 15	41 71
			[illegible] - 11 9	29 56	
			11.9 - [illegible]		
[illegible] Wool [illegible]eted	[ft³]	17	0 - [illegible]	0	0 51
			[illegible] - 11 9	[illegible]	
			[illegible]9 - [illegible]	[illegible]	
Low Density Fiberglass Unjacketed	[ft³]	17	0 - 7		[illegible]
			[illegible] - 11 9	[illegible]	
			[illegible]9 - [illegible]	0	
Calcium Silicate Jacketed	[ft³]	5 45	0 - 2.7	10 91	[illegible]
			2.7 - 5 45	[illegible]	
Calcium Silicate Cloth Jacketed	[illegible]	28 6	0 - 2[illegible]		[illegible] 71
			2 7 - 28 6	[illegible]	
Transco[illegible]	[ft³]	2	NA	NA	[illegible]

TABLE 5.2-8: SB1 (SMALL BREAK) INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE (D)	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wrap Jacketed	[ft³]	7	0 - 5	11.17	20.03
			5 - 7	8.86	
Nukon Unjacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Low Density Fiberglass Jacketed	[ft³]	17	0 - 7	0	1.29
			7 - 11.9	0.42	
			11.9 - 17	0.87	
Mineral Wool Jacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Low Density Fiberglass Unjacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Calcium Silicate Jacketed	[ft³]	5.45	0 - 2.7	0	0
			2.7 - 5.45	0	
Calcium Silicate Cloth Jacketed	[ft³]	28.6	0 - 2.7	0	1.43
			2.7 - 28.6	1.43	
Transco RMI	[ft³]	2	NA	NA	0

TABLE 5.2-9: SB2 (SMALL BREAK) INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE (D)	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wrap Jacketed	[ft³]	–	0 - 5	0	0
			5 - 7	6	
Nukon Unjacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Low Density Fiberglass Jacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Mineral Wool Jacketed		1a	0 - 7	8.66	46.2
			7 - 11.9	22.69	
			11.9 - 37	14.85	
Low Density Fib-reglas: Unjacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	6	
Calcium Silicate Jacketed	[ft³]	5.45	0 - 2.7	6	1.42
			2.7 - 5.45	1.42	
Calcium Silicate Cloth Jacketed		28.6	0 - 2.7	0	3.82
			2.7 - 28.6	3.82	
Transco RMI	[ft²]	–	NA	NA	0

TABLE 5.2-10: SB3 (SMALL BREAK) INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE (D)	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wrap Jacketed	[ft³]	7	0 - 5	11.17	23.5
			5 - 7	12.33	
Nukon Unjacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Low Density Fiberglass Jacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Mineral Wool Jacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Low Density Fiberglass Unjacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Calcium Silicate Jacketed	[ft³]	5.45	0 - 2.7	0	0
			2.7 - 5.45	0	
Calcium Silicate Cloth Jacketed	[ft³]	28.6	0 - 2.7	0	0
			2.7 - 28.6	0	
Transco RMI	[ft²]	2	NA	NA	0

TABLE 5.2-11: SB4 (SMALL BREAK) INSULATION TOTALS					
DEBRIS TYPE	UNITS	ZOI (D)	SUBZONE (D)	SUBZONE TOTAL	TOTAL (INSIDE ZOI)
Nukon/Thermal Wrap Jacketed	[ft³]	7	0 - 5	10.56	10.79
			5 - 7	0.23	
Nukon Unjacketed	[ft³]	17	0 - 7	0	0.89
			7 - 11.9	0	
			11.9 - 17	0.89	
Low Density Fiberglass Jacketed	[ft³]	17	0 - 7	0.48	0.96
			7 - 11.9	0.41	
			11.9 - 17	0.07	
Mineral Wool Jacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Low Density Fiberglass Unjacketed	[ft³]	17	0 - 7	0	0
			7 - 11.9	0	
			11.9 - 17	0	
Calcium Silicate Jacketed	[ft³]	5.45	0 - 2.7	0.51	2.14
			2.7 - 5.45	1.63	
Calcium Silicate Cloth Jacketed	[ft³]	28.6	0 - 2.7	0	0
			2.7 - 28.6	0	
Transco RMI	[ft²]	2	NA	NA	0

NRC Request

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

ENO Response

The total surface area of the all signs, placards, tags, tape, and similar miscellaneous materials are listed in the Table 3a3 in the previous Section 3.a.

References

3.b.1 EA-MOD-2005-04-06, Revision 4, "Acceptance of Debris Generation Calculation 2005-01340, Revision 3," June 9, 2009

3.b.2 EA-MOD-2005-004-12, "Calculation for Latent Debris (Dust & Dirt) for Palisades Containment for Resolution of GSI-191," June 20, 2006

3.b.3 WCAP-16727-P, "Evaluation of Jet Impingement and High Temperature Soak Tests of Lead Blankets For Use Inside Containment of Westinghouse Pressurized Water Reactors," February 2007, and, Westinghouse Report by C.H. Hutchins, "Evaluation of the Impact on Systems at Callaway Plant Resulting From Installation of Lead Blankets Inside Containment," August 24, 2004

3.b.4 EA-EC496-04, "Containment Sump Passive Strainer Assembly Surface Area Flow and Volume (PCI Calc TDI-6013-01)," March 2, 2009

3.b.5 SE by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, NEI Guidance Report (Proposed Document Number NEI 04-07), "Pressurized Water Reactor Sump Performance Evaluation Methodology," issued December 6, 2004

3.b.6 MPR Report DRN 0098-0804-02, "Applicability Review of WCAP-16836-P ZOI for Palisades LDFG Insulation," September 30, 2008

3.b.7 WCAP-16836-P, "Arkansas Nuclear One – Jet Impingement Testing of Insulation Materials," Westinghouse Electric Company LLC, October 2007

3.b.8 AREVA Document 66-9082447-000, "Palisades Test Report for ECCS Strainer Performance May 2008 Testing," October 23, 2008

3.b.9 ENO letter for PNP to NRC, "Response to Request for Additional Information Regarding Supplemental Responses to NRC Generic Letter 2004-02 (TAC No. MC4701)," March 20, 2009

3.b.10 Engineering Report PLP-RPT-09-00018, dated April 20, 2009, Enercon ENTP-003-PR-01, "Fiberglass Cloth Covered Calcium Silicate Insulation Evaluation for Palisades," January 6, 2009

3.b.11 WCAP-16710-P, Revision 0, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON® Insulation for Wolf Creek and Callaway Nuclear Operating Plants," October 2007

3.c. Debris Characteristics

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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.*

ENO Response

Enercon, Alion and Westinghouse provided assistance in determining the debris size distributions. Debris types fiberglass, mineral wool, and CalSil, were assigned size distributions within the ZOI as a function of the distance from the break location. To accomplish this purpose, the Section 3.b debris generation tables divided each ZOI into sub-ZOIs and determined the quantities of debris in assigned radial increment of the ZOI. In general, insulation closer to the breaks result in more fines than that further away.

The resulting debris size distribution tables for the limiting breaks are listed below.

Large Break number S5

Insulation Type	Total Amount Destroyed	Units	Subzone (D)	Subzone Total	Fines	Small Pieces	Large Pieces	Intact Blankets
Nukon/Thermal Wrap Jacketed	581.95	[ft³]	0 – 5	453.74	81.67	190.57	181.50	0.00
			5 – 7	128.21	0.00	0.00	0.00	128.21
Nukon Unjacketed	0.80	[ft³]	0 – 7	0.00	0.00	0.00	0.00	0.00
			7 – 11.9	0.80	0.10	0.43	0.13	0.14
			11.9 -17	0.00	0.00	0.00	0.00	0.00
Jacketed Low Density Fiberglass	10.10	[ft³]	0 – 7	7.51	1.50	6.01	0.00	0.00
			7 – 11.9	2.59	0.34	1.40	0.41	0.44
			11.9 -17	0.00	0.00	0.00	0.00	0.00
Jacketed Mineral Wool	148.44	[ft³]	0 – 7	0.00	0.00	0.00	0.00	0.00
			7 – 11.9	148.44	19.30	80.16	23.75	25.23
			11.9 -17	0.00	0.00	0.00	0.00	0.00
Unjacketed Low Density Fiberglass	0.59	[ft³]	0 – 7	0.52	0.10	0.42	0.00	0.00
			7 – 11.9	0.07	0.01	0.04	0.01	0.01
			11.9 -17	0.00	0.00	0.00	0.00	0.00
Jacketed Calcium Silicate	50.94	[ft³]	0 – 2.7	2.97	1.49	1.49	0.00	0.00
			2.7 - 5.45	47.97	11.99	7.68	0.00	28.30
Unjacketed Calcium Silicate	11.41	[ft³]	0 – 2.7	0.00	0.00	0.00	0.00	0.00
			2.7 – 28.6	11.41	2.85	1.83	6.73	0.00
Transco RMI	844.92	[ft²]	0 - 2	844.92	633.69		211.23	0

Large Break number S6

Insulation Type	Total Amount Destroyed	Units	Subzone (D)	Subzone Total	Fines	Small Pieces	Large Pieces	Intact Blankets
Nukon/Thermal Wrap Jacketed	534.70	[ft³]	0 – 5	404.89	72.88	170.05	161.96	0.00
			5 – 7	129.81	0.00	0.00	0.00	129.81
Nukon Unjacketed	1.79	[ft³]	0 – 7	1.79	0.36	1.43	0.00	0.00
			7 – 11.9	0.00	0.00	0.00	0.00	0.00
			11.9 -17	0.00	0.00	0.00	0.00	0.00
Jacketed Low Density Fiberglass	41.71	[ft³]	0 – 7	12.15	2.43	9.72	0.00	0.00
			7 – 11.9	29.56	3.84	15.96	4.73	5.03
			11.9 -17	0.00	0.00	0.00	0.00	0.00
Jacketed Mineral Wool	0.51	[ft³]	0 – 7	0.00	0.00	0.00	0.00	0.00
			7 – 11.9	0.51	0.07	0.28	0.08	0.09
			11.9 -17	0.00	0.00	0.00	0.00	0.00
Unjacketed Low Density Fiberglass	0.00	[ft³]	0 – 7	0.00	0.00	0.00	0.00	0.00
			7 – 11.9	0.00	0.00	0.00	0.00	0.00
			11.9 -17	0.00	0.00	0.00	0.00	0.00
Jacketed Calcium Silicate	69.32	[ft³]	0 – 2.7	10.91	5.46	5.46	0.00	0.00
			2.7 - 5.45	58.41	14.60	9.35	0.00	34.46
Unjacketed Calcium Silicate	32.71	[ft³]	0 – 2.7	0.00	0.00	0.00	0.00	0.00
			2.7 – 28.6	32.71	8.18	5.23	19.30	0.00
Transco RMI	250.56	[ft²]	0 - 2	250.56	187.92		62.64	0

Small Break number SB1

Insulation Type	Total Amount Destroyed	Units	Subzone (D)	Subzone Total	Fines	Small Pieces	Large Pieces	Intact Blankets or Remains on Target
Nukon/Thermal Wrap Jacketed	20.03	[ft³]	0 – 5	11.17	2.01	4.69	4.47	0
			5 – 7	8.86	0	0	0	8.86
Nukon Unjacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Low Density Fiberglass Jacketed	1.29	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0.42	0.05	0.23	0.07	0.07
			11.9 -17	0.87	0.070	0.061	0.357	0.383
Mineral Wool Jacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Low Density Fiberglass Unjacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Calcium Silicate Jacketed	0	[ft³]	0 – 2.7	0	0	0	0	0
			2.7 - 5.45	0	0	0	0	0
Calcium Silicate Cloth Jacketed	1.43	[ft³]	0 – 2.7	0	0	0	0	0
			2.7 – 28.6	1.43	0.36	0.23	0.84	0
Transco RMI	0	[ft²]	0 - 2	0	0		0	-

Small Break number SB2

Insulation Type	Total Amount Destroyed	Units	Subzone (D)	Subzone Total	Fines	Small Pieces	Large Pieces	Intact Blankets or Remains on Target
Nukon/Thermal Wrap Jacketed	0	[ft³]	0 – 5	0	0	0	0	0
			5 – 7	0	0	0	0	0
Nukon Unjacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Low Density Fiberglass Jacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Mineral Wool Jacketed	46.2	[ft³]	0 – 7	8.66	1.732	6.928	0	0
			7 – 11.9	22.69	2.95	12.25	3.63	3.86
			11.9 -17	14.85	1.19	1.04	6.09	6.53
Low Density Fiberglass Unjacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Calcium Silicate Jacketed	1.42	[ft³]	0 – 2.7	0	0	0	0	0
			2.7 - 5.45	1.42	0.355	0.2272	0	0.8378
Calcium Silicate Cloth Jacketed	3.82	[ft³]	0 – 2.7	0	0	0	0	0
			2.7 – 28.6	3.82	0.96	0.61	2.25	0
Transco RMI	0	[ft²]	0 - 2	0	0		0	-

Small Break number SB3

Insulation Type	Total Amount Destroyed	Units	Subzone (D)	Subzone Total	Fines	Small Pieces	Large Pieces	Intact Blankets or Remains on Target
Nukon/Thermal Wrap Jacketed	23.5	[ft³]	0 – 5	11.17	2.01	4.69	4.47	0
			5 – 7	12.33	0	0	0	12.33
Nukon Unjacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Low Density Fiberglass Jacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Mineral Wool Jacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Low Density Fiberglass Unjacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Calcium Silicate Jacketed	0	[ft³]	0 – 2.7	0	0	0	0	0
			2.7 - 5.45	0	0	0	0	0
Calcium Silicate Cloth Jacketed	0	[ft³]	0 – 2.7	0	0	0	0	0
			2.7 – 28.6	0	0	0	0	0
Transco RMI	0	[ft²]	0 - 2	0	0		0	-

Small Break number SB4

Insulation Type	Total Amount Destroyed	Units	Subzone (D)	Subzone Total	Fines	Small Pieces	Large Pieces	Intact Blankets or Remains on Target
Nukon/Thermal Wrap Jacketed	10.79	[ft³]	0 – 5	10.56	1.90	4.44	4.22	0
			5 – 7	0.23	0	0	0	0.23
Nukon Unjacketed	0.89	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0.89	0.071	0.062	0.365	0.392
Low Density Fiberglass Jacketed	0.96	[ft³]	0 – 7	0.48	0.096	0.384	0	0
			7 – 11.9	0.41	0.0533	0.2214	0.0656	0.0697
			11.9 -17	0.07	0.006	0.005	0.029	0.031
Mineral Wool Jacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Low Density Fiberglass Unjacketed	0	[ft³]	0 – 7	0	0	0	0	0
			7 – 11.9	0	0	0	0	0
			11.9 -17	0	0	0	0	0
Calcium Silicate Jacketed	2.14	[ft³]	0 – 2.7	0.51	0.255	0.255	0	0
			2.7 - 5.45	1.63	0.4075	0.2608	0	0.9617
Calcium Silicate Cloth Jacketed	0	[ft³]	0 – 2.7	0	0	0	0	0
			2.7 – 28.6	0	0	0	0	0
Transco RMI	0	[ft²]	0 - 2	0	0		0	-

NRC Request

- *Provide assumed specific surface areas for fibrous and particulate 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.*

ENO Response

The NUREG/CR-6224, "Parametric Study of the Potential for [Boiling Water Reactor] BWR ECCS Strainer Blockage Due to LOCA Generated Debris," constants for specific surface area in the table below were applied in the head loss calculation for the passive strainer assembly. Additionally, the NUREGICR-6224 correlation was applied to the initial sizing of the strainer design. However, the final PNP strainer design is based on testing prototypical plant configurations. The values in the table below were used for NUREG/CR-6224 scoping evaluations in support of the November 2008 testing.

NUREG/CR-6224 Design Inputs for Scoping Calculations for S5 Break					
Fibrous Debris Type	**As-Fab. Volume (ft^3)**	**Mass (lbm)**	**As-Fab. Density (lbmlft)**	**Solid Density (lbmlft)**	**Specific Surface Area (ft^2/ft^3)**
NUKON/Thermal Wrap - Jacketed	180.216	432.5184	2.4	159	173,913
Low Density Fiberglass - Jacketed	5.008	12.0192	2.4	159	173,913
Low Density Fiberglass - Unjacketed	0.306	0.7344	2.4	159	173,913
NUKON - Unjacketed	0.295	0.708	2.4	159	173,913
Mineral Wool - Jacketed	29.691	237.528	8	90	240,000
Latent Debris - Fiber	12.5	30	2.4	159	173,913
Fiber Mixture	228.016	713.508	3.1292	126.6706	207,514.80
Particulate Debris Type	**Sludge Volume (ft^3)**	**Mass (lbm)**	**Sludge Density (lbm/ft)**	**Solid Density (lbm/ft)**	**Specific Surface Area (ft^2/ft^3)**
Latent Particulate (Dirt & Dust)	1.7	170	100	156	462,000
Carboline Phenolic 300 P/F	23.9896	460.6	19.2	94	183,000
Carboline Carbozinc 11	8.5718	799.75	93.3	457	183,000
Inorganic Zinc Silicate	7.1024	662.65	93.3	457	183,000
Unqualified Coatings	98.4063	1,889.40	19.2	94	183,000
Calcium Silicate Cloth Covered	4.305	62.423	14.5	94	457,200
Calcium Silicate Metal Jacketed	15.317	222.097	14.5	94	457,200
Particulate Mixture	159.3921	4,266.92	26.77	132.0351	236,640.70
Particulate/Fiber Mass Ratio			5.9802		
Bed Specific Surface Area			232,548.20	(ft^2/ft^3)	

Note: All the coatings used the same particle size and specific surface area

To facilitate a holistic approach to head loss testing, a CFD model of the PNP containment sump was performed at ARL under the direction of AREVA.

The calculated debris amounts were used by AREVA, along with the CFD results, and debris characteristics inherent in their standard methodology, to compute the quantity, size, and amount of debris that arrives at the screens. This debris, or surrogates for this debris, was used in the ARL large flume test that forms the basis for the design of the PNP containment sump strainers. Also, included in this flume test were scaled amounts of the chemical precipitates that are predicted by the PWROG WCAP-16530-NP (Reference 3.c.3) spreadsheet, as modified by WCAP-16785-NP (Reference 3.c.4) for aluminum and silicon effects. The debris was generated per WCAP-16530-NP, Section 7, and PCI's white paper on debris generation (Reference 3.c.2).

Since the "bounding design basis test" was successfully completed, the appropriately scaled amount of debris and chemical precipitates in the flume during that test are the design basis of the PNP sump strainers.

NRC Request

- *Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance.*

ENO Response

The technical bases for debris characterization assumptions are provided below in the noted references for low density fiberglass, mineral wool and CalSil. Since the existing guidance documents only report a two size distribution for a single ZOI, it is necessary to do further analysis to get the desired 4 component size distribution for transport analysis and flume testing. Size distributions were provided by Alion and Westinghouse.

Alion provided the size distributions for most of the insulation debris material. The basic approach was to curve fit existing NUREG and industry test data to produce damage fractions versus destructive pressure. The chosen ZOIs each have a destructive pressure range associated with them. The particle size curves are integrated over this range of pressures (e.g., 0-6 psi, 6-12 psi, 12-24 psi, etc.) to get the size distribution for each ZOI and sub-ZOI for each material. References 3.c.5 and 3.c.7 give the data and the details of the process used to get the size distribution.

Size distributions for jacketed Nukon and Thermal Wrap insulation from 0 to 7 D were provided by Westinghouse via Reference 3.c.8.

The rest of the debris, including qualified coatings with a ZOI of 10D and 100% transport of non-qualified coatings, is consistent with the NRC-approved guidance.

In summary, refer to the above tables for breaks S5, S6, SB1, SB2, SB3, and SB4:

The debris generation calculation gives the values in the column titled "Subzone Total."

The size distribution calculation described here then gives the values in the in the last four columns, "Fines," "Small Pieces," "Large Pieces," "Intact Pieces or Remains on Target."

S5 is the worst large break for fiber, S6 is the worst break for CalSil, and SB2 (with its 46 cu ft of mineral wool) is believed to be the worst small break for most purposes.

The remaining requests below in this section are from the December 24, 2008 NRC RAI

NRC Request

2. Section 3.c of the supplemental response does not provide debris characteristics for all of the debris types listed on Page 17 of the response. Therefore, please provide the following information requested by the NRC Content Guide needed by the NRC staff to complete its debris characteristics review:

a. The size distribution for calcium silicate debris (both that debris generated within a break ZOI and from containment spray impingement) and the assumed resultant particle size.

b. The size distribution for fibrous debris generated by containment spray impingement on fibrous insulation.

c. The size distribution for debris generated from Marinite board.

d. The form assumed for all types of unqualified coatings (i.e., particulate or chips) and the assumed characteristic sizes for each debris type. Page 59 of the supplemental response states the methodology for determining the form of unqualified coatings debris (it was assumed to be particulate unless supported by specific testing to prove otherwise), but the final result of applying this methodology to the specific quantities of these coatings present at Palisades was not clearly stated.

ENO Response

For Items a and b, containment spray is not considered a debris generator for intact items not in the ZOI. The calcium silicate was redefined to have a ZOI of 28.6D if it had cloth jacketing with mastic applied. Its size distribution is covered in the tables. There,is a small quantity of unjacketed fiberglass (0.6 cu ft) and it is treated as having a ZOI of 17D and has the same size distribution as jacketed fiberglass. Outside the ZOI it is not eroded by spray.

Debris from erosion of submerged insulation is modeled as fines

For item c, the Marinite® is assumed to be in large pieces and it does not transport or erode. This is consistent with the NEI guidance.

For item d., the unqualified coatings are assumed to be paint, as shown in the below Tables 2d.1, 2d.2, and 2d.3 from Reference 3.c.9. Per Reference 3.c.10, they are modeled in the flume test as:

The total 21.1 ft^3 unqualified coatings should be split as shown:

- 2.42 ft^3 fail as chips. Use appropriate chip surrogate assuming epoxy paint (Modeled as acrylic chips 1/64" to ¼").
- 4.35 ft^3 fail as dense aluminum paint (or denser coating), which has a specific gravity of 2.7. Use appropriate powder surrogate modeled as SIL-CO-SIL 53 powder
- 0.25 ft^3 fail as dense Carbozinc 11. Use appropriate powder surrogate modeled as SIL-CO-SIL 53 powder
- The balance, 14.08 ft^3, can be considered failed alkyd coatings modeled as acrylic powder surrogate.

Table 2d.I-Epoxy Coatings That Fail as Chips

Component	Surface Area (Sq. Ft.)	Thickness (Mils)	Volume (ft^3)
Reactor Lift System	2242	12	2.42
Total			**2.42**

Table 2d.2-Dense Coatings

Component	Coating	Surface Area (Sq. Ft.)	Thickness (Mils)	Minimum Specific Gravity	Volume (ft^3)
Containment Air Coolers	Lead Primer/Iron Oxide Rust[1]	12,410	2.5	5.24	2.59
Pipes and Supports	Aluminum Paint[2]	4,235	5	2.7	1.76
Reactor Coolant Pump D	Carbozinc (zinc primer)	1200	2.5	7.1	0.25
Total					**4.6**

[1] The density of iron oxide is conservatively provided. The density of the red lead (lead oxide) is higher than the density of iron oxide.
[2] The density of aluminum is conservatively provided. A large portion of the coatings are likely to be iron oxide or red lead (lead oxide). However, a specific reference identifying what portion of the coatings are aluminum, iron oxide or red lead (lead oxide) was not identified.

Table 2d.3-Unidentified Coatings

Coating Classification	Volume (ft^3)
Degraded	0.615
Unqualified	12.44
Total	**13.05**

NRC Request

3. *When the final supplemental response is submitted, please include a discussion of any changes that have been made to the analysis that are associated with debris characterization at a level of detail consistent with the NRC supplemental response content guide. The NRC staff will review this information when submitted, and as a result of such review, the NRC staff could request additional information in this subject area if needed.*

ENO Response

A review of the November 21, 2007, version of the content guide was performed. The above provided information is consistent with the level of detail required by the content guide.

As a clarification, ENO has not performed any destruction testing in determining the ZOIs for its insulation materials that have not been previously made available to the NRC.

Westinghouse, Alion and Enercon have re-analyzed some of the existing NUREG and licensee test data to fit the PNP GSI-191 situation. Those reports are referenced in this section and restraint of some of the details is necessary to protect those organization's interests.

Similarly, the technical basis for the deviations from NRC approved guidance for debris characterization assumptions, if any exist, are also covered in these referenced reports. Every effort was made to minimize these deviations. In any case, none of the technical methods or data applied are unique to PNP. The details and NRC approval tools are many, varied, and sometimes subjective. It is therefore difficult to make a simple conclusive summary statement.

The final PNP design basis flume test did rely on a PCI/AREVA/Alden Research "holistic" test "protocol," which covered issues such as debris surrogates, flume debris introduction techniques, flume debris introduction rates and concentrations, and other items at the fringe of formal NRC review and formal acceptance. These "test protocol" criteria were informally presented to the NRC by various methods before testing began, and later by NRC attendance at tests. In some cases, NRC lack of "disapproval" might have been interpreted as tacit approval. This condition and these methods were shared by all licensees that used the PCI strainers and who tested at the ARL facility and were, primarily, not PNP specific. Before any safety related testing began, these "protocol" guided inputs were formally swept into the PNP-specific test plan where they were enforced, documented, signed off, and preserved. The test plan (Reference 3.c.12) was made available to the NRC during a site visit.

NRC Request

4. *Please provide the physical properties of the Alpha Maritex cloth material land the characteristic form and size of the debris formed from this material (e.g., fines, small pieces). In addition, please provide the technical basis for determining the transportability of debris generated from Alpha Maritex cloth.*

ENO Response

4. Permanent lead blankets inside containment at PNP are controlled by the as low as reasonably achievable (ALARA) program and are described as follows:

    There are two layers of covering made of Alpha Maritex per military specification MIL-Y-1140C for glass cloth. The material of the inside covering is made of 15 ounces per square yard material and the outside covering is made of heavier specification of 34 ounces per square yard.

    The covering is designed for continuous temperature of +500 degrees F. and meets NRC Regulatory Guide 1.36, "Nonmetallic Thermal Insulation for Austenitic Stainless Steel," as well as military specification MIL-1-24244 for insulation material.

    Drawing C-279 contains note 4 that states the Alpha-Maritex is style 8459-2-SS (or equivalent).

    WCAP-16727 (Reference 3.c.11) describes characteristic debris size and form as:

Approximately 25% of the outer cover material and approximately 10% of the inner cover material is destroyed and is characterized as small pieces and strands of material (fines). Debris consisting of the lead blanket cover material has been shown to readily settle on deposition.

Sedimentation tests of particles in the WCAP-16727 document show that the material settles quite rapidly. WCAP-16727 page 1-4 states:

Once the debris has settled, transport is unlikely due to the low velocities expected to be present in the post LOCA sump environment. Transport experimentation performed with paint chips (Reference 5) shows that chips do not readily transport at flow velocities of 0.2 ft/sec or less. Since the cover materials (inner and outer covers) have a density and thickness similar to coatings applied in containment, it is expected that transportability of the lead blanket cover material would be similar.

The above concept is again restated in section 8.4 of the WCAP as follows:

8.4 DEBRIS CHARACTERIZATION

The debris characterization evaluation presented in Appendix A was designed to determine the specific gravity and settling characteristics of samples (sedimentation test), and to provide insight into how the material would perform when subjected to high temperatures. The samples for the debris characterization test were taken from the inner and outer covers of the lead blanket (#1) used in the High Temperature Soak Test. The specimens were allowed to dry after the High Temperature Soak Test and the dimensions and weights of each sample were recorded. Samples were cut from both the inner and outer 'front' cover of the lead blanket. Sample swatches ranging in size from ½ x ½ inches, up to 2 x 2 inches were used in the debris characterization. Details of the sedimentation test can be found in Table 6 of Appendix B, which shows that all of the samples readily settled within 8 seconds and on average within 5.4 seconds.

The debris characterization evaluation indicates that any blanket cover material debris resulting from direct jet impingement would readily settle immediately on deposition following the impact. Once the debris has settled, transport is unlikely due to the low velocities expected to be present in the post LOCA sump environment. Transport experiments performed with paint chips (Reference 5) show that chips do not readily transport at flow velocities of 0.2 *ft/sec* [feet per second] *or less, and that the incipient velocity required for initiation of transport is, on average, much greater than 0.2 ft/sec. Since the cover materials (inner and outer covers) have a density and thickness similar to coatings applied in containment, it is expected that its transportability would be similar. Reference 5 indicates that the small percentage of paint debris that was transported to the sump screen was mostly floating on the surface. As noted above, test samples of the blankets' cover materials readily sank. Results from this portion of the test program show that the cover materials will readily settle and are unlikely to transport.*

Description of the testing of the Alpha-Maritex material by ENO at Alden Research is provided below.

To determine the transportability of the Alpha-Maritex, cut squares of this material were placed in the design basis flume test at Alden Research. The material did not transport beyond the depth of the flume. The test flume was specifically set up to represent transport flow in the PNP containment.

Since they were being treated as foreign material, the material squares were not seen as needing a size distribution. Conservatively, small pieces were chosen for testing. Typical of other foreign materials, no guidance was given in NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," for this material.

The above PNP flume test experience supports WCAP-16727 test results.

References

3.c.1 Palisades EA-MOD-2005-04-10, "Head Loss Calculations Supporting Resolution of GSI-191," August 3, 2005

3.c.2 PCI White Paper, "Sure-Flow ® Suction Strainer – Testing Debris Preparation & Surrogates," Technical Document No. SFSS-TD-2007-004, Revision 4, January 16, 2009

3.c.3 WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," Revision 0, PWROG, Westinghouse Electric Company LLC, February 2006.

3.c.4 WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model," Revision 0, PWROG, Westinghouse Electric Company LLC, May 2007.

3.c.5 Enercon ENTP-003-PR-02, "Project Report for Entergy: GSI-191 Debris Size Distribution and Debris Erosion Report for Palisades Nuclear Station," dated February 5, 2009

3.c.6 WCAP-16836-P, "Arkansas Nuclear One – Jet Impingement Testing of Insulation Materials" Westinghouse Electric Company LLC, October 2007

3.c.7 ALION-REP-ALION-2806-01, Revision 3, "Insulation Debris Size Distribution for use in GSI-191 Resolution," April 13, 2006

3.c.8 Westinghouse Letter Report CPAL-09-3, "Fibrous Debris Size Distribution for Palisades Nuclear Plant Based on Jet Impingement Testing of Jacketed NUKON Insulation Pillows Reported in WCAP-16710-P," January 30, 2009

3.c.9 ENERCON Services Report Number: ENTP-003-PR-03, "Unqualified and Degraded Coatings Evaluation for Palisades Nuclear Station," February 5, 2009

3.c.10 E-mail from G.H.Goralski, Entergy to Jim Bleigh, PCI, October 28, 2008 Subject: "Design Input for Palisades Strainer Testing - Updated" with attached document "Palisades Strainer Testing Design Input," October 28, 2008

3.c.11 WCAP-16727-NP, Revision 0, "Evaluation of Jet Impingement and High Temperature Soak Tests of Lead Blankets For Use Inside Containment of Westinghouse Pressurized Water Reactors," November 2007

3.c.12 AREVA Document 63-9095797-001, "Palisades Test Plan for ECCS Strainer Performance Testing," as completed version, December 4, 2008

3.d. Latent Debris

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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.*

ENO Response

The quantity of latent debris in containment is documented in the "Calculation for Latent Debris (Dust & Lint) for Palisades Containment for Resolution of GSI-191" (Reference 3.d.1). This calculation documents the results of the containment latent debris sampling walkdown, which confirmed, based on 46 sample locations within containment, that the latent debris quantity in containment is approximately 156 pounds. Therefore, the 200 pounds of latent debris quantity assumption previously used in the debris generation and transportation calculation was conservative.

The latent debris evaluation provided a reasonable approximation of the amount and types of latent debris existing within the containment and its potential impact on sump screen head loss. A statistical approach was used to determine the amount of latent debris accumulated in the PNP containment area that will impact the assessment of effects of GSI-191 events. A 90% confidence level was used for this calculation.

NRC Request

- *Provide the basis for assumptions used in the evaluation.*

ENO Response

It was assumed that the debris is normally distributed for a given surface type. This assumption is supported by walk-down observation that debris distribution appeared to be uniform for a given surface type. Vertical surfaces typically do not gather significant amounts of dust and lint, hence, vertical sample weights are generally lower than the weights of the horizontal samples.

Also assumed were the duct run, cable tray run and piping run dimensions identified through review of heating ventilation and air conditioning (HVAC) duct, cable tray and piping drawings. Various structural steels, concrete, equipment, and other miscellaneous components were identified from available drawings. Where applicable, dimensions were extracted by scaling from these drawings. Dimensions were approximated on the conservative side. Additional lengths were added in the area calculation to account for any missing items, and to add additional conservatism.

A final assumption was made due to limited access to horizontal HVAC ducts that no samples were taken of this type of surface. Samples collected for horizontal cable trays were used for horizontal HVAC ducts due to their structural similarities in surface areas.

NRC Request

- *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 **c.** above.*

ENO Response

"Calculation for Latent Debris (Dust & Lint) for Palisades Containment for Resolution of GSI–191" (Reference 3.d.l) documents the results of the 2006 refueling outage containment latent debris sampling walkdown, which confirmed, based on 46 sample locations within containment, that the latent debris quantity in containment is approximately 156 pounds. For PNP design basis analysis and strainer testing, 170 pounds of fine particulate and 30 pounds of fine fiber was assumed for the latent debris.

The request below is from the December 24,2008, NRC RAI.

NRC Request

5. *The February 27,2008, GL 2004-02 Supplemental Response (ADAMS Accession No. ML080630253) stated that samples were taken for containment latent debris during the 2006 refueling outage. However, sufficient detail was not provided regarding the types of areas sampled, the number of samples taken for each area type, and the containment elevations sampled. Please provide these details, and describe how the sample results were extrapolated in order to estimate a total latent debris amount in the containment.*

ENO Response

The latent debris sampling and the analysis of the data were done by Sargent & Lundy using methodology used for other pressurized water reactor (PWR) plants.

The containment was divided into different types of surfaces. The total area of each type of surface in containment was calculated.

The surface types were:

- Floor Areas
- Containment Liner
- Horizontal Ventilation
- Vertical Ventilation
- Horizontal Cable Trays
- Vertical Cable Trays
- Walls
- Horizontal Equipment
- Vertical Equipment
- Horizontal Piping
- Vertical Piping
- Grating
- Miscellaneous Items

A sample plan was developed to sample each type of surface in various accessible areas.

Each chosen area was sampled, the sample was bagged, and the area sampled was recorded. Forty-six samples were taken from the twelve types of areas. The miscellaneous items were not sampled. Table 3d1 below summarizes the sampling for each surface type.

Table 3dl Surface Type Sample Area

Surface Type/ Elevation	Surface Area Sampled (ft^2) Per Elevation (#Samples)	Surface Area Sampled (ft^2) Total	Total Containment Area for Surface Type (ft^2)
Floor Areas		32.00	18,778
590'	19.00 (2)		
649'	13.00 (2)		
Containment Liner		35.03	68,876
590'	19.78 (2)		
Below 607'-6"	6.25 (1)		
Below 625'	9.00 (1)		
Horizontal Ventilation	None (horizontal cable tray data used)		4,860
Vertical Ventilation		21.20	9,752
590'	14.83 (2)		
625'	2.60 (1)		
649'	3.67 (1)		
Horizontal Cable Trays		22.32	6,078
590'	12.00 (3)		
Below 625'	6.94 (1)		
Below 649'	3.38 (1)		
Vertical Cable Trays		23.04	2,415
590'	15.63 (1)		
Above 590'	3.28 (1)		
607'-6	1.88 (1)		
Below 649'	2.25 (1)		
Walls		38.00	72,142
590'	24.25 (2)		
607'-6	6.25 (1)		
Below 649'	7.50 (1)		
Horizontal Equipment		12.67	4,474
590'	11.27 (3)		
625'	1.40 (1)		
Verticai Equipment		20.70	17,396 17,396
590'	10.50 (1)		
607'-6	4.42 (1)		
625'	5.78 (2)		
Horizontal Piping		21.57	17,319
590'	9.75 (2)		
625'	0.93 (1)		
Below 649'	2.36 (1)		
649'	8.53 (1)		
Vertical Piping		14.21	14,763
590'	9.43 (2)		
607'-6	1.78 (1)		
Below 625'	3.00 (1)		
Grating		2.70	4,129
607'-6	0.42 (1)		
Below 649'	0.63 (1)		
649'	1.65 (2)		

The samples were weighed and divided by the area sampled to get a surface loading in weight per unit area. Multiple samples of like surfaces were averaged. The data was statistically analyzed and a 90% confidence upper limit was obtained.

The total area within containment was multiplied by the 90% upper limit unit surface loading to get the total latent debris on each surface type.

The total latent debris in containment was obtained by adding all of the surface type totals.

Miscellaneous items, such as various structural steel, pipe, conduit, cable tray, support steel, control rod drive mechanisms, cooling fans, heat exchangers and smaller items such as junction boxes, valve operators, air handlers, seismic restraints, hanging lamps, electrical panels, monitoring devices, and others, are not addressed individually in this calculation. The conservatism adopted in the calculation in estimating total areas of major items addressed above is considered to provide enough margin to cover areas of miscellaneous items inside the containment.

The total latent debris in containment is estimated to be 156 pounds. However, the originally assumed 200 pounds was retained in the calculations of debris loading for the design basis flume test.

End of the December 24,2008, NRC RAI

NRC Request

- *Provide amount of sacrificial strainer surface area allotted to miscellaneous latent debris.*

ENO Response

A postulated amount of 200 pounds latent debris was characterized as 30 pounds of fibrous debris and 170 pounds particulate debris. These two debris types were incorporated into the total LOCA-generated debris in sizing the total required strainer surface area.

A miscellaneous debris walkdown was performed at PNP in 2004 as a part of the insulation walkdown. In the original ENO February 27, 2008, supplement, it was not well noted that NEI 04-07 section 3.5.2.2.2, "Evaluate the Quantity of Other Miscellaneous Debris," was a part of the latent debris issue since a good part of this material was in containment as the result of past accepted practice. The above RAI answer from the March 20, 2009, ENO response, in effect, corrects that notation. Although none of the miscellaneous debris transported in the flume test, ENO has reserved 100 sq.ft. of strainer area for possible miscellaneous debris that might be found in containment in the future that might not have been covered by flume tested debris types.

References

3.d.1 EA-MOD-2005-004-12, "Calculation for Latent Debris (Dust & Lint) for Palisades Containment for Resolution of GSI-191," Revision 0, July 18, 2006

3.d.2 Work order WO 26555 latent debris walkdown results April 21, 2006, includes plan and completed data sheets, completed April 24, 2006

3. e. Debris Transport

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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.

ENO Response

Two different debris transport analyses methods have been used for PNP.

<u>Original Method</u>

The original effort reported in the response to GL 2004-02 used the "baseline" method (Reference 3.e.l). This method uses only the default generically accredited transport attrition allowed by NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," (Reference 3.e.4) in the decision trees given on page 3-53.

No credit is taken for settlement of debris, other than that incorporated into NEI 04-07 generic tables, in the original "baseline" analysis for head loss across the sump screen.

The original method was included in the previous supplemental response because it justified earlier material on the docket provided in responses to GL 2004-02.

The original method, which was mostly generic, has been superseded by more PNP-specific analysis previously called Refined Transport Analysis that is described below.

<u>Refined Transport Analysis</u>

The baseline analysis was applied as an input in sizing the 2007 installed sump passive strainers, but the design basis for the strainers used the CFD-based transport methodology.

For the final "holistic" test methodology, including chemical effects testing, it was necessary to reduce conservatism. A series of CFD analyses were performed by AREVA and Alden Research Lab for use in configuring the test flume for the May 2008 and the November 2008 testing. The November testing was designed to execute a "test for success" strategy to minimize the time to reach a GSI-191 solution. This required multiple CFD cases. All of the CFD analysis, except the portion supporting successful test number 4, is considered historic and not a portion of the plant design basis. The results of the CFD were used for refined transport analysis based on sump flow patterns and velocities on the containment floor.

The debris quantities predicted by the debris generation calculation (see Sections 3.a, 3.b, and 3.h) were included in the CFD analysis, and the quantity that reached the sump strainer assemblies was listed in the CFD report. The type and amount of each type of debris that reached the strainers became a part of the strainer design bases. The original baseline analysis and debris quantities became historic documents at that point.

The debris that reached the vicinity of the sump strainer assemblies from the CFD analysis were used to compute, based on test flume scaling factors, the amount of debris or surrogate debris material to be placed in the test flume during the final holistic strainer pressure drop and bypass testing.

Additional adjustments are also made to the chemical precipitate calculation to reduce previously employed excessive conservatisms. This helped to retain the ECCS design margin for the strainers. Since all (100%) chemical precipitates are assumed to transport to the strainers, no transport adjustments were required for the precipitates.

The test plan, the test protocol, the flume setup, and the debris addition techniques used for the final holistic design basis testing, were designed to allow for near field settlement of any or all the debris tested to the same extent it would be expected to happen in the containment sump post-LOCA. This would include chemical precipitates as well, should that occur.

Details of the CFD Transport Analysis (Reference 3.e.3)

Blowdown

During blowdown, 25% of small fine debris will transport to the 649 ft. elevation of containment with a portion of that debris transporting back down to the 608 ft. 6 in. elevation. This assumption adheres to NEI 04-07 guidelines (Section 3.6.3.1.) for a highly compartmentalized containment.

During blowdown, 75% of small fine debris will remain on the 608 ft. 6 in. elevation of containment and be susceptible to transport. This assumption adheres to NEI 04-07 guidelines (Section 3.6.3.1.) for a highly compartmentalized containment.

Debris that transports into upward levels by blowdown is assumed to distribute evenly across the entire 649 ft. elevation. This is reasonable since there are very few obstructions on this level, and the volume above is wide-open.

Large debris generated on the 608 ft. 6 in. level will not transport to the basement. This is a reasonable assumption since large debris will either settle during pool fill, be unable to overtop the curbing, or be held from further transport by stairwell grating. This calculation treats this as 0% transport of large debris.

Washdown

The percentage of debris that transports through each individual flow path is directly proportional to the breaklspray flow rates through that flow path.

It is conservative to ignore any grating and assume that all debris that transports from the 649 ft. elevation, via the two flow paths that bypass the 608 ft. 6 in. elevation, reaches the basement 590 ft level.

Small Debris From 649 ft. elevation

Per NEI guidance, 25% of all small fine debris generated during blowdown travels upward through the 649 ft. elevation of containment. It is conservatively assumed that all debris transporting to the 649 ft. elevation will distribute evenly across that level. Immediately following blowdown transport, some of the RMI and non-RMI debris will leave the 649 ft. elevation by falling unobstructed through flow path openings in the 649 ft. level floors. All remaining non-RMI debris is conservatively assumed to transport via spray header run-off flow through the same openings. This non-RMI debris will land on either steam generator (SG) A or B floors, or an opening in the 608 ft. 6 in. elevation leading directly to the 590 ft. level basement. However, according to NEI 04-07, RMI small fine debris will not transport via spray header run-off flow.

Small Debris From 608 ft. 6 in. elevation

Based on NEI guidance, 75% of all small fine debris generated during blowdown will remain on SG A or B floors. During washdown, this level is susceptible to spray and spray run-off flow from the 649 ft. elevation during pool fill due to curbing, run-off curb overtopping and run-off via uncurbed sections of floor. Sheeting action and incipient tumbling velocities are such that it is reasonable to assume that all small fine debris will eventually transport to one of six proximity zones at the 590 ft. basement level via various flow paths through the 608 ft. 6 in. elevation. Debris transport from the SG A and B floors is assumed to be proportional to the amount of run-off flow leaving the SG floors.

Large Debris 649 ft. elevation

Based on NEI 04-07, no large debris will transport to the 649 ft. elevation.

Large Debris 608 ft. 6 in. elevation

It is expected that large debris generated will not transport off SG Room A or B floor. Any large debris that does transport to the basement during the initial LOCA blast will settle and not transport to the strainers. The large debris that remains on the 608 ft. 6 in. elevation will be subject to erosion due to break flow and containment spray. The large debris will be eroded to fine debris and distributed to the applicable proximity zones utilizing the ratio of the flow exiting each flow path to the total flow draining off of the 608 ft. 6 in. elevation.

Figure 3el Spray and Run-Off Flow Paths into Palisades **590 ft.** Level

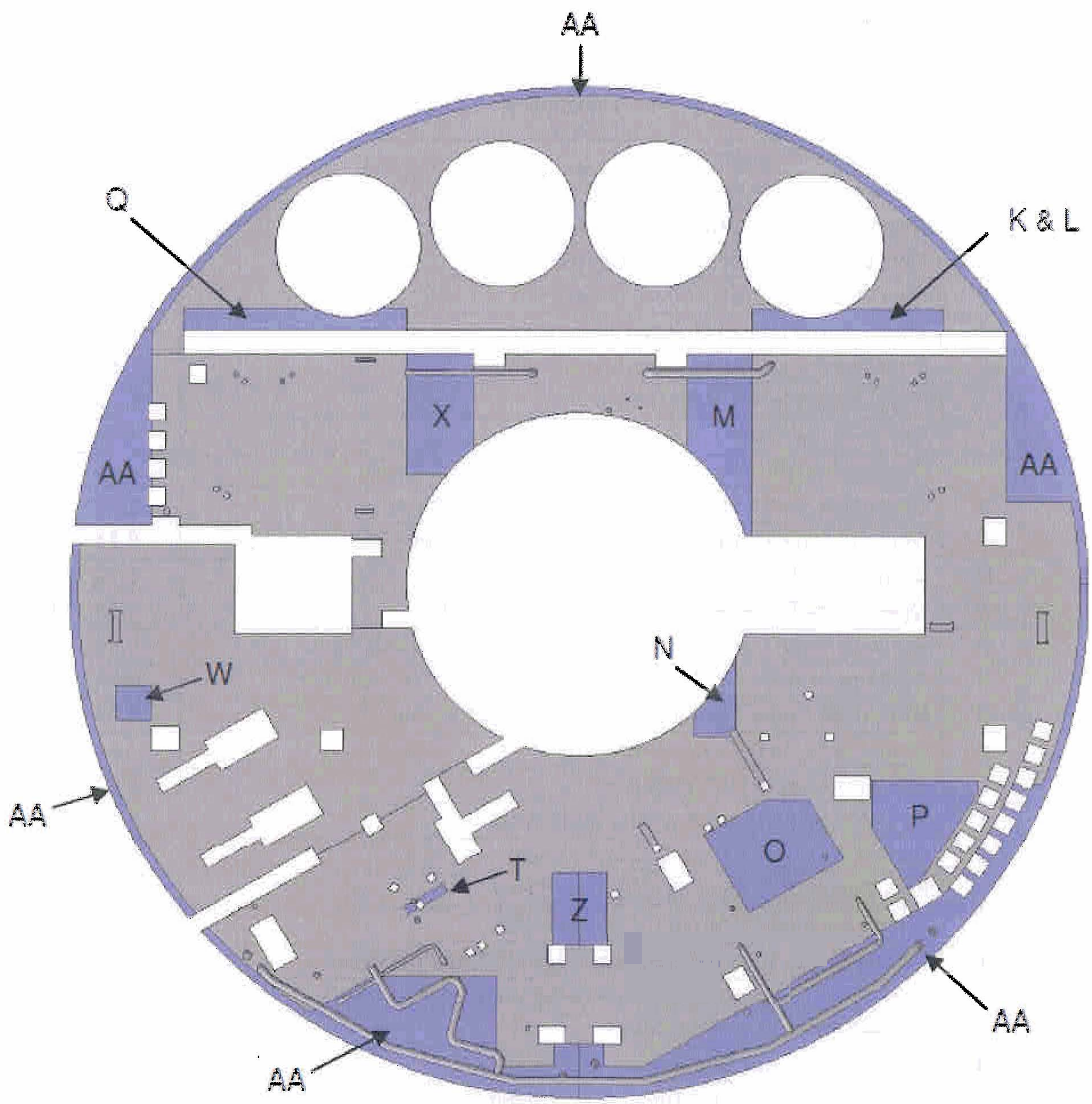


Table 3e1 Total Break and Spray Flows

Flow	gal/min	ft^3/s
Spray Flow	1987	4.43
Break Flow	1487	3.31
TOTALS	3474	7.74

Table 3e2 Spray and Break Flows via Paths Defined in the CFD Input for A and B SG Side Breaks

Path	Description	Break A ft^3/s	Break B ft^3/s
A	Opening into Refueling Cavity	3.47	0.47
B	Opening for Steam Generator A	3.33	0.33
C	Opening for Steam Generator B	3.33	0.33
D	Floor Opening to East of Steam Generator A	0.69	0.69
E	Floor Opening to East of Steam Generator B	0.69	0.69
F	Floor Opening to West of Steam Generator A	0.26	0.26
G	Floor Opening to West of Steam Generator B	0.50	0.50
H	Floor Opening to NW of Pressurizer Shed	0.23	0.23
I	Crane Access Hatch	0.09	0.09
J	Opening Between Inner Contarnment and Containment Wall	0.83	0.83
K	Uncurbed Cable Trench Leading to CWST Room	**1.59**	**1.17**
L	Spillage Over Curbing Adjacent to CWST Room	**0.71**	**0.00**
M	Opening to Basement SE of Reactor Shield	**0.76**	**0.08**
N	Opening to Basement SW of Reactor Shield	**1.04**	**0.48**
O	Spillage Over Curbing to Basement Under Quench Tank	**0.86**	**0.20**
P	Spillage to Basement through Grating under Pressurizer	**0.35**	**0.05**
Q	Uncurbed Cable Trench Leading to CWST Room	**0.09**	**0.29**
R	Stairs Leading to SDC Valve Room	0.67	2.13
S	Run-off Leading to SDC Valve Room	0.27	0.97
T	Passage under Fuel Transfer Structure	**0.19**	**0.70**
U	Run-off into West Opening SDC Va ve Room	0 17	0.62
V	Flow Through East Opening SDC Valve Room	0.98	3.14
W	Flow into Basement via North Stairwell	**1.15**	**3.75**
X	Opening into Basement to Northeast of Reactor Shield	**0.08**	**0.08**
Y	Spray Flow Intercepted by Steam Pipe Support Platform	0.13	0.13
Z	Run-off through Crane Hatch	**0.22**	**0.22**
AA	Direct Spray into Basement	**0.70**	**0.70**

Note: Bold entries denote paths that flow into basement. Refer to figure 3e1 above.

Pool-fill-up

Washdown occurs during fill up. All vertical migration of debris in containment, including fill-up phase erosion, is assumed to occur during fill-up.

The percentage of debris that transports through each individual flow path is directly proportional to the break/spray flow rates through that flow path.

The containment floor is divided into six zones. Approximately 32 separate flow paths (A through AA and six J paths) for break flow and spray flow are defined from the upper elevations, each of which lands in one of the six zones or on the 608 ft. elevation and re-transports to one of the 6 zones. During fill-up, the debris stays (assumed uniformly distributed) within the zone in which it dropped, and does not move until after RAS. No CFD case was done to mockup the "sheeting" flow process and variable depths that would exist during fill-up. Since no bias toward the screens exists, and the debris would be transported away from the higher velocity water fall locations, this is conservative. It is noted that a part of the PNP sump, which has a floor elevation of 585 ft. would cause flow in this direction for a very short period during fill-up.

The volume of this area is $V = \pi R^2 H = 3.14 \times 11 \times 11 \times 3.5 = 1330$ cu ft out of 30,000 cu ft minimum sump volume, or 4.4% of the sump volume. Most of this water would be expected to be hot PCS water out of the break and would likely precede spray flow actuation.

Table 3e3 Base Case Break S5 Debris Allocation Table for Alden CFD Input

	Debris Type	Size	Units	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Insulation	Nukon / Thermal Wrap Jacketed	Eroded Large*	ft^3	9.297	2.749	0.000	6.104	0.000	0.000
		Large		0.000	0.000	0.000	0.000	0.000	0.000
		Small	ft^3	81.011	25.259	2.001	64.508	4.993	12.768
		Fine	ft^3	34.71[illegible]	10.838	0.858	27.645	2.140	5.472
	Calcium Silicate Metal Jacketed	Large	ft^3	[illegible]	0.000	0.000	0.000	0.000	0.000
		Small	ft^3	4.094	1.278	0.101	3.260	0.252	0.645
		Fine		[illegible]	1.789	0.142	4.563	0.353	0.903
	Transco RMI	Large	ft^2	0.000	0.000	0.000	0.000	0.000	0.000
		Small	ft^2	251.669	76.486	3.295	184.214	8.425	15.054
		Fine	ft^2	0.000	0.000	0.000	0.000	0.000	0.000
	Low Density Fiberglass Jacketed	Eroded Large*	ft^3	0.021	0.006	0.000	0.014	0.000	0.000
		Large	ft^3	0.000	0.000	0.000	0.000	0.000	0.000
		Small	ft^3	3.150	0.983	0.078	2.508	0.194	0.496
		Fine	ft^3	0.782	0.244	0.019	0.623	0.048	0.123
	Calcium Silicate Cloth Covered	Eroded Large*	ft^3	0.576	0.170	0.000	0.378	0.000	0.000
		Large	ft^3	0.000	0.000	0.000	0.000	0.000	0.000
		Small	ft^3	0.825	0.257	0.020	0.657	0.051	0.130
		Fine	ft^3	1.212	0.378	0.030	0.965	0.075	0.191
	Low Density Fiberglass Unjacketed	Eroded Large*	ft^3	0.001	0.000	0.000	0.000	0.000	0.000
		Large	ft^3	0.000	0.000	0.000	0.000	0.000	0.000
		Small	ft^3	0.196	0.061	0.005	0.156	0.012	0.031
		Fine	ft^3	0.047	0.015	0.001	0.037	0.003	0.007
	Nukon Unjacketed	Eroded Large*	ft^3	0.007	0.002	0.000	0.004	0.000	0.000
		Large	ft^3	0.000	0.000	0.000	0.000	0.000	0.000
		Small	ft^3	0.183	0.057	0.005	0.146	0.011	0.029
		Fine	ft^3	0.043	0.013	0.001	0.034	0.003	0.007
	Mineral Wool Jacketed	Eroded Large*	ft^3	1.217	0.360	0.000	0.799	0.000	0.000
		Large	ft^3	0.000	0.000	0.000	0.000	0.000	0.000
		Small	ft^3	34.076	10.637	0.842	27.134	2.100	5.371
		Fine	ft^3	8.204	2.561	0.203	6.533	0.506	1.293
Coatings	*Qualified Coatings*	Large	ft^3	0.000	0.000	0.000	0.000	0.000	0.000
		Small	ft^3	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
		Fine	ft^3	3.433	1.072	0.085	2.733	0.212	0.541
	Unqualified Coatings	Large	ft^3	0.000	0.000	0.000	0.000	0.000	0.000
		Small	ft^3	0.000	0.000	0.000	0.000	0.000	0.000
		Fine	ft^3	8.545	2.667	0.211	6.804	0.527	1.347
	Latent Debris	Large	lb_m	0.000	0.000	0.000	0.000	0.000	0.000
		Small	lb_m	0.000	0.000	0.000	0.000	0.000	0.000
		Fine	lb_m	85.020	26.540	2.100	67.700	5.240	13.400

*The **portion of eroded large debris that transports is made up of fines that eroded off the large debris as a result of reactor blow down and pool fill.**

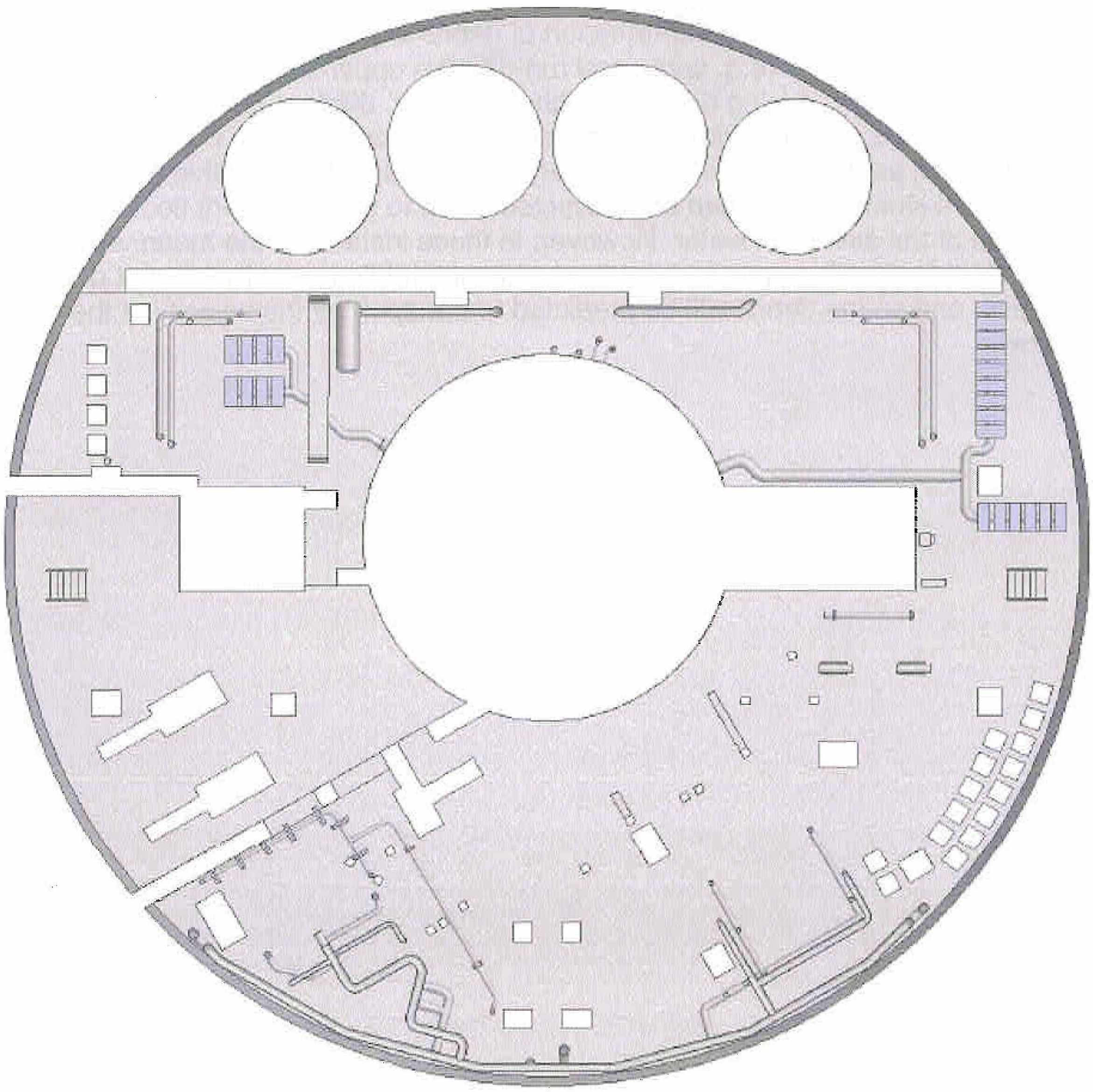
Recirculation

LOCA Break and Spray Flows into Basement

Two limiting break scenarios were modeled in the transport calculations. Break S5 occurs in the hot leg adjacent to SG A, and break S6 occurs adjacent to SG B. The falling water from these breaks would impinge on the 607' level floor of the respective steam generator rooms, combine with spray and run-off, and then drain into the 590' basement by various paths through containment. Non-CFD deterministic calculations were performed to determine the paths and the distribution of flow entering the 590' basement for both A and B side breaks. Each of the flows determined in this calculation was applied as individual mass flow boundary zones on the top of the CFD model. The velocity and mass flux of spray flow through each of these surfaces was assumed to be uniform within its applied boundary area.

Turbulent kinetic energy from the introduction of break and run-off flows was assumed not to influence the transport of debris allocated to the basement floor. For distributed flows (e.g. spray and run-off from upper levels), the turbulence developed by the raining drops, though significant, dissipates very close to the water surface and does not act to suspend debris on the floor. For concentrated flows such as high concentration waterfalls or breaks, it is possible that high turbulent kinetic energy can be convected down to the basement floor due to the inertia of the stream of water. However, in these instances, the mean velocity of the fluid likely will greatly exceed the incipient tumbling velocity of most debris types, and so the debris will be predicted to transport by the velocity of the mean flow.

Figure 3e2 Plan View of Palisades CFD Model with Existing Geometry with 593.25 ft Pool Surface Elevation



Debris Size Classification

ENO provided the size distribution of debris generated by each break (as discussed in section 3.c) in terms of larges, smalls, and generated fines. The transport analysis spreadsheets then allocated this generated debris to each zone, accounting for the creation of additional fines due to the erosion of larges above the 590' level. In order to track the amounts of debris from each source, the fines were tabulated separately. The debris allocation for each zone was presented in four size categories large, small, fine, and fines from eroded larges above the 590' elevation (eroded during washdown and pool fill).

A fifth size classification, fines from eroded smalls in the 590' elevation, accounted for the erosion of allocated smalls remaining in containment during recirculation transport. Each of the sources of fines (generated fines, fines from eroded larges above the 590' elevation, and fines from eroded smalls in the 590' elevation) was tabulated separately to facilitate potential future calculations with different erosion factors, if necessary.

Debris Transport Characteristics
Settling velocities and incipient tumbling velocities for the small debris insulation types found in the PNP containment are given in NUREGICR-6772 and are summarized in NEI 04-07 Table 4-2. These data have been summarized in Table 3e4 for the insulation materials and other debris types found in the PNP containment. The incipient tumbling velocities correspond to the lowest applicable values cited in the documents referenced in the NEI 04-07 Table 4-2 for each of these debris types. This data is applicable to the fractions of small debris insulation types that remain after erosion during the blowdown and washdown phases.

NUREGICR-6772, Section 3.1.1, Table 3.1 provides test results for incipient transport velocities for small low-density fiberglass (Nukon) insulation debris. Figure 3.1 in NUREG/CR-6772 shows that the insulation tested is for material that would pass through typical 4-inch grating and is therefore considered small debris. Accordingly, the lowest (conservative) incipient transport velocity of 0.06 ft/sec in Table 3.1 of NUREG/CR-6772 was used for small Nukon and small fiberglass insulation debris types, both jacketed and unjacketed.

NUREGICR-6772, Section 3.2.1, Table 3.4 indicates that various flat and crumpled pieces of aluminum RMI foil up to two inches in size start moving at a velocity of 0.20 ft/sec. Therefore, this incipient tumbling velocity was used for the small Transco RMI aluminum foil debris.

NUREG/CR-6772, Section 3.3.1 provides data that shows small CalSil debris chunks have an incipient transport velocity of 0.25 ft/sec. A lower incipient transport velocity of 0.10 ft/sec is indicated for "dust and fibers."

However, for this analysis, dust and fibers are characterized as fines produced by erosion and are conservatively assumed to transport 100% to the strainer modules, and 0.25 ft/sec is applied to the remaining small CalSil debris.

All other coatings and latent debris are conservatively assumed to transport 100% to the strainer modules. One hundred percent of fiber and particulate fines were assumed to transport to the strainers.

Table 3e4 Tumbling velocities and erodible fractions

Debris Type	Erosion Factor	Incipient Tumbling Velocity (ft/s)
Nukon Thermal Wrap Jacketed	10%	0.06
Calcium Silicate Metal Jacketed	17%	0.25
Transco RMI	N/A	0.20
Low Density Fiberglass Jacketed	10%	0.06
Calcium Silicate Cloth Covered	17%	0.25
Low Density Fiberglass Unjacketed	100%	0.06
Nukon Unjacketed	10%	0.06
Mineral Wool Jacketed	10%	0.30
Qualified Coatings	N/A	100% transport assumed
Unqualified Coatings	N/A	100% transport assumed
Latent Debris	N/A	100% transport assumed

Alden performs CFD simulations of a given containment configuration. The results of these simulations are post-processed to show isocontours of velocity corresponding to the incipient tumbling velocity of a given debris type and size, as indicated in NEI-04-07. For example, isocontours of 0.06 ft/sec (the incipient tumbling velocity of small fiberglass) are shown in Figure 3e4 below.

These isocontours are examined as follows:

a. Any isocontours of velocity that are not contiguous with an active strainer module are removed (examples shown in red, Figure 3e3). It is assumed that any debris that would be moved from these isolated regions of velocity would drop out before reaching the strainer. It is also assumed that the debris will drop out into areas where the flow velocity is lower than the incipient tumbling velocity for that debris, so that debris will not transport to another contour and will not become susceptible to additional transport.

b. Remaining isocontours are overlaid with flow pathlines (Figure 3e8) to identify any sections of these contours that form isolated eddies or otherwise do not convey material toward the strainers. Such regions would also be removed from the transport analysis.

c. Using the remaining isocontours (blue contours in Figure 3e3), the subareas of these contours occupying each proximity zone shown in Figure 3e9 are determined using AutoCAD and are recorded.

The projected plan areas of each zone are determined from AutoCAD and are recorded (Table 3e6)

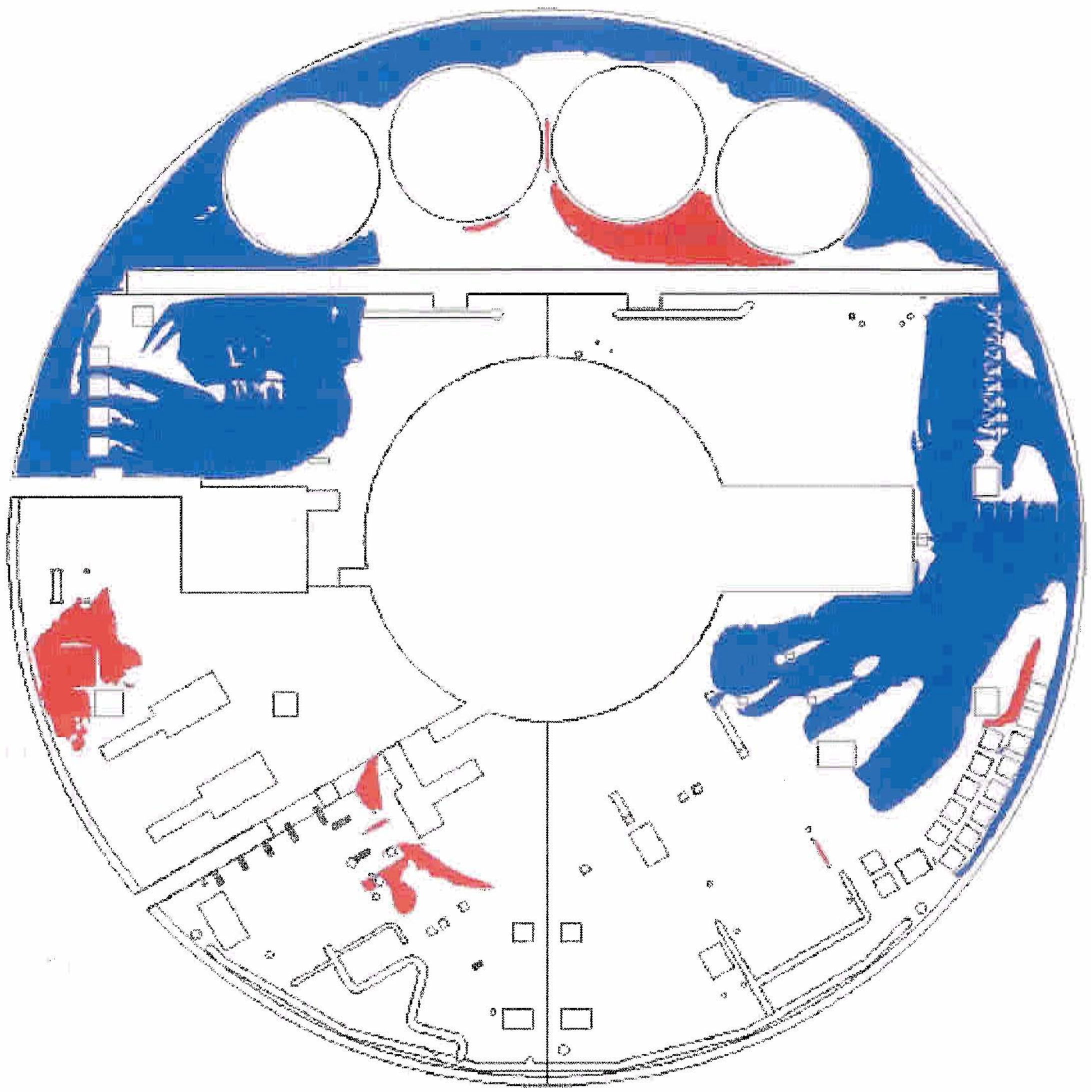
The amount of debris allocated to each zone is tabulated by size: large, small, fine, fines from eroded larges above the 590' elevation (eroded during washdown and pool fill). Fines from eroded smalls in 590' elevation (eroded during recirculation) are not allocated and are calculated during the transport.

The fraction of small debris transported from each zone is calculated as the ratio of isocontour area to the area of the entire zone. This fraction is then multiplied by the amount of small debris in that zone to determine the amount of small debris transported from that zone to the strainer.

The PNP design input specified that an erosion factor of 10% is to be applied to small fiberglass debris that does not transport to the strainers. It is assumed that 100% of these fines transport to the strainers. Similarly, 100% of the fines from eroded larges above the 590' level and 100% of the allocated fines above 590' level are assumed to transport to the strainers, and are tabulated separately.

The calculations in the previous two paragraphs are repeated for all zones, and these amounts are summed to determine the total amount of fiberglass debris transported to the strainers. The results for this calculation are provided below in Tables 3e7 and 3e8 for the worst large breaks.

Figure 3e3 Sample Isolated Isocontours of Velocity (shown in red) that are removed from Transport Analysis



NRC Request

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

ENO Response

The methods and assumptions applied in the debris transport analysis conform to those of NEI 04-07 to the extent practical. As discussed at length above, the refined transport analysis takes credit for debris settlement in the sump water based on debris tumbling velocity that were largely taken from the NEI 04-07 tables or were augmented by analysis and other NUREG and industry data if not covered in the NEI report.

In general, the requirements of NEI 04-07, Section 4.2.4.2, "Three Dimensional Computational Fluid Dynamics (CFD)," were met by the CFD contractor who has a substantial history of past analysis, however, a specific list of variances was not given in the CFD Report (Reference 3.e.3).

NRC Request

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

ENO Response

The CFD analysis used FLUENT Version 6.1.22, GAMBIT Version 2.1.6, AutoCAD Version 2008, and Microsoft Excel 2007 for the refined transport analysis.

The results, which are highly graphically oriented, are discussed above and in Reference 3.e.3 that was made available to the NRC during site visits.

<u>CFD Results</u>

Below are the graphic results for the limiting S5 LBLOCA.

Figure 3e4 Isocontours of Velocity: 0.06 ft/sec and above, Base Case, Break S5, East Air Room Door Closed.

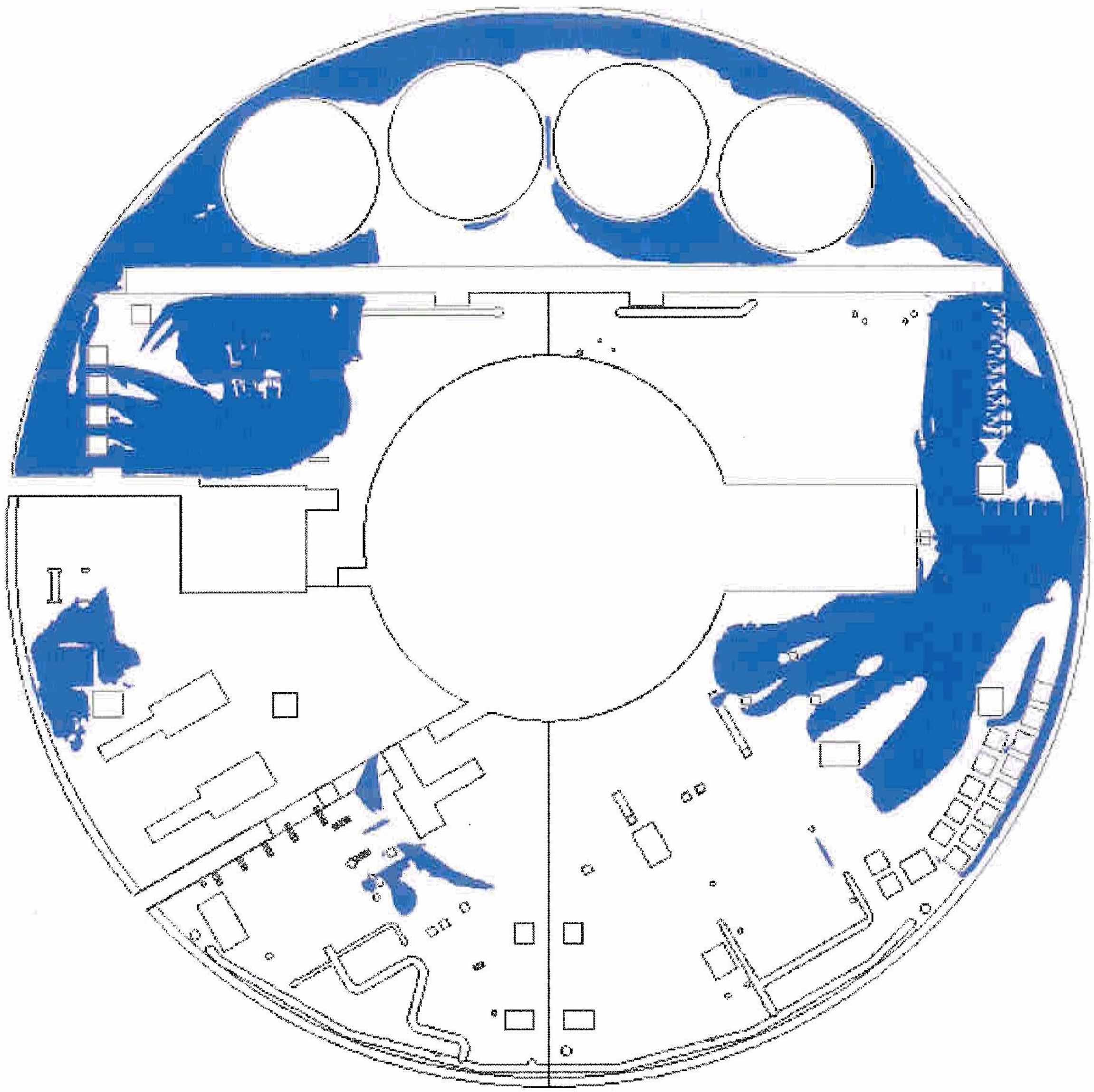


Figure 3e5 Isocontours of Velocity: 0.20 ft/sec and above, Base Case, Break S5, East Air Room Door Closed.

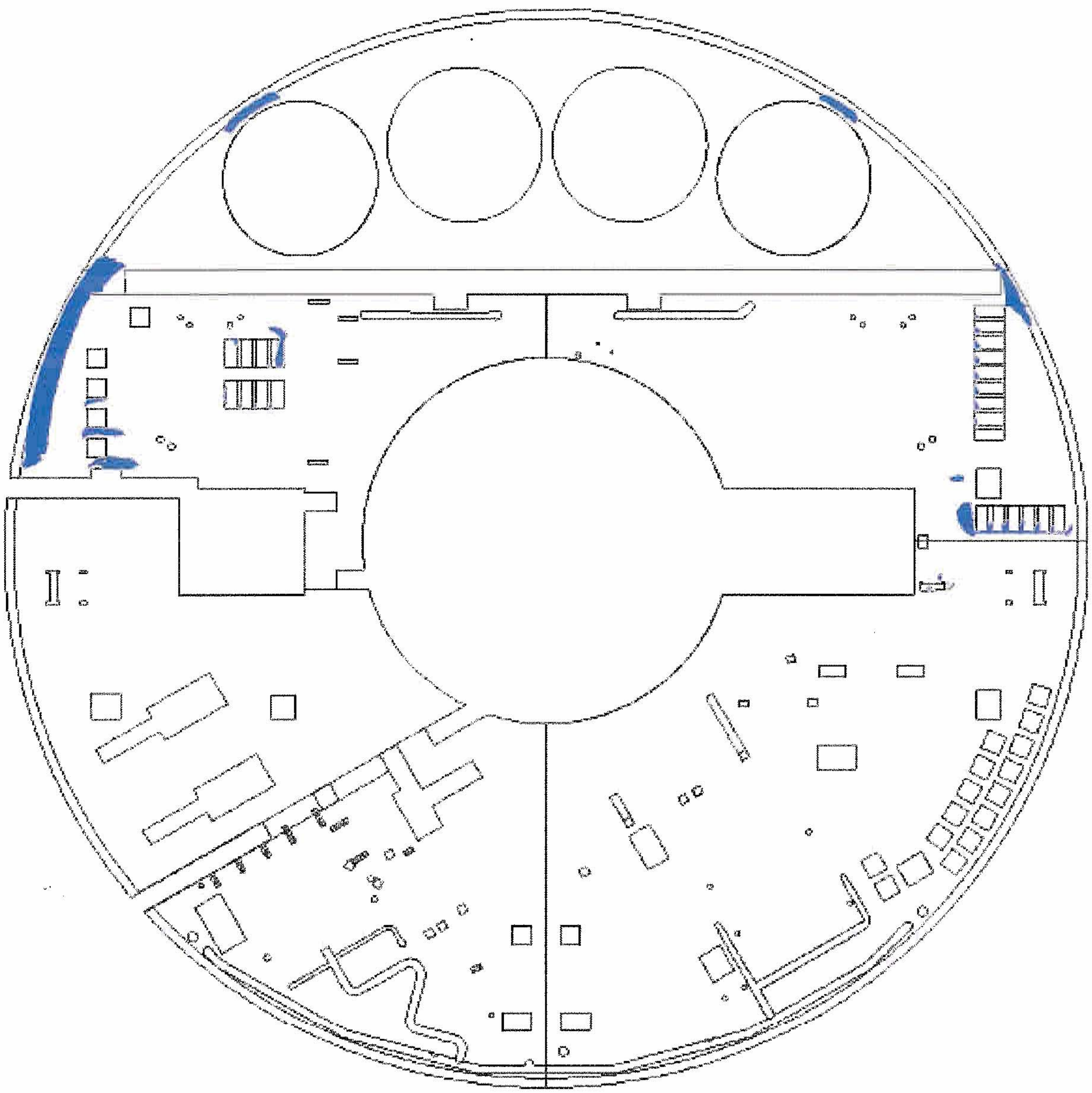


Figure 3e6 Isocontours of Velocity: 0.25 ft/sec and above, Base Case, Break S5, East Air Room Door Closed.

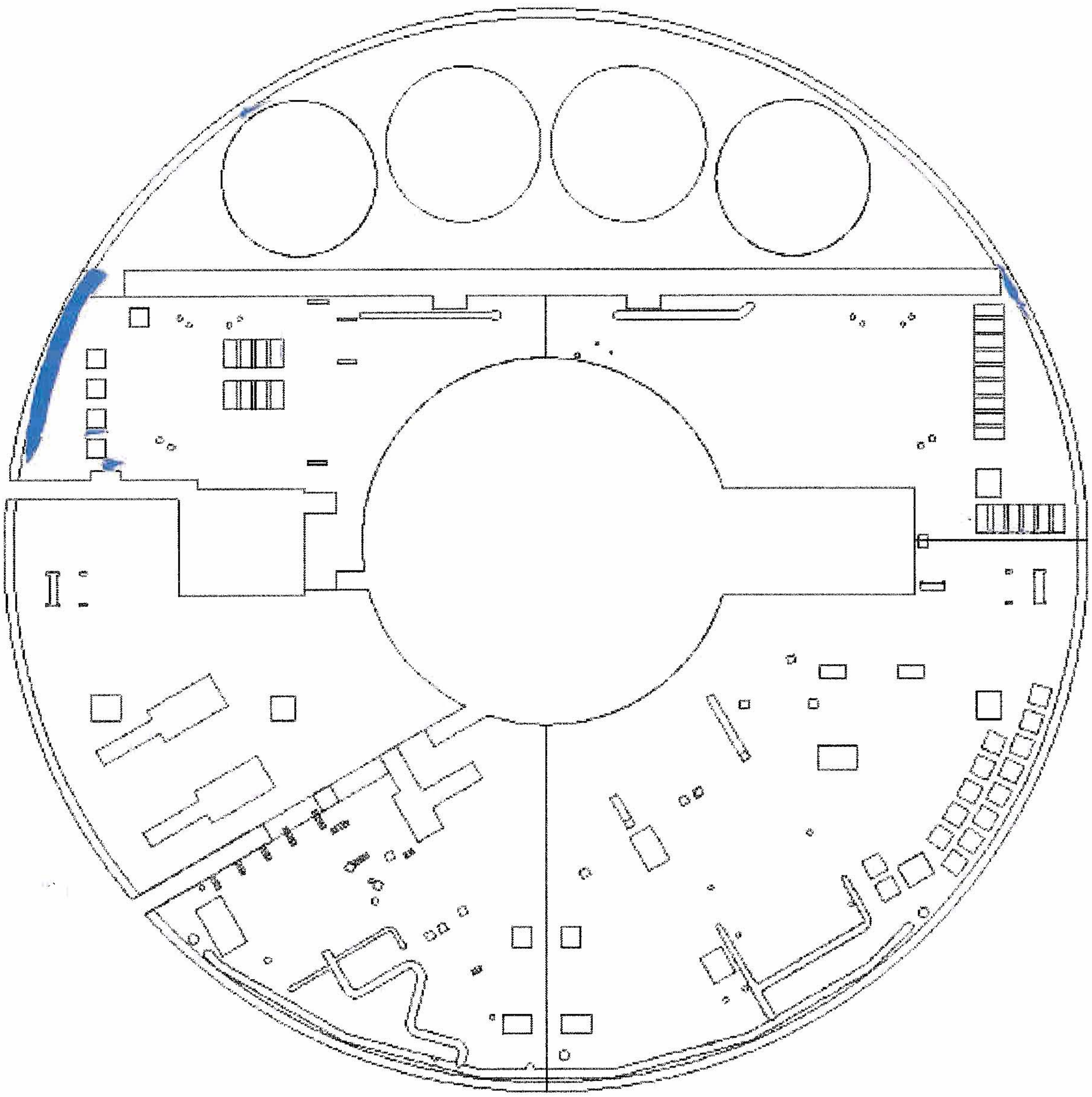


Figure 3e7 Isocontours of Velocity: 0.30 ft/sec and above, Base Case, Break S5, East Air Room Door Closed.

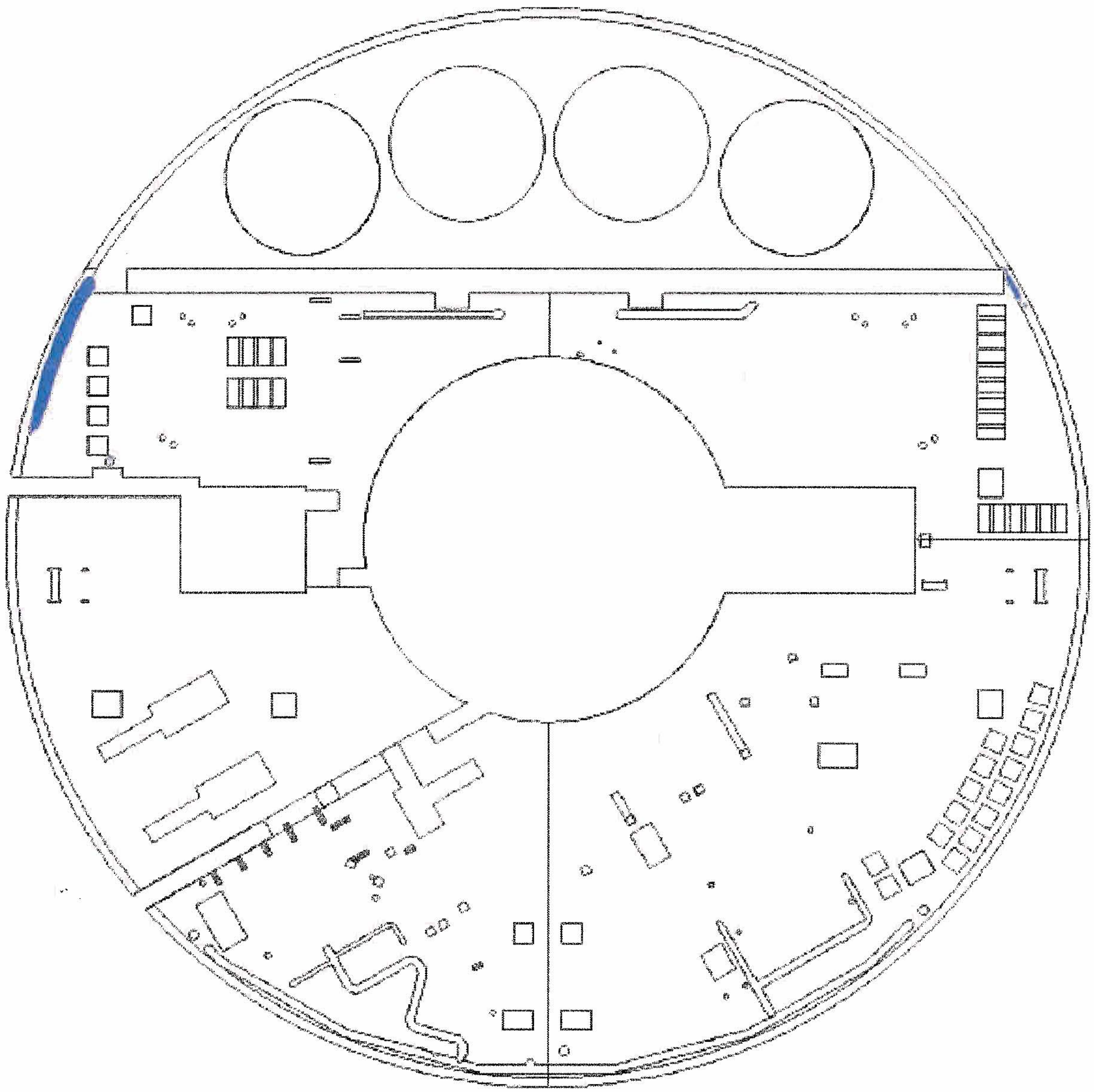
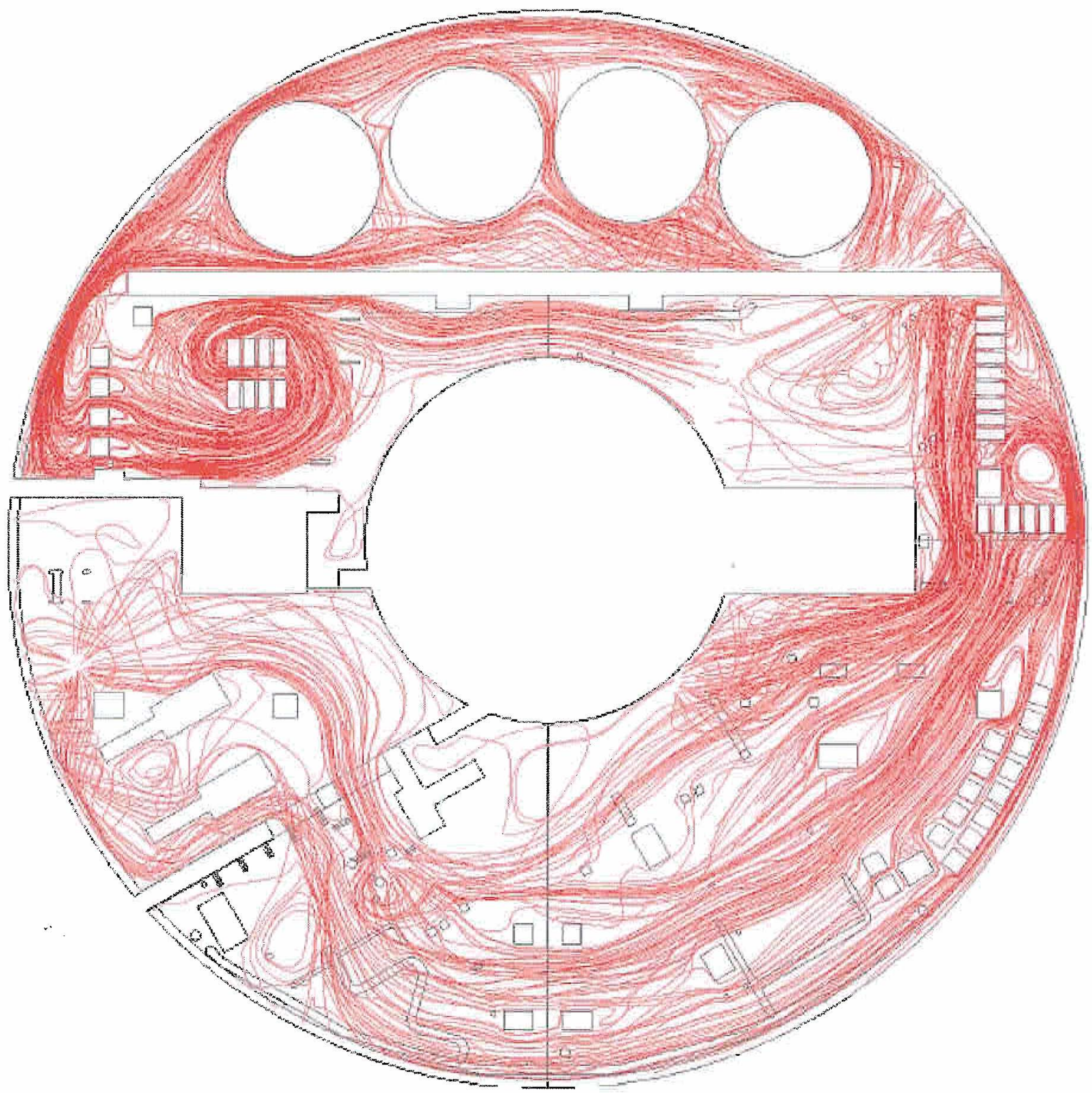


Figure 3e8 Pathlines: Base Case, Break S5, East Air Room Door Closed.



In the above plot, line ends in white spaces (not at strainers/water sinks) and with generally radial flow pattern, are the locations of falling water (water sources). S5 break is on top of the right hand "key way" that is the SG " A support pedestal. Water fall is about 15 feet (608'-593') vertical and is directed by the EL. 608'-6" floors and curbs.

The major source pattern (star) on the left in the air room is largely spray flow runoff falling down a major egress route filled with open steel grating and flights of open grate steel stair steps. That water is running off from both EL 649' and EL 608'-6" floors. Water is leaving the air room through its engineered "blowout" panels.

NRC Request

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

ENO Response

ENO is not taking credit for debris interceptors for PNP.

NRC Request

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

ENO Response

As stated above, the CFD transport analysis assumes 100% transport of fine debris.

NRC Request

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

ENO Response

The debris transport fractions of the transport analysis are shown in Figure 3e9 and Tables 3e5 through 3e8. Tables 3e7 and 3e8 provide the total quantities of each type of debris transported to the strainers.

Table 3e5 Transport Fractions

Contour Areas of Incipient Tumbling Velocity and Transport Fractions, Base Case Simulations

		Contour Areas						Transport Fractions					
Break	Velocity (ft/s)	Zone 1 (ft^2)	Zone 2 (ft^2)	Zone 3 (ft^2)	Zone 4 (ft^2)	Zone 5 (ft^2)	Zone 6 (ft^2)	Zone 1 (%)	Zone 2 (%)	Zone 3 (%)	Zone 4 (%)	Zone 5 (%)	Zone 6 (%)
A (S5)	0.06	479.78	290.62	491.01	493.49	0.00	0.00	51.90%	33.21%	59.04%	25.67%	0.00%	0.00%
	0.20	0.00	2.38	2.02	0.00	0.00	0.00	0.00%	0.27%	0.24%	0.00%	0.00%	0.00%
	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
B (S6)	0.06	0.00	545.34	215.16	1344.19	521.28	615.71	0.00%	62.32%	25.87%	69.93%	57.59%	62.74%
	0.20	0.00	91.46	0.00	21.03	0.00	0.00	0.00%	10.45%	0.00%	1.09%	0.00%	0.00%
	0.25	0.00	33.76	0.00	0.00	0.00	0.00	0.00%	3.86%	0.00%	0.00%	0.00%	0.00%
	0.30	0.00	0.13	0.00	0.00	0.00	0.00	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
B (S6) Door OPEN	0.06	49.73	253.09	584.81	530.35	307.99	613.74	5.38%	28.92%	70.32%	27.59%	34.03%	62.54%
	0.20	0.00	8.70	3.31	0.00	0.00	0.00	0.00%	0.99%	0.40%	0.00%	0.00%	0.00%
	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Figure 3e9 Zone Definitions on EL. 590' (in Sump)

[Note: Z1 floor area is reduced by 4 large tanks not shown]

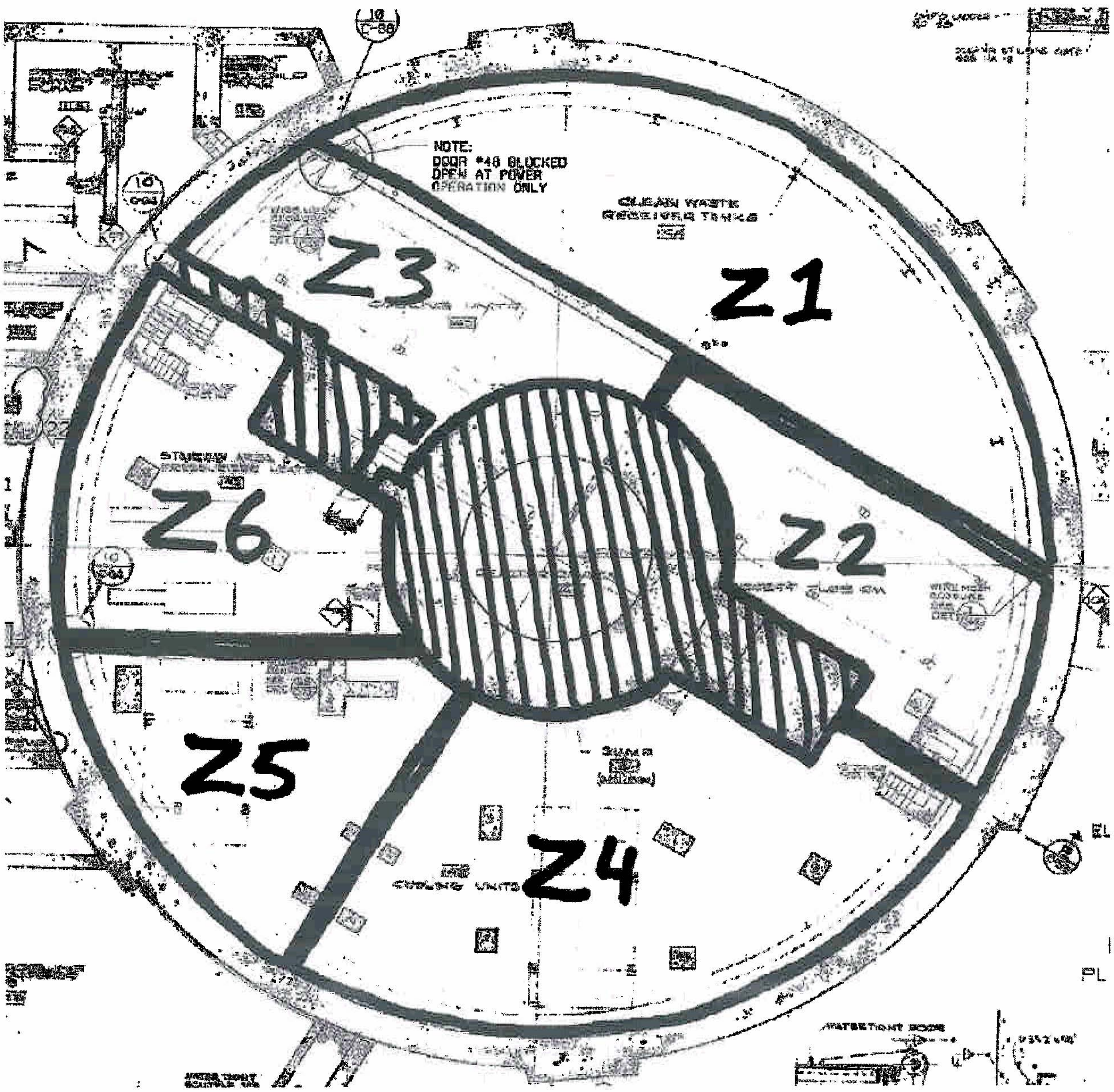


Table 3e6 Projected Plan Area of Each Proximity Zone.

Zone 1 (ft^2)	Zone 2 (ft^2)	Zone 3 (ft^2)	Zone 4 (ft^2)	Zone 5 (ft^2)	Zone 6 (ft^2)
924.40	875.06	831.68	1922.13	905.16	981.31

Table 3e7 Amount of Debris Transported for Break in A Steam Generator "Vault", S5 Break, Current Insulation, 593.25' Water Level, Air Room door Closed

Debris Type	Size	Erode	Tumb Vel	Units	Debris Allocation Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Debris Transport Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Total Transport
Nukon/Thermal Wrap Jacketed	Large			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.06	ft^3	81.011	25.289	2.001	64.508	4.993	12.768	42.047	8.399	1.181	16.562	0.000	0.000	68.188
	Fine			ft^3	34.718	10.838	0.858	27.645	2.140	5.472	34.718	10.838	0.858	27.645	2.140	5.472	81.670
	Fines from Eroded Larges Above 590'			ft^3	9.297	2.749	0.000	6.104	0.000	0.000	9.297	2.749	0.000	6.104	0.000	0.000	18.150
	Fines from Eroded Smalls In 590'			ft^3	-	-	-	-	-	-	3.896	1.689	0.082	4.795	0.499	1.277	12.238
Calcium Silicate Metal Jacketed	Large			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	17%	0.25	ft^3	4.094	1.278	0.101	3.260	0.252	0.645	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			ft^3	5.730	1.789	0.142	4.563	0.353	0.903	5.730	1.789	0.142	4.563	0.353	0.903	13.480
	Fines from Eroded Larges Above 590'			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fines from Eroded Smalls In 590'			ft^3	-	-	-	-	-	-	0.696	0.217	0.017	0.554	0.043	0.110	1.637
Transco RMI	Large			ft^2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	N/A	0.20	ft^2	251.669	76.486	3.295	184.214	8.425	15.054	0.000	0.208	0.008	0.000	0.000	0.000	0.216
	Fine			ft^2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Low Density Fiberglass Jacketed	Large			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.06	ft^3	3.150	0.983	0.078	2.508	0.194	0.496	1.635	0.327	0.046	0.644	0.000	0.000	2.651
	Fine			ft^3	0.782	0.244	0.019	0.623	0.048	0.123	0.782	0.244	0.019	0.623	0.048	0.123	1.840
	Fines from Eroded Larges Above 590'			ft^3	0.021	0.006	0.000	0.014	0.000	0.000	0.021	0.006	0.000	0.014	0.000	0.000	0.041
	Fines from Eroded Smalls In 590'			ft^3	-	-	-	-	-	-	0.152	0.066	0.003	0.186	0.019	0.050	0.476
Calcium Silicate Cloth Covered	Large			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	17%	0.25	ft^3	0.825	0.257	0.020	0.657	0.051	0.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			ft^3	1.212	0.378	0.030	0.965	0.075	0.191	1.212	0.378	0.030	0.965	0.075	0.191	2.850
	Fines from Eroded Larges Above 590'			ft^3	0.576	0.170	0.000	0.378	0.000	0.000	0.576	0.170	0.000	0.378	0.000	0.000	1.125
	Fines from Eroded Smalls In 590'			ft^3	-	-	-	-	-	-	0.140	0.044	0.003	0.112	0.009	0.022	0.330
Low Density Fiberglass Unjacketed	Large			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.06	ft^3	0.196	0.061	0.005	0.156	0.012	0.031	0.101	0.020	0.003	0.040	0.000	0.000	0.165
	Fine			ft^3	0.047	0.015	0.001	0.037	0.003	0.007	0.047	0.015	0.001	0.037	0.003	0.007	0.110
	Fines from Eroded Larges Above 590'			ft^3	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001
	Fines from Eroded Smalls In 590'			ft^3	-	-	-	-	-	-	0.009	0.004	0.000	0.012	0.001	0.003	0.030
Nukon Unjacketed	Large			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.06	ft^3	0.183	0.057	0.005	0.146	0.011	0.029	0.095	0.019	0.003	0.037	0.000	0.000	0.154
	Fine			ft^3	0.043	0.013	0.001	0.034	0.003	0.007	0.043	0.013	0.001	0.034	0.003	0.007	0.100
	Fines from Eroded Larges Above 590'			ft^3	0.007	0.002	0.000	0.004	0.000	0.000	0.007	0.002	0.000	0.004	0.000	0.000	0.013
	Fines from Eroded Smalls In 590'			ft^3	-	-	-	-	-	-	0.009	0.004	0.000	0.011	0.001	0.003	0.028
Mineral Wool Jacketed	Large			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.30	ft^3	34.076	10.637	0.842	27.134	2.100	5.371	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			ft^3	8.204	2.561	0.203	6.533	0.506	1.293	8.204	2.561	0.203	6.533	0.506	1.293	19.300
	Fines from Eroded Larges Above 590'			ft^3	1.217	0.360	0.000	0.799	0.000	0.000	1.217	0.360	0.000	0.799	0.000	0.000	2.375
	Fines from Eroded Smalls In 590'			ft^3	-	-	-	-	-	-	3.408	1.064	0.084	2.713	0.210	0.537	8.016
Qualified Coatings	Large			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	0%		ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			ft^3	3.433	1.072	0.085	2.733	0.212	0.541	3.433	1.072	0.085	2.733	0.212	0.541	8.075
Unqualified Coatings	Large			ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	0%		ft^3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			ft^3	8.545	2.667	0.211	6.804	0.527	1.347	8.545	2.667	0.211	6.804	0.527	1.347	20.100
Latent Debris	Large			lbm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	0%		lbm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			lbm	85.020	26.540	2.100	67.700	5.240	13.400	85.020	26.540	2.100	67.700	5.240	13.400	200.000

Table 3e8 Amount of Debris Transported for Break in B Steam Generator "Vault"

S6 Break, Current Insulation, 593.25' Water Level, Air Room door Closed

Debris Type	Size	Erode	Tumb Vel	Units	Debris Allocation Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Debris Transport Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Total Transport
Nukon/Thermal Wrap Jacketed	Large			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.06	ft³	20.207	1.547	1.786	10.883	23.444	112.182	0.000	0.964	0.462	7.611	13.501	70.387	92.926
	Fine			ft³	8.661	0.663	0.765	4.664	10.048	48.079	8.661	0.663	0.765	4.664	10.048	48.079	72.880
	Fines from Eroded Larges Above 590'			ft³	0.989	0.000	0.000	0.000	2.387	12.820	0.989	0.000	0.000	0.000	2.387	12.820	16.196
	Fines from Eroded Smalls In 590'			ft³	-	-	-	-	-	-	2.021	0.058	0.132	0.327	0.994	4.179	7.712
Calcium Silicate Metal Jacketed	Large			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	17%	0.25	ft³	1.828	0.140	0.161	0.984	2.120	10.146	0.000	0.005	0.000	0.000	0.000	0.000	0.005
	Fine			ft³	2.384	0.183	0.211	1.284	2.766	13.234	2.384	0.183	0.211	1.284	2.766	13.234	20.062
	Fines from Eroded Larges Above 590'			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fines from Eroded Smalls In 590'			ft³	-	-	-	-	-	-	0.311	0.023	0.027	0.167	0.360	1.725	2.614
Transco RMI	Large			ft²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	N/A	0.20	ft²	12.794	0.789	0.977	5.995	23.344	115.964	0.000	0.082	0.000	0.066	0.000	0.000	0.148
	Fine			ft²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Low Density Fiberglass Jacketed	Large			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.06	ft³	3.052	0.234	0.270	1.644	3.540	16.941	0.000	0.146	0.070	1.149	2.039	10.630	14.033
	Fine			ft³	0.745	0.057	0.066	0.401	0.864	4.136	0.745	0.057	0.066	0.401	0.864	4.136	6.270
	Fines from Eroded Larges Above 590'			ft³	0.029	0.000	0.000	0.000	0.070	0.374	0.029	0.000	0.000	0.000	0.070	0.374	0.473
	Fines from Eroded Smalls In 590'			ft³	-	-	-	-	-	-	0.305	0.009	0.020	0.049	0.150	0.631	1.165
Calcium Silicate Cloth Covered	Large			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	17%	0.25	ft³	0.661	0.051	0.058	0.356	0.767	3.668	0.000	0.002	0.000	0.000	0.000	0.000	0.002
	Fine			ft³	0.972	0.074	0.086	0.524	1.128	5.396	0.972	0.074	0.086	0.524	1.128	5.396	8.180
	Fines from Eroded Larges Above 590'			ft³	0.197	0.000	0.000	0.000	0.475	2.553	0.197	0.000	0.000	0.000	0.475	2.553	3.225
	Fines from Eroded Smalls In 590'			ft³	-	-	-	-	-	-	0.112	0.008	0.010	0.060	0.130	0.624	0.945
Low Density Fiberglass Unjacketed	Large			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.06	ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fines from Eroded Larges Above 590'			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fines from Eroded Smalls In 590'			ft³	-	-	-	-	-	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nukon Unjacketed	Large			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.06	ft³	0.084	0.006	0.007	0.045	0.098	0.468	0.000	0.004	0.002	0.032	0.056	0.294	0.388
	Fine			ft³	0.021	0.002	0.002	0.012	0.025	0.119	0.021	0.002	0.002	0.012	0.025	0.119	0.180
	Fines from Eroded Larges Above 590'			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fines from Eroded Smalls In 590'			ft³	-	-	-	-	-	-	0.008	0.000	0.001	0.001	0.004	0.017	0.032
Mineral Wool Jacketed	Large			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	10%	0.30	ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fines from Eroded Larges Above 590'			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fines from Eroded Smalls In 590'			ft³	-	-	-	-	-	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Qualified Coatings	Large			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	0%		ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			ft³	0.960	0.073	0.085	0.517	1.113	5.327	0.960	0.073	0.085	0.517	1.113	5.327	8.075
Unqualified Coatings	Large			ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	0%		ft³	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			ft³	2.389	0.183	0.211	1.286	2.771	13.260	2.389	0.183	0.211	1.286	2.771	13.260	20.100
Latent Debris	Large			lbm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Small	0%		lbm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Fine			lbm	23.767	1.820	2.100	12.800	27.573	131.941	23.767	1.820	2.100	12.800	27.573	131.941	200.000

The requests below are from the December 24,2008, NRC RAI.

NRC Request

8. Please provide the final results of the analysis of the potential for transport of fragments of the lead blankets and specify whether this material was included as miscellaneous material.

ENO Response

8. The final results of the analysis of the potential for transport of fragments of lead blankets were provided by the May 2008 PNP strainer testing performed at ALDEN Laboratory in Holden, Massachusetts. As part of the strainer testing, debris transport testing was performed for a variety of debris types. To address potential lead blanket debris, Alpha Maritex lead blanket material transportability was tested by placing sample material in the test flume under the same flow conditions used for design basis debris head loss testing. The Alpha Maritex lead blanket material settled on the floor of the flume approximately two feet from the drop zone. This result agrees well with WCAP-16727 results that tested the same fabric (reference responses to items 1 and 4 provided in Sections 3.b and 3.c). Since this material did not transport, it was excluded from the design basis debris testing per the testing protocol.

   Lead blanket material was not included as part of the "miscellaneous" category given in the table on page 17 of the ENO February 27, 2008, supplemental response. The lead blanket Alpha Maritex material was itemized separately in the table on page 17 of the supplemental response. See response to item 7 provided in Section 3.b, for what was included in the miscellaneous category.

NRC Request

9. The supplemental response states that a computational fluid dynamics analysis is being performed and that the containment debris transport analysis is being revised. When the final supplemental response is submitted, please include a discussion of the computational fluid dynamics analysis and the changes that have been made to the transport calculation at a level of detail consistent with the NRC supplemental response content guide. The NRC staff will review this information when the licensee submits it and, as a result of such review, the NRC staff could request additional information in this subject area if needed.

ENO Response

9. The above portions of this section 3.e are intended to meet this requirement.

NRC Request

10. The supplemental response discusses the applicability of Westinghouse letter LTR-SEE-05-172 to the settling of coating chips within the containment pool. In the NRC staff's audit of Waterford 3 (ADAMS Accession No. ML080140318), this letter was reviewed by the NRC staff and was considered to have significant technical deficiencies as a basis for justifying the settling of coating chips in a containment pool. Section 3.5.5.2 of the Waterford 3 audit report states three main NRC staff concerns: (1) the size distribution assumed for the failed chips, (2) the failure to distinguish between chip diameter and chip thickness, and (3) the consideration of vertical flow conditions that are typically inapplicable to containment pools. Please state whether this letter will be credited as a basis for assumptions concerning unqualified coating chip transport in the revised transport analysis, and, if credit is taken, please address the three deficiencies summarized above.

ENO Response

10. The ENO February 27, 2008, GL 2004-02 supplemental response referred to the Westinghouse letter LTR-SEE-05-172 as potential conservatism to the approach taken for PNP up to that point, which was documented as assuming all coatings fail as small fines. ENO has not credited the subject Westinghouse letter for any coating transport assumptions. The follow-up supplemental response has removed any reference to Westinghouse letter LTR-SEE-05-172.

Following the submittal of the PNP GL 2004-02 supplemental response on February 27, 2008, revised and new basis calculations were performed in support of the PNP November 2008 strainer testing.

All qualified and unqualified coatings are assumed to transport to the strainers in the debris transport calculation that is unchanged from the February 27, 2008, supplemental response.

For determining the appropriate surrogate material to use in strainer testing for the various coating materials, most of the coatings (26.75 ft^3) are assumed to fail as fine particulate and the appropriate surrogate is added in the form of powder to the test flume. For a relatively small portion of the coating material (2.42 ft^3), the coating was evaluated to fail as chips since this portion is epoxy outside the qualified coating zone of influence. The appropriate surrogate for this material was added in the form of 1/32" chips to the test flume. A small chip size was used and no attempt was made to credit a size distribution.

NRC Request

11. Page 25 of the supplemental responses states that no curbs or debris interceptors were credited with inhibiting debris transport. However, Figures 3.e.2 and 3.e.5 in the supplemental response (which are debris transport logic trees) clearly indicate that debris curbs were credited with inhibiting debris transport. Please describe the debris curbs for which credit was taken and clarify whether similar credit will be taken in the revised debris transport analysis.

ENO Response

11. This issue is a matter of semantics. Per assumption 5 (stated below) of Appendix C, "Debris Allocation," of the transport analysis, the debris landing on elevation 608 ft. 6 in. will not transport to elevation 590 ft.

    5. Large debris generated on the 608 ft. 6 in. level will not transport to the basement. This is a reasonable assumption since large debris will either settle during pool fill, be unable to overtop the curbing or be held from further transport by stairwell grating. This calculation treats this as 0% transport of large debris.

    Further explanation is available in section C.3.3, "Large Debris," subsection C.3.3.2, "608 ft. 6 in. elevation" as given below:

    > *C.3.3.2 608 ft. 6 in. elevation*
    > *It is expected that large debris generated will not transport off SG Room A or B floor. Based on Assumption 5, any large debris that does transport to the basement during the initial LOCA blast will settle and not transport to the strainers. The large debris that remains on the 608 ft. 6 in. elevation will be subject to erosion due to break flow and containment spray. The large debris will be eroded to fine debris and distributed to the applicable proximity zones utilizing the ratio of the flow exiting each flow path to the total flow draining off of the 608 ft. 6 in. elevation. These flow ratios are presented in Table C.5.3-1 (Break S5) and Table C.5.5-1 (Break S6) as "% Total Flow From SG Room Floor To Basement."*

    In effect, it makes almost no difference if the debris stays on elevation 608 ft. 6 in. or drops to elevation 590 ft. because, in either case, the large debris does not transport and in both cases it is assumed to erode. The assumption 5 wording does include curbing as a part of the reason for the assumption.

The curbs on elevation 608 ft. 6 in. are assumed to be uniform and 6-inches high except for a 9-inch curb cut that is treated separately. The flow rate over the curbs would vary with the break location being analyzed and in some cases there would be no water flow over the curbs.

References

3.e.l. EA-MOD-2005-04-10, Head Loss Calculations Supporting Resolution of GSI-191, Revision.0, August 3, 2005, superseded.

3.e.2 Not used

3.e.3 EA-EC7833-01, Revision 1, "Palisades Nuclear Power Station – Debris Transport AREVA 32-9099369-000", February 23, 2009

3.e.4 NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, December 2004

3.f. Head Loss and Vortexing

This section of the follow-up supplemental response is revised from previous information provided in the PNP supplemental response to GL 2004-02 on February 27, 2008 (Reference 3.f.5). Besides addressing the specific items requested by the NRC November 2007 content guide (Reference 3.f.9), RAIs 13 and 14 provided by NRC letter, dated December 24, 2008 (Reference 3.f.6), are also addressed in this section as committed to in the ENO PNP letter dated March 20, 2009 (Reference 3.f.7). Also, the NRC chemical effects audit open items documented in NRC letter dated May 13, 2009 (Reference 3.f.8), are addressed in this section.

NRC Request

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).

ENO Response

As references of the ECCS and CSS, piping and instrument diagrams (P&IDs) M-203-A and M-204-A are provided in Attachments 3 and 4 of this document. An overview of the PNP design of safeguards to a LOCA is included below.

Safety injection is automatically initiated upon receipt of a safety injection signal (SIS). The SIS starts the HPSI and low pressure safety injection (LPSI) pumps, opens the safety injection valves and closes the PCS check valve leakage paths. The rest of the system is always aligned for safety injection during power operation. The SITs will discharge into the PCS when the pressure drops to approximately 240 psig. Motor-operated valve and system piping design are such that safety injection flow will be distributed approximately equally between the four PCS cold legs. No throttling of motor-operated valves or other operator action is required to distribute flow. The CSS is initiated upon receipt of a containment high pressure signal, which starts the CSS pumps and opens the isolation valves to the dual containment spray headers.

When the water in the safety injection and refueling water tank (SIRWT) reaches a predetermined low level, a RAS is initiated on coincident one-out-of-two (taken twice) low-level switch actuation. The RAS opens the containment sump valves, closes the SIRWT valves, stops the LPSI pumps and closes the valves in the pump minimum flow,lines, provided that the control room operators have enabled the close permissive by placing the minimum flow valve hand switches to a closed position. The valves in the minimum flow recirculation lines have also been provided with an isolation contact and redundant position indication in the control room to meet single failure criterion. RAS also throttles the containment spray valves CV-3001 and CV-3002 to a predetermined throttled position to ensure the spray pumps have sufficient NPSH. The stroke times on the containment sump and SIRWT valves are set up to ensure an adequate overlapping stroke in order to provide a continuous supply to the engineered safeguards pumps during transfer of suction, and the close stroke times of the pump minimum flow line valves are set to isolate the containment sump from the SIRWT. One or more spray pumps can also be used to augment flow to the core after the pressure is reduced. In addition, in order to meet NPSH requirements, the RAS opens the HPSl subcooling valve CV-3071 if the associated HPSl pump is running. After the containment sump valve CV-3030 opens from RAS, HPSl subcooling valve CV-3070 will open if the associated HPSl pump is running. Also, RAS will close containment spray valve CV-3001, if the containment sump valve CV-3030 does not open. During the first 5-112 to 6-112 hours after the LOCA, the hot-leg injection lines are isolated from the PCS. Hot-leg injection is initiated by operator action to realign two valves in each HPSl train for simultaneous hot and cold-leg injection. There are two HPSl pumps, each capable of supplying sufficient injection water. Normally, one HPSl pump is aligned to the HPSl train 1 header and the second HPSl pump is aligned to the HPSl train 2 header.

During simultaneous hot-leg and cold-leg injection, the operating HPSl pump(s) continue to be supplied by CSS pump discharge via the subcooling line(s). The HPSl pumps discharge approximately 50% of the flow to the hot-leg drain nozzle in hot leg 1, and the remainder to the four injection nozzles in the cold legs. One branch run from HPSl train 1 joins a branch run from HPSl train 2 into one line that connects to the hot-leg drain line. To prevent HPSl pump runout, cold-leg injection flow is diverted through restricting orifices and hot-leg injection flow is throttled by preset valve limit switches. To ensure the system is not misaligned by operator actions, interlocks exist between valve operators to prevent opening of hot-leg injection valves until the restricting orifice bypass valves are closed.

NRC Request

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

ENO Response

The design specification for the strainers specifies a maximum allowed head loss of 2.6 ft water at 212°F for the LBLOCA at 3,591 gpm with all HPSl and CSS pumps running. This head loss applies to the clean strainer and associated piping head loss and the debris head loss (Reference 3.f.11). The clean strainer and associated piping head loss for these conditions was calculated to be 1.026 ft water. This results in 1.57 ft water head loss being available for debris head loss (Reference 3.f.17). As shown in Section 3.g, the total strainer head loss and NPSH margin varies depending on single failure assumptions. For the full flow case with all HPSl and CSS pumps running and no single failures, a NPSH margin of 5.16 ft water exists when the maximum strainer design head loss value is used (Reference 3.f.12). Additional head loss is available for clean strainer head loss or debris head loss when NPSH margin exists.

The strainers and associated piping have been evaluated structurally for 15 ft and 9.75 ft water differential pressure, respectively (References 3.f.13 and 3.f.14). It can be seen that the piping is limiting. The design pressure drop for the strainer and pipe assembly is 2.6 ft. Therefore, the design pressure drop margin is (9.75 - 2.6) / 2.6 = 275%.

The PNP vented sump configuration also imposes a strainer head loss limitation of 4.85 ft water for the LBLOCA and 3.84 ft water for the SBLOCA to avoid potential air ingestion concerns (Reference 3.f.16).

The design maximum head loss for the LPSl failure to trip case starts with a 1.026 ft water clean strainer head loss and 0.40 ft water debris head loss at 212°F and 3591 gpm with all HPSl and CSS pumps running. When the 6894 gpm total higher flow is applied due to a LPSl failing to trip, the total strainer head loss is 4.82 ft water (Reference 3.f.12). The LPSl failure to trip is discussed in more detail below in Section 3.f under RAI 13 response.

The design debris head loss for the SBLOCA is conservatively assumed to be 0.80 ft water for NPSH evaluations, which is one half of the LBLOCA design debris head loss value (Reference 3.f.15).

Strainer partial submergence and the vented sump are discussed in more detail below in the associated Section 3.f response.

NRC Request

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

ENO Response

PNP strainer testing performed in November 2008 demonstrated the ability of the strainer to either resist the formation of a thin bed or accommodate partial thin bed formation (Reference 3.f.18). The debris introduction sequence of fine particulate first followed by fine fiber in incremental small batches was intended to conservatively address thin bed formation, if it were to form. Though the strainer was observed to have a thin layer of fiber and particulate on it before the addition of chemical debris, a high head loss thin bed was not present. The resultant head loss was acceptable as described in more detail in Section 3.f head loss testing response and the chemical effects audit response.

NRC Request

- *Provide a summary of the methodology, assumptions and results of the vortexing evaluation*

ENO Response

The strainer design features of protection from vortex and air ingestion potentials are described in PCI proprietary document Sure-Flow 8 Suction Strainer - Vortex Issues Technical Document No. SFSS-TD-2007-003, Revision 1, August 20, 2008, which has been submitted to the NRC (Reference 3.f.4).

Vortex and air ingestion have been specifically evaluated for the PNP installed strainers (References 3.f.15 and 3.f.20). The PCI SureFlow 8 design has been tested and designed to prevent the formation of a vortex. The largest opening for water to enter the sump is through the perforated plate holes (0.095"). The size of the holes by themselves would preclude the formation of a vortex. In the unlikely event that a series of "minivortices" developed through the holes and combined in the interior of a disk to form a vortex, the combination of the wire stiffener "sandwich," the physical closeness of the disk perforated plates, and the small openings and passages (a tortuous path) that direct the flow of water to the strainer core tube would further preclude the formation of a vortex in the core tube or the sump. Guidance is provided in regards to vortex suppressors that specify that standard 1.5" floor grating or its equivalent has the ability to suppress the formation of a vortex with six inches of submergence (Reg. Guide 1.82, Rev. 3, Table A6).

The PNP strainers only have approximately two inches submergence for a large break LOCA. However, there is approximately one foot of submergence to the top of the core tubes (top elevation of 592.2 ft). Testing performed on the PCI Sure-Flow 8 strainer prototype determined that even when partially uncovered, the strainer did not exhibit any characteristics associated with a vortex or vortex formation. Therefore, the PCI Sure-Flow 8 strainer is thus inherently designed to preclude the formation of a vortex. The design of the core tube results in rectangular slots cut into the strainer module internal core tube to allow both the flow of post-LOCA water as well as to control the velocity of the water flow through the perforated plates. By sizing the slots correctly, the flow will be approximately uniform along the axis of the core tube, which will result in approximately uniform flow to the strainer surface. When the strainer is clean (without debris) the design is such to provide uniform flow through the strainer modules. Therefore, high velocities in the clean strainer near the downcomer, which could lead to vortexing, will not occur. In addition, the debris will be deposited on the screen uniformly since the debris will transport to the parts of the strainer with less blockage; i.e., once part of the strainer is blocked, the debris will transport to a less blocked (open) portion. This will allow the flow through the strainer modules and core tubes to remain uniform even in the presence of debris, thus preventing potential high velocity areas through open/clean portions of the strainer or downcomers, which could lead to vortices.

The small break LOCA was also specifically evaluated for vortex and air ingestion (References 3.f.15 and 3.f.21). The minimum water level for a small break LOCA is 2.34 feet (2'4"), which is at the 592.34 ft elevation. This is just over one-foot (1.01 ft) lower than for a large break LOCA (3.35 ft). The lower water level will result in portions of the strainer modules not being fully submerged. The partial submergence conditions with a small break LOCA were evaluated. The core tube centerline elevation of the strainer is 591'8 9/16", and the top of the strainer elevation is 593'2 118". Thus, the total wetted strainer area that can be credited following a SBLOCA is approximately 2519 ft^2. Using 100 ft^2 for foreign materials, the wetted area is reduced to 2419 ft^2. The PNP strainer testing (Reference 3.f.18) did not specifically test for SBLOCA debris loads; however, testing was performed during drain down of the other large break LOCA (LBLOCA) cases to simulate SBLOCA conditions to evaluate the potential for air ingestion. Three tests were performed; a fiber bypass test (Test 7), a particulate bypass test (Test 8), and the design basis test (Test 4) with maximum debris including chemical. The water level within the flume was monitored during the tests and flow was maintained at the design flow rate. As the water level decreased, air ingestion was noted for each test. The water levels where ingestion was noted were 23 ¼" for the fiber bypass test, 21 ¼" for the particulate bypass test, and 30 718" for the maximum debris including chemical test. The water levels for the first two tests are lower than the SBLOCA water level. For the third test, the use of the results is extremely conservative because:

1) Significantly less debris will be generated from a SBLOCA than a LBLOCA, which would result in a lower head loss, and, therefore, the water level where air ingestion would occur would be lower. A comparison of select debris is given below for the LBLOCA, which generates the least debris of the analyzed cases, and the SBLOCA, which generates the most debris.

Table 3fI Selected Debris Comparisons

Debris Type	Units	LBLOCA case with least debris of analyzed cases (S3)	SBLOCA Limiting Case (SB2)
Nukon/Thermal Wrap Jacketed	ft^3	244.58	0
Calcium Silicate Jacketed	ft^3	21.61	1.42
Low Density Fiberglass Jacketed	ft^3	9.18	0
Mineral Wool Jacketed	ft^3	148.44	46.2
Calcium Silicate Cloth Jacketed	ft^3	11.41	3.82
Qualified Coatings	ft^3	7.491	0.5

2) The SBLOCA water level considers a sufficiently small break such that the pressure in the PCS remains high enough to prevent the SITs and significant quantity of PCS inventory from discharging into the containment building. This back pressure within the PCS will reduce the safety injection flow rate to below the flow rate considered in the LBLOCA maximum debris load test. This lower flow rate will reduce the overall head loss for the SBLOCA and result in a decreased water level at which air ingestion into the strainer modules would be observed.

Therefore, air ingestion due to vortexing into the containment sump during a SBLOCA event is not predicted.

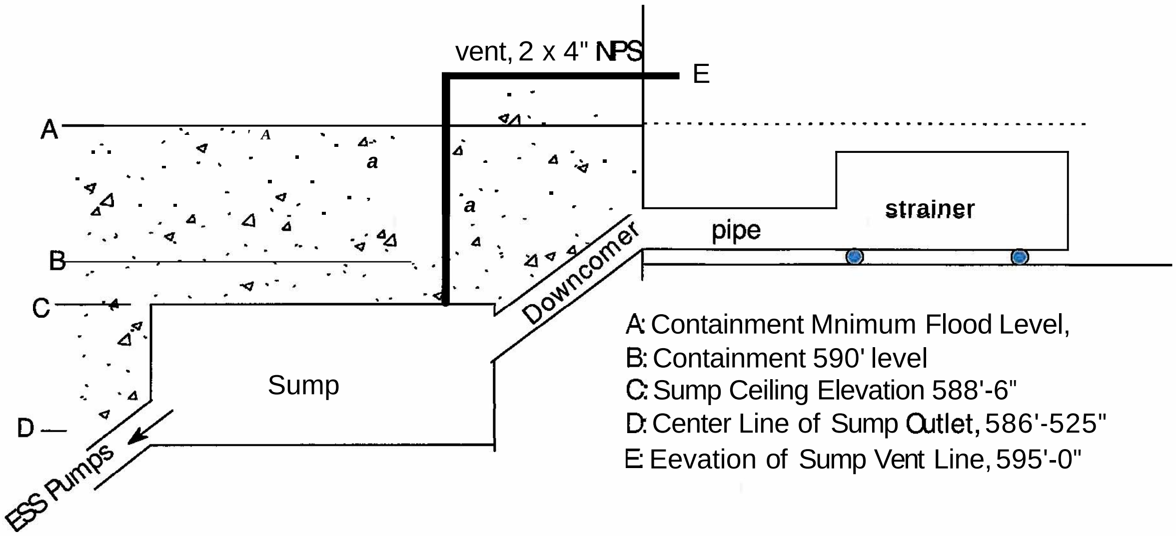
NRC Request

- *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.*

ENO Response

PNP has a vented containment sump (depicted in Figure 3fl below) with two 4-inch vent lines open above the containment minimum flood level (approximately 1.65 feet above minimum LBLOCA flood level). An analysis was performed to demonstrate that a vented containment sump envelope does not adversely affect the ECCS or CSS pump performance (Reference 3.f.16). The analysis also considered the potential vent path via the corium plugs, which are located as shown in Attachment 2. The analysis addressed both SBLOCA and LBLOCA and associated containment water levels for each. For the SBLOCA, conservative water holdup assumptions result in the strainers not being fully submerged as discussed in the preceding vortex response. The minimum LBLOCA containment water level results in the strainers being fully submerged during recirculation.

Figure 3fl: Containment Sump Elevation Overview



The two sump vents and reactor cavity drains (without containment spray operation) will not ingest air unless the total strainer head loss is greater than the hydraulic grade of water above the top of the sump 588'6" elevation. Reference 3.f.16 showed that the strainer head loss is less than the static head for all design basis flow rates, and therefore air ingestion will not occur. The vent lines are situated so there is a downward facing elbow where the vent line protrudes from the biological shield concrete. If the containment water level were to rise up to the elevation of the perforated plate over the vent openings (El 595'0"), the water would be unable to enter the vent lines due to the bubble of air trapped between the vent exit and the water level in the vent line coming up from the sump. As noted above, this bubble would not be ingested into the sump unless the strainer head loss is larger than the hydraulic grade of water above the top of the sump, which is not the case.

For postulated events that lead to containment spray actuation, the flow of spray is more than sufficient to keep the reactor cavity filled to the level of the loop penetrations. Therefore, the sump will not ingest air through the reactor cavity drains when containment spray is in operation. As discussed above, air ingestion through the reactor cavity drains will not occur when spray is not in operation since the total strainer head loss is less than the hydraulic grade of water above the top of the sump 588'6 elevation.

NRC Request

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

ENO Response

The major conservatisms in the head loss and vortexing calculations include the application of bounding case debris loading in the strainer head loss analysis and the application of the containment minimum flood level in assessing the vortexing potential. The conservatisms in determining the containment minimum flood level are described in Section 3.g of this document. The minimum water level for the head loss and vortexing evaluations only considers the SIRWT filled to the minimum Technical Specifications level of 250,000 gallons, rather than the higher administrative limit of 275,970 gallons that is maintained in the tank. This larger water volume would result in an increase in the containment water level of approximately 0.44 ft. The evaluations do not rely on this additional water level and the 0.44 ft is considered additional administrative margin (Reference 3.f.12).

NRC Request

- *Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.*

ENO Response

The worst case minimum water level for a LBLOCA was determined to be at elevation 593.35 ft. The corresponding minimum submergence of the strainer under this LBLOCA condition is predicted to be approximately two inches as the top of the strainer is at approximately elevation 593.18 ft. For a SBLOCA, the RAS could occur before PCS pressure drops to the SIT actuation pressure. As a result, the SIT inventory would not be available to the sump for a SBLOCA. Assuming the maximum water hold up in the PCS, the minimum water level for a SBLOCA is predicted to be at 592.34 foot. For these conservatively bounding SBLOCA assumptions, the strainers are not predicted to be fully submerged. For the minimum LBLOCA submergence and the minimum SBLOCA partial submergence, the evaluation of potential vortex and air ingestion were addressed above in the associated Section 3.f response. The evaluation of flashing is addressed below in the associated Section 3.f response.

NRC Request

- *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.*

ENO Response

Prototypical head loss test for the PNP site-specific strainers, including both site-specific debris loading and site-specific chemical effects, was completed in November 2008. This was a large flume test prototypical to plant specific parameters. PCI was contracted to conduct the test using the facility at ARL. In support of the testing, a CFD analysis was performed by AREVA/Alden for refining debris transport to the sump strainer. The testing was controlled by a PNP site-specific test plan. The test plan incorporated the then current version of the PCI generic test protocol to the extent it is applicable to PNP. The generic test protocol had been updated to reflect the NRC's input, and the testing experience gained in testing other licensee's strainers in the ARL full size strainer element test flume.

Combined debris and chemical head loss strainer testing for PNP was initially performed in May 2008. The testing performed in May 2008 was unsuccessful. Following the May 2008 testing, additional debris reduction measures were pursued. Refined calculations were performed (see Section 3.a for more detail) and potential modifications were evaluated including debris interceptors, more strainers, insulation replacement, and new strainers with larger holes. The approach taken was the next strainer testing effort would "test for success" meaning upfront work was done for determining associated design inputs for testing each of the various potential modifications, if necessary.

In November 2008, strainer testing was completed by PCI at ARL using the large flume test protocol. The initial design basis test was unsuccessful using refined design inputs and a strainer with 0.045 inch diameter holes corresponding to the then installed strainers at PNP. The design basis test pursued next was successful with the use of a strainer having perforated plate with 0.095 inch diameter holes. The remainder of this response relates to the successful design basis test performed in November 2008, which is also referred to as Test 4.

The strainer testing used a full size strainer that was prototypical of what is now installed at PNP (Reference 3.f.2). The amount of debris that is predicted to transport to the strainers, as detailed in Section 3.e, is scaled down for the test flume based on strainer surface area. The scaling factor is 0.04475 for both debris amounts and flow rate.

The strainer testing was performed to address the limiting LBLOCA debris. For conservatism, and to bound two break cases with one test, the strainer test used bounding debris values as inputs including the worst case break for fiber (break S5) and the worst case break for CalSil (break S6). This is highest particulate and highest fiber amounts combined. The water level during strainer testing was 40", which bounds the minimum LBLOCA water level of 40.2.

Velocity and turbulence within the test flume, compared to conditions within the plant, is discussed later in Section 3.f under the near-field credit response.

The surrogate test debris was prepared in a prototypical or conservative manner with respect to the plant. The size distribution of the debris generated and transported to the strainers was defined in earlier Sections 3.c and 3.e. PCI selected and prepared surrogates that would be representative or bounding of the defined debris for PNP. PCI's general approach in this area is defined in PCI proprietary document, Sure-Flow® Suction Strainer – Testing Debris Preparation & Surrogates Technical Document No. SFSS-TD-2007-004, Revision 4, January 16, 2009, which has been submitted to the NRC (Reference 3.f.4). Table 3f2 shows the various plant specific debris, which was scaled and associated with an appropriate surrogate for design basis Test 4 (Reference 3.f.24). In general, the density of the surrogate is either representative of plant material, or less dense to assure the volume of the test debris introduced is conservative.

Table 3f2
Test Plan Debris Allocation Design Basis Test 4

TEST SCALING FACTOR	%	**4.475%**	**23**	**SFS Modules Basis**			
PUMP FLOW RATE @START UP	gpm	**160.7**	**14.48**	**minutes for 1 pool turnover**			PTO bared on 40" Water Level
			Wt Conversions	Debris Scaled	**Debris Qty +**		
Debris Type	UIM	**Quantity**	**(lbs / ft^3 or ft^2)**	to Test **Module**		**U/M**	Debris Form (Surrogate)
Fibers (Design Basis)							
Percent of Fiber Basis for Thin Bed		**100%**	**Percent** of Fiber Basis for Thin Bed TBD				
NUKON / Thermal Wrap / LDFG	ft^3	71.158	2.4	7.879	7.7	ibm	NUKON Smalls' **Wood Chipper** w/ fines removed
NUKON / Thermal Wrap / LDFG	ft^3	83 720	2.4	8.991	9.0	ibm	HT NUKON Fines, processedihru **Shredder**
NUKON Thermal Wrap / LDFG (Erosion)	ft^3	30.977	2.4	3.327	3.4	ibm	HT NUKON Fines, processed thfu Shredder
Mineral Wwl	ft^3	0.00	8.0	0 000	0.0	ibm	Mineral Wool Smalls; processedlhru Wood Chipper
Mineral **Wool**	ft^3	19 300	8.0	6 909	7 0	ibm	Mineral **Wool Fines; processed** thru Shedder
Mineral Wool (Erosion)	ft^3	10.391	8.0	3 720	3.8	ibm	Mineral **Wool** Fines; processed **thru Shredder**
Latent **Fibers**	ft^3	12.633	2.4	1,342	1.4	lbm	HT NUKON Fines; **processed** thru Snredder
				Total Fibrous Debris	**32.3**		
Particulates							
Cal Sil	ft^3	**0.000**	14.5	0.000	**0.0**	lam	Cal **Sil** (Smalls) pulverized powder
Cal Sil	ft^3	**28.249**	14.5	**18.329**	**18.4**	lbm	Cal Sil **pulverized** powder
Cal **Sil** (Erosion)	ft^3	**6.784**	14.5	**4.402**	**4.5**	lbm	Cal Sil **pulverized powder**
Latent **Particulate**; Dirt & Dust	lbm	**170.0**	n/a	**7.61**	**7.7**	lbm	**PCI** PWR **Dirt** Mix
				Total Particulate Debris	**30.6**		
Coatlngs **(lbs)**							
Qualified Coatings							
Carboline Carbozinc **11**	ft^3	1.735	457	35.480	**35.5**	lbm	
Inorganic Zinc Silicate	ft^3	1.439	**457**	**29.427**	**29.5**	lbm	
Unqualified coatings. Carbozinc **11**	ft^3	0.250	457	**5.112**	**5.2**	lbm	
				Zinc Coatings Sub-totals (Tin **Powder)**	**70.2**	lbm	Powder **(Tin** Powder)
Carboline **Phenoline 300 Primer/Finish**	ft^3	**4.887**	**94.0**	20 556	**20.6**	lbm	
Dense Aiuminum	ft^3	**0.008**	**168.5**	0.060	0.1	lbm	
Zinc Chromate	ft^3	**0.006**	**81.1**	0 022	0.1	lbm	
Unqualified Coatings, Alkyd	ft^3	**14.080**	**94.0**	59.224	**59.3**	lbm	
				Top **Coatings** Sub-totals **(Powder)**	**80.1**	lbm	**Powder** (**Acrylic Powder)**
Unqualified Coatings: **Dense Aluminum**	ft^3	4.35	168.5	**32.795**	**32.8**	lbm	
				Top Coatings Sub-totals **(Chips)**	**32.8**	lbm	**SIL-CO-SIL** 53 Powder
Unqualified Coatings: Chips	ft^3	**2.42**	**94.0**	**10.179**	**10.2**	lbm	
				Top Coatings **Sub-totals (Chips)**	**10.2**	lbm	Chips (Acrylic 1164" up to 114")
				Total Coating Debris	193.3	lbm	
Chemical Debris Concentrations		**Desi n Basis**	**Adjusted** Basis				
Sodium Aluminum Silicate. $NaAlSi_3O_8$	lbm		0.00	**0.00**	0.00	lbm	WCAP **Chemical** Surrogate- AIOOH
Aluminum Oxyhydroxlde; AIOOH	lbm		**930** 77	41 **65**	41.7	lbm	WCAP Chemical Surrogate - AIOOH
Calcium Phosphate; $Ca_3(PO_4)_2$	lbm		**0.00**	**0.00**	**0.0**	lbm	WCAP Chemical Surmgale- **Ca3(PO4)2**
				Total WCAP Surrogate Debris	**41.70**	lbm	Note: **Test Basis** Adjusted **for** Overflow & **Soluability**
Miscellaenous Debris (Previously Tested / Found **NOT TO TRANSPORT)**							
Lables Stickers Tape Placards. Tags	ft2	**534.9**	nla	23.94	**24.0**	ft^2	**Not** Required IF Flow Stream is bounded **by** prior test
Glass	ft2	**0.000**	**0 04305**	0.00	0.0	ft^2	Not Required **F Flow Stream** is bounded by prior test
Adhestves	R3	**0.000**	nla	**0.00**	0.0	ft^2	Not Required **IF** Flow **Stream** is bounded by prior test
RMI (Smalls)	ft2	**83.620**	**0 0813**	3.74	**3.8**	ft^2	Not Required IF Flow Stream is bounded by prior test
RMI (Larges)	ft2	**0.000**	**0 0813**	**0.00**	0.0	ft^2	Not Required **IF** Flow Stream **is** bounded by prior test
Insulation Jackettng (Smalls)	R2	**0.000**	0 **0813**	**0.00**	0.0	ft^2	Not Required IF Flaw Stream **is** bounded by prior test
Insulation Jacketing (Larges)	ft2	**0.000**	**00813**	**0.00**	0.0	ft^2	Not Required IF **Flow** Stream is bounded **by** prior test

The fiber smalls were prepared by processing NUKON through a wood chipper and then screening through 1" x 4" openings. This is conservative compared to the 4 x 4" opening that has been used by the industry to define the upper bound for small-fines. As fiber fines are conservatively introduced separately in the test flume, some attempt was made to remove fines from the fiber smalls to avoid double counting fines. Fiber fines were prepared by processing through a shredder. The resulting size distribution has been observed to be suspended in the test flume following introduction. The make-up of the dry fiber fines was observed by the NRC, as well as the mixing and dilution in buckets, prior to introduction into the test flume. Early feedback from the NRC during the initial PCI strainer protocol testing in January 2008 was used to further dilute the fiber fines before introduction into the test flume. PNP testing implemented the improved dilution that had been incorporated into the PCI's test protocol. More details on the preparation and introduction of the fiber debris are discussed later in Section 3.f under the chemical effects audit response.

For the various coatings in the plant, powder of appropriate density was used as a surrogate. A small portion of the coatings was justified to fail as chips based on being epoxy coatings outside any ZOI (Reference 3.f.25). The surrogate material for the epoxy chips was acrylic chips 1/32" in size, which was selected to be representative or bounding of the expected chip size from a LOCA.

The chemical surrogate used was AlOOH, which was generated using the industry guidance in WCAP-16530-NP (Reference 3.f.3). The November 2008 testing added an amount of chemical that represented the design basis amount at the time. Additional chemical was then added that resulted in more than two times the design basis amount of chemical included in the test. Since the November 2008 testing, the design basis amount of chemical was refined slightly (Reference 3.f.l). The tested amount still bounds the design basis value by more than a factor of two. Section 3.0 provides more details on chemical effects.

The performance of the strainer testing can be summarized as:

1. The initial flume conditions are established for temperature (~110 to 120°F) and water level (40").

2. The test flume pump is started and the required flow rate is established.

3. Clean strainer testing head loss testing is performed at varying flow rates.

4. Flow rate is returned to the design flow rate and miscellaneous debris transport testing is performed. (This step was not repeated in November 2008, as the May 2008 testing was bounding.)

5. Pump is turned off and miscellaneous debris is removed from the flume. Any miscellaneous debris that transported to the strainers would be

considered for inclusion in the upcoming design basis testing, which is the subject of all below steps.

6. Initial flume conditions are verified for temperature and water level.

7. 25% of the latent fiber debris is introduced along the flume length prior to the strainer. All remaining debris is introduced at a common introduction point 30 feet from the strainer.

8. The test flume pump is started and the design flow rate is established.

9. Fine particulate debris is introduced into the flume inclusive of calcium silicate, coating surrogates and particulate from latent debris.

10. Fine fibrous debris is introduced, which for PNP test 4 was NUKON and mineral wool.

11. Small particulate debris is introduced, which for PNP test 4 consisted of the acrylic paint chips.

12. Small fibrous debris is introduced, which for PNP test 4 was NUKON only, as no mineral wool smalls were calculated to be transported to the strainer.

13. Fine calcium silicate particulate debris is introduced representing the quantity that would erode over time (which is longer than the time it would take for each previously introduced debris to transport to the strainer).

14. Fine NUKON and mineral wool fibrous debris is introduced representing the quantity that would erode over time.

15. Once all the above non-chemical debris in introduced, the flume is monitored for at least five pool turnovers before chemical debris addition starts.

16. Chemical debris is introduced initially in three separate batches to achieve the same concentration that would exist in the plant for the design basis amount of AlOOH.

17. Subsequent smaller batches of chemical were introduced with two flume turnovers between batches until all design basis chemical is introduced.

18. Once all design basis chemical is introduced, the flume is monitored for at least 15 pool turnovers before beyond design basis chemical debris addition starts.

19. Beyond design basis chemical debris is added similarly to Step 17.

20. Once all chemical debris is introduced, the flume is monitored until at least 15 flume turnovers and less than 1% change in head loss in 30 minutes is observed.

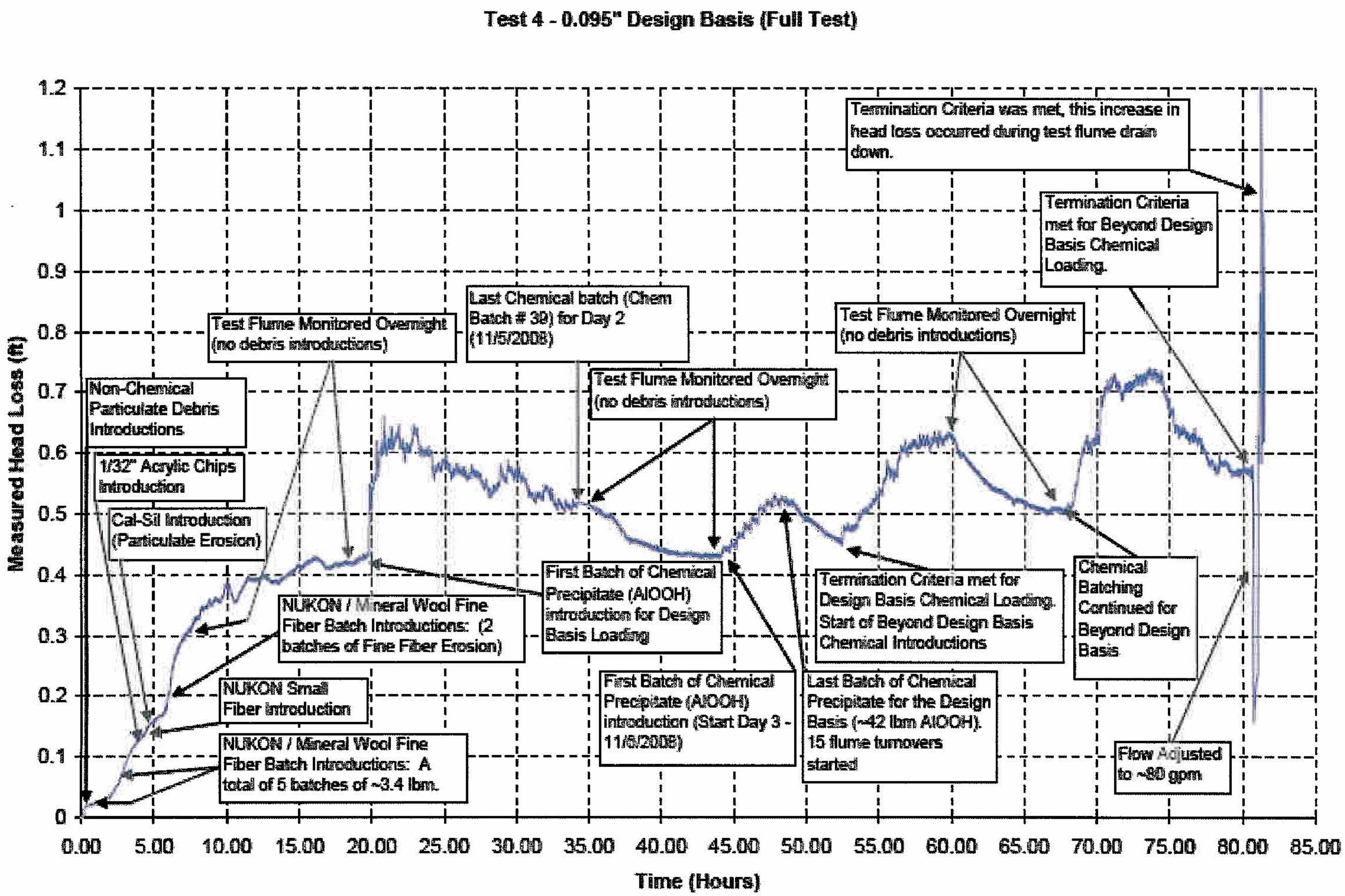
21. Before the test is terminated, the flow rate is reduced to 50% of the design flow to monitor head loss and observe if bore holes may have formed.

22. PNP November 2008 testing also returned the flow rate back to the design flow and then monitored flume for votexing and air ingestion during the drain down.

The acceptable results of the head loss testing, including chemical effects, are shown in Figure 3f2. The maximum measured head loss, which occurred shortly after the introduction of chemical batch 3, was 0.66 ft of water at an average flow rate of 163.8 gpm and a temperature of 106.2°F for the design basis quantity of chemical (~42 lbm AlOOH). The maximum measured head loss, which occurred shortly after the introduction of chemical batch 88, was 0.74 ft of water at an average flow rate of 163.8 gpm and a temperature of 111.6°F, for the beyond design basis quantity of chemical (~102 lbm AlOOH).

The test termination criteria for the design basis test was: (1) the change in head loss is less than 1% in the last 30 minute time interval, and (2) a minimum of 15 flume turnovers after all the debris has been inserted into the test flume. Typically, a regression line is plotted for the head loss data collected during the last 15 pool turnovers of the test. This regression line is then used to provide an estimated head loss for a given mission time, which is 30 days for PNP. However, for PNP plotted data, it is apparent that the head loss depletes with respect to time at the end of the test. If a regression line is plotted using this data, the head would trend to zero. It is expected instead that the head loss would diminish to a constant value. Since the head loss depleted with respect to time, the maximum head loss value observed during the tests bounds the head loss value.

Figure 3f2: Measured Head Loss vs. Time Plot for Test 4



NRC Request

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

ENO Response

As discussed above in Section 3.f, the strainer design was tested to demonstrate it can accommodate the maximum volume of debris based on the bounding debris generation and transport cases, S5 and S6, which are described in Sections 3.b, 3.c and 3.e.

NRC Request

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

ENO Response

The clean strainer head loss calculation uses the results of clean strainer head loss hydraulic testing previously conducted at the Fairbanks Morse Pump Company, and at the Electric Power Research Institute (EPRI) Charlotte, North Carolina, Non-Destructive Examination Center for PCI Prototypes I and II, respectively. The testing is applicable to the current PCI Sure-Flow 8 Strainer. The methodology of the clean head loss is described in detail in the PCI proprietary document, Sure-Flow 8 Suction Strainer - Suction Flow Control Device (SFCD) Principles and Clean Strainer Head Loss Design Procedures Technical Document No. SFSS-TD-2007-002, Revision 1, dated December 11, 2008, which has been submitted to the NRC (Reference 3.f.4). The methodology for determining head loss in the piping and fittings used standard hydraulic head loss equations based on Crane Technical Paper 410.

The results of the total clean strainer head loss (TCSHL) calculation (Reference 3.f.26), inclusive of the strainers, piping up to the downcomer openings, and uncertainty was 1.024 feet of water at 255°F, 1.026 feet of water at 212°F, and 1.031 feet of water at 120°F for the limiting strainer banks A and B to their associated downcomer 1 (see Attachment 2 for layout). Orifice plates are sized and installed on the common line from strainer banks A and B and before the combining tee for strainer bank D in order to balance the head loss and enable flow at the apportioned design flow rate into the sump through downcomers 1 and 5. The TCSHL for bank C with nine modules, which has no associated orifice plate, is 0.801 feet of water at 212°F. The TCSHL for bank D with six modules, including its associated orifice plate, is 0.815 feet of water at 212°F.

As discussed in PCI Technical Document No. SFSS-TD-2007-002, the clean strainer head loss is adjusted for temperature using the kinematic viscosity of water for the laminar portion of the equation. As the above TCSHL cited values at 120°F, 212°F and 255°F show, the adjustment is minor.

The limiting TCSHL is less than the maximum design head loss of 2.6 feet of water at 212°F for the combined maximum flow of 3591 gpm for all strainer banks flowing into the downcomers. This results in a minimum of 1.57 feet of head loss margin at 212°F that would be available to address any head loss specifically associated with debris on the strainers. Use of 1.57 feet as the limit for debris head loss at 212°F is conservative for banks C and D, which have less TCSHL.

NRC Request

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

ENO Response

The total head loss is the combined total of the clean head loss associated with the strainer and attached piping and the debris head loss. The clean strainer and associated piping head loss is as described in the preceding 3.f response. The debris head loss is determined based on actual test results for the PNP strainer, corrected for the plant's specification design basis post-LOCA water temperature.

For head loss calculation purposes, the following temperatures were used: 255°F (initiation of post-LOCA recirculation maximum temperature), 212°F (post-LOCA recirculation period), and 120°F (post-LOCA long-term recirculation). The maximum head loss from the November 2008 PNP strainer testing for the design basis chemical debris (Test 4) was corrected to 120°F, 212°F and 255°F and then used in determining the associated total head loss. The head loss resulting from flow through a fiber-particulate debris bed at the approach velocity for the PNP strainer (0.0023 ft/sec) is 100% viscous flow. As viscous flow, head loss is linearly dependent on the product of viscosity and velocity. Therefore, to adjust the measured head loss across a debris bed with colder water, a ratio of water viscosities, between the warmer specified post-LOCA water temperature and the colder test temperature, can be multiplied by the measured head loss to obtain a prediction of the head loss with water at the specified post-LOCA temperature. The results are summarized in Table 3.f.3 below.

Table 3.f.3: Strainer Debris Laden Total Head Loss Summary

Total Clean Strainer Head Loss, Temperature Corrected (ft of water)			Debris Head Loss, Temperature Corrected (ft of water)			Total Debris Laden Head Loss, Temperature Corrected (ft of water)		
120°F	212°F	255°F	120°F	212°F	255°F	120°F	212°F	255°F
1.031	1.026	1.024	0.562	0.284	0.226	1.593	1.310	1.250

In Table 3.f.3, the limiting strainer banks A and B total clean strainer head loss is used. The debris head loss uses the measured head loss of 0.660 feet of water at 106.2°F, reduced by measured clean strainer head of 0.014 feet of water at 117°F.

The total debris laden head loss is within the maximum specified design head loss of 2.6 ft water at 212°F and 3591 gpm.

NRC Request

- *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.*

ENO Response

The strainer testing approach credits near field settlement. The plant CFD debris transport calculation (Reference 3.f.23) was used to determine representative bounding approach velocities for the plant, which could be duplicated in the test flume by appropriately locating side walls given the set flow rate and water level. The method to determine test flume velocities is detailed in the response to RAI 12 provided later in this section. A brief summary of the method follows:

- The CFD was used to define the path the water follows to the different strainer module banks.
- Using the defined paths, vertical planes at 1-foot increments back from the module banks were defined.
- At each 1-foot increment, the cross section average velocity was derived.
- For modules with more than one approach flow direction, the average from each direction was calculated.
- An overall average velocity at each 1-foot increment was calculated for the different strainer banks.

- A module weighted average velocity was then determined. For conservatism, the maximum velocity of the different banks at every 1-foot increment was double weighted.
- The width of the test flume along the 30 foot distance from the strainer was calculated based on the module weighted average.

The turbulence within the flume was similar, and likely higher, to that of containment post-LOCA flow conditions following RAS. The following turbulence comparison discussion was provided by PCI and Alden (Reference 3.f.27).

In comparing flume and containment turbulence, there are three separate items to address. The first item to consider is whether or not the flume is operated in the turbulent Reynolds number regime. The second item to consider is whether or not the level of turbulent kinetic energy in the flume is similar or bounding and conservative to containment conditions. The third issue to consider is whether or not both containment and flume contain the same scales of turbulence.

i. The Reynolds number in the flume can be estimated as follows:
   Kinematic Viscosity = 0.6 E-5 ft^2/sec (water at 120 deg F)
   Velocity = 0.12 ft/sec
   Length Scale:
   Flume = 4*Rh = 4*(A/P) = 19.85 in
   Where: Rh = Hydraulic Radius
   A = Cross Sectional Area = Depth x Width
   P = Perimeter = Depth + Depth +Width
   Depth (Flume) = 39 inches
   Width (Flume-minimum) = 11.375 inches
   Depth (Plant) = 39 inches
   Re = Velocity x Length/Kinematic Viscosity = 33,091

   The Reynolds number for the flume is well into the turbulent range. Once a flow is turbulent, a further increase in Reynolds number serves to decrease the smallest scales of turbulence existing in the turbulent flow spectrum. These smallest scales are not likely to be involved in transport. Therefore, the only requirement with respect to Reynolds number in the flume is that the flow is turbulent.

ii. The level of turbulent kinetic energy in the flume is likely to be higher than that in containment because containment does not have as many turbulence producing shear regions as the flume. The flume walls and floor serve as significant shear, and therefore, turbulence producers, whereas by and large, within 30 feet of strainer banks, only the floor serves as a shear-producing boundary in containment. Once flow is turbulent, the energy loss of the flow is mostly caused by turbulent energy dissipation. The energy loss per unit momentum of flow is greater in a more confined flow. In order for the energy to be dissipated through turbulence, the turbulence must first be produced through shear, as explained above.

iii. The scales of turbulence likely play a role in the ability of turbulence to potentially prevent debris settlement. The length scale used in the Reynolds number computation is the best measure available to characterize the energy containing turbulence scales of a turbulent flow. For containment, the scale is some factor of the water depth (~39 in). In the flume, the length scale was calculated to be 19.85 in. Although these length scales are quite different, both are much larger than the largest debris sizes tested. Therefore, the turbulent structures that may keep debris from settling in containment still exist in the flume, and based on the reasoning above under item ii, actually contain a greater amount of energy, hence, providing a bounding and conservative environment of turbulence in the flume.

The energy associated with the inflow of the water at the pool surface (spray and drainage flow) was included in the CFD performed for the PNP containment with turbulent kinetic energy specified at these inflow boundaries. Review of these energy levels in the CFD, and consideration of the relative positions of the spray drainage inflows to each strainer bank, lead to the following conclusions:

1. Energy associated with the spray drainage (being a combination of spray flow and disassociated run-off flow) through the openings in the containment above the water surface was not predicted to propagate laterally and dissipated very near the area where the flow impacted the pool.

2. It was decided that attempts to introduce energy between the test strainer and the point of debris injection in the flume could inhibit the ability of the debris and chemicals to transport down the length of the flume, and debris could be non-conservatively sequestered upstream of the turbulence zone. This was considered non-prototypical for the PNP test.

3. It was further decided that flow energy introduced into the flume near the strainer could disturb the formation of the debris bed in a non-conservative manner and was not prototypical for PNP.

For these stated reasons, additional energy was not introduced into the test flume flow stream, beyond that associated with flow shear and the introduction of material into the flume.

NRC Request

- *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.*

ENO Response

As discussed earlier in Section 3.f under the debris head loss analysis response, temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. The assumption that the debris bed head loss is linearly dependent on the product of viscosity and velocity was partially checked by the flow sweep that was performed at the end of the design basis head loss test.

Once the test termination criteria were met following the last batch of chemical debris in Test **4,** the flow rate was reduced approximately in half (from –163 gpm to –82 gpm) causing the head loss decrease from –0.57 ft of water to –0.22 ft of water. The flow was returned to the design flow rate and the head loss returned to –0.62 ft of water.

The change in head loss with the reduced flow is supportive of no significant bore holes being present. The change in head loss seen is supportive of the head loss being linearly dependent on the product of viscosity and velocity. In the flow reduction testing steps, the temperature of the flume was essentially unchanged over this small time period. The head loss reduced by a factor of 2.6 as the velocity was reduced by a factor of two. Head loss changing by an exact factor of two would not be expected, as other effects such as a small change in debris bed compaction, can play a role.

NRC Request

- *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.*

ENO Response

Containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface. Post-LOCA minimum containment flood levels provide only marginal or partial strainer submergence. Given the design basis value of strainer head loss, strainer flashing is postulated if containment overpressure is insufficient or is not credited. The potential for flashing was evaluated for the PNP strainers and it was concluded that flashing would not occur (Reference 3.f.15).

The methodology for the strainer flashing evaluation considered the current design basis LOCA containment analyses, as well as the results using a more comprehensive integrated model, to better represent post-accident conditions expected for the strainers.

Design basis containment response analyses are biased to give high containment pressures and temperatures and high sump temperatures in order to demonstrate the associated containment and ECCS design bases are met. Conservative simplification and decoupling is employed in defining these biases.

For the LBLOCA, about 1.0 psi of containment overpressure is needed to prevent strainer flashing at the top of the strainer assembly for the design basis strainer head loss:

LBLOCA minimum water level - top of strainer - design basis head loss
593.35 ft - 593.18 ft - 2.6 ft = -2.4 ft = -1.0 psi

The design basis large break containment response cases indicate that containment overpressure is driven to a minimum (at or near zero) from 18 to 30 minutes prior to recirculation mode initiation at the RAS. After RAS, containment overpressure immediately begins to recover due to: (1) the containment pressure spike resulting from the spray flow temperature increase and increased PCS steaming rate resulting from the lower injection flow, and increased injection temperature relative to suction from the SIRWT, and (2) sump water continues to be cooled by mixing with the injection spillage and containment spray that is cooled by the shutdown cooling heat exchanger(s). Containment overpressure reaches 1.0 psi between 200 and 400 seconds for all cases.

Therefore, there is the potential for strainer flashing to occur for a short period (up to 7 minutes) post-RAS, based on the simplified, decoupled design basis analysis. However, the following is noted:

1. Limiting flashing at the top of the strainer is not considered a significant concern since flow must descend to the level of the core tube and below to reach the sump, which provides additional pressure to re-collapse any voids.

2. The core tube is approximately 1'0" below the top of the strainer. At this level, an overpressure of only about 0.6 psi is required to ensure no flashing. The design basis LOCA cases indicated the lowest post-RAS overpressure is 0.4 psi and exists for at most 200 seconds.

3. While the flow rates are expected to achieve the post-RAS flow rates quickly due to the tripping of the LPSI pumps, the transition of the suction to the containment sump occurs over a longer period of one to two minutes. During this time, injection water comes from the SIRWT. This results in colder injection water than is modeled in the design basis analysis.

4. The 2.6 ft design basis strainer head loss includes the clean strainer head loss and head loss due to debris. However, immediately following RAS, actual head loss would be lower, since only a relatively small fraction of the total debris load would be transported to the strainers during this time. The 2.6 ft head loss also includes the pipe head loss, not just the debris and perforated plate head loss.

5. Items 2 and 4 above, when considered together, result in a small margin to predicted strainer flashing at the elevation of the top of the sump core tube (593.35 ft - 592.2 ft - 1.03 ft = +0.1 ft). Note that 1.03 ft is the maximum clean strainer head loss, and 592.2 ft is the elevation of the top of the core tube.

Given the biases and limitations involved in the design basis containment response analyses that are intended to result in high containment pressures and temperatures, as well as high sump temperatures, it is difficult to assess whether the potential for sump strainer flashing indicated by the design basis analyses actually exists. A more comprehensive integrated model can provide additional insight.

A more comprehensive scoping evaluation of a related problem (ECCS pump post-RAS NPSH) was previously performed. These calculations indicated the importance of break spillage rate and temperature, relative to other effects like pool heat transfer and spray drop size distributions. In the post-blowdown period, these calculations allowed the overflow of water from the PCS pipe break (break spillage) to be at water temperatures less than the sump water temperature. These calculations represent the PCS as a coarsely noded lumped parameter model, using the Henry Fauske choked flow model. Containment sprays and containment air coolers were also included in the integrated evaluation. This previous scoping evaluation concluded that a minimum containment overpressure of two psi exists for the spectrum of cases evaluated.

In support of the strainer flashing evaluation, several additional cases from the NPSH evaluation were reevaluated using an updated multimode model of containment. The calculation examined the small break LOCA scenario in which containment flood levels are expected to be minimized due to increased PCS holdup and the isolation of the safety injection tanks prior to actuation and, therefore, may have the greatest potential for strainer flashing, assuming the design basis strainer head loss. It is noted that strainer flashing may not represent a concern during some small break scenarios in which the strainer is not fully submerged since the potential for vapor phase transport through the strainers is minimal, given the interior of the strainer is in direct communication with the containment atmosphere. The analysis evaluated containment pressure after the switch to recirculation mode to determine if adequate containment overpressure exists to preclude strainer flashing. The analysis considers a 4-inch diameter small break LOCA near the top of the pressurizer. Available injection sources include only HPSI; the safety injection tanks are assumed to be isolated per procedure prior to PCS pressure falling below 250 psig. Containment sprays are used in different combinations to determine the impact on containment pressure.

Sensitivity cases were run that determined SIT isolation results in the minimum containment overpressure and sump subcooling. Sensitivity cases were also performed for all cases to demonstrate that the conclusions remain valid under a limiting range of service water temperatures. The evaluation showed that for all cases the containment overpressure is high enough to preclude strainer flashing during recirculation mode, given a vapor space small break LOCA. In all cases, containment overpressure was calculated to be more than 7 psid and sump subcooling was calculated to be greater than 30°F.

Therefore, although post-LOCA minimum containment flood levels provide only marginal strainer submergence for a large break LOCA and can result in an uncovered strainer for a small break LOCA, it is judged that containment overpressure is more than adequate to preclude strainer flashing during the short time period after the switchover to recirculation mode and before significant subcooling in the sump begins. This has been supported by (1) evaluating the design basis containment response analyses and addressing various conservatisms and biases in the analysis and (2) by independently evaluating containment overpressure for a limited set of scenarios by utilizing a more realistic, integrated assessment of post-LOCA containment response than is available in the design basis analyses.

The requests below for items 12, 13 and 14 are from the December 24,2008 NRC RAI.

NRC Request

12. *Please describe how the flume velocity was determined for the final strainer head loss testing to be conducted for Palisades based upon the plant computational fluid dynamics calculation, specifically addressing the potential for non-uniform velocities on the approach to the actual strainer installed in the plant.*

ENO Response

12. The flume setup calculation is Appendix F in the debris transport computational fluid dynamics (CFD) analysis.

In the test flume, the approach velocity is modeled by changing the width of the flume as the flow progresses down the flume toward the strainer. The goal is to model in the flume the average approach velocity to a strainer module as installed in the PNP sump. There is one full size module in the test and there are 23 modules in the plant. There are four banks of strainers in the plant. A bank is defined as a group of modules, that are plumbed so that the core tubes of each module pass flow in series, so that the output from the first module's core tube must pass through the core tube of the second and all the rest in that bank to reach the pump suction.

Each bank of strainers passes flow in parallel to the pump suction. The plant has four banks labeled A, B, C, and D. Banks A and B have four modules, bank C has nine modules, and bank D has six modules.

The calculation of the flume configuration uses the results of the CFD debris transport study to define the average approach velocities to each strainer array. In doing so, the flow to each module group was identified by using the CFD results to track the trajectory of the fluid passing through each strainer module group throughout the containment. With the water path to each module bank identified, vertical planes at one-foot increments back from the bank, along the calculated trajectories were defined. Each plane was analyzed to ensure that the velocities within that plane were sufficient to convey water to the module. At each of these incremental planes, the cross section average of the velocity was recorded. If the paths diverged around objects in the flow, each bifurcated path was analyzed individually.

This methodology was used for each individual bank. For modules with more than one approach flow direction, the flow paths were averaged. Once the averaging was complete, the module weighted average of the flow streams, approaching the four banks, at each vertical plane was conducted. Plots of the calculated module weighted average velocity, versus incremental distance back from the module bank, was used to calculate the width of the test flume at each one-foot increment using the relation $Q = (H)(W)(V)$. In this expression, Q = flow rate, H = water depth, W = flume width, and V = cross section velocity.

The transition of the flume near the test strainer module was defined by the trajectory'of the water as it approaches the modules in the prototype installation. These flow patterns were calculated in the CFD debris transport analysis. Engineering judgment was used to interpret these flow patterns and define the shape of the flume at the test module.

The full (proprietary) calculation, with graphics, is available at PNP for NRC inspection.

NRC Request

13. The single failure of a low-pressure safety injection (LPSI) pump to trip at the time of switchover to recirculation was not fully addressed in the supplemental response. The supplemental response also noted that a LPSI pump could be restarted later in the event if necessary. Therefore, please address how the following items related to the potential operation (including failure to trip) of a LPSI pump during recirculation are addressed in the strainer performance analysis:

a. Increased flow from an operating LPSI pump could lead to increased debris transport that was not considered in the debris transport calculation or flume testing.

b. Increased flow from an operating LPSI pump could lead to a larger clean strainer head loss value than was calculated in the existing analysis.

c. Increased flow from an operating LPSI pump could result in higher than analyzed flow through the strainer. Events that would result in higher than analyzed flow through the strainer should be evaluated and shown to result in acceptable NPSH margin.

ENO Response

13. The ability to restart a LPSI pump later in the event, if necessary, was a carry over from a step that once existed in PNP Emergency Operating Procedure EOP-9.0, "Functional Recovery Procedure." The step was removed from EOP-9.0 in late 2001. Procedures that govern actions following a LOCA are EOP-4.0, "Loss of Coolant Accident Recovery," and EOP-9.0. These procedures contain no steps for restarting a LPSI pump post-RAS. The follow-up supplemental response has removed reference to restarting a LPSI pump. Items a, b, and c of the NRC Request are addressed below for the failure of a LPSI pump to trip at RAS.

The CFD and debris transport analysis described in Section 3.e, and the resulting amount of limiting detrimental debris that would be introduced into the test flume, would not be affected by the higher flow. The limiting detrimental debris is referring to the predicted fine particulate and fine fiber transport, which is assumed to be 100% in the debris transport calculation. The amount of fiber smalls that would be predicted to transport may increase and the amount that would have been introduced into the flume would then have increased. However, the amount of fiber smalls added into the flume was already conservative, as discussed below in the response to the chemical effects audit. Fiber smalls would have a smaller effect on pressure drop than the particulate fines and fiber fines, which are the main contributors to strainer non-chemical debris head loss. A case can be made for additional smalls reducing head loss if transported to the strainer by interfering with development of a thin bed. With respect to chemical debris, the LPSI pump would be secured before any significant chemical debris occurred.

The EOPs direct the operators to manually trip the LPSI pumps if they continue to operate post-RAS. The trip verification happens very soon after RAS, and simulator experience shows that the LPSI pump could be tripped, or its supply bus could be tripped, within 15 minutes of RAS.

The PNP strainer testing did not include the higher flow, assuming a LPSI pump was also running, given the low probability of a LPSI failure to trip on top of the low probability of a medium or large break LOCA. It would have been difficult to incorporate this higher flow rate, which would be limited to the short duration, as indicated above for the PNP containment, into the strainer testing protocol without being extremely conservative. Even if the LPSI failure to trip at RAS is a very low likelihood event, it is still a credible single failure event and has been analytically evaluated.

The maximum flow rate with a LPSI pump failure to trip at RAS was calculated to be 7148 gpm. Adequate NPSH was shown to exist for all CSS and HPSI pumps (Reference 3.f.12). The operating LPSI pump was shown to not have adequate NPSH margin and will likely cavitate. However, post-recirculation LPSI pump operation is not credited. The head loss through the strainers, strainer piping, and downcomers is not high enough to cause air and water vapor from the containment atmosphere to be drawn through the vents into the sump. The NPSH calculation models the strainers so the increase in the clean strainer head loss is explicitly addressed for the higher flow. See Section 3.g, which discusses this in more detail.

NRC Request

14. *The NRC's June 27,2008, Generic Letter 2004-02 extension approval letter addressed the following program plan for Palisades:*

    i. *Complete chemical effects strainer testing by September 30, 2008.*

ii. *Complete strainer debris and chemical effects test report including supporting analyses for testing and inputs by December 31, 2008.*

iii. *Complete any necessary modifications prior to restart from the 2009 refueling outage.*

iv. *Complete design and license bases updates, and provide final update to GL 2004-02 supplemental response by February 27, 2009, if no modification is required, or 60 days following completion of the 2009 refueling outage if modification is required.*

Because the final head loss and vortexing evaluation has not yet been transmitted to the NRC, no actual RAIs could be developed in this area. However, the head loss and vortexing testing subject areas and/or issues listed below should be addressed in the final supplemental response:

a. *Information requested by the content guide that was not previously submitted due to the testing being incomplete or that changed due to the testing results.*

ENO Response

Information requested by the content guide has been provided above in this section.

NRC Request

b. *Flow rates in the flume.*

ENO Response

The flow rate in the flume was within +5% and -0% of the target flow rate, which was 160.7 gpm. The approach velocity to the strainer for the debris transport ranged from 0.072 to 0.116 ft/sec.

NRC Request

c. *Scaling factors for testing.*

ENO Response

A full scale strainer module was used for the testing. The debris and volumetric flow rate scaling factors were based on the ratio of test surface area to the total surface area of the installed strainers reduced for 100 ft^2 sacrificial area for miscellaneous debris. The debris and flow rate scaling factor was 0.04475. The scaling factor for water volume in the flume compared to the plant was 0.0059 to 0.0107 for the maximum and minimum plant volumes, respectively.

NRC Request

d. Debris amounts added for testing, including debris size distributions where appropriate.

ENO Response

Table 3f2 and earlier discussion in Section 3.f provides the requested information.

NRC Request

e. Debris preparation and introduction methods.

ENO Response

The requested information is provided above in Section 3.f under the strainer testing response. Additional details on the preparation and introduction of the fiber debris are discussed later in Section 3.f under the chemical effects audit response.

NRC Request

f. Head loss results -time based chart with significant data included (e.g. flow, temperature, debris addition times).

ENO Response

Figure 3f2 provides the timed based chart with most of the requested information included. Besides the flow sweep at the end of the test, which is identified on Figure 3f2, flow was maintained during the test at +5% and -0% of the target flow rate, which was 160.7 gpm. The design Test 4 was performed over a 4-day period from November 4 to 7, 2008. During this period, flume temperature ranged from around 105°F to 115°F.

NRC Request

g. At the beginning of recirculation for a small-break loss-of-coolant accident (SBLOCA), the strainer stacks are submerged by about 3/4 inch. The supplemental response stated that the vortexing evaluation was performed assuming a submergence of 3 7/8 inches. The licensee should demonstrate that, at the calculated minimum submergence that occurs during a SBLOCA, vortex formation does not occur.

ENO Response

The PNP SBLOCA minimum water level calculation has been revised. The strainers have been evaluated for partial submergence, as discussed earlier in Section 3.f under the vortex response.

NRC Request

h. The Palisades sump is vented. If head loss becomes greater than the containment water level elevation minus the elevation of the vent entrance into the sump (about 4.5 feet), air will be drawn into the emergency core cooling system (ECCS) pump suction plenum. In addition, it is likely that air voids will begin to form inside the strainer. These events could lead to increased head loss or air entrainment in the ECCS pump suction. The licensee should demonstrate that head loss will not exceed 4.5 feet or otherwise show that the strainer will not fail to perform its function due to air voids.

ENO Response

As discussed earlier in Section 3.f under design basis head loss response, the PNP vented sump configuration imposes a strainer head loss limitation of 4.85 ft water for the LBLOCA and 3.84 ft water for the SBLOCA to avoid potential air ingestion concerns.

Testing has demonstrated that the strainers will not exceed the allocated design head loss of 2.6 feet for clean strainer, associated piping and debris head loss, which is below the above noted values where air being drawn in through vent paths would become a concern. For scenarios that were strictly analyzed and not tested, such as the LPSI failure to trip'event, the resulting total strainer head loss is also verified to be within the above limitations to avoid potential air ingestion concerns.

NRC Request

i. The vents to the sump are about 1.5 feet above the minimum water level. It was not stated in the supplemental response what the maximum water level is. If the water level reaches the vent openings, debris could bypass the strainer and enter the ECCS pump suction directly. The licensee should demonstrate that this form of debris bypass does not occur.

ENO Response

The maximum water level is at Elevation 596'-11.5", which is above the two noted vent openings (Reference 3.f.28). These openings are covered by perforated plate with 0.045" holes, which is smaller than the strainer perforated plate 0.095" holes. The tortuous path provided by the coriurn plugs also eliminates any debris bypass concerns. Openings to the sump are properly protected and monitored as required by PNP Technical Specifications SR 3.5.2.9 (Reference 3.f.29).

NRC Request

A drawing (Attachment 2) included with the supplemental response shows seven 4-inch floor drains with debris screens that bypass the strainer and drain directly into the sump. The licensee should verify that the debris screens will not allow bypass of debris different (larger) from that already included in the bypass evaluation. The licensee should also verify that any bypass through these drains has been included in the downstream evaluation. In addition, it should be demonstrated that these drains will not allow air entrainment into the ECCS pump suction.

ENO Response

The floor drains are included in the openings to the sump that are properly protected and monitored as required by PNP Technical Specifications SR 3.5.2.9. All openings to the sump are bounded by the strainer 0.095" hole size. For sump water flow path conservatisms, no credit is taken for any flow through openings to the sump besides through the strainers. The openings that exist besides the strainers are approximately 0.3% of the total strainer surface area. However, the downstream evaluations are not sensitive to the strainer or screen surface area. The screen openings being' bounded by the strainer hole size assures the bypass evaluations cover the strainers and the screened openings. All openings to the sump were evaluated for potential air ingestion (Reference 3.f.16). The limiting openings, which are the two sump vents and the two coriurn plugs, were discussed previously in Section 3.f. The limiting openings will not allow air ingestion as long as the associated strainer head loss limitations are met. All remaining openings were demonstrated to not allow air ingestion.

NRC Request

k. The supplemental response did not consider the potential effects of water (from the break or from spray drainage) falling near the strainer. During the period of relatively small submergence, effects from the falling water could entrain air near the strainer resulting in air being drawn through the strainer and into the ECCS pump suction header. The licensee should demonstrate that this effect either will not occur or will not have a significant effect on ECCS pump net positive suction head (NPSH).

ENO Response

There is minimal direct spray flow that would land near any strainers. For the small amount that would land near strainers, the CFD analysis (Reference 3.f.23), has evaluated the turbulent kinetic energy of the spray as dissipating very close to the water surface. Therefore, there would be no air entrainment concerns for direct spray. The runoff water from break and spray flow evaluated in the CFD analysis does not fall to the containment basement elevation near the strainers. Therefore, there would be no air entrainment concerns.

NRC Request

l. The Performance Contractors Incorporated (PCI) clean strainer head loss (CSHL) calculation is founded on a correlation based on prototype boiling water reactor (BWR) strainer testing. However, the BWR strainers have a significantly different geometry than pressurized-water reactor (PWR) strainers. In the Prairie Island audit report (ADAMS Accession No. ML071070057), the NRC staff stated that the applicability of the BWR prototype correlation to PWR strainers has not been shown to be valid. The NRC staff is awaiting test data from PCI strainer testing for Wolf Creek and Callaway to validate the CSHL assumptions used in the PWR calculations. The licensee referenced a document in the supplemental response that PCI provided to the NRC staff regarding the CSHL, but the NRC staff has not accepted this document's validity. The licensee should resolve this NRC staff concern.

ENO Response

Since the above RAI was written, it is understood by ENO that PCI has resolved the CSHL concern with the NRC, which concluded with PCI submittal of March 25, 2009 (Reference 3.f.4).

NRC Request

m. No CSHL value was provided in the supplemental response. The licensee should provide the CSHL value, and discuss the methodology used to derive this value.

ENO Response

This information has now been provided, see previous Section 3.f discussion.

NRC Request

n. The supplemental response did not discuss the ability of the strainer to accommodate the maximum debris load. The response stated that the break selection section (3.b) of the supplemental response addressed the issue. However, no discussion of the strainer was included in section 3.b. The intent of the question in the NRC staff Content Guide is to ensure that the strainer either has a large enough area to prevent a circumscribed bed or that the formation of a circumscribed bed will not result in excessive head loss.

ENO Response

This information has now been provided, see previous Section 3.f discussion.

NRC Request

o. The supplemental response stated in several places that a thin bed would be precluded due to the complex surface design of the Palisades PCI strainer. Based on tests of PCI strainers that resulted in a relatively thin filtering bed (including Palisades and Point Beach), and the Palisades potentially challenging debris loads, the NRC staff believes that the thin bed should be evaluated for the Palisades installation. The licensee should demonstrate either that a thin bed at Palisades can not form, or that if it does form, it does not result in unacceptable strainer head loss.

ENO Response

ENO has revised the response to address the potential for a thin bed. See previous Section 3.f discussion.

NRC Request

p. The supplemental response references 2.86 feet as the maximum allowable head loss. Based on recent Palisades test results it appears that this value may increase. The supplemental response should be revised to reflect the final allowable head loss. This value also can affect the NPSH margin and structural evaluation results.

ENO Response

The response has been revised to reflect updated calculations and the November 2008 strainer testing. See previous Section 3.f discussion and Section 3.g.

NRC Request

q. The supplemental response states that containment accident pressure was not credited in evaluating flashing across the strainer. However, the submergence of the strainer is small when compared to the strainer head loss. In the supplemental response the licensee's discussion of air ingestion into the strainer is questionable. The licensee stated on Page 41 that the NUREG/CR-6224 correlation indicates 0.0% void fraction downstream of the screen. This statement does not appear correct, particularly in light of the statement on Page 46 of the supplemental response that no containment accident pressure was credited in the flashing calculation. The bases for the conclusion that flashing will not occur should be provided.

ENO Response

ENO has evaluated flashing in more detail and concluded that there is a small period of time where credit for containment pressure may be required before sub-cooling of the sump water occurs. For this short period of time, ENO has concluded that adequate containment pressure would exist to avoid flashing within the strainer. See previous Section 3.f discussion.

Below are responses to items identified in NRC letter dated May 13, 2009 (Reference 3.f.8), regarding chemical effects audit open items.

NRC Request

<u>Open Item 6.1</u>
The licensee should provide justification that Test 4 resulted in a realistic or conservative head loss for the strainer. Specifically, the licensee should provide additional information that justifies that a change in strainer hole size from 0.045

inches to 0.095 inches would result in a change in head loss of greater than an order of magnitude. The issues discussed in Section 5.4.1 of this report should be considered in the development of the response to this open item.

ENO Response

The change in hole size from 0.045 inches to 0.095 inches can result in a change in head loss, which was seen in the PNP November 2008 testing. The issues discussed in Section 5.4.1 of the audit report were specifically considered and are addressed below.

NRC Request

NRC Audit Report Section 5.4.1 item I [No Data or Analysis Provided on Head Loss Reduction with Increased Hole Size]

The licensee stated that the strainer vendor had information from tests conducted for Japanese plants that indicated that strainers with small hole sizes were likely to attain higher head losses than strainers with larger holes tested under similar conditions. Specifically, PCI has data from Japanese testing that indicates strainers with 0.033 and 0.045 holes result in higher head losses than those with 0.062 and 0.066 holes. The information provided to the staff regarding the Japanese testing was verbal and no details were available. No test data or test conditions were provided for staff review. No analysis comparing the results of the Japanese tests considering the relevant variables was provided.

ENO Response

Testing in the Alden small flume on 0.033, 0.045" and 0.0625" hole perforated plate by PCI for a client has shown significant improvement in strainer performance when hole size was increased, particularly from 0.045" to 0.0625" holes. The detailed data is considered proprietary by PCI and has been provided in a separate submittal. It compares two sets of test results with equivalent test conditions, except for hole size. An evaluation of hole size using the PCI large flume testing data would be very subjective due to the many different variables. Regardless, there is support that the 0.045" hole strainer did not perform as well as larger hole strainers when the amount of fine fiber per strainer surface area is explicitly considered.

The NRC March 2008 review guidance (Reference 3.f.10) acknowledges that the particulate filtration efficiency for a layer of fibrous debris depends on several factors including, "likely the diameter of the screen holes or wire mesh size." This is noted in relationship to being difficult to analytically evaluate whether there is insufficient fjber to form an effective thin-bed with chemical precipitates and particulate debris.

NRC Request

NRC Audit Report Section 5.4.1 item 2 [Head Loss in Test 4 Does Not Appear High Enough to Result in Bed Degradation]

The head loss in Test 4 did not appear to be high enough to result in bed degradation. If the degradation had been due to hole size, head loss would have built similarly in both tests, but limited due to degradation once it reached a value that would promote that phenomenon. Instead the non-chemical head loss in Test 4 continued to increase and did not reach a plateau even after several hours.

ENO Response

The non-chemical head loss did reach a plateau of approximately 0.42 ft water after around 10 hours. The lower head loss in Test 4 than Test 2 has been postulated to be due to a different particulate and fiber buildup due to the larger hole size. This is thought of as an initial bed formation phenomenon and not necessarily a bed degradation occurring due to high differential pressure.

NRC Request

NRC Audit Report Section 5.4.1 item 3 [Mixing of Mineral Wool and NUKON fines]

It was noted that the Nukon fines were added separately from the mineral wool fines in Test 2, but the fibrous debris was mixed during Test 4. It was also noted that when the mineral wool was added to Test 2 that no increase in head loss occurred. Therefore it appears that the mineral wool may not transport similarly to the Nukon. It is possible that the Nukon/mineral wool mixture did not transport as readily as the separate Nukon would. Because the debris concentration in the test flume is much higher than it would be in the plant, it is unlikely that the Nukon and mineral wool would have a large probability of mixing in a manner similar to that which the test introduction methods created.

ENO Response

The mixing is considered to best represent what occurs and is appropriate as detailed below. The mixing is not believed to have impacted the transportability of the fines as detailed below. Similar transport would have been expected for each type of fines; just the order that they may have reached the screen would differ if introduced separately.

The testing protocol conservatively introduces each class of debris (i.e., fines, smalls, and larges) separately. The NRC input during the development of the PCI strainer test protocol helped establish this approach. Further segregation within each class was not a topic of concern or discussion during the development of the test protocol.

Mixing is prototypical based on the distribution of the debris following a LOCA. In accordance with the NEI 04-07 guidelines for a highly compartmentalized containment, such as PNP's, during blowdown, 25% of small fine debris will transport to the 649 ft. elevation level of containment, with a portion of that debris transporting back down to the 608 ft. 6 in. elevation level. 75% of small fine debris will remain on the 608 ft. 6 in. elevation level of containment and will be susceptible to transport. Based on engineering judgment, it is reasonable to assume that the debris types will mix together upon blowdown and washdown transport once entering the containment pool.

Transportability when mixed is expected to be similar to transportability when introduced separately. Although the as-fabricated density of mineral wool is higher than the as-fabricated density of NUKON (8 lbs/ft^3 versus 2.4 lbs/ft^3), the micro density of NUKON and mineral wool is considered to be similar. NEI 04-07 Table 3-2 states mineral wool density is 90 lbs/ft^3 versus 159 lbs/ft^3 for NUKON. A higher micro density for mineral wool could be assumed to be 193 lbs/ft^3 based on its source density, basalt rock. Information contained in NUREG/CR-2982 (Reference 3.f.31) performed by Alden for the NRC states in part, "Mineral wool does not readily absorb water and can remain afloat for several days." Additionally, NUREG/CR-2982 states in part ... "Fiberglass insulation readily absorbs water, particularly hot water, and sinks rapidly (from 20 seconds to 30 seconds in 120 degree F water)."

Given.the density similarities or minor differences, along with differences for remaining afloat, this further justifies the mixing of fibers since it cannot be concluded with any certainty, which sequencing of "fines" will transport debris more easily to the screen; NUKON or mineral wool. When fibrous debris is introduced as a "fines" class debris form and diluted to the same degree as implemented by the PCI protocol requirements for each debris type, there is no specific evidence to suggest the transport behavior in the test flume is affected. In conclusion, when faced with uncertainty such as the above, it is best to be as prototypical to the accident as is possible, which is, again, why the fiber "fines" were justifiably mixed together for Test 4.

Regarding the concentration of debris in the test being higher than that of the postulated break, this was understood at the outset of the PCI test protocol reviews with the NRC. Not all scaling is one-to-one, nor can it be one-to-one without a full scale test in containment. The test protocol implemented by PCI does scale one-to-one more of the relevant factors affecting head loss than any other test protocol implemented in the industry. The affect of particulate debris concentration in recirculation water is not addressed by industry guidelines or documents; however, PCI has observed the affect of particulate concentrations in flow streams on fiber transport. These observations suggest higher particulate concentration may actually increase fiber transport.

Regardless of whether more fiber transports in flow streams with higher concentrations of particulate or not, introducing particulates first yields the highest head losses. It is this sequencing that is most important, versus the mixing of two fibers. Since PCI implemented "particulates" first in the test protocol, the most conservative test condition for achieving a high head loss was implemented. Overall, the test protocol is considered appropriate and conservative in this area.

Regarding why Test 2 did not see a head loss increase when mineral wool was added is speculated as possibly being due to the thin bed already being fully developed. Mineral wool fines do transport and have increased head loss as witnessed during other PCI strainer testing.

NRC Request

*NRC Audit Report Section 5.4.1 item **4*** [Differences in debris beds between Test 2 and Test 4]

From post-test photographs it appeared that there were differences in the debris beds between the Test 2 and Test 4. Test 4 appeared to be a mostly chemical debris bed with little non-chemical debris under it. Test 2 appeared to have a debris bed with a thicker underlying non-chemical bed. It does not seem plausible that the debris bed appearance would change significantly solely due to a change in strainer hole size. However, the staff is aware that the appearance of the debris bed may change during the drain down of the flume.

ENO Response

The debris introduction sequence of fine particulate first, followed by fine fiber in incremental small batches, was intended to conservatively address thin bed formation, if it were to form. Test 2 debris bed was all non-chemical and was a thin bed, 1/16" to 1/8" thick, with a resultant high head loss. Though the strainer was observed in Test 4 to have a thin layer of fiber and particulate on it before the addition of chemical debris, a high head loss thin bed was not present. Overall, direct comparison between the Test 2 and Test 4 debris beds is difficult, given the presence of chemical debris in Test 4. The underlying non-chemical debris bed for Test 4 was not problematic like Test 2.

NRC Request

Open Item 6.2

The licensee should provide information that the test methodology resulted in realistic or conservative strainer head loss testing results. In particular, debris preparation and introduction methods used during testing should be justified as prototypical or conservative. Items 1, 2, and 3 discussed in Section 5.4.2 should be considered when developing the response to this open item.

ENO Response

The test methodology used was developed to provide representative or conservative strainer head loss testing results. In addressing items raised by the NRC from the chemical effects audit, not adding eroded fines for the fiber smalls added to the flume that did not transport, is considered one area that was perhaps not representative, and, at least, not conservative. However, other factors more than offset this item as described further below. The debris preparation and introduction methods are considered prototypical or conservative. The issues discussed in Section 5.4.2 of the audit report were specifically considered and are addressed below.

NRC Request

NRC Audit Report Section 5.4.2 item 1 [Fiber preparation not as fine or agglomeration occur during introduction process]

Observation of test video documenting the addition of fibrous debris indicated that the debris may not have been prepared as finely as staff guidance would suggest. Alternately, the debris may have been prepared to the proper size distribution, but agglomerated during the debris introduction process. There are several examples on the video that indicate that fiber preparation and/or introduction may not have been controlled to the degree prescribed in staff guidance.

ENO Response

The size distribution used for PNP testing'is representative of the post-LOCA conditions. There will be a size distribution of "fines" in transport to the strainers, including some clumping along with separated fibers in the post-LOCA. The introduction is consistent with PCI's proposed protocol to the NRC and is consistent with other tests implemented for other PCI's clients. The protocol is as implemented on other tests with NRC witnessing. Some variation in the debris form is expected based on how the debris is produced and processed for introduction, but not enough variation so as to question the outcome of a test (Reference 3.f.27).

Within the industry, smalls / fines is defined as those dry clumps (also containing fines), which would pass through a 4 x 4 opening. PCI conservatively prepares the smalls by screening dry clumps of fibers through a 1" x 4" opening. Therefore, the smalls introduced into the flume were bounding and conservative to the postulated accident for this size fiber class.

Also note that when diluting and mixing fibers with the paddle mixer prior to introduction, this process helps to break up the dry clumps of fibers. PCI has experimented with mixing versus not mixing, and mixing seems to clearly improve separation of fibers and clumps. Also, it should be noted that what may appear as large clumps of fibers pouring out of a bucket is not agglomeration. Fibers pouring out of the end of the bucket will be forced to pour out side by side; but not agglomerated. By observation, these disperse again after entering the flow stream.

Use of the video alone to judge agglomeration is not recommended. The video did not capture any aspects of what occurred once the debris went into the flow stream. The resulting size distribution that was introduced into the test flume is considered representative of the post-LOCA event and acceptable to establish the performance of the PNP PCI strainer.

NRC Request

NRC Audit Report Section 5.4.2 item 2 [Debris sequencing was not performed in accordance with the procedure previously discussed with the NRC]

The debris introduction sequence for the testing did not appear to be performed in accordance with the procedure previously discussed between PCI/AREVA and the staff. Some more easily transportable debris was added after less transportable debris. For example, debris added as eroded fibrous material was added after larger fibrous pieces. This is a potential non-conservative practice because in the test a large debris pile may form in the test flume. This pile may act as an impediment to the transport of debris that may otherwise transport if the pile was not present. In the plant such a debris pile is less likely to form because the concentration of debris is much lower than in the test. The debris captured in the flume overflow filters was also added at the original drop zone which is behind the debris pile. A portion of the latent fiber was added to the test flume prior to starting the recirculation pump. This may be non-conservative from a transport perspective because washdown and pool fill up transport is not modeled. It has been noted that the velocity of the flume is increased if a debris pile is present. While the debris pile will increase flume velocity to some extent, a porous debris pile on the flume bottom could capture debris such that the affect *of higher flume velocity is negated. There are many variables that affect debris transport. The staff could not determine that an adequate evaluation of these variables and their uncertainties was attained prior to the determination of debris introduction sequencing.*

ENO Response

The addition of eroded debris near the end of debris introduction, but before chemical debris, is representative of what would occur in the plant. The addition of eroded material after the introduction of smalls was a sequence previously observed by the NRC during another plant's July 2008 strainer testing at Alden. The rate of addition at the point of entry for the eroded debris is slow enough that the much larger volume of water that is flowing past is able to carry the added debris downstream in the flume past the pile of small fiber debris.

The debris captured from the overflow filters is added at the same point in the flume as the other debris. Similar to the discussion provided above, this fine debris is able to transport in the flume beyond the pile of small fiber debris.

The addition of 25% of the latent fiber to the flume before pump start up is considered representative of plant conditions where some fiber may be present in this area during containment flood up. This step was added to the generic PCI protocol following the initial PCI strainer testing in January 2008. This material amounts to 1.4% of the total fiber fines added during the test. Around five minutes after the addition of 25% of the latent fibers, the pump is turned on. From the resultant head loss that is seen, compared to the clean strainer head loss, transport of at least some of this material to the strainer occurs.

NRC Request

NRC Audit Report Section 5.4.2 item 3 [Some fine fibrous debris appeared to clump into balls]

In some photos, especially the fiber only test photos, some fine fibrous debris appeared to be clumped into balls. The staff has observed other tests where shredded fiber can clump into balls if not properly blended. The observed fibrous debris did not appear to exhibit properties that would be expected to result from jet impingement,

ENO Response

See Open Item 6.2 discussion above under video observation response.

NRC Request

NRC Audit Report Section 5.4.2 item 4 [Erosion of smalls put in flume, but which did not transport, was not considered for amount added for erosion.]

The head loss testing did not appear to include fiber to represent the erosion of this debris that was analytically assumed to have transported to the strainer yet settled in the test flume. Therefore the licensee's consideration of debris erosion may be non-conservative. Neither the analysis nor the head loss testing accounted for the erosion of debris that settled during the head loss testing, but was assumed to reach the strainer as a result of the transport evaluation.

ENO Response

The testing added 7.7 lbs of fiber smalls in the flume. If it were assumed that none of this material transported and none was placed in the flume, then it would have been representative to add another 0.77 lbs of fiber fines in the test flume due to erosion. The CFD and debris transport analysis (Reference 3.f.23) did use a conservatively low incipient tumbling velocity for the NUKON fiber smalls to conservatively predict the amount that may transport to the strainers. The addition of the predicted fiber smalls to the flume was a required step following the testing protocol. Given the fiber smalls have a size distribution, not including this material would have been non-conservative, as some of the fiber from the fiber smalls likely transports to the strainer.

Although it would have been conservative, and perhaps representative, to add eroded fibers from the fiber smalls that did not transport in the flume, the amount of fiber fines used in the test still bounds required amounts for PNP due to the following:

- A value of 10% was used for eroding larges and smalls that did not transport. 10% is considered conservative based on testing data (Reference 3.f.32).

- The CFD and debris transport analysis takes no credit for any fine fiber being held up by any of the large debris, which will exist.

- Some of the smalls in the flume likely transported to the strainer and a portion likely eroded and transported to the strainer during the November 4 to 7, 2008 test duration.

- The CFD and debris transport analysis takes no credit for settling any fiber fines in holdup areas such as the reactor cavity. The reactor cavity contains around 5,000 ft^3 of water, which is approximately 15% of the containment sump water volume. This item alone would more than offset not adding an additional **0.77** lbs eroded fiber in the flume. The amount of non-eroded fines in the flume was **16.0** lbs (excludes latent). The amount of eroded fine was **7.2** lbs. **15%** of **16.0** lbs = **2.4** lbs of fiber fines, which likely would be in the reactor cavity. **0.77** lbs is approximately 1/3 of this margin.

- The CFD and debris transport analysis takes no credit for any hold up of small fiber in upper levels of containment where erosion due to spray flow, which would be minor or negligible. All fiber smalls are assumed to be transported to the sump pool where they either transport or are subjected to the **10%** erosion value. The total amount of fiber smalls in the sump pool for the S5 break is **279.031** ft^3. The amount of fiber smalls that are calculated to transport is **71.158** ft^3. The PNP debris transport calculation assumes **25%** of the small fine debris transports to the upper containment. Twenty-five percent of **279.031** ft^3 = **69.76** ft^3. An undefined percentage of **69.76** ft^3 will likely hold up in the upper containment and be subjected to spray flow only.

NRC Request

NRC Audit Report Section 5.4.2 item 5 [Some debris may enter the containment closer than **30** ft from strainers where test introduces in flume.]

Some debris may enter the containment pool closer than 30-40 *ft from strainers during the blowdown, washdown and pool fill-up phases of the LOCA. This debris would be more likely to transport to the strainer and less likely to contribute to the debris pile in the test flume. The test procedure did not attempt to model this aspect of the postulated event. This potential issue would likely have more influence as flume flow velocities decrease because settling would tend to occur over a shorter distance in a low velocity flow stream. The PNP velocities are relatively low.*

ENO Response

The amount of debris expected to be in Zones **2** (includes strainer banks C&D) and **3** (includes strainer banks A&B) is approximately **13%** and 1%, respectively, before RAS. The majority of the fine debris (particulate and fiber) would be >> **30** feet from the strainers. The conservative assumption of the CFD calculation that **100%** of this material transports to the strainers covers the fact that the flume testing places all the material, except **25%** of the latent fiber, into the flume **30** ft from the strainer.

Besides the initial filling of the sump proper, **22** feet diameter by **3.5** feet high = ~ **1,330** ft^3, there is no driving force to the strainers until RAS. For this initial fill due to the relative height for the strainer core tube, it is likely the flow would be through the four screened downcomers and floor drains unless they become clogged by debris. Following initial sump fill, there is no driving force for debris to move towards the strainers until RAS. Only the normal flow paths to the 590' level will get debris near the strainers (or not) during the remaining flood up (of ~20,000 ft^3 of additional water on the 590' level) until RAS.

Given the even distribution of fiber fines that would be assumed to exist in each of the containment floor zones, as discussed in Section 3.e, the average distance that the fiber fines would travel to the strainers would be much greater than 30 feet. The introduction of all fiber fines at 30 feet in the flume is considered very conservative. The fiber smalls introduced in the flume will, on average, be closer to the strainers than the fiber fines. On average, the fiber smalls will be greater than 30 feet from the strainer. The introduction of all fiber smalls at 30 feet in the flume is considered representative and conservative.

NRC Request

NRC Audit Report Section 5.4.2 item 6 [Relatively low flume volume affect on debris concentration.]

The relatively low flume volume has an effect on the concentration of particulate and fine debris suspended in the flume. The volume of the flume affects the scaling between the strainer surface and the pool volume. Having a flume with a larger volume could avoid some of the concerns with over-concentration of debris in the flume and may reduce agglomeration. Flume debris concentration is significantly higher than the plant condition.

ENO Response

See previous Open Item 6.1 discussion above under mixing response.

References

3.f.1. Calculation EA-EC7539-01, Revision 1, February 18, 2009, "Aluminum Location, Corrosion & Precipitation Post LOCA in the ECCS Sump for GSI-191"

3.f.2 Engineering Change EC 12249 implemented during the PNP 2009 refueling outage, new containment sump strainers with modified perforated plate

3.f.3 WCAP-16530-NP, Revision 0, and Spreadsheet, "Evaluation of Post Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," February 2006

3.f.4 Performance Contracting Inc letter to US Nuclear Regulatory Commission dated March 25, 2009, "Request for Withholding Proprietary Information from Public Disclosure Pursuant to 10CFR2.390 Performance Contracting, Inc. Suction Flow Control Device (SFCD) Technology Documents and Related Reports"

3.f.4.a Sure-Flow® Suction Strainer - Vortex Issues Technical Document No. SFSS-TD-2007-003, Revision 1, August 20, 2008

3.f.4.b Sure-Flow® Suction Strainer – Testing Debris Preparation & Surrogates Technical Document No. SFSS-TD-2007-004, Revision 4, January 16,2009

3.f.4.c Sure-Flow® Suction strainer - Suction Flow Control Device (SFCD) Principles and Clean Strainer Head Loss Design Procedures Technical Document No. SFSS-TD-2007-002, Revision 1, dated December 11,2008

3.f.5 Entergy letter dated February 27, 2008, to NRC, "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accident at Pressurized Water Reactors'"

3.f.6 NRC letter dated December 24, 2008, "Palisades Nuclear Plant – Issuance of Request for Additional Information Regarding Supplemental Responses to GL 2004-02 (TAC NO. MC4701)"

3.f.7 Entergy letter dated March 20, 2009, to NRC, "Response to Request for Additional Information Regarding Supplemental Responses to NRC Generic Letter 2004-02 (TAC No. MC4701)"

3.f.8 NRC letter dated May 13, 2009, Palisades Plant – Report on Results of Staff Audit of Chemical Effects Related Actions to Address Generic Letter 2004-02 (TAC No. MC4701)"

3.f.9 NRC letter dated November 21, 2007, Revised Content Guide for Generic Letter 2004-02 Supplemental Responses

3.f.10 NRC letter dated March 28, 2008, Revised Guidance for Review of Final Licensee Responses to Generic letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"

3.f.11 Specification M0802 Technical Specification for passive Containment Sump Strainers as revised by EC12249 April 2009

3.f.12 Calculation EA-MOD-2005-004-03, Revision 3, dated April 6, 2009, "ESS Flow Rates and NPSH During Recirc Mode with CSS Throttling"

3.f.13 Calculation EA-EC496-05, Revision 3, dated March 3, 2009, AES Document Number No. PCI-5798-S01, Revision 3, "Structural Evaluation of Passive Containment Sump Strainers"

3.f.14 Calculation EA-EC496-12, Revision 1, dated March 3, 2009, AES Document Number No. PCI-5798-S02, Revision 1, "Evaluation of Piping for the Passive Containment Sump Strainers"

3.f.15 Calculation EA-EC496-11, Revision 1, dated April 12, 2009, "Containment Sump Passive Strainer Assembly Design Margin Assessment"

3.f.16- Report PLP-RPT-09-0011, Revision 0, dated March 12, 2009, Enercon Document ENTP-003-PR-05 Containment Sump Air Ingestion Evaluation

3.f.17 Calculation EA-EC496-09, Revision 2, dated June 17, 2009, "Total Head Loss (PCI Calc TDI-6013-06)"

3.f.18 AREVA Document 66-9097941-000 dated February 17, 2009, "Palisades Test Report for ECCS Strainer Performance November 2008 Testing"

3.f.19 AREVA Document 63-9095797-001 dated November 18, 2008, Palisades Test Plan for ECCS Strainer performance Testing

3.f.20 Calculation EA-EC496-10, Revision 1, dated March 2, 2009, Containment Sump Passive Assembly Vortex, Air Ingestion & Void Fraction (PCI Calc TDI-6013-07)

3.f.21 Report PLP-RPT-09-0010, Revision 0, dated March 10, 2009, Enercon Report ENTP-003-PR-06 Containment Sump Strainer SBLOCA Evaluation for Palisades

3.f.22 Calculation EA-SDW-97-003, Revision 3, dated March 3, 2009, "Minimum Post-LOCA Containment Water Level Determination"

3.f.23 Calculation EA-EC7833-01, Revision 1, dated February 23, 2009, "Palisades Nuclear Power Station – Debris Transport AREVA 32-9099369-000"

3.f.24 PCI Calculation TDI-6013-02, Revision 2, dated February 24, 2009, "Debris allocation - Design Input for Test Plan Palisades Nuclear Plant"

3.f.25 Enercon Report ENTP-003-PR-03, dated February 5, 2009, "Unqualified and Degraded Coatings Evaluation for Palisades Nuclear Station"

3.f.26 Calculation EA-EC496-08 Revision 2, dated June 17, 2009, "Clean Strainer Head Loss – Palisades Nuclear Plant (PCI Calc TDI-6013-05)"

3.f.27 PCI letter number 6031-002, dated June 12, 2009 "Chemical Effects Audit Open Item Resolution"

3.f.28 Calculation EA-EC7435-01, Revision 0, dated July 31, 2006, "Containment Maximum Flood Level in Support of Candidate Operator Action Number 5"

3.f.29 Palisades Technical Specifications 3.5.2, Emergency Core Cooling Systems – Operating

3.f.30 NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, December 2004

3.f.31 NUREG/CR-2982 "Bouyancy, Transport, and head Loss of Fibrous Reactor Insulation," June 1983

3.f.32 Alion Report ALION-REP-ENT-7199-21, Revision 0, dated January 6, 2009, "Palisades Fiberglass Debris Flow Erosion Testing Report"

3.g. Net Positive Suction Head (NPSH)

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008 (Reference 3.g.5).

NRC Request

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.*

ENO Response

In order to reduce the post-LOCA hydraulic demand, and establish adequate NPSH margin when the passive strainers are aligned to the containment sump, ENO replaced the open/closed style CSS containment isolation spray valves (CV-3001/CV-3002), air operators (VOP-3001/VOP-3002), solenoid valves (SV-3001/SV-3002), valve position switches (POS-3001/POS-3002) and air pressure regulators (PCV-3001/PCV-3002) with CCI DRAG style replacement valves, actuators and accessories. These modifications provide the capability for the valves to be placed in the OPEN/CLOSED or fixed THROTTLED position.

Post-LOCA, the CSS isolation valves (CV-3001, CV-3002) will automatically reposition themselves from fully open to a fixed throttled position on receipt of a RAS signal. The valves will remain in this position for the duration that CSS is required, or until termination of CSS flow through their associated CSS spray header. The throttle position was set to maintain a minimum differential pressure of approximately 16 psi across the most remote spray nozzle on the spray headers. This differential pressure was set for the maximum throttling of the containment spray flow while maintaining a predictable spray performance.

Strainer head loss and pump NPSH varies depending on initial assumed conditions and single failure assumptions. NPSH margin was evaluated for LBLOCA and SBLOCA. Single failure assumptions included left channel failure, right channel failure, LPSI failure to trip, and other cases. A summary of the limiting results, as well as the nominal expected results if there is no single failure, is provided in Table 3gI. The high NPSH margin shown for the HPSI pumps is due to being supplied subcooled water via the CSS pumps through the shutdown cooling heat exchanger following RAS.

Table 3gl Limiting and Nominal NPSH Results

Case	Description	Pump Flow (gpm) NPSH Margin (ft) CSS Pump P-54A	CSS Pump P-54B	CSS Pump P-54C	HPSI Pump P-66A	HPSI Pump P-66A	LPSI Pump P-67A	Strainer Flow (gpm) Strainer/Downcomer Head Loss (ft)
1AMt	Left Channel Failure (Max P-54A Flow)	1774 2.49			791 418			1774 1.10
1AM252t	Left Channel Failure (SBLOCA, 252 psig in PCS)	1723 1.85			731 432			1723 1.06
2BCMt	Right Channel Failure (Max Spray Flow)		1798 1.26	1614 2.04		790 412		3412 2.60
2ACMt	CCW HX LCO (CSS B Isolated)	1761 1.06		1655 2.03	756 406	756 408		3416 2.61
3Ncit	No Failures Clean Strainer	1142 6.77	1207 6.86	1125 7.19	743 439	743 441		3474 1.04
3Ndit	No Failures Dirty Strainer	1140 5.16	1205 5.25	1122 5.58	743 437	743 440		3467 2.66
2ACDGt	CCW HX LCO DG Frequency Case (CSS B Isolated)	1897 0.29		1396 4.44	749 381	742 385		3293 2.48
4AMext	P-67A Failure to Trip Partially Dirty Strainer	1176 2.21	1258 2.44	1168 2.77	759 456	759 459	3292 -20.4	6894 4.82

The most limiting design condition for the strainer assemblies is the LBLOCA case with one of the CSS pumps isolated, concurrent with one of the CCW heat exchangers out of service, and assuming the diesel generators powering each CSS pump are operating at opposing frequencies. This case, designated as Case 2ACDGt in the hydraulic design analysis, has the lowest NPSH margin under post-LBLOCA recirculation mode of operation. In this scenario, CSS pumps P-54A and P-54C supply HPSI pumps P-66A and P66B, two throttled CSS headers, and four cold legs. The NPSH margin of the ECCS pumps under this system alignment is calculated as 0.29-ft of water, which includes the strainer and downcomer head loss of 2.48 ft at a 3293 gpm system flow rate. Details of the limiting cases and associated assumptions are described in more detail below.

This NPSH margin value was derived from the conservative approaches, as discussed below.

Reference 3.g.1 determined the minimum sump water level for various LOCA scenarios. The assumptions applied in determining the water level include the following:

- The maximum residual SIRW tank level after RAS is the minimum suction switchover set point, including instrument error.

- The water vapor inside containment after LOCA is at saturated conditions for the containment atmosphere. The initial liquid and vapor inventories inside containment are neglected.

- The vapor inventory, spray header filling volume, and the spray drop inventory in the containment atmosphere are all accounted. Holdup volume in the containment includes the volumes on the floor due to curbing, inside cubicles, in the tilt pit of the refueling cavity and in the reactor cavity. The water held on the vertical surface is also included. The water held up in the reactor cavity is to flood the cavity to the mid-loop elevation (plant elevation 618'-2.5"). This holdup volume is in accordance with the cavity flooding design. The purpose of the flooding operation is to cool the reactor vessel during severe accidents that may progress to core melting. During these events, insufficient or no core cooling flow is available to remove the core decay heat. These accidents are beyond the scope of the events included in Chapter 14 of the FSAR. As a result, no credit is taken for the flooding system to mitigate the events described in the FSAR.

- For large break LOCA cases, the levels associated with the pressurizer surge line break is used. The break in the pressurizer surge line is the highest possible elevation that a large break LOCA can occur. This results in the maximum PCS holdup during a LBLOCA event, which in turn results in the lowest associated sump level. The minimum sump water level at 212°F will vary slightly for the pressurizer surge line break based on the scenario being evaluated as shown by the following examples:

  - For left channel failure, value is 3.42 ft
  - For right channel failure, value is 3.35 ft
  - For CCW heat exchanger isolated, value is 3.39 ft

- For SBLOCA cases, the level associated with the PCS being water solid is used. This results in the maximum PCS holdup during an event, which in turn results in the lowest sump level. As discussed below, the SBLOCA also assumes SIT water inventory is not available to the sump.

- The water inventories of the SIRW tank and SITs are based on the minimum volumes required by Technical Specifications (TS). It is noted that 250,000 gallons minimum SIRW tank inventory is required by TS for plant modes 1, 2 and 3. The administrative limit on SIRW tank minimum level is 275,970 gallons (at 92% level) for plant modes 1, 2 and 3. This administrative limit is a NRC commitment per NRC Bulletin 2003-01, and the volume is verified daily, as required by the PNP TS Surveillance Procedure DWO-1.

- The containment flood level is calculated based on a correlation of volume displacement and the sump water volume. The volume displacement includes the volumes of equipment, concrete structures, pipes and steel supports. The assessment of the volumes of the pipes, supports, and the small equipment under the flood level were supported by the field measurements.

The resultant containment minimum water level under the 2ACDGt case is predicted to occur at 9712 seconds after the LOCA event with the primary parameters listed in Table 3g2 below.

Table 3g2 Primary Parameters for Sump Pool Level

Initial coolant inventory	2,554,452 lbm
Primary coolant system	
Temperature	242.0°F
Liquid volume	6765.4 ft^3
Liquid density	59.02 lbm/ft^3
Vapor volume	4177.1 ft^3
Vapor density	0.06335 lbm/ft^3
Liquid and vapor mass	399,555 lbm
Containment atmosphere	
temperature	190.3 °F
Total volume	1.64×10^6 ft^3
Liquid fraction	0.022622 ft^3/ft^3
Vapor density	0.02458 lbm/ft^3
Vapor mass	39,399 lbm
Containment holdup	
temperature	212.0 °F
Liquid volume	7799 ft^3
Liquid density	59.812 lbm/ft^3
Liquid mass	466,474 lbm
Containment spray header and spray drop inventory	
Liquid mass	13,304 lbm
Containment condensation holdup on surfaces	
Liquid mass	5,515 lbm
Containment sump liquid mass	
temperature	212.0 °F
Liquid mass	1,630,205 lbm
Liquid density	59.812 lbm/ft^3
Liquid volume	27,257 ft^3
Containment water level	3.39 ft

In determining the system flow rate, the following assumptions were applied:

- The ECCS pump curves account for a 59.5 to 61.2 hertz (Hz) variation in emergency diesel generator (EDG) frequency. The required NPSH by the pump manufacturer at 60 Hz frequency was adjusted due to the EDG frequencies and the consequent higher pump speed changes based on the pump similarity law. The pump curves used depend on the purpose of the scenario:

    1. For minimum NPSH margin scenarios, the maximum flow through one of the containment spray pumps is required. Since the HPSI pumps are

located downstream of the containment spray pumps, the HPSI pumps will always have adequate NPSH margin. The curves used depend on how many and which containment spray pump is in operation:

- When one CSS pump is in operation, all of the pumps use the maximum pump curves.

- When P-54A or B and P-54C are in operation, P-54C is the weak pump –
    - P-54C uses the degraded pump curve at 61.2 Hz
    - P-66A, P-66B and P-54A or B use the maximum pump curves at 61.2 Hz

  This results in P-54A or B overpowering the P-54C pump, resulting in maximum flow through P-54A or B.

- When P-54A and P-54B are in operation, P-54A is the weak pump.
    - P-54A uses the degraded pump curve at 61.2 Hz
    - P-66A, P-66B, and P-54B use the maximum pump curves at 61.2 Hz

  This causes P-54B to overpower the P-54A pump, resulting in maximum flow through P-54B.

2. For minimum flow scenarios (containment response analysis inputs), it is more conservative to have minimum shutdown cooling (SDC) heat exchanger flow than it is to have minimum containment spray flow (using a degraded or nominal HPSI curve results in the minimum SDC heat exchanger flow and minimum containment spray flow respectively). Therefore, all of the pumps use degraded pump curves at 59.5 Hz.

3. For minimum containment nozzle pressure scenarios, the minimum containment spray flow is required.

4. For the nominal flow scenarios, all of the pumps use nominal curves at 60 Hz.

5. For the maximum flow scenarios including the LPSI failure to trip scenarios, all of the pumps use maximum curves at 61.2 Hz.

- For the NPSH limiting cases such as Case 2ACMt identified in Table 3g1, where two CSS pumps are operating, each powered by a different diesel generator, a more detailed evaluation was'performed to determine which pump curves to use for determining minimum NPSH. The new limiting case identified as 2ACDGt in Table 3gl conservatively assumes the two diesel generators have different frequencies at the opposing limits. This case is described as:

- Maximum P-54A, P-66A, nominal P-66B, and degraded P-54C in operation
  - DG 1-2 supplying P-54A and P-66A runs at a higher frequency, and DG 1-1 supplying P-54C and P-66B runs at a lower frequency. This causes the P-54A pump to overpower the P-54C pump, resulting in a higher flow, higher inlet pressure, and lower NPSH margin.
  - The NPSH results were not acceptable when the strong containment spray pump was assumed to be at 61.2 Hz. To assure that adequate NPSH is provided for this set of single failure scenarios, an administrative limit of 60.5 Hz is set for the maximum allowable DG frequency.
  - The strong containment spray pump, P-54A, is assumed to be powered at 60.5 Hz while the weak containment spray pump is assumed to be powered at 59.5 Hz.

- The pump curves applied in the design analysis also include a 7% allowance for flow degradation in the CSS pumps, and an 8% allowance for flow degradation in the HPSI pumps, based on inservice test program degradation limits.

- Containment sump temperature is 212°F.

- The NPSH calculation models head loss through the strainers, associated piping and downcomers, and through the debris bed. The starting assumptions for limiting associated head loss are based on design head loss values noted in Section 3.f. Specifically at 212°F and 3591 gpm, limiting clean strainer and associated piping head loss is 1.037 ft and debris head loss is the balance, 1.563 ft water, to the 2.6 ft water total strainer head loss design value. These Flo-Series model derived values are consistent and in close agreement with the Section 3.f cited values of 1.026 ft total clean head loss and 1.57 ft for debris.

- The debris head loss is proportional to the flow through the debris (laminar flow). The head loss through the strainers and piping is proportional to flow squared (turbulent flow).

For a SBLOCA, the RAS could occur before primary coolant system pressure drops to the SIT actuation pressure. As a result, the SIT inventory would not be available to the sump for a SBLOCA. For a four-inch SBLOCA with a single failure of left channel ECCS redundant system, the minimum sump level is predicted to be at 592.34 foot elevation, or 2.34 feet above the containment base slab. With a higher PCS pressure, the system flow rate and the head loss in the SBLOCA case is less than those of the LBLOCA cases. Also, the SBLOCA-generated debris is substantially less than the debris generated due to a LBLOCA as discussed in Section 3.a.

Table 3gl shows the NPSH margin for the left channel SBLOCA is 0.64 ft less than the associated LBLOCA. The values shown in the table used the same assumptions for debris head loss for both the large break and SBLOCA scenarios. The actual SBLOCA debris head loss assumptions are conservatively based on being one half of the large break. Therefore, at the design flow rate of 3591 gpm, the previously noted debris head loss value of 1.563 ft would be approximately 0.78 ft for the small break. For the limiting LBLOCA case 2ACDGt at 3293 gpm, the small break debris head loss would be approximately 0.72 ft versus the approximately 1.43 ft debris head loss used in case 2ACDGt. The LBLOCA remains limiting over the small break due to the lower resultant debris head loss.

To mitigate the LPSI pump fail to trip condition, operator action would be required. Per Emergency Operating Procedure (EOP) Supplement 42 (Reference 3.g.3), the first post-RAS action is to ensure both LPSI pumps are tripped. Tripping a LPSI pump consists of taking the hand switch on the control panel to trip. If the hand switch on the control panel would not trip the pump, operators would dispatch an auxiliary operator (AO) to trip the pump locally at the breaker. LPSI pump breaker numbers are on the LPSI pump hand switch labels. The AOs are recalled to the control room during a LOCA event and they would remain in the control room until the emergency Operations Support Center is activated. Therefore, the AOs would be immediately available to locally trip the affected LPSI pump breaker, in one of the switchgear rooms immediately below the control room. However, a single credible active failure, of the LPSI pump breaker to trip, due to breaker contact fusion, or breaker mechanical trip linkage failure would prevent the LPSI pump from being tripped both in the control room, via its associated hand switches on the C03L/R panels, or locally at the breaker. In this case, the operating LPSI pump would be stopped by de-energizing the appropriate electrical bus. Simulator experience shows that the LPSI pump could be tripped or its supply bus could be tripped within 15 minutes of RAS.

In assessing the head loss at the subject high flow condition, the loss due to debris bed on the strainer surfaces is included. Due to the short time period that the LPSI pump will be operating, for this analysis, the amount of debris assumed to be on the strainer is reduced from the maximum value. Since the event pertains to the beginning phase of recirculation operation, there is little concern about chemical precipitation in the sump pool. Additionally, only a portion of the non-chemical debris will transport to the strainers during the brief period before the LPSI pump is tripped. A conservative value of 0.40 ft debris head loss was assumed for the LPSI failure to trip case, at 3591 gpm design flow before being scaled up to the higher LPSI failure to trip resultant flow. As summarized in Table 3g1, the CSS pumps and HPSI pumps are shown to maintain adequate NPSH margin. Without taking credit for the containment accident pressure, the operating LPSI pump will not have adequate NPSH margin. However, post-recirculation LPSI pump operation is not credited.

As part of the NPSH calculation (Reference 3.g.2) the total strainer and downcomer head loss was determined and compared to associated SBLOCA and LBLOCA limitations to avoid air ingestion concerns through sump vent paths. These limitations were discussed in Section 3.f. All evaluated design basis cases met the air ingestion limitations, which are 4.85 ft for LBLOCA and 3.84 ft for SBLOCA. The NPSH calculation Table 3gl shows the results for the limiting NPSH cases.

NRC Request

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

ENO Response

For the NPSH limiting condition of the aforementioned 2ACDGt case, the predicted flow rates for the CSS pumps are 1897 gpm and 1396 gpm for P-54A and P-54C, respectively. The flow rates for the HPSI pumps are 749 gpm and 742 gpm for P-66A and P-66B, respectively. The total recirculation sump flow rate is 3293 gpm with this system alignment. The sump temperature for the limiting condition is 212°F. The predicted minimum containment water level is 3.39 feet above the containment base slab.

NRC Request

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

ENO Response

Conservative assumptions listed in the previous pages were applied in calculating the pump flow rates and containment water level. The assumptions were based on the deterministic approach in calculating the NPSH margins for the ECCS pumps.

NRC Request

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

ENO Response

The required NPSH for the pumps is based on the vendor certified pump performance data. The certification was in accordance with the test standards set forth by the Hydraulic Institute, whereas, the NPSH available is based on conservative assumptions of the minimum sump flood level and a containment pressure of 0 psig.

NRC Request

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

ENO Response

Flow losses are accounted for in calculating the minimum NPSH margin. The head loss through the debris bed, the strainer surface, the strainer core tubes, the associated piping between the strainer and the sump, the exit loss from the downcomer pipe to the sump are all combined with the head loss through the suction pipes of the ECCS pumps.

NRC Request

- *Describe the system response scenarios for LBLOCA and SBLOCAs.*

ENO Response

The system response for a LBLOCA and SBLOCA are similar. Except for the limiting SBLOCA evaluations, the SITs are assumed not to inject due to PCS pressure. Also, the LPSI pumps will not inject since system pressure is above the shutoff head of the LPSI pumps. A more detailed description of the system response to LOCA scenarios is included in Section 3.f. of this document.

NRC Request

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

ENO Response

Before the RAS, the CSS, HPSI and LPSI pumps are all in operation. The LPSI pumps are stopped automatically at RAS. After RAS, the CSS pumps supply the two HPSI pumps and the two containment spray headers.

NRC Request

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

ENO Response

The most limiting design condition for the strainer assemblies is the LBLOCA case with one of the CSS pumps isolated, concurrent with one of the CCW heat exchangers out of service. This case, designated as Case 2ACM in the hydraulic design analysis, has the lowest NPSH margin. The associated case 2ACDGt was a refined evaluation of this limiting case assuming the associated diesel generators are operating at opposing frequency limits. This is the new limiting NPSH case and is described in more detail earlier in this section.

NRC Request

- *Describe how the containment sump water level is determined.*

ENO Response

The containment sump water level was determined based on a correlation of water volume and the physical space in the containment. The correlation was developed analytically in Reference 3.g.4 and evaluated and adjusted in Reference 3.g.l for assuring conservative for minimum water level determinations.

NRC Request

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

ENO Response

The significant assumptions associated with the minimum water level analysis are presented earlier in this section.

NRC Request

- *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.*

ENO Response

The volumes of empty spray pipe, water droplets, condensation and holdup on containment floors have been accounted for in the determination of containment minimum water level. The holdup volume on the vertical surfaces in the containment was also accounted for in the latest pool level calculation (Reference 3.g.l).

NRC Request

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

ENO Response

The volume displacement for pool level calculation includes the following major equipment: reactor vessel, reactor vessel insulation, bioshield, clean waste receiver tanks, pressurizer heater transformers. The volume displacement equation includes a 200 cubic foot volume for the containment buffer agent, which is expected to be dissolved in water. This volume represents a less than 0.5% deviation of the total sump pool volume and is negligible. The volume displacement equation also includes the volumes of miscellaneous equipment such as pipe, steel supports, etc. The miscellaneous equipment volume applied in the calculation was confirmed by walkdown survey.

NRC Request

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

ENO Response

The pool water volume and the sources are provided above. The predicted pool volume was based on conservative assumptions that yield the minimum pool level as described above.

NRC Request

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

ENO Response

The NPSH calculation does not take credit for containment accident pressure.

NRC Request

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

ENO Response

The NPSH margin calculation considered the condition of 0 psig containment pressure and the maximum sump temperature at saturation of 212 °F.

NRC Request

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

ENO Response

The containment accident pressure was not credited in the NPSH calculation. The saturation vapor pressure of the sump fluid is set at 0 psig containment pressure.

A temperature-dependent NPSH evaluation was performed to assess the design limiting condition for the strainer head loss. A summary of the more limiting right channel failure time dependent NPSH values is shown in Table 3.g.3 below. For other cases such as left channel failure, the time to reach 190 °F is closer to seven hours versus 18 hours for the right channel failure. Though there is large NPSH margin with time shown, the strainer loss limits would still be bounded by the more limiting air ingestion limitations discussed above.

Table 3g3 Representative Time Dependent NPSH available

Time after LOCA hours	Sump Temperature °F	Vapor Pressure psia	NPSH Available ft	NPSH Margin ft
8.4	212.0	14.70	15.73	1.75
9.4	209.2	13.92	17.58	3.60
10.6	206.5	13.21	19.26	5.28
14.4	197.7	11.02	24.45	10.47
18.3	190.3	9.40	28.24	14.25
24.2	181.9	7.87	31.79	17.81
48.1	164.6	5.31	37.64	23.66
72.2	154.0	4.13	40.30	26.32

From 18.4 hours to 30 days post-accident, the containment emergency sump provides at least twice the required NPSH to any alignment of CSS and HPSI pumps.

NRC Request

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

ENO Response

The design limiting condition for the strainer is a CSS pump NPSH margin of 0.29 foot of water as described earlier in this section.

References

3.g.1 EA-SDW-97-003, "Minimum Post-LOCA Containment Water Level Determination," Revision 3, March 3, 2009

3.g.2 EA-MOD-2005-004-03, "ESS Flow Rates and NPSH during Recirc Mode with CSS Throttling," Revision 3, April 6, 2009

3.g.3 EOP Supplement 42, "Pre and Post-RAS Actions," Revision 7

3.g.4 EA-C-PAL-94-0016A-01, "Containment Flood Analysis," Revision 1, December 4, 1994

3.g.5 Entergy letter dated February 27, 2008 to NRC, "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accident at Pressurized Water Reactors'"

3.h. Coatings Evaluation

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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.

- *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.*

ENO Response

Coatings may be dislodged during a LOCA and then transported to the drainage system for the sump. Coatings are classified as qualified or unqualified. Qualified coatings are defined as coatings that will remain in place under design basis accident conditions (temperature, radiation, humidity, and pressure). These coatings, if in good condition, will become debris only in the ZOI. All unqualified coatings and damaged qualified coatings become debris during a LOCA, even when outside the ZOI.

Qualified coatings turn into debris within a ZOI radius of 10 D. The sources of information for the coatings inside containment come from the walkdowns performed for GL 98-04, the early walkdowns performed for GSI-191, the walkdown to define containment heat sink characteristics used in the containment LOCA-response analysis, and the PNP painting schedule (Reference 3.h.1) first versions generated during the initial construction period.

The S1, S2, S3, S5 and S6 breaks (see Figure 3al) all have ZOIs that are extremely large in comparison to the vault (35 ft. for S1, S2, S5, S6 and 25 ft. for S3). For this reason, these breaks will conservatively impact all of the qualified coatings identified in the vault where they are located. The vaults as used here are not literally vaults, but are the semi-enclosed area in which each of the two steam generators reside. They are open to a common plenum at the loop piping elevation from elevation 608'-6" to approximately elevation 620'. There are numerous cutouts in the "vaults" at the elevation of the primary coolant system loops.

Qualified coatings within the ZOI radius for break S4 are calculated based on the ratio of 11.19"/42" of the qualified coating within vault 1 calculated for the S1 break.

Table 3hl below summarizes all of the coatings affected by the LB on both the SG A side and SG B side of the plant. It is noted that the A side (S5 break side) is limiting for coatings.

Table 3hl Coatings affected by LBLOCA in SG A and B Side "vaults"

ITEM	SURFACE AREA	COATING TYPE	THICKNESS (in.)	VOLUME (ft3)
STEEL - LOOP A				
649' Elevation Structural Steel	787.4	Carbozinc 11	0.004	0.262
Tie Struts	1223	Inorganic zinc silicate	0.004	0.408
Rupture Restraints	1932	Inorganic zinc silicate	0.003	0.483
Blast Shields	518.01	Carbozinc 11	0.004	0.173
Primary Coolant Pump Supports	2194.9	Inorganic zinc silicate	0.003	0.549
Pressurizer Support Steel	724.02	Carbozinc 11	0.004	0.241
Platform Supports	1691.54	Carbozinc 11	0.004	0.564
Embedded Steel	627.1	Carbozinc 11	0.004	0.209
Pressurizer Quench Tank	679	Carbozinc 11	0.003	0.170
Letdown Heat Exchanger	50.9	Aluminum paint	0.002	0.008
Letdown Heat Exchanger	50.9	Zinc chromate	0.0015	0.006
SG Supports	465	Carbozinc 11	0.003	0.116
		TOTALS - LOOP A		
		Carbozinc 11		1.735
		Inorganic Zinc silicate		1.439
		Aluminum paint		0.008
		Zinc chromate		0.006
ITEM	**SURFACE AREA**	**COATING TYPE**	**THICKNESS (in.)**	**VOLUME (ft3)**
STEEL - LOOP B				
649' Elevation Structural Steel	453.9	Carbozinc 11	0.004	0.151
Tie Struts	1268.2	Inorganic zinc silicate	0.004	0.423
Rupture Restraints	1932	Inorganic zinc silicate	0.003	0.483
Blast Shields	518.01	Carbozinc 11	0.004	0.173
Primary Coolant Pump Supports	2194.9	Inorganic zinc silicate	0.003	0.549
Platform Supports	1240.19	Carbozinc 11	0.004	0.413
Embedded Steel	395.4	Carbozinc 11	0.004	0.132
Letdown Heat Exchanger	50.9	Aluminum paint	0.002	0.008
Letdown Heat Exchanger	50.9	Zinc chromate	0.0015	0.006
SG Supports	465	Carbozinc 11	0.003	0.116
649' structural steel	363.3	Carbozinc 11	0.006	0.182
649' structural steel	363.3	Carboline 3912	0.003	0.091
		TOTALS - LOOP B		
		Carbozinc 11		1.167
		Inorganic Zinc silicate		1.454
		Aluminum paint		0.008
		Zinc chromate		0.006
		Carboline 3912		0.091

ITEM	SURFACE AREA	COATING TYPE	THICKNESS (in.)	VOLUME (ft3)
CONCRETE				
SG **A** Compartment floor	1230.90	Phenoline 300 primer-sealer	0.01	1.026
SG A Compartment floor	1230.90	Phenoline 300	0.015	1.539
SG A Compartment walls	1424.9	Phenoline 300 primer sealer	0.01	10187
SG A Compartment walls	1424.9	Phenoline 300	0.008	0.950
Letdown HX catwalk walls (112)	111.00	Phenoline 300 primer sealer	0.01	0.093
Letdown HX catwalk walls (112)	111.00	Phenoline 300	0.008	0.074
SG B Compartment floor	974.90	Phenoline 300 primer-sealer	0.01	0.812
SG B Compartment floor	974.90	Phenoline 300	0.015	1.219
SG B Compartment walls	955.8	Phenoline 300 primer sealer	0.01	0.797
SG B Compartment walls	955.8	Phenoline 300	0.008	0.637
Letdown HX catwalk walls (112)	111.00	Phenoline 300 primer sealer	0.01	0.093
Letdown HX catwalk walls (112)	111.00	Phenoline 300	0.008	0.074
		CONCRETE TOTALS		
		LOOP A		
		Phenoline 300 primer-sealer		2.306
		Phenoline 300		2.563
		LOOP B		
		Phenoline 300 primer-sealer		1.701
		Phenoline 300		1.930

NRC Request

Provide *a summary of type(s) ofcoatingsystems usedincontainment, e.g., Carboline CZ 11 Inorganic Zinc primer, Ameron 90 epoxy finish coat.*

ENO Response

The coating systems.used in containment at PNP are classified as qualified (acceptable) and unqualified. A qualified coating in the PNP safety-related coatings program is one that has been determined to have reasonable assurance to not detach under normal or accident conditions. The qualified coatings in the PNP containment (Reference 3.h.6) include the following:

- Carboline Phenoline 305 phenolic modified epoxy (not top coated) on concrete
- Carboline Phenoline 300 phenolic modified epoxy primer-sealer with Carboline Phenoline 300 phenolic modified epoxy finish coat on concrete
- Carboline Carbo Zinc 11 primer with Carboline Inorganic 3912 finish coat on carbon steel
- Carboline Carbo Zinc 11 primer with Carboline Phenoline 305 phenolic modified epoxy on carbon steel
- Carboline Carbo Zinc 11 (not top coated) on carbon steel

Coating systems in the PNP containment that are not considered qualified include alkyd, epoxy, aluminum and inorganic zinc.

Because the November 2008, flume design basis test was run with the above inputs, they are being retained as the plant design basis even though a subsequent revision of Reference 3.h.6 (see Reference 3.h.4) was issued after the test was complete, and contained slightly less volume of slightly different Carboline trade name "epoxy" coating types for qualified concrete coating.

NRC Request

- *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 what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.*

ENO Response

The head loss testing was performed under contract to PCI, the strainer vendor. It was performed per an AREVA test plan (Reference 3.h.5) that controlled the surrogates used and the method of introduction of the surrogates into the flume. The test plan was designed to mockup and credit near strainer debris transport and drop out. It assumed 100% post-LOCA paint debris is transported to the sump and therefore 100% of the coatings debris was entered into the flume. The test plan incorporated the standard PCI test protocols (Reference 3.h.3), which included selection of the surrogates.

The coating debris included in the head loss testing was assigned to three categories; inorganic zinc coating (IOZ), epoxy, and metal or metal oxide based paint. The test material of coatings, including the surrogate material, is described in the Test Plan (Reference 3.h.5).

Qualified Coatings
Qualified coatings become debris within a ZOI radius of 10 D. The amount of each of the coating types is taken from the debris generation calculation (Reference 3.h.4), which identifies the amount of qualified coatings that will contribute to the debris loading.

Steel qualified coating areas and thicknesses are from Reference 3.h.7 and are all Carbozinc 11 or IOZ of some kind.

Concrete coating areas are from Reference 3.h.1, while coating thicknesses are from Reference 3.h.l and 3h.2.

The systems given in Reference 3.h.l have numerous options for coating manufacturers. For the quantity calculation, Carboline was used as the brand option for analyzing coatings, which is conservative since they are thicker.

Table 3h2 Coating Quantities in Containment and Surrogate Quantities Test Flume

Coating Type		in Containment	Density		# in Test Flume		Surrogate Used
Coatings (lbs)							
Qualified Coatings							
Carboline Carbozinc 11	ft^3	1.735	457	35.480	35.5		
Inorganic Zinc Silicate	ft^3	1.439	457	29.427	29.5		
Unqualified Coatings: Carbozinc 11	ft^3	0.250	457	5.112	5.2	lbm	
				Zinc Coatings Sub-totals (Tin Powder)	70.2	lbm	Powder (Tin Powder)
Carboline Phenoline 300 Primer/Finish	ft^3	4.887	94.0	20.556	20.6	lbm	
Dense Aluminum	ft^3	0.008	168.5	0.060	0.1	lbm	
Zinc Chromate	ft^3	0.006	81.1	0.022	0.1	lbm	
Unqualified Coatings; Alkyd	ft^3	14.080	94.0	59.224	59.3		
				Top Coatings Sub-totals (Powder)	80.1	lbm	Powder (Acrylic Powder)
Unqualified Coatings; Dense Aluminum	ft^3	4.35	168.5	32.795	32.8	lbm	
				Top Coatings Sub-totals (Chips)	32.8	lbm	SIL-CO-SIL 53 Powder
Unqualified Coatings; Chips	ft^3	2.42	94.0	10.179	10.2	lbm	
				Top Coatings Sub-totals (Chips)		lbm	Chips (Acrylic 1/64" up to 1/4")
				Total Coating Debris	193.3		

All debris scaled by in containment weight times 0.0447 in the flume

Table 3h2 is an excerpt from the AREVA test plan.

The S1, S2, S3, S5 and S6 breaks all have ZOIs that are extremely large in comparison to the vault (35 ft. for S1, S2, S5 and S6, 25 ft. for S3). For this reason, these breaks will conservatively hit all of the qualified coatings identified in the vault where they are located.

Unqualified and Degraded Coatings

All unqualified coatings and degraded coatings will become debris following a break. The unqualified coatings and degraded coatings in containment originally came from walkdowns performed during the 1998 refueling outage. Areas are provided in Reference 3.h.2 for unqualified coatings. There are also a limited number of coatings in Reference 3.h.2 that also provide a thickness. This calculation assumed an average thickness for the unqualified coatings. However, the latest version of the calculation used input from PNP for the total volume of unqualified coatings, which includes the 1998 thicknesses and the results of recent coatings inspections. The strainer testing added an additional one cubic foot for margin.

Qualified coatings within the ZOI radius for break S4 are calculated based on the reduced ZOI for the alternate break. The concrete coating total was reached by conservatively calculating an affected wall area equal to the full 10 D ZOI. The floors are not within the ZOI. Steel coatings that were outside the ZOI were excluded, and the entire totals for other coatings were conservatively included in the total, even though not all of the coatings would fall within the zone of influence.

Coating results and calculations are summarized in Table **3h3**.

Table **3h3** Debris Generated Summary

Debris Type	ZOI (D)	Units	Break S1	Break S2	Break S3	Break S4	Break S5	Break S6
			HL A	HL B	CLS 1B	Alternate Break	H i A	HL B
COATINGS*								
Carboline - Phenoline 300 Primer	10	[ft^3]	2.306	1.701	2.306	0.275	2.306	1.701
Carboline - Phenoline 300 Finish	10	[ft^3]	2.563	1.930	2.563	0.252	2.563	1.930
Carboline – Carbozinc 11	10	[ft^3]	1.735	1.167	1.735	0.975	1.735	1.167
Inorganic Zinc Silicate	10	[ft^3]	1.439	1.454	1.439	0.891	1.439	1.454
Aluminum Paint	10	[ft^3]	0.008	0.008	0.008	0	0.008	0.008
Zinc Chromate	10	[ft^3]	0.006	0.006	0.006	0	0.006	0.006
Carboline 3912	10	[ft^3]	0	0.091	0	0	0	0.091
QUALIFIED COATINGS TOTAL		[ft^3]	8.057	6.357	8.057	2.392	8.057	6.357
UNQUALIFIED COATINGS		[ft^3]	20.1	20.1	20.1	20.1	20.1	20.1

Testing Surrogates

Due to state law at the test location, tin powder was used instead of zinc powder for the IOZ coatings. The surrogate material for IOZ is tin powder with a particle size range of -10 to 44 microns. Note: Zinc has a specific density of 7.133 (445.3 lb/ft^3) and tin has a specific density of 7.29 (455.1 lb/ft^3). The tin powder was essentially the same weight and size distribution as the zinc powder specified for Carbozinc 11 coatings. This is covered in Reference 3.h.3. The tin powder is also used as a surrogate for generic inorganic zinc silicate coating and Carboline 3912. The generic IOZ was applied by material suppliers as required by the PNP purchase specification, however, alternate vendors in addition to Carboline were listed in the specifications. It is also noted that the primary characteristic of the unqualified Carbozinc 11 in the 1998 walkdown was light rust bleed through, not flaking or chipping, so the particulate powder is applicable (Reference 3.h.2).

The surrogate for Carboline Phenoline 305 phenolic modified epoxy, Carboline Phenoline 300 phenolic modified epoxy primer-sealer, a small amount of dense aluminum paint (0.008 cu ft), a small amount of zinc chromate paint (0.006 cu ft), and a large amount of unqualified alkyd paint, was acrylic powder. The substitution was on a pound for pound basis so volumetrically it is conservative. The average density of the acrylic powder is 77 lb/cu ft and the average size is 50 microns so virtually all of the paint in the plant will settle more readily than that used in the flume.

Some of the unqualified plant coatings were known to be metal or metal oxide based paints. These included aluminum paint and iron oxide and lead primer. These were represented in the flume test by granular silicate particles SIL-CO-SIL-53 powder. SIL-CO-SIL 53 ground silica is ground quartz with a specific gravity of 2.65. The mean size of the ground silica powder is approximately 10-11 microns. The density of this material is essentially equal to aluminum that is the lowest density of the three pigments. Reference 3.h.8 calculated the quantity and selected the density of the surrogate. Table 3h4 below summarizes the results.

Table 3h4 Dense Coatings

Component	Coating	Surface Area (Sq. Ft.)	Thickness (Mils)	Constituent Density (g/cm^3)	Volume (ft^3)
Containment Air Coolers	Lead Primer	10,337	2.5	11.34	2.154
	Iron Oxide	2,073	2.5	5.24	.432
Pipes and Supports	Aluminum Paint	4235	5	2.7	1.76
RCP "D"	Carbozinc 11	1200	2.5	7.14	.25

The reactor head lift system and associated shielding are documented to be coated with epoxy. This material was determined in Reference 3.h.8 to fail as chips. The surrogate for this material is acrylic chips from 1/64 to ¼ inch sizes. The substitution is based on References 3.h.8 and 3.h.3.

NRC Request

- *Describe any ongoing containment coating condition assessment program.*

ENO Response

Engineering manual procedure EM-09-23, "Safety Related Coatings Program," requires that assessments of coatings in containment be performed each refueling outage. These assessments are performed using permanent maintenance procedure CLP-M-7, "Containment Coating Condition Assessment." The assessment procedure generally conforms to the guideline of ASTM D 5163, "Standard Procedures to Monitor the Performance of Safety Related Coatings in an Operating Nuclear Power Plant," and EPRI "Guideline on Nuclear Safety-Related Coatings," Revision 1 (formerly TR-109937). The use of ASTM D 5163 is endorsed by the NRC in Regulatory Guide 1.54, "Service Level I, II and III Protective Coatings Applied to Nuclear Power Plants," Revision 1.

CLP-M-7 requires a general visual inspection of all accessible surface areas inside of containment. The coating assessment inspections are performed by at least two individuals who are qualified in accordance with the procedural requirements. The inspections are performed to identify changes in the amount of degraded qualified and unqualified coatings that have occurred from the previous assessment.

Containment degraded qualified and unqualified coatings are documented in a log. Potential changes to the containment coatings log identified during the assessment are evaluated with revisions to the log, as appropriate. Additional destructive or non-destructive testing may be performed if required. Acceptance criteria are provided in the assessment procedure to ensure design limits are maintained. If the acceptance criteria are exceeded, then the procedure requires that a condition report be initiated for evaluation using the corrective action process.

EM-09-23 and CLP-M-7 require that an assessment report be generated upon completion of the assessment. The report includes a summary of the results of the assessment, details of the quantity of degraded qualified and unqualified coatings identified in containment, comparisons to the acceptance criteria, and recommendations for repair. The report provides a mechanism to ensure that the appropriate levels of plant management are cognizant of the assessment results.

The containment coating condition assessment performed, during the fall 2007 and spring 2009 refueling outages, found that the overall condition of containment qualified coatings remained good, and was essentially unchanged from the previous inspection. No large areas of qualified coating delamination were identified during the inspection and the qualified coatings were adhering as expected. The volume of degraded qualified and unqualified coatings identified in containment was determined to be acceptable based on current design limits.

NRC Request

- *Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.*

ENO Response

As stated in section 3.e the CFD transport analysis assumed 100% of the paint debris transported. Therefore, the flume test employed 100% of the scaled quantity of the coatings as predicted by the debris generation analysis, as discussed in section 3.b.

The flume test modeled near strainer transport and dropout, so, in effect, some credit was taken for settlement by testing in the flume, although the amount of settlement was not determined in the test. Since the conservative test protocol required the particulate to be entered before the fibrous debris, it was not possible to determine how much of the head loss was due to the paint.

The modeling of the paint in the design basis flume test is discussed above in this section and to some degree in most of the previous sections.

References

3.h.1 Palisades Drawing C-83, Exterior Painting Schedule, Revision 4.

3.h.2. Sargent & Lundy DIT-CPC-038-00 "Palisades Containment Coatings-Summary of Findings," August 28, 1998

3.h.3 Sure-Flow® Suction Strainer – Testing Debris Preparation & Surrogates Technical Document No. SFSS-TD-2007-004, Revision 4, January 16,2009

3.h.4 EA-MOD-2005-04-06 Debris Generation Revision 3 "Acceptance of Debris Generation" Calculation 2005-01340," (Sargent & Lundy), Revision 2, February 9,2009

3.h.5 AREVA Document 63-9095797-001 "Palisades Test Plan for ECCS Strainer Performance Testing," Revision 1 (for November 2008 Testing, signed off as executed), December 4, 2008, Table 9-5

3.h.6 EA-MOD-2005-04-06 Debris Generation, Revision 2, "Acceptance of Debris Generation Calculation 2005-01340, Revision 1 of April 13, 2007" (Sargent & Lundy), February 9,2009

3.h.7 EA-Gothic-04-02! Revision 0, "Calculation of Palisades Containment Heat Sink Surface volumes and Areas for Input to GOTHIC 7.1 Containment response Analysis," August 17, 2004

3.h.8 Enercon Report ENTP-003-PR-03, Revision 0, "Unqualified And Degraded "Coatings Evaluation For Palisades Nuclear Station," February 5, 2009

3.i. Debris Source Term

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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.*

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

In responding to GL 2004 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*

ENO Response

Programmatic controls that address GL 2004-02 Requested Information Item 2(f) are described below:

- Administrative Procedure (AP) 1.10, "Plant System, Structure, and Component Labeling," was identified in the August 25, 2005, NMC response to GL 2004-02. AP 1.10 addresses the use of proper labeling materials inside the containment building. AP 1.10, Section 5.2.3 states, "Temporary tags may be used in the Containment Building during an outage, but shall be removed prior to containment closeout." Therefore, the requirements of AP 1.10 ensure problem identification tags are removed prior to containment closeout.

- AP 1.01, "Materiel Condition Standards and Housekeeping Responsibilities," was identified in the August 25, 2005, NMC response to GL 2004-02. AP 1.01 has since been revised. Section 6.10 of the procedure addresses "Areas Requiring Special Housekeeping Standards." Section 6.10.1.a. identifies general cleanliness requirements in the reactor building by stating that general cleanliness "should be maintained by periodic cleanup efforts of the work areas. This is especially important during refueling outages when multiple in-progress jobs can result in large accumulations of tools, materials, supplies, debris, etc, some of which, may be highly radioactive or contaminated. Reference Permanent Maintenance Procedure MSM-M-71, "Containment Cleanliness Implementation Plan and Containment Closeout," for specific instructions."

- AP 5.34, "Special Process Control," was identified in the August 25, 2005, NMC response to GL 2004-02. AP 5.34 identifies that if a failure of the special process could adversely affect a safety-related or important to safety structure, system, or component (e.g., could an unanalyzed failure of a coating/paint lead to clogging of the containment sump) then the special process shall be fully controlled by AP 5.34.

- Specification A-130, "Technical Specification for Painting," was identified in the August 25, 2005, NMC response to GL 2004-02. Specification A-130 was revised to update the requirements of coating applications inside containment in accordance with current regulatory and industry standards. The primary changes of the specification involve the definitions of service levels of coatings and their requirements. The specification revision enhanced the requirements for the selection, surface preparation, application, inspection and personnel training for qualified Service Level 1 coating inside containment. The definition of the ZOI (in Attachment 3 of the existing revision) from the GL 98-04 compliance is replaced by the ZOI definition in line with GSI-191 requirements.

- Specification M-136, "Furnishing and Installing Conventional Type Insulation," was identified in the NMC August 25, 2005, response to GL 2004-02. Specification M-136 incorporated GSI-191 resolution changes explicitly requiring an engineering change process for replacing the thermal insulation material inside containment, except for the like-for-like replacements of piping insulation and for replacing the aluminum pipe insulation jackets with the stainless jacketing.

- Fleet Modification Procedure FP-E-MOD-04, "Design Inputs," was identified in the NMC August 25,2005, response to GL 2004-02. QF-0515A (FP-E-MOD-04) Design lnput Checklist (Part A-Engineering Programs and Departmental Reviews)," is required to be completed to obtain design inputs for modifications per procedure FP-E-MOD-04, Revision 3. The Design lnput Checklist incorporated a Containment Sump Blockage design checklist to determine if the proposed plant modification affects the containment sump analysis. If the answer to any of the questions is yes, it requires a consultation with the containment debris coordinator (Design Engineering) or other suitable subject matter expert. The ENO design modification procedures have since been adopted at PNP. In ENO procedure EN-DC-115, "Engineering Change Development," the design modification controls of the debris source are incorporated in the checklists for a two level design impact evaluation. The impact on coating, insulation, labels, aluminum or other metal/non-metallic sources in the containment are required to be addressed by the procedure.

- Fire Protection Surveillance Procedure FPSP-RP-12, "Fire Rated Assemblies and Fire Protection Assemblies," was identified in the NMC August 25,2005, response to GL 2004-02. FPSP-RP-12 is used to inspect cable tray fire stops located in containment. This surveillance requires that a visual inspection of the integrity of fire rated assemblies and fire protection assemblies be performed every 18 months, thus reducing the potential containment debris source from the fire protection assemblies.

- Technical Specification Surveillance Procedure RT-142, "Containment lnservice Inspection-Metal Liner," was identified in the NMC August 25, 2005, response to GL 2004-02. RT-142 is used to perform inspections of the containment liner to fulfill TS surveillance and administrative control requirements. This procedure requires that inspected areas, which are painted or coated be examined for flaking, blistering, peeling or discoloration.

  Technical Specification Surveillance Procedure RT-92, "Inspection of Containment Sump Envelope," was identified in the NMC August 25, 2005, response to GL 2004-02. RT-92 verifies, by visual inspection, that each containment sump inlet debris screen, containment sump passive strainer assembly, and other containment sump entrance pathways are not restricted by debris and show no evidence of structural distress or abnormal corrosion in order to satisfy TS SR 3.5.2.9. This procedure also performs a cleanliness inspection of the containment sump, condition assessment of the sump level switches, sump drain screen, and the containment sump liner. The inspection includes the biological cleanliness of the sump. Any documented foreign material in the containment sump, including slime, algae, and biological growth are removed.

- General Operating Procedure GOP-2, "Mode 5 to Mode 3 ≥ 525 F," was identified in the NMC August 25, 2005, response to GL 2004-02. GOP-2 contains requirements to remove caution tags from containment and to perform inspections of containment in accordance with System Operating Procedure SOP-1A, "Primary Coolant System."

- System Operating Procedure SOP-1A, "Primary Coolant System," was identified in the NMC August 25, 2005, response to GL 2004-02. SOP-1A identifies the senior reactor operator inspections in support of containment closeout to ensure the integrity of the containment sump envelope and containment sump screens, and to remove unauthorized material.

- Permanent Maintenance Procedure MSM-M-71, "Containment Cleanliness Implementation Plan and Containment Closeout," ensures containment cleanliness throughout outage and/or online work activities in containment and to provide guidelines to prepare for the final closeout inspection performed by the operations department under SOP-1A, Attachment 6, Checklist CL 1.4, " Containment Closeout Walk-Through."

- Permanent Maintenance Procedure CLP-M-7, "Containment Coating Condition Assessment," provides instructions for condition assessments of protective coatings within the PNP containment and to report the results. These assessments are performed to meet the requirements of the PNP EM-09-23, "Safety Related Coatings Program."

  Containment coatings condition assessments are performed to identify changes in the amount of degraded qualified and unqualified coatings, which have occurred from the previous assessment.

- Permanent Maintenance Procedure ESS-M-43, "Containment Sump Envelope Access Control," provides instructions for removing and installing containment sump envelope passive strainers and debris screens during operating modes 5 and 6.

- Engineering Manual Procedure EM-09-23, "Safety-Related Coatings Program," defines the requirements of the program that applies to coatings on the interior surfaces of the containment, exposed surfaces of equipment located in containment, and linings of tanks and piping where detachment could adversely affect the function of safety-related structures, systems or components and thereby impair safe shutdown.

  This program systematically ensures that safety-related coatings systems are properly selected, applied, maintained, assessed, repaired, or removed to assure required coating integrity and design function performance. The program helps ensure that the design limits associated with potential containment post-accident coating based debris are not exceeded.

- Permanent Maintenance Procedure MSM-M-42, "Application of Qualified Service Level I Coatings (Paint)," provides requirements for application of qualified Service Level I protective coatings to surfaces inside, or to systems, structures or components that will be installed inside, the containment. Qualified Service Level I (safety related) coatings are assumed to remain in place during accident conditions and their failure could adversely affect the operation of post-accident fluid systems and thereby, impair safe shutdown. This procedure provides controls for the application of Qualified Service Level I coatings, which help ensure they perform as designed and tested.

- Technical Specification Surveillance Procedure RM-124, "Sodium Tetraborate (STB) Basket Weights," is a technical surveillance procedure that ensures a sufficient amount of sump buffering agent is installed inside containment. In order to minimize the risk of chemically breaking down the insulation material under the post-LOCA environment, the procedure controls the amount of STB installed to the lowest practical level. The weight of the STB in the 20 baskets is compared to the minimum weight required to achieve a post-LOCA sump pH value of 7.0.

NRC Request

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.

ENO Response

The permanent plant changes are implemented by the engineering change process. The controls of the debris source are required by the modification change procedure EN-DC-115, "Engineering Change Development," via the use of checklists. Two checklists required by EN-DC-115 are the Impact Screening Summary and the Detailed Impact Screening Criteria. These checklists include the screening criteria of impact on the coating, insulation, labels, and aluminum and metal/non-metallic sources of debris in the containment building. Any change of the screened parameters is subjected to evaluation to ensure compliance to the design bases.

NRC Request

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

ENO Response

Maintenance activities, including associated temporary changes in the containment, are subject to the procedural requirements of MSM-M-71, "Containment Cleanliness Implementation Plan and Containment Closeout." This procedure ensures containment cleanliness throughout an outage and/or online work activities in containment and provides guidelines to prepare for the final closeout inspection performed by the operations department under SOP-1A, Attachment 6, Checklist CL 1.4, "Containment Closeout Walk-Through." MSM-M-71 provides specific housekeeping standards, inspection schedule information and detailed inspection checklists. The procedure includes a list of items that have been approved to remain in containment and a questionnaire to be used when requesting that other items be left in containment on a permanent basis. The questionnaire includes questions related to sump screen plugging, chemical effects and downstream effects. The stated intent of the containment close out inspection is, "to ensure that loose material capable of plugging the containment sump strainers, containment downcomer or vent screens, and 590' elevation floor drains is removed."

EN-DC-136, "Temporary Modifications," provides controls to ensure operator awareness, conformance with design intent and operability requirements, and preservation of plant safety and reliability. The procedure addresses the alteration of any quality-related structure, system, or component and the addition of aluminum into containment. The process provides specific guidance for the use of tags associated with temporary modifications in containment and the potential for them becoming sump debris. The procedure further requires evaluation of the temporary modification materials' compatibility with the service and environment, evaluation for impact on adjacent quality-related equipment, and evaluation for the impact of failures on other equipment, including common mode failures.

AP 4.02, "Control of Equipment," AP 2.09, "Outage Planning, Scheduling and Management," and EN-WM-109, "Scheduling," all provide procedural guidance and requirements to minimize risk associated with conducting work. Procedure EN-WM-109 ensures that on-line schedules are risk assessed using both quantitative and qualitative risk analysis and that risk evaluations are performed prior to and during outage schedule implementation. Procedure AP 4.02 provides guidance for assessing and managing risk associated with scheduled on-line activities (Mode 1, 2 and 3) prior to the execution of planned equipment outages, and for re-evaluating the risk impact of emergent changes that are made to the original schedule, as required by 10 CFR 50.65 (a)(4) of the Maintenance Rule.

AP 2.09 ensures that risk assessments are performed on the outage schedule and further provides specific requirements for the assessments.

EN-WM-105, "Planning," provides instructions to ensure that work is planned in a manner consistent with its importance to plant safety. In addition to the normal work order planning process, the procedure requires completing an impact assessment for the component that includes evaluating if other components are directly affected by this work activity and evaluating the impact on TS associated with the affected systems or components. The procedure specifically requires reviewing the required task for foreign material exclusion consideration or requirements, cleanliness control requirements, insulation and paint removal or application.

Specification A-130, "Technical Specification for Painting," requires the notification of the safety related coatings program owner whenever there is an addition, removal, repair, or touch up of coatings inside of containment or any areas outside containment where coatings failure could adversely affect the safety function of a safety-related structure, system or component. It further requires a review by the safety related coatings program owner for modifications or repairs of equipment inside of containment, which includes paint or coatings.

EM-09-23, "Safety-Related Coatings Program," requires that modifications or repairs of equipment inside of containment, which includes paint or coatings, be evaluated for impact on the quantity of qualified, degraded qualified or unqualified coatings. The procedure also requires a review of all coating work inside of containment be performed for potential impact. Changes to coatings in containment are provided to design engineering or analysis personnel for evaluation, as appropriate. Changes to the quantity of unqualified or degraded qualified coatings within containment are maintained on a coatings log to help ensure that coatings will not impact safe operation of the containment sump and engineered safeguards equipment subsequent to a DBA.

NRC Request

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

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

ENO Response

No recent or planned insulation change-outs to reduce the debris burden have been performed.

NRC Request

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

ENO Response

No actions have been taken to reduce the debris burden by modifying existing insulation.

NRC Request

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

ENO Response

To reduce the chemical effects described in NRC Information Notice 05-26, ENO replaced the sump buffering agent during the fall 2007 refueling outage, replacing the trisodium phosphate with sodium tetraborate. This modification is described in section 3.0 of this document.

NRC Request

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

ENO Response

The enhancement of monitoring the containment coating is implemented in the Procedure CLP-M-7, "Containment Coating Condition Assessment."

With regard to control and reduction of plant debris source and the NRC RAI of December 24,2008, the material below was also provided in RAI 18 response on March 20,2009 (Reference 3.b.9).

NRC Request

18. Page 66 of the February 27,2008, supplemental response indicates that Palisades Technical Specification Surveillance Procedure RT-92 addresses the biological cleanliness of the sump, and specifies that algae and/or slime in the sump that could impede ECCS operation be removed. Please discuss the typical amounts of algae and/or slime that are removed from the sump and justify why this amount of biological material does not need to be considered as an additional debris source after a postulated LOCA.

ENO Response

18. The sump area is a confined space and typically has been a high radiation area and a very high contamination area. Radiological doses up to two rads per hour at contact and contamination levels to 1,000,000 dpm/100 cm^2 have been reported during some refueling outages. There is no lighting in the area and the entrance is via a 10-foot long, 24-inch diameter tube with a severe downward slope. The sump is circular, 22 feet in diameter and 3.5-feet high. The floor of the sump is uneven due to the way concrete was placed. The center of the floor is on the order of %-inch higher than the outer edges. The old screens are at the periphery, as are most of the floor drain inputs. This complicates reporting of residual water level in the sump during inspections and also prevents complete gravity draining of the sump.

    The combination of personnel protection gear and poor available lighting makes measurements, data taking, and color fidelity problematical. Due to a significant safety focus, most attention in the past was placed on the old sump screens. The old sump screens were removed from the sump.

    The historic data that exists was mostly casually taken by radiation protection technicians and written on the radiation work permits (RWPs). Going back to 1990, the reports of residual water level on the floor, after gravity draining the sump to the dirty radioactive waste system, range in the ½ to 1 ½ inch area. These levels are thought to have been maximum levels, to control the protective clothing choice, taken on the edge of the sump either at the location of the 24" entrance or in front of the screens. Both are known to be sump low points. Most of these reports also include a smear taken at the center of the sump that was frequently reported as a dry smear.

    The sump was typically cleaned by vacuuming the material into a 55 gallon drum and transporting it out of containment by crane, as opposed to flushing it out to radioactive waste. The material did all fit in the drum and the drum was usually around ¾ full (for example in 2001). It was reported that less than half of the drum was "sludge" and the rest was water. There were at least two methods of judging the fraction of the sludge component. One method was by dip-sticking the drum and another by variation of contact dose rate as the meter was 'moved up the outside diameter of the drum. The drum represents a significant radiation source during cleaning and must be monitored to ensure a high radiation area is not created. Thus, the radiation meter method is readily available for judging how much sludge is present.

If it is assumed the drum was full and half of the contents were sludge, then the sludge volume would be 27.5 gallons. It is noted that a full uniform depth of one inch in the sump would equal 237 gallons. The difference from 55 gallons relates to the non-uniform floor elevation and the tendency to estimate and report the maximum sludge depth rather than actually measure it. If volume had been reported, average depth readings would be needed to yield a good volume estimate. Taking the time to do that, without a good reason, would not, at the time, have been considered to be ALARA.

The 27.5 gallon conservative estimate was for material removed from the sump floor. The volume of material removed from the screens while they were cleaned would have been very small. Cleaning was rendered difficult due to the low ceiling and the fact that only one side of the screen was accessible to brush. Also, the high viscosity of the material made a bubble form in the small screen squares and it resisted removal by a stiff wire brush that rode over the high points on the screens. Adding soapy cleaning solution did nothing to help this phenomenon. This kind of bubble does not support any differential pressure so is not a plugging concern. More recent efforts successfully used high pressure spray with hot water. This is quicker, easier for the decontamination technicians to apply, and is more effective from an ALARA standpoint.

The use of "algae" is not found in the documents written by those who handle the material. The words used to describe the material include: sludge, sediment, oil and water mixture, muddy water, and slimy/oily water. Algae may be used as a "conservative" assumption. Since the containment air cooler condensate leaves containment via the sump, and since leakage of lake water from the cooling coils had been known to occur in the past, it is possible that algae and other biological material are present. The -possibility that a significant fraction of it is emulsified oil from the primary coolant pumps is quite high since their RMI insulation has a tendency to hold oil and significant quantities of oil went unaccounted for in past spill cleanups. Hot boric acid containing leakage from pump seals could easily complex with the oil and transfer it to the sump.

The new screens are all above the sump on the 590' elevation of containment and are not exposed to the material in the sump until after it has gone through a containment spray pump, a high pressure safety injection pump, the recirculation heat exchanger, and either through the core and line break or through the containment spray valves and spray nozzles, and then on to the 590' elevation containment sump pool containing sodium tetraborate.

The post-LOCA containment sump pool contains approximately 250,000 gallons of hot borated water containing a significant amount (8,000 lbs) of sodium tetraborate. The sodium tetraborate is the same material sold as borax for use in laundry as a surfactant. There is little doubt that 250,000 gallons of hot soapy sump water can easily dissolve 27.5 gallons of either oily emulsion or algae created biological material. Similar surfactants are also sold as algaecides. Extreme agitation as it transits through the above described path will ensure good mixing takes place and will enhance the process of dissolution of solubles or suspension of small particles.

3.j. Screen Modification Package

This section of the follow-up supplemental response is revised from previous information provided in the PNP supplemental response of February 27, 2008 (Reference 3.j.l). Changes are minor and reflect the new strainers installed during the 2009 refueling outage as described in Section 2.

NRC Request

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.*

ENO Response

The intent of the modification was to perform the hardware changes required to bring PNP into full resolution with NRC GSI-191. This modification replaced the existing ECCS suction inlet screens for the PNP containment sump, which were located interior to the containment sump in the containment building (Attachment 1), with an engineered strainer system installed on the containment base slab (590 ft elevation).

The containment sump at PNP is a chamber located under the reactor cavity floor at a lower elevation than the containment 590 ft elevation to permit floor drain collection of system leakage within containment during normal plant operation and following a LOCA. The containment sump entrance pathways consist of containment sump downcomers, containment floor drains, containment sump vent lines, and reactor cavity drains. There are six containment sump downcomers, which are located two inches above the containment floor at the 590 ft elevation. The downcomers provide a connection between the containment sump and the containment 590 ft elevation. The containment floor drains collect and transport system leakage via embedded drain lines to the containment sump. The containment sump vent lines assist in the release of air that may be collected at the top of the containment sump during LOCA flood up. The reactor cavity drain lines contain reactor cavity corium plugs. The reactor cavity corium plugs are designed to inhibit the flow of core debris (corium) into the containment sump. The containment sump exit pathways consist of two suction pipes that provide flow paths to the ECCS pumps and one containment sump drain line. Following an accident, during the recirculation mode of emergency core cooling, the sump supplies a suction source of water to the ECCS and CSS pumps with adequate NPSH.

The modification installed passive, safety-related Sure-Flow® Strainer assemblies, engineered, manufactured, and qualified by PCI.

The passive Sure-Flow 8 Strainer assembly system consists of two strainer assemblies, which are composed of four strainer sub-assemblies (Attachment 2). Two strainer sub-assemblies consist of four modules each and connect to one of the two associated downcomers. The other two strainer sub-assemblies consist of nine modules and six modules and connect to the other associated downcomer.

The PCI Sure-Flow 8 suction strainer assemblies for PNP are various combinations of horizontally oriented modules, each containing ten disks. The disks are a nominal 5/8" thick and are separated nominally one inch from each adjacent disk. The interior of the disks contain rectangular wire stiffeners for support, configured as a "sandwich" made up of three layers of wires. The disks are completely covered with perforated plate having 0.095" holes. The end disk of a module is separated approximately 4" from the end disk of the adjacent module. The 4" space between adjacent modules is connected together by means of a solid sheet metal collar fitted over the core tubes and secured by two bolts that is used to prevent debris from entering the system between the two modules. This connection permits relative motion in the axial direction as the core tube can slide relative to the stainless steel collar. Each of the modules has cross-bracing on the two exterior vertical surfaces of each module. Based on the design configuration of the PNP strainer assembly, the largest opening for water to enter into the sump is through the perforated plate 0.095" holes. Each module is independently supported. The modules are pin-connected to a mounting track, which in turn is bolted to the containment slab. The mounting track is made of structural shapes: angles and plates. The strainer design allows for disassembly, replacement of modules, or addition of future modules as needed. The modules are essentially identical with the only difference being the "window" slot sizes in the core tube. The Sure-Flow® Strainer module core tubes are 12.13 ID, 16-gauge, stainless steel pipe.

The horizontally oriented strainer assemblies have a total strainer surface area of approximately 3,524 ft^2. The strainer approach velocity value is 0.0023 ft/sec, an extremely low approach velocity when compared to the design value for the original ECCS screens. The strainer approach velocity is defined as the quotient of strainer flow rate and total surface area. The flow rate at the circumscribed area is 0.011 ft/sec. The strainer configuration was originally sized to limit the head loss to less than 2.6 feet during post-LOCA design debris loading.

The ECCS and CSS design flow path is from the passive strainer module assemblies and enters one of the two downcomers before discharging into the enclosed sump, which is directly connected to the ECCS and CSS pump suction lines.

In order to balance the clean strainer head losses between the two separate passive Sure-Flow® Strainer assemblies entering the two separate sump downcomers, each assembly has differing strainer assembly discharge pipe diameters and associated balancing orifice installed.

The two 4-module units to downcomer 1 use 12-inch schedule 10 stainless steel pipe, associated pipe fittings and a 8-7/8 inch diameter orifice installed at the last flange before the downcomer to balance the head loss of the units to the other strainer to deliver the strained water into the sump through downcomer 1.

The 9-module and 6-module units to downcomer 5 use 16-inch schedule 10 stainless steel pipe, associated pipe fittings and a 9-7116 inch diameter orifice installed at the last flange on the 6-module unit before the 6 and 9 module units tee to the common downcomer to balance the head loss of the units to the other strainer to deliver the strained water into the sump through downcomer 5.

These two containment sump downcomer pipes provide the post-LOCA credited flow pathway from the post-LOCA inventory, which has accumulated on the 590 ft elevation of containment through the passive strainer assemblies to the containment sump to provide the RAS suction source of water to the ECCS and CSS pumps.

In addition to the passive containment sump strainer assemblies, debris screens have been installed on the remaining open containment sump entrance pathways, which include the four remaining downcomer pipes, the seven containment floor drains, and the two containment sump vent lines.

The reactor cavity corium plugs, located in the reactor cavity drain lines, contain ceramic pellets within the corium plug tube, tube end cap, and tube bottom cup support assembly, which form a debris interceptor similar in functionality to the debris screens. The strainer assemblies, together with the debris screens and the reactor cavity drain plugs, protect the common containment sump, rather than protecting only the ECCS/CSS pump suction lines.

The passive Sure-Flow® Strainer assembly with associated debris screens, and the placement of the corium plugs, provide 100% debris retention outside of the containment sump envelop of greater than 0.095" diameter debris and thereby prevent the degraded operation of the HPSI and CSS resulting from debris during accident conditions. The original strainer modification was installed during the 2007 refueling outage. During the 2009 refueling outage, all strainer modules were replaced with equivalent modules with the key change that the original perforated plate 0.045" hole size was changed to 0.095".

NRC Request

- *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.*

ENO Response

The sump strainer modification was designed with the objective of minimizing the impact on plant installed equipment and structures. The installation of the sump strainers did not require the modification of pipe, supports or missile shields. The only relocation of equipment involved in the sump modification was the baskets of the containment buffering agent. Due to the installation of the strainer assemblies during the 2007 refueling outage, the 20 containment buffer baskets containing STB, were relocated on the containment base slab. During the 2009 refueling outage, some containment buffer baskets were moved further from the nine and six module strainer banks to reduce flow approach velocities up stream to these strainers.

<u>References</u>

3.j.1 Entergy letter dated February 27, 2008 to NRC, "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accident at Pressurized Water Reactors'"

3.k. Sump Structural Analysis

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008 (Reference 3.k.1). Changes are minor and reflect the new strainers installed during the 2009 refueling outage as described in Section 2.

NRC Request

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).

> *GL 2004-02 Requested Information Item 2(d)(vii)*
> *Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under flow conditions.*

- *Summarize the design inputs, design codes, loads, and load combinations used for the sump strainer structural analysis.*

ENO Response

The sump replacement strainer pressure retaining components have been designed and analyzed to the standards of American National Standards Institute (ANSI), American Society of Mechanical Engineers; (ASME) B31.1, Power Piping 1973 Edition through summer 1973 Addenda, for the specified normal and accident conditions inside containment. The strainers are classified as "other pressure-retaining components," as described in Paragraph 104.7 of the ANSI (ASME) B31.1 Code. Many of the strainer components are unique, and ANSI (ASME) B31.1 does not provide specific design guidance for these types of components.

The ASME Code is used for the qualification of pressure retaining parts of the strainer, which are not covered in B31.1 (perforated plate, and internal wire stiffeners). Some parts of the strainers (external radial stiffeners, seismic stiffeners, tension rods, edge channels, etc.) are classified as part of the support structure. Structural support members are designed and fabricated to the standards of USA Standards Institute (ASME) B31.1 and the American Institute of Steel Construction (AISC) Structural Steel Specification, Eighth Edition, 1980." Strainer assembly angle iron support tracks were evaluated per AISC 9th Edition.

Additional guidance is also taken from other codes and standards where the AISC code does not provide specific rules for certain aspects of the design. For instance, the strainers are made from stainless steel materials. The AISC Code does not specifically cover stainless steel materials. Therefore, ANSI/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities," was used to supplement the AISC in any areas related specifically to the structural qualification of stainless steel. Note that only the allowable stresses are used from this N690-1994 Code and load combinations and allowable stress factors for higher service level loads are not used.

The strainer also has several components made from thin gage sheet steel, and cold formed stainless sheet steel. Therefore, Structural Engineering Institute/American Society of Civil Engineers (SEI/ASCE) 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members," was used for certain components where rules specific to thin gage and cold form stainless steel are applicable. The rules for allowable stress design, as specified in Appendix D of this code were used. This was further supplemented by the American Iron & Steel Institute (AISI) Code, 1996, "Specification for the Design of Cold-Formed Steel Structural Members," where the ASCE Code is lacking specific guidance. Finally, guidance is also taken from American Welding Society (AWS) D1.6, "Structural Welding Code - Stainless Steel," as it relates to the qualification of stainless steel welds.

The design conditions for the strainer modules, as defined in the strainer procurement specification, include the live load, differential pressure loads, thermal loading, and seismic events (safe shutdown earthquake (SSE) and operating basis earthquake (OBE)). The limiting condition considered is a SSE that occurs while the strainer is in a submerged condition after a LOCA. The ability of the strainers to perform their safety functions during and/or after an OBE and SSE has been demonstrated in the supporting analyses (References 3.k.2 and 3.k.3). The load combinations for the strainer discharge piping and piping supports are defined in discussion that follows and are in conformance with FSAR Section 5.10.1.1 and 5.10.1.2 requirements.

Dead Weight Loads

Dead weight load due to debris on the strainer was determined by calculating the quantity of debris that would be deposited onto each PCI strainer module by the most limiting break. In addition to the analysis, PCI performed strainer testing that simulated the actual debris loading conditions using PNP's bounding post-LOCA debris concentrations. The analysis and testing demonstrate that the strainers are capable of withstanding the force of full debris loading in conjunction with design basis conditions, including seismic activity.

Debris Load

The strainers were designed to ensure that they are capable of withstanding the force of full debris loading, in conjunction with design basis conditions. The effect of the debris load was reflected in the dead weight and suction pressure terms of the analysis. The strainers are capable of withstanding the force of full debris loading for the design basis load combinations discussed below.

Live Load

In addition to the dead weight loads, live loads, which would occur only during the refueling outage and strainer installation, were considered in the design analyses.

Hvdrodvnamic Mass

Hydrodynamic forces were considered in the seismic analysis of the strainer assemblies and associated discharge piping. Specifically, the dynamic effects of surrounding water on the submerged strainer structure during an earthquake, i.e., added water mass, inertia coupling, impulse, sloshing, wave actions, damping, and participation of added water mass in the forcing term were considered. A generic seismic sloshing analysis performed by the strainer vendor (PCI) concluded that the sloshing loads on the strainers are negligible. The analysis was based on a close form solution where the containment was modeled as an annular tank. An equivalent mechanical model of the slosh, caused by a horizontal excitation of the tank, was composed of a series of oscillating slosh masses supported by mechanical springs. The water mass was broken into two parts; a rigid mass that behaves like a mass that is rigidly attached to the tank, and a sloshing mass that oscillates between the tank walls. The model was used to determine the sloshing velocity, which in turn was used to calculate the drag forces in the strainer modules. Although the values of the parameters used in the generic analysis are different than the values associated with PNP, the differences would not result in a different conclusion (i.e. sloshing loads are insignificant compared to the other seismic loads). The conservatism in the hydrodynamic mass determination outweighs any load resulting from sloshing of the water inside containment. Therefore, seismic slosh loads are neglected from the stress analysis.

Thermal Loads

Strainer assembly thermal expansion loads would be zero because the strainers are essentially freestanding structures and, for the most part, are free to expand without restraint. Therefore, thermal loads were considered negligible and were taken equal to zero. The thermal expansion of the strainer assembly discharge piping was taken at a temperature equal to the maximum sump water temperature. Small gaps were modeled for certain supports in the thermal analysis to account for the gaps in the pipe supports. A 1/16" gap was modeled on top of the pipe for all supports, and a 1/16" gap was modeled on either side of the shear lugs for the three-way supports. The gaps are designed to minimize unrealistic thermal loads on the sump piping. To allow for relative thermal expansion between adjacent strainer assembly modules, as well as the strainer discharge piping and the reactor building, adjacent modules are installed with a gap between them. The gap would be sealed with a load compliant metallic sleeve.

Seismic Loads

The seismic loading considered both the reactions of seismic inertia and seismic sloshing. The hydrodynamic mass of the strainer, which would be subject to seismic accelerations, was calculated based on the mass of water enclosed by the strainer, plus the added mass from the water surrounding the strainer. The strainer purchase specification included the amplified response spectra used in the seismic analysis, which are the SSE and OBE seismic response spectra for all three directions at two-percent damping. The strainer modeling was excited in each of the three mutually perpendicular directions, two horizontal and one vertical. The modal combination was performed by the ten percent method combination per the PNP FSAR, which refers to Section 1.2 of Regulatory Guide 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis," for closely spaced modes. Seismic response from the vertical and two horizontal directions were combined by the use of the square-root-sum-of-the-squares (SRSS) method. The cutoff frequency was taken at 33 Hertz. Zero period acceleration (ZPA) residual mass effects were considered. The ZPA response was conservatively added to the response spectra loads by SRSS. The seismic analysis report for the replacement sump strainers states that the strainers have been analyzed, as required, for the specified normal and accident conditions inside containment, and the strainer meets all the acceptance criteria for all applicable loadings. The seismic analysis report for the strainer discharge piping and supports demonstrates that the pipe stresses and support loads are acceptable. The piping stresses, flanges, and support component stresses are within their respective applicable limits and are, therefore, acceptable.

Differential Pressure Loads

A conservative pressure loading of 6.5 pounds per square inch (psi), which is equivalent to a pressure head of 15 feet of water, was applied to the structural analysis of the strainers 4.22 pounds per square inch (psi), which is equivalent to a pressure head of 9.75 feet of water, was applied to the structural analysis of the strainer discharge piping and supports.

Other Dynamic Effects

The potential of jet impingement and pipe whip were also evaluated and found to be not creditable. The PCS loop pipes, including the pressurizer surge line, and the strainer assemblies are separated by a concrete floor. There are no direct pathways between the strainer locations and any high energy line break associated piping locations.

Load Combinations

The replacement strainer assemblies and the discharge piping segments are designed to the following service loadings:

Sump Strainers

Loading Conditions	Loading Combinations
(1a) Normal Operating	DW +DEB + DP
(1b) Normal Operating (outage/Lift Load)	DW + LL
(2) Upset	DW + DEB + DP + OBE
(3) Faulted	DW + DEB + DP + SSE

Where:
DW = Dead Weight
LL = Live Load (Additional Live loads acting on strainer assembly during outage and installation)
DP = Differential Pressure
DEB =Weight of Debris
OBE =Operating Basis Earthquake (2% damping seismic response spectra)
SSE = Design basis earthquake = Safe Shutdown Earthquake = 2 x OBE

Strainer Discharge Piping

Loading Conditions	Loading Combinations
(1a) Hoop Stresses	DP
(1b) Normal (pressure + Sustained)	P+DW
(2) Upset	P + DW + OBE
(3) Faulted	P + DW + SSE
(4) Secondary	T1

Where:
DP = Design Pressure Hoop Stress
P = Differential Pressure
OBE =Operating Basis Earthquake
ASME Code Case N-411 method is employed.
SSE =Safe Shutdown Earthquake = 2 x OBE
T1 = Thermal Expansion (maximum sump water temperature of 264°F)

Strainer Discharge Pipe Support Structural Components

Loading Conditions Loading	Combinations
Normal	DW + T1
Upset	DW + OBE + T1
Faulted	DW + SSE + T1

Where:
DW = Dead Weight Load
OBE =Operating Basis Earthquake
SSE = Safe Shutdown Earthquake
T1 = Thermal Expansion (maximum sump water temperature of 264°F)

NRC Request

- *Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.*

ENO Response

Detailed stress analyses have been performed on strainer parts, strainer assembly connecting piping, piping flanges and supports. All the component stresses analyzed meet the design allowables set forth in the design codes and standards described in the preceding discussion. The most limiting interaction ratio of the computed stress and the stress allowable for the strainer assembly is 1.00. This interaction ratio occurs at the sleeve banding, which connects the strainer modules. The most limiting interaction for the strainer support is 0.98, which occurs at an expansion anchor to floor location. The most limiting interaction ratio for pipe and pipe supports was calculated as 0.99, which occurs at a base plate of one of the pipe supports. The limiting interactions for a few components were expected to be near 1.00 as the differential pressure loads were increased in the analyses to the value where the structural limits would be reached for the limiting component. The strainers and associated piping have been evaluated structurally for 15 ft and 9.75 ft water differential pressure, respectively, (reference earlier discussion in Section 3.k and Section 3.f). It can be seen that the piping is limiting. The design pressure drop for the strainer and pipe assembly is 2.6 ft. Therefore, the design pressure drop margin for the applied differential loads is (9.75 - 2.6) / 2.6 = 275%.

NRC Request

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

ENO Response

The evaluations performed for dynamics are discussed in the preceding description of the design loadings.

NRC Request

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

ENO Response

Back flushing is not credited in the PNP design of containment sump strainers.

<u>References</u>

3.k.1 Entergy letter dated February 27, 2008 to NRC, "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accident at Pressurized Water Reactors'"

3.k.2 Calculation EA-EC496-05, Revision 3, dated March 3, 2009, "AES Document No. PCI-5798-SO1 Rev 3 Structural Evaluation of Passive Containment Sump Strainers"

3.k.3 Calculation EA-EC496-12, Revision 1, dated March 3, 2009, "AES Document No. PCI-5798-SO2 Rev 1 Evaluation of Piping for the Passive Containment Sump Strainers"

3.1. Upstream Effects

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008 (Reference 3.1.1). Changes are minor and reflect the revised water level calculation (Reference 3.1.2).

NRC Request

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

Provide a summary of the upstream effects evaluation including the information requested in GL 2004-02 <u>Requested Information</u> Item 2(d)(iv).

<u>GL 2004-02 Requested Information Item 2(d)(iv)</u>
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.*

ENO Response

As is described in Section 3.j., and shown on Attachment 2, the PNP containment sump entranceways are protected from debris by perforated screens and strainer assemblies. The only pathway to sump credited for the post-LOCA recirculation flow is the PNP strainer assemblies, which are installed on the floor of the containment base slab at 590'elevation. The 590' elevation is largely open at the floor level. Design modifications in 2004 eliminated two potential choke points; the opening of the clean waste receiver tank (CWRT) room door, and the installation of a new blowout panel in the air room.

Referring to Attachment 2 of this document, a north-south run wall separates the CWRT room from the other area of the 590' elevation. On one end of the wall to the containment shell is a wire-fenced opening. The size of the opening is limited and is prone to be clogged by debris. On the other end of the wall, there is a door for controlling personnel entrance to this high radiation area during refueling outages. A door stop was installed in 2004 to keep the door open during reactor power operation. Thus, it ensures the recirculation water would not be held up in the CWRT room.

The blowout panel in the air room is a part of the Appendix R design requirements to impede the air flow to the area. The panel also serves as a locked high radiation area personnel isolation boundary. A breakable panel made of Marinite® I material is installed. This breakable panel design will relieve water build up inside the air room in the event of a LOCA. It is designed to rupture, either by the LOCA pressure blowout, or by a differential water level across the panel exceeding two feet.

NRC Request

- *Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.*

ENO Response

The holdup water volume considered in the containment minimum flood level analysis was attributed, either by design, or by conservative assessment, when accurate quantification is difficult. Of the total 7799 ft^3 holdup volume, 4822 ft^3 is retained in the reactor cavity due to the design of the cavity flooding system. The remaining 2977 ft^3 water volume is retained on the 649' elevation floor, the 607' elevation floor, and the tilt pit and refueling cavity floor. The depths of water on the floors assessed vary from one to six inches. In most of the cases, the depth of the water retained on the floor is conservatively assumed as the height of the curbing in the area, even though the area is not completely enclosed by the curbing. As a point of clarification, the 4822 ft^3 reactor cavity holdup volume is the amount of holdup in the reactor cavity above the first three feet. The first three feet would already be covered by the containment water volume to water level correlation for large break water levels. For determining the small break water level, the reactor cavity holdup volume is increased to 5149 ft^3 resulting in the total holdup increasing to 8126 ft^3. Section 3.g provides additional discussion on the water level calculation.

References

3.1.1 ENO letter dated February 27, 2008 to NRC, "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accident at Pressurized Water Reactors'"

3.1.2 Calculation EA-SDW-97-003, Revision 3, dated March 3, 2009, "Minimum Post-LOCA Containment Water Level Determination"

3.m. Downstream effects - Components and Systems

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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 susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.*

ENO Response

The initial response to GL 2004-02 (Reference 3.m.7), for PNP, discussed the evaluation of the potential flow path blockage due to debris bypassing the strainers. The discussion referred to the then-proposed active strainers and a flow path evaluation based on 118-inch x 118-inch sump screen mesh size. Since then, a passive strainer system with a 0.095-inch hole size perforated screen design was been adopted and installed in 2009. The downstream clearance evaluation performed for the active strainer is applicable for the new passive strainer design, since using the smaller holes size design is more limiting for both the debris bypass quantity and size.

Debris screens with 0.045-inch perf-orated holes were installed on the remaining open containment sump entrance pathways in the 2007 refueling outage, which include the four remaining downcomer pipes, and the two containment sump vent lines. A noted change to this statement is that the seven containment floor drains were also replaced with screens with 0.095 inch holes in the 2009 refueling outage. The flow paths from the reactor cavity are protected by the two coriurn plugs. These corium plugs contain ceramic pellets within the corium plug tube, tube end cap, and tube bottom cup support assembly, which form a debris interceptor similar in functionality to the debris screens. The migration of LOCA-generated debris larger than the strainer perforation diameter through the two one-inch reactor cavity drain line corium plugs is not considered to be credible. The passive Sure-Flow ® Strainer assemblies with associated debris screens, and the placement of the corium plugs, provide 100% debris retention outside of the containment sump envelope of greater than 0.095" diameter debris.

Periodic inspection of the sump entrance pathways is administrated under the TS surveillance testing program. It requires that within every 18 months:

> "Verify, by visual inspection, the containment sump passive strainer assemblies are not restricted by debris, and the containment sump passive strainer assemblies and other containment sump entrance pathways show no evidence of structural distress or abnormal corrosion."

NRC Request

- *If NRC-approved methods were used (e.g., WCAP-16406-P with accompanying NRC SE)I, 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.*

ENO Response

Two different debris transport analyses have been used. ENO has revised the second analysis in response to a change in the methodology in the guiding WCAP (Reference 3.m.1) generic report.

Original Down Stream Analysis

The original downstream analysis effort was done during planning to use active strainers. Also, at that time, the intention was to continue using TSP as a post-LOCA sump pH buffer. This analysis was used in the original reply to GL 2004-02.

This analysis (Reference 3.m.2) used the guidance of WCAP-16406-P, Draft Revision 0, of March 2005, and WCAP-16406-P, final Revision 0, version dated June 2005. The intention of the WCAP was to be consistent with NEI 04-07, which in turn was evaluated in the NRC NEI 04-07 SE. The analysis also relied upon Los Alamos Reports LA-UR-04-5416 (Reference 3.m.4), and LA-UR-01-6640 (Reference 3.m.5). No credit was taken for any kind of settlement of particulate debris or fiberglass since the active screens do not accumulate any debris. Screen bypass factors were applied, which were primarily taken from WCAP-16406 and the two Los Alamos reports. The wear due to chemical precipitates was not considered. It was believed, at the time, that all chemical precipitates would be soft flocculent particles, which would break up under strainer passage and pump impeller flow conditions to become particles too small (sub micron size) to cause surface contact and abrasive wear, and too light to cause erosive wear (wear being proportional to the square of the particle mass).

This analysis has been superseded by the analysis described below.

Analvsis Using Passive Strainers
ECCS equipment and core plugging concerns due to bypassed material were significant factors in the decision to discontinue the pursuit of active strainers. Accordingly, the downstream wear evaluation was bundled with the passive screen design and construction contract to allow trade off among all of the screen's functions and avoid debris grinding as an anti-plugging technique.

The passive strainer chosen was a relatively conventional square disk type strainer, which has excellent debris removal and retention capacity. The supplier chose AREVA to do the downstream wear effects analysis. ENO has continued to use them for the latest analysis, which reflects the WCAP-16406, Revision 1, guidance, as well as conforming to the NRC SE on the review of that generic report, and consideration of the new screen hole size of 0.095". Reference 3.m.10 documents most current downstream wear effects for the passive strainers.

The inputs of the analysis are summarized in the tables that follow.

Table 3ml Debris Size Distribution

Debris	Type	[1]Large Particle ("Yo)	[1]Medium Particle ("Yo)	[1]Small Particle (Yo)
RMI	**RMI**	100.0%	0.0%	0.0%
Coatings	[4]Qualified Coatings (except IOZ)	0.0%	0.0%	100.0%
	Unqualified Alkyds	94.0%	4.5%	1.5%
	Qualified IOZ	0.0%	0.0%	100.0%
Fibers	NUKON	100.0%	0.0%	0.0%
	NUKON unjacketed	100.0%	0.0%	0.0%
	Fiberglass	100.0%	0.0%	0.0%
	Fiberglass Unjacketed	100.0%	0.0%	0.0%
	Mineral Wool Jacketed	100.0%	0.0%	0.0%
	Latent Fiber	100.0%	0.0%	0.0%
Particulate	[2]CalSil	100.0%	0.0%	100.0%
	[2]CalSil Unjacketed	100.0%	0.0%	100.0%
	[3]Latent Particulate	62.9%	0.0%	37.1%
Chemical	[5]AIOOH	0.0%	0.0%	100.0%

Table notes:

[1]Sizes based on Westinghouse LTR-SEE-005-174

[2]Since the failure size is unknown for these constituents, it is assumed that they fail 100% large and 100% small

[3]Latent particulate sizes based on NEI 04-07 Vol. 2

[4] Qualified coating fail as 10 micron-sized particles, WCAP-16406-P, Appendix F

[5] The chemical debris constituent (AIOOH) agglomerates between 10 to 100 microns based on. The chemical debris is assumed to be present as individual particles or small agglomerations, with a debris sizing of 10 microns.

Also Note: The size distribution applied in the downstream effects analysis is not the same as that applied during debris generation calculations as guided by NEI 04-07. Each evaluation activity requires independent selection and batching of debris types, as directed by industry guidance.

Since limited information is available for the failure sizes of CalSil debris constituents, it is assumed that they fail as 100% large and 100% small.

Based on WCAP-16406, that recommends a screen capture efficiency of 95%, and NUREG/CR-6885 (Los Alamos National Laboratory Report LA-UR-04-5416), "Screen Penetration Test Report," October 2005, Table 3mla below lists the screen bypass fraction used for the various debris types.

Table 3mIa Debris Bypass Fraction Used

Debris	Type	Debris Bypass (%)
RMI	RMI	74.00%
Coatings	Qualified Unqualified Alkyds	100.0% 100 0%
Fibers	NUKON NUKON unjacketed Fiberglass Fiberglass Unjacketed Mineral Wool Latent Fiber	5.00% 5.00% 5.00% 5.00% 5.00% 5.00%
Particulate	CalSil CalSil Unjacketed Latent Particulate	100.00% 100.00% 100.00%
Chemical	AlOOH	103 0%

The debris quantity inputs to the analysis are summarized in table 3m2 below.

Table 3m2 Wear Evaluation Debris Inputs

Type		Debris Input (ft^3)	Material Density (lbm/ft^3)	Packing Density (lbm/ft^3)	Large Particle (Oh)	Medium Particle (%)	Small Particle (Oh)	Large Particle (lbm)	Medium Particle (lbm)	Small Particle (lbm)
RMI	RMI	0.0528	170	NIA	100.0%	0.0%	0.0%	8.976	0.000	0.000
Coatings	[1]Qualified (except IOZ)	4.877	98	N/A	0.0%	0.0%	100.0%	0.000	0.000	477.946
	Unqualified Alkyds	21.1	98	N/A	94.0%	4.5%	1.5%	1943.732	93.051	31.017
	Qualified IOZ	3.18	457	N/A	0.0%	0.0%	100.0%	0.000	0.000	1453.260
Fibers	NUKON	272.24	159	2.4	100.0%	0.0%	0.0%	653.376	0.000	0.000
	NUKON unjacketed	0.89	159	2.4	100.0%	0.0%	0.0%	2.136	0.000	0.000
	Fiberglass	31.95	159	2.4	100.0%	0.0%	0.0%	76.680	0.000	0.000
	Fiberglass Unjacketed	0.57	159	2.4	100.0%	0.0%	0.0%	1.368	0.000	0.000
	Mineral Wool Jacketed	99.46	90	10	100.0%	0.0%	0.0%	994.600	0.000	0.000
	Latent Fiber	0.32	94	NIA	100.0%	0.0%	0.0%	30.080	0.000	0.000
Particulate	CalSil	22.681	144	14.5	100.0%	0.0%	100.0%	328.875	0.000	328.875
	CalSil Unjacketed	12.352	144	14.5	100.0%	0.0%	100.0%	179.104	0.000	179.104
	Latent Particulate	1.01	169	NIA	62.9%	0.0%	37.1%	107.364	0.000	63.326
Chemical	AlOOH	11.894	187.91	NIA	0.0%	0.0%	100.0%	0.000	0.000	2235.00

Table 3m3 Debris Mass Concentration by Size

Debris	Type	PPMw	PPMw	PPMw
RMI	RMI	3.541	0.000	0.000
Coatings				
	Qualified (except IOZ)	0.000	0.000	254.769
	Unqualified Alkyds	1036.104	49.601	16.534
	Qualified IOZ	0.000	0.000	774.659
Fibers				
	NUKON	17.414	0.000	0.000
	NUKON unjacketed	0.0569	0.000	0.000
	Fiberglass	2.044	0.000	0.000
	Fiberglass Unjacketed	0.036	0.000	0.000
	Mineral Wool	26.509	0.000	0.000
	Latent Fiber	0.802	0.000	0.000
Particulate				
	CalSil	175.306	0.000	175.306
	CalSil Unjacketed	95.471	0.000	95.471
	Latent Particulate	57.230	0.000	33.756
Chemical				
	AlOOH	0.000	0.000	1191.365
Total		1414.514	49.601	2541.859

<u>Debris Decav Coefficient</u>
The debris decay coefficient for particles that decay with respect to time is 0.07 based on Appendix K of WCAP-16406-P, Revision 1.

Table 3m4 Recirculation Fluid Properties

Recirculating Fluid Inputs	
Minimum Sump Mass (lbm):	1,876,000
Minimum Sump Volume (ft^3):	30,072
Maximum Temp (F):	264
Density at max temp (lbm/ft^3):	58.4

<u>Mission Time</u>
The PNP-required mission time following a postulated LOCA is 30 days for the HPSI system and the CSS.

The results of the passive strainer downstream analysis are summarized below.

Valves, Orifices, Piping, and Heat Exchangers
The limiting passageway was found to be larger than the largest assumed debris diameter. Therefore, blockage of the ECCS and CSS passageways due to debris-laden fluid is not a concern.

Erosive wear in the ECCS and CSS components due to debris laden fluid has been analyzed. The HPSl valves (MO-3007, MO-3009, MO-3011, MO-3013, MO-3062, MO-3064, MO-3066, and MO-3068), as well as the containment spray valves CV-3001 and CV-3002, were found to have adequate thickness such that erosive wear due to debris laden fluid will not compromise their design functions for the required mission time. Also, in general, the PNP ECCS and CSS heat exchanger tubing, instrument tubing, piping, nozzles, and orifices were found to have adequate thickness such that erosive wear due to debris laden fluid will not compromise the design functions of these components for the required mission time. However, orifices RO-3081 and RO-3080 are likely to be compromised due to wear using WCAP-based acceptance criteria. These orifices split the ECCS flow between hot leg injection and cold leg injection lines. Since the wear criteria is exceeded late in the 30-day period when decay heat has significantly diminished, the exact split is not critical to core cooling. The most critical split is between 5.5 hours (hot leg injection initiation) and about 24 hours while decay heat is rapidly dropping. RO-3081 and RO-3080 meet the acceptance criteria $\Delta Q/Q \leq 0.03$ until approximately 296 and 303 hours, respectively, have passed post-LOCA. Therefore, it can be determined that the additional wear for these orifices has no significant or adverse impact on system operation.

Pumps - Hydraulic Performance
Based on the results and limitations of the wear analysis done per WCAP-16406, Revision 1 (References 3.m.l and 3.m.11), the CSS and HPSl pumps will provide their design function for the required mission times. In addition, the degradation of hydraulic performance of the ECCS and CSS pumps due to the debris laden fluid is expected to be minimal for the designated mission times with the following corroborative bases:

- Testing petformed in support of the upgrade (modifications) of the Davis-Besse high pressure injection pump showed that these running clearances can double or triple over a period of 30 days of operation with the constant debris loading calculated for a containment sump of the Davis-Besse containment building. The wear ring clearances in this pump were hard faced with stellite to provide good resistance to wear. Despite the increase in the running clearances within this pump, resulting in increased leakage across the wear rings, the loss of hydraulic efficiency was determined to be insignificant. This is based on the results of the testing and analysis reported in Davis-Besse that indicate "the loss of hydraulic performance due to worn wear rings that are within the normal replacement limit of two times the design clearance is insignificant."

According to the WCAP-16406-P, Revision 1, Worthington Pump International has performed testing on the effect of increased wearing clearances on the hydraulic performance of centrifugal pumps and found that even at 1000% (or 10 times) of design clearance, the loss of total dynamic head and efficiency is less than 5% of the values at the best-efficiency point.

- According to WCAP-16406-P, Revision 1, the effects on pump hydraulics due to debris laden fluid have been evaluated for slurries using concentrations of solids in the pumping fluid of up to 50% (by mass) in slurry evaluations. These concentrations are several orders of magnitude greater than the debris concentration calculated for ECCS and CSS pumps taking suction from the containment sumps following a postulated LOCA.

  NUREG/CR-2792 shows a 1% loss of hydraulic efficiency with 1% solid mass in the slurry. Considering the mass concentration of debris in the containment sump for a postulated large break LOCA is less than 1%, the conclusion can be drawn that the effect of debris on the hydraulic efficiency of the ECCS and CSS pumps is insignificant.

Since the hydraulic performance of the ECCS pumps are affected minimally by the debris-laden fluid, the pump capabilities credited in the FSAR and license bases analyses ensure that PCT limits are not exceeded during the time and flow critical transient portion of a design basis LOCA. The HPSI pump capability is also critical during the early injection phase of a design basis steam line rupture event, and for maintaining PCS inventory during a small break LOCA. However, by the time that containment sump recirculation is initiated during a design basis LOCA, both PCS pressure and core decay heat loads have both been substantially reduced. At that point, core decay heat removal requirements demand a few hundred gallons to make up for boil-off (–400-500 gpm) and system spillage out of the break (–100 gpm), and system pressure has been reduced to near containment pressure. Since the required boil-off rate for the design base LOCA is –400-500 gpm, significant degradation of the ECCS pumps hydraulic performance would have to occur before the required boil-off rate would not be met, which is unlikely for the 30-day mission time for the ECCS pumps.

Table 3m5 Small Debris Mass Fractions for Pump Evaluations

Debris	Type	Quantity (ft3)	Quantity (lbm)	PPMw	Mass Fraction Small Debris	Small Debris Size (microns)	$mf * \left(\frac{SSP}{100\mu m}\right)^2$
RMI							
	RMI	0.000	0.000	0	0.00000	N/A	N/A
Coatings							
	Qualified	4.877	477.946	254.769	0.10023	10	0.0010
	Unqualified Alkyds	0.317	31.017	16.534	0.00650	50	0.0016
	Qualified IOZ	3.18	1453.260	774.659	0.30476	10	0.0030
Fibers							
	NUKON	0.000	0.000	0.000	0.00000	N/A	N/A
	NUKON unjacketed	0.000	0.000	0.000	0.00000	NIA	N/A
	Fiberglass	0.000	0.000	0.000	0.00000	N/A	N/A
	Fiberglass Unjacketed	0.000	0.000	0.000	0.00000	N/A	N/A
	Mineral Wool	0.000	0.000	0.000	0.00000	N/A	N/A
	Latent Fiber	0.000	0.000	0.000	0.00000	N/A	N/A
Particulate							
	CalSil	2.284	328.875	175.306	0.06897	50	0.0172
	CalSil Unjacketed	1.244	179.104	95.471	0.03756	50	0.0094
	Latent Particulate	0.375	63.326	33.756	0.01328	50	0.0033
Chemical							
	AlOOH	11.894	2235.000	1191.365	0.46870	50	0.1172
	Totals:	24.170	4768.528	2541.859	1.00000		0.1528

Pumps - Mechanical Shaft Seal

The evaluation of the PNP CSS and HPSI pump mechanical seals has concluded that during a post-LOCA condition, the seal flush system (including the seal coolers) will not be impeded by the debris-laden recirculating fluid; however, the design of these seals cannot be credited to perform their design function during the required mission time. In addition, the PNP maximum allowable ECCS leakage rate of 0.2 gpm precludes the ability to rely on the disaster bushing to sufficiently limit the seal leakage in the event of a seal failure.

The evaluation recommended that the existing Durametallic type BRO and PTO mechanical seals in the PNP CSS and HPSI pumps be replaced with mechanical seals that are designed for applications with the concentration and sizes of debris that is assumed to be present in the PNP post-LOCA recirculating fluid, or have the mechanical seal vendor qualify the mechanical seals with a plant-specific debris mix. However, further evaluation (Reference 3.m.8) of the CSS pump mechanical seal has concluded that the BRO type seal does not need be replaced. The evaluation took the inputs from Flowserve, the vendor for the CSS pumps. In summary, the amount of the debris that may enter the seal chamber will be minimal at most and will not impair the seal over a continuous operation of 30 days. One of the significant attributes of the conclusion relates to CSS pump seal flush system, which is designated as Plan 23 by American Petroleum Institute (API). The Plan 23 system is essentially a closed loop. The system initially contains clean water, and the close bushing clearance will limit the amount of mixing between the process fluid and fluid in the seal chamber. Other attributes to the evaluation conclusion include that the flow path to enter the seal chamber is torturous, the low flow velocity in the heat exchanger tube would promote debris to settle in the heat exchanger and the kinematics of debris is likely to further limit the potential of the amount and the size of the debris that could enter the seal chamber.

Westinghouse WCAP-16406-P, Revision 1, also recommends that cyclone separators should be removed due to concerns about plugging by fibrous debris.

CSS Pump Wear

The total erosive wear (for a one-hour time interval) is 1.359×10^{-4} mils on each wear surface or 2.718×10^{-4} mils total.

The total wear on the pump wear components is the summation of the abrasive wear and the erosive wear. For example, at t = 1 (the first hour of recirculation), the CSS pump impeller front hub and impeller wear ring experience abrasive wear of 0.115 mils and erosive wear of 0.000267 mils. The total wear on the CSS pump impeller front hub and impeller wear ring is approximately 0.11513 mils for the first hour of recirculation. The same calculation is repeated up to t =720 hours for the CSS pumps.

The diametrical clearance increases due to wear from debris laden fluid of the listed components for a mission time of 30 days are shown in Table 3m6 below. The increased clearances from the debris are then combined with the maximum clearances to determine if the wear components have exceeded the acceptance criteria defined in WCAP-16406-P, Revision 1. Table 3m6 shows CSS Pump Wear Analysis

Table 3m6 CSS Pumps Wear Analysis

CCS Pumps						
CCS Pump Internals	Design Diametrical Clearance (mils)	Maximum As-Found Diametrical Clearance (mil)	Diametrical Wear From Debris (mil)	Total Diametrical Clearance (mil)	Two Times Design Clearance Limit (mil)	Pass / Fail the 2X Design Running Criteria
Impeller Front Hub and Case Wear Rings	23	31	5.47463399	36.474634	46	Pass
Impeller Back Hub and Stuff Box Wear Rings	23	31	5.47463399	36.474634	46	Pass

<u>Pump Vibration</u>

Per WCAP-16406-P, Revision 1, multistage pumps are required to be evaluated for pump vibration. The CSS pumps at PNP are single stage pumps and do not require pump vibration analysis.

The HPSl pumps at PNP are multistage pumps and are evaluated for pump vibration. Since limited information exists from PNP and the HPSl pump manufacturer related to the HPSl pump rotor dynamics, it is assumed that this information is not available. Therefore, the WCAP-16406-P wear model is used for the pump vibration evaluation.

The wear rate model in WCAP-16406-P, Revision 1, was used to assess the extent of wear on wear components and its effect on HPSl pump vibration and hydraulic efficiency. It was determined in Table 3m7 below that following a LOCA, debris-induced wear on the pump wear components is not expected to exceed the two times the design running clearance limit specified for the each of the wear components during the mission time of 30 days. Therefore, per WCAP-16406-P, Revision 1 criterion, and the limits prescribed in Table 3m8 below, the HPSl pump meets the requirements for vibration operability following a postulated LOCA and no further rotor dynamic analysis is required.

In the tables below, the dimensions of each interface are applied to each independent subcomponent after the total wear (summation of abrasive and erosive wear) is calculated. The results of these final calculations are reported independently, as shown in Table 3m7 and Table 3m8 below. The diametrical clearance increases due to wear from debris laden fluid of the listed components for a mission time of 30 days are shown in Table 3m8 below. The increased clearances from the debris are then combined with the maximum clearances to determine if the wear components have exceeded the acceptance criteria defined in WCAP-16406-P, Revision 1.

Table 3m7 HPSI Pump Wear Analysis – Free Flowing Wear

HPSI Pumps						
SI Pump Internals	Design Diametrical Clearance (mils)	Maximum As-Found Diametrical Clearance (mil)	Diametrical Wear From Debris (mil)	Total Diametrical Clearance (mil)	Two Times Design Clearance Limit (mil)	Pass / Fail 2X Design Running Criteria
Impeller - Stage 1 / Casing Ring - Stage 1	15	22.5	0.49167428	22.9916743	30	Pass
Impeller - Stages 2 thru 7 / Casing Ring - Series	14	21	0.49167428	21.4916743	28	Pass

Table 3m8 HPSI Pump Wear Analysis – Free Flowing + Packing Type Wear

SI Pump Internals	Design Diametrical Clearance (mils)	Maximum As-Found Diametrical Clearance (mil)	Side / Location of Wear Rings	Wear Model Applied	Diametrical Wear From Debris (mil)	Total Diametrical Clearance (mil)	Ratio of Final Clearance to Design Clearance	Pass / Fail Design Criteria
Impeller - Stage 1 / Casing Ring - Stage 1	15	22.5	Suction	Free Flowing	0.49167428	22.99167428	1.532778285	Pass
Impeller - Stages 2 thru 7 / Stage Piece - Series	12	18	Discharge	Free Flowing + Archard	33.0555727	51.0555727	4.254631058	Pass
Impeller - Stages 2 thru 7 / Casing Ring - Series	14	21	Suction	Free Flowing	0.49167428	21.49167428	1.535119591	Pass
Impeller - Stages 2 thru 7 / Stage Piece - Series	12	18	Discharge	Free Flowing + Archard	33.0555727	51.0555727	4.254631058	Pass
Shaft Center Sleeve / Center Stage Piece	11	16.5	Discharge	Free Flowing + Archard	29.9717565	46.4717565	4.224705137	Pass

Bearings

The CSS and HPSI pump bearings are anti-friction oil lubricated ball bearings mounted in the pump frame. These bearings are equipped with various stages of protection against leakage of hot liquid from the shaft seals and will not be affected by the debris laden fluid.

Conservatisms
The downstream component evaluation applied the following conservatisms:

- Only the minimum volume of recirculating fluid is assumed to be available through the entire mission time.

- When evaluating the shutdown cooling heat exchanger tubing and the system piping, a constant wear rate is used (debris concentration is assumed to remain constant).

- It was assumed that debris constituent sizes remained unchanged throughout this evaluation. It is expected that some debris will deteriorate into smaller sizes as the debris passes through various components of the ECCS system.

- Since the particulate debris failure size distribution was not known (except for dirt and dust); it was assumed that 100% of all PNP particulate debris fails as both large and small. This essentially doubled the quantity of the particulate debris (except for dirt and dust).

- According to WCAP-16530-NP, Revision 0, the chemical debris, which agglomerates, cannot withstand shear forces. It is expected that turbulent flows of the fluid within the ECCS and CSS components, as well as interaction with the components themselves, will result in the disassociation of the chemical debris into very small particles, which will contribute to minimal wear of the components downstream of the strainer.

- The erosive wear rate of carbon steel is used to evaluate the erosive wear of the components downstream of the strainer. This is conservative since stainless steel is more resistant to wear than carbon steels.

NRC Request

- *Provide a summary of design or operational changes made as a result of downstream evaluations.*

ENO Response

HPSI Pump Seal Modification
Using Westinghouse WCAP-16406-P methodology to evaluate the downstream impact of sump bypass debris on the performance of the ECCS under post-LOCA conditions, it was identified that the HPSI pump mechanical seal system may not be suitable for long term operation under design basis post-LOCA debris conditions present following RAS. The HPSI pumps employed a cyclone separator in the seal flush path to remove particulate debris in order to extend the life of the pump seals. The HPSI pump mechanical seal cooling cyclone separator

(DOXIE) was determined to be susceptible to fouling with the postulated fibrous material passing through the HPSI pump, potentially resulting in a loss of pump seal cooling water and premature seal failure. Also identified was the potential for fibrous debris to become lodged in the mechanical seal small linear loading springs, potentially resulting in non-uniform pressure applied to the seal faces resulting in premature seal failure. Therefore, in order to ensure that the HPSI pumps are capable of performing their safety related design function during their required mission time of 30 days under post-LOCA conditions, the HPSI pump mechanical seal system has been replaced with a mechanical seal system not susceptible to post-LOCA debris-induced failure.

The replaced seal and flush arrangement was configured as an API standard Plan 41. The pumps used Durametallic, Type PTO, cartridge seals and a Dorr-Oliver DOXIE cyclone separator in the seal flush line. The API Plan 41 configuration uses the pump's flow from the first stage cross-under. The HPSI pump flow first passes through a pressure breakdown orifice, then through the DOXIE cyclone separator, which removes particulate debris from the flow stream. The flow stream then passes through a Borg-Warner helical coil seal cooler, cooled by component cooling water (CCW) to reduce the seal fluid temperature before injection into the Durametallic PTO cartridge seal chamber located on each HPSI pump end pump stuffing box. Seal injection is necessary to flush and cool the seals. Each Durametallic PTO seal uses 14 small linear coil springs to provide the uniform loading force on the seal faces. The springs are directly exposed to the seal cooling fluid flow.

The issues associated with the API plan 41 HPSI seal system relative to the fibrous debris are twofold:

1. Assuming that the fibrous debris, which is contained in the HPSI pump discharge fluid, passes through the DOXIE cyclone separator (which is not efficient at removing low density material) the debris would pass directly into the pump seal chamber (stuffing box) creating a potential for the fibrous debris to become lodged in the mechanical seal small linear loading springs, potentially resulting in non-uniform pressure to be applied to the seal faces, and resulting in premature seal failure, and

2. Cyclone separators have been identified to be prone to fouling under fibrous debris loads, therefore creating a potential for the DOXIE cyclone separator to partially or fully plug, resulting in loss of adequate seal cooling water flow, again potentially resulting in premature seal failure.

To resolve the above issues, the API Plan 41 configuration has been replaced with an API Plan 23 seal cooling configuration. The Durametallic PTO mechanical pump seals have been replaced with Chesterton Type 180PR Spiral Trac seals that are more suitable for long term operation under design basis post-LOCA conditions.

An API Plan 23 configuration does not use pump flow for seal flushing or cooling. Instead, the API Plan 23 recirculates a clean fluid volume contained in the seal system (including the seal cavity, seal coolers and seal connection lines). For the API Plan 23 HPSI pump configuration, the seal system volume is filled and vented with clean water from the SIRW Tank. Each seal circulates seal water in the essentially closed loop from the seal cavity, through the shell side of a shell and tube seal cooler dedicated to that seal to remove the approximate 1702 Btu/hr seal face friction heat load, and return the cooled seal water to the seal cavity.

The motive force for circulating the seal water in this closed loop is a pumping ring, integral to the Chesterton Type 180PR Spiral Trac cartridge seal design selected for this application, which develops a differential head of approximately ten feet of water and a flow rate of approximately two gpm to cool the seals. The seal water is cooled with CCW on the tube side of the cooler.

In an API plan 23 configuration, the only potential for debris to enter the seal chamber is via a minimal amount of fluid exchange, due to normal fluid thermal expansion and contraction in the seal cavity. The seal cavity is contained in the pump stuffing box, which is separated from the HPSI pump first and third suction stages by pressure reduction bushings. These bushings have very small diametrical clearances (30-40 mils for the throat bushing and 13 to 15 mils for the throttle bushing) between the shaft bushing and the stuffing box casing bushings.

The flush water inventory is essentially contained, as there are no differential pressure forces from the stuffing box into the seal cavity that would cause any significant amount of fluid to pass from the pump impeller side of the throat/throttle bushings to the stuffing boxes under normal seal operation. Therefore, the amount of fluid mixing across these bushing clearances is expected to be minimal.

The Chesterton Type 180PR Spiral Trac seals also use multiple seal loading springs, similar to the existing Durametallic design, however the Chesterton seal loading springs are located outside of the seal cavity and pump stuffing box and are therefore not exposed to any water volume. This design results in the seal loading springs being immune to the presence of debris, including fiber, in the pumps fluid. In addition, the Chesterton design uses a Spiral Trac feature, which transports debris away from the seal cavity face in the stuffing box to create a lower debris concentration in the stuffing box than could be present without this feature. By creating a lower debris concentration at the seal cavity boundary, this design reduces the potential to introduce debris in the seal cavity volume due to the exchange of fluid from thermal expansion and contraction.

A design modification installed during the 2007 refueling outage removed the HPSI pump Durametallic PTO cartridge seals along with the existing API Plan 41 seal flush system consisting of cooling line flow restricting orifices, DOXIE cyclone separators, Borg-Warner helical coolers, HPSI pump stuffing box jacket water coolers, and associated piping between the HPSI pump first stage cross-under and the stuffing boxes, along with CCW piping to and from the existing seal coolers. The associated first stage cross-under and unused CCW connections have been capped as they are no longer used as part of the API Plan 23 seal flush system configuration.

Each new mechanical seal (two seals per HPSI pump) is provided with an external seal cooler, cooled by CCW.

The request below is from the December 24,2008 NRC RAI.

NRC Request

15. The supplemental response to item (m) "Downstream Effects-Components and Systems" includes a detailed description of the downstream effects evaluations performed by the licensee. However, these evaluations were performed prior to the issuance of the approved WCAP-16406-P, Rev 1, ["Evaluation of Downstream Sump Debris Effects in Support of GSI-191"] *and the NRC safety evaluation (SE) of that document. The Entergy Nuclear Operations Inc. (ENO) supplemental response states that the current evaluations will be revised, applying the guidance provided in the approved WCAP-16406-P, Rev. 1 and data obtained through additional testing. ENO stated that a revised final response will be submitted once the evaluations are completed. The NRC staff requests that ENO provide the final description of the downstream effects evaluations in accordance with the request under item (m) in the Revised Content Guide for Generic Letter 2004-02 Supplemental Response dated November 2007.*

ENO Response

The above material in this section reflects the latest down stream effects analysis and is intended to satisfy the RAI request.

References

3.m.l WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1, August 2007

3.m.2 EA- MOD-2005-04-09, "GSI-191 GL-2004-02 Downstream Effects," Revision 0, August 3, 2005

3.m.3 EA-EC496-15, "Palisades GSI-191 Downstream Effects Evaluation of ECCS Components," Revision 0, August 10, 2007

3.m.4 Los Alamos Reports LA-UR-04-5416, "Screen Penetration Test Report," November 2004

3.m.5 Los Alamos Report, LA-UR-01-6640, "Development of Debris-Generation Quantities in Support of the Parametric Evaluation," November 2001

3.m.6 EA-EC8349-03, Sargent & Lundy Document No. 2007-03464, "Post LOCA Chemical Effects Analysis in Support of GSI-191," May 17, 2007

3.m.7 NMC letter to NRC "Nuclear Management Company Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for Palisades Nuclear Plant," August 25, 2005

3.m.8 Sargent and Lundy document SL-Pal-07-0013, "GSI-191 HPSI/CS Pump Seal assemblies Evaluation," March 4, 2007

3.m.9 EA-EC7107-01 Rev 0,"Palisades GSI-191 Downstream Effects Evaluation of ECCS Components AREVA 32-9034164-02," February 9, 2009

3.m.10 EA-EC7107-01 Rev 1,"Palisades GSI-191 Downstream Effects Evaluation of ECCS Components AREVA 32-9034164-04," May 4,2009

3.m.11 Final Safety Evaluation For Pressurized Water Reactor Owners Group (PWROG) Topical Report (TR) WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1 (TAC NO. MD2189), December 20,2007, ML073520295

3.n. Downstream Effects - Fuel and Vessel

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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.*

ENO Response

Westinghouse perform the LOCA deposition modeling (LOCADM) and fuel blockage analysis of the core for PNP. This analysis used as input, the conservative debris loading that was used in the May 2008 flume testing.

The purpose of the evaluation was to:

(a) Use the LOCADM spreadsheet to predict the growth of fuel cladding deposits and to determine the clad/oxide interface temperature that results from coolant impurities entering the core following a LOCA.

(b) Determine the impact on the fuel where debris may pass through the containment sump screens following a high-energy line break (HELB).

LOCADM Analysis

The calculation method of the LOCADM spreadsheet is described in Reference 3.n.2 and OG-07-534 as described below. The analysis makes some conservative simplifications to the required inputs. In general, the following modifications are considered conservative for this evaluation:

- Increases to the amount of insulation and debris will result in the formation of more precipitates that can be carried to the core.

- Increasing the duration of sump recirculation will result in a larger amount of precipitate deposition on the fuel.

OG-07-534 contains additional guidance for use in constructing and running the LOCADM model. This analysis uses the "Pre-Filled Reactor and Sump Option" of OG-07-534. Use of this option assumes that the entire sump volume is present in the sump at time zero, precluding the need to specify individual break flow rates. This is also conservative, as the entire sump volume is immediately available to react with submerged debris.

Item 13 of the NRC's draft conditions and limitations addresses the aluminum release predicted by LOCADM. The last sentence of Item 13 states that the method shall not under-predict the aluminum concentrations measured during the initial 15 days of integrated chemical effects test (ICET) 1. The following is an excerpt from the ICET 1 document immediately following Figure 43.

> "As seen in Figure 43, the aluminum concentration increased in a linear fashion over the test period until day 16. After day 18, the concentration appeared to level off at approximately 350 mg/L."

The aluminum concentrations from the graphical data of ICET 1 Figure 43 can be approximated for several time points in order to be compared to the PNP LOCADM analyses that predicted aluminum release using WCAP-16530-NP-A, Revision 0, methodology. One run of LOCADM for PNP with the minimum sump volume resulted in predicted aluminum release concentrations that are greater than the ICET 1 aluminum concentrations. The same is true for one run of LOCADM with the maximum sump volume.

The PNP LOCADM analyses do not under-predict the aluminum concentrations obtained from ICET Test 1. Therefore, LOCADM, as originally configured and input with PNP specific data, satisfies item 13 from the NRC's draft conditions and limitations. ENO does not need to apply a factor of two to the aluminum release as stated in item 13, because the LOCADM analyses for PNP predicts aluminum concentrations over the first fifteen days that exceed the aluminum concentrations observed in ICET 1.

LOCADM does not contain an input for debris that bypasses the sump screen and is available for deposition in the core. Only material released from corrosion or dissolution processes is considered. However, some debris fines may bypass the sump screen and enter the core area where it could be deposited.

Per OG-07-534 a quantitative estimate of the effect of the fiber on deposit thickness and fuel temperature can be accounted for in LOCADM by use of a "bump-up" factor applied to the initial debris inputs. The "bump-up" factor is set such that total release of chemical products after 30 days is increased by the best estimate of the mass of the fiber that bypasses the sump screen. This allows the bypassed material to be deposited in the same manner as a chemical reaction product.

Assessment of Fuel Blockage
To demonstrate reasonable assurance of long-term core cooling, a PWROG program captured in WCAP-16793-NP, Revision 0, demonstrated that the effects of fibrous debris, particulate debris, and chemical precipitation would not prevent adequate long-term core cooling flow from being established for all plants.

Acceptance Criteria for LOCADM Analysis

1. Clad temperature shall not exceed 800°F after the initial quench of the core. Section A.4 of WCAP-16793-NP, Revision 0

2. Total debris deposition on the fuel rods (oxide + crud + precipitate) shall be less than 50 mils (0.050"). OG-07-477

Results
The results are summarized as follows:

LOCADM Analysis
For the minimum sump water volume case, use of the LOCADM spreadsheet predicted a maximum scale thickness of 664.3 microns. When added to the oxide thickness of 185 microns (PNP analysis) and crud thickness of 140 microns (OG-07-419), this yields a total of 989.3 microns (38.9 mils). This is less than the acceptance criteria of 50 mils.

For the maximum sump water volume case, use of the LOCADM spreadsheet predicted a maximum scale thickness of 313.6 microns. When added to the oxide thickness of 185 microns (Reference 3.n.3) and crud thickness of 140 microns (OG-07-419), this yields a total of 638.6 microns (25.1 mils). This is less than the acceptance criteria of 50 mils.

The maximum temperature of the fuel cladding after the onset of recirculation was 328.6°F, and continued to decrease throughout the event. This is significantly less than the acceptance criteria of 800°F.

For the minimum sump water volume case, LOCADM was also run with increased quantities of debris – in accordance with the "bump-up" factor methodology described in OG-07-534. The "bump-up" factor had a negligible effect on both the total deposition thickness and fuel cladding temperature. The predicted scale thickness is 756.2 microns. When added to the oxide thickness of 185 microns (PNP analysis) and crud thickness of 140 microns, this yields a total of 1081.2 microns (42.6 mils). This is less than the acceptance criteria of 50 mils.

Assessment of Fuel Blockage
The conclusions drawn by WCAP-16793-NP, Revision 0, are applicable to all plants and therefore are applicable to PNP. The conclusions are as follows:

- Adequate flow to remove decay heat will continue to reach the core even with debris from the sump reaching the RCS [reactor coolant system] and core. Test data has demonstrated that debris that bypasses the screen and collects at the core inlet will provide some resistance to flow but this is not likely to build up an impenetrable blockage at the core inlet. In the case where large blockage does occur, numerical analyses have demonstrated that core decay heat removal will continue.

- Decay heat will continue to be removed even with debris collection at the fuel assembly spacer grids. Test data has demonstrated that any debris that bypasses the screen is small and consequently is not likely to collect at the grid locations. Further, any blockage that may form will be limited in length and not be impenetrable to flow. In the extreme case that a large blockage does occur, numerical and first principle analyses have demonstrated that core decay heat removal will continue.

- Should fibrous debris enter the core region, it will not tightly adhere to the surface of fuel cladding. Thus, fibrous debris will not form a "blanket" on clad surfaces to restrict heat transfer and cause an increase in clad temperature. Therefore, adherence of fibrous debris to the cladding is not plausible and will not adversely affect core cooling.

  Furthermore, the core design for PNP is unique in that it includes crucifix-like control rods that are inserted between fuel assemblies. There is open flow area between the tips of the adjacent wings of the crucifixes. This open flow area extends the entire length of the fuel, including past the bottom nozzles that rest on the core support plate. The gap between fuel assemblies is 0.377 inches and the gap between the tips of the crucifix-like control rods is 4.47 inches. This yields an area of approximately 1.69 in^2. Also, there is an additional flow path in the narrow slot between the surfaces of the control rod and the surfaces of the fuel assembly.

  As previously mentioned, the gap between fuel assemblies is 0.377 inches. Subtracting the width of the control rod blade of 0.18 inches, results in a dimension of 0.197 inches. Assuming the control rod is centered between the fuel assemblies, that dimension is divided by two in order to arrive at a gap width of 0.0985 inches on either side of the control rod blade. By dimensional analysis, these flow areas contain dimensions that are wide enough (4.47 inches, 0.337 inches, and 0.0985 inches) that they do not block with fiber, since the sump screen hole size is 95 mils (0.095 inches). Thus, it is concluded that any debris passing the sump screen does not have the size needed to block these flow paths.

  Also, the LOCADM analysis for PNP resulted in a predicted total deposition thickness of less than 50 mils and also predicted that chemical plate-out on the fuel does not result in the prediction of quenched fuel cladding reheating to temperatures approaching the 800°F acceptance criterion.

Given the above conclusions and LOCADM results, it is therefore concluded that reasonable assurance of acceptable long-tem core cooling with debris and chemical products in the recirculating fluid is demonstrated for PNP.

It is noted that at the time this summary report was prepared, WCAP-16793-NP, Revision 0, was still under review with the NRC. Furthermore vendor generic fuel testing was being preformed in this time period.

WCAP-16793-NP, Revision 1

WCAP-16793-NP, Revision 1, was issued on April 22, 2009 (Reference 3.n.4). It reflects the results of the fuel inlet flow blockage testing. On May 6, 2009, the AREVA Fuel Test Report became available to ENO.

It is our understanding that both Westinghouse and AREVA consider that PNP is appropriately enveloped by the test conditions and that the results do apply and that our presently calculated debris quantity is acceptable.

ENO anticipates supporting the NRC's schedule for a submittal following the issuance of an SE on WCAP-16793-NP, Revision 1 unless some of the debris inputs covered in this submittal are found deficient by NRC before that time.

Below are quotations from the WCAP-16793-NP, Revision 1, document:

Debris Acceptance Criteria

Debris loads used in the FA test program were based on sump screen bypass information provided by licensees. The FA testing was reported in proprietary submittals that support this document. The results from these FA tests are discussed in the proprietary test reports. As part of the effort to invoke this WCAP in the plant licensing basis, each plant will compare their plant specific debris load against the FA debris masses tested. Plants that have bypass debris loadings that are within the limits of the debris masses tested are bounded by the test. Plants will also have to demonstrate that the available driving head (for both hot and cold leg breaks) is equal to or greater than the limits adhered to in this test program.

Results of the* WCAP-16793-NP, *Revision 1, for plants that meet the above acceptance criteria are given below.

This evaluation considered the design of the PWR, the design of the open-lattice fuel, the design and tested performance of replacement containment sump screens, the tested performance of materials inside containment, and the tested performance of fuel assemblies in the presence of debris. Specific areas addressed in this evaluation included:

- *Blockage at the core inlet,*
- *Collection of debris on fuel grids,*
- *Collection of fibrous material on fuel cladding,*
- *Protective coating debris deposited on fuel clad surfaces,*
- *Production and deposition of chemical precipitants,*
- *Boric acid precipitation, and*
- *Coolant delivered from the top of the core.*

The following acceptance criteria were selected for the evaluation of the topical areas identified above (Note all section numbers below refer to sections in the parent report Reference 3.n.3):

1. *The maximum clad temperature shall not exceed 800°F.*

2. *The thickness of the cladding oxide and the fuel deposits should not exceed an average of 0.050 inches in any fuel region.*

These acceptance bases were applied after the initial quench of the core and are consistent with the LTCC requirements stated in 10 CFR 50.46 (b)(4) and 10 CFR 50.46 (b)(5). They do not represent, nor are they intended to be, new or additional LTCC requirements. These acceptance bases provide for demonstrating that local temperatures in the core are stable or continuously decreasing and that debris entrained in the cooling water supply will not affect decay heat removal. The evaluations performed for the areas identified above provide reasonable assurance of LTCC for all plants. Specifically,

- *Adequate flow to remove decay heat will continue to reach the core even with debris from the sump reaching the RCS and core. Plants that operate at the debris loads identified in Table 10-1, can state that debris that bypasses the screen will not build an impenetrable blockage at the core inlet. While any debris that collects at the core inlet will provide some resistance to flow, in the extreme case that a large blockage does occur, numerical analyses have demonstrated that core decay heat removal will continue. The details supporting this evaluation are provided in* [Reference 3.n.3] *Section* 3.

- *Decay heat will continue to be removed even with debris collection at the FA spacer grids. Plants that operate at the debris loads identified in Table 10-1, can state that debris that bypasses the screen will not build an impenetrable blockage at the fuel spacer grids. In the extreme case that a large blockage does occur, numerical and first principle analyses have demonstrated that core decay heat removal will continue. The details supporting this evaluation are provided in* [Reference 3.n.3] *Section 4.*

Fibrous debris, should it enter the core region, will not tightly adhere to the surface of fuel cladding. Thus, fibrous debris will not form a 'Blanket" on clad surfaces to restrict heat transfer and cause an increase in clad temperature. Therefore, adherence of fibrous debris to the cladding is not plausible and will not adversely affect core cooling. The details supporting this evaluation are provided in [Reference 3.n.3] *Section 5.*

- *Protective coating debris, should it enter the core region, will not restrict heat transfer and cause an increase in clad temperature. Therefore, adherence of protective coating debris to the cladding is not plausible and will not adversely affect core cooling. The details supporting this evaluation are provided in* [Reference 3.n.3] *Section 6.*

- *The chemical effects method developed in WCAP-16530-NP-A was extended to develop a method to predict chemical deposition of fuel cladding. The calculational tool, LOCADM, will be used by each utility to perform a plant-specific evaluation. It is expected that each plant will be able to use this tool to show that decay heat would be removed and acceptable fuel clad temperatures would be maintained. The details for using LOCADM are provided in* [Reference 3.n.3] *Section* 7 *and Appendix E.*

- *The commonly used approach for demonstrating adequate boric acid dilution in a post-LOCA scenario includes the use of simplified methods with conservative boundary conditions and assumptions. In light of NRC staff and ACRS challenges to the simplified methods commonly used, it has recently become clear that additional insights and new methodologies are needed to answer fundamental questions about boric acid mixing and transport in the RCS and potential precipitation mechanisms that may occur both during the ECCS injection phase and the sump recirculation phase after a LOCA. This will be addressed in a separate PWROG program. This program is discussed in* [Reference 3.n.3] *Section 8.*

The PWROG FA test results demonstrated that sufficient flow will reach the core to remove core decay heat. UPI plants that operate at the debris loads identified in Tables 10-1, can state that debris that bypasses the screen will not build an impenetrable blockage within the core region. The details supporting this evaluation are provided in [Reference 3.n.3] *Section* 9.

Table 10-1 Acceptance Criteria Debris Limits	
Debris Type	Debris Load per Fuel Assembly (Note 1)
Fiber	< 0.33 lb
Particulate	< 29 lb
Chemical	< 13 lb
Calcium silicate	< 6 lb
Microporous Insulation	< 3.2 lb
Note 1 These are generic acceptance criteria Please refer to the fuel vendor proprietary test reports for vendor-specific data	

PNP uses AREVA fuel with FuelGuard lower end fitting filter so the above table applies.

The AREVA report (Reference 3.n.5) requires:

Hot Leg Break Flow Rates: AP due to debris < 10.6 psid
Cold Leg Break Flow Rates: AP due to debris < 1.5 psid

For fuel designs that incorporate the **TRAPPER coarse mesh** or **FUELGUARD** debris filters or **no filter** at all, the following limits apply:

Debris Type	Debris Load Per Fuel Assembly
Fiber	≤0.33 lb
Particulate	≤29 lb
Chemical	≤13 lb
Calcium silicate	≤6 lb
Microporous Insulation	≤1.2 lb

It is noted that AREVA curtailed the amount of Microporous Insulation possibly due to the fact that the lower number enveloped their customers needs (Reference 3.n.5 Section 3.2.5).

The request below is from the December 24,2008, NRC RAI

NRC Request

16. *The NRC staff considers in-vessel downstream effects to not be fully addressed at Palisades Nuclear Plant (Palisades), as well as at other PWRs. The ENO supplemental response for Palisades refers to draft*

WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The NRC staff has not issued a final SE for WCAP-16793-NP. The licensee may demonstrate that in-vessel downstream effects issues are resolved for Palisades by showing that the licensee's plant conditions are bounded by the final WCAP-16793-NP and the corresponding final NRC staff SE, and by addressing the conditions and limitations in the final SE. The licensee may also resolve this item by demonstrating without reference to WCAP-16793-NP or the NRC staff SE that in-vessel downstream effects have been addressed at Palisades. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on WCAP-16793-NP. The NRC staff is developing a Regulatory Issue Summary to inform the industry of the NRC staffs expectations and plans regarding resolution of this remaining aspect of GSI-191.

ENO Response

16. A preliminary response to this request is provided above. As specified in the NRC RAI letter, dated December 24, 2008, ENO will provide a final response to include any additional NRC SE requirements within 90 days following issuance of the final NRC staff SE on WCAP-16793-NP.

<u>*References*</u>

3.n.l WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-91," Revision 1, August 2007

3.n.2 WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate and Chemical Debris in the Recirculation Fluid," Revision 0, May 2007

3.n.3 *EA-EC7109-01 Rev 0, LOCADM and Fuel Blockage Analysis for Palisades CN-SEE-1-08-44, CPAL-08-16," January 29, 2009*

3.n.4 WCAP-16793-NP, Revision 1, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," April 2009

3.n.5 AREVA Document 51-9102685-000, "GSI-191 FA Test Report for PWROG," March 20,2009

3.0. Chemical Effects

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008.

NRC Request

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. ML0726007425).*

NRC Staff Review Guidance Regarding GL 2004-02 Closure in the Area of Chemical Effect Evaluations, dated March 2008, provided the following issues to be address as a structured approach in plant specific responses.

I. Sufficient Clean Strainer Area

Those licensees performing a simplified chemical effects analysis should justify the use of this simplified approach by providing the amount of debris determined to reach the strainer, the amount of bare strainer area and how it was determined, and any additional information that is needed to show why a more detailed chemical effects analysis is not needed.

ENO Response

1. The PNP strainer was sized before the quantity of chemicals was known. Although the sizing was accomplished by vendor proprietary processes that were derived from testing of prototype strainers, it was believed to be sized largely based upon the amount of insulation debris (fiber) present. At that time, a small allowance, such as 10% or 15% head loss increase, was reserved for chemical "bump up" factors based upon Boiling Water Reactor experience.

NRC Request

2. *Debris Bed Formation*

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

ENO Response

2. The sources of the precipitates at PNP are largely due to aluminum contact with ECCS and CSS water after RAS. The primary sources of aluminum are the 0.65 mil aluminum foil in the RMI on the Reactor Vessel (RV) and the one-mil foil in the RMI on some of the PCS lines and components. There is 16 mil thick aluminum jacketing on some of the pipe insulation. The "Reactor Vessel Flooding System" (a beyond-design-basis system that floods the OD of the RV and possibly avoids core melt or RV melt-through if ECCS fails), ensures that the RV insulation is submerged for any break large enough to cause RAS. The CSS is assumed to operate for all breaks for 30 days because the HPSI pumps are piggybacked on the CSS pumps after RAS, and also because CSS is the water source for the RV flooding system. The CSS in turn wets a portion of the 16 mil pipe jacketing for all large breaks.

   Therefore, the amount of precipitate is nearly independent of the break size and location. For this reason, the worst break is determined by the maximum fiber and particulate generated from the insulation within the ZOI. WCAP-16530 chemical spreadsheet sensitivity studies indicate the amount of precipitate is not very debris load dependent and informal observations of the flume testing behavior also support the fact that the fiber is likely most important in generating maximum chemical head loss. It is noted that precipitate plugging, if it occurs at all, usually does so very quickly after the chemical precipitate introduction is initiated and does not appear to be hyper sensitive to the exact quantity on the strainer debris bed.

NRC Request

3. *Plant-Specific Materials and Buffers*

   Licensees should provide their assumptions (and basis for the assumptions) used to determine chemical effects loading: pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects.

ENO Response

3. PNP uses the WCAP-16530 spreadsheet calculation method and the nominal base cases use silicate suppression triggered at 75 ppm as allowed by WCAP-16785-NP.

   pH
   As noted elsewhere, ENO has changed the sump buffer to STB. Of the available buffers this material is advantageous to plants with aluminum because the pH is restricted by the material to about eight, even at high buffer concentrations. It is located dry in baskets in the sump area and the initial injection water contains no buffer, so its pH is approximately 4.5 based largely on Safety Injection and Refueling Water Tank (SIRWT) boron concentration that is controlled by plant Technical Specifications. ENO operates the baskets with an inventory nominally aimed at pH 7.5 after RAS during the 30 days of long term cooling. Because the SIRWT boron concentration has an allowable range that varies about 20%, the total volume of water in the sump varies about a factor of two depending on break size and failure assumptions, and concentration of the spilled PCS fluid varies from approximately 0 to 1500 ppm boron, the sump pH is also slightly variable. This is very well countered with the buffering characteristics of STB and the precipitate analysis uses 7.7 as a nominal "holistic" expectation.

   Sump temperature versus time
   The sump temperature comes from the Gothic containment heat transfer calculation. The Gothic time steps were manually averaged to fit the Westinghouse pre-chosen non-linear time steps. The EA-MOD-2005-04-04 case for diesel generator (DG) 1-2 failure (right channel ECCS) was chosen due to the higher initial temperatures than DG1-1 failure. This maximizes alu'minum dissolution that is quite temperature sensitive. The case assumes RAS at approximately 53 minutes.

   Attempts to calculate the effect of ECCS without any failures for sensitivity purposes was not possible because no Gothic or ECCS calculations exist for this case. This is primarily due to the wording of 10 CFR 50, Appendix K, which requires a single failure.

   Sump Pool Volume (ft^3)
   The sump volume is set to the value used in the nominal pH calculation, which is about 40,000 cu ft. It was originally set to the lowest volume corresponding to the lowest possible level used in the NPSH calculation. It was believed that this leads to the highest chemical concentrations, which were assumed to be the most conservative. Experience with the WCAP spreadsheet has shown this is not necessarily the case because the amounts of boron and buffer are not directly input but are only represented by the pH. Thus, more volume at

the same pH inputs more boron and more buffer, in effect. Therefore, volume is set to a value consistent with the pH.

Aluminum Source

The surface area of the aluminum in containment that was not submerged and was covered by either itself (as in the ID of the insulation jacketing) or other ceilings, floors or engineered covering was not included in the sprayed surface area if it was outside the ZOI of the pipe break being analyzed. Since the amount of aluminum in the ZOI was not a major fraction, the quantity in the maximum break was used for all breaks.

The surface area of the submerged aluminum was wet on both sides. However, it was found that the thin aluminum foil inside the RMI, when attacked on both sides, was quickly eaten up by the very conservative WCAP-16530 spreadsheet aluminum dissolution rates. Therefore, the aluminum area was represented by a table of area vs thickness. When enough aluminum mass was dissolved to correspond to the foil half thickness, its area was removed from the calculation. The RV RMI is the primary recipient of this credit since it is assumed submerged instantly for all breaks. A similar table was used for the sprayed aluminum, but due to the 16 mil thickness of the sprayed lagging, the table is never entered for the base case. Extremely high pH or very high temperatures post-RAS, such as might be used in a postulated sensitivity case, would use the sprayed variable area table.

Aluminum Submerged

Area of the submerged aluminum was input as 58,190.94 sq. ft. Weight of the submerged aluminum was input as 1,626.17 pounds.

Aluminum Not-Submerged

Area of the sprayed aluminum was input as 13,689.5 sq. ft. Weight of the sprayed aluminum was input as 3,664.7 pounds

Other Insulation in the ZOI

The insulation quantity within the ZOI of break S5 was found to be the limiting quantity for flume testing and was therefore used in the chemical precipitate analysis also.

The items input were calcium silicate insulation (at 14.5 lb./cu. ft.) 62.35 cu. ft., low density fiberglass (Nukon at 2.4 lb/cu. ft.) 582.75 cu. ft., mineral wool (eight pounds) 148.44 cu. ft., concrete 60,263 sq. ft.

NRC Request

4. *Approach to Determine Chemical Source Term*
   Licensees should identify the vendor who performed plant-specific chemical effects testing.

ENO Response

4. PNP-specific chemical testing was done by PCI under contract to AREVA and Alden Research Laboratories. The test was a "Design Basis Test" in a large test flume that modeled near-field settlement and utilized WCAP-16530 style gelatinous precipitates which were generated under AREVA's Quality Assurance Program. The inputs were design basis debris quantities. The major measured test results were flow rate and strainer module pressure drop.

NRC Request

5. *Separate Effects Decision*

   Within this part of the process flow chart two different methods of assessing the plant specific chemical effects have been proposed. The WCAP-16530 study WCAP (see item 7. Base Model below) uses predominantly single-variable test measurements.

ENO Response

5. The WCAP-16530 method was used for PNP.

NRC Request

6. *AECL Model*

ENO Response

6. The AECL model is not applicable, per 5 above.

NRC Request

7. *WCAP Base Mode*

   b. Technical Issues

   i. WCAP-16530 provides useful information especially on a wide range of *materials not included in ICET. However, care must be taken in interpreting the results as they are single-component effects. The model assumes that a linear combination of these single-effects tests can be summed to get a multiple effect result.*

ii WCAP-16530 notes that none of the precipitated materials that formed settled rapidly.

iii. The knowledge of which precipitates can form is not complete. The model in WCAP-16530 assumes that these precipitates are AIOOH, sodium aluminum silicate (NaAlSi3O8) and calcium phosphate (Ca3(PO4)2).

iv In the presence of dissolved Si, the WCAP model assumes that NaAlSi3O8 precipitates before AIOOH. The model uses mass as a measure of the pressure drop experienced by the filter and does not consider volume of the highly hydrated precipitate.

v. The WCAP model considers the surrogate precipitate to be an inert material and the filterability of AIOOH and NaAlSi3O8 to be equivalent. The NRC staff is currently sponsoring independent tests to confirm this assumption.

vi. The aluminum release rate shown in equation 6-2 of WCAP-16530 underpredicts aluminum corrosion rates observed in ICET 1 and ICET 5 prior to passivation, although it gives a reasonable estimate of the aluminum corrosion rate over the entire 30 day period.

vii. Relative comparison of WCAP-16530-NP conservative assumptions (e.g., all dissolved aluminum precipitates) and non-conservative aspects (e.g., does not account for RCS crud) is provided in the staff safety evaluation of the topical report.

ENO Response

7.b. i National laboratories have found the WCAP-16530 spreadsheet to be conservative.

ii. PNP testing used surrogate precipitates made by the WCAP-16530 approved method. They met the NRC's concentration and settlement criteria given on pages 16 and 17 of'their December 21, 2007, SE.

iii. For PNP all the predicted precipitates were converted to the amount of AIOOH that would have been produced by the spread sheet predicted amount of aluminum that was dissolved. This was necessary due to the test organizations restrictions against sodium aluminum silicate. This has been found to be conservative by national lab testing (NUREG/CR-6915) and the sodium aluminum silicate version is believed to be less gelatinous (sticky).

iv.&v. ENO understands that the NRC's sponsored independent tests did confirm the assumption that AlOOH is equivalent to sodium aluminum silicate for strainer testing purposes.

vi. The PNP chemical precipitate analysis for flume testing the strainers used only 30 day totals so this is not an issue.

Additionally, a Westinghouse model (LOCADM), which uses the WCAP-16530 spreadsheet internally, found it does not under-predict the ICET-1 and 5 rates, probably due to the quantity of aluminum input being near the ICET used quantities and/or input temperatures being higher than ICET used.

vii. PNP analysis used silicate suppression credit. An extensive sensitivity analysis showed that the existence of silicate in the sump is not excessively break sensitive. It took credit only as a step function when silicate reached levels of 75 ppm or above. Some researchers predict significant dissolution at much lesser amounts of silicate and the WCAP also allowed some benefit at 50 ppm for those who never reached 75 ppm.

ENO understands that NEI and the PWROG have produced enough information to show the crud example stated above not to be a concern.

NRC Request

7.c. Staff Expectations

i. Input of plant parameters (e.g., sump temperature, pH, and containment spray durations) into the WCAP-16530 spreadsheet should be done in a manner that results in a conservative amount of precipitate formation. In other words, plant parameter inputs selection will not be biased to lower the predicted amount of precipitate beyond what is justified.

ii. Analysis, using timed additions of precipitates based on WCAP-16530 spreadsheet predictions, should account for potential non-conservative initial aluminum release rates. This comment is not applicable to tests with the projected 30-day chemical load added near the start of the test.

ENO Response

7.c. i The PNP inputs are directly from the debris generation calculation. The inputs to that calculation were not biased by chemistry concerns because the analysis was done by separate organizations. The sensitivity analysis considered major variation in most input parameters and showed how they affect precipitate quantities. That analysis has been provided to NRC for on-site review.

ii. The PNP calculation of record was a 30-day analysis.

A preliminary timed analysis was informally done as a step in the "test for success" strategy and it suggested that the WCAP-16530 method was very conservative in determining time of precipitation relative to almost all known test results.

NRC Request

7. d. GL Supplement Content

i. Licensees should justify any deviations from the WCAP base model spreadsheet (i.e., any plant specific refinements) and describe how any exceptions to the base model spreadsheet affected the amount of chemical precipitate predicted.

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

ENO Response

7.d. i. For PNP two modifications to the spreadsheet were made. First, the spreadsheet used an aluminum area vs thickness table to reduce the dissolution rate after the thin RMI aluminum foils were predicted to be eaten away. This was a matter of the limitations of the standard input sheet, which did not anticipate the need to input aluminum foil from RMI. The same effect can be achieved by interrupting the time march to remove the area and mass of the foil and re-inputting the amount left.

The second modification to the base mode was to use the silicate suppression method allowed by WCAP-16785-NP. That was justified by the sensitivity analysis provided with the calculation. Additionally, the flume test used enough precipitate to more than bound the credit from silicate suppression.

ii. See ENO response to item 9.iv. below.

NRC Request

8. *WCAP Refinements*

c. Staff Expectations

i. Conservative assumptions in the WCAP-16530 base model were intended to balance uncertainties in GSI-191 chemical effects knowledge. Therefore, licensees using refinements to the base model should demonstrate that their overall chemical effects assessment remains conservative when implementing these model refinements.

ENO Response

8.c. i The silicate suppression WCAP refinement was used in the base case calculation. It used the 75 ppm threshold method and equations. There is almost no concern that silicate suppression does not exist. The basic issue is to ensure it will be in the sump for the break in question. This is an issue because the ZOI and debris generation calculations are so very conservative. The sensitivity analysis showed that silicate would be available from a variety of sources not just calcium silicate Insulation. As previously stated, the amount of precipitate in the sump design basis test enveloped the amount from silicate credit.

The sensitivity analysis also shows that the silicate credit and the credit for area reduction due to the foil being gone are not additive. This is true because, for the PNP inputs, the foil is gone before the silicate reaches 75 ppm. The silicate credit relates primarily to the last half of the 30 day period. By that time, the temperature is low and the attack rate has abated by low temperature.

NRC Request

9. Solubility of Phosphates, Silicates and Al Alloys

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

ii. 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.

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

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

ENO Response

9. i. See Item 8 above.

ii. This is not an issue for the spreadsheet time march. Since the credit is taken as a step change in the reaction rate late in the analysis and in the time between zero and the rate reduction, it has been going on at the full unmodified rate, and there is more than adequate time to form any film that might be required.

The PNP analysis uses continuous spray from seconds after the break out to 30 days.

iii. The PNP analysis spreadsheet did incorporate some solubility credits. However, those credits are taken out at 140°F and the credit is immediately added back in the very next time step. Since ENO has used only the 30-day totals, there is no effect of any solubility credit left in the total used in the design basis flume test.

iv. Below is a list of the precipitates calculated by the WCAP-16530 spreadsheet for the PNP base case.

Case, Note values at 30 days	Dissolved Calcium Kg	Dissolved Silicon Kg	Dissolved Aluminum Kg	Ppt NaAlSi3O8 Kg	Ppt AlOOH Kg	Precipitate Total Kg	Total # ppt	NAS Aluminum Equivalent Kg	AlOOH Aluminum Equivalent Kg	Total ppt Aluminum Equivalent Kg
Base Case	149.6	137.0	190.2	426.2	324.8	751.0	1655.6	43.9	146.1	189.9

NRC Request

10. Precipitate Generation

The second method creates a surrogate precipitate in a separate mixing tank. This surrogate solution is then injected into the flowing system to simulate the carrying of precipitated material to the sump screen area.

Staff Expectations

i. Analysis of the water used for precipitate generation should be performed to ensure spurious effects (from contaminants in the water) are not realized.

ii. Test parameters such as temperature, pH, and concentration of species should be appropriately controlled such that precipitation processes are understood and are either representative or conservative.

ENO Response

10. i. The test flume used locally available tap water. This was found to be less prone to precipitate dissolution than demineralized water.

ii. Both the flume temperature and pH were periodically monitored to ensure they did not get high enough to re-dissolve the AlOOH surrogate precipitate. The order of debris addition to the flume was such that the addition of calcium silicate (which drives pH up sharply) was not near the time of precipitate addition.

NRC Request

11. *Chemical Injection into the Loop*

GL Supplement Content

i. 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.

ii. 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.

iii. Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100 percent, 140 percent of the amount calculated for the plant).

ENO Response

This method was not used.

NRC Request

12. *Pre-mix in Tank*

Technical Issues

i. Pre-mix tank concentrations affect the precipitate agglomeration and settlement behavior.

ii. A minimum one-hour mixing time is required by WCAP-16530 to allow for precipitate hydration and reaction completion.

iii, The surrogate precipitate has a defined shelf life. Potential changes to the precipitate as it ages make it important to measure settlement properties with 24 hours of testing.

Staff Expectations

i. Chemical precipitate should be added in a manner that is representative or conservative (e.g., add predicted 30-day load early in the test) with respect to the formation of the precipitate during the event chronology.

ii. Chemical precipitate concentrations in the mixing tank do not exceed the recommended values in WCAP-16530 values (e.g., AlOOH is 11 g/L).

GL Supplement Content

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

ENO Response

12. The above listed guidance was met during the PNP flume testing. These issues were addressed by controls in the approved test plan.

    An initial quantity of precipitate equal to the amount required to bring the flume concentration up to the predicted plant sump concentration was added fairly quickly. After that, additional precipitates were added very slowly in small batches in a manner designed to approximate the anticipated deposition rate on the strainer. This was continued until the entire amount was inserted over a time span of several hours.

NRC Request

13. Technical Approach to Debris Transport

Test vendors have selected two basic debris transport approaches. Those licensees that attempt to credit settlement of debris away from the strainer surface, i.e., "near-field" settlement use item 14 below.

ENO Response

13. ENO used the item 14. method of testing (below). The flume setup was guided by a CFD analysis of the plant sump. The CFD was also used to calculate debris transport and settlement throughout the 590 ft. level of containment, which constitutes the ECCS Sump (as discussed at length in section 3.e).

NRC Request

14. and 14a. Integrated Head Loss Test With Near- Field Settlement Credit Technical Issues

- *i. There are a number of non-chemical related technical issues related to "nearfield" settlement. These are discussed outside the scope of this document (see NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing (ADAMS Accession No. ML080230038)).*
- *ii. Since the objective of tests with near field settlement include settling chemical precipitate, it is critical that the precipitate used in these tests settle no more rapidly than would be expected in the projected plant environment.*

Staff Expectations

- *i. Precipitate settling rate should not exceed the settling rate of the 2.2 g/L surrogate aluminum solution shown in Figure 7.6-1 of WCAP-16530.GL Supplement Content. Licensees should provide the one-hour or two-hour precipitate settlement values measured within 24 hours of head loss testing.*
- *ii. Licensees should provide a best estimate of the amount of surrogate chemical debris that settles away from the strainer during the test.*

ENO Response

14. and 14a:

During the PNP testing, all chemical surrogates were made within 24 hours of the test. The above mentioned settlement rates for the generated precipitates were met as a condition of use of the chemical batch. This is covered in the test plan and each step was signed off.

Table 3o1 Surrogate Precipitate Settling Test Results

	Units	Batch 11/4	Batch 11/5	Batch1 11/6	Batch2 11/6	Batch 1in
Vol. of 11g/L sample from batch	mL	2	2	2	2	2
Vol. of water to make 2.2 g/L	mL	8	8	8	8	8
Start time	N/A	4:15	2:15	8:15	6:00	9:15
Finish time	N/A	5:15	3:15	9:15	7:00	10:15
Volume settled after one hour	mL	9.3	9.3	9.3	9.3	9.2
Settling Test Results Acceptable (Y/N)	N/A	Y	Y	Y	Y	Y

The data to respond to the issue of estimating the chemical settlement in the flume test does not exist.

The available test report did not estimate the amount of precipitate that settled away from the strainer. Given the required order of addition of the debris types, the large size of the test flume, the volume and variety of other particulate debris added, and the lack of visibility in the test flume, it would not be possible to estimate the amount of precipitate that settled. In essence, the fine particulate from the paint surrogates, the CalSil insulation fines, the miscellaneous debris surrogate fines and the chemical precipitate surrogate merge into one off color "mud" with the constituents hiding each other.

Given their documented characteristics, it is almost certain that the drain down moved'the chemical precipitates (and other "mud" constituents) around and away from their position during the test.

The NRC has been shown pictures of the flume after drain down.

NRC Request

15. and 15a. Head Loss Testing Without Near Field Settlement

ENO Response

15. and 15a.

This method was not used.

NRC Request

16. Test Termination Criteria

GL Supplement Content

i Licensees should provide the test termination criteria.

ENO Response

16. i

Below is a quote from the approved test plan.

"The acceptance criterion or the termination criterion for this test is if the change in head loss is less than 1% in the last 30 minute time interval and a minimum of 15 flume turnovers after all the debris has been inserted into the test flume."

NRC Request

17. Data Analysis

GL Supplement Content

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

ii. ·Licensees should explain any extrapolation methods used for data analysis.

ENO Response

17. The test pressure drop curve is included in section 3.f

No extrapolation was necessary because the test the pressure drop was in an extended down trend at the end of the test.

NRC Request

18. Integral Generation (Alion)

ENO Response

18. This method was not used.

NRC Request

19. Tank Scaling/Bed Formation

Staff Expectations

i. Scaling factors for the test facilities should be representative or conservative relative to plant-specific values.

ii Bed formation should be representative of that expected for the size of materials and debris that is formed in the plant specific evaluation.

ENO Response

19. The test flume width was sized to duplicate the flow velocity of the last 30 feet of the flow path to the strainers in the plant as determined from averaging the cross section of the dominant flow paths to the strainers. Since one strainer module was used and the plant has 23 strainers the screen area scaling was approximately 1 to 23. When corrected for end conditions and strainer hook up pipes, the target scale on screen area was 1 to 0.0447. The depth of the flume was targeted to be equal to the limiting level in the plant for a LBLOCA.

    The bed formation was as expected, given the known variability of the test results, and the difficulty of formation of a uniform thin bed on a convoluted strainer surface.

NRC Request

20. Tank Transport

Staff Expectations

i. Transport of chemicals and debris in testing facility tanks should be representative or conservative with regard to the expected flow and transport in the plant-specific conditions.

ENO Response

20. i. The PNP flume test tank was setup to be "holistically" representative of the plant in the final 30 feet of the flow path to the strainers. It was designed to mockup near field transport and debris dropout.

NRC Request

21. 30-day Integrated Head Loss Test

GL Supplement Content

i. Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.

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

ENO Response

21. The PWROG has sponsored the WCAP-16530 method, which PNP has used as a defendable conservative analysis of the quantity of precipitates. The NRC has reviewed that generic report and written a SE, which placed conditions on its use. The plant has met the intent of those conditions. The NRC has sponsored confirmatory testing at three national labs. There is agreement that the technique is conservative. The plant has placed the calculated amount of surrogate precipitate into a test flume at a respected research laboratory and passed the design basis test. Therefore, we conclude this constitutes a conservative chemical effects evaluation.

See 17. above and section 3.f for the requested pressure drop curve.

NRC Request

22. Data Analysis Bump Up Factor

The staff is working with the vendor to resolve technical issues related to the validity of using a "bump-up" factor from these tests.

GL Supplement Content

i. 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.

ENO Response

22. For PNP, a full scale test of a full strainer module was used with full scale debris including precipitates. There is no need for a bump-up factor.

References

3.o.1 EA-EC 7539-01, Revision 1, Aluminum & Chemical Ppt Calc, "Aluminum Location, Corrosion & Precipitation Post LOCA in the ECCS Sump for GSI-191," February 18, 2009

3.o.2 WCAP-16530, Revision 0, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," February 2006.

3.o.3 WCAP-16785-NP, Revision 0, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model," May 2007

3.o.4 Westinghouse Letter LTR-SEE-1-07-14, Revision 2, "Implementation of Refinements to WCAP-16530-NP," August 14, 2007, Attachment 1

3.o.5 NUREG/CR-6915, "Aluminum Chemistry in a Prototypical Post-Loss-of-Coolant-Accident, Pressurized-Water-Reactor Containment Environment," M. Klasky, J. Zhang, M. Ding, and B. Letellier (Los Alamos National Laboratory) D. Chen and K. Howe (University of New Mexico) published in December of 2006 and made available to the public by NRC in mid-2007.

3.o.6 WCAP-16530-NP-A, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," Original Version: February 2006, Approved Version: March 2008

3.o.7 AREVA Document 63-9095797-001 "Palisades Test Plan for ECCE Strainer Performance Testing," Revision 1 (for November 2008 testing, signed off as executed), dated December 4, 2008

3.p. Licensing Basis

This section of the follow-up supplemental response is revised from previous information provided by the PNP supplemental response of February 27, 2008 (Reference 3.p.l).

NRC Request

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

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

ENO Response

ENO does not plan to request any additional license changes in association with the compliance to the Generic Letter. Two license changes for the containment sump passive strainer and change to the containment buffering agent have been requested and approved by the NRC. These two changes and modifications to the containment spray isolation valves were made to ensure compliance with the regulatory requirements listed in the generic letter and are summarized below.

Containment Sump Passive Strainer Assembly Modification
On October 4,2007, the NRC approved and issued Amendment No. 228 (ML072550057) to the Renewed Facility Operating License changing Technical Specifications (TS) Surveillance Requirement 3.5.2.9 to reflect the configuration of the containment recirculation sump strainer modification. The resultant modification is described in section 3.j of this enclosure.

TS Bases Section B 3.5.2, "ECCS - Operating," incorporating the strainer modification was revised under 10 CFR 50.59, and became effective on October 8, 2007.

The Updated Final Safety Analysis Report (UFSAR) was changed incorporating the strainer modification following the modification that was performed during the 2007 refueling outage. The new strainers installed during the 2009 refueling outage did not require further UFSAR updates.

Containment Sump Bufferina Agent Modification
On October 2,2007, the NRC approved and issued Amendment No. 227 (ML072530735) to the Renewed Facility Operating License changing TS Limiting

Condition for Operation 3.5.5 and Surveillance Requirements 3.5.5.1 and 3.5.5.2 to reflect the change of the containment buffering agent from TSP to STB.

TS Bases Sections B 3.5.4, "SIRWT," B 3.5.5, "STB," and B 3.6.6, "Containment Cooling Systems," incorporating the change of the containment sump buffering agent from TSP to STB was revised under 10 CFR 50.59, and became effective on October 8, 2007.

The UFSAR was changed incorporating the containment buffering agent modification that was performed during the 2007 refueling outage.

<u>Containment Spray Isolation Valve Modification</u>
TS Bases Sections B 3.5.2, "ECCS – Operating," and B 3.6.6, "Containment Cooling Systems," were revised under 10 CFR 50.59, and became effective on October 8, 2007. The bases revision reflects the modification that throttles the containment spray flow during the containment sump recirculation mode of operation to ensure adequate CSS pump NPSH.

The updated FSAR was changed incorporating the modification of the containment spray valves that was performed during the 2007 refueling outage.

<u>Other Design and Licensing Basis Changes</u>
As discussed in Section 1, PNP design basis debris values for addressing GL 2004-02 is based on using jet impingement testing, as documented in WCAP-16836-P, WCAP-16710-P, and WCAP-16727-NP (References 1.4, 1.5, and 1.6). Use of specific testing instead of conservative values stated in NEI 04-07 is an allowance provided by NEI 04-07, provided appropriate justification is given. Use of these WCAPs has been evaluated as appropriate for PNP by the comparison of material tested to that installed in the plant. This is described in more detail in Section 3.b. Some generic open questions exist regarding the jet impingement WCAP testing that are being responded to by the PWROG. ENO will follow resolution of generic questions to assure currently assumed ZOI's remain supported.

As discussed in Section 3.g, the limiting NPSH case administratively lowered the upper emergency diesel generator allowed frequency from 61.2 Hz to 60.5 Hz. ENO is tracking this item in the corrective action system (Reference 3.p.2) to either: 1) restore the required limit back to the TS value of 61.2 Hz through various means, or 2) submit a license amendment request to change the TS allowed maximum steady state frequency from 61.2 Hz to 60.5 Hz.

References

3.p.l Entergy letter dated February 27, 2008 to NRC, "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accident at Pressurized Water Reactors'"

3.p.2 Corrective Action Document CR-PLP-2009-02006

ENCLOSURE 2

ATTACHMENT DRAWINGS

FOR

FOLLOW-UP SUPPLEMENTAL RESPONSE

TO

NRC GENERIC LETTER 2004-02

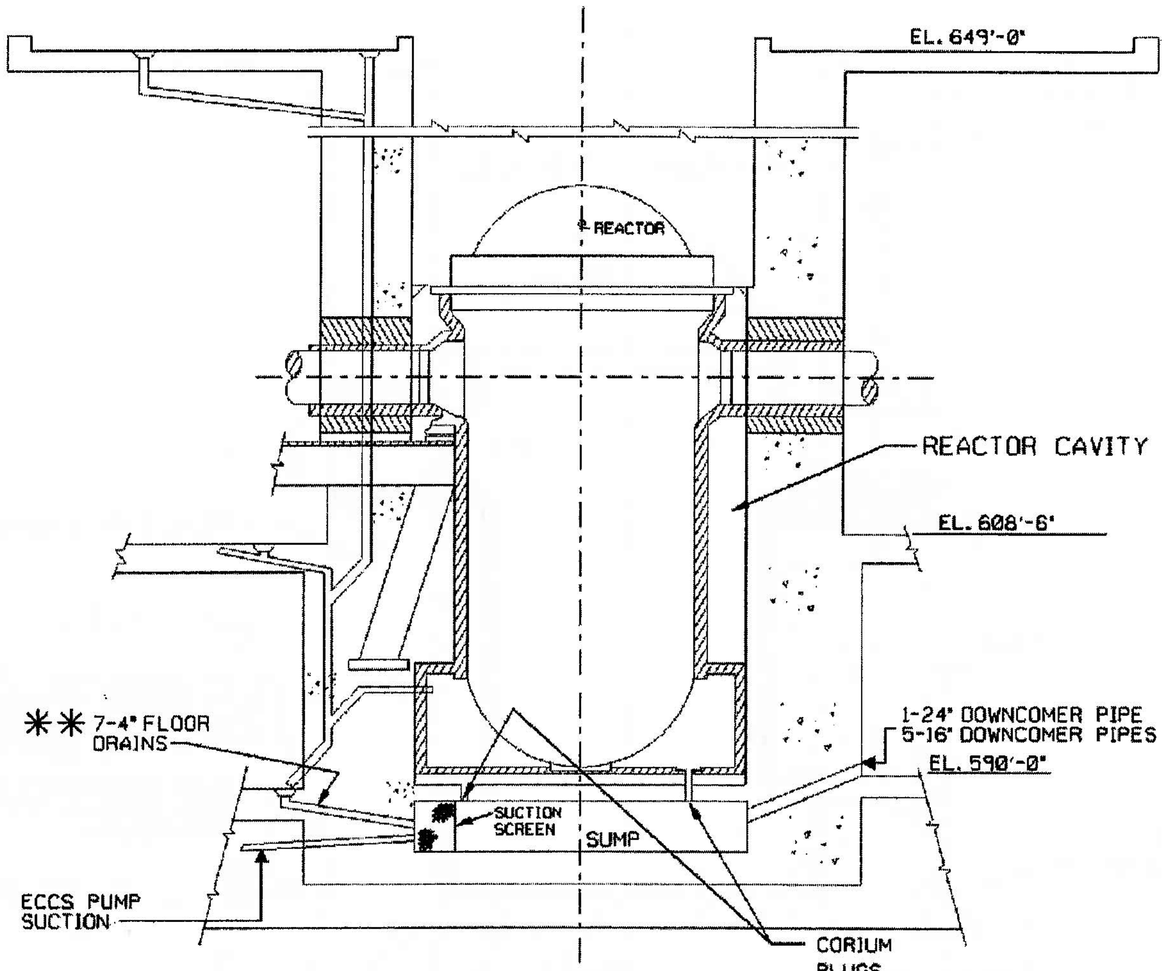
"Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"

Six Pages

List of Attachments

Attachment 1	Schematic of Containment Sump Entrance Pathways Prior to Modification
Attachment 2	Two pages: Schematic of Containment Sump Entrance Pathways After Modification Vendor Drawing **VEN-M802,** sheet 2, revision 1, Sure-Flow Strainer General Arrangement
Attachment 3	Drawing M-203, sheet A, revision 7, System Diagram Safety Injection, Containment Spray and Shutdown Cooling System
Attachment 4	Drawing M-204, sheet A, revision 8, System Diagram Safety Injection, Containment Spray and Shutdown Cooling System

Attachment 1

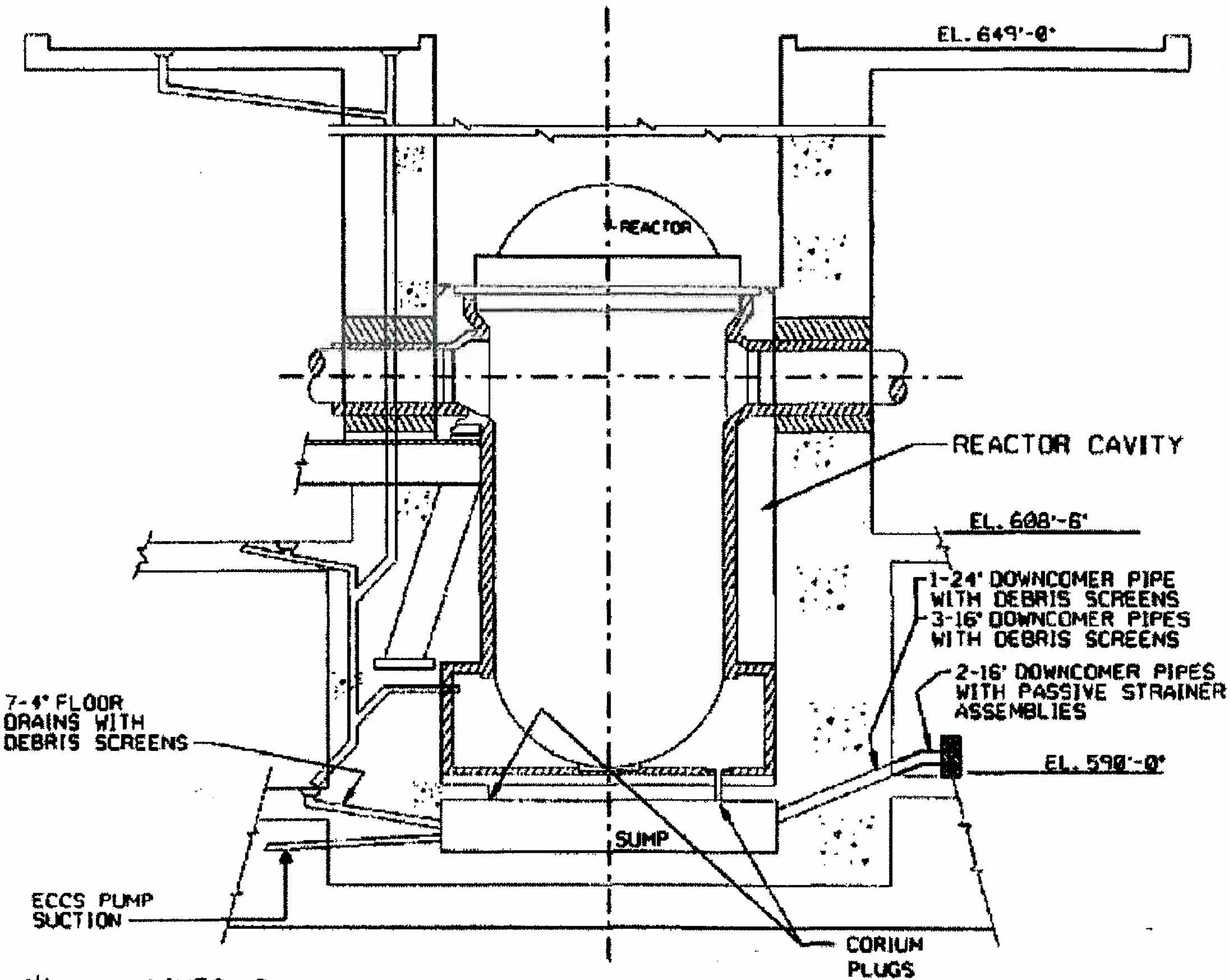


✳ VENT LINES (2) NOT SHOWN

✳✳ FLOOR DRAINS DISCHARGE INTO SUMP OUTSIDE THE SUCTION SCREEN AREAS

SCHEMATIC OF CONTAINMENT
SUMP ENTRANCE PATHWAYS
(NOT TO SCALE)

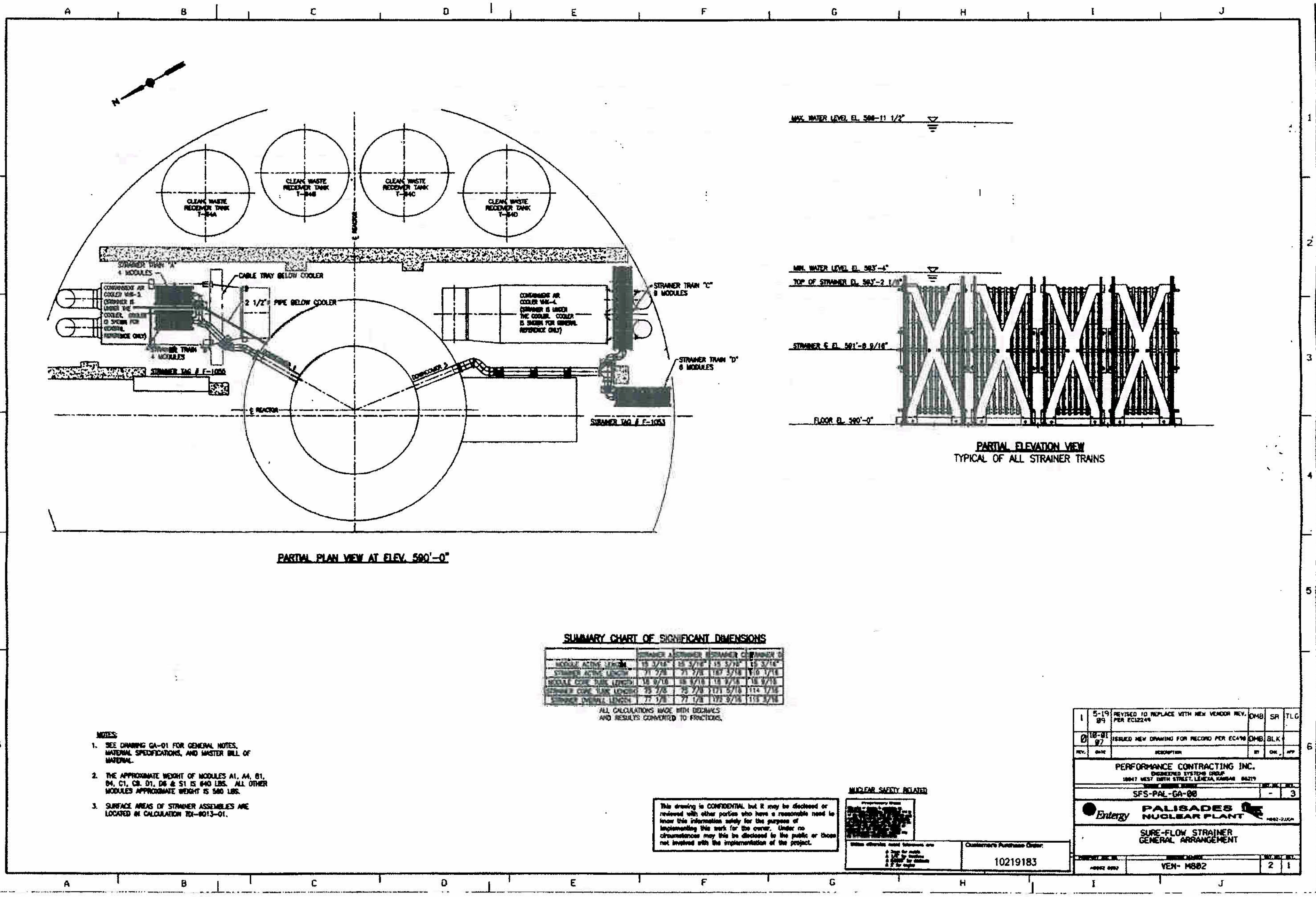
Attachment 2



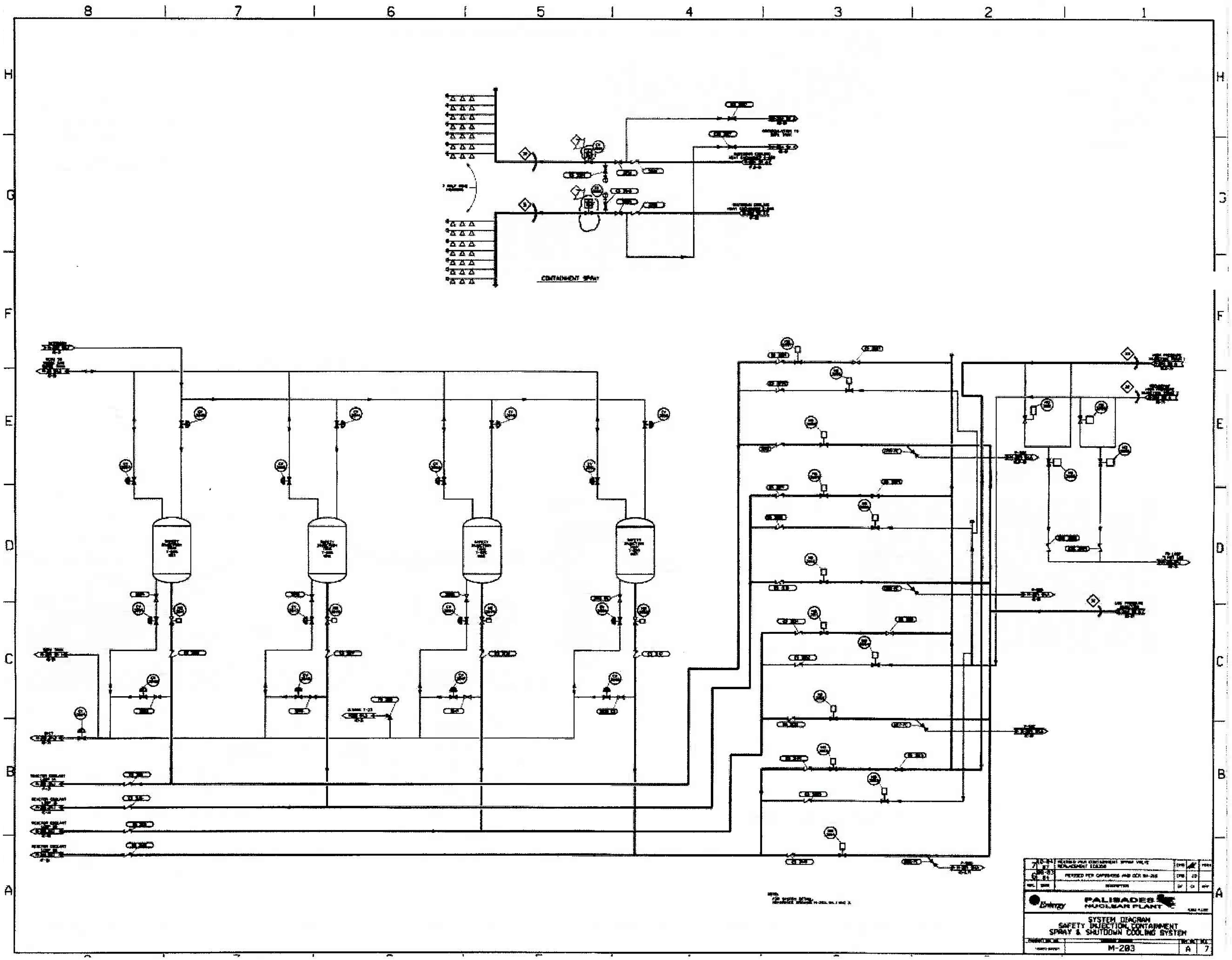
✱ VENT LINES (2) WITH DEBRIS SCREENS NOT SHOWN

SCHEMATIC OF CONTAINMENT SUMP ENTRANCE PATHWAYS AFTER MODIFICATION (NOT TO SCALE)

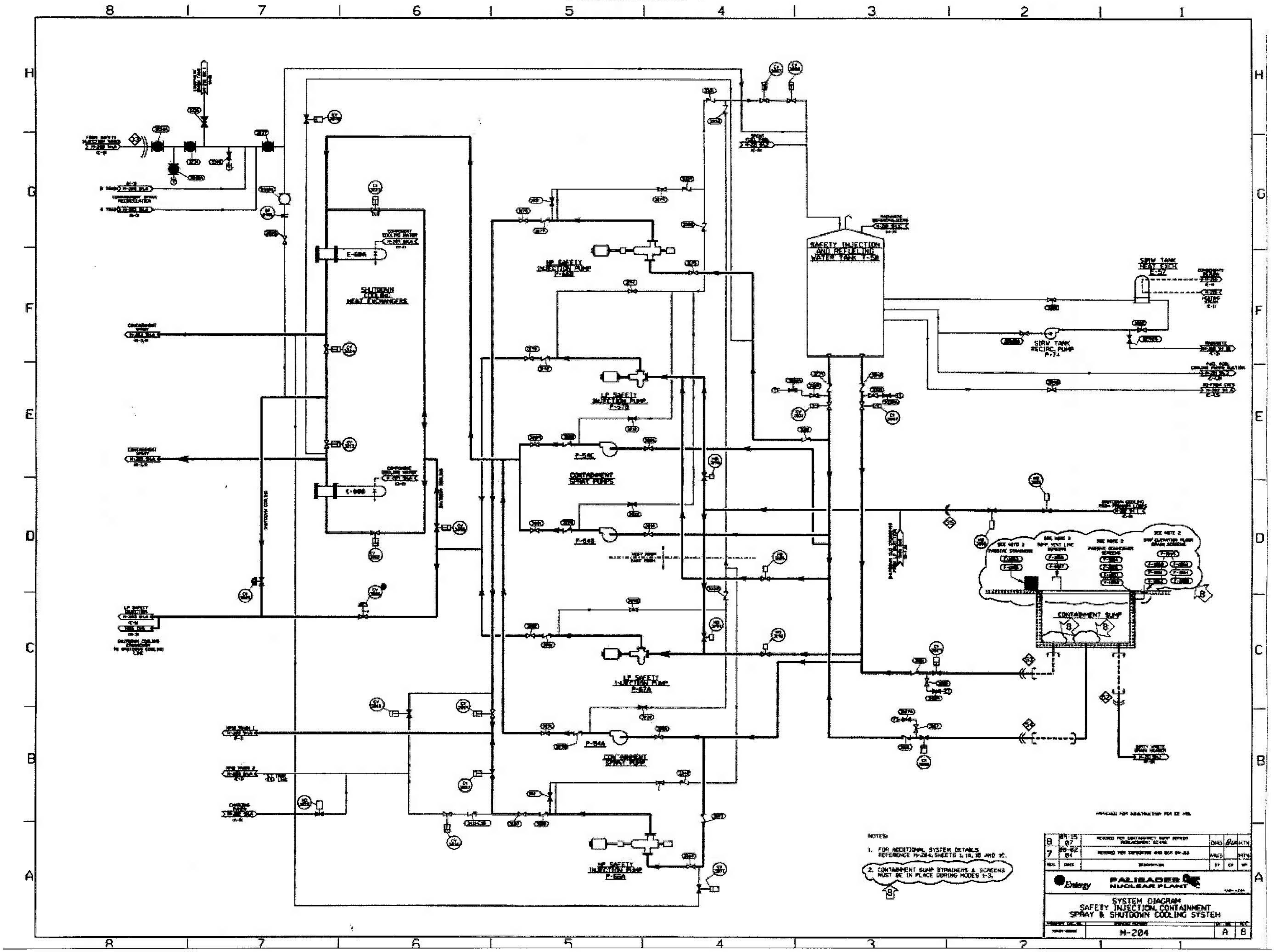
Attachment 2
General Arrangement Drawing Showing Location of Strainer Assemblies



Attachment 3



Attachment 4



ENCLOSURE 3

LIST OF REGULATORY COMMITMENTS

One page

ENCLOSURE 3

FOLLOW-UP SUPPLEMENTAL RESPONSE TO NRC GENERIC LETTER 2004-02

LIST OF REGULATORY COMMITMENTS

NEW COMMITMENT	TYPE		SCHEDULED COMPLETION DATE
	ONE-TIME ACTION	CONTINUING COMPLIANCE	
ENO will follow resolution of generic questions to assure currently assumed ZOIs remain supported.	X		Following resolution of generic questions
REPEATED COMMITMENT			
ENO will report how it has addressed the in-vessel downstream effects issue within 90 days following the issuance of the NRC SE for WCAP-16793	X		Within 90 days following issuance of SE on WCAP-16793
COMPLETED COMMITMENTS			
Submit follow-up to the GL 2004-02 supplement response within 60 days following restart from the2009 refueling outage if modifications were required to resolve GSI-191 issues.	X		July 1, 2009: 60 days following plant restart on May 2,2009.
Provide responses to RAI items 2, 3, 9, 13, 14, 15, & 17 in follow-up supplemental letter to GL 2004-02	X		July 1, 2009: 60 days following plant restart on May 2,2009.