NEXTera ENERGY SEABROOK

January 31, 2018
SBK-L-18010
GL 2004-02

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

Re: NextEra Energy Seabrook, LLC
Seabrook Station, Docket No. 50-443

Updated Final Response to NRC Generic Letter 2004-02

With this letter, NextEra Energy Seabrook, LLC (NextEra) provides an updated final response to Generic Letter (GL) 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors, for Seabrook Station (Seabrook). In GL 2004-02, the U.S. Nuclear Regulatory Commission (NRC) requested licensees to evaluate the potential for post-accident debris blockage and debris-laden fluids to impede or prevent Emergency Core Cooling System (ECCS) and Containment Spray System (CSS) recirculation phase performance following a postulated design basis accident, and to implement any plant modifications determined necessary to ensure ECCS and CSS system functionality. GL 2004-02 cited the findings of Generic Safety Issue (GSI) 191, Assessment of Debris Accumulation on PWR Sump Performance, which identified that recirculation sump clogging at Pressurized Water Reactors (PWR) is a credible concern, and established a schedule for licensee response.

Attachment 1 to this letter identifies the documents referenced herein. In References 1 and 2, NextEra, the licensee for Seabrook, submitted responses to the information requested in GL 2004-02. In References 3 through 8, NextEra responded to requests for additional information that the NRC determined were necessary to complete its review, established commitments for completion of specified corrective actions and provided supplemental information summarizing testing, analyses and modifications that were planned or completed at Seabrook.

In Reference 9, the NRC Commission approved the NRC staff's recommendation to provide licensees three options for resolution of GSI-191 with recognition that licensee measures completed thus far have contributed greatly to the safety of U.S. nuclear power plants. In Reference 10, NextEra notified the NRC staff of its selection for resolution of GSI-191 in accordance with the closure options specified in Reference 9 and additionally summarized the remaining GL 2004-02 related actions requiring completion.

Throughout this time, NextEra has implemented plant upgrades, defense in-depth measures and mitigation strategies at Seabrook which have bolstered the capacity of the containment sump screens, minimized the generation of debris that could affect ECCS and CSS recirculation phase performance, and managed containment sump inventory to ensure proper ECCS and CSS performance. In addition, recent industry and plant-specific analyses have demonstrated that the risk of GSI-191 related failures is very low.

Based upon these significant improvements in plant safety, NextEra hereby rescinds the GSI-191/GL 2004-02 related commitments described in previous correspondence submitted on behalf of Seabrook and submits the enclosed bases for resolution of GSI-191 and thereby closure of GL 2004-02. Consistent with the recommendations specified in Option 2a of Reference 9, upon completion of the regulatory commitments identified in Attachment 2 to this letter, NextEra can conclude with reasonable assurance that the long-term core cooling requirements of 10 CFR 50.46(b)(5) will be satisfied for any design basis accident requiring containment sump recirculation phase performance at Seabrook.

Enclosure 1 to this letter provides NextEra's bases for closure of GL 2004-02 which contains input based on both sound engineering judgement as well as documents verified through a 10 CFR 50 Appendix B program. The inputs from engineering judgement have been prepared, verified, and approved by knowledgeable engineers. The bases for closure include the completion of an alternate evaluation as described in Section 6 of NEI 04-07, Pressurized Water Reactor Sump Performance Evaluation Methodology (Reference 11), using NRC accepted methods as described in the associated safety evaluation (SE) for NEI 04-07 (Reference 12), and a core blockage analysis using the methodology described in WCAP-17788, Comprehensive Analysis and Test Program for GSI-191 Closure (Reference 13). NextEra recognizes that the NRC's review of WCAP-17788 has not been finalized. Accordingly, upon NRC approval of WCAP-17788, the completed in-vessel blockage analysis for Seabrook will be reviewed and if warranted, a reanalysis will be performed.

An additional plant modification is planned, as described in Enclosure 1, which serves to further enhance Seabrook's capability to withstand GSI-191 related failures. To assure compliance with the long-term cooling requirements of 10 CFR 50.46(b)(5), NextEra will additionally request by no later than April 2018, an exemption from the single failure criterion of 10 CFR 50, Appendix A, General Design Criterion (GDC) 35, *Emergency Core Cooling*; 38, *Containment Heat Removal*; 41, *Containment Atmosphere Cleanup, for a select* (Region II) range of loss-of-coolant accident (LOCA) break sizes. Accordingly, the assumptions and inputs used to establish the bases for GL 2004-02 closure are consistent with the Seabrook licensing basis pending completion of the remaining plant modification and approval of a limited exemption from GDC 41. As such, no new changes pursuant to 10 CFR 50.90 are being proposed as a result of this submittal. Upon NRC approval of the limited exemption request and closure of GL 2004-02, the Seabrook updated final safety analysis report (UFSAR) will be reviewed to determine if further changes to the licensing basis are appropriate in accordance with 10 CFR 50.71(e).

Section 1 of Enclosure 1 provides NextEra's statement of compliance with the *Applicable Regulatory Requirements* section of GL 2004-02 on behalf of Seabrook. Section 2 of Enclosure 1 describes the corrective actions that were completed in response to GL 2004-02, provides a schedule for the remaining actions requiring completion and lists significant margins and conservatisms that were utilized in the analyses. In keeping with the NRC's Revised Content Guide for GL 2004-02 (Reference 14), Section 3 provides an evaluation of the sixteen identified issue areas, including the methodologies employed to arrive at a determination of acceptable performance and their bases for use. Section 3 also describes key aspects of completed plant modifications, process changes and supporting analyses that were applied in order to demonstrate with high confidence that the risk of GSI-191 related failures at Seabrook has been reduced to an acceptable level. Section 4 lists the documents referenced in Enclosure 1.

Attachment 2 provides the current list of commitments related to closure of GSI-191 for Seabrook.

This letter supersedes all previous regulatory commitments identified in References 1 through 8, 10, and related correspondence on behalf of Seabrook.

If you have any questions or require additional information, please contact Mr. Kenneth J. Browne, Licensing Manager, at 603-773-7932.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on January 31, 2018.

Sincerely,

NextEra Energy Seabrook, LLC

Christopher Domingos
Site Director – Seabrook
NextEra Energy

Attachments:
Attachment 1 - List of References
Attachment 2 - Summary of Commitments

Enclosure 1 - Updated Final Response to NRC Generic Letter 2004-02

cc: NRC Region I Administrator
NRC Project Manager
NRC Senior Resident Inspector

Director Homeland Security and Emergency Management
New Hampshire Department of Safety
Division of Homeland Security and Emergency Management
Bureau of Emergency Management
33 Hazen Drive
Concord, NH 03305

Mr. John Giarrusso, Jr., Nuclear Preparedness Manager
The Commonwealth of Massachusetts
Emergency Management Agency
400 Worcester Road

ATTACHMENT 1

REFERENCES

1. Florida Power and Light (FPL) Company/FPL Energy Seabrook LLC letter L-2005-034, NRC Generic Letter 2004-02 Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors, dated March 4, 2005 (ADAMS Accession Number ML050670429)

2. FPL/FPL Energy Seabrook LLC letter L-2005-181, NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors - Second Response, September 1, 2005 (ADAMS Accession Number ML052490339)

3. FPL/FPL Energy Seabrook LLC letter L-2005-145, NRC Generic Letter 2004-02 Request for Additional Information Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors, dated July 20, 2005 (ADAMS Accession Number ML052080038)

4. FPL/FPL Energy Seabrook LLC letter L-2006-028, GL 2004-02 Supplement to Response to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors, dated January 27, 2006 (ADAMS Accession Number ML060310245)

5. FPL/FPL Energy Seabrook LLC letter L-2007-155, Request for Extension of Completion Date of the St. Lucie Unit 1, St. Lucie Unit 2 and Turkey Point Unit 3, Generic Letter 2004-02 Actions, dated December 7, 2007 (ADAMS Accession Number ML073450338)

6. FPL Energy Seabrook LLC letter SBK-L-08033, 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 28, 2008 (ADAMS Accession Number ML080630273)

7. FPL Energy Seabrook LLC letter SBK-L-08136, Final Response and Notice of Completion for NRC Generic Letter 2004-02 NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors, dated August 4, 2008 (ADAMS Accession Number ML080630273)

8. FPL/FPL Energy Seabrook LLC/FPL Energy Point Beach LLC letter L-2012-323, Strainer Fiber Bypass Test Protocol, dated August 10, 2012 (ADAMS Accession Number ML12228A330)

9. Staff Requirements Memorandum - SECY-12-0093 - Closure Options for Generic Safety Issue - 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance, dated December 14, 2012 (ADAMS Accession Number ML12349A378)

10. FPL letter L-2013-163, Path Forward for Resolution of GSI-191, May 9, 2013, (ADAMS Accession Number ML13179A349)

11. Nuclear Energy Institute (NEI) 04-07, Volume 1, Pressurized Water Reactor Sump Performance Evaluation Methodology, Revision 0, December 2004 (ML050550138)

12. Nuclear Energy Institute (NEI) 04-07, Pressurized Water Reactor Sump Performance Evaluation Methodology, Volume 2, Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Revision 0, December 6, 2004 (ADAMS Accession Number ML050550156)

13. Westinghouse WCAP-17788, Volume 1, Comprehensive Analysis and Test Program for GSI-191 Closure, Revision 0, July 2015 (ADAMS Accession No. ML15210A669)

14. Revised Content Guide for Generic Letter 2004-02 Supplemental Responses, Enclosure, November 2007 (ADAMS Accession No. ML073110278)

ATTACHMENT 2

List of Regulatory Commitments

The following table identifies the regulatory commitments in this document.

COMMITMENT	TYPE		SCHEDULED COMPLETION DATE
	ONE-TIME	CONTINUING COMPLIANCE	
NextEra will request a limited exemption from the single failure criterion of 10 CFR 50, Appendix A, General Design Criterion (GDC) 35, *Emergency Core Cooling; 38, Containment Heat Removal;* 41, *Containment Atmosphere Cleanup,* and 10 CFR 50.46(b)(5), *Long-Term Cooling* for Region II LOCA break sizes.	X		By no later than April 2018
Upon NRC approval of the in-vessel blockage effects methodology of WCAP-17788, the completed in-vessel blockage analysis will be reviewed and if warranted, a reanalysis will be performed. (Section 2, General Description and Schedule for Corrective Actions)	X		Within 6 months following NRC approval of the WCAP-17788 methodology
A modification is planned to install strainers over all refueling cavity drains and to modify the drain lines to ensure the drains will not be clogged during recirculation. (Section 2, General Description and Schedule for Corrective Actions)	X		May 2020

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Updated Final Response to NRC Generic Letter 2004-02

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Enclosure 1
Updated Final Response to NRC Generic Letter 2004-02

This enclosure provides NextEra's final response to Generic Letter (GL) 2004-02 (Reference 1) in the form of a stand-alone document that supersedes all previous GL 2004-02 submittals for Seabrook. Previous requests for additional information (RAIs) are not specifically addressed in this submittal since this document is providing the information necessary to address the required information delineated in GL 2004-02. This enclosure follows the format and guidance provided by the Nuclear Regulatory Commission (NRC) (Reference 2; 3; 4; 5) and addresses all topical areas in those documents. The text from the NRC guidance is presented in italic script.

This enclosure includes the use of engineering judgment to establish technical information in support of resolution. Not all input documentation has been verified through a 10 CFR 50 Appendix B program. The inputs and methodologies utilized have been prepared, reviewed, and approved by knowledgeable engineers thereby establishing a sound basis for engineering judgment.

NRC Request, Summary-Level Description

The GL 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. Licensees should address commitments and/or descriptions of plant programs that support conclusions.

Summary-Level Description for Seabrook

The key aspects of the approach chosen by NextEra to resolve the concerns identified in GL 2004-02 are stated below for clarity:

- Extensive design modifications to significantly reduce the potential effects of post-accident debris and latent material on the functions of the emergency core cooling system (ECCS) and containment spray system (CSS) during the recirculation phase of accident mitigation.
- Extensive testing and analysis to determine break locations, identify and quantify debris sources, quantify debris transport, determine upstream and downstream effects, and confirm the recirculation function.
- Changes to the Seabrook licensing basis to reflect the plant modifications and the change to a mechanistic sump strainer blockage evaluation.
- Extensive changes to plant programs, processes, and procedures to limit the introduction of materials into containment that could adversely impact the recirculation function, and establish monitoring programs to ensure containment conditions will continue to support the recirculation function.

- Application of conservative measures to assure adequate margins throughout the actions taken to address the GL 2004-02 concerns.

More details are provided for the plant-specific analyses, changes to the licensing basis, improvements in processes and programs, and conservatisms and margins.

Analyses

An extensive debris generation analysis has been performed for Seabrook, which determined the debris generated for the range of break sizes from 0.5 inches up to 31 inches at all Class 1 in-service inspection (ISI) welds inside the first isolation valve at locations where reactor coolant system (RCS) pressure is expected to be present. The locations were analyzed as double-ended guillotine breaks (DEGBs), single-ended guillotine breaks (SEGBs) (where a closed valve is within 10 pipe diameters), and partial breaks at 45 degree intervals around the circumference of the pipe. This debris generation analysis was an automated evaluation based on a detailed computer-aided design (CAD) model of containment. Additional discussion of the debris generation analysis is provided in the Responses to 3.a and 3.b.

As discussed in the Response to 3.b.1 and 3.h.5, there were no reductions in the zone of influence (ZOI) sizes from the accepted values in Nuclear Energy Institute (NEI) Report 04-07 (Reference 6; 7) for any materials except qualified coatings, which used a ZOI size based on testing that has been reviewed and accepted by the NRC (Reference 8 p. 2). The ZOI size that is being used for qualified coatings is 4.0D. As shown in Table 3.h.1-1, all types of qualified coatings at Seabrook are epoxy coatings.

Seabrook has performed extensive testing for strainer head loss. Additional discussion is provided in the Responses to 3.f and 3.o.

For debris bypass analyses, the Seabrook results were established through comparison with the large-scale debris bypass testing of St. Lucie Unit 1. Additional discussion is provided in the Response to 3.n.

The core blockage analysis methodology documented in WCAP-17788 (Reference 9) has not yet been finalized and the safety evaluation (SE) has not been issued by the NRC. The methodology currently contained in WCAP-17788, which is under NRC review, was used to determine the core inlet and in-vessel debris quantities for Seabrook. Seabrook meets the debris limits currently identified in WCAP-17788. Following receipt of the NRC SE on WCAP-17788, any changes from the current methodology will be evaluated to determine if the current results still apply, and if so, an update is not anticipated.

NEE has elected to use the Alternate Evaluation Methodology defined in NEI 04-07 Section 6 to address the effects of loss-of-coolant accident (LOCA)-generated debris on

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ECCS and CSS recirculation functions for Seabrook. This is described in more detail in the Alternate Evaluation Methodology section.

Seabrook's use of the Alternate Evaluation Methodology follows the criteria set forth in the Safety Evaluation presented in NEI 04-07, Volume 2. One element of the alternate evaluation methodology includes relaxation of single failure criteria for evaluating Region II breaks. Seabrook has determined that an Exemption Request should be submitted for exemption from General Design Criteria (GDC) 41. GDC 41 requires the performance capability of the ECCS to accommodate a single failure. No license amendment request is associated with this change as the station is implementing an alternate evaluation methodology approved by the NRC for its intended purpose. No change is proposed to existing station Safety Analyses. No change is required to the existing station LOCA response procedures.

Changes to the Licensing Basis

NextEra had previously completed changes to the Seabrook updated final safety analysis report (UFSAR) to recognize the mechanistic evaluation of the effect of post-accident debris on the ECCS and CBS recirculation function. The UFSAR will be reviewed after approval of the Seabrook-specific exemption request and receipt of the final closeout letter from the NRC to determine if any further changes are determined to be necessary.

If changes are determined to be necessary, then the UFSAR updates will occur after receipt of the final closeout letter from the NRC. This is discussed in the Response to 3.p.

The Technical Specification (TS) surveillance requirements were updated to expand the recirculation sump inspection requirements to include the entire sump strainer system. This is discussed in the Response to 3.p.

Improvements in Processes and Programs

NextEra has completed a review of plant procedures, processes, and programs and has updated those procedures and design specifications or standards that will ensure the analysis inputs and assumptions can be maintained. This is discussed in the Response to 3.i. The changes to those programs and processes determined to be necessary to support the transition to the mechanistic evaluation methodology licensing basis were in place prior to, or at the time of the change to the licensing basis.

Conservatisms and Margins

NextEra applied conservative measures to assure adequate margins throughout the actions taken to address the GL 2004-02 concerns. The key areas in which these conservative measures were applied are discussed later in the Margins and Conservatisms section.

1. Overall Compliance

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

> *GL2004-02 Requested Information Item 2(a)*
> *Confirmation that the ECCS and CSS recirculation functions under debris loading conditions are or will be in compliance with 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.*

Response to 1:

Confirmation

NextEra has completed all necessary analyses, with the exception of NRC acceptance of the in-vessel blockage analysis, and has updated the Seabrook licensing basis to reflect that the ECCS and CSS recirculation functions under debris loading conditions are in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of GL 2004-02. NextEra still plans to implement a modification to install strainers over all reactor cavity drains and to modify the drain lines to ensure the drains will not be clogged during recirculation (see Response to 3.l). The debris transport calculation will be updated as part of the modification process. The results are expected to have a negligible impact on total debris transported (less than 1%), resulting head loss, and quantity of fiber in the core.

Applicable Regulatory Requirements

The applicable regulatory requirements identified in GL 2004-02 are addressed in Table 1-1:

10 CFR 50.46 "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors"
10 CFR 50.67 "Accident Source Term"
10 CFR 100 "Reactor Site Criteria"

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Table 1-1: Seabrook GL 2004-02 Regulatory Compliance

Regulation	Applicable Requirement	Seabrook Basis for Compliance with GL 2004-02
10 CFR 50.46 (b)(5)	Long-term cooling. After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.	• New sump strainers ensure adequate net positive suction head (NPSH) during recirculation with new margins based on head loss testing with chemical precipitates. • Installation of debris interceptors within containment limit the quantity of debris transported to the strainers post-LOCA. • Sump surveillance procedures ensure that strainer design basis debris loads will not be exceeded by verifying the installation and integrity of the debris interceptors. • Containment integrity and foreign material exclusion procedures track and control foreign material to ensure adequate sump strainer performance. • Periodic sump strainer inspections ensure the strainers are maintained in accordance with their design basis. • Permanent and temporary design processes and procedures ensure all design changes evaluate impacts to post-LOCA sump strainer performance. • Walkdowns and the design basis sump water level calculation confirm that adequate water supply will be available. The modification to the refueling cavity drains discussed previously will support this. • Downstream effects evaluations confirmed that no other modifications are required to ensure long-term cooling capability is maintained. • Inspections by qualified personnel during each refueling outage ensure that the quantity of unqualified/ degraded qualified coatings are adequately controlled. • Evaluation of in-vessel chemical effects confirms that fuel temperatures will be maintained at an acceptably low value. • Seabrook will submit an exemption request to the single active component failure criterion separate from this submittal.
10 CFR 50, Appendix A, GDC 35	Criterion 35--Emergency core cooling. A system to provide abundant emergency core cooling shall be provided. The system safety function shall be to transfer heat from the reactor core following any loss of reactor coolant at a rate such that (1) fuel and clad damage that could interfere with continued effective core cooling is prevented and (2) clad metal-water reaction is limited to negligible amounts.	The assurance of long-term cooling capability during recirculation ensures that the design basis emergency core cooling capabilities are maintained. Seabrook will submit an exemption request to the single active component failure criterion separate from this submittal.

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Regulation	Applicable Requirement	Seabrook Basis for Compliance with GL 2004-02
10 CFR 50, Appendix A, GDC 38	Criterion 38--Containment heat removal. A system to remove heat from the reactor containment shall be provided. The system safety function shall be to reduce rapidly, consistent with the functioning of other associated systems, the containment pressure and temperature following any loss-of-coolant accident and maintain them at acceptably low levels.	The assurance of long-term cooling capability during recirculation ensures that the design basis containment heat removal capabilities are maintained. Seabrook will submit an exemption request to the single active component failure criterion separate from this submittal.
10 CFR 50, Appendix A, GDC 41	Criterion 41--Containment atmosphere cleanup. Systems to control fission products, hydrogen, oxygen, and other substances which may be released into the reactor containment shall be provided as necessary to reduce, consistent with the functioning of other associated systems, the concentration and quality of fission products released to the environment following postulated accidents, and to control the concentration of hydrogen or oxygen and other substances in the containment atmosphere following postulated accidents to assure that containment integrity is maintained.	Assurance that containment spray capability is maintained during recirculation ensures that containment atmosphere cleanup capability is preserved. Seabrook will submit an exemption request to the single active component failure criterion separate from this submittal.

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2. General Description of and Schedule for Corrective Actions:

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). (Note: All requests for extension should be submitted to the NRC as soon as the need becomes clear, preferably no later than October 1, 2007.)

> *GL 2004-02 Requested Information Item 2(b)*
> *A general description and implementation schedule for all corrective actions, including any plant modifications that you identify while responding to this generic letter. Efforts to implement the identified actions should be initiated no later than the first refueling outage starting after April 1, 2006. All actions should be completed by December 31, 2007. Provide justification for not implementing the identified actions during the first refueling outage starting after April 1, 2006. If 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.*

Response to 2:

The corrective actions to address the concerns identified in GL 2004-02 at Seabrook consisted of plant modifications, testing and analysis, changes to plant programs and processes, and changes to the licensing basis. These actions have been completed in accordance with NextEra regulatory commitments and NRC-approved extensions.

Plant Modifications and Walkdowns

The original sump screens have been removed and replaced with new strainer systems. These systems ensure adequate NPSH during recirculation with margin for chemical effects. This modification was performed in Spring 2008. Seabrook also installed debris interceptors within containment in Fall 2006 to limit the transported quantities of debris that could reach the sump strainers.

Containment spray drain tubing downstream of the drain valves was rerouted and supported from the top of the “B” sump platform to support installation of the new sump strainers.

Walkdowns have been performed to confirm the absence of potential choke points in the flow path from potential break locations to the recirculation strainers.

NextEra plans to install strainers over all refueling cavity drains and modify the drain lines to ensure the drains will not be clogged during recirculation. The modification is to be completed by May 31, 2020.

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Testing and Analyses

Large-scale head loss testing was performed in 2008. The results of the Seabrook debris penetration analyses are established through comparison with the large-scale penetration testing of St. Lucie Unit 1.

The in-vessel blockage analysis was performed using a methodology that is not yet approved by the NRC. Within 6 months following the NRC's approval of the methodology, a review will be performed to determine if the methodology changed from that used to provide the results in this submittal. If the review determines that the methodology is the same, then NextEra is not planning any further actions. If the review determines the methodology has changed to alter the results provided in this submittal, then a reanalysis will be performed and the results provided to the NRC for their review and acceptance.

Plant Programs and Processes

Significant program and process changes necessary to address the GL 2004-02 concerns were completed by Spring 2008.

The containment and containment spray recirculation sump surveillance procedure requires inspection of all accessible areas to verify that no loose debris, fibrous materials that could degrade into loose debris, or bubbling/chipping paint is present prior to setting containment integrity. In addition, any entry performed while containment integrity is set requires subsequent walkdowns of areas affected by the entry to confirm no loose debris or fibrous material was left in containment. Shift Manager authorization is required for any materials to be left in containment.

The maintenance director is responsible for maintaining the general housekeeping of containment, which includes tracking the overall cleanliness of containment and promptly correcting identified deficiencies.

Foreign material exclusion programmatic controls are in place, which ensure that proper work control is specified for debris-generating activities within the containment building. This assists in preventing introduction of foreign material into containment, which could challenge the containment recirculation function. Additionally, the foreign material exclusion program requires that engineering be consulted any time foreign material covers are placed on, or modifications are performed on, the containment sump strainers. Lastly, the containment entry procedure provides additional controls to evaluate foreign materials to be brought into containment and ensure they are removed during at power entries.

Seabrook engineering change processes and procedures ensure modifications that may affect the ECCS, including sump performance, are evaluated for GL 2004-02 compliance. During engineering change preparation, the process requires specific critical attributes be listed, evaluated, and documented when affected. This includes the introduction of materials into containment that could affect sump performance or lead to equipment degradation. It also includes repair, replacement, and installation of coatings inside containment, including installing coated equipment.

Seabrook has adopted the industry's standard change process, including the industry procedure IP-ENG-001. The standard process and tools are intended to facilitate sharing of information, solutions and design changes throughout the industry. This process requires activities that affect UFSAR described structure, system, or component (SSC) design functions to be evaluated as a design change in accordance with NextEra's 10 CFR 50 Appendix B program. This includes modifications that would impact the containment sump. Design changes require a final impact review meeting (i.e., final design workshop) and assessment in accordance with 10 CFR 50.59. Additional meetings may be required based on complexity and risk of the change. A failure modes and effects analysis is required if the design change introduces any new failure modes or changes failure modes for the affected SSCs.

Temporary configuration changes are controlled by plant procedure, which maintain configuration control for non-permanent changes to plant structures, systems, and components while ensuring the applicable technical and administrative reviews and approvals are obtained.

In accordance with 10 CFR 50.65 (Maintenance Rule), an assessment of risk resulting from the performance of maintenance activities is required. Prior to performing maintenance, Seabrook assesses and manages the increase in risk that may result from the proposed maintenance activities. In general, the risk assessment ensures that the maintenance activity will not adversely impact a dedicated/protected train, which ensures a system is capable of performing its intended safety function.

<u>Licensing Basis</u>

The licensing basis changes performed to address the GL 2004-02 concerns consisted of changes to the UFSAR reflecting the plant modifications and evaluations performed to address GL 2004-02, as well as changes to the TS surveillance procedure to include inspection of the strainers and debris interceptors for visible damage or corrosion, and to confirm that there is no debris present on the strainers or debris interceptors.

The UFSAR will be reviewed after approval of the Seabrook-specific exemption request and receipt of final closeout letter from the NRC to determine if any further changes are necessary.

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Alternate Evaluation Methodology

Section 6 of the NEI 04-07 Guidance Report (GR) describes an alternate evaluation methodology for demonstrating acceptable containment sump performance (Reference 6 p. 6−1 to 6−18). The alternate evaluation methodology proposes separate analysis methods for two distinct break size regions (Reference 7 p. 113):

- Region I:
  - o Defined as all breaks up to and including DEGBs on the largest piping connected to the RCS loop piping AND partial breaks on the RCS loop piping up to a diameter of 196.6 in^2 (equivalent to a 15.8-inch diameter break). This is referred to as the alternate break size in the GR (Reference 6 pp. 6−3 to 6-4). The terms alternate break size and debris generation break size (DGBS) are used synonymously in the NRC safety evaluation report (SER) (Reference 7 pp. 110-115).
  - o Analysis methods must meet the typical design basis rules for a deterministic evaluation.
- Region II:
  - o Defined as breaks larger than the Region I break size up to and including DEGBs on the RCS loop piping.
  - o Mitigative capabilities must be demonstrated, but the fully deterministic design basis rules do not necessarily apply.

The alternate evaluation methodology can be used to demonstrate reasonable assurance of adequate long term core cooling for the bounding breaks in Region II by allowing for the use of more realistic assumptions and methods, credit for mitigative operator actions, and use of non-safety related equipment (Reference 6 p. 6−2). Based on various considerations, the staff determined that the division of the pipe break spectrum proposed for evaluating debris generation is acceptable based on operating experience, application of sound engineering judgment, and consideration of risk-informed principles. Licensees using the methods described in Section 6 of the GR can apply the DGBS for distinguishing between Region I and Region II analyses (Reference 7 p. 114). Based on this guidance, a single failure was not assumed for Seabrook Region II analyses.

As shown in this submittal there is reasonable assurance that none of the Region II breaks would fail because of debris and that these breaks would be successfully mitigated.

<u>Region I Evaluation</u>

The Seabrook evaluation for Region I considered DEGBs for Class 1 ISI welds on piping connected to the RCS main loops, which have a maximum nominal pipe diameter of 14 inches, as well as 17-inch partial breaks on the main loop piping (including multiple break orientations at each main loop ISI weld location). The debris quantities for the bounding Region I break locations are described in the Response to 3.b. The conservatively calculated debris quantities at the bounding break locations are greater than the conventional debris quantities used in the head loss testing. However, the tested quantities are considered bounding with consideration of the excess chemical debris source term.

These bounding Region I breaks were evaluated in accordance with NRC-approved methods for a deterministic evaluation (with the exception of the WCAP-17788 methodology, which is still being reviewed by the NRC), and were shown to meet the intent of the acceptance criteria. The details of this evaluation are described in Section 3.

Region II Evaluation

The Region II evaluation for Seabrook was limited to breaks larger than 17 inches on the main loop piping, and these breaks were analyzed using bounding DEGB quantities at the worst-case break locations. The debris quantities for the bounding Region II break locations are described in the Response to 3.b.

Ex-vessel downstream effects were evaluated for the bounding Region II breaks in accordance with NRC-approved methods for a deterministic evaluation and were shown to meet the relevant acceptance criteria (see the Response to 3.m). Therefore, the use of the alternate evaluation methodology is limited to strainer head loss concerns and downstream in-vessel effects.

The debris quantities that were used in the prototypical strainer head loss testing were less than the bounding Region II break debris quantities. Therefore, these breaks cannot be addressed using the standard deterministic methodology and were evaluated using the alternate evaluation methodology. There is reasonable assurance that these breaks would not fail based on:

- Proceduralized operator actions
- Realistic assumptions and methods
- Use of non-safety related equipment

Operator Actions

Following a loss-of-coolant accident (LOCA) at Seabrook, the following sequence of events would occur based on automated actions and operator actions performed in accordance with the plant emergency operating procedures (EOPs):

- Upon receipt of a prerequisite safety actuation signal, both trains of residual heat removal (RHR) pumps, safety injection (SI) pumps, and centrifugal charging pumps (CCPs) would be started automatically with suction from the refueling water storage tank (RWST).

- The containment building spray (CBS) pumps would be automatically started upon receipt of a containment spray actuation signal (e.g., due to high containment pressure), and draw suction from the RWST.
- The two RHR pumps would be automatically aligned for recirculation after the RWST level reaches the Low-Low-1 level setpoint.
- The two CCPs and the two SI pumps would continue to draw suction from the RWST until they are realigned for cold leg recirculation piggy-backed off of the RHR pumps.
- Five to six hours after initiation of the LOCA, the Seabrook ECCS would be aligned to hot leg recirculation, with the SI and RHR pumps supplying flow to the RCS hot legs. The CCPs would continue to supply flow to the cold legs. This step is taken to prevent boric acid precipitation.
- Once the containment pressure drops below 4.0 psig, the CBS pumps would be secured.
- If, at any point, Seabrook containment sump recirculation cannot be verified, the operators would enter an emergency contingency action (ECA) procedure.
- Within the loss of emergency coolant recirculation ECA procedure, operator actions would be taken to provide RWST makeup from the boric acid blender, in order to provide a viable water supply to the ECCS pumps. Operator actions to add makeup to the RCS from the volume control tank (VCT) could also be taken, if necessary.
- The loss of emergency coolant recirculation ECA procedure also includes provisions for re-starting one or more containment fan coolers.

As shown in the list above, several operator actions are in place to help prevent and mitigate sump blockage and reactor core blockage, such as initiating hot-leg recirculation, providing RWST and RCS makeup from the boric acid blender and VCT, respectively, and securing the CBS pumps when they are no longer needed. Securing the CBS pumps reduces the total flow through the strainer, resulting in a reduction in debris head loss and an increase in NPSH margin. It should also be noted that the CBS pumps have the most limiting NPSH margin, and securing them eliminates the most significant NPSH concern during recirculation.

Realistic Assumptions and Methods

The models, assumptions, and equipment availability for mitigation used for the Region II analysis must be realistic and demonstrated as functionally reliable, but do not need to be safety-related or single failure proof (Reference 7 p. xii). Therefore, two-train operation during recirculation was considered for the Seabrook Region II analysis (e.g. a single failure of an ECCS Train or a CBS pump is not considered for Region II analyses). This is a realistic assumption that is appropriate considering the low frequency associated with Region II breaks (described further below) and the plant procedures in place to ensure that the RHR and CBS pumps are properly maintained and would perform their intended duty during a LOCA. Additionally, surveillance procedures are in place to ensure that the sump components (i.e., screens, suction inlets, and debris interceptors) are not restricted by debris, show no evidence of structural distress or abnormal corrosion, and would fulfill their intended purpose during a LOCA.

In an effort to help mitigate the quantity of debris that would transport to the strainers post-LOCA, debris interceptors (DIs) were installed throughout containment. The DIs were installed within the bioshield, on the scuppers in the bioshield wall, and throughout the annulus. Extensive testing was performed to determine the effect that these DIs would have on the quantity of debris that would transport to the sump strainers. Testing for the annulus debris interceptors was performed with debris prepared as fines, similar to the fibrous debris prepared for head loss testing. Additionally, testing was performed at a variety of flow velocities so that the different hold-up results could be accurately applied to the individual debris interceptors based on the flow velocity experienced during post-LOCA recirculation.

Although the testing showed significant amounts of hold-up at the debris interceptors (up to 80%), the debris transport analysis performed for the Seabrook Region I analysis conservatively neglected any hold-up of fines at the debris interceptors and only credited a partial hold up of small pieces. For the Region II analysis, it is appropriate to incorporate the results of the debris interceptor testing into the debris transport analysis to determine a more realistic quantity of fines transported to the strainer. The DI testing results were incorporated in a conservative manner, with only annulus debris interceptors credited with retaining debris. Additionally, only 75% of the hold-up percentages observed during testing were applied at the annulus debris interceptors. Refer to the Response to 3.e.4 for more details on how the debris interceptor test results were applied to develop a more realistic quantity of transported fiber fines for the Region II analysis.

Lastly, NEI 04-07 Section 6 also demonstrates the ability to take credit for initial containment air pressure as a more realistic assumption for the NPSH evaluation (Reference 6 p. 6−12; 7 pp. 120-124). Since all ECCS and CBS pumps were demonstrated to have positive NPSH margin without crediting the initial containment air pressure (see the Response to 3.g), this more realistic assumption serves to further increase the pump NPSH margins for Seabrook. As shown in the Response to 3.g.16, considering the initial containment air pressure increases the limiting NPSH margin (evaluated at 212°F) by 12.9 psi, or 29.76 feet.

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Use of Non-Safety Related Equipment

The design of the Seabrook Containment Heat Removal System (CHRS) does not include a safety-related containment air cooling system. The plant instead relies on the CBS, acting together with the ECCS and passive heat sinks, to limit containment pressure and temperature to within acceptable limits.

Although the NPSH margins for the CBS pumps are shown to be positive in the Response to 3.g and a post-LOCA loss of the CBS is not expected, if it were to occur, the non-safety related fan coolers could be used in parallel with the ECCS and passive heat sinks to protect the integrity of the containment structure. Provisions for re-starting one or more containment fan coolers are included in the loss of emergency coolant recirculation ECA and the severe accident management guidelines (SAMGs). The containment structure cooling system consists of six fan coil units (one unit is a standby). Therefore, although the containment cooling fans are non-safety related, it is reasonable to consider their use for the mitigation of Region II breaks.

Analysis

As shown in the Responses to 3.f.7, using the design basis rules and accepted methodology for a deterministic GSI-191 evaluation (e.g., single failure criteria and 100% recirculation transport for fine debris), the quantity of debris generated and transported for the bounding Region II breaks at Seabrook exceeds the quantity that was tested during the Seabrook large-scale head loss testing. However, when the more realistic assumption of two-train operation is considered in parallel with the conservative application of the debris interceptor test results to the hold-up of fiber fines at the annulus debris interceptors, it can be reasonably demonstrated that the debris quantities transported to the sump strainers are bounded by the quantities tested during the large-scale head loss tests. As discussed in the Responses to 3.g.16, the results of the head lost testing demonstrated that positive NPSH margin would be maintained for all pumps. The in-vessel downstream effects analysis also demonstrated that the acceptance criteria would be met with the Region II debris loads. A failure of a single component is not considered necessary for Region II breaks. Per NEI 04-07 Section 6.5, establishing a combination of extremely low probability of needing containment sump recirculation and challenging the containment sump performance will provide suitable justification for the regulatory intent to be met by not assuming single failures of active components. Thus, the defense in depth and safety margin considerations in Regulatory Guide 1.174 can be implicitly assured by the low probabilities of the events.

Risk Evaluation

The relaxation of requirements for Region II breaks is appropriate based on the low frequency associated with breaks that are greater than or equal to 15.8 inches. Based on NUREG-1829 Table 7.19, the mean frequency of breaks greater than or equal to 14 inches is only 2.0E-07 yr^{-1} (Reference 10 pp. 7-55). In other words, if any Region II break were to fail due to the effects of debris, the risk associated with this failure (in terms of change in core damage frequency, or ΔCDF) would be less than 1.0E-06 yr^{-1}, which is defined as a very small change in Regulatory Guide (RG) 1.174 (Reference 11 pp. 15-17).

Defense-in-Depth

As described in the NEI document with defense-in-depth measures for GSI-191 (Reference 12; 13), there are a range of measures at operating pressurized water reactors (PWRs) that either currently exist or could be developed to detect or mitigate potential sump blockage.

Detection of potential sump blockage issues and/or core blockage concerns would be performed in the event of a LOCA via monitoring instructions provided in the cold-leg recirculation procedure. The detection actions are instructed to remain in effect during both cold-leg and hot-leg recirculation. To detect inadequate recirculation strainer flow, the flow rates, suction pressures, discharge pressures, amperages, and bearing temperatures are monitored for the CCPs, SI pumps, RHR pumps, and CBS pumps. With regard to inadequate reactor core flow, in-vessel blockage monitoring instructions are provided that include recording and assessing core exit thermocouple (TC) temperatures, reactor vessel level instrumentation system level, and total ECCS flow. Additional mitigative measures applicable to Seabrook are described below.

A reduction in flow through a strainer debris bed will result in a reduction in head loss across the strainer (Reference 13). The cold-leg recirculation procedure includes steps to place the SI, CCP, and/or CBS pumps in “Pull To Lock” upon notification that an ECCS or CBS pump is in distress. Placing any of these pumps in “Pull To Lock” would immediately reduce the flow through the strainer debris bed. The minimum flow required to remove decay heat would then be determined, and the Technical Support Center (TSC) would be consulted to determine whether the RHR pump flow should be throttled to reduce further blockage. Additionally, the ECA procedure for loss of emergency coolant recirculation provides steps to re-align the charging pump and CBS pump suction to the RWST if strainer blockage were to occur, and to add makeup water to the RWST via the boric acid blender. These actions would also serve to reduce the flow through the strainer debris bed.

Injection flow from alternate sources can also be used to provide core cooling, if necessary. The ECA procedure for loss of emergency coolant recirculation provides guidance to add makeup to the RCS from the VCT, using one of the CCPs. Additionally, as a result of the implementation of FLEX at Seabrook, the diesel-driven FLEX high pressure pump (FHPP) would be available to provide high pressure makeup into the RCS (drawing suction from the boric acid tanks or the RWST) and the FLEX low pressure pump (FLPP) would be available to provide low pressure makeup into the RCS (drawing suction from the RWST) (Reference 14 pp. 20, 25).

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Transferring from cold leg recirculation to hot leg recirculation has the potential to disturb any debris collected on the bottom of the fuel that could be preventing adequate core cooling. Per the loss of reactor coolant procedure, the operators are instructed to initiate hot leg recirculation five to six hours after the event initiation. As described above, the cold leg recirculation procedure includes an in-vessel blockage monitoring and evaluation requirement, which would be used to initiate early hot leg recirculation if necessary.

Another proceduralized action that can be used to mitigate core blockage is to start an RCP in an idle RCS cooling loop. The response to inadequate core cooling functional recovery procedure instructs that if the core exit TCs indicate a temperature greater than 1,100°F, an RCP should be started to attempt to remove core blockage and allow normal recirculation injection flow paths to become effective at maintaining adequate core cooling.

Finally, even if long term core cooling was lost and core damage did occur, the SAMGs for Seabrook would be implemented to effectively mitigate the event and protect plant personnel and the public. The SAMGs include steps to determine the availability of both the CBS pumps and the containment fan coolers to serve as containment heat sinks. Based on availability, the operators are instructed to evaluate the potential effects and limitations of these heat sinks and to implement actions as appropriate. The SAMGs also include instructions to determine all potential makeup sources to the RWST. Possible makeup sources that are included for evaluation are the reactor makeup water storage tank and boric acid tank, the demineralized water storage tank, the condensate storage tank, the fire water system, and the Browns River via the local fire department or the portable tower makeup pump.

<u>Conclusion</u>

Region I breaks (including all breaks 17-inches and smaller) have been fully addressed using deterministic methods.

There is reasonable assurance that long term core cooling can be provided for the bounding Region II breaks at Seabrook based on the combination of proceduralized operator actions, application of more realistic assumptions, use of non-safety related equipment, assuming two ECCS/CBS trains are available (i.e. not assuming a single failure), significant margins and conservatisms (described in the following section), and the ability to use additional mitigative measures as described above.

Finally, a bounding evaluation shows that the risk associated with the loss of long-term core cooling due to the effects of debris in Region II is very small, as defined by RG 1.174.

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Margins & Conservatisms

The following list documents the margins and conservatisms utilized in the GSI-191 analysis.

Debris Generation

Margins:

- The amount of latent debris at Seabrook was conservatively increased to 100 lbm, rather than using the walkdown value (40.7 lbm).
- The amount of miscellaneous debris (e.g. tags and labels) at Seabrook was conservatively increased to 133 ft^2, rather than using the walkdown value (39.8 ft^2).

Conservatisms:

- Shadowing by the reactor or structures was not considered for reactor nozzle breaks. ZOIs at these breaks were truncated to the primary shield wall and a line-of sight cone projecting out the closest primary shield penetration to the radius of the ZOI sphere.
- 100% of unqualified coatings were assumed to fail for all breaks, conservatively maximizing the potential unqualified coatings load in the recirculation pool.
- Qualified epoxy inside the ZOI was assumed to fail as 100% particulate, conservatively treating it as the most easily transportable debris type.

Debris Transport

Margins:

- During pool fill, the transport to the inactive cavity (reactor cavity) was conservatively limited to 15% for fine debris. Note that the transport to the inactive cavity without the limitation was calculated to be 37%.

Conservatisms:

- It was conservatively assumed that all unqualified coatings are located in lower containment and fail at the start of the event (t=0). This is conservative since it results in 100% of unqualified coatings being present in the pool at the start of recirculation and results in 100% transport of this debris.
- All fine debris blown to upper containment was conservatively assumed to be washed back down by the containment spray flow. This conservatively includes debris blown up onto holdup areas protected from the containment spray path (on the primary shield walls, the shield walls around the pressurizer, and the bottom side of the over-head floor slabs).
- Small pieces of debris on the operating deck were assumed to wash to lower containment without any retention on grating.
- Additional levels of grating below the operating deck were neglected during washdown. This is conservative, since the maximum amount of debris will be

washed down to lower containment without any credit for additional retention on gratings.

- Turbulent kinetic energy (TKE) and velocity plots were created to determine the recirculation transport fractions. The TKE sufficient to suspend debris was conservatively assumed to exist at any elevation in the pool, when it may only exist at a discreet elevation. This conservatism results in all applicable debris at that location being assumed to remain in suspension and transport, when in some cases, the TKE would only keep debris at select elevations (such as the pool surface) in suspension.
- It was assumed that the debris interceptors in the bioshield and annulus would become completely blocked with debris in the computational fluid dynamics (CFD) model. This conservatively causes all of the flow from inside the bioshield to exit to the annulus via the open passageway on the east side of containment, which increases the velocity in the annulus. With the debris interceptors blocked, the velocity in the annulus is further increased due to the fact that the flow of water would have to travel up and over the interceptors.
- The flow of water falling from the reactor coolant system breach was assumed to do so without encountering any structures before reaching the containment pool. This is conservative since any impact with structures would dissipate the momentum of the water and decrease the turbulent energy in the pool.
- When given a size range for insulation debris, the debris was conservatively treated as if it existed entirely at the smaller end of the size range. For example, large pieces of fiberglass debris (larger than 6 inches on a side) were treated as 6 inch pieces. This ignores the fact that larger pieces in the size range would be less easily transported.

Water Volume and Level

Conservatisms:

- The TS minimum initial RWST level (minus an amount for trip error) was used for the initial RWST water level. With a trip error of 1.7 inches and a volume of 947.9 gallons of water per inch of RWST height, the volume of water between the TS minimum level and the TS minimum level minus trip error is 1,611 gal.

NPSH

Margins:

- As provided in Tables 3.g.16-1 and 3.g.16-2, after accounting for debris bed head losses with chemical effects, plenum and doghouse losses, debris interceptor losses, and clean strainer head losses:
    - The Train A RHR pump has an NPSH margin of 7.59 ft at 212°F.
    - The Train A CBS pump has an NPSH margin of 0.14 ft at 212°F.
    - The Train A RHR pump has an NPSH margin of 30.87 ft at 160°F.
    - The Train A CBS pump has an NPSH margin of 23.42 ft at 160°F.

- For the Region II analysis, when the initial partial pressure of air in containment is considered, the NPSH margins at 212°F presented above are increased by 29.76 ft.

Conservatisms:

- NPSH margins were based on minimum containment water levels.
- The minimum NPSH margins were calculated at a sump pool temperature of 212 °F which occurs for a short period of time at the beginning of recirculation. Additionally, this high pool temperature was conservatively assumed to be coincident with the strainer head loss due to the full conventional debris loads.
- The large-break LOCA (LBLOCA) sump volumetric flow rate used to calculate the NPSH margin was maximized by assuming maximum sump temperature. This conservatively maximizes the NPSH required and minimizes the NPSH available (see the Response to 3.g.2).
- Head loss testing was conducted using water at approximately 80 °F. Head loss values were inserted into the NPSH equations without scaling the head loss to plant sump temperature. Since scaling up the temperature would have reduced the head loss across the strainer, resulting in greater NPSH margin, this is conservative.

Strainer Structural Analysis

Margins:

- The strainer system, which includes strainer structure and debris interceptor analysis, provides margin to design allowable stresses, which ensures that the strainer system will perform its function as long as necessary following an event that requires its use. Table 3.k.2-1 through Table 3.k.2-3 in the Response to 3.k.2 contain itemized strainer and debris interceptor component lists and the margins for each component.

Conservatisms:

- Use of the code of record provides the conservatism inherent within the code itself (Reference 15).

Head Loss

Margins:

- The maximum quantity of AlOOH precipitate expected is 174 kg, but the tested quantity of AlOOH precipitate was 367.2 kg at plant scale for single train operation (Region I analysis) and 750.1 kg for two-train operation (Region II analysis). Note a single failure is not assumed for Region II analyses.

Conservatisms:

- Due to the lower testing temperatures and higher testing approach velocities, the head loss recorded during the head loss testing was conservatively higher than what would be experienced at plant conditions. However, the test head loss values were not corrected for temperature or approach velocity and were conservatively assumed to be applicable to the plant conditions.

Penetration

Conservatisms:

- No particulate debris was used in the penetration testing credited for Seabrook in-vessel analysis. Particulate debris hastens bed formation by filling gaps and plugging holes within the network of entangled fibers on the strainer. This, in turn, increases head loss across the debris bed, causing bed compression. The combination of these effects results in a reduction of available paths for fiber to traverse its way through the debris bed and through the strainer perforations. Thus, the exclusion of particulate debris for penetration testing is conservative.

Chemical Effects

Margins:

- The quantity of unsubmerged aluminum used for the chemical effects analysis (776.2 ft^2) includes a 90 ft^2 design contingency. The quantity of submerged aluminum used for the chemical effects analysis (190.1 ft^2) includes a 6.9 ft^2 design contingency.
- The quantity of Nukon used for the chemical effects analysis (2,809 ft^3) includes a design contingency of 12.8% over the maximum E-Glass debris predicted in the debris generation calculation.
- The design contingency applied to the Nukon and aluminum quantities results in an AlOOH precipitate mass margin of 17 kg (out of 174 kg total).

Conservatisms:

- Debris quantities bound the maximum amount of debris predicted from the bounding LOCA break.
- Maximum pH values were conservatively used to increase the calculated aluminum release, and minimum pH values were conservatively used to decrease the calculated aluminum solubility.
- The maximum containment sump pool mass was conservatively used for the 30-day post-LOCA event to increase the calculated aluminum release. The minimum containment sump pool mass was used to maximize the aluminum concentration for the purpose of conservatively maximizing the aluminum precipitation temperature.

- Maximum temperature profiles were conservatively used for the 30-day post LOCA event to increase the calculated aluminum release.
- The containment sprays were assumed to be active for the full 30-day event to conservatively maximize aluminum release.
- All destroyed and latent debris was conservatively assumed to be submerged.
- It was conservatively assumed that the submerged quantity of aluminum would be available to interact with the sump pool and that the unsubmerged quantity of aluminum would be available to interact with the containment spray. This is conservative because some of the listed materials would not be sprayed or would be submerged in a portion of the pool that does not interact with the fluid that recirculates through the containment sump strainer.
- The total quantity of aluminum in solution was assumed to precipitate as AlOOH after the concentration exceeds the calculated solubility limit.

In-Vessel

Conservatisms:

- When calculating the in-vessel fiber load, the effect of containment spray operation was minimized. This was done by assuming CBS minimum operation time and the minimum CBS flow rate. For the Region I analysis, only a single CBS train was credited to be in operation to further limit the debris diverted away from the reactor.
- The penetration correlation curve-fit uncertainty was added to the final in-vessel debris loads. This conservatively increases the in-vessel fiber loads.
- The maximum RHR flow rate was used for the recirculation phase to increase the flow split to the reactor vessel. This results in a larger quantity of fiber transporting to the reactor vessel (see the Response to 3.n.1).

LOCADM

Margins:

- The maximum peak cladding temperature (PCT) in the LOCADM analysis is 408.7 degrees F with an acceptance criterion of 800 degrees F, resulting in a margin of 391.3 degrees F.
- The maximum deposition thickness (DT) in the LOCADM analysis is 16.13 mils with an acceptance criterion of 50 mils, resulting in a margin of 33.87 mils.

Conservatisms:

- The containment sump pool pH was assumed to remain at the maximum final containment sump pool pH throughout the duration of the analysis.
- Conservative sump temperature and containment temperature profiles were used in the analysis because higher temperatures yield conservatively higher amounts

of calculated aluminum release, thereby increasing the total amount of deposition.

- The amount of fibrous debris that bypasses the sump strainer and is available for deposition in the core was assumed to be 100 g/FA. This value, which is greater than the bypassed fiber mass determined from testing, conservatively accounts for additional operating margins and leads to greater deposition thickness.
- When calculating fuel rod DT and PCT, the entire fine particulate, fine fiber, and chemical precipitate loads were assumed to be available to collect on the fuel rods, with no credit taken for accumulation on the strainer.

Ex-Vessel

Conservatisms:

- Rather than using the transported quantities of Nukon and coatings associated with a specific break, it was conservatively assumed that the maximum quantities of both Nukon and coatings transport to the strainer, regardless of break. This means that the debris quantities presented do not represent a single break, but instead maximize the amount of Nukon and coatings analyzed, conservatively bounding all break scenarios.
- The minimum sump pool volume following a small-break LOCA (SBLOCA) was combined with the maximum debris loads from an LBLOCA to determine debris concentration. This is conservative because minimizing the mass of recirculating water maximizes the debris concentration, and thus the amount of wear. Additionally, water volumes such as portions of the RCS inventory or the volume of water in the RHR piping could also be proven to be part of the recirculation flow path, but were conservatively excluded for the downstream effects calculations.
- Although the actual maximum spherical particulate size that is expected to bypass the strainer is 0.068 inches, the maximum particulate size that bypasses the strainer was assumed to be 0.100 inches for the downstream effects evaluations.

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3. Specific Information Regarding Methodology for Demonstrating Compliance

a. Break Selection

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.

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

Response to 3.a.1:

The Seabrook debris generation calculation followed the methodology of NEI 04-07 and associated NRC SE (Reference 6 pp. 3-5 - 3-26, 4-1 - 4-5; 7 pp. 12-35, 85-91), with the exception that it analyzed a full range of breaks, rather than just the worst-case breaks as suggested by NEI 04-07. The purpose of the debris generation calculation was to obtain debris quantities for the full range of possible break scenarios. This method ensures that the most challenging break for Region I and Region II can be identified. The calculation evaluated debris generation quantities for breaks on every ISI weld within the Class 1 pressure boundary inside the first isolation valve, including breaks at the reactor nozzles. The following types of LOCA breaks were considered:

- Double-ended guillotine breaks (DEGBs) with the largest break being a 31” DEGB,
- Partial breaks, orientated 45 degrees apart, at size increments of 0.5, 2, 4, 6, 8, 10, 12, 14, 17, 20, 23, and 26 inches,
- Single-ended guillotine breaks (SEGBs) within 10 pipe diameters of a normally closed isolation valve or termination point.

In the debris generation calculation, a three-dimensional computer-aided design (CAD) model of the Seabrook containment building was updated to work with ENERCON’s BADGER software. BADGER was used to place ZOIs representing possible breaks on every 0.5” or larger ISI weld identified in containment inside the first isolation valve. Figure 3.a.1-1 shows the graphical representation of these weld locations for Seabrook.

Per Section 3.3.5.2 of the NRC SE of NEI 04-07, evaluating breaks at equal increments is “only a reminder to be systematic and thorough” (Reference 7 p. 17). The use of Class 1 ISI welds as break locations is both systematic and thorough because they are closer to the components that contain the greatest quantity of debris sources as opposed to a span of straight pipe further away from these sources (see Figure 3.a.1-1). Also, welds are almost exclusively recognized as likely failure locations because they can have relatively high residual stress, are preferentially-attacked by many degradation mechanisms, and are most likely to have preexisting fabrication defects (Reference 10 p. xviii). Since each of the weld locations were evaluated for determination of the quantity of debris that would be generated, these locations, by observation, represent the limiting break locations.

In the alternate evaluation methodology, the breaks are separated into two regions based on an alternate break size. Breaks less than or equal to the threshold break size (17”) were considered to be in Region I. Break sizes greater than the threshold break size were considered to be in Region II. Since the debris generation calculation evaluated the full range of break sizes (up to a DEGB) for each ISI weld in containment inside the first isolation valve, there are an extensive set of breaks to choose from for either Region I or Region II analysis.

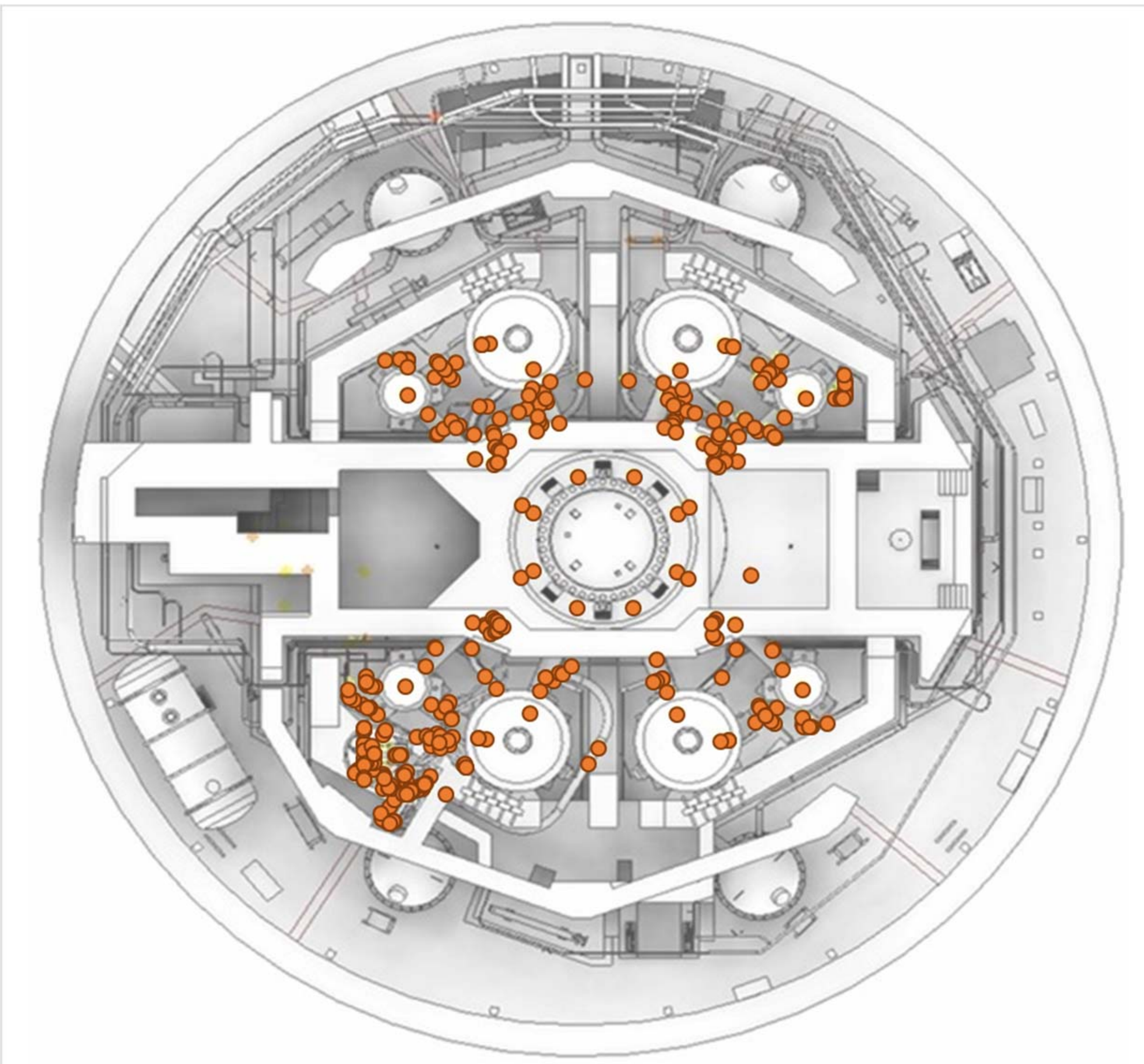

Figure 3.a.1-1: Weld Locations Where Postulated LOCAs Occur

The most limiting breaks are those that contain sufficient fiber to result in the highest head loss across the strainer. Strainer head loss testing was used to determine the debris quantities that would result in either acceptable or unacceptable strainer head loss (see the Response to 3.f.4).

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

Response to 3.a.2:

Feedwater and main steam piping were not considered for potential break locations because ECCS in recirculation mode is not required for Main Steam or Feedwater line breaks (Reference 16 p. 5).

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

Response to 3.a.3:

The quantities of debris generated by the full range of breaks has been determined for Seabrook (see the Responses to 3.a.1 and 3.b.4). The debris generation calculation for Seabrook takes into account a spectrum of break sizes on every ISI weld within the Class 1 pressure boundary inside the first isolation valve. The purpose of this calculation is to characterize the debris generation for the range of possible break scenarios. This includes the debris generated by the worst-case scenario LOCAs (DEGBs on the main loop piping).

Given that most large breaks generate similar quantities of debris from latent dirt/dust, miscellaneous debris (e.g., stickers, tags, labels, and tape), coatings in the ZOI, and unqualified coatings, the breaks that present the greatest challenge to post-accident sump performance are breaks that generate limiting amounts of fibrous debris (as discussed in the Response to 3.a.1). Areas with the potential to generate significant quantities of fibrous debris were identified.

For Seabrook, the alternate evaluation methodology was used. The breaks were separated into two regions based on an alternate break size. Breaks less than or equal to 17” were considered to be in Region I. Breaks greater than 17” were considered to be in Region II. In both regions, the break that generated the largest quantity of overall fibrous debris and the break that generated the largest quantity of fines and small pieces were selected; see Table 3.a.3-1 for descriptions of these locations and see the Response to 3.b.4 for quantities.

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Table 3.a.3-1: Bounding Region I and Region II Breaks for Seabrook

Region	Limiting Debris Type	Weld Location	Location Description
II	DEGB Maximum Total Generated Fiber	RC-0007-01-03	Loop 3 Hot Leg at SG Nozzle
II	DEGB Maximum Generated Fiber Fines + Smalls	RC-0001-01-03	Loop 1 Hot Leg at SG Nozzle
I	17” Maximum Total Generated Fiber	RC-0010-01-02 45°	Loop 4 Hot Leg at Elbow
I	17” Maximum Generated Fiber Fines + Smalls	RC-0001-01-02 315°	Loop 1 Hot Leg at Elbow

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

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; (2) the amount of debris generated by the break jet forces.

1. *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/SE, or if using other than default values, discuss method(s) used to determine ZOI and the basis for each.*

Response to 3.b.1:

In a pressurized water reactor (PWR) reactor containment building, the worst-case pipe break would typically be a DEGB. In a DEGB, jets of water and steam would blow in opposite directions from the severed pipe. One or both jets could impact obstacles and be reflected in different directions. To take into account the double jets and potential jet reflections, NEI 04-07 (Reference 6 pp. 1-3; 7 p. vii) proposes using a spherical ZOI centered at the break location to determine the quantity of debris that could be generated by a given line break.

For DEGBs, the ZOIs are defined in the analysis as a spherical volume about the break in which the jet pressure is higher than the destruction/damage pressure for certain types of insulation, coatings, or other materials impacted by the break jet.

For any break smaller than a DEGB (i.e., a partial break), NEI 04-07, Volume 2, accepts the use of a hemispherical ZOI centered at the edge of the pipe (Reference 7 p. 6). Because these types of breaks could occur anywhere along the circumference of the pipe, the partial breaks were analyzed using hemispheres at eight different angles that are 45 degrees apart from each other around the pipe.

Because different insulation types have different destruction pressures, different ZOIs were determined for each type of insulation. Table 3.b.1-1 shows the primary side break equivalent ZOI radii divided by the break diameter (L/D) for each representative material in the Seabrook containment building. Note that the Reactor Vessel Head has Microtherm and Temp-Mat insulation installed on the top head and bottom head, respectively; however, neither insulation type is listed in the table below because it was assumed that neither would become a source of debris.

Table 3.b.1-1 – Primary Side Break ZOI Radii for Seabrook Insulation Types

Insulation Type	Destruction Pressure (psi)	ZOI Radius/Break Diameter (L/D)
Unjacketed and Jacketed Nukon	6*	17.0*
Transco RMI	114*	2.0*
Qualified Coatings	40***	4.0**

*NRC SE for NEI 04-07 (Reference 7 p. 30)
** Revised Guidance Regarding Coatings Zone of Influence for Review of Final Licensee Responses to Generic Letter 2004-02 (Reference 8 p. 2)
***40 psi corresponds to a 4D ZOI in Table 3-1 of the SER (Reference 7 p. 27)

In some cases, if the ZOI for a particular material is very large (i.e., it has a low destruction pressure or is located on a large pipe); the radius of the sphere may extend beyond robust barriers located near the break. Robust barriers consist of structures, such as concrete walls that are impervious to jet flow and prevent further expansion of the jet. Insulation in the shadow of large robust barriers can be assumed to remain intact to a certain extent (Reference 6 pp. 3-14 through 3-15). Due to the compartmentalization of containment in Seabrook, the insulation on the opposite side of the compartment walls can be assumed to remain intact. However, the steam generator (SG) compartments share an opening where a break jet could extend, so this was accounted for by including destruction of some of the insulation in these areas. All ZOIs were truncated to account for robust barriers per NEI 04-07 Volume 2 (Reference 7 p. vii). ZOIs at the restrained reactor nozzle break locations were also analyzed, but were determined to not be limiting since the reactor vessel is insulated with Transco RMI.

For reactor nozzle breaks, the ANSI 58.2-1988 jet model methodology was implemented to evaluate the ZOI length of a nozzle break subjected to partial separation of the two pipe ends. ANSI 58.2-1988 postulates two break types and determines the jet impingement pressures resulting from a high-energy line break: fully separated breaks with unrestrained pipe ends and partially separated breaks with highly restrained pipe ends. The fully separated breaks were analyzed in the SER to derive the ZOI radii found in the SER by solving for isobaric impingement pressures radially and axially from the jet centerline and converted to a volume-equivalent spherical ZOI radius (Reference 7 p. 30). One limitation of the ANSI Jet methodology is that the maximum radial separation of a partially separated break is one pipe wall thickness before defaulting to a full sized break. For breaks with radial separation larger than a pipe wall, a combination of the two break methodologies must be used to increase the ZOI size appropriately. This was performed by applying a crescent shaped jet profile to the area generated by a partially offset break bounded by the inside diameter of the pipe and the outer diameter of the pipe wall from the offset half. The volume of the jet generated by the equivalent fully offset break is combined with the volume of the jet generated by the axial offset, and generates a conservatively larger ZOI.

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Table 3.b.1-2 contains the maximum allowable separation distances for hot and cold leg breaks and the ZOI dimensions for reactor nozzle breaks.

Table 3.b.1-2 – ZOI Adjustments for Partially Separated Reactor Nozzle Breaks

	Hot Leg Nozzles	**Cold Leg Nozzles**
Pipe I.D. (in)	29	27.5
Pipe O.D. (in)	33.9	32.22
Axial Separation (in)	0.09	2.82
Radial Separation (in)	7.83	8.05
Insulation	**ZOI Radius**	
Nukon	7.2D	8.4D
Epoxy	1.8D	2.3D
Transco RMI	0.9D	1.2D

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

Response to 3.b.2:

See the Response to 3.b.1.

3. *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).*

Response to 3.b.3:

Seabrook applied the ZOI refinement discussed in NEI 04-07 Volume 2 (Reference 6 p. Section 4.2.2.1.1), which allows the use of debris-specific spherical ZOIs. No new destruction testing was used to determine the ZOIs listed above.

For reactor nozzle breaks, the ANSI 58.2-1988 jet model methodology was implemented to evaluate the ZOI length of a nozzle break subjected to partial separation of the two pipe ends. See the Response to 3.b.1 for additional information.

The only ZOI that is being used that is different from those listed in NEI 04-07 is that for qualified coatings. This is discussed in the Response to 3.h.5.

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4. *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.*

Response to 3.b.4:

Using the ZOIs listed in this section, the breaks selected in the Response to 3.a, and the size distribution provided in the Response to 3.c of this enclosure, quantities of generated debris for each break case were calculated for each type of insulation. Table 3.b.4-1 shows the quantities of debris generated for the two most limiting DEGBs with respect to fiber, as determined in the Seabrook debris generation calculation. Table 3.b.4-2 shows the same information for the two most limiting 17” partial breaks. Note that break generated coatings quantities are provided in the tables for completeness, but are discussed further in the Response to 3.h. The fiber quantities presented in Tables 3.b.4-1 and 3.b.4-2 were converted to mass (lb) by multiplying the calculated volumes by their associated density.

Table 3.b.4-1: Seabrook Worst-Case Fiber DEGBs

Break Location		**RC-0007-01-03**		**RC-0001-01-03**	
Location Description		Loop 3 Hot Leg at SG Nozzle		Loop 1 Hot Leg at SG Nozzle	
Break Size		31"		31"	
Break Type		DEGB		DEGB	
Nukon (lb)	Fine	738.5		758.8	
	Small	2493.3		2648.8	
	Large	1318.7		1104.8	
	Intact	1424.8		1193.5	
Transco RMI (ft^2)	Small (<4”)	0		0	
	Large (≥ 4”)	0		0	
K&L #6548	Fine	91.02 lb	0.65 ft^3	40.01 lb	0.28 ft^3
K&L #D-1 / K&L E-1	Fine	60.19 lb	0.54 ft^3	30.05 lb	0.27 ft^3
K&L #4000	Fine	56.16 lb	0.48 ft^3	55.91 lb	0.48 ft^3

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Table 3.b.4-2: Seabrook Worst-Case Fiber 17" Partial Breaks

Break Location		**RC-0010-01-02**		**RC-0001-01-02**	
Location Description		Loop 4 Hot Leg at Elbow		Loop 1 Hot Leg at Elbow	
Break Size		17"		17"	
Break Type		Partial (Angle – 45°)		Partial (Angle – 315°)	
Nukon (lb)	Fine	184.9		184.6	
	Small	561.6		563.0	
	Large	510.1		503.2	
	Intact	551.3		543.7	
Transco RMI (ft^2)	Small (<4")	0		0	
	Large (≥ 4")	0		0	
K&L #6548	Fine	5.10 lb	0.04 ft^3	5.10 lb	0.04 ft^3
K&L #D-1 / K&L E-1	Fine	3.06 lb	0.03 ft^3	3.06 lb	0.03 ft^3
K&L #4000	Fine	0.45 lb	0.00 ft^3	0.45 lb	0.00 ft^3

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

Response to 3.b.5:

Labels, tags, stickers, placards and other miscellaneous or foreign materials were evaluated via two walkdowns at Seabrook. The amount of miscellaneous foreign materials found by the walkdowns was 39.8 ft^2. However, for conservatism, a total surface area of 133 ft^2 was assumed in the Seabrook debris generation analysis.

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c. Debris Characteristics

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.

1. *Provide the assumed size distribution for each type of debris.*

Response to 3.c.1:

A summary of the material properties of the accident generated debris types found within containment are listed in Table 3.c.1-1 below (Reference 6 pp. 3-22, Tables 3-2 and 3-3). Note that the Reactor Vessel Head has Microtherm and Temp-Mat insulation installed on the top head and bottom head, respectively; however, neither insulation type is listed in the table below because it was assumed that neither would become a source of debris.

Table 3.c.1-1 – Debris Material Properties

Debris	Distribution	Density (lbm/ft³)	Characteristic Size (μm)
Nukon	See section below	2.4 (bulk) 159 (fiber)	7
Transco RMI	75% small pieces 25% large Pieces	-	<4” ≥4”
Qualified Epoxy Coatings	100% Particulate	141 (K&L #6548)	10
		111 (K&L #D-1 / K&L E-1)	
		116 (K&L #4000)	
Unqualified Coatings	100% Particulate	208 (IOZ)	10
		94 (Epoxy)	

Nukon Insulation

The debris characteristics for Nukon are listed in Table 3.c.1-1.

A baseline analysis of Nukon low density fiberglass (LDFG) includes a size distribution with two categories—60 percent small fines and 40 percent large pieces per NEI 04-07 (Reference 6 p. Section 3.4.3.3.1). The debris generation calculation uses a four-category size distribution based on the guidance in NEI 04-07 Volume 2 (Reference 7 pp. Appendix II and Appendix VI, p. VI-14). This guidance provides an approach for determining a size distribution for LDFG using the air jet impact test (AJIT) data, with conservatism added due to the potentially higher level of destruction from a two-phase jet. Within the 17.0D ZOI, the size distribution varies based on the distance of the insulation from the break (i.e., insulation debris generated near the break location consists of more small pieces than insulation debris generated near the edge of the ZOI).

Consequently, the following equations were developed to determine the fraction of fines (individual fibers), small pieces (less than 6 inches), large pieces (greater than 6 inches), and intact blankets of Nukon LDFG as a function of the average distance between the break point and the centroid of the affected debris measured in units of break diameter (C).

$$F_{LDFG\ Fines}(C) = \begin{cases} 0.2 & \text{if } 0 < C \leq 4 \\ -0.01364 \cdot C + 0.2546 & \text{if } 4 < C \leq 15 \\ -0.025 \cdot C + 0.425 & \text{if } 15 < C \leq 17 \end{cases}$$

$$F_{LDFG\ Small}(C) = \begin{cases} 0.8 & \text{if } 0 < C \leq 4 \\ -0.0682 \cdot C + 1.0724 & \text{if } 4 < C \leq 15 \\ -0.025 \cdot C + 0.425 & \text{if } 15 < C \leq 17 \end{cases}$$

$$F_{LDFG\ Large}(C) = \begin{cases} 0 & \text{if } 0 < C \leq 4 \\ 0.0393 \cdot C - 0.157 & \text{if } 4 < C \leq 15 \\ -0.215 \cdot C + 3.655 & \text{if } 15 < C \leq 17 \end{cases}$$

$$F_{LDFG\ Intact}(C) = \begin{cases} 0 & \text{if } 0 < C \leq 4 \\ 0.0425 \cdot C - 0.170 & \text{if } 4 < C \leq 15 \\ 0.265 \cdot C - 3.505 & \text{if } 15 < C \leq 17 \end{cases}$$

2. *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.*

Response to 3.c.2:

See the Response to 3.c.1 for the material and bulk densities of the various types of debris.

3. *Provide assumed specific surface areas for fibrous and particulate debris.*

Response to 3.c.3:

Specific surface areas could be calculated for each debris type based on the characteristic diameter described in the Response to 3.c.1. However, testing was used to determine strainer head loss and not an analytical method, so specific surface areas were not calculated or used for the Seabrook head loss evaluations (see Response to 3.f).

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

Response to 3.c.4:

The debris characterizations for all debris types follow NRC-approved guidance.

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d. Latent Debris

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.

1. *Provide the methodology used to estimate the quantity and composition of latent debris.*

Response to 3.d.1:

Walkdowns have been completed for Seabrook specifically for the purpose of characterizing latent and miscellaneous debris. These walkdowns utilized the guidance in NEI 02-01 and the staff's SE of NEI 04-07.

The NRC's SE for NEI 04-07 (Reference 7, Section 3.5.2.2) recommended that walkdowns be performed to assess debris sources inside containment.

Samples were collected from eight surface types: floors, containment liner, ventilation ducts, cable trays, walls, equipment, piping, and grating. Where feasible, for each surface type a minimum of four samples were collected, bagged and weighed to determine the quantity of debris that was collected. A statistical approach was used to estimate an upper limit of the mean debris loading on each surface. The horizontal and vertical surface areas were conservatively estimated. The total latent debris mass for a surface type was calculated using the upper limit of the mean debris loading multiplied by the conservatively estimated area for that surface type. The total latent debris was calculated using the sum of the latent debris for each surface type.

Seabrook containment walkdowns were performed for the purpose of identifying and measuring plant labels, stickers, tape, tags, and other debris. Based on the walkdown data and the subsequent removal of cable tray adhesive labels, the quantity of miscellaneous debris in the Seabrook containment was estimated to be 39.8 ft^2. As discussed in the Response to 3.b.5, a total surface area of 133 ft^2 of miscellaneous debris was conservatively assumed in the Seabrook debris generation calculation.

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

Response to 3.d.2:

See the Response to 3.d.3 for assumptions regarding material properties of latent debris.

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3. *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.*

Response to 3.d.3:

Latent debris includes dirt, dust, lint, paint chips, fines, and shards of loose thermal insulation fibers that could potentially transport to the sump strainers during recirculation. Latent debris can be introduced into containment several ways, including deterioration of items such as insulation and coatings, and by personnel tracking in particulate and fibers from outside containment. The quantity of latent debris is provided in the debris generation calculation. A walkdown at Seabrook was performed to measure quantities of latent debris, and the total quantity was calculated based on those samples. The total amount of latent debris calculated was 40.7 lbm, but 100 lbm was assumed in the debris generation calculation. This conservatively bounds the 40.7 lbm of actual latent debris with ample operating margin. Table 3.d.3-1 lists the assumed latent fiber and particulate constituents and their material characteristics.

Latent debris was assumed to consist of 15 percent fiber and 85 percent particulate by mass per NEI 04-07 Volume 2 (Reference 7 p. 50). Based on NEI 04-07 Volume 2 (Reference 7 pp. 50-52, V-11), the size and density of latent particulate were assumed to be 17.3 µm (specific surface area of 106,000 ft^{-1}) and 168.6 lbm/ft^3 (2.7 g/cm^3), respectively. Additionally, the bulk density and microscopic density of latent fiber were assumed to be 2.4 lbm/ft^3 and 93.6 lbm/ft^3 (1.5 g/cm^3), respectively.

Latent fiber was assumed to have a characteristic size of 5.5 µm. This is reasonably conservative, as it is the smallest fiber diameter listed in Table 3-2 of the general reference for LDFG found in NEI 04-07 (Reference 6, p 3-28).

Table 3.d.3-1: Latent Fiber and Particulate Constituents

	Latent Debris (lbm)	Bulk Density (lbm/ft^3)	Microscopic Density (lbm/ft^3)	Characteristic Size (µm)
Particulate (85%)	85	-	168.6	17.3
Fiber (15%)	15	2.4	93.6	5.5
Total	100			

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

Response to 3.d.4:

As discussed in the Response to 3.b.5, a total surface area of 133 ft^2 of miscellaneous debris was conservatively assumed. This surface area would result in a 100 ft^2 reduction in strainer area (75% of 133 ft^2) (Reference 7 p. 49).

e. Debris Transport

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.

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

Response to 3.e.1:

The methodology used in the transport analysis is based on the NEI 04-07 guidance and the associated NRC SE (Reference 7) for refined analyses, as well as the refined methodologies suggested by the SE in Appendices III, IV, and VI (Reference 7). The specific effect of each of the four modes of transport was analyzed in the debris transport calculation for each type of debris generated. These modes of transport are:

- Blowdown Transport – the vertical and horizontal transport of debris to all areas of containment by the break jet
- Washdown Transport – the vertical (downward) transport of debris by the containment sprays, break flow, and condensation
- Pool Fill-Up Transport – the transport of debris by break and containment spray flows from the RWST to regions that may be active or inactive during recirculation
- Recirculation Transport – the horizontal transport of debris from the active portions of the recirculation pool to the sump screens by the flow through the ECCS

The logic tree approach was applied for each type of debris determined from the debris generation calculation. The logic tree shown in Figure 3.e.1-1 is slightly different from the baseline. This departure was made to account for certain non-conservative assumptions identified by the NRC SE (Reference 7) including the transport of large pieces, erosion of small and large pieces, the potential for washdown debris to enter the pool after inactive areas have been filled, and the direct transport of debris to the sump screens during pool fill-up.

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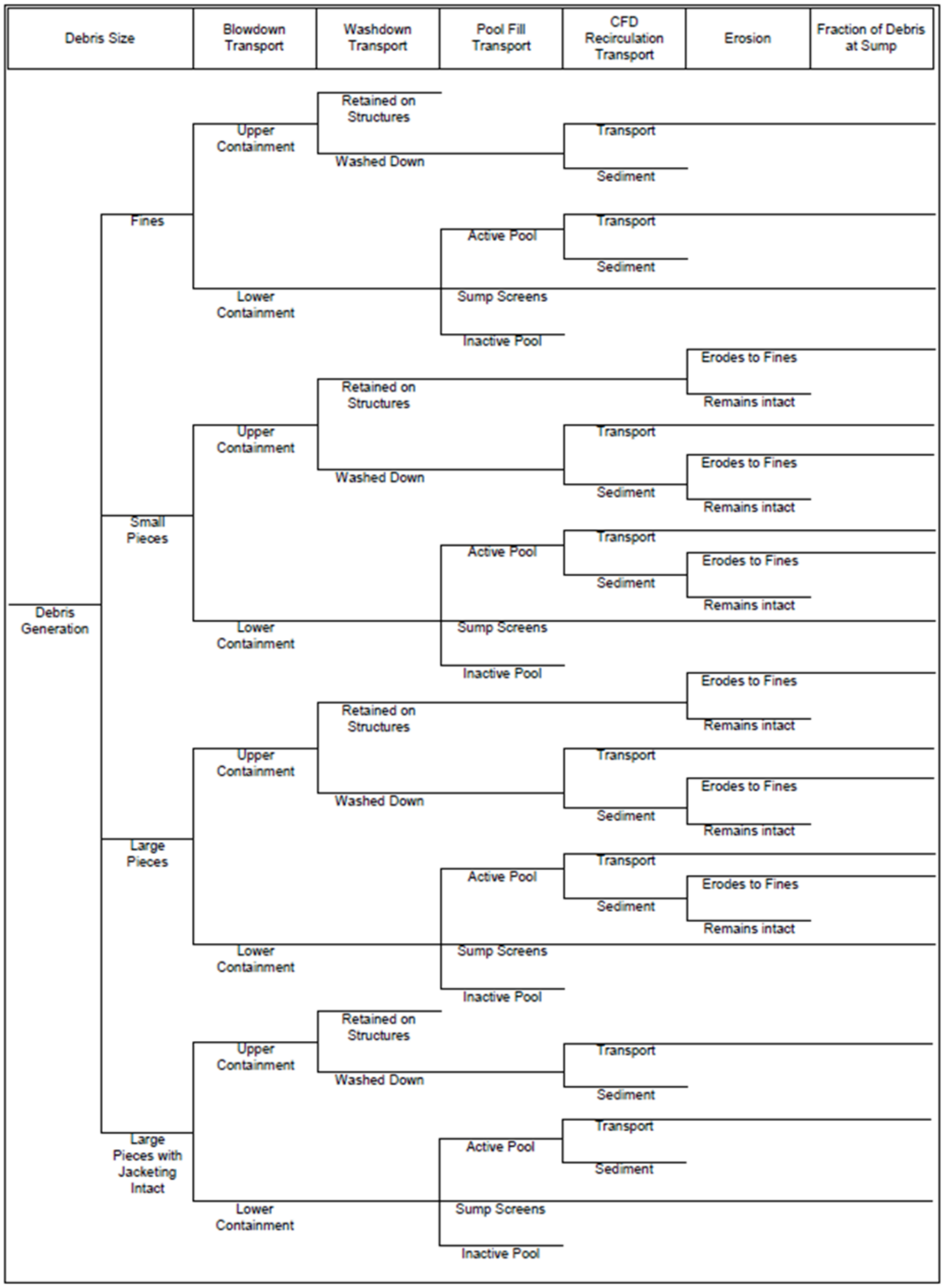

Figure 3.e.1-1: Generic Debris Transport Logic Tree

The basic methodology for the Seabrook transport analysis is summarized below.

1. The CAD model was provided as input to determine break locations and sizes.
2. The debris generation calculation was provided as input into the calculation for debris types and sizes.
3. Potential upstream blockage points were qualitatively addressed.
4. The fraction of debris blown into upper containment and lower containment for each compartment was determined based on the volumes of upper and lower containment.
5. The fraction of debris washed down by containment spray flow was determined along with the locations where the debris would be washed down.
6. The quantity of debris transported to inactive areas or directly to the sump strainers was calculated based on the volume of the inactive and sump cavities proportional to the water volume at the time these cavities are filled.
7. The location of each type/size of debris at the beginning of recirculation was determined based on the break location.
8. A CFD model was developed to simulate the flow patterns that would develop during recirculation.
9. A graphical determination of the transport fraction of each type of debris was made using the velocity and turbulent kinetic energy (TKE) profiles from the CFD model output, along with the determined initial distribution of debris.
10. The initial recirculation transport fractions from the CFD analysis were gathered to determine the final recirculation transport fractions for input into the logic trees.
11. The quantity of debris that could experience erosion due to the break flow or spray flow was determined.
12. The overall transport fraction for each type/size of debris was determined by combining each of the previous steps into logic trees.

Potential Upstream Blockage Points

Potential upstream blockage points were qualitatively addressed in the debris transport calculation. It was determined that the refueling canal drains are potential upstream blockage points in the Seabrook containment building. Upstream effects are discussed in the Response to 3.l.

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CFD Model of Containment Recirculation Pool

A diagram showing the significant parts of the CFD model is shown in Figure 3.e.1-2. The strainer module mass sinks and the various direct and runoff spray regions are highlighted.

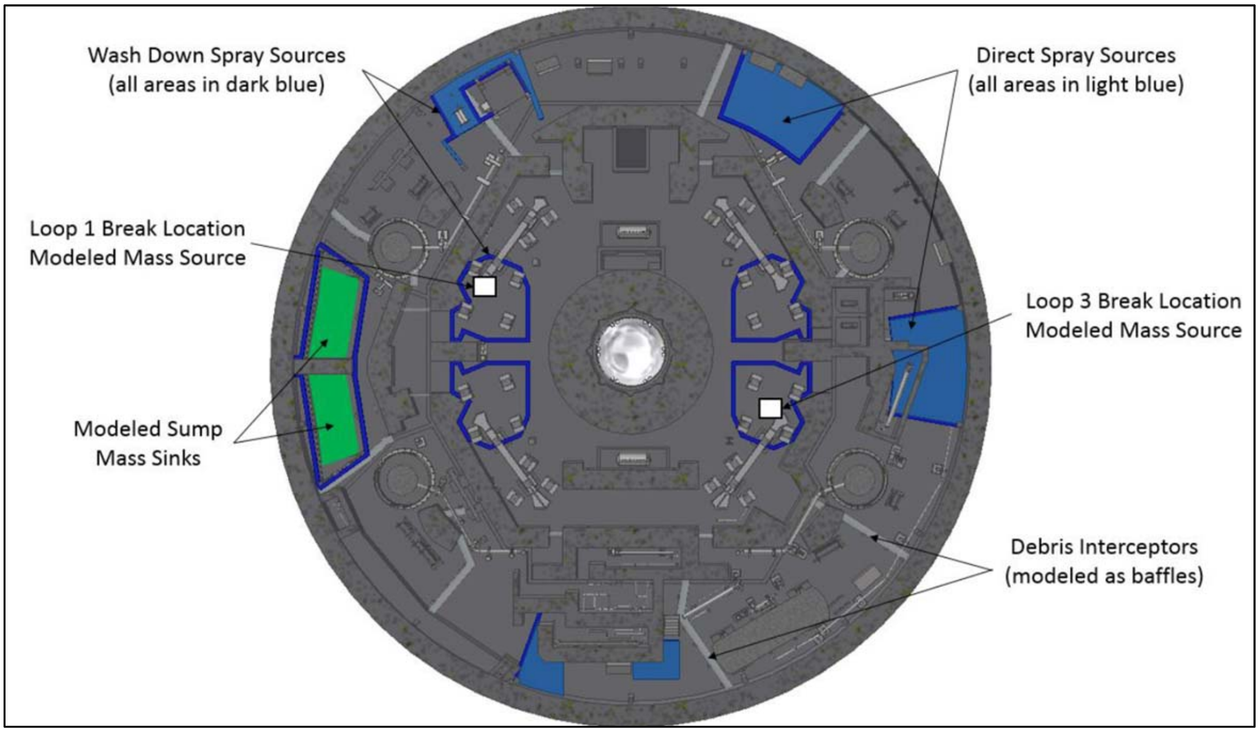

Figure 3.e.1-2: Significant Features in CFD Model

The key CFD modeling attributes/considerations included the following:

Computational Mesh

A rectangular mesh was defined in the CFD model that was fine enough to resolve important features, but not so fine that the simulation would take excessively long to run. A 6-inch cell length was chosen as the largest cell size that could reasonably resolve the concrete structures in the Seabrook containment. For the cells right above the containment floor, the mesh was set to 3 inches tall in order to closely resolve the vicinity of settled debris. The total cell count in the model was 4,000,000.

Modeling of Containment Spray Flows

Various plan and section drawings, as well as the containment building CAD model, were considered when determining the spray flow path to the pool. Spray water would drain to the pool through many pathways. Some of these pathways include the steam generator compartments through the open area above the steam generators, through the annulus via the various sections of grating, and through the refueling canal drains. The sprays were defined as regions and populated with discrete mass source particles. The appropriate flow rate and velocity was set for the sprays in each region.

Modeling of Break Flow

The water falling from the postulated break would introduce momentum into the containment pool that influences the flow dynamics. This break stream momentum was accounted for by introducing the break flow to the pool at the velocity a freefalling object would have if it fell the vertical distance from the location of the break to the surface of the pool.

Modeling of the Sump Strainers

The emergency sump cavities at Seabrook consist of two cavities with a dividing wall between them. Both sump cavities are enclosed within a 6-inch steel curb. The mass sinks used to pull flow from the CFD model were defined within the sump curbs. Note that the specific details of the sump strainers were not specifically modeled. Therefore, the model accurately predicts pool flows up to the sump curbs, but does not accurately predict flow in the sump itself. A negative flow rate was set for the sump module, which tells the CFD model to draw the specified amount of water from the pool over the entire exposed surface area of the module obstacle.

Turbulence Modeling

Several different turbulence-modeling approaches can be selected for a Flow-3D calculation. The approaches (ranging from least to most sophisticated) are:

- Prandtl mixing length
- Turbulent energy model
- Two-equation k-ε model
- Renormalized group theory (RNG) model
- Large eddy simulation model

The RNG turbulence model was determined to be the most appropriate for this CFD analysis. The RNG model has a large spectrum of length scales that would likely exist in a containment pool during emergency recirculation. The RNG approach applies statistical methods in a derivation of the averaged equations for turbulence quantities (such as TKE and its dissipation rate). RNG-based turbulence schemes rely less on empirical constants while setting a framework for the derivation of a range of models at different scales.

Steady-State Metrics

The CFD model was started from a stagnant state at a defined pool depth and run long enough for steady-state conditions to develop. A plot of mean kinetic energy was used to determine when steady-state conditions were reached. Checks were also made of the velocity and turbulent energy patterns in the pool to verify that steady-state conditions were reached.

Debris Transport Metrics

The metrics for predicting debris transport during recirculation are the TKE necessary to keep debris suspended, and the flow velocity necessary to tumble sunken debris along the floor or lift it over a curb. Debris transport metrics have been derived or adopted from data. The metrics utilized in the Seabrook transport analysis originate from the sources below.

- NUREG/CR-6772 Table 3.1 (Reference 17 p. 16)
- NUREG/CR-6808 Figure 5.2, Table 5-1 and Table 5-3 (Reference 18, pp. 5-14, 5-22, and 5-33)

Graphical Determination of Debris Transport Fractions for Recirculation

The following steps were taken to determine what percentage of a particular type of debris could be expected to transport through the containment pool to the emergency sump screens. Detailed explanations of each bullet are provided in the paragraphs below.

- Colored contour velocity and TKE maps were generated from the Flow-3D results in the form of bitmap files indicating regions of the pool through which a particular type of debris could be expected to transport.
- The bitmap images were overlaid on the initial debris distribution plots and imported into AutoCAD with the appropriate scaling factor to convert the length scale of the color maps to feet.
- Closed polylines were drawn around the contiguous areas where velocity and TKE were high enough that debris could be carried in suspension or tumbled along the floor to the sump strainers for uniformly distributed debris.
- The areas within the closed polylines were determined using an AutoCAD querying feature.
- The combined area within the polylines was compared to the initial debris distribution area.
- The percentage of a particular debris type that would transport to the sump strainers was determined based on the above comparison.

Plots showing the TKE and the velocity magnitude in the pool were generated for each case to determine areas where specific types of debris would be transported.

The limits on the plots were set according to the minimum TKE or velocity metrics necessary to move each type of debris. The overlying yellow areas represent regions where the debris would be suspended, and the red areas represent regions where the debris would be tumbled along the floor (see Figure 3.e.1-5). The yellow TKE portion of the plots is a three-dimensional representation of the TKE. Since the TKE is a three-dimensional representation, the plots do not show the TKE at any specific elevation. Rather, any debris that is shown to be present in this yellow area will transport, regardless of the elevation of TKE in the pool. The velocity portion of the plots represents the velocity magnitude just above the floor level (1.5 inches), where tumbling of sunken debris could occur. Directional flow vectors were also included in the plots to determine whether debris in certain areas would be transported to the sump strainers or transported to less active regions of the pool where it could settle to the floor (blue regions).

Due to the many debris interceptors present at Seabrook, specific regions were defined to analyze the transport of debris through/over the interceptors. The regions are shown in Figure 3.e.1-3. These regions were used in cases where there is not continuous transport to the sump within the initial distribution areas. (i.e., washdown distribution).

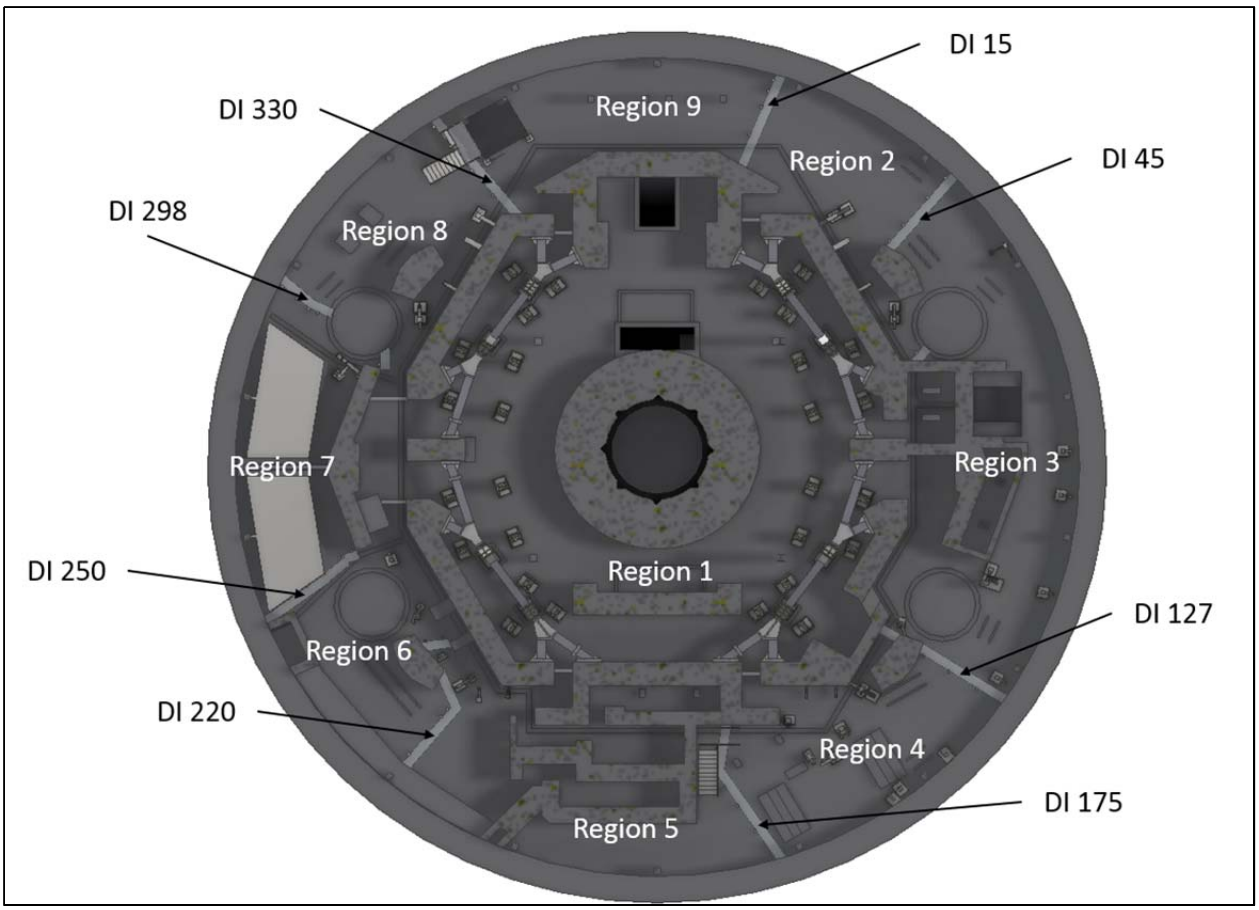

Figure 3.e.1-3: Region Definitions

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The following figures and discussion are presented as an example of how the transport analysis was performed for a generic small debris type. This same approach was used for other debris types analyzed at Seabrook.

As shown in Figure 3.e.1-4, the small debris (depicted by green shading) was initially assumed to be distributed in the vicinity of the break location at the beginning of recirculation.

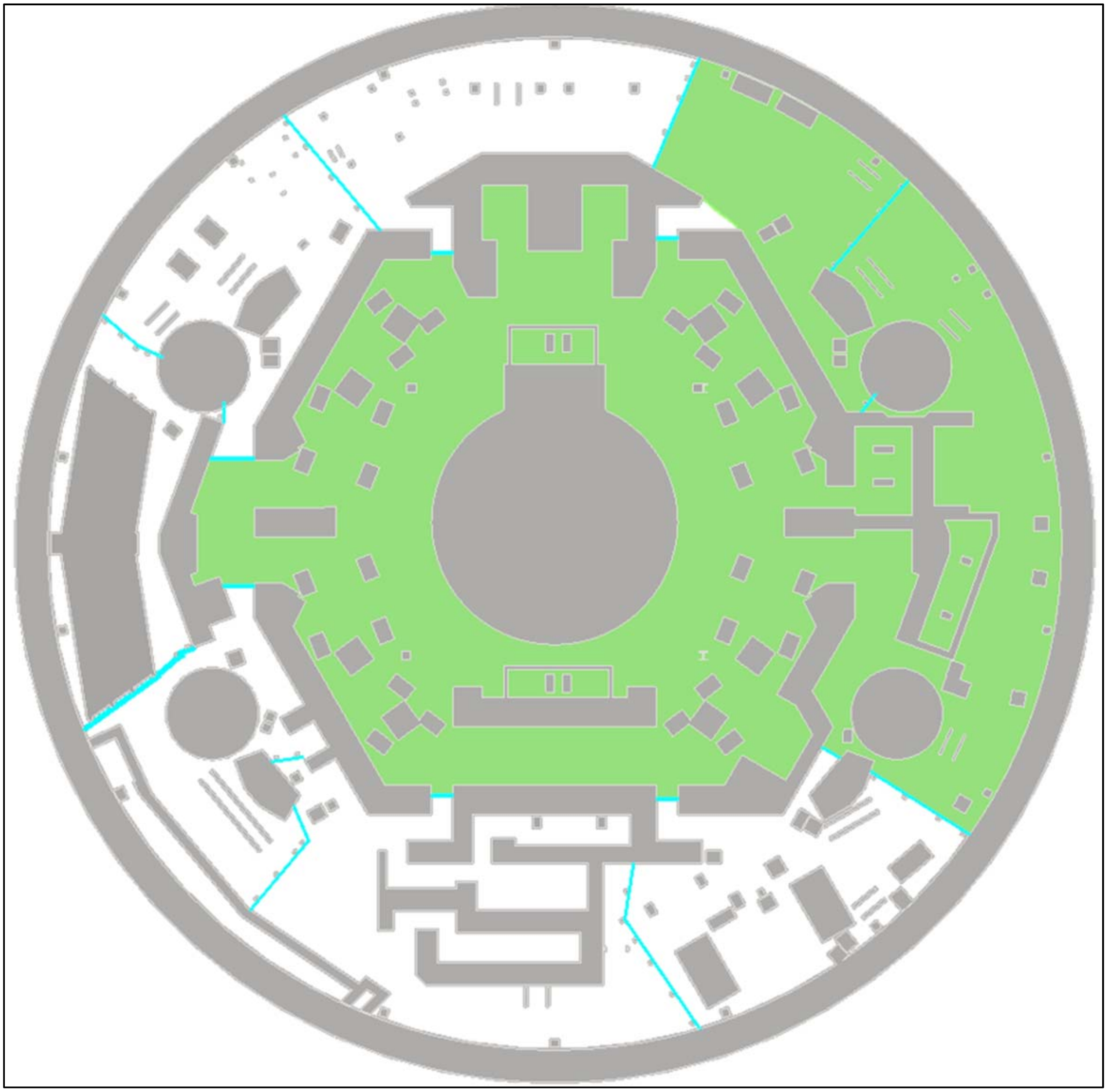

Figure 3.e.1-4: Distribution of Small Debris in Lower Containment

Figure 3.e.1-5 shows that the turbulence of the yellow regions and the velocity of the red regions in the pool are high enough to transport the small pieces of fiberglass

due to the break flow to the sump strainers during recirculation. The blue regions do not have sufficiently high turbulence and velocity to transport small pieces of fiberglass. The initial distribution area (Figure 3.e.1-4) was overlaid on top of the plot showing tumbling velocity, TKE, and flow vectors (Figure 3.e.1-5) to determine the recirculation transport fraction, represented by the hatched portion (Figure 3.e.1-6).

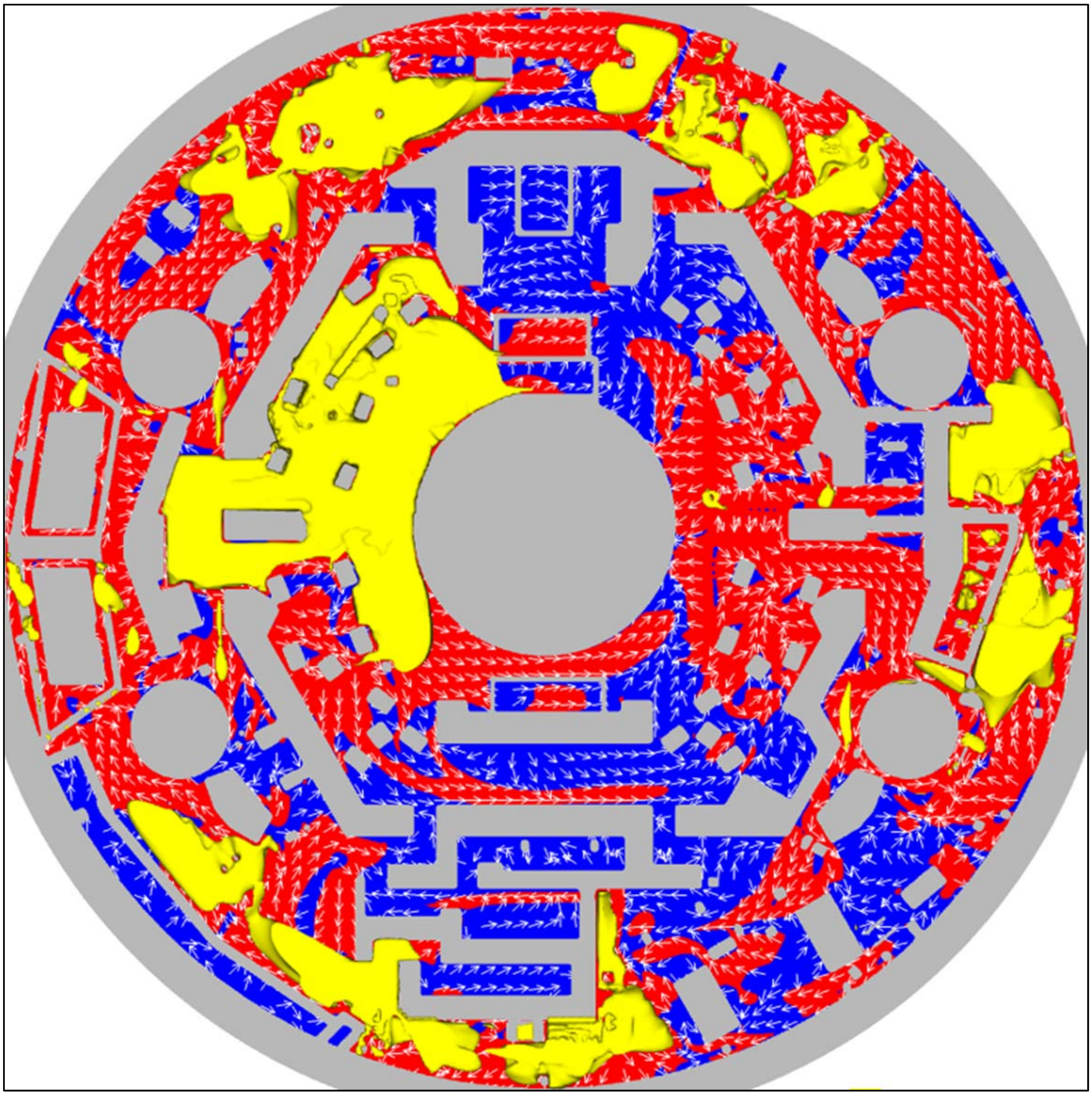

Figure 3.e.1-5: TKE and Velocity with Limits Set at Suspension/ Tumbling of Small Pieces of Fiberglass Debris

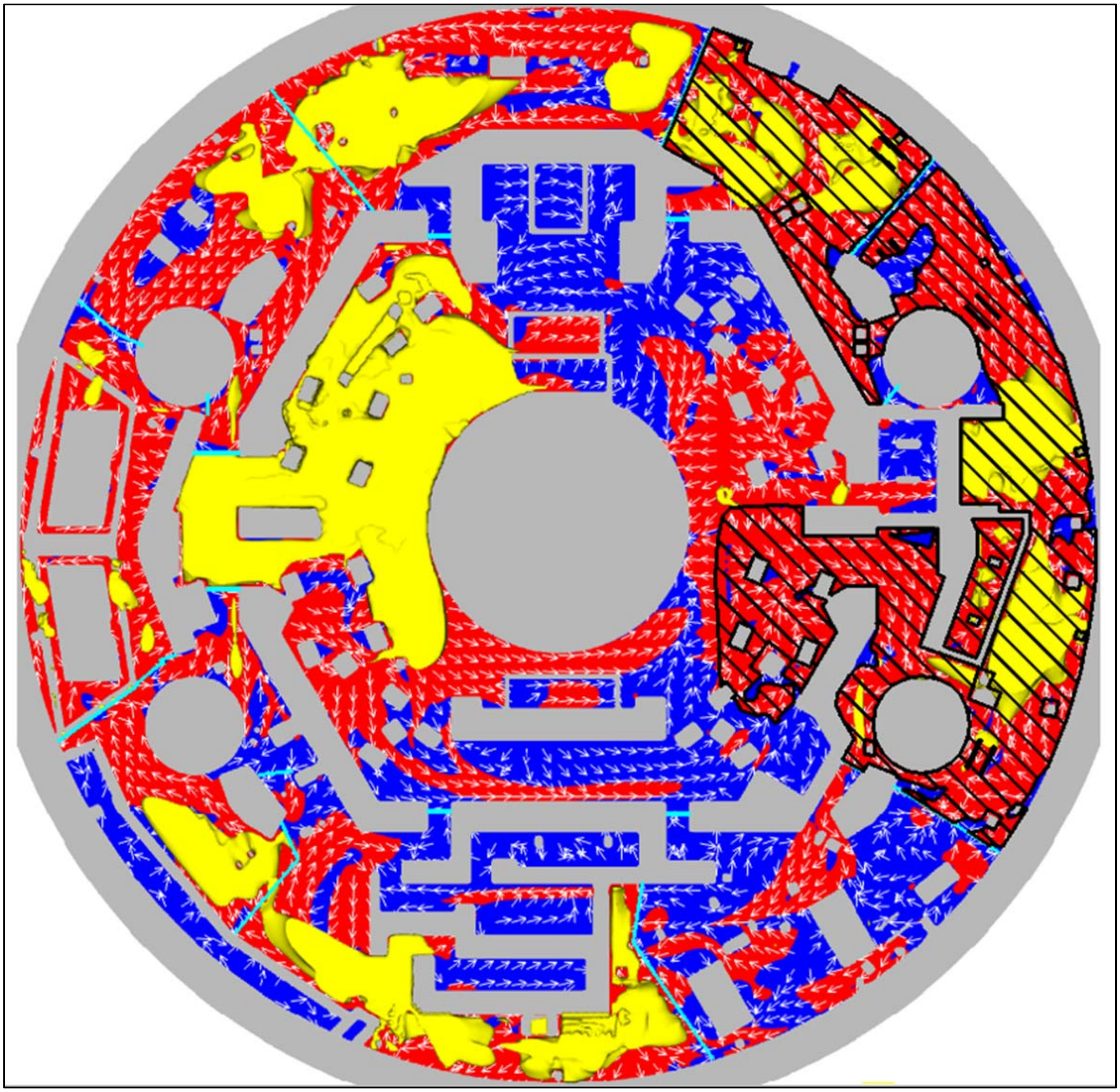

Figure 3.e.1-6: Floor Area where Small Pieces of Fiberglass Debris Would Transport to the Sump Strainers

This same analysis was applied for each type of debris at Seabrook. Recirculation-pool transport fractions were identified for each debris type associated with the location of its initial distribution. This includes a recirculation transport fraction for debris blown to lower containment, debris washed down in the bioshield, and debris washed down through the annulus.

To quantify the small fiberglass debris that reaches the sump strainers, an analysis was performed for the debris interceptors. This analysis is schematically shown in Figure 3.e.1-7. Note that the analysis below does not follow the standard logic tree

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approach depicted by Figure 3.e.1-1. Rather, the amount of debris that is not held up, or not intercepted, by an interceptor is presented on each branch. Also note that since the area where debris will transport is uniform from inside the bioshield to the annulus, debris holdup by DI 45 is conservatively not accounted for due to the difficulty of determining how much debris would pass through this interceptor (see Figure 3.e.1-6). Since the sump strainers are located between DI 250 and DI 298, the debris that transports past these interceptors is the debris that transports to the sump strainers.

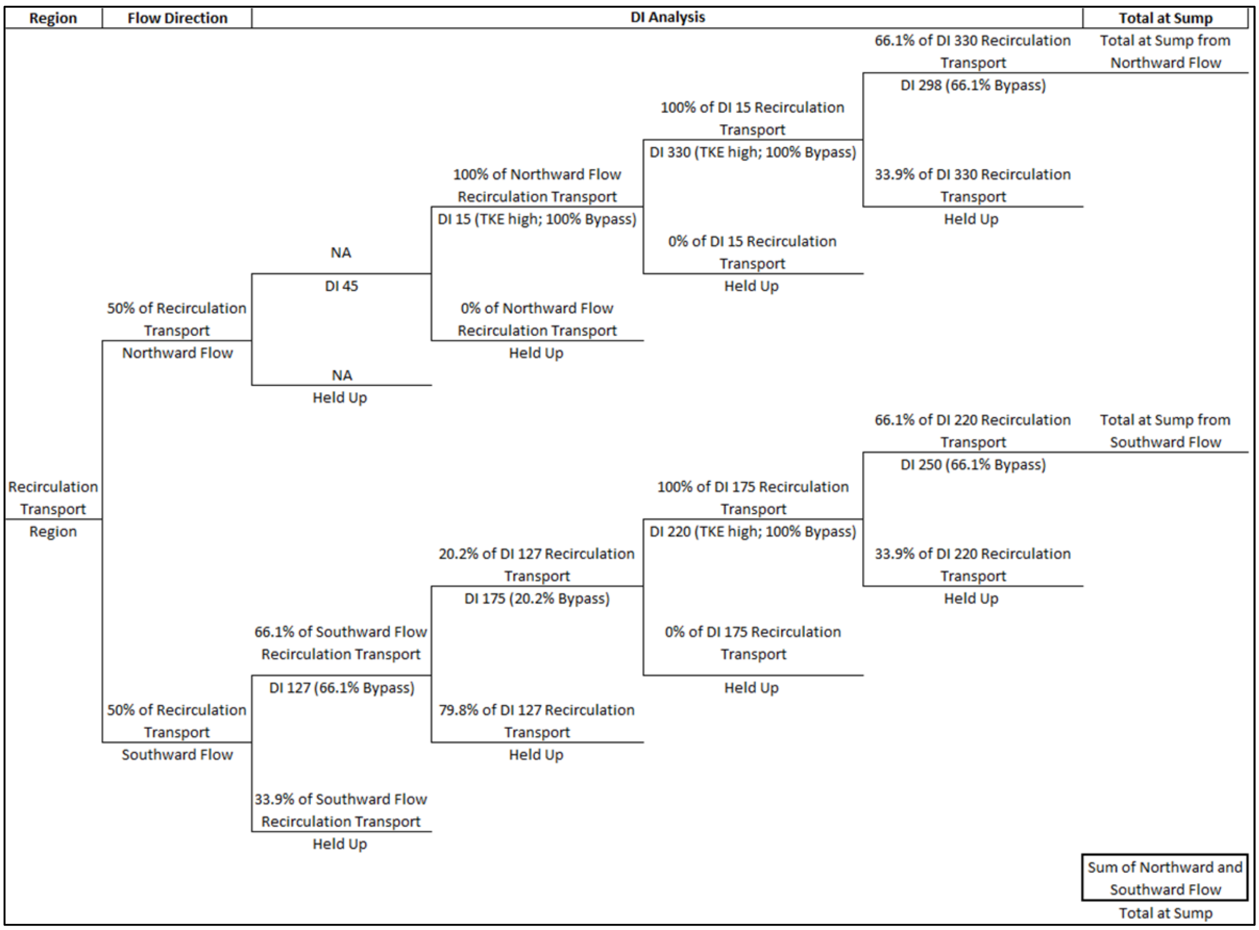

Figure 3.e.1-7: Sample debris interceptor analysis

Erosion Discussion

Due to the turbulence in the recirculation pool and the force of break and spray flow, Nukon debris may erode into smaller pieces, making transport of this debris to the strainer more likely. To estimate erosion of trapped or non-transportable debris that would occur in the recirculation pool, site specific 30-day erosion testing was performed. Based on a validation that the test results apply to Seabrook (ensuring that the flow rates and turbulence values are similar to what is expected in the recirculation pool), an erosion fraction of 10% was used for the small and large pieces of fiberglass debris in the pool. This fraction was applied to both transportable debris and settled debris present in the pool to maximize the amount of erosion. Also, based on this testing, an erosion fraction of 10% was applied to the small and large pieces of fiberglass captured at the debris interceptors. For pieces of debris held up on grating above the pool, an erosion fraction of 1% was used for fiberglass debris.

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

Response to 3.e.2:

The methodology used in the transport analysis is based on and does not deviate from the NRC approved NEI 04-07 guidance (Reference 6) and the associated NRC SE (Reference 7) for refined analyses, as well as the refined methodologies suggested by the SE in Appendices III, IV, and VI.

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

Response to 3.e.3:

To assist in the determination of recirculation transport fractions, several computational fluid dynamics (CFD) simulations were performed using Flow-3D, a commercially available software package.

Four break cases form the basis for the debris transport analysis to determine the recirculation transport fractions. First, an LBLOCA in Loop 1 and an LBLOCA in Loop 3 were evaluated with two trains operational. The bounding location for these simulations was then chosen for the next two cases to analyze – an LBLOCA in Loop 3 with single CBS pump failure, and an LBLOCA in Loop 3 with single train failure. Cases were chosen to represent and bound the different LOCA scenarios that could occur at Seabrook. All cases were run with the maximum ECCS flow rate for each configuration (6,010 gpm/sump for 2 train operation, 6,010 gpm/3,000 gpm for single CBS failure for A/B sump, and 7,400 gpm for single train operation), and with the minimum water level (2.93 ft). Using the maximum flow rates and minimum water level maximize the turbulence and velocity in the pool. Note that the minimum water level used in the transport analysis is lower than the value for LBLOCAs discussed in the Response to 3.g (3.15 ft), and is therefore conservative and bounding in terms of debris transport.

The simulation results include a series of contour plots of velocity and TKE. These results have been combined with settling and tumbling velocities from the GSI-191 literature to determine the recirculation transport fractions for all debris types present in the Seabrook containment building. See the Response to 3.e.1 for additional discussion of the CFD results.

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

Response to 3.e.4:

Debris interceptors are installed in the annulus and in the bioshield. Only the annulus debris interceptors were credited with retaining debris in the transport analysis; all flow and debris in the bioshield was forced to exit into the annulus via the east passageway because the bioshield debris interceptors were assumed to become completely blocked. Testing was performed to determine the bypass fractions for each interceptor. The results of the debris interceptor bypass testing were used in the transport calculation to credit the retention of small debris during recirculation transport for Region I breaks (≤17”). Refer to the Alternate Evaluation Methodology section for the definition of Region I and Region II breaks. The annulus debris interceptor testing that was used for the transport analysis is summarized below.

Table 3.e.4-1: Debris Interceptor Testing Data Used for the Transport Analysis

Test Name	Mass Fiber Added (lbm)	Mass Behind DI (lbm)	Bypass Fraction	Test Flow Rate (gpm)	Approach Velocity (ft/s)
2-762F-2H	15.0	9.61	35.9%	762	0.384
4-630F-2H	54.0	48.50	10.2%	630	0.318
5C-1025F-2H	18.0	7.905	56.1%	1,025	0.517

The dual train data in the containment debris interceptor transport analysis was used to determine which test is applicable to each debris interceptor. For conservatism, the retention fractions were reduced by 10% in the transport analysis (bypass fraction increased by 10%). The data used in the transport analysis is summarized below.

Table 3.e.4-2: Data used for Debris Interceptor in the Transport Analysis

Debris Interceptor	Flow Rate (gpm)	Approach Velocity (ft/s)	Test to Use	Bypass Fraction	Bypass fraction with 10% Increase
15	5,545	0.341	2-762F-2H	35.9%	45.9%
45	5,545	0.341	2-762F-2H	35.9%	45.9%
127	7,635	0.409	5C-1025F-2H	56.1%	66.1%
175	7,635	0.293	4-630F-2H	10.2%	20.2%
220	7,635	0.409	5C-1025F-2H	56.1%	66.1%
250	7,635	0.416	5C-1025F-2H	56.1%	66.1%
298	5,545	0.569	NA	56.1%	66.1%
330	5,545	0.304	4-630F-2H	10.2%	20.2%

Note that if there is sufficient TKE near the interceptors to lift debris up and over the interceptor, all debris would transport up and over the interceptor. In these cases, a bypass fraction of 100% is applied except as noted below.

For Region II breaks (>17"), fine debris was assumed to be retained on the interceptors in the annulus. To calculate the amount of fines that transport during recirculation for these breaks, only 75% of the retention fraction determined during testing was applied at each interceptor. For breaks inside the bioshield, all flow and debris in the bioshield was forced through the annulus DIs.

Debris Interceptor Testing Discussion

There were two types of tests run on debris interceptors to determine how much debris the debris interceptors would retain: the Bioshield Interceptor Tests and the Annulus Interceptor Tests.

For both tests, shredded Nukon fiber was used as the fibrous debris. The debris was all finely shredded, no large or intact pieces were tested. The debris was shredded by the manufacturer (PCI) as fines and small pieces. The fiber was wet prior to addition for both tests. No tests were conducted with the debris interceptors fully blocked.

Bioshield Interceptor Tests

The Bioshield Interceptor Tests tested how much debris would be retained within the bioshield area. During the recirculation phase, the amount of debris that exits the bioshield through the open bioshield doorway or gets trapped by a debris interceptor was determined. Figure 3.e.4-1 illustrates the schematic of the test setup for the bioshield debris interceptor testing. The overall diameter of the containment model was 18' (about 1/8 scale).

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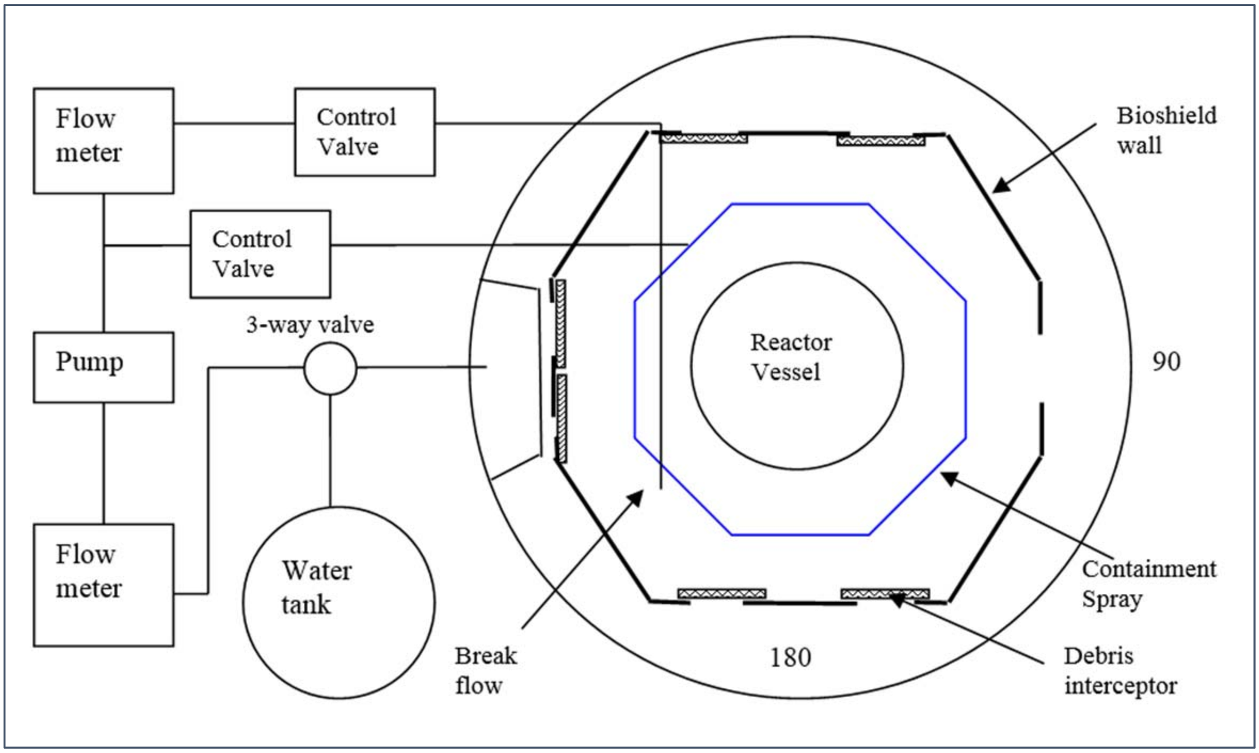

Figure 3.e.4-1: Schematic of test setup showing a break at 225° (other break locations were also modeled)

To start the test, finely shredded fiberglass was spread uniformly over a 180° section of the area inside the bioshield centered on the break location. Then the flow was started using the external water tank as the water source. Once the water level reached the desired water height, then the 3-way valve was switched to pull suction from the test facility. Testing continued until the rate at which fiber left the bioshield area was less than or equal to 0.01 lb per hour of wet fiber. After the test the fiber that remained in the bioshield was dried and weighed as was the fiber that left the bioshield. Debris that remained in the annulus even if it did not reach the screens surrounding the sump in the annulus was also counted as transporting.

The results for the bioshield debris interceptor testing are summarized in Table 3.e.4-3.

Table 3.e.4-3: Bioshield Debris Interceptor Testing Results

Run No.	Break Flow Rate (gpm)	CS Flow Rate (gpm)	Debris Location	Break Flow Location	Initial Fiber in Bioshield (lbs)	Final Fiber in Bioshield (lbs)	Transport Percentage (%)
2-S2-1T	142	94	135-315°	225°	31.9	15.6	51
2A-S2-1T	145	0	135-315°	225°	31.9	15.7	51
1-S3-1T	140	22	45-225°	135°	37.5	11.4	70
3-S3-2T	229	37	45-225°	135°	37.5	17.6	53

Note that this data was not used in the transport analysis. The debris interceptors in the bioshield were assumed to be completely blocked in the CFD model, forcing all flow to exit out of the open east doorway into the annulus.

Annulus Interceptor Tests

The Annulus Interceptor Tests evaluated how much debris an annulus debris interceptor can capture and retain as a function of flow rate.

This test had two phases. The first phase determined how much fiber the debris interceptor would retain by adding debris until the debris bed behind the interceptor increased in bed length and height by less than 1/8” in an hour. The second phase examined how much debris, if any, is removed from the bed formed behind the annulus debris interceptors by the water flow. The second phase of testing continued until the rate of fiber erosion was less than or equal to 0.01 lb_m per hour.

The Annulus Interceptor Tests were conducted at water velocity representative of the plant in a 2-ft wide x 6-ft high x 20-ft long flume. Since the tested water height was less than the currently expected water level, there is a potential that some additional fines would transport over the debris interceptor. In consideration of this, a reduction in the assumed hold-up of fines was taken, as was discussed earlier in this section. The facility is shown schematically in Figure 3.e.4-2.

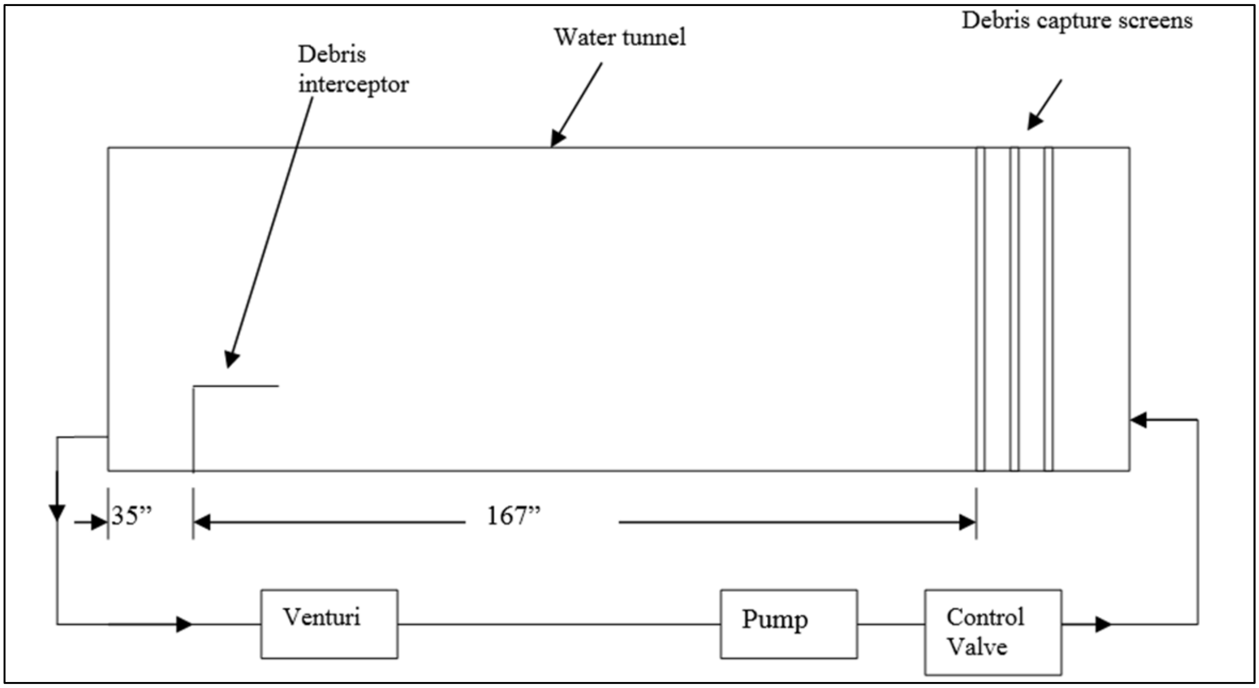

Figure 3.e.4-2: Schematic of Annulus Debris Interceptor Test Facility

The debris interceptor spanned the entire 2-foot width of the flume. Debris was added just downstream of the debris capture screens. One test was run with particulate (10-micron silicon carbide) in combination with the fiber. Typically, fiber additions were batched in one pound increments.

The tests were repeated at debris interceptor approach flow rates of 370, 500, 630, 760, and 1,025 gpm for the 2-foot wide test article.

The applicable results for the annulus debris interceptor testing are summarized in Table 3.e.4-4. Note that the installed debris interceptors at Seabrook vary in height from 14 to 18 inches (see the Response to 3.l), which is equal to or shorter than the tested heights.

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Table 3.e.4-4: Annulus Debris Interceptor Testing Results

Test	Flow Rate (gpm)	Water Depth (ft)	DI Height (in)	Mass Fiber Added (lbm)	Mass Behind DI (lbm)	Mass Bypass DI (lbm)	Eroded Fiber Mass (lbm)	Mass Un-accounted for (lbm)	Remarks
5C-1025F-2H	1025	2.21	18	18.0	7.905	9.955	0.0075	0.13	
1-370F-5H	370	5.25	18	3.0	2.835	0.054	N/A	0.11	
2-762F-2H	760	2.21	18	15.0	9.610	5.420	0.0118	(0.03)	
6-500F-2H	500	2.21	18	46.0	36.15	9.800	0.0028	0.05	
7-762F-2H OBST	760	2.21	18	10.0	1.065	8.840	N/A	0.10	A 12” diameter obstacle 12” upstream of DI
4-630F-2H	630	2.21	18	54.0	48.500	5.250	0.0022	0.25	
3-762F-2H-P	760	2.21	18	15	13.900	1.050	0.0022	0.05	Similar to 2-762F-2H but w/ particulate added

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

Response to 3.e.5:

No credit was taken for settling of fine debris.

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

Response to 3.e.6:

The following debris transport fractions are shown for blowdown, washdown, pool fill, and recirculation. Note that these fractions result in the bounding quantity of debris transported to the strainer. Cells with a “-“ in the tables of this subsection represent values that are not applicable (i.e., debris type not generated for a specific location, debris type not available for washdown/pool-fill, etc.).

Blowdown Transport

Table 3.e.6-1 shows the bounding blowdown transport fractions (the minimum amount of debris remaining in the compartment) as a function of break location and debris type. Note that only the limiting break locations with respect to the maximum overall debris transport fractions are listed in these tables. Also, RMI exists solely on the reactor vessel and would only become a source of debris for a break at a reactor nozzle. It was assumed that any RMI that is generated from a reactor nozzle break

would fall to the reactor cavity floor and would not transport to the sump strainers. Hence, RMI is not listed in the tables in this section. Additionally, it was assumed that neither Microtherm nor Temp-Mat would become debris sources (see the Responses to 3.b.1 and 3.c.1).

Table 3.e.6-1: Blowdown Transport Fractions

Break Location	Debris Type	Transport Fraction		
		To UC	To LC	Remaining in Compartment
Steam Generator Compartments	Fines/Particulate (all)	78%	22%	0%
	Nukon Small Pieces	45%	55%	0%
	Nukon Large Pieces	20%	80%	0%
	Nukon Intact Blankets	0%	0%	100%
	Qualified Coatings	78%	22%	0%
	Unqualified Coatings	-	-	-
	Latent Debris	-	-	-
Reactor Cavity	Fines/Particulate (all)	78%	22%	0%
	Nukon Small Pieces	45%	55%	0%
	Nukon Large Pieces	20%	80%	0%
	Nukon Intact Blankets	0%	0%	100%
	Qualified Coatings	78%	22%	0%
	Unqualified Coatings	-	-	-
	Latent Debris	-	-	-
Pressurizer Compartment	Fines/Particulate (all)	78%	22%	0%
	Nukon Small Pieces	76%	21%	3%
	Nukon Large Pieces	40%	15%	45%
	Nukon Intact Blankets	0%	0%	100%
	Qualified Coatings	78%	22%	0%
	Unqualified Coatings	-	-	-
	Latent Debris	-	-	-

Washdown Transport

Table 3.e.6-2 shows the bounding washdown transport fractions (maximum amount of debris washed to lower containment) as a function of containment spray activation and debris type. Note that these transport fractions do not depend on the location of the break.

Table 3.e.6-2: Washdown Transport Fractions

Debris Type	Transport Fraction		
	Washed Down in Annulus	Washed Down Through Steam Generator Comps	Washed Down RFC Drains
Fines/Particulate (all)	81%	9%	10%
Small Nukon	70%	8%	0%
Large Nukon	0%	7%	0%
Intact Nukon Blankets	-	-	-
Qualified Coatings	81%	9%	10%
Unqualified Coatings	-	-	-
Latent Debris	-	-	-

Pool-Fill Transport

Since a 6-inch high steel curb surrounds the ECCS sump cavity, the pool level would have to reach the 6-inch elevation before it would begin to fill. Before this time, the curbing would prevent the turbulent, sheeting-type flow from carrying debris into the ECCS sump cavity. Once the pool level reaches the 6-inch height necessary to begin filling the ECCS sump cavity, the pool would be less turbulent. All debris-laden break flow would also have to pass through a minimum of two debris interceptors before it could reach the ECCS sump cavity. Given the previous, along with the fact that any debris-laden break flow has a long, torturous path to the ECCS sump cavity, a minimal quantity of debris would travel to the ECCS sump cavity. Based upon this information, a 2% transport fraction to the ECCS sump cavity was used (1% to each strainer).

For cases of single train failure, the inactive sump would be an inactive cavity. The transport to the active sump would be 1% and the transport to inactive cavities would be limited to 15% (1% to the inactive sump, and 14% to the reactor cavity), as limited to 15% by Section 3.6.3 of the SER (Reference 7).

Once the ECCS sump cavity fills, the water level would have to rise to a level of 2'-6" to the top of the curb surrounding the reactor cavity. The volume of the reactor cavity plus the 2'6" water level inside the curb was calculated to be 13,893 ft^3, and the pool volume at 2'-6" was calculated to be 30,040 ft^3. Of the remaining 98% of debris (100% minus 2% transport to both of the sump strainers), the transport fraction to the inactive reactor cavity during pool fill-up was calculated to be 37% (limited to 15% by Section 3.6.3 of the SER (Reference 7)).

Table 3.e.6-3 shows the bounding (minimum) pool fill transport fractions as a function of debris type for two train operation.

Table 3.e.6-3: Pool fill Transport Fractions (Two Trains Operational)

Debris Type	Pool Fill Transport Fraction		
	Sump A	Sump B	Reactor Cavity
Fines/Particulate (all)	1%	1%	15%
Small Nukon	0%	0%	0%
Large Nukon	0%	0%	0%
Qualified Coatings	1%	1%	15%
Unqualified Coatings	0%	0%	0%
Latent Debris	1%	1%	15%

Table 3.e.6-4: Pool fill Transport Fractions (One Train Operational)

Debris Type	Pool Fill Transport Fraction	
	Active Sump	Inactive Cavities (Inactive Sump & Reactor Cavity
Fines/Particulate (all)	1%	15%
Small Nukon	0%	0%
Large Nukon	0%	0%
Qualified Coatings	1%	15%
Unqualified Coatings	0%	0%
Latent Debris	1%	15%

Recirculation Transport

For the recirculation transport fractions, four different break cases form the basis for the debris transport analysis, and were evaluated for Seabrook:

- Case 1: LBLOCA in SG Compartment Loop 1, Two Trains Operational
- Case 2: LBLOCA in SG Compartment Loop 3, Two Trains Operational
- Case 3: LBLOCA in SG Compartment Loop 3, Two Trains Operational, One CBS pump failure
- Case 4: LBLOCA in SG Compartment Loop 3, One Train Operational

It was assumed that for any breaks that could occur in the reactor cavity or in the pressurizer compartment, the recirculation transport fractions for a break inside the bioshield (Loop 1 or Loop 3 for a reactor cavity break, and Loop 3 for a pressurizer break) could be applied.

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The bounding (maximum) recirculation transport fractions for Nukon small and large debris as a function of evaluation case are shown in Table 3.e.6-5. For Region I, no credit was taken for the settling of fine debris, so the recirculation transport fraction for fine Nukon, qualified coatings, unqualified coatings, and latent debris are 100% transport during recirculation for all cases. See Response to 3.e.4 for Region II credit of debris interceptors.

See the Response to 3.e.1 for the methodology used for recirculation transport. Note that the recirculation transport fractions for small and large debris for Region II breaks is the same as Region I breaks, so only the fine debris recirculation transport fraction is presented for Region II breaks in the table below.

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Table 3.e.6-5: Recirculation Transport Fractions for Nukon Debris

Case	Region	Debris Size	Debris in Lower Containment		Debris Washed in Bioshield		Debris Washed in Annulus	
			Sump A	Sump B	Sump A	Sump B	Sump A	Sump B
1	I & II	Small	7.5%	7.5%	1.5%	1.5%	28.5%	28.5%
		Large	0%	0%	-	-	-	-
2	I & II	Small	6%	6%	3%	3%	27.5%	27.5%
		Large	0%	0%	-	-	-	-
3	I & II	Small	2%	1%	3%	1%	17%	9%
		Large	0%	0%	-	-	-	-
4	I & II	Small	3%	-	4%	-	25%	-
		Large	0%	-	-	-	-	-
1	II	Fine	6.8%	6.8%	6.8%	6.8%	24.3%	24.3%
2	II	Fine	6.8%	6.8%	6.8%	6.8%	24.3%	24.3%
3	II	Fine	9.1%	4.5%	9.1%	4.5%	32.5%	16%
4/II	II	Fine	13.6%	-	13.6%	-	48.6%	-

Overall Debris Transport

Transport logic trees were developed for each size and type of debris generated. These trees were used to determine the total fraction of debris that would reach the sump strainers in each of the postulated cases. The overall transport fractions are provided in Table 3.e.6-6 through Table 3.e.6-8. Note that transport fractions specific to the Region II analysis are only presented for breaks inside the bioshield. Region II transport fractions for reactor cavity breaks are not needed because the reactor vessel is insulated with Transco RMI and these breaks are not limiting (See the Response to 3.b.1). Region II transport fractions for breaks within the pressurizer compartment are not needed because no Region II breaks occur in the pressurizer compartment.

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Table 3.e.6-6: Overall Transport Fractions for a Break inside the Bioshield

Debris Type		1 Train		2 Train			Single CBS Pump Failure		
		Alpha	Bravo	Alpha	Bravo	Total	Alpha	Bravo	Total
Fine Nukon (Region I)		97%	97%	48%	48%	96%	65%	32%	97%
Fine Nukon (Region II)		36%	36%	18%	18%	36%	24%	12%	36%
Small Nukon	Transport as Erosion Fines	9%	9%	5%	5%	10%	6%	3%	9%
	Transport as Small Pieces	9%	9%	12%	12%	24%	6%	3%	9%
Large Nukon	Transport as Erosion Fines	8%	8%	4%	4%	8%	6%	3%	9%
	Transport as Large Pieces	0%	0%	0%	0%	0%	0%	0%	0%
Intact Nukon Blankets		0%	0%	0%	0%	0%	0%	0%	0%
Qualified Epoxy		97%	97%	48%	48%	96%	65%	32%	97%
Unqualified Epoxy		100%	100%	50%	50%	100%	67%	33%	100%
Unqualified IOZ		100%	100%	50%	50%	100%	67%	33%	100%
Latent Debris, Dirt/Dust		85%	85%	43%	43%	86%	57%	28%	85%

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Table 3.e.6-7: Overall Transport Fractions for a Reactor Cavity Break

Debris Type		1 Train		2 Train			Single CBS Pump Failure		
		Alpha	Bravo	Alpha	Bravo	Total	Alpha	Bravo	Total
Fine Debris		100%	100%	50%	50%	100%	67%	33%	100%
Small Nukon	Transport as Erosion Fines	10%	10%	5%	5%	10%	6%	3%	9%
	Transport as Small Pieces	4%	4%	6%	6%	12%	3%	2%	5%
Large Nukon	Transport as Erosion Fines	10%	10%	5%	5%	10%	7%	3%	10%
	Transport as Large Pieces	0%	0%	0%	0%	0%	0%	0%	0%
Intact Nukon Blankets		0%	0%	0%	0%	0%	0%	0%	0%
Qualified Epoxy		97%	97%	48%	48%	96%	65%	32%	97%
Unqualified Epoxy		100%	100%	50%	50%	100%	67%	33%	100%
Unqualified IOZ		100%	100%	50%	50%	100%	67%	33%	100%
Latent Debris, Dirt/Dust		85%	85%	43%	43%	86%	57%	28%	85%

Table 3.e.6-8: Overall Transport Fractions for a Pressurizer Compartment Break

Debris Type		1 Train		2 Train			Single CBS Pump Failure		
		Alpha	Bravo	Alpha	Bravo	Total	Alpha	Bravo	Total
Fine Debris		97%	97%	48%	48%	96%	65%	32%	97%
Small Nukon	Transport as Erosion Fines	8%	8%	4%	4%	8%	5%	3%	8%
	Transport as Small Pieces	13%	13%	15%	15%	30%	9%	5%	14%
Large Nukon	Transport as Erosion Fines	2%	2%	1%	1%	2%	2%	1%	3%
	Transport as Large Pieces	0%	0%	0%	0%	0%	0%	0%	0%
Intact Nukon Blankets		0%	0%	0%	0%	0%	0%	0%	0%
Qualified Epoxy		97%	97%	48%	48%	96%	65%	32%	97%
Unqualified Epoxy		100%	100%	50%	50%	100%	67%	33%	100%
Unqualified IOZ		100%	100%	50%	50%	100%	67%	33%	100%
Latent Debris, Dirt/Dust		85%	85%	43%	43%	86%	57%	28%	85%

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The transported debris quantities for the most limiting break cases identified in the Response to 3.b.4 are presented below. Overall debris transport fractions were taken from Table 3.e.6-6 for two train operation for Region I breaks. Overall transport values for Region II breaks were calculated separately. These values were then applied to the debris generated values for Regions I and II from Table 3.b.4-2 and Table 3.b.4-1, respectively. Note that the overall transport values developed for a DEGB are bounding for all other breaks (including partial breaks) because the flow rates and water level used for the transport analysis are bounding (maximum flow rates and minimum water levels).

Table 3.e.6-9, Table 3.e.6-10, and Table 3.e.6-11 show the quantities of debris transported for the most limiting Region I break cases for Seabrook for two train operation, single train operation, and single CBS failure, respectively. Note that the transported amount of fine debris includes the quantity of fines plus the fines generated due to erosion of small and large pieces.

Table 3.e.6-9: Transported Debris for the Worst-Case Fiber Breaks (Limiting Region I Breaks) for Two Train Operation

<table>
<tr><th colspan="2">Break Location</th><th colspan="2">RC 0010 01 02</th><th colspan="2">RC 0001 01 02</th></tr>
<tr><td colspan="2">Location Description</td><td colspan="2">Loop 4 Hot Leg at Elbow</td><td colspan="2">Loop 1 Hot Leg at Elbow</td></tr>
<tr><td colspan="2">Break Size</td><td colspan="2">17"</td><td colspan="2">17"</td></tr>
<tr><td colspan="2">Break Type</td><td colspan="2">Partial (Angle – 45°)</td><td colspan="2">Partial (Angle – 315°)</td></tr>
<tr><td rowspan="4">Nukon (lbm)</td><td>Fine</td><td colspan="2">274.47</td><td colspan="2">273.78</td></tr>
<tr><td>Small</td><td colspan="2">134.79</td><td colspan="2">135.11</td></tr>
<tr><td>Large</td><td colspan="2">0.00</td><td colspan="2">0.00</td></tr>
<tr><td>Intact</td><td colspan="2">0.00</td><td colspan="2">0.00</td></tr>
<tr><td rowspan="2">Transco RMI (ft^2)</td><td>Small (<4”)</td><td colspan="2">0.00</td><td colspan="2">0.00</td></tr>
<tr><td>Large (≥ 4”)</td><td colspan="2">0.00</td><td colspan="2">0.00</td></tr>
<tr><td>K&L #6548</td><td>Fine</td><td>4.90 lbm</td><td>0.04 ft^3</td><td>4.90 lbm</td><td>0.04 ft^3</td></tr>
<tr><td>K&L #D-1 / K&L E-1</td><td>Fine</td><td>2.94 lbm</td><td>0.03 ft^3</td><td>2.94 lbm</td><td>0.03 ft^3</td></tr>
<tr><td>K&L #4000</td><td>Fine</td><td>0.43 lbm</td><td>0.00 ft^3</td><td>0.43 lbm</td><td>0.00 ft^3</td></tr>
</table>

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Table 3.e.6-10: Transported Debris for the Worst-Case Fiber Breaks (Limiting Region I Breaks) for Single Train Operation

Break Location		**RC 0010 01 02**		**RC 0001 01 02**	
Location Description		Loop 4 Hot Leg at Elbow		Loop 1 Hot Leg at Elbow	
Break Size		17"		17"	
Break Type		Partial (Angle – 45°)		Partial (Angle – 315°)	
Nukon (lbm)	Fine	270.70		270.00	
	Small	50.55		50.67	
	Large	0.00		0.00	
	Intact	0.00		0.00	
Transco RMI (ft^2)	Small (<4”)	0.00		0.00	
	Large (≥ 4”)	0.00		0.00	
K&L #6548	Fine	4.95 lbm	0.04 ft^3	4.95 lbm	0.04 ft^3
K&L #D-1 / K&L E-1	Fine	2.97 lbm	0.03 ft^3	2.97 lbm	0.03 ft^3
K&L #4000	Fine	0.44 lbm	0.00 ft^3	0.44 lbm	0.00 ft^3

Table 3.e.6-11: Transported Debris for the Worst-Case Fiber Breaks (Limiting Region I Breaks) for Single CBS Failure

Break Location		**RC 0010 01 02**		**RC 0001 01 02**	
Location Description		Loop 4 Hot Leg at Elbow		Loop 1 Hot Leg at Elbow	
Break Size		17"		17"	
Break Type		Partial (Angle – 45°)		Partial (Angle – 315°)	
Nukon (lb)	Fine	275.80		275.03	
	Small	50.55		50.67	
	Large	0.00		0.00	
	Intact	0.00		0.00	
Transco RMI (ft^2)	Small (<4”)	0.00		0.00	
	Large (≥ 4”)	0.00		0.00	
K&L #6548	Fine	4.95 lbm	0.04 ft^3	4.95 lbm	0.04 ft^3
K&L #D-1 / K&L E-1	Fine	2.97 lbm	0.03 ft^3	2.97 lbm	0.03 ft^3
K&L #4000	Fine	0.44 lbm	0.00 ft^3	0.44 lbm	0.00 ft^3

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Table 3.e.6-12, Table 3.e.6-13, and Table 3.e.6-14 show the quantities of debris transported for the most limiting Region II break cases for Seabrook for two train operation, single train operation, and single CBS failure, respectively. Note that the transported amount of fine debris includes the quantity of fines plus the fines generated due to erosion of small and large pieces.

Table 3.e.6-12: Transported Debris for the Worst-Case Fiber Breaks (Limiting Region II Breaks) for Two Train Operation

Break Location		**RC 0007 01 03**		**RC 0001 01 03**	
Location Description		Loop 3 Hot Leg at SG Nozzle		Loop 1 Hot Leg at SG Nozzle	
Break Size		31"		31"	
Break Type		DEGB		DEGB	
Nukon (lb)	Fine	620.68		626.42	
	Small	598.39		635.72	
	Large	0.00		0.00	
	Intact	0.00		0.00	
Transco RMI (ft^2)	Small (<4")	0.00		0.00	
	Large (≥ 4")	0.00		0.00	
K&L #6548	Fine	87.38 lbm	0.62 ft^3	38.41 lbm	0.27 ft^3
K&L #D-1 / K&L E-1	Fine	57.78 lbm	0.52 ft^3	28.85 lbm	0.26 ft^3
K&L #4000	Fine	53.91 lbm	0.46 ft^3	53.67 lbm	0.46 ft^3

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Table 3.e.6-13: Transported Debris for the Worst-Case Fiber Breaks (Limiting Region II Breaks) for Single Train Operation

Break Location		**RC 0007 01 03**		**RC 0001 01 03**	
Location Description		Loop 3 Hot Leg at SG Nozzle		Loop 1 Hot Leg at SG Nozzle	
Break Size		31"		31"	
Break Type		DEGB		DEGB	
Nukon (lb)	Fine	595.75		599.93	
	Small	224.40		238.39	
	Large	0.00		0.00	
	Intact	0.00		0.00	
Transco RMI (ft^2)	Small (<4”)	0.00		0.00	
	Large (≥ 4”)	0.00		0.00	
K&L #6548	Fine	88.29 lbm	0.63 ft^3	38.81 lbm	0.27 ft^3
K&L #D-1 / K&L E-1	Fine	58.38 lbm	0.52 ft^3	29.15 lbm	0.26 ft^3
K&L #4000	Fine	54.48 lbm	0.47 ft^3	54.23 lbm	0.47 ft^3

Table 3.e.6-14: Transported Debris for the Worst-Case Fiber Breaks (Limiting Region II Breaks) for Single CBS Failure

Break Location		**RC 0007 01 03**		**RC 0001 01 03**	
Location Description		Loop 3 Hot Leg at SG Nozzle		Loop 1 Hot Leg at SG Nozzle	
Break Size		31"		31"	
Break Type		DEGB		DEGB	
Nukon (lb)	Fine	608.94		610.98	
	Small	224.40		238.39	
	Large	0.00		0.00	
	Intact	0.00		0.00	
Transco RMI (ft^2)	Small (<4”)	0.00		0.00	
	Large (≥ 4”)	0.00		0.00	
K&L #6548	Fine	88.29 lbm	0.63 ft^3	38.81 lbm	0.27 ft^3
K&L #D-1 / K&L E-1	Fine	58.38 lbm	0.52 ft^3	29.15 lbm	0.26 ft^3
K&L #4000	Fine	54.48 lbm	0.47 ft^3	54.23 lbm	0.47 ft^3

The quantity of latent debris that transports to the sump strainers for all breaks (Region I and Region II) is 72.25 lbm latent particulate and 12.75 lbm (5.3125 ft^3)

latent fiber for the single train and single CBS failure cases, and 73.1 lbm latent particulate and 12.9 lbm (5.375 ft^3) latent fiber for the two-train case.

f. Head Loss and Vortexing

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.

1. *Provide a schematic diagram of the emergency core cooling system (ECCS) and containment spray systems (CSS).*

Response to 3.f.1:

See Figure 3.f.1-1 for the ECCS and CBS schematic of Seabrook.

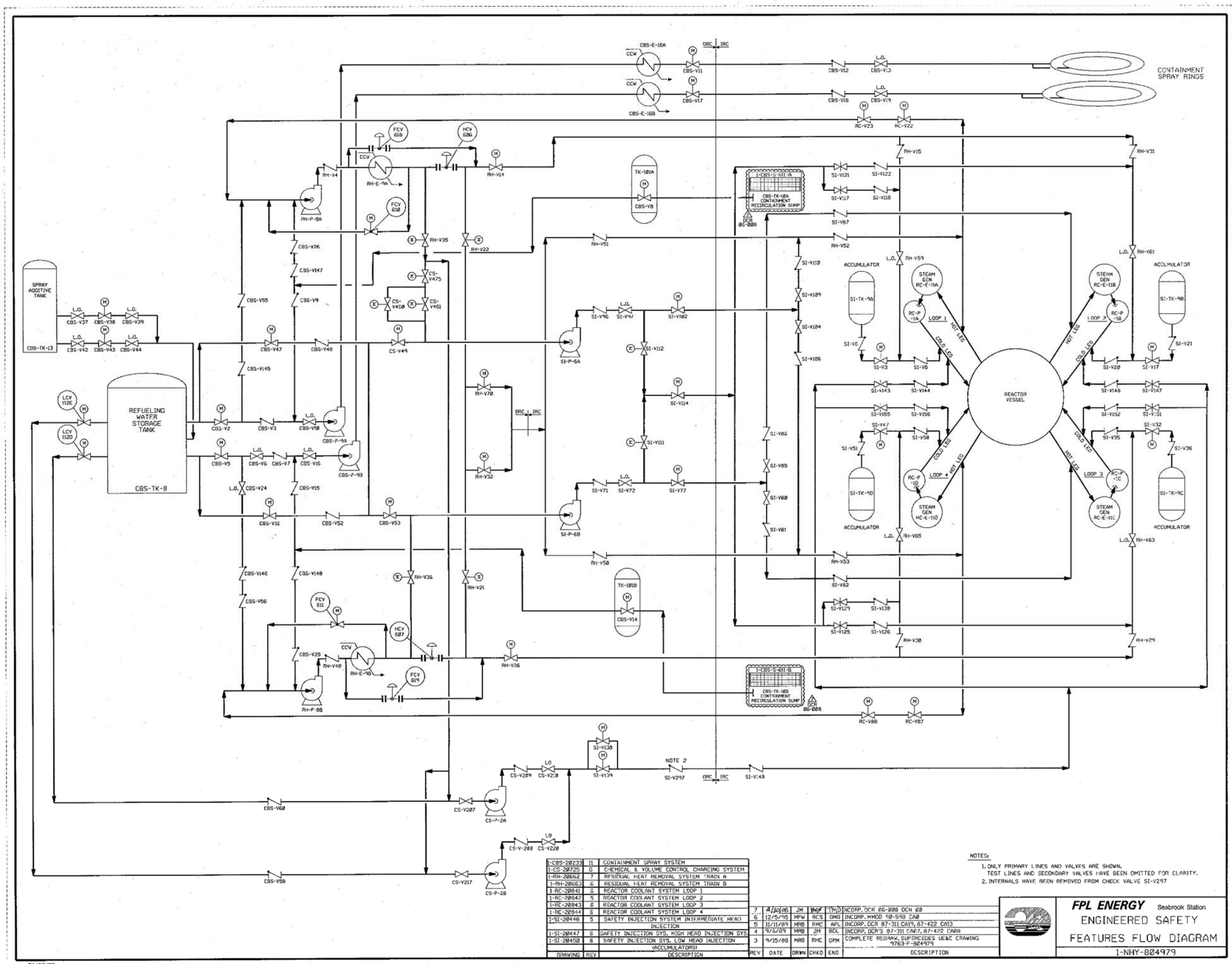

Figure 3.f.1-1 Seabrook Emergency Core Cooling System and Containment Building Spray System Schematic

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

Response to 3.f.2:

See the Response to 3.g.1 for the minimum submergence of the strainers due to an SBLOCA and LBLOCA.

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

Response to 3.f.3:

The maximum flow rate through the strainer is 8,045 gpm and occurs when the RHR pump on the opposite train is assumed to trip. The 8,045 gpm total strainer flow rate includes an RHR pump flow rate of 4,388 gpm and a CBS pump flow rate of 3,657 gpm, which corresponds to an average approach velocity of 0.00775 ft/s for a total net strainer area of 2,312 ft^2. This total net strainer area was calculated by deducting 100 ft^2 from the actual strainer surface area to account for the effect of miscellaneous debris, such as labels and tags. As shown in the Response to 3.g.1, the minimum water level results in a strainer submergence of 9.12 inches at recirculation.

Vortex testing was incorporated into the head loss test program described in the Response to 3.f.4. For each of the conventional debris only head loss tests, a clean screen vortex test was performed prior to addition of debris to the test tank. The strainer was submerged approximately 2.5 inches and vortexing was not observed under these conditions. During the debris introduction portions of the tests, the water level was maintained between 3 inches and 4 inches above the strainer. There were no visible signs of air ingestion during any of the tests. The nominal flow rate during the conventional debris only head loss testing was 451 gpm, which corresponds to an approach velocity of 0.00828 ft/s for a test strainer surface area of 121.343 ft^2.

Vortexing was not observed during the head loss test when the submergence of the clean strainer was below the plant’s minimum strainer submergence and vortexing was not recorded for the debris laden strainer throughout any of the tests. In addition, the vortexing test was performed at an approach velocity (0.00828 ft/s) which is greater than the approach velocity of the plant strainer (0.00775 ft/s), as shown above. Therefore, vortexing during sump recirculation is not a concern.

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

Response to 3.f.4:

Head loss tests were performed in 2008 to measure the head losses caused by conventional debris (fiber and particulate) and chemical precipitate debris generated and transported to the sump strainers following a LOCA. The test program used a test strainer and flow rates that were prototypical to the plant strainer.

Two sets of head loss tests were conducted: one set that evaluated the effects of both conventional and chemical debris and one set that evaluated the effects of conventional debris only. Each of the sets of head loss tests are described below.

<u>Fiber, Particulate, and Chemical Effects Testing</u>

Head loss tests were performed to measure the head losses caused by conventional debris (fiber and particulate) and chemical precipitate debris generated and transported to the sump strainers following a LOCA. The test program used a test strainer and flow rates that were prototypical to the plant strainer.

Test Setup

Seabrook has two separate and independent containment sump recirculation strainers, one to support Train A of the ECCS and CBS systems and one to support Train B. Each of the recirculation strainers use an arrangement of parallel, rectangular strainer disks that include perforated plates and woven wire mesh to capture debris. For a given strainer, the flow through each section of strainer disks is combined in a plenum at the base of the disks, where it flows to the “dog house”, where the ECCS suction pipe is located. Both of the recirculation strainers are located in a sump, with the top of the disks extending approximately two feet above the containment floor. The sump A strainer is shown below in Figure 3.f.4-1 and Figure 3.f.4-2.

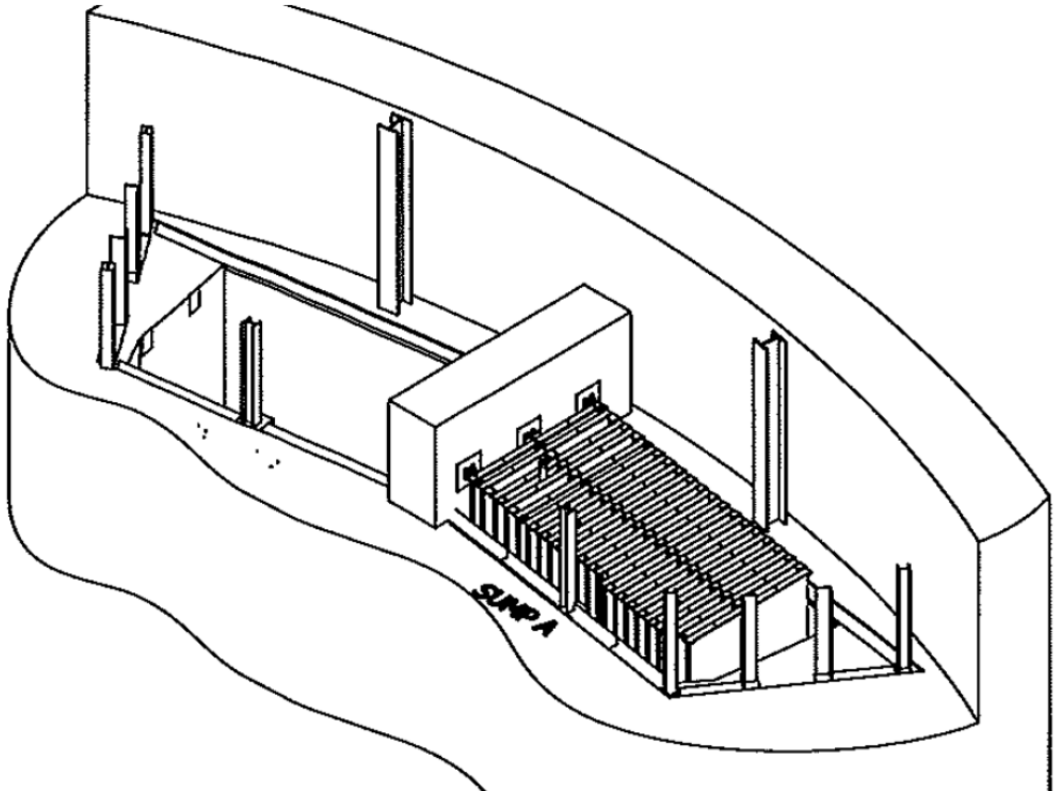

Figure 3.f.4-1: Sump A Strainer

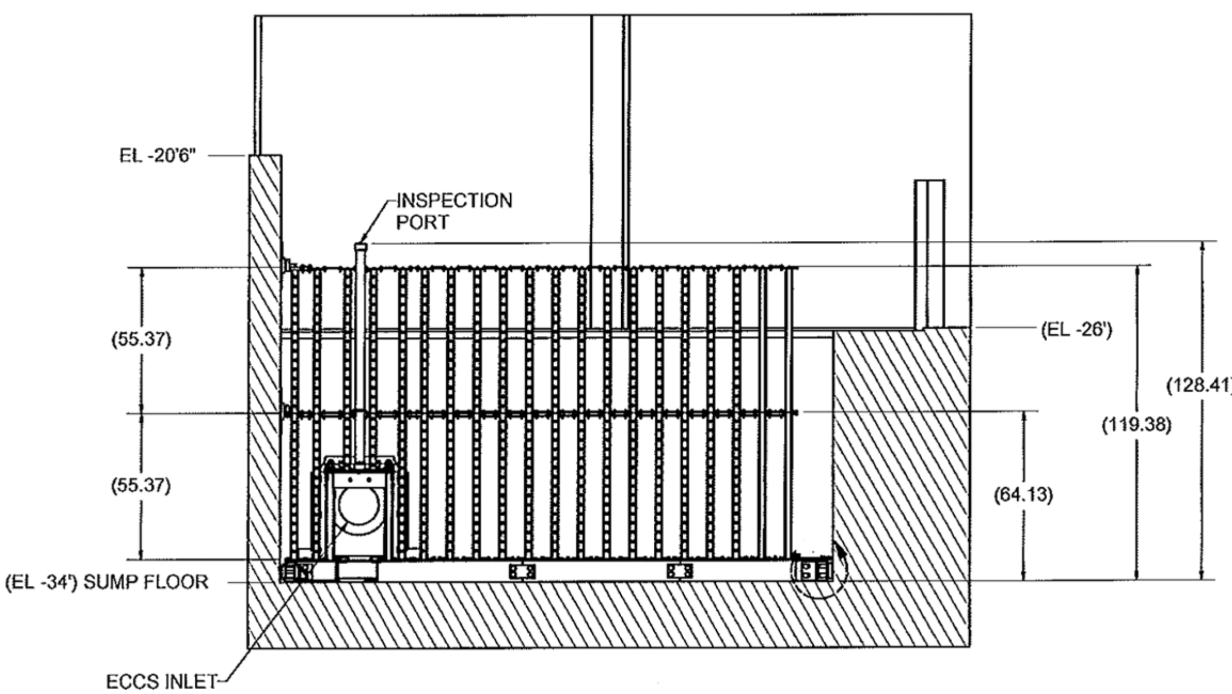

Figure 3.f.4-2: Sump A Strainer Elevation View

For head loss testing, the test strainer consisted of two full-scale strainer disks with the same characteristics as the strainer disks installed at Seabrook. The unobstructed surface area of the test strainer was 121.343 ft^2 (see the Response to 3.f.3). The test strainer was placed in a test tank such that suction was drawn from the bottom of the disks to simulate the plenum sitting on the sump floor. A mixing tank was modeled upstream of the test strainer, at a higher elevation, to simulate flow from the containment floor. The flow from the mixing tank enters the test strainer at an elevation prototypical of the containment floor.

A schematic piping diagram of the test loop is provided in Figure 3.f.4-3 below. The flow path for the test loop was from the mixing tank (where debris was introduced) to the test strainer, through the test strainer into the plenum, through the flow meter, pump, and control valve, and finally back into the mixing tank. As shown in Figures 3.f.4-3 and 3.f.4-4, the flow and debris was directed to the test strainer. The mixing tank was agitated to ensure debris transport to the test strainer. Agitation in the mixing tank was provided primarily by the return flow from the pump. Additional agitation was provided by two motor driven propeller agitators approximately three feet from the test strainer, as shown in Figure 3.f.4-5. This distance helped to ensure that the agitation did not affect the debris bed on the test strainer in a non-prototypical way. This was supported by observation of the flow into the test strainer, which was observed to be smooth and parallel.

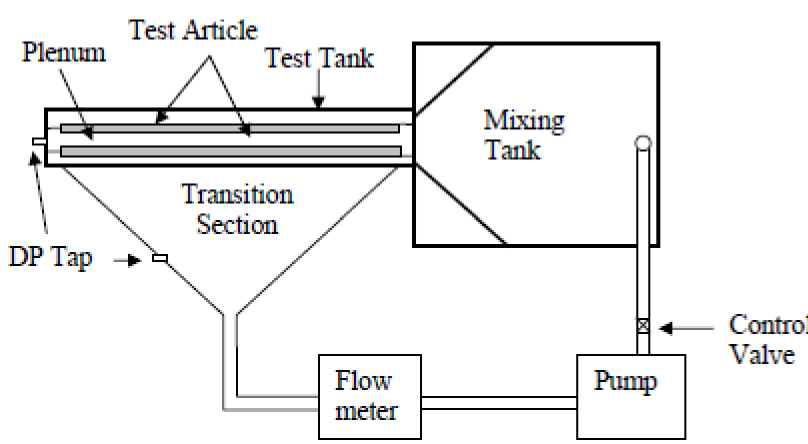

Figure 3.f.4-3: Schematic of Strainer Test Loop

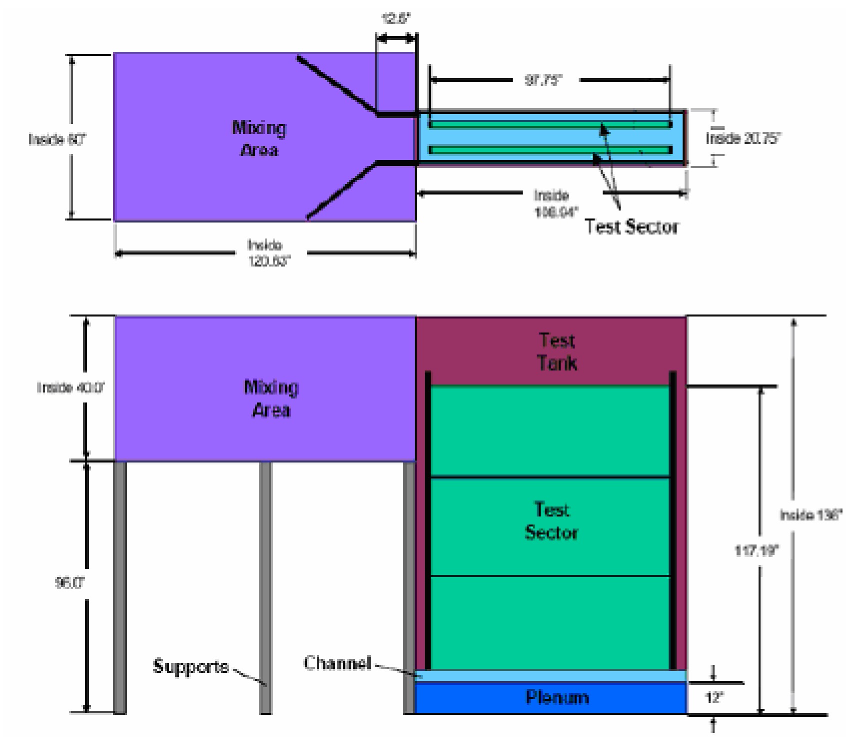

Figure 3.f.4-4: Plan View and Elevation View of Strainer Test Loop

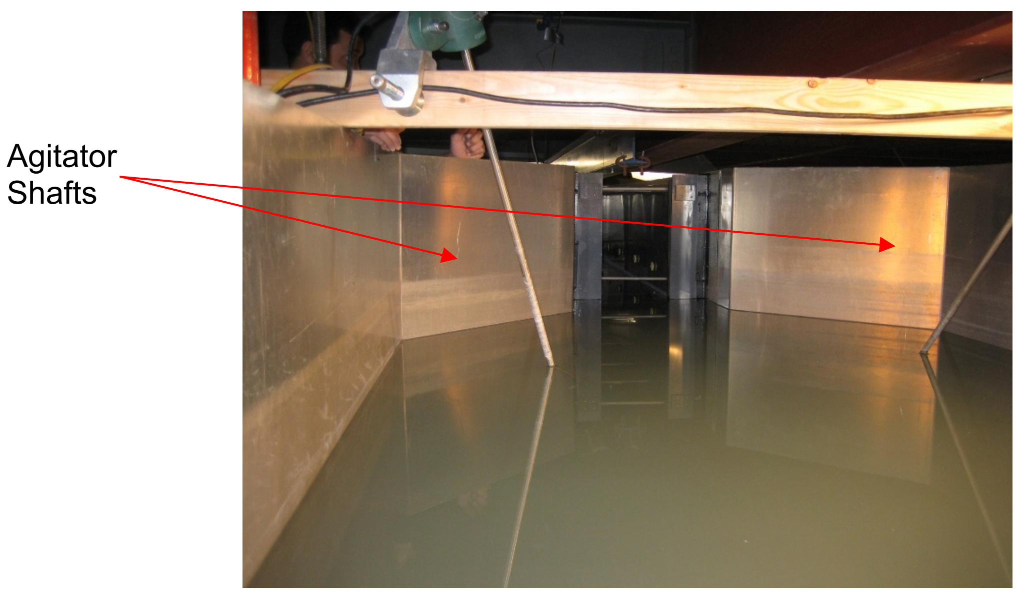

Figure 3.f.4-5: Photo Taken from Mixing Tank Looking into Test Strainer

Test Parameters and Scaling

The test strainer replicated the key hydraulic dimensions of the plant strainer disks, including perforated plate opening diameter and arrangement, wire cloth dimensions, and spacing between adjacent disks. The test debris quantities were scaled based on the calculated plant values at the time testing was performed. For additional discussion on how the tested debris loads were applied to the revised debris quantities, see the Response to 3.f.7. The debris quantities and test flow rate were scaled based on the ratio of the test strainer surface area (121.343 ft^2, as shown earlier in this section) to plant strainer net surface area (2,312 ft^2 for one strainer and 4,724 ft^2 for two strainers (see the Response to 3.f.3)). This ratio was calculated to be 0.0525 assuming single train operation (Region I analysis) and 0.0257 assuming two-train operation (Region II analysis). Note that a single failure is not assumed for Region II analyses. The test flow rate is 449 gpm and corresponds to a test strainer approach velocity of 0.00824 ft/sec, using the test strainer surface area shown above. This test approach velocity bounds the plant strainer average approach velocity of 0.00775 ft/sec (see the Response to 3.f.3).

Prior to adding debris, head loss data was obtained for the test strainer under clean screen conditions for each of the three tests.

Debris Materials and Preparation

Conventional debris consists of fiber and particulate debris from failed insulation and coatings, and latent materials that could be transported to the sump strainers following a LOCA. The conventional debris types that transport to the sump strainers include Nukon fibrous insulation, qualified and unqualified coatings, and latent debris. For head loss testing, Nukon was used to simulate Nukon blanket insulation and latent fiber, and silicon carbide was used to represent all coatings and latent particulate debris. The Nukon debris was purchased directly from Performance Contracting, Inc. (PCI), where it was shredded. Prior to use, it was shredded a second time by Continuum Dynamics, Inc. (CDI) . The shredded fines debris was then wetted prior to introduction into the test tank. Photos of the prepared debris, both shredded and after being wetted, are shown in Figure 3.f.4-6 and Figure 3.f.4-7 below.

Figure 3.f.4-6: Photograph of Dry Prepared Fiber

Figure 3.f.4-7: Photograph of Wetted Fiber used in Head Loss Testing

All fiber introduced during testing was prepared as described above. No prepared fiber smalls were used during testing.

The silicon carbide was acquired from Electro Abrasives, and was measured to have an average diameter of approximately 10 microns using a Helio particle size analyzer and a density of approximately 94 lbm/ft^3. The silicon carbide matches the bulk density and particle size of the majority of the coatings and is, therefore, acceptable to use as a surrogate for qualified and unqualified coatings. Similar to the fibrous debris, the particulate debris was wetted and made into a slurry prior to adding it to the test tank.

Aluminum oxyhydroxide (AlOOH) was used in the head loss testing to simulate chemical effects debris. The AlOOH was fabricated and tested based on the guidelines put forth in WCAP-16530-NP. The chemical effects debris was mixed for a minimum of 60 minutes prior to use. To determine if the debris was suitable for use in testing, two samples were taken. The first sample of AlOOH was tested by diluting the sample to 9.7 g/l and allowing the precipitate to settle for 60 minutes. If the turbid portion was more than 90% of the total height in a graduated cylinder, the simulated debris was suitable for use in testing. The second sample was tested by diluting the sample to 2.2 g/l and allowing the precipitate to settle for 60 minutes. For the simulated debris to be used in testing, the turbid portion could not be less than 40% of the total height in a graduated cylinder. If the debris did not pass both tests it was stirred and retested. More details on the acceptance testing and justification for using the prepared chemical debris surrogate in head loss testing is provided in Section 3.o.2.12 of the Response to 3.o, Chemical Effects.

Debris Introduction

As previously discussed, the shredded Nukon was wetted prior to introduction into the test. The wetted fiber was added directly to the mixing tank. Particulate debris was also made into a slurry and added directly to the mixing tank. Both the fibrous and particulate debris were weighed dry, prior to being wetted, and introduced into the test tank. The chemical debris was measured volumetrically and added as a liquid suspension directly to the test tank.

For all three head loss tests, the wetted particulate was introduced first. The particulate was added to the mixing tank at least four feet from the entrance of the test tank. After all of the particulate debris had been added, the wetted fibrous debris was added manually to the back of the mixing tank. All fiber was added within a 35-minute period.

Once the conventional debris had been added and the test had achieved a steady state, the chemical debris additions began. The chemical debris was added in seven batches. After each chemical batch addition, the test was allowed to achieve steady state prior to the introduction of the next batch. The test was considered to have reached steady state when the incremental change in head loss over a 30-minute period was less than or equal to 1% or 0.1 inch of water, whichever was greater. If the head loss was varying up and down, the average head loss was used to determine if the steady state criterion had been met.

No debris was observed to have settled in the mixing tank during the head loss testing.

Head Loss Test Cases and Results

The conventional debris loads for the three chemical effects head loss tests are summarized in Table 3.f.4-1 below and scaled to equivalent plant debris loads for both single train operation (Region I analysis) and two-train operation (Region II analysis). The debris loads are converted from test scale to plant scale by dividing the test scale quantities by the ratio of the test-scale strainer surface area to the plant-scale strainer surface area. The test strainer surface area was 121.343 ft^2 (see the Response to 3.f.3), and the sump strainer surface area is 2,412 ft^2 per train. After considering the sacrificial strainer area of 100 ft^2, these yield scaling factors of 0.0525 and 0.0257 for single train and two-train operation, respectively. The tested debris loads are divided by these scaling factors to calculate the plant-scale debris loads presented in the table below. Note that a single failure is not assumed for Region II analyses.

Table 3.f.4-1: Conventional Debris Loads for the Seabrook Head Loss Tests

Test	Single Train Operation		Two-Train Operation	
	Silicon Carbide (lbm)	Nukon (lbm)	Silicon Carbide (lbm)	Nukon (lbm)
S3-1S	1,514.3	312.38	3,093.4	638.13
S3-2S	3,026.7	121.90	6,182.9	249.03
S3-3S	3,026.7	57.14	6,182.9	116.73

After all conventional debris was added, the head loss was allowed to stabilize and chemical precipitate debris was added to the test tank. The chemical precipitate debris batches were identical for all three head loss tests. The chemical debris batches are summarized in Table 3.f.4-2 below and scaled to equivalent plant debris load. The tested debris loads are divided by the scaling factors discussed above to calculate the plant-scale chemical debris loads presented in the table below.

Table 3.f.4-2: Chemical Precipitate Debris Batches for the Seabrook Head Loss Tests

Batch Number	Single Train Operation		Two-Train Operation	
	AlOOH (gal)	AlOOH (kg)	AlOOH (gal)	AlOOH (kg)
1	1504.8	63.07	3073.9	128.84
2	742.9	31.10	1517.5	63.54
3	342.9	13.82	700.4	28.24
4	933.3	38.88	1906.6	79.42
5	1771.4	73.44	3618.7	150.02
6	1752.4	73.44	3579.8	150.02
7	1752.4	73.44	3579.8	150.02

Seabrook S3-1S Head Loss Test Results

For the first head loss test performed, Test S3-1S, the clean screen head loss was 0.4 inches, and the peak conventional debris head loss was 0.8 inches at 67 °F and 456 gpm (8,689 gpm strainer flow at plant scale).

Head loss increased relatively quickly when the first batch of chemicals was added to the test tank. However, after the head loss had stabilized, the magnitude of the increase in head loss observed for the following batches was substantially smaller. Eventually, additional batches did not result in higher head loss peaks. Figure 3.f.4-8 shows a plot of raw head loss test data for the S3-1S test with key testing activities identified. Note that the head loss values have not been adjusted to subtract the test strainer's clean screen head loss.

After the completion of chemical debris additions, the test pump was turned off for five minutes and then restarted. Upon restarting the pump, the head loss climbed above the stabilized value after the final chemical debris addition and eventually stabilized (using the criteria of an incremental head loss of less than or equal to 1% or 0.1 inch of water, whichever was greater, over a 30-minute period). Therefore, the head loss after the pump was restarted was taken as the peak chemical debris bed head loss. The peak chemical debris bed head loss observed during the test was 3.4 inches at 79 °F and 460 gpm.

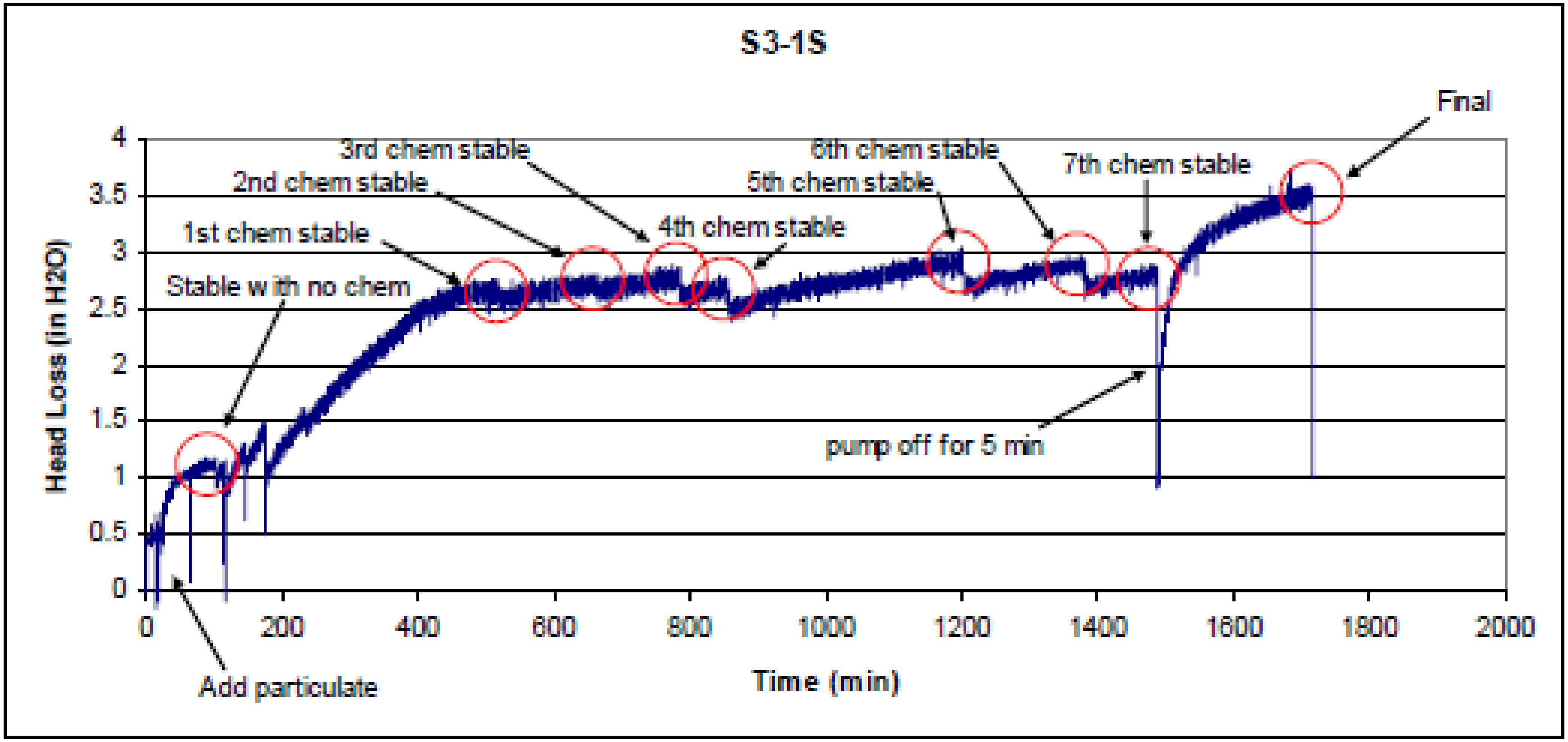

Figure 3.f.4-8: Seabrook S3-1S Head Loss Test Timeline

Seabrook S3-2S Head Loss Test Results

For the second head loss test performed, test S3-2S, the clean screen head loss was 0.6 inches, and the peak conventional debris head loss was 0.8 inches at 71 °F and 462 gpm (8,804 gpm strainer flow rate at plant scale).

After the first chemical debris batch addition, the head loss sharply decreased for a short period of time, and then increased gradually until it became stable. For all of the remaining chemical batches, a small gradual increase was observed before the head loss stabilized, but no new head loss peaks were observed. The head loss during the chemical debris additions did not exceed the peak conventional debris head loss. Figure 3.f.4-9 shows a plot of raw head loss test data for the S3-2S test with key testing activities identified. Note that the head loss values have not been adjusted to subtract the test strainer’s clean screen head loss.

After the completion of chemical debris additions, the test pump was turned off for five minutes and then restarted. Upon restarting the pump, the head loss climbed slightly above the stabilized value after the final chemical debris addition, but remained below the peak conventional debris head loss. Therefore, the conventional debris head loss, as reported above, is taken as the peak head loss.

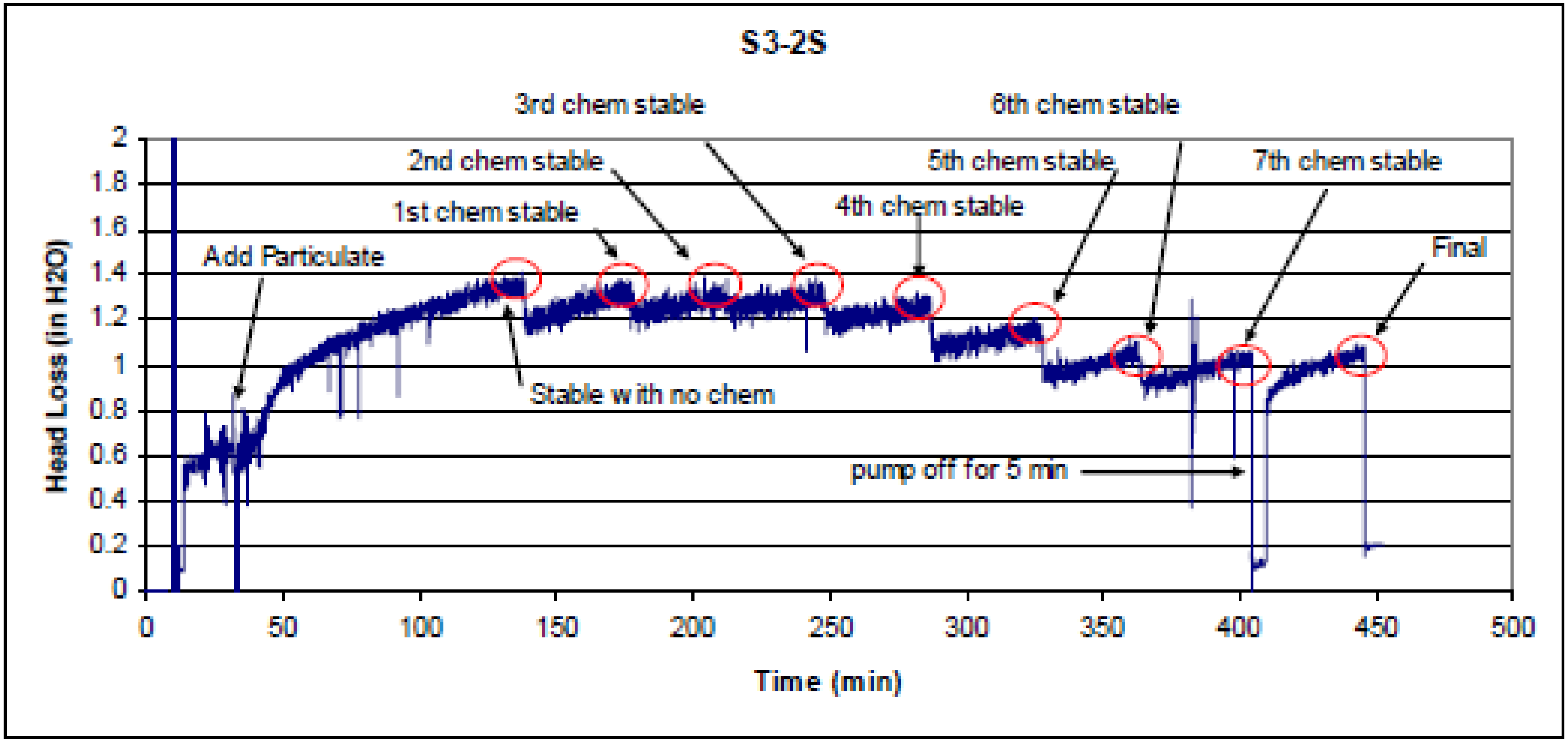

Figure 3.f.4-9: Seabrook S3-2S Head Loss Test Timeline

Seabrook S3-3S Head Loss Test Results

For the final head loss test performed, test S3-3S, the clean screen head loss was 0.5 inches, and the peak conventional debris head loss was 0.5 inches at 67 °F and 461 gpm (8,785 gpm at plant scale).

Head loss increased relatively quickly when the first batch of chemicals was added to the test tank. However, after the head loss had stabilized, the magnitude of the increase in head loss observed for the following batches was substantially smaller. Eventually, additional batches did not result in higher head loss peaks. Figure 3.f.4-10 shows a plot of raw head loss test data for the S3-3S test with the key testing activities identified. Note that the head loss values have not been adjusted to subtract the test strainer's clean screen head loss.

The peak or maximum chemical debris bed head loss observed during the test was 0.8 inches at 69 °F and 462 gpm.

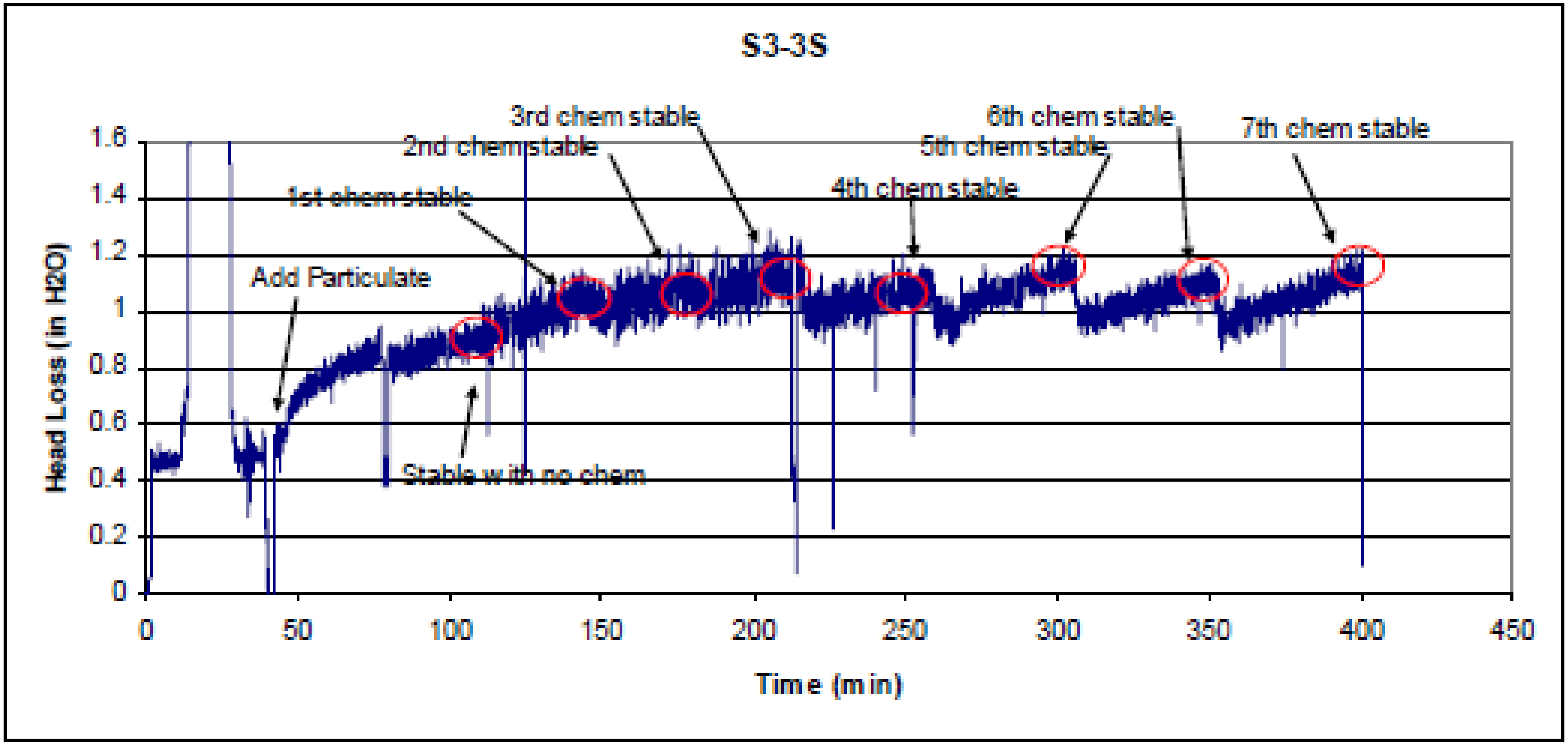

Figure 3.f.4-10: Seabrook S3-3S Head Loss Test Timeline

A summary of the debris head loss results from the chemical effects tests is provided in Table 3.f.4-3 below. The maximum conventional and chemical debris head losses are indicated in bold face. These are the head losses that were used to evaluated pump NPSH, void faction, flashing, and strainer integrity (after being extrapolated to a 30-day head loss value, as described below).

Table 3.f.4-3: Summary of Seabrook Conventional and Chemical Debris Head Loss Test Results

Test Point	Debris Head Loss (in)	Test Flow Rate (at Plant Scale) (gpm)	Temperature (°F)
S3-1S			
Conventional Debris Max Head Loss	**0.8**	**456 (8,689)**	**67**
Conventional Debris Stable Head Loss	0.7	460 (8,766)	67
Aluminum Precipitate Max Head Loss	**3.4**	**460 (8,766)**	**79**
Aluminum Precipitate Stable Head Loss	3.1	460 (8,766)	79
S3-2S			
Conventional Debris Max Head Loss	0.8	462 (8,804)	71
Conventional Debris Stable Head Loss	0.7	463 (8,823)	71
Aluminum Precipitate Max Head Loss	0.8	462 (8,804)	73
Aluminum Precipitate Stable Head Loss	0.5	463 (8,823)	73
S3-3S			
Conventional Debris Max Head Loss	0.5	461 (8,785)	67
Conventional Debris Stable Head Loss	0.4	461 (8,785)	67
Aluminum Precipitate Max Head Loss	0.8	462 (8,804)	69
Aluminum Precipitate Stable Head Loss	0.6	463 (8,823)	72

For all three head loss tests, the test was terminated after all debris was introduced and the test termination criterion was met. The test termination criterion was for the head loss to have stabilized to a 1% change or less in 30 minutes. In order to calculate the projected 30-day head loss from the head loss at the termination of testing, a 5% termination factor was applied.

The 5% termination factor was calculated by analyzing a conventional debris only head loss test performed for Seabrook (see description below) as well as tests from several other plants that used the same test termination criterion as Seabrook (a 1% change or less in head loss in 30 minutes). In order to develop a relationship between the final test head loss and the maximum expected head loss, the test data were fit to an exponential equation:

$$HL = A\left(1 - e^{-\frac{\alpha}{\tau}t}\right)$$

Where:

HL = Measured test head loss
A = Maximum projected head loss
t = time
α/τ = effective turnover time

The result of the series of curve fits showed that tests that met the termination criterion had an HL/A ratio of greater than 0.98. Therefore, dividing the measured final test head loss by 0.95 (i.e., applying a 5% termination factor) produces a conservative estimate of the maximum head loss.

The bounding tested head loss was the maximum aluminum precipitate head loss of 3.4 inches for test S3-1S, as presented in Table 3.f.4-3 above. After applying the conservative 5% termination factor, a head loss of 3.6 inches was used to evaluate pump NPSH, void fraction, flashing, and strainer integrity.

<u>Conventional Debris Only Head Loss Testing</u>

Head loss tests were performed to measure the head losses caused only by conventional debris (fiber and particulate) transported to the sump strainers following a LOCA. The test program used a test strainer and flow rates that were prototypical to the plant strainer.

Test Setup

The test setups for the chemical effects head loss tests and the conventional debris only head loss tests were the same. Refer to the description above for the details of the test setup.

Test Parameters and Scaling

The test strainer used for the conventional debris only head loss tests was the same as the test strainer used for the chemical effects tests. Refer to the description above for the details of the test parameters and scaling. Margin was added to the test flow rate, and as a result the test strainer approach velocity at 451 gpm (0.00828 ft/sec) bounds the plant strainer average approach velocity at 8,045 gpm (0.00775 ft/sec).

Prior to adding debris, head loss data was obtained for the test strainer under clean screen conditions.

Debris Materials and Preparation

The same conventional debris surrogates were used for both the conventional and chemical effects head loss testing except for Nukon and latent fiber. For the conventional debris only test, Thermal-Wrap was used as a surrogate for Nukon and latent fiber. Refer to the description above for other details of the debris materials and preparation.

Debris Introduction

The debris introduction for the conventional debris only head loss tests followed the same process used in the chemical effects head loss testing. Refer to the description above for details regarding the debris introduction.

Head Loss Test Cases and Results

The tested debris loads for the conventional debris only head loss tests are summarized in Table 3.f.4-4 below and scaled to equivalent plant debris loads for both single train operation (Region I analysis) and two-train operation (Region II analysis).

Table 3.f.4-4: Debris Loads for the Seabrook Conventional Debris Only Head Loss Tests

Test	Single Train Operation		Two-Train Operation		Debris Head Loss (in H_2O)	Water Temp. (°F)	Flow Rate (gpm)
	Silicon Carbide (lbm)	Nukon (lbm)	Silicon Carbide (lbm)	Nukon (lbm)			
S3-6S-3.5	3043.8	67.62	6217.9	138.13	0.13	77	451
S3-4S-13.8	3043.8	270.48	6217.9	552.53	0.16	84	451
S3-3S-27.6	3043.8	540.95	6217.9	1105.1	0.37	80	451
S3-2S-55.2	3043.8	1080.0	6217.9	2206.2	2.29	75	451
S3-7S-75.8	3043.8	1485.7	6217.9	3035.0	11.35	84	451
S3-1SA-100	3043.8	2026.7	6217.9	4140.1	22.18	77	451

After all conventional debris was added, the head loss was allowed to stabilize until the termination criterion was achieved. As with the chemical effects testing, a 5% termination factor was used to determine the final 30-day head loss value. These values are presented in Table 3.f.4-5 below.

Table 3.f.4-5: Clean Strainer and Debris Head Loss Values

Test	Flow Rate (gpm)	Water Temperature (°F)	Clean Strainer Plate Head Loss (in)	Total Debris Head Loss with 5% Termination Factor (in)	Total Head Loss (Clean Strainer Plate + Debris) (in)
S3-6S-3.5	451	77	0.37	0.14	0.51
S3-4S-13.8	451	84	0.48	0.17	0.65
S3-3S-27.6	451	80	0.47	0.39	0.86
S3-2S-55.2	451	75	0.51	2.41	2.92
S3-7S-75.8	451	84	0.45	11.95	12.40
S3-1SA-100	451	77	0.52	23.35	23.87

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

Response to 3.f.5:

As discussed in the Response to 3.f.4, the head loss tests used test strainers that are prototypical to the plant strainer designs. Additionally, the test debris loads were scaled based on the ratio of the test strainer surface area and the plant's net strainer surface area. The arrangement of the test strainer with respect to the test tank models the configuration in the vicinity of the plant strainer. The gap between the test strainer disks was prototypical of the gap between disks at the plant, and all of the tested debris load was funneled to the volume between the disks. With these considerations, the impact of debris volume on the plant strainer can be directly determined from the head loss test results.

As discussed in the Response to 3.f.7, the particulate debris quantity used for testing, scaled to plant scale, was less than the predicted quantity. The acceptability of this difference is dispositioned in that section of the response.

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

Response to 3.f.6:

The "thin-bed effect" is defined as the relatively high head losses across a thin bed of fibrous debris, which can sufficiently filter particulate debris to form a dense (or high particulate-to-fiber ratio) debris bed. As discussed in the Response to 3.f.4 above, the head loss testing introduced the full particulate load into the test tank first, followed by the fibrous debris. This batching schedule allowed the formation of a debris bed with a high particulate to fiber ratio. As a result, any thin-bed effects, should they occur, would be captured by the measured head losses. None of the three chemical effects tests observed high head losses during conventional debris introductions, with the maximum conventional debris load head loss being 0.8 inches. Additionally, for tests S3-1S and S3-3S, the chemical debris bed head loss bounds the conventional debris bed head loss.

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

Response to 3.f.7:

Comparison of Plant and Head Loss Test Flow Rates

As discussed in the Response to 3.f.3, the maximum flow rate through the strainers is 8,045 gpm with an approach velocity of 0.00775 ft/s. During head loss testing, the nominal flow rates for the chemical effects testing and the conventional debris only testing were 449 gpm and 451 gpm, respectively. These flow rates correspond to approach velocities of 0.00824 ft/s and 0.00828 ft/s, and both bound the plant condition.

Comparison of Plant and Head Loss Test Conventional Debris Loads

Region I

As described in the Response to 3.a.3, most large breaks generate similar quantities of debris from latent dirt/dust, miscellaneous debris, and unqualified coatings. Note that the unqualified coatings quantity (same for all breaks) is much larger than the qualified coatings quantity that varies with each break. The difference between these two debris types is greater than an order of magnitude for all break scenarios (Reference Table 3.b.4-1, Table 3.h.1-2). Therefore, breaks that generate the limiting amounts of fibrous debris present the greatest challenge to post-accident sump performance. Therefore, the bounding Region I breaks consist of the 17" partial breaks on the main loop that result in a bounding quantity of fine fiber. The bounding breaks for Region I are listed in Table 3.f.7-1 below. These breaks bound all 17" and smaller breaks.

Table 3.f.7-1: Seabrook Bounding Region I Breaks

Title	Location	Location Description	Break Size	Pipe ID	Orientation
17" Bounding Fine Fiber	ISI RC-0010-01-02	Loop 4 Hot Leg at Elbow	17"	29"	45°
17" Bounding Fine Fiber	ISI RC-0001-01-02	Loop 1 Hot Leg at Elbow	17"	29"	315°

As shown in the head loss test results provided in the Response to 3.f.4, the conventional and chemical head losses from the S3-1S test are greater than the other two chemical effects tests. Table 3.f.7-2 compares the tested debris loads from the S3-1S chemical effects test, which have been converted to plant scale, with the debris loads for the bounding Region I break. Note that the test debris loads were divided by a scaling factor of 0.0525 to show plant scale (see the Response to 3.f.4 for discussion on scaling factor). The debris loads for the bounding Region I break (RC-0010-01-02) are presented in Table 3.e.6-10, which considers single-train operation. The quantity of unqualified coatings was taken from the Response to 3.h.

Table 3.f.7-2: Comparison of Test Debris Loads with Region I Breaks

Debris Type	17" Bounding Break	Test S3-1S Debris Loads
Total Fine Fiber (lbm)	283.45	312.38
Latent Particulate (ft^3)	0.43[1]	16.11
Qualified Coatings (ft^3)	0.07	
Unqualified Coatings (ft^3)	39.55	

The total amount of particulate surrogate (silicon carbide) tested at plant scale was 16.11 ft^3, which is less than the value for the bounding Region I break. Two observations from the head loss test program provide assurance that an increase in the tested particulate load would not substantially increase the head loss results. The first observation is from the results of the conventional debris only head loss test S3-3S-27.6. The total amount of Nukon fines tested at plant scale for this test was 540.95 lbm, a 73% increase over the S3-1S test. The total amount of particulate surrogate tested at plant scale was 32.38 ft^3, a 100% increase over the S3-1S test. Despite the large increase in both fiber and particulate, the conventional debris head loss for this test was 0.37 inches, which is lower than the conventional debris head loss of 0.8 inches reported for the S3-1S test. The second observation is that the quantity of chemical precipitates added to the S3-1S test (367.2 kg plant scale based on Table 3.f.4-2) was more than double the maximum predicted precipitate amount at the plant, 174 kg. When the entire quantity of particulate and precipitates (both silicon carbide and chemical precipitates) in the S3-1S test are considered, in combination with the results from the conventional debris test S3-3S-27.6 (0.39 inches of debris head loss after application of the termination factor), the S3-1S chemical effects test is judged to be bounding over the plant debris loads. Therefore, the maximum debris head loss that would occur in the plant can be determined using the S3-1S head loss test.

As described in the Response to 3.f.4, no small pieces of Nukon were used in the head loss tests. The center-to-center spacing between strainer disks is 9.95 inches, and each of the disks are 2.70 inches wide, resulting in a gap between disks of 7.25 inches. Based on the large gaps between the disks and the results of head loss testing for other plants, using engineering judgement it is reasonable to conclude that small pieces of fiber would have a negligible impact on the overall head loss.

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[1] The quantity of latent particulate presented in the Response to 3.e for the single-train case is 72.25 lbm. This was converted to ft^3 using the microscopic density of 168.6 lbm/ft^3, presented in Table 3.d.3-1.

The peak debris head loss of 3.6 inches observed during chemical precipitate debris addition (with the 5% termination factor applied) was used to determine the NPSH margin, void fraction, flashing, and strainer integrity.

Region II

The bounding Region II breaks consist of the DEGBs on the main loop piping that result in the bounding quantity of fiber fines. As described in the Response to 3.a.3, most large breaks generate similar quantities of debris from latent dirt/dust, miscellaneous debris, and coatings. Therefore, breaks that generate the limiting amounts of fibrous debris present the greatest challenge to post-accident sump performance. The bounding breaks for Region II are listed in Table 3.f.7-3 below.

Table 3.f.7-3: Seabrook Bounding Region II Breaks

Title	Location	Location Description	Break Size	Pipe ID
DEGB Bounding Fibrous	ISI RC-0007-01-03	Loop 3 Hot Leg at SG Nozzle	31”	31”
DEGB Bounding Fibrous	ISI RC-0001-01-03	Loop 1 Hot Leg at SG Nozzle	31”	31”

As shown in the head loss test results provided in the Response to 3.f.4, the conventional and chemical head loss from the S3-1S test was greater than the other two chemical effects tests. Table 3.f.7-4 compares the tested debris loads from the S3-1S chemical effects test, which have been converted to plant scale, with the debris loads for the bounding Region II break. Note that the test debris loads were divided by a scaling factor of 0.0257 (see the Response to 3.f.4) to show plant scale. This scaling factor was developed assuming two-train operation. A single failure of a CBS pump or train would result in elevated debris loading and head loss that would result in unacceptable pump NPSH margins. Crediting two-train operation for the Region II analysis is described in more detail in the Alternate Evaluation Methodology section. The debris loads for the bounding Region II break (RC-0001-01-03) are presented in Table 3.e.6-12, which considers two-train operation. The quantity of unqualified coatings was taken from the Response to 3.h.

Table 3.f.7-4: Comparison of Test Debris Loads with Region II Breaks

Debris Type	31" Bounding Break	Test S3-1S Debris Loads
Total Fine Fiber (lbm)	639.32	638.13
Latent Particulate (ft^3)	0.43[2]	32.91 ft^3
Qualified Coatings (ft^3)	1.00	
Unqualified Coatings (ft^3)	39.55	

The total amount of particulate surrogate (silicon carbide) tested at plant scale was 32.91 ft^3. Although the tested quantity of particulate is less than the value provided for the bounding Region II break, it is not expected that an increase in the particulate load would substantially impact the head loss results, as discussed in the Region I analysis section. When the entire quantity of particulate and chemical precipitates (both silicon carbide and AlOOH) in the S3-1S test are considered in combination with the results from the conventional debris test S3-3S-27.6, the S3-1S chemical effects test results are judged to be bounding over the plant debris loads.

As described in the Region I analysis, small pieces of fiberglass are judged to have a negligible impact on the overall head loss results, and no small pieces were used in the head loss tests.

The peak debris head loss of 3.6 inches observed during chemical precipitate debris addition (with the 5% termination factor applied) was used to determine the NPSH margin, void fraction, flashing, and strainer integrity.

Comparison of Plant and Head Loss Test Chemical Debris Loads

<u>Region I</u>

When scaled for single train operation (using a scaling factor of 0.0525), the total amount of AlOOH precipitate debris added to each of the three chemical effects head loss tests was 367.2 kg at plant scale. This quantity is greater than the maximum amount of AlOOH precipitate debris (174 kg) calculated to form in the sump (see the Response to 3.o.2.7.ii).

[2] The quantity of latent particulate presented in the Response to 3.e for the two-train case is 73.1 lbm. This was converted to ft^3 using the microscopic density of 168.6 lbm/ft^3, presented in Table 3.d.3-1.

Region II

When scaled for two-train operation (using a scaling factor of 0.0257) the total amount of AlOOH precipitate debris added to each of the three chemical effects head loss tests was 750.1 kg at plant scale. This quantity is greater than the maximum amount of AlOOH precipitate debris (174 kg) calculated to form in the sump (see the Response to 3.o.2.7.ii).

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

Response to 3.f.8:

Vortexing Testing

Testing was conducted to determine whether vortexing could occur. As discussed in the Response to 3.f.3, the vortex tests were performed at both clean strainer and debris laden conditions.

The vortex test used a strainer approach velocity of 0.00828 ft/s for both the clean screen and conventional debris laden conditions, which is higher than the maximum approach velocity expected for the plant strainer of 0.00775 ft/s.

The clean strainer vortex test conservatively used a submergence of 2.5 inches, which is less than the 9.1 inches minimum submergence from an SBLOCA. The debris laden vortex test used a submergence of 3 to 4 inches, which also bounds the minimum submergence from an SBLOCA.

Strainer Head Loss

The quantity of latent debris used to determine the strainer head loss was 100 lbm, but the actual amount of latent debris documented for the plant is only 40.7 lbm. Similarly, the amount of miscellaneous debris used in the analysis was 133 ft^2, but, as stated in the Response to 3.b.5, the actual amount of miscellaneous debris is 39.8 ft^2. Finally, the maximum quantity of AlOOH precipitate expected is 174 kg, but the tested quantity of AlOOH precipitate was 367.2 kg at plant scale for single train operation (Region I analysis) and 750.1 kg for two-train operation (Region II analysis). Note that a single failure is not assumed for Region II analyses.

Due to the lower test temperatures and higher test approach velocities, the head loss recorded during the head loss testing is conservatively higher than what would be experienced at plant conditions. However, the test head loss values were not corrected for temperature or approach velocity and were conservatively assumed to be the head loss experienced at plant conditions.

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

Response to 3.f.9:

The clean strainer head loss consists of three components: the clean strainer plate head loss, the plenum and “dog house” head losses, and the debris interceptor head loss.

As described in the Response to 3.f.4, the head loss testing was performed with a test strainer made up of two, full scale strainer disks. Each strainer at the plant consists of 80 strainer disk assemblies. Flow travels through the disks, into a plenum below the disks, and into a “dog house” where the flow from all the disks merges and flows out of the sump through the ECCS suction piping. The clean strainer head loss must account for losses through the strainer disk, the losses experienced as flow travels through the plenum, and the mixing losses when the flow from all the disks is combined within the “dog house”.

The head loss across the test strainer that was recorded for each head loss test prior to the introduction of debris captures the portion of the clean screen head loss that includes flow traveling through the disks. Therefore, the clean strainer plate head loss portion of the total clean strainer head loss was determined from the values recorded during testing.

The second portion of the total clean strainer head loss was determined by modeling the strainer assembly as a series of parallel flow ducts. To calculate the losses through the plenum and “dog house”, it was conservatively assumed that the water entering the Seabrook strainers approaches with a uniform velocity. This assumption increases the calculated flow rate through the strainer discs furthest from the plenum exit, thus increasing the calculated clean strainer head loss. Additionally, this assumption is appropriate because it is expected that as the strainer is loaded with debris, the flow through the strainer will become more uniform.

The bounding plenum head loss was determined by summing the limiting path head losses through the strainer assembly, which includes the strainer panel furthest from the ECCS pipe inlet and the plenum head losses along the longest plenum run. The “dog house” losses associated with the mixing flows from various portions of the plenums and the “dog house” strainer disks were then modeled. The total plenum and “dog house” head losses for this path were calculated to be 0.554 ft, or 6.65 inches.

The final portion of the total clean strainer head loss is the debris interceptor head loss. For a total strainer flow rate of 8,050 gpm (which bounds the maximum strainer flow rate of 8,045 gpm, presented above), the debris interceptor loss was determined to be 0.48 inches.

The total clean strainer head loss is the calculated sum of the clean strainer plate loss from testing, the 6.65 inches loss through the plenum and “dog house”, and the 0.48 inches debris interceptor loss.

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

Response to 3.f.10:

The total strainer head loss was calculated by combining the debris head losses shown in the Response to 3.f.7 and the clean strainer head loss shown in the Response to 3.f.9. Refer to each individual section for the specific head loss value used.

The total strainer head losses, used to evaluate ECCS and CBS pump NPSH, void fraction, flashing, and strainer structural integrity are provided in Table 3.f.10-1 below.

Table 3.f.10-1: Seabrook Strainer Head Loss

Clean Strainer Head Loss (in)	Plenum + Debris Interceptor Loss (in)	Debris Head Loss (in)	Total Head Loss (in)	Notes
0.4	7.13	0.8	8.33	Based on conventional debris head loss
0.4	7.13	3.6	11.13	Based on aluminum chemical debris head loss

It should be noted that the debris head losses were measured at conditions more conservative (lower temperature and higher flow rate) than actual plant conditions. For conservatism, scaling was not used to adjust the head losses to actual plant conditions.

11. *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.*

Response to 3.f.11:

As shown in Table 3.g.1-1, the minimum water level was adequate to ensure the strainers remain submerged for all SBLOCAs and LBLOCAs. Additionally, the containment sump strainers are not designed with any vents. The strainers contain an elevated inspection port that is sealed with a locking pipe cap. Therefore, no vents/penetrations exist that connect the strainer internal volume to the containment atmosphere above the minimum water level.

12. *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.*

Response to 3.f.12:

No near-field settling was credited for head loss testing. Tank tests were performed for Seabrook. Sufficient turbulence was provided in the test tank to ensure that all debris had an opportunity to suspend in the water column and transport to the test strainer. The level of turbulence was also controlled to avoid disturbing the debris bed formation.

13. *State whether temperature/viscosity was used to scale the results of the head loss test 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.*

Response to 3.f.13:

As stated in the Response to 3.f.10, scaling was not used to adjust the measured debris head losses to actual plant conditions.

14. *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.*

Response to 3.f.14:

Flashing would occur if the pressure downstream of the strainer was lower than the vapor pressure at the sump temperature. The pressure downstream of the strainer can be calculated by combining the strainer submergence and containment pressure before subtracting the strainer head loss.

As stated in the Response to 3.f.10, the maximum strainer head loss for an LBLOCA was calculated to be 11.1 inches based on head loss testing and the clean strainer head loss calculation. Table 3.g.1-1 provides the minimum LBLOCA strainer submergence to be 1.20 ft (or 14.4 inches). Therefore, because the minimum LBLOCA strainer submergence is greater than the total LBLOCA strainer head loss, flashing was shown not to occur even when no credit is taken for containment pressure.

No head loss testing data is available For the SBLOCAs. However, considering their much smaller debris loads than the LBLOCAs, it is judged that the strainer head loss for the SBLOCAs would be much lower and would not result in flashing.

g. Net Positive Suction Head

The objective of the NPSH section is to calculate the NPSH margin for the ECCS and CSS pumps that would exist during a LOCA, considering a spectrum of break sizes.

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

Response to 3.g.1:

Seabrook Pump/ Sump Flow Rates

Following an LBLOCA both trains of the RHR pumps, CCPs, SI pumps and CBS pumps would be automatically started. Operation of the CBS pumps is initiated by high containment pressure. Operation of the other pumps is initiated by the safety injection signal. Recirculation is not initiated until at least 26 minutes after the LBLOCA. Recirculation is initiated by the RWST Lo-Lo level signal. Upon receipt of this signal, the RHR and CBS pumps are automatically re-aligned to take suction from the recirculation sumps. The CCPs and SI pumps are then re-aligned to take suction from the RHR pumps' discharge ("piggyback" mode). Approximately 5 to 6 hours after the accident, the SI and RHR pumps are aligned to hot leg recirculation supplying flow to the RCS hot legs. The CCPs continue to supply flow to the cold legs.

The maximum design flow rate is 8,045 gpm per sump for the highest flow cases during recirculation. The maximum flow per sump is the sum of RHR pump flow (4,388 gpm) and the CBS pump flow (3,657 gpm). Since the Train A flow rates bound the Train B flow rates, the bounding flow rates/velocities were used for Train B.

As noted, the CCPs and SI pumps operate in "piggyback" mode during recirculation, so flowrates for these pumps are already included in the total.

The maximum ECCS and CBS flows were calculated for both cold leg and hot leg recirculation conditions following an LBLOCA.

Seabrook Minimum Containment Water Level

The containment water level calculation evaluated bounding minimum sump pool volumes and levels. Table 3.g.1-1 summarizes the results of the containment water level calculation.

The pool floor elevation is -26 ft, and the top surface of the top strainer disk is at an elevation of -24.05 ft.

The minimum water level elevations in Table 3.g.1-1 were calculated by adding the pool heights to the pool floor elevation. The submergence values in Table 3.g.1-1 were calculated by subtracting the top elevation of the strainers from the water level elevations.

Table 3.g.1-1: Minimum Sump Pool Water Levels

Break Case	Temperature	Minimum Water Level Elevation (ft)	Pool Height (ft)	Strainer Submergence (ft)
SBLOCA	Long Term – 160°F	-23.29	2.71	0.76
LBLOCA	Long Term – 160°F	-22.85	3.15	1.20

Seabrook Sump Temperature

The relevant sump pool temperatures are:

- Maximum Temperature: 260°F
- Design Temperature: 212°F
- Long Term Temperature 160°F

Testing for head loss was performed at a test temperature between 65°F and 85°F, with 85°F conservatively used as the assumed test temperature. NPSH margin was determined at 212°F and 160°F. Justification for the use of these temperatures is provided in the Response to 3.g.14.

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

Response to 3.g.2:

Seabrook Pump and Sump Flow Rates

The following assumptions were made in association with flow rates used to calculate the NPSH margin:

- Flow rates were conservatively assumed to apply for the duration of the event, and credit for operator action to reduce or terminate ECCS or CBS flow was not taken.
- Flow rates from the highest sump flow cases that were analyzed in recirculation flow calculations were used to determine the minimum NPSH margin. Train A flow rates are bounding for both trains and were therefore used in the NPSH margin determination for Train B pumps.

- Since volumetric flow rate increases with increasing sump temperature, the maximum recirculation flow rate was determined by assuming a maximum sump temperature of 260°F.
- Volumetric flow rate is maximized when the CBS and RHR heat exchangers are not operating; therefore, the heat exchangers were assumed to not be operating in the flow analysis.
- The CBS, RHR, SI, and CCPs were assumed to be operating at the manufacturer's nominal performance curves without degradation.
- The maximum sump water elevation of -20.71 ft was used to maximize recirculation flows. However, the minimum water level was used to determine NPSH margin.
- In order to calculate a maximum integrated ECCS/CBS volumetric flow rate with one train in operation, the loss coefficient value with no screen or grate blockage was used.

Seabrook Minimum Containment Water Level

The significant assumptions used in the water volume calculation are listed as follows.

1. It was assumed that 8,200 gpm of water (1-train operation) will continue to be pumped from the RWST for a duration of one minute following the "Lo-Lo-1" level signal. This estimated switchover duration allows time for the automatic opening of the sump isolation valves and for the operators to close the RWST discharge isolation valves (excluding valve closing time).

2. It was assumed that shortly after the accident, the RCS would be filled solid with water for an SBLOCA.

3. It was assumed that the refueling canal drains are open and un-clogged; therefore, there is no water trapped in the refueling canal. A modification will be performed to the refueling canal drain system to enhance draining capability.

4. It was assumed that water from the RCS would contribute to the containment pool following an LBLOCA.

Seabrook Sump Temperature

The following assumptions were made in association with sump temperature during the calculation of NPSH margin:

- Fluid properties such as density and viscosity were assumed to be at the temperature used to determine the maximum flowrate (i.e., 260°F). At 212°F, fluid viscosity will be higher and Reynold's number will be lower, resulting in a slightly higher friction factor and slightly lower flowrate. Conservatively, pump flowrates were determined at the higher sump temperature of 260°F, at which volumetric flow rates are maximized.

- The water temperature of 85°F assumed for testing is conservative since at lower temperatures, larger fluid viscosity and density would have resulted in larger measured losses.
- The measured debris head loss values were applied directly and were not scaled to plant temperatures.

3. *Provide the basis for the required NPSH values, e.g., 3 percent head drop or other criterion.*

Response to 3.g.3:

The basis for the required NPSH values used in calculating NPSH margin is the information provided from the original manufacturer's certified pump test curves at the maximum expected pump flow rates. NPSH required curve is based on actual NPSH test results. The methods used by the vendor were in accordance with the test procedures outlined in the Standards of the Hydraulic Institute.

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

Response to 3.g.4:

The hydraulic system model includes nominal RHR, SI, CCP, and CBS pump performance curves and industry standard system frictional and form losses. Steady-state boundary (operating) conditions were selected such that maximum system flows result. The NPSH required was taken from RHR and CBS pump curves for the design basis flow for each pump.

Frictional and flow losses were calculated and accounted for in the NPSH margin for all piping and equipment from the sump strainers to the inlet of the ECCS and CBS pumps. The piping frictional loss was calculated using standard formulas and friction factors (Reference 19 pp. A-24). The head losses of the components (e.g., valves, elbows, reducers, and tee junctions) on the pump suction piping were calculated using the loss coefficients from standard industry handbooks. Debris interceptor, debris, and disk losses were determined from testing, while plenum and doghouse losses were determined through analysis (see the Response to 3.f.9). These losses were added to calculated piping losses. Debris laden losses included particulate, fiber and chemical debris (see the Response to 3.f.4).

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

Response to 3.g.5:

See the Response to 3.g.1.

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

Response to 3.g.6:

Pump Operational Status

Prior to the initiating event, the ECCS and CBS pumps will be in a state of stand-by readiness. One CCP is operated during normal CVCS operations and will be automatically aligned for cold leg injection upon receipt of a safety injection signal.

Injection Phase
During the injection phase of ECCS operation, no manual actions are required and all equipment is designed to operate automatically. Upon receipt of a safety injection signal, the RHR pumps, CCPs and SI pumps start automatically. The CBS pumps are initiated by high containment pressure. The RWST provides a suction source for the RHR pumps, CCPs, SI pumps, and CBS pumps operating in injection mode. The switchover from injection mode to recirculation mode occurs when two of the four RWST Lo-Lo level setpoints are reached in conjunction with a safety injection signal.

Switchover to Cold Leg Recirculation
The change from the injection phase to the recirculation phase is initiated automatically and completed by operator action. An RWST Lo-Lo level signal in conjunction with a safety injection signal shifts the ECCS from the injection phase to the recirculation phase of emergency core cooling. The containment recirculation valves automatically open and align to the RHR and CBS pump suctions. The RHR and CBS pumps continue to operate during the switchover. The RHR and CBS pumps take suction from both the containment sump and RWST until manual isolation of the RWST is performed once each sump isolation valve has reached the full open position.

The CCPs and SI pumps continue to take suction from the RWST until operator action is taken to align these pumps to take suction from the RHR pump discharge.

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

Response to 3.g.7:

The Train A RHR and CBS pumps, both take suction from a common sump, while the Train B RHR and CBS pumps take suction from a separate common sump during cold or hot leg recirculation. Both RHR pumps discharge to a common hydraulic network. Therefore, a maximum Train A RHR and CBS pump flow (the greatest challenge to required NPSH) occurs when the Train B RHR pump is inoperable. During Region I analyses, for each case analyzed, the limiting single failure is the failure of the opposite train RHR pump. All other ECCS pumps (SI pumps and CCPs) and valves are assumed operable to maximize the flow through the operating RHR pump. Therefore, this is the limiting single failure scenario for sump strainer performance for Region I analyses.

A failure of a single component is not considered necessary for Region II breaks. More detailed discussion is presented in the “Alternate Evaluation Methodology” section.

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

Response to 3.g.8:

The water volume calculation used the methodology described below to calculate the minimum containment sump water level:

1. A correlation was first established for the relationship between the containment water level and the water volume at the -26’-0” elevation.
2. The quantity of water added to containment from the RWST, SI accumulators, RCS (LBLOCA only), and SAT was calculated.
3. The quantity of water that is diverted from the containment sump by the following effects was evaluated:
    - RCS liquid volume shrinkage (SBLOCA only).
    - Water required to fill steam space in pressurizer (SBLOCA only).
    - Water required to fill cavities in containment below the -26’-0” elevation.
    - Volume of water available to contribute to containment water level from RWST pumpdown during switchover from injection to recirculation.
4. Given the net mass of water added to the containment floor based on Items 2 and 3 listed above, the post-LOCA containment water level was calculated using the correlation established in Item 1.

The calculation determined bounding minimum containment water levels for LBLOCA and SBLOCA using break size-specific injection volumes and holdup volumes.

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

Response to 3.g.9:

The assumptions provided in the Response to 3.g.2 ensure that minimum (conservative) containment water levels were calculated in the containment water volume calculation.

10. *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.*

Response to 3.g.10:

The filling of empty containment spray piping was deemed to be negligible based upon the relatively small volume of piping holdup compared to the pool volume; the estimated holdup volume of 450 ft^3 translates to a change of pool level of less than 0.5 inches (0.04 ft). Other potential holdup volumes include atmospheric steam, spray droplets, and other falling water. The largest volumetric holdup among these would be spray droplets, which, if accounted for, would translate to a change of pool level of less than 0.16 inches (0.013 ft); thus, the aforementioned holdup volumes are considered negligible.

The hold-up on containment surfaces, although not accounted for in the water volume calculation, is shown to be more than offset by conservatism taken when calculating the water volume injected from the RWST. As described in the Response to 3.g.6, switchover from injection to cold-leg recirculation occurs automatically upon an RWST Lo-Lo level alarm in conjunction with a safety injection signal. However, as detailed in the Response to 3.g.12, only the volume of water between the TS minimum initial RWST level (minus an amount for trip error) and the upper safety analysis limit (USAL) (which is above the Lo-Lo alarm level) was considered when calculating the minimum containment water level. The elevation difference between the USAL and the Lo-Lo level is 2.4 inches when instrument uncertainty is considered. Each inch of RWST water level height corresponds to a volume of 947.9 gallons. This equates to 2,275 gallons of water between the USAL and Lo-Lo level. The maximum containment surface hold-up volume for Seabrook was calculated to be 1,916 gallons. Therefore, this volume is more than offset by not crediting the 2,275 gallons of water between the USAL and the Lo-Lo level in the RWST.

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

Response to 3.g.11:

The pieces of equipment and supports credited when evaluating the sump pool water level are summarized below:

- Pads for pressure relief tanks, excess letdown, reactor coolant drain tanks and reactor coolant drain tank heat exchangers
- Supports for the steam generators and reactor coolant pumps
- Cross-over legs
- In-core instrumentation hatches
- Concrete walls, concrete columns, and secondary shield wall

The dimensions of the equipment and supports from plant design drawings were used to calculate their cross-sectional areas. No assumptions were made.

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

Response to 3.g.12:

The following design inputs provided the basis for water sources and their volumes to determine the minimum containment water level:

- The TS minimum initial RWST level (minus an amount for trip error) was used for the initial RWST water level, and the USAL, which is above the Lo-Lo level, was used for the final RWST water level. The injected volume between these two levels is approximately 350,000 gal (369.2 inches drop in RWST water level at 947.9 gallons of water per inch of RWST height).
- The minimum combined volume of the SI accumulators is 25,434 gal (3,400 ft^3).
- The volume of water provided by the spray additive tank is 8,960 gal.
- The volume of water provided by the RCS for an LBLOCA is 12,926 gal (1,728 ft^3).
- A flow of 8,200 gpm of water will continue to be pumped from the RWST following initiation of “Lo-Lo” level signal for a one-minute duration during the switchover from injection to cold leg recirculation.

13. *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.*

Response to 3.g.13:

No credit was taken for containment accident pressure at Seabrook. See the Response to 3.g.14.

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

Response to 3.g.14:

Seabrook Containment Accident Pressure

Containment accident pressure was not credited in determining available NPSH. The TS minimum containment pressure is 14.6 psia. The temperature at which the vapor pressure of water is equal to the minimum containment pressure is approximately 212°F (Reference 20). For the NPSH margin calculations, the containment pressure was assumed to be equal to the minimum containment pressure. This approach conservatively neglected the pre-accident air partial pressure and the increase in the air partial pressure due to heat up of the containment atmosphere following the accident. For the NPSH margin determined at 160°F, the change in vapor pressure of water due to the sump cooling was considered, but any pressurization of the containment atmosphere due to the accident was neglected.

Note that for the Region II analysis, the additional margin gained by considering the pre-accident partial pressure of air was quantified, as described in the Response to 3.g.16. This additional margin only applies to the calculated NPSH margin at 212°F.

Seabrook Sump Temperature

NPSH was evaluated at sump temperatures of 212°F and 160°F. This is appropriate given the conservative containment pressure used. As discussed above, the containment pressure was assumed to be the minimum containment pressure (14.6 psia) for sump temperatures at or below 212°F. For sump temperatures above 212°F, the containment pressure was assumed to be equal to the vapor pressure at the corresponding sump temperature, conservatively neglecting any accident pressure or air partial pressure of the containment atmosphere.

The NPSH available was calculated by combining the containment pressure and elevation difference between the sump water level and RHR suction before subtracting the total head loss on the suction side of the pump (including the strainer head loss) and vapor pressure at the sump temperature. For sump temperatures below 212°F, the vapor pressure is less than the assumed containment pressure of 14.6 psia. Therefore, the difference between the assumed containment pressure and the vapor pressure would increase the pump NPSH available and resulting NPSH margin. As a result, the NPSH margin becomes less limiting as temperature drops below 212°F. This is demonstrated by the results presented in Tables 3.g.16-1 and 3.g.16-2.

Determining margin at temperatures of 212°F and 160°F is acceptable since these temperatures are higher than the head loss testing temperatures, and at higher sump temperatures debris bed head loss will decrease.

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

Response to 3.g.15:

As discussed in the Response to 3.g.14, for Region I breaks, the containment pressure was set at 14.6 psia for sump temperatures below or equal to 212°F. For sump temperatures above 212°F, the containment pressure was set equal to the vapor pressure corresponding to the sump liquid temperature.

For Region II breaks, the pre-accident air partial pressure was credited when calculating pump NPSH margin at a sump temperature of 212°F. See the Response to 3.g.16 for details.

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

Response to 3.g.16:

NPSH Margin Results

Tables 3.g.16-1 and 3.g.16-2 provide a summary of the minimum NPSH margins for the RHR and CBS pumps in recirculation mode. The most limiting NPSH margin occurs for the Train A CBS pump at a sump temperature of 212 °F. The case presented in the table below represents flow rates obtained from the single failure of the Train B RHR pump, which is described in the Response to 3.g.7.

The NPSH margin after strainer losses includes clean screen head loss, debris interceptor losses, plenum and doghouse losses and debris laden (particulate, fiber and chemical) losses. NPSH margin was evaluated at two temperatures: 212°F, where the containment pressure is equal to the vapor pressure, and 160°F, to demonstrate the margin gained by the change in vapor pressure as the sump cools. As described in the Response to 3.o.2.7.ii, the maximum temperature where aluminum precipitation could occur in the containment sump pool is 116.8°F. Conservatively, the full tested head loss (including chemical debris) is used for the NPSH calculation at both temperatures, even though they are above the predicted precipitation temperature.

The margin results for the NPSH evaluation at a sump temperature of 212°F are presented in Table 3.g.16-1 below.

Table 3.g.16-1: RHR and CBS Pumps NPSH Margin at 212 °F

	Train A RHR Pump	Train A CBS Pump
Total Sump Flow Rate (gpm)	8045	
Pump Flow Rate (gpm)	4388	3657
Sump Temperature (°F)	212	212
NPSHr (ft)	18	23.6
NPSH Margin After Strainer Losses (ft)	7.59	0.14

As the sump pool cools below 212°F, the difference between the assumed containment pressure and the vapor pressure would increase the pump NPSH available and resulting NPSH margin. For the NPSH evaluation at a sump temperature of 160 °F, both conventional and chemical debris head losses were considered. The change in vapor pressure due to the cooling of the sump was also considered and incorporated into the NPSH margin calculation. The NPSH margin results for this case are presented in Table 3.g.16-2 below.

Table 3.g.16-2: RHR and CBS Pumps NPSH Margin at 160 °F

	Train A RHR Pump	Train A CBS Pump
Total Sump Flow Rate (gpm)	8045	
Pump Flow Rate (gpm)	4388	3657
Sump Temperature (°F)	160	160
NPSHr (ft)	18	23.6
NPSH Margin After Strainer Losses (ft)	30.87	23.42

In Tables 3.g.16-1 and 3.g.16-2, the minimum NPSH margin for any given case is positive. Therefore, adequate NPSH margin is available for the Seabrook ECCS and CBS pumps to ensure their design functions after a LOCA.

Table 3.g.16-3 presents the maximum RHR and CBS cold leg recirculation pump flows for 1-train operation, 2-train operation with all pumps available, and 2-train operation assuming a single RHR pump failure. Based on flow rates presented in this table it was concluded that the Train A CBS flows are bounding for both trains. Additionally, the NPSH margins presented in Tables 3.g.16-1 and 3.g.16-2 for the RHR and CBS pumps are determined for the 2-train operation case with B RHR Pump failed since this case results in the highest total strainer flow rate, 8045 gpm (4388 + 3657 gpm).

Table 3.g.16-3: Maximum RHR and CBS Pump Flow Rates During Cold Leg Recirculation

	Train A RHR Pump Flow (gpm)	Train A CBS Pump Flow (gpm)	Train B RHR Pump Flow (gpm)	Train B CBS Pump Flow (gpm)
1-Train Operation	3752[3]	3660	3804[4]	3484
2-Train Operation (All Pumps Available)	2997	3660	2997	3484
2-Train Operation (with B RHR Pump Failure)	**4388**	**3657**	0	3486
2-Train Operation (with A RHR Pump Failure)	0	3663	4281	3482

Region II Analysis

Note that the above evaluation of pump NPSH margin at a sump temperature of 212°F conservatively neglects the partial pressure of air in the containment atmosphere prior to the accident. For Seabrook, the TS minimum containment pressure is 14.6 psia. The TS maximum containment temperature is 120 °F. At this containment temperature and assuming 100% relative humidity, the water vapor pressure is 1.693 psia. The minimum air partial pressure prior to the accident would be 12.9 psi (14.6-1.693 psia). Therefore, the margins provided above for the NPSH evaluation at 212°F (where the containment pressure was assumed to be equal to the vapor pressure) would be increased by 12.9 psi, or 29.76 feet by considering the partial pressure of air. As described in the Alternate Evaluation Methodology section, crediting the initial containment air pressure is a realistic assumption that is acceptable for use in the Region II analysis.

[3] This RHR flow rate was determined using a pump curve with 10% degradation. Even if this flow rate is increased by 10%, the total strainer flow rate for this single train case, 7787 gpm (3752 x 1.1 + 3660 gpm) is still bounded by the case used for the NPSH margin evaluation, 8045 gpm (4388 + 3657 gpm).

[4] This RHR flow rate was determined using a pump curve with 10% degradation. Even if this flow rate is increased by 10%, the total strainer flow rate for this single train case, 7668 gpm (3804 x 1.1 + 3484 gpm) is still bounded by the case used for the NPSH margin evaluation, 8045 gpm (4388 + 3657 gpm).

h. Coatings Evaluation

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

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

Response to 3.h.1:

The types of coating and systems used in containment are presented in Table 3.h.1-1.

Qualified Coatings

Table 3.h.1-1: Seabrook Qualified Coatings Systems Used in Debris Generation Analyses

Substrate	Layer	Type	DFT (mil)	Density (lbm/ft^3)
Steel Surfaces	1st Coat	Keeler and Long (K&L) #6548 - Epoxy	8	141
	2nd Coat	K&L #D-1 / K&L E-1 – Epoxy	6	111
		Total	14	--
Concrete Surfaces	1st Coat	K&L #4000 – Epoxy Primer/Surfacer	50	116
	2nd Coat	K&L #D-1 – Epoxy	6	111
		Total	56	--

Unqualified Coatings

Unqualified coatings are those that fail under design basis accident conditions and create debris that could be transported to the containment recirculation strainers. Unqualified coatings are applied over numerous substrates within containment. In addition, coatings on Westinghouse equipment were considered to be unqualified, but are not counted in the unqualified coatings log. The quantity and properties of these unqualified coatings at Seabrook are shown in Table 3.h.1-2.

Table 3.h.1-2: Seabrook Unqualified Coatings Properties and Quantities Used in Debris Generation Analyses

Coating Type	Volume (ft^3)	Density (lb/ft^3)	Mass (lb)	Characteristic Size (μm)
Epoxy	15.64	94	1470	10
IOZ	4.72	208	982	10
Epoxy (Westinghouse)	5.87	94	552	10
IOZ (Westinghouse)	13.32	208	2770	10

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

Response to 3.h.2:

The following assumptions related to coatings were made in the Seabrook debris transport analysis:

- It was conservatively assumed that all unqualified coatings are located in lower containment. This is conservative since it results in 100% of unqualified coatings being present in the pool at the start of recirculation and results in 100% transport of this debris type.
- It was assumed that the settling velocity of particulate debris (insulation, dirt/dust, and coatings) can be calculated using Stokes' Law. This is a reasonable assumption since the particulate debris is generally spherical, small in size, and would settle slowly (within the applicability of Stokes' Law). This assumption has been addressed in the San Onofre (Reference 21) and Indian Point (Reference 22) Audit Reports, and it has been concluded that it is not a significant factor with respect to debris transport since no credit is taken for debris settling using this approach.
- It was assumed that the unqualified coatings debris would be uniformly distributed in the recirculation pool. This is a reasonable assumption since these coatings are scattered around containment in small quantities.
- Unqualified coatings outside the ZOI were assumed to fail after pool fill-up has occurred, so the transport fraction for this debris during fill-up is 0%.

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

   Response to 3.h.3:

   Electro Carb® Black Silicon Carbide with a density of 94 lb/ft^3 and a particle size of 10 µm was used as the surrogate for the qualified and unqualified coatings for head loss testing.

4. *Provide bases for the choice of surrogates.*

   Response to 3.h.4:

   See the Response to 3.f.4.

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

   Response to 3.h.5:

   The following assumptions related to coatings were made in the debris generation calculation:

   - The debris size distribution for qualified coatings are not well known, and were therefore assumed to be 100% 10 µm particulate as recommended by the Guidance Report (Reference 6 pp. 3-30).
   - The size and density of all epoxy unqualified coatings were assumed to be 10 µm and 94 lb/ft^3, as recommended by the GR. All unqualified IOZ was assumed to have a particulate size of 10 µm and a density of 208 lb/ft^3 (27.81 lb/ gal). This density corresponds to Carbozinc 11 – a typical IOZ used in nuclear power plants.
   - It was assumed that the accumulators, RCP motors, RCP motor supports, and RCP motor air coolers (all Westinghouse equipment) have a total coating thickness of 15 mil, which consists of both IOZ and epoxy. Based on the Carbozinc 11 application recommendations, it was assumed that this is split into 6 mil IOZ and 9 mil epoxy.
   - Qualified coatings were analyzed within a 4.0D ZOI. This ZOI has been previously accepted by the NRC (Reference 8 p. 2).

   For reactor nozzle breaks, the ANSI 58.2-1988 jet model methodology was implemented to evaluate the ZOI length of a nozzle break subjected to partial separation of the two pipe ends. See the Response to 3.b.1 for additional information.

The amount of unqualified coatings in containment were quantified based on detailed logs maintained over the life of the plant and are contained in Table 3.h.1-1. The quantities apply to all breaks, regardless of size or location.

The quantity of qualified coatings shown in Table 3.h.5-1 and Table 3.h.5-2 were applied to the two respective worst-case DEGB and 17" fiber breaks.

Table 3.h.5-1: Seabrook Qualified Coatings Debris for the Two Worst-Case DEGB Fiber Breaks

Break Location	**RC 0007 01 03**		**RC 0001 01 03**	
Location Description	Loop 3 Hot Leg at SG Nozzle		Loop 1 Hot Leg at SG Nozzle	
Break Size	31"		31"	
Break Type	DEGB		DEGB	
K&L #6548 (Epoxy)	91.02 lbm	0.65 ft^3	40.01 lbm	0.28 ft^3
K&L #D-1 / K&L E-1 (Epoxy)	60.19 lbm	0.54 ft^3	30.05 lbm	0.27 ft^3
K&L #4000 (Epoxy Primer/Surfacer)	56.16 lbm	0.48 ft^3	55.91 lbm	0.48 ft^3

Table 3.h.5-2: Seabrook Qualified Coatings Debris for the Two Worst-Case 17" Fiber Breaks

Break Location	**RC 0010 01 02**		**RC 0001 01 02**	
Location Description	Loop 4 Hot Leg at Elbow		Loop 1 Hot Leg at Elbow	
Break Size	17"		17"	
Break Type	Partial (Angle - 45°)		Partial (Angle - 315°)	
K&L #6548 (Epoxy)	5.10 lbm	0.04 ft^3	5.10 lbm	0.04 ft^3
K&L #D-1 / K&L E-1 (Epoxy)	3.06 lbm	0.03 ft^3	3.06 lbm	0.03 ft^3
K&L #4000 (Epoxy Primer/Surfacer)	0.45 lbm	0.00 ft^3	0.45 lbm	0.00 ft^3

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

Response to 3.h.6:

In accordance with the guidance provided in NEI 04-07 (Reference 6 pp. 3-12, 3-13) and the associated NRC SE (Reference 7 p. 22), all coating debris was treated as 10-micron particulate. See the Responses to 3.h.1, 3.h.2, and 3.h.5 for additional debris characteristics description.

7. *Describe any ongoing containment coating conditions assessment program.*

Response to 3.h.7:

Seabrook Containment Coating Condition Assessment Program

The current program for controlling the quantity of unqualified/ degraded coatings includes two separate inspections by qualified personnel during each refueling outage, and notification of plant management prior to restart if the volume of unqualified/ degraded coatings approaches pre-established limits.

The first inspection takes place at the beginning of every refueling outage, when areas and components from which peeling coatings have the potential for falling into the reactor cavity are inspected by the NextEra coating supervisor and NextEra design engineering coating specialist. The second inspection takes place at the end of every refueling outage when the condition of containment coatings is assessed by a team using guidance from EPRI. Accessible coated areas of the containment and equipment are included in the second inspection. Plant management is notified prior to restart if the volume of unqualified/ degraded coatings approaches pre-established limits.

The initial coating inspection process is a visual inspection. The acceptability of visual inspection as the first step in monitoring of containment building coatings is validated by EPRI. Following identification of degraded coatings, the degraded coatings are repaired per procedure if required. For degraded coatings that are not repaired, areas of coatings determined to have inadequate adhesion are removed, and the nuclear coatings specialist assesses the remaining coating to determine if it is acceptable for use. The assessment is by means of additional nondestructive and destructive examinations as appropriate (Reference 16 p. 25).

i. Debris Source Term

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

Provide the information requested in GL 2004-02 Requested Information Item 2(f) regarding programmatic controls taken to limit debris sources in containment.

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

In responding to GL2004-02 Requested Information Item 2(f), provide the following:

1. *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.*

Response to 3.i.1:

Seabrook has procedural controls in place to reduce and control the amount of loose debris and fibrous materials in containment. The *Containment and Containment Spray Recirculation Sump Surveillance* procedure requires inspection of all accessible areas to verify that no loose debris, fibrous materials that could degrade into loose debris, or bubbling/chipping paint is present prior to setting containment integrity. In addition, any entry performed while containment integrity is set requires subsequent walkdowns of areas affected by the entry to confirm no loose debris or fibrous material. Shift Manager authorization is required in order for any materials to be left in containment.

The maintenance director has been placed in charge of maintaining the general housekeeping of containment which includes tracking the overall cleanliness of containment and promptly correcting identified deficiencies.

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

   Response to 3.i.2:

   Foreign material exclusion programmatic controls are in place at Seabrook, which consider the containment building as a plant system. This ensures that proper work control is specified for debris-generating activities within the containment building in order to prevent introduction of foreign material into the containment sump or strainers. Additionally, the foreign material exclusion program requires that engineering be consulted anytime foreign material covers are placed or modifications are performed on the containment sump strainers.

   Furthermore, the containment entry procedure provides additional controls to evaluate foreign materials to be brought into containment and ensure they are removed. The procedure requires tracking of all non-bulk items brought into containment. Procedural controls are also in place to evaluate aluminum or zinc prior to being taken into containment.

3. *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.*

   Response to 3.i.3:

   NextEra engineering change processes and procedures ensure that temporary or permanent modifications that may affect the ECCS, including sump performance, are evaluated for GL 2004-02 compliance. During engineering change preparation, the process requires affected critical attributes to be listed, evaluated, and documented when affected. This includes the introduction of materials into containment that could affect sump performance or lead to equipment degradation (e.g., GSI-191). It also includes repair, replacement, and installation of coatings inside containment, including installing coated equipment.

   NextEra implemented the industry's standard design change process including the industry procedure IP-ENG-001. The standard process and tools are intended to facilitate sharing of information, solutions, and design changes throughout the industry. This process requires activities that affect UFSAR described SSC design functions to be evaluated as a design change in accordance with NextEra's 10 CFR 50 Appendix B program. This includes modifications that would impact the containment sump. Design changes require a final impact review meeting (i.e., final design workshop) and assessment in accordance with 10 CFR 50.59. Additional meetings may be required based on complexity and risk of the change. A failure modes and effects analysis is required if the design change introduces any new failure modes or changes failure modes for the affected SSCs.

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

Response to 3.i.4:

Seabrook maintenance activities (including temporary changes or temporary system alterations) are controlled by plant procedure, including having all temporary modifications developed though the plant modification procedure. This process maintains configuration control for non-permanent changes to plant systems, structures, and components while ensuring the applicable technical reviews and administrative reviews and approvals are obtained. If, during at-power operation conditions, the temporary alteration associated with maintenance is expected to be in effect for greater than 90 days, the temporary alteration is subject to the requirements of 10 CFR 50.59 prior to implementation.

Seabrook has established a procedure to assess the on-line maintenance activities. The main goal of the assessment is to minimize the plant risk and trip concerns associated with planned maintenance work during Modes 1 through 4. Additionally, the procedure provides instructions for determining overall plant risk as required by 10 CFR 50.65 (a)(4) “Maintenance Rule”. The routine assessment of the work week schedule meets the requirements of 10 CFR 50.65 (a)(4) using the guidance in NEI/NUMARC 93-01, Section 11, Rev. 4A. The plant Probabilistic Risk Assessment (PRA) model and the on-line maintenance evaluation tools (Safety Monitor) meet the recommendations in NEI documents for quantitative evaluation.

5. *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.*

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

      Response to 3.i.5.a:

      There have not been any recent or planned insulation change-outs in containment to reduce the debris burden at the sump strainer.

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

      Response to 3.i.5.b:

      There have not been any recent or planned insulation jacketing or banding modifications to reduce the debris burden at the sump strainer.

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

Response to 3.i.5.c:

Four types of debris interceptors are installed at Seabrook in order to reduce the debris transported to the sump strainers. The debris interceptor types and their locations are described in the Response to 3.j.1. Additionally, accessible cable tray, raceway and node junction adhesive labels inside containment were removed to reduce the debris transported to the strainer.

d. *Actions taken to modify or improve the containment coatings program.*

Response to 3.i.5.d:

The programmatic controls related to coatings are provided in the Response to 3.h.7.

j. Screen Modification Package

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

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

Response to 3.j.1:

The original sump screens were replaced with new strainer modules during outage OR12 (Spring 2008). Debris interceptors had already been installed to reduce the quantity of debris that could be transported to the strainer modules.

The new strainers and debris interceptors are passive (i.e., there are no active components and the strainers do not utilize backflushing).

The new strainer system uses the General Electric (GE) disk strainers. The installed strainer surface area is 2,412 ft^2 for each sump. The strainer perforations are nominal 1/16-inch diameter round holes (0.0625-inch diameter openings). The strainer modules use an arrangement of parallel, rectangular strainer disks that have exterior debris capturing surfaces of perforated plate covered with woven wire mesh. The wire mesh decreases the head loss across the strainer plates by breaking up debris beds. Each strainer disk, constructed of two plates, has an open interior to channel disk flow downward to the strainer plenum. The disks are mounted on the discharge plenum, which channels disk flow to the suction piping. All strainers are fabricated from stainless steel.

Each strainer module interfaces with its associated ECCS inlet pipe. The ECCS inlet pipe is located inside a strainer “dog house” which is directly open to the strainer plenum. The “dog house” interface seals the “dog house” against the wall to preclude fibers passing into the ECCS lines. The roof of the “dog house” is equipped with cover plates similar to those used in the rest of the plenum.

The volume of debris at the screen is discussed in the Response to 3.e. The capability to provide the required NPSH with the debris volume is discussed in the Response to 3.g. The capability to structurally withstand the effects of the maximum debris volume is discussed in the Response to 3.k.

See the Response to 3.g.8 for a discussion of containment sump water level.

Four types of debris interceptors have been installed in the Seabrook containment.

- Bioshield Debris Interceptors
  Bioshield debris interceptors are installed in the passageways in the bioshield wall except for the eastern-most door. (This is to ensure that there is at least one unobstructed passageway for water from the break to the annulus.) They

are approximately 6-feet tall and have hinged gates (doors) where needed to allow for personnel and equipment access.

- Annulus Debris Interceptors
  Annulus debris interceptors are located radially around the containment building in the outer annulus area between the bioshield wall and the containment wall. The locations are shown in Figure 3.j.1-1. They have a hinged gate at each location to allow for personnel and equipment access. Most annulus debris interceptors also have an 18-inch wide horizontally oriented debris interceptor panel mounted on top.
- Accumulator Skirt Debris Interceptors
  Where an annulus debris interceptor adjoins the support structure for an accumulator (accumulator skirt), the skirt serves as part of the debris interceptor span. Debris interceptor panels are installed on the accumulator skirt openings.
- Bioshield Scupper Debris Interceptors
  Bioshield scupper debris interceptors have been installed on one end of 18 scuppers in the bioshield wall to prevent debris bypassing the annulus debris interceptors via the scuppers. The scuppers are small passageways (approximately 4-inches square) through the bioshield wall that allow water leaking inside the bioshield to pass through the wall to the floor drains located outside the bioshield. Installing debris interceptors on the scupper openings prevents potential fiber bypass around the annulus debris interceptors.

Figures 3.j.1-1 and 3.j.1-2 provide an overview of the strainer layout and configuration within containment. Figures 3.j.1-3 through 3.j.1-5 provide details on the strainer assembly and disk assemblies.

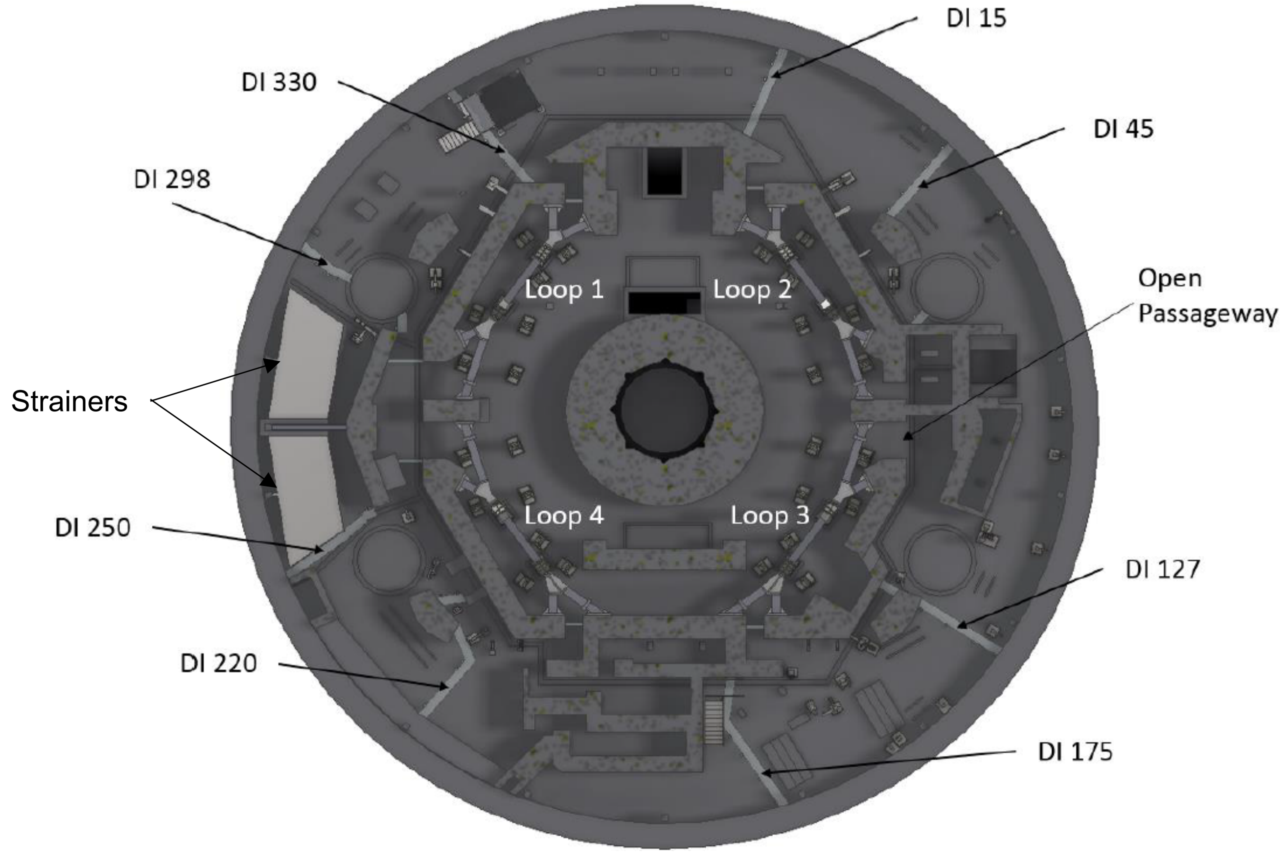

Figure 3.j.1-1: Plan View of Seabrook Lower Containment with Annulus Debris Interceptors Labeled

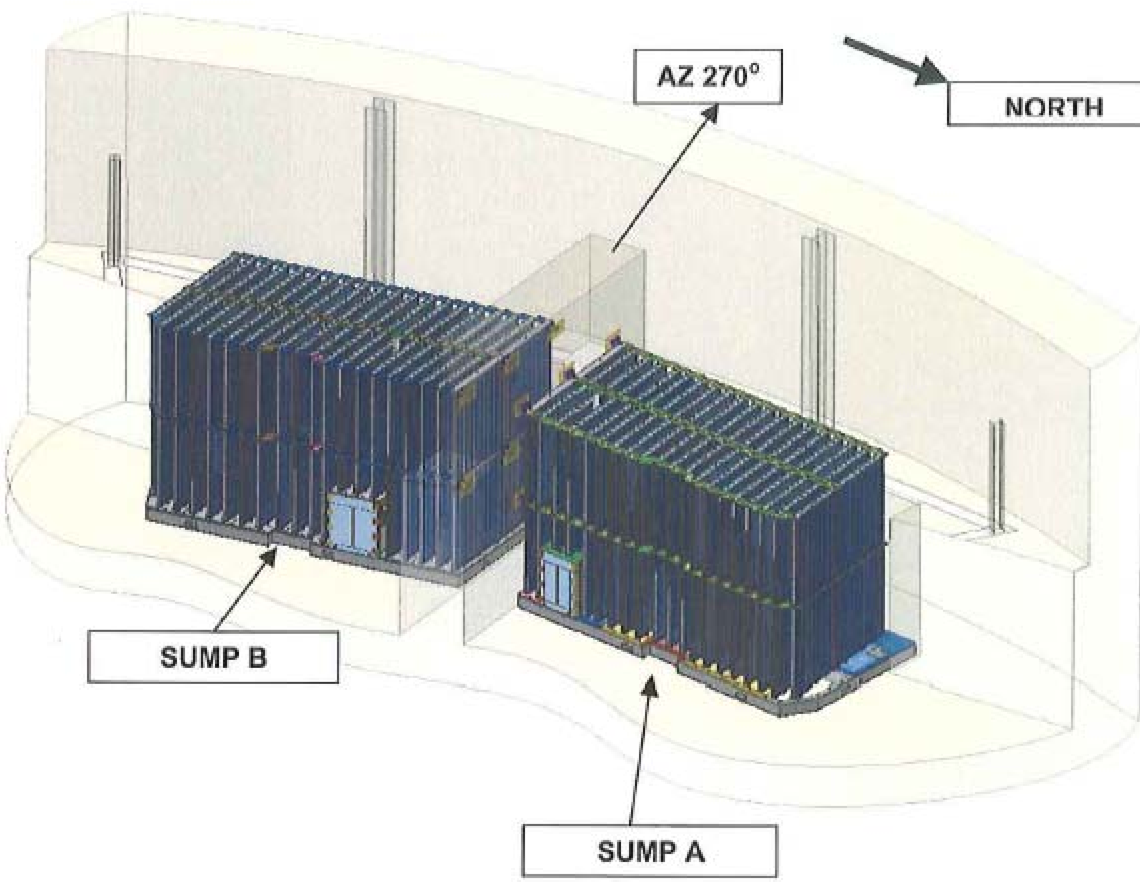

Figure 3.j.1-2: Seabrook Station Unit 1 Containment Sump Strainer System General Arrangement

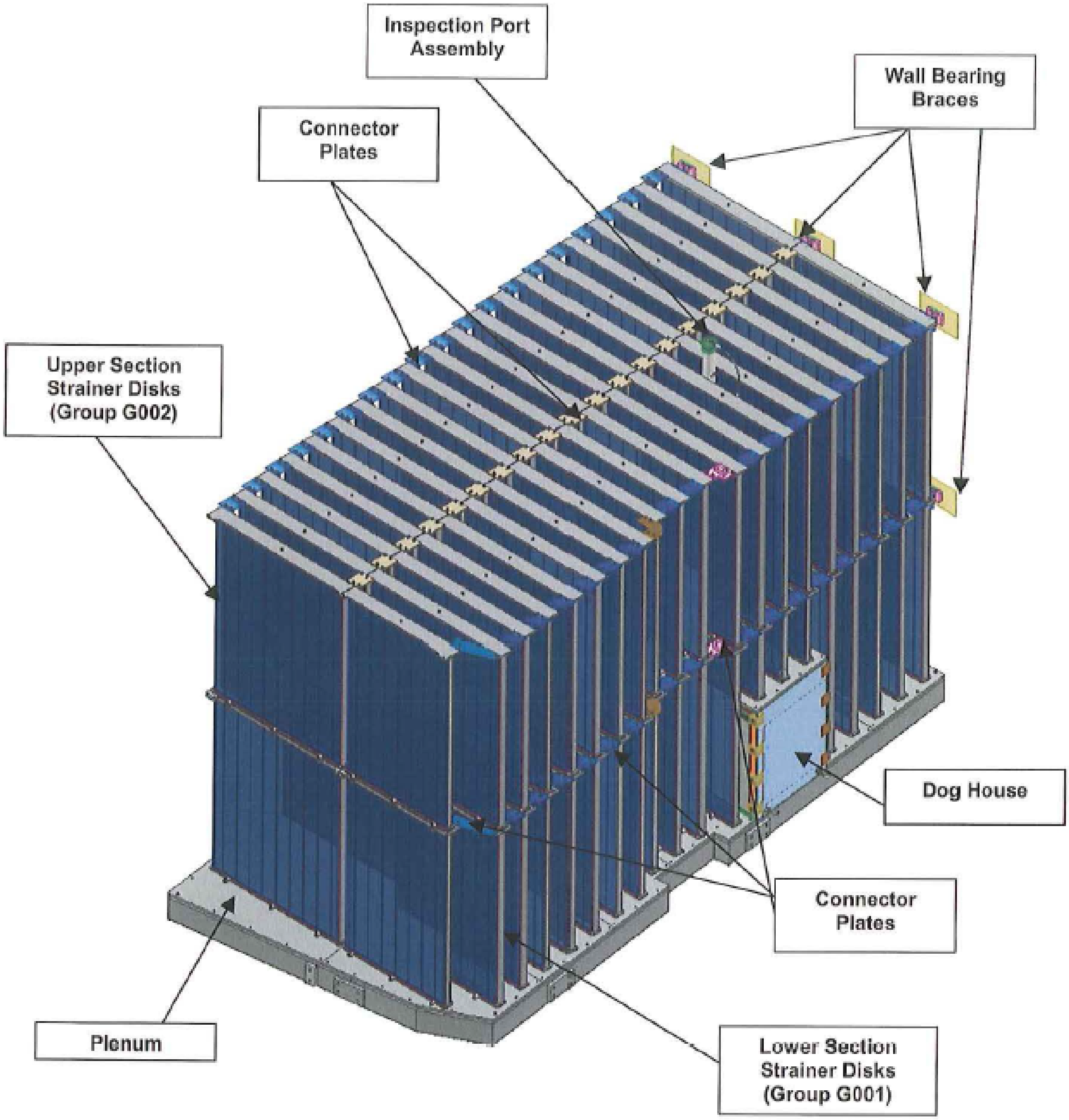

Figure 3.j.1-3: Sump B Assembly

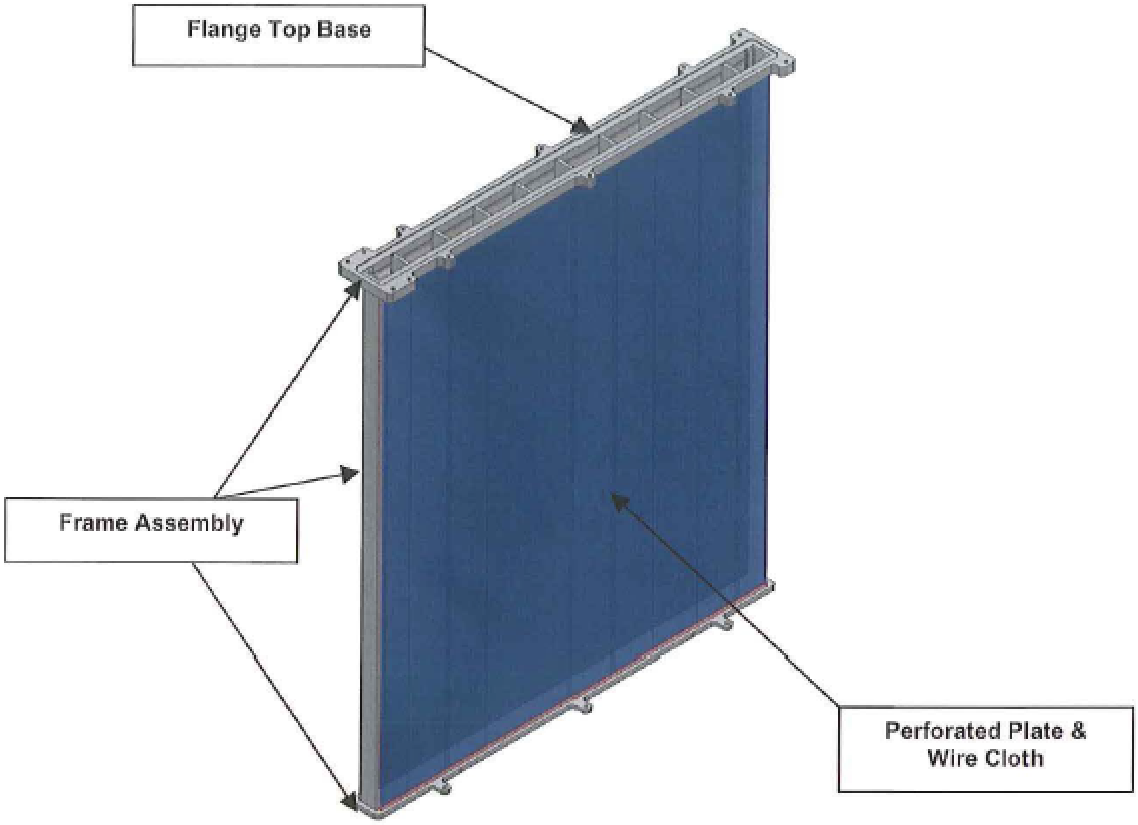

Figure 3.j.1-4: Lower Section – Strainer Disk Assembly (Typical)

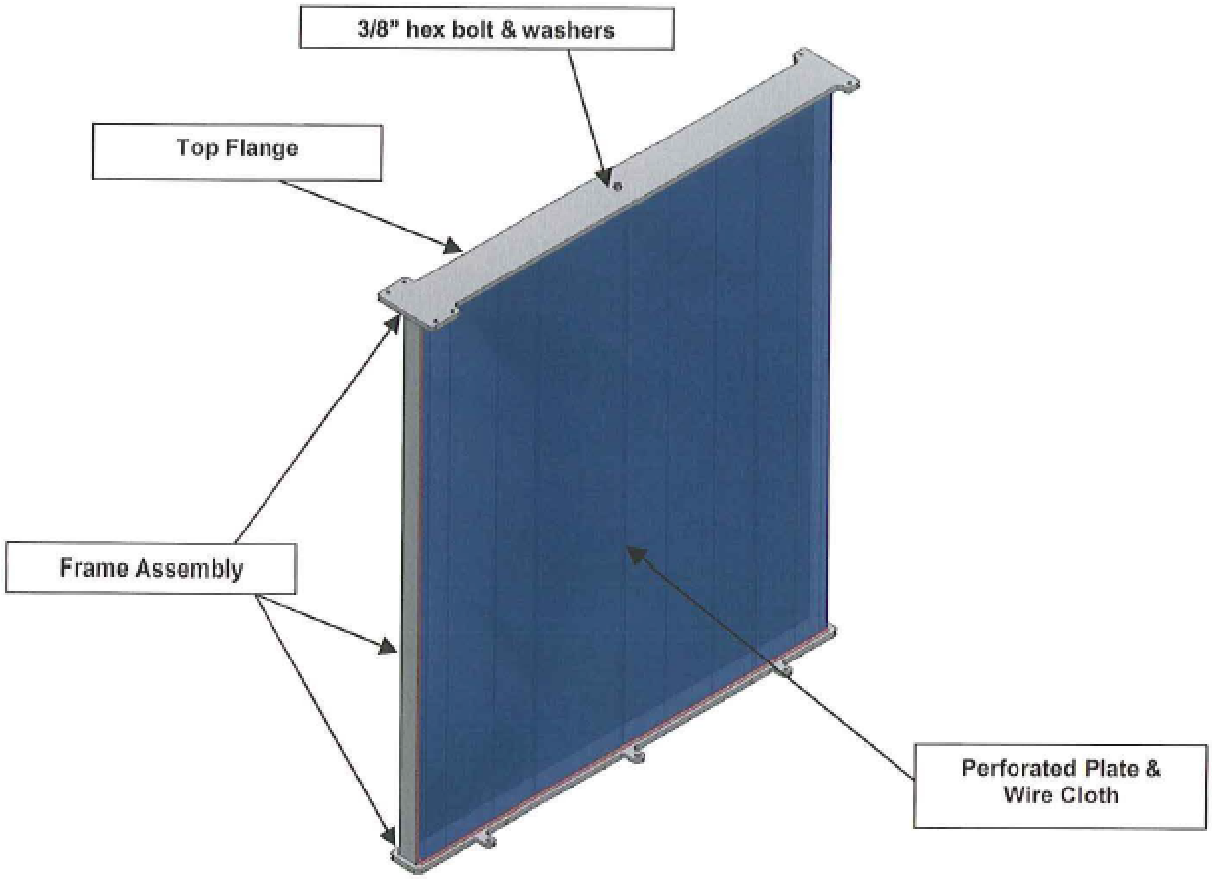

Figure 3.j.1-5: Upper Section – Strainer Disk Assembly (Typical)

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

Response to 3.j.2:

Containment spray drain tubing downstream of the drain valves required reroute to facilitate installation of the new sump strainers. Tubing was rerouted and supported from the top of the "B" sump platform.

k. Sump Structural Analysis

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

Provide the information requested in GL2004-02 <u>Requested Information</u> Item 2(d)(vii).

> *<u>GL 2004-02 Requested Information Item 2(d)(vii)</u>*
> *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.*

1. *Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.*

Response to 3.k.1:

<u>Seabrook Sump Structural Analysis</u>

The previous sump strainers have been completely replaced by new strainer modules and debris interceptors.

The Seabrook containment has two independent sumps. Each sump has its own strainer module consisting of 20 strainer disk sets. Each disk set is composed of four individual strainer disks with two side by side and an additional two mounted above the lower disks. The disks are bolted vertically to each other and to a bottom plenum by means of flanged connections. The disk sets are bolted to those in adjoining vertical planes by means of connector plates attached to the flanges. All strainer components are fabricated from stainless steel and the anchorage details are designed to accommodate thermal expansion. Therefore, there are no internal component thermal stresses.

The trash rack function is incorporated into the debris interceptors and strainer module design. Separate trash racks are not required.

The strainers and their components were analyzed using a detailed ANSYS structural analysis model. The strainers and their supports were designed and analyzed using the ASME BP&V Code, Section III, Subsection NC, Class 2 (for the components) and Subsection NF (for the supports) as a guide. The capability of the strainer perforated plate disks as structural members is based on an equivalent plate approach similar to that presented in ASME III, Appendix A, Article A-8000. ASME Service Level B allowables are used as a guide for the stress evaluation of both normal and accident conditions. Thus, ASME III Subsection NF paragraph NF-

3251.2 was used for Class 2 plate and shell type components and NF-3350 for Class 2 linear type supports. For bolts, the stress limits of NF-3324.6, increased by values provided in Table NF-3225.2- 1, were used. Welds were evaluated per paragraph NF-3324.5. Expansion anchors were evaluated using the ultimate capacity values with a safety factor of four.

The structural load symbols are provided in Table 3.k.1-1. The strainer structural loads and load combinations are summarized in Table 3.k.1-2. The interaction ratios for the components in the models are provided in Table 3.k.2-1. The results of the calculation indicate the interaction ratios for the strainer assembly components are less than or equal to 1.0, and the strainers meet the acceptance criteria for all applicable loadings.

Table 3.k.1-1: Structural Load Symbols

Symbol	Load Definition
D	Dead Load, in air
D’	Dead Load Debris Weight plus Hydrodynamic Mass (Submerged)
L	Live Load
T_o	Normal Operating Thermal Load
T_a	Accident Thermal Load
E_{o1}	Earthquake Load, OBE in air
E_{o2}	Earthquake Load, OBE in water
E_{ss1}	Earthquake Load, SSE in air
E_{ss2}	Earthquake Load, SSE in water
P_{CR}	Differential (Crush) Pressure

Table 3.k.1-2: Strainer Loads and Load Combinations

Load	Strainer Load Combination
1	$D + L + E_{o1}$
2	$D + L + T_o + E_{o1}$
3	$D + L + T_o + E_{ss1}$
4	$D' + L + T_a + E_{o2} + P_{CR}$
5	$D' + L + T_a + E_{ss2} + P_{CR}$

Note: The RH pipe is not directly connected to the strainer so there are no reaction loads transmitted to the strainer.

<u>**Seabrook Debris Interceptors Analysis**</u>

The debris interceptors and supports are fabricated from stainless steel and carbon steel. The bioshield and annulus debris interceptors are constructed from stainless steel bars (1-inch by 3/16-inch) overlaid with stainless steel wire cloth and are supported by a combination of vertical floor-mounted support posts and wall mounts. The accumulator skirt debris interceptors are similar in design, but are bolted to the accumulator skirt without physically modifying the skirt. The scupper debris interceptors are constructed from perforated stainless steel sheet approximately 5.34-inch by 4.38-inch and 0.12-inch thick.

The structural adequacy of the debris interceptors and their components was confirmed using hand analysis methods. Seismic adequacy was confirmed using an equivalent static analysis. The debris interceptor acceptance criteria used the guidance in the AISC Manual of Steel Construction, 9th Edition. Expansion anchors were evaluated using the ultimate capacity values with a safety factor of four.

The debris interceptor structural loads and load combinations are summarized in Table 3.k.1-3 below. The interaction ratios for the debris interceptors in the models are provided in Table 3.k.2-3 for the bio-shield wall debris interceptors and Table 3.k.2-2 for the annulus debris interceptors. The results of the calculation indicate the interaction ratios for the debris interceptors are below 1.0, and meet the acceptance criteria for all applicable loadings.

Table 3.k.1-3: Bounding Debris Interceptor Loads and Load Combinations

Load	Bioshield and Annulus DI Load Combinations (Notes 1-4)
1	D + L
2	D + L + Eo1
3	0.63(D + Ess1) + PCR

Notes:
1. Thermal expansion stresses, T_a, are negligible and therefore, are not included.
2. The differential pressure load is 500 lb per panel. This is the hydrodynamic force during the pool fill-up or recirculation.
3. The hydrodynamic effects during an SSE, E_{SS2}, are negligible and therefore, are not included.
4. Live load, L, is 0.0 for debris interceptors.

2. *Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.*

Response to 3.k.2:

The structural qualification results and margins for the sump strainer structural assembly are presented in the tables below.

Table 3.k.2-1: Strainer Module Stress Ratio Results

Component	**Stress/Load Value**	**Allowable**	**Ratio to Allowable**
Disk			
Perforated Plate	28.6 ksi	31.0 ksi (2S)	0.92
Wire Cloth	25.8 ksi	31.0 ksi (2S)	0.83
Frame/Rib	8.5 ksi	12.3 ksi (1.33 x $0.4S_y$)	0.69
Weld of Perf to End Channels	5.2 ksi	12.3 ksi (1.33 x $0.4S_y$)	0.42
Weld of Perf to Flanges	4.8 ksi	12.3 ksi (1.33 x $0.4S_y$)	0.39
Resistance Weld of Wire Cloth	36 lbs	750 lbs	0.05
Weld of Ribs to Frame	8 ksi	12.3 ksi (1.33 x $0.4S_y$)	0.65
Disk to Disk Bolting	9.3 ksi	23.3 ksi ($0.345S_U$)	0.40
Disk to Plenum Bolting	3.3 ksi	23.3 ksi ($0.345S_U$)	0.14
Disk Connector Plates	10.2 ksi	23.05 ksi (1.33 x $0.75S_y$)	0.44
Connector Plate Bolting (max single shear)	19.96 ksi	19.96 ksi ($0.1426S_U$)	1.00
Connector Plate Bolting (max double shear)	14.6 ksi	19.96 ksi ($0.1426S_U$)	0.73
Separator Wall Anchorage Detail			
Weld/bolt of Disk Flange to Intermediate Plate	17.3 ksi	23.3 ksi ($0.345S_U$)	0.74
Intermediate Plate	3.7 ksi	23.1 ksi	0.16
1-1/8" Diameter Stud	91.2 ksi	102.8 ksi	0.89
Clip Brackets	14.5 ksi	23.1 ksi	0.63
Weld of Brackets to Base Plate	3.5 ksi	12.3 ksi (1.33 x $0.4S_y$)	0.29
Hilti Base Plate	13.7 ksi	23.1 ksi	0.59
Hilti Expansion Anchors-Tension	2.8 kips	3.1 kips	0.91
Supporting Base Frame and Plenum Roof			
Frame Tubing	14.6 ksi	31.0 ksi (2S)	0.47
Tube Splice Connection	7.8 ksi	9.63 ksi ($0.1426S_U$)	0.81
Plenum Roof Plates	<19.3 ksi	31.0 ksi (2S)	<0.62
Plenum Roof Bolts	15.3 ksi	19.96 ksi ($0.1426S_U$)	0.77
Floor Anchorage Detail			
Weld Gusseted Bracket to Tube Member	2.7 ksi	12.3 ksi (1.33 x $0.4S_y$)	0.22
Shoulder Bolts – Tension/Shear Interaction	N/A	N/A	0.52

Component	Stress/Load Value	Allowable	Ratio to Allowable
Hilti Base Plate	17.8 ksi	23.1 ksi	0.77
Hilti Expansion Anchors – Tension/Shear	N/A	N/A	0.96
“Dog House”			
Side Walls	See “Disks”	N/A	N/A
Eastern End Plate	30 ksi	31.0 ksi (2S)	0.97
Eastern End Plate Clip Connection	10.1 ksi	23.05 ksi (1.33 x 0.75S_y)	0.44
East to West Section Bolted Connections	11.5 ksi	19.96 ksi (0.1426S_U)	0.58
Connections to Base Frame	15.6 ksi	19.96 ksi (0.1426S_U)	0.78
ECCS Wall Connections			
Interface Plate	15.9 ksi	31.0 ksi (2S)	0.51
Clamp Bolt	23.1 ksi	23.3 ksi (0.345S_U)	0.99
Hilti Expansion Anchors	2.1 kips	3.13 kips	0.66
Catch Basin Pan			
Hilti Expansion Anchors-Shear	107 lbs	1.26 kips	0.09

Table 3.k.2-2: Interaction Ratios for Annulus Sump Strainer Debris Interceptors

Component		Limiting Stress	Design	Allowable	Ratio to Allowable
Horizontal Grate Panel	72” Length	Strength Capacity	250 lbs	351 lbs	0.71
	14” Cantilever	Bending Stress	7730 psi	20000 psi	0.39
Vertical Grate Panel	24” Span	Strength Capacity	210 psf	1053 psf	0.20
	72” Span	Strength Capacity	76.9 psf	117 psf	0.66
	14” Cantilever	Bending Stress	7540 psi	20000 psi	0.38
	20” Cantilever	Bending Stress	9776 psi	20000 psi	0.49
W5X16, 24” height, Local Stresses		Flange Bending	19000 psi	22500 psi	0.84
W5X16, 24” height		Bending	1190 psi	13800 psi	0.09
Weld between W5X16 to Base Plate		Weld Size	0.06 in	0.25 in	0.24
Weld between Brace to Vertical Leg of Horizontal Bracket	Trim Vertical Leg 1” at Bottom	Weld Size	0.036 in	0.25 in	0.14
	Trim Vertical Leg 2 ¼” at Bottom	Weld Size	0.065 in	0.25 in	0.26
Horizontal Bracket C-C Bolt=8.25”	L 1½X1½X¼	Bending	10900 psi	13800 psi	0.79
	L 1½X1½X¼	Local Stress	11765 psi	17250 psi	0.68
	3/8” A193 GR B8	IR	0.6	1.0	0.6
Gate Hinge		Horizontal Strength	3181 lbf	7380 lbf	0.43
		Vertical Strength	312 lbf	1580 lbf	0.20
Wall Hinge	3/8” dia, 1 5/8” emb	IR	0.83	1.0	0.83
	Wall Hinge Plate	Bending Stress	1602 psi	17250 psi	0.09
4 Bolt Base Plate W5X16 Post	5/8” dia, 2 ¾” emb	IR	0.54	1.0	0.54
	¾” Plate	Bending Stress	9005 psi	17250 psi	0.52
2 Bolt Base Plate W5X16 Post ue 36.5” Span	5/8” dia, 2 ¾” emb	IR	0.85	1.0	0.85
	¾” Plate	Bending Stress	13582 psi	17250 psi	0.79
3 Bolt Base Plate Gate Post, 73” Span	5/8” dia, 3 ½” emb	IR	0.82	1.0	0.82
	¾” Plate	Bending Stress	5448 psi	17250 psi	0.32
Horizontal Bracket C-C Bolt=5.875”	L 1½X1½X¼	IR (Axial+Bending)	0.22	1.0	0.22
	3/8” A193 GR B8	IR	0.266	1.0	0.266
Horizontal Panel Supported by Vertical Panel	72” Length CB Clip Qualification	Bending Stress	16862	17250	0.98
Perforated Plate	72” lg	Max. Cantilever	Various	19 in	OK
Trench DI	3/8” A193 GR B8	IR	0.045	1.0	0.045

Table 3.k.2-3: Interaction Ratios for Bioshield Wall Debris Interceptors

Component		Limiting Stress	Design	Allowable	Ratio to Allowable
Vertical Grate Panel	36" Span	Strength Capacity	76.9 psf	468 psf	0.16
W5X16, 73" height, Local Stress		Flange Bending	2921 psi	16800 psi	0.17
W5X16, 73" height	Combined Axial + Bending Ratio		0.35	1.0	0.35
Weld between W5X16 to Base Plate		Weld Size	0.182 in	0.25 in	0.73
Gate Hinge	Horizontal Strength		80 lbf	7380 lbf	0.01
	Vertical Strength		40 lbf	1580 lbf	0.03
	½" dia Bolt, SA193 GR B8		0.084	1.0	0.084
Wall Hinge	3/8" dia, 1 5/8" emb	IR	0.12	1.0	0.12
	Wall Hinge Plate	Bending Stress	363 psi	16800 psi	0.02
3 Bolt Base Plate Gate Post	5/8" dia, 3 ½" emb	IR	0.958	1.0	0.958
	¾" Plate	Bending Stress	13618 psi	16800 psi	0.81
Angle 6X4X3/8		Bending Stress	3808 psi	16800 psi	0.23
	3/8" A193 GR B8	IR	0.614	1.0	0.614
Perforated Plate	72" lg	Max. Cantilever	Various	19 in	OK
Trench DI	3/8" A193 GR B8	IR	0.045	1.0	0.045

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

Response to 3.k.3:

The locations of the debris interceptors have been analyzed for susceptibility to missiles, jet impingement and pipe whip. Postulated missiles will not strike the debris interceptors. None of the bioshield or annulus debris interceptors are in the path of a postulated pipe whip or jet spray.

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

Response to 3.k.4:

Each strainer assembly and each debris interceptor is a passive unit (i.e., there are no active components and the strainers do not utilize backflushing). They are described in the Response to 3.j.

I. Upstream Effects

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

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.*

1. *Summarize the evaluation of the flowpaths from the postulated break locations and containment spray washdown to identify potential choke points in the flow field upstream of the sump.*

Response to 3.I.1:

The following areas / items were considered as part of the evaluation to determine potential choke points for flow upstream of the sump:

- Refueling Canal
- Lower Containment
- Containment Spray Washdown
- Upstream Blockage Points Walkdown

Refueling Canal

The refueling canal at Seabrook is drained by three drains. One of these drains is located on the north side of the reactor cavity at the (-) 2'-11" elevation, and the other two are on the south side of the reactor at the (-) 12'-10½" and (-) 16'-4¼" elevations. Any containment spray flow falling directly into the refueling canal must flow through these drains. The pipes that comprise each drain exit are 4 inches in diameter, which eventually converge into one 2-inch exit pipe. If these drains were to become blocked with large debris that could be present in the refueling canal during washdown, it could cause a large volume of water to be held up. An engineering change will be implemented to modify the drain lines so that there is an open flow path to the containment sump pool. See the Response to 3.I.4 for more information.

Lower Containment

The lower containment at Seabrook consists of two compartments – the containment area inside the bioshield wall, and the annulus outside the bioshield wall. Water travels from inner containment to the annulus by means of two doorways on the north side of containment, two doorways on the south side of containment, two passageways on the west side of containment, and one passageway on the east side of containment. With the exception of the passageway on the east side of containment, all doorways and passageways have debris interceptors installed that cover the space of each doorway/passageway. These debris interceptors are made of a wire mesh cloth with grate panels. If debris were to build up and block the passage of water through one of the doors/passageways, water would flow through the other doors/passageways or out of the passageway on the east side of containment, which does not have a debris interceptor installed. There are debris interceptors in the annulus that may cause a potential upstream blockage point as well. These interceptors vary in height from 14 inches to 18 inches. These interceptors are comprised of wire mesh cloth and grating, and have a horizontal lip at the top. If debris were to block the passage of water through these interceptors, water will flow over the top of them because they were designed to have sufficient clearance for flow at the minimum water level.

Containment Spray Washdown

Containment spray washdown has a clear path to the containment sump area. Large sections of the floor on each level in containment are covered with grating that allows the water to pass.

A complete evaluation of the containment CAD model, along with a review of the CFD model, indicated no significant areas with the exception of the refueling canal that could become blocked with debris and hold up water during the sump recirculation phase.

Upstream Blockage Point Walkdown

A walkdown and analysis of the Seabrook containment was performed to assess potential chokepoints in the path from the RCS loops to the ECCS sump, including gates and screens. The walkdown confirmed that there are no potential chokepoints that would adversely affect operation of the ECCS and CBS in the recirculation mode or cause the sump water level to be less than the design basis values. The walkdown flow path survey included curbs, ledges, gates, tool boxes, etc., but because of the timing, did not cover the debris interceptors. Note that a separate walkdown specifically for the refueling canal drain lines was performed (see the Response to 3.I.4).

2. *Summarize measures taken to mitigate potential choke points.*

Response to 3.I.2:

Per the Response to 3.I.1, no measures were necessary to mitigate potential choke points for lower containment and containment spray washdown. However, measures to mitigate the potential choke point in the refueling canal will be implemented. See the Response to 3.l.4 for more information.

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

Response to 3.l.3:

The debris interceptor design and layout ensures that the debris interceptors do not create new choke points. The debris interceptors in the annulus are designed so that there are several inches of clearance between the top of the debris interceptor and the minimum water level. The passageway on the east side of containment does not have a debris interceptor to ensure that there is at least one completely unobstructed pathway for water to flow from the break to the outer annulus.

4. *Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.*

Response to 3.l.4:

The Seabrook refueling canal drains and the associated drain lines have the potential to become clogged by debris following a LOCA. If the drains were to become blocked, the water held up in the refueling canal could significantly reduce the containment pool water level and sump strainer submergence. This would result in a reduction in allowable head loss across the strainer.

Using the refueling canal drain walkdown results as inputs, an engineering change package will be implemented to modify the refueling canal drains and the associated drain lines. The purpose of this engineering change is to ensure that, with the modifications, the drains will not be clogged during post-accident sump recirculation. The engineering change will implement strainers over all three drains in the reactor cavity and will modify the drain lines so that there is an open flow path to the containment sump pool.

m. Downstream Effects – Components and Systems

The objective of the downstream effects, components and systems section is to evaluate the effect 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 2004-02 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.*

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

Response to 3.m.1:

Seabrook performed evaluations to address ex-vessel downstream effects in accordance with WCAP-16406-P-A and the associated NRC SER. The limitations and conditions provided in the NRC SER were addressed as part of the evaluations and it was shown that the WCAP-16406-P-A methodology was appropriate for use at Seabrook. All refinements or modifications that were applied to the WCAP-16406-P-A methodology are described below.

The following methodology was employed in the ex-vessel downstream effects evaluations.

Maximum Debris Ingestion Determination

Blockage and wear of the ECCS and CBS components and piping in the post-LOCA recirculation flowpaths downstream of the sump screen were addressed within the downstream effects evaluations. Seabrook has screens with a nominal hole diameter of 0.068 inches. The maximum spherical size particulate that is expected to pass through the strainer system and into the ECCS and CSS recirculation flowpaths is 0.068 inches. The adequacy of the sump screens' mesh spacing or strainer hole size was conservatively addressed by assuming that the maximum spherical size of particulate debris that can pass through the strainers is 0.1 inches.

Additionally, the maximum quantity of fines debris transported to the sump strainers for each debris type was assumed. Of these maximum quantities, 100% of fiber, qualified coatings, and latent debris that are generated and transported as fines were assumed to bypass the strainer. For unqualified coatings, the size distribution presented in WCAP-16406-P-A was used to determine what percentage of debris was small enough to bypass the strainer.

A surveillance procedure is in place to inspect the strainers and debris interceptors for visible evidence of structural distress or abnormal corrosion, that the inspection ports are capped and locked, and to confirm that there is no debris present on the strainers or debris interceptors.

Initial Debris Concentrations

Initial debris concentrations were developed using the assumptions and methodology described in Chapter 5 of WCAP-16406-P-A. The total maximum initial debris concentration was determined to be 4,557.65 ppm, with fiber debris contributing 3,004.00 ppm, and particulate debris contributing 1,553.65 ppm. The downstream effects evaluations were performed using conservative overall fiber and particulate concentrations.

Flowpaths and Alignment Review

Both trains of the ECCS and CSS were reviewed to ensure all flowpaths and components impacted by the debris-laden recirculation flow were considered. Documents used for this effort included piping and instrumentation diagrams (P&IDs) and other plant design documents as applicable.

The components within the recirculation flowpaths were categorized as either "smaller", "further evaluation required", "larger", or "excluded" . The "smaller" category contains components with flow clearances known to be physically too small to pass the debris. The "further evaluation required" category includes components that are determined by industry guidance to have the potential to become plugged under debris loading. The "larger" category includes components with clearances sufficiently large enough to pass recirculation debris without causing blockage, and the "excluded" category contains components for which industry guidance suggests are not susceptible to debris blockage.

Component Blockage and Wear Evaluations Methodology

All component evaluations were performed based on WCAP-16406-P-A. Components addressed in the evaluations include pumps, heat exchangers, orifices, spray nozzles, instrumentation tubing, system piping, and valves required for the post-LOCA recirculation mode of operation of the ECCS and CBS. The evaluations included the following steps:

- Identifying all components in the ECCS and CBS flowpaths (see Flowpaths and Alignment Review above).
- Applying the appropriate wear models for pumps. Pumps experience erosive wear and abrasive wear due to debris ingestion. Two abrasive wear models were developed in WCAP-16406-P-A including the free flowing abrasive wear model and Archard abrasive wear model. Each model was used as appropriate in the evaluations.
- Applying the appropriate erosive wear model for heat exchangers, orifices, spray nozzles, system piping, and valves.
- Evaluating the potential for plugging of heat exchanger tubes, orifices, spray nozzles, system piping, and valves by comparing the maximum debris size expected to be ingested through the sump screen to the clearances within the components.
- Evaluating the potential for debris sedimentation inside system piping, heat exchanger tubing, and valves that move or reposition during post-LOCA recirculation phase (and must go fully closed) by comparing operating line velocity to minimum line velocity required to avoid sedimentation (0.42 ft/s).
- Evaluating the potential for debris collection in the instrument sensing lines.

2. *Provide a summary and conclusions of downstream evaluations.*

Response to 3.m.2:

The following is the summary of results and conclusions of the downstream effects evaluations:

ECCS/CBS Pumps

The evaluation for pumps addressed the effects of debris ingestion through the sump screen on three aspects of operability: hydraulic performance, mechanical-shaft seal assembly performance, and mechanical performance. The effect of recirculating sump debris on the hydraulic and mechanical performance of the ECCS and CBS pumps was determined to be acceptable. The mechanical shaft seal assembly performance evaluation found that no Seabrook ECCS or CBS pumps used cyclone separators in the seal piping arrangements. The RHR pumps have an API Plan 23 piping arrangement, which precludes the injection of debris laden post-LOCA fluids into the seal cavity chamber. The CBS pumps utilize an API Plan 21 seal cooling arrangement and the charging and safety injection pumps utilize an API

Plan 01 seal cooling arrangement, both of which allow the injection of pump fluid for seal cooling. An evaluation of these arrangements concluded that the debris concentration in the seals will have no detrimental impact on the operation or integrity of the seals. The RHR and CBS pumps have backup bushings made of carbon material. An engineering evaluation was provided for the continued use of the RHR and CBS pumps' carbon backup bushings which determined that the backup bushings are "Acceptable As-Is". Additional analysis showed that, if wear and failure of the primary seals are assumed to occur, the disaster bushing would wear a negligible amount in 30 minutes, and that the leakage rate of the pump is kept to an acceptable limit until the leakage is isolated and another train of ECCS or CS could be started.

When evaluating pump wear as part of the hydraulic performance evaluation, a modification to the WCAP-16406-P-A methodology was used to refine the distribution of abrasive versus erosive particulate debris. WCAP-16406-P-A considers 50 microns to be the constant lower threshold size for abrasive debris (which is equal to 40% the wear ring gap of the hypothetical pump considered therein). The Seabrook analysis used 40% the actual wear ring gap at any given time to define the threshold for abrasive-sized particulate. In other words, as the wear ring gap opens due to wear over time, the threshold size for abrasive debris increased and the amount of abrasive debris is reduced. However, the amount of abrasive debris that was reduced was assumed to contribute to erosive wear. As noted in the Response to 3.m.1, the initial debris concentrations used for the downstream effects evaluations are conservative.

The evaluation for pumps determined that the effects of debris ingestion through the screen is not an issue with regard to hydraulic performance, mechanical-shaft seal assembly performance, and mechanical performance.

ECCS/CBS Valves

WCAP-16406-P-A provides the criteria for wear and plugging analysis for ECCS and CSS valves due to debris-laden fluid (Reference 23 pp. 8-27 and 8-28). The following tables are a summary of the criteria that would necessitate an evaluation. The valves that do not meet these criteria are not critically impacted by wear and plugging due to debris laden fluid.

Table 3.m.1: Valve Evaluation Blockage Criteria (Reference 23 pp. 8-28)

Valve Type	Size (inches)	Position During the Event
Gate	≤ 1	Open
Globe	≤ 1-1/2	Open
Globe	> 1 (Cage Guide)	Open
Check Valves/ Stop Check	≤ 1	Open
Butterfly	< 4	Throttled < 20°
Globe Valves	All	Throttled
Hermetically Sealed Valves	All	Open

Table 3.m.2: Valve Evaluation Erosive Criteria (Reference 23 pp. 8-27)

Valve Type	Size (inches)	Position During the Event
Globe	All	Throttled
Butterfly	All	Throttled

Valves were evaluated for blockage in the downstream effects evaluations. Valves that were determined to be “larger” or “excluded” did not warrant further evaluation, but those valves identified as “further evaluation required” received a more detailed evaluation. It was determined that all valves passed the acceptance criteria for the blockage evaluation.

Valves were evaluated for debris sedimentation. Valves identified as “larger” or “excluded” did not require additional analysis, but valves identified as “further evaluation required” were analyzed further. The line velocities for all valves analyzed was found to be greater than 0.42 ft/s, thus, debris sedimentation was not an issue.

Valves were screened to determine if an evaluation of the wear impact was required. All manually throttled valves in the post-LOCA recirculation flowpath were evaluated to determine the extent of erosion. The initial debris concentration provided above was used to calculate the initial wear rate, and then the large debris (all fiber, unqualified epoxy ≥ 675 μm, and unqualified IOZ ≥ 125 μm) was depleted over time using a depletion coefficient of $\lambda = 0.07$, as recommended by WCAP-16406-P-A. It was determined that all valves passed the acceptance criteria for the erosive wear evaluation, with the most limiting flow area increase being 2.878% for the sample purge throttle valve (SS-V208), below the 3% acceptance criteria provided by WCAP-16406-P-A.

ECCS/CBS Heat Exchangers, Flow Restrictions, and System Piping

Heat exchanger tubes, flow restrictions, and system piping were evaluated for the effects of erosive wear for the initial debris concentrations presented in the

Response to 3.m.1 over the mission time of 30 days. The erosive wear on these components was determined to be insufficient to affect system performance.

The smallest clearance found for Seabrook heat exchangers, orifices, spray nozzles, and system piping in the recirculation flowpaths that were not categorized as “excluded” is 0.375 inches, for the CBS spray nozzles. The maximum diameter of downstream debris was conservatively assumed to be 0.100 inches. Therefore, no blockage of the flowpaths is expected.

System piping and heat exchanger tubing was evaluated for plugging based on system flow and material settling velocities. For all piping, the minimum flow velocity was found to be greater than 0.42 ft/s, the minimum velocity required to prevent debris sedimentation. All system piping passed the acceptable criteria for plugging due to sedimentation.

ECCS/CBS Instrumentation Tubing

Instrumentation tubing (or sensing lines) was evaluated for debris settling from the process streams. According to WCAP-16406-P-A, Section 8.6.6, instrument tubing is designed to remain water solid without taking flow from the process stream. This prevents direct introduction of debris laden fluid into the instrument tubing. Settling of the debris is the only process by which the debris is introduced into the instrument tubing. Since the sensing lines are water solid and stagnant, the introduction of either fibrous or particulate debris by flow into the sensing lines is not possible. The terminal settling velocities of the debris sources in the process streams are small by comparison to the process fluid velocities; therefore, introduction of debris by settling into the instrument tubing is not expected. It was found that all instruments identified as required post-LOCA are located either on the top or side of the applicable headers. This excludes the possibility of debris settling in the subjected instrument tubing. Therefore, blockage and wear of ECCS or CSS instrument tubing due to debris laden fluid are not expected. An evaluation of the effects of debris laden recirculation fluid on the reactor vessel level monitoring system (RVLMS) was also performed, and it was determined that RVLMS is acceptable.

3. *Provide a summary of design or operational changes made because of downstream evaluations.*

Response to 3.m.3:

No plant design changes were made as a result of the downstream effects evaluations.

The only operational change made related to downstream effects is that surveillance requirements were updated for the new strainer system. A surveillance procedure is in place to inspect the strainers and debris interceptors for visible damage or corrosion, and to confirm that there is no debris present on the strainers or debris interceptors.

n. Downstream Effects – Fuel and Vessel

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

i. Show that the in-vessel effects evaluation is consistent with, or bounded by, the industry generic guidance (WCAP-16793-NP), 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 where exceptions were taken, and summarize the evaluation of those areas.

Response to 3.n.1:

In-vessel downstream effects for Seabrook were evaluated per the methodology and acceptance criteria in WCAP-16793-NP, the associated NRC SE, WCAP-17788-P, and WCAP-17788-NP. The evaluation included the following:

1. Peak cladding temperature (PCT) due to deposition of debris on fuel rods (WCAP-16793-NP).
2. Deposition thickness (DT) due to collection of debris on fuel rods (WCAP-16793-NP).
3. Amount of fiber accumulation at reactor core inlet and inside reactor vessel (WCAP-17788-P).

These analyses concluded that post-accident long-term core cooling (LTCC) will not be challenged by deposition of debris on the fuel rods, accumulation of debris at the core inlet, or accumulation of debris in the heated region of the core for all postulated LOCAs inside containment. A brief summary of the relevant testing and analyses is provided below.

Adoption of PSL1 Test Data for Seabrook

Seabrook used the penetration data from St. Lucie Unit 1 (PSL1) to evaluate in-vessel downstream effects. Although the general layout of the PSL1 and Seabrook strainers inside the containment are different, the two strainers share a high level of similarity in regard to plant parameters that have a significant impact on fiber penetration rate: strainer perforated plate opening size, strainer approach velocity, fiber debris type, and sump water chemistry, as discussed below.

<u>Strainer Design</u>

Both the Seabrook and the PSL1 strainers were designed by GE. They are each non-flow-controlled, consisting of rectangular disks mounted on their bottom side to a plenum box, as shown in Figure 3.n.1-1.

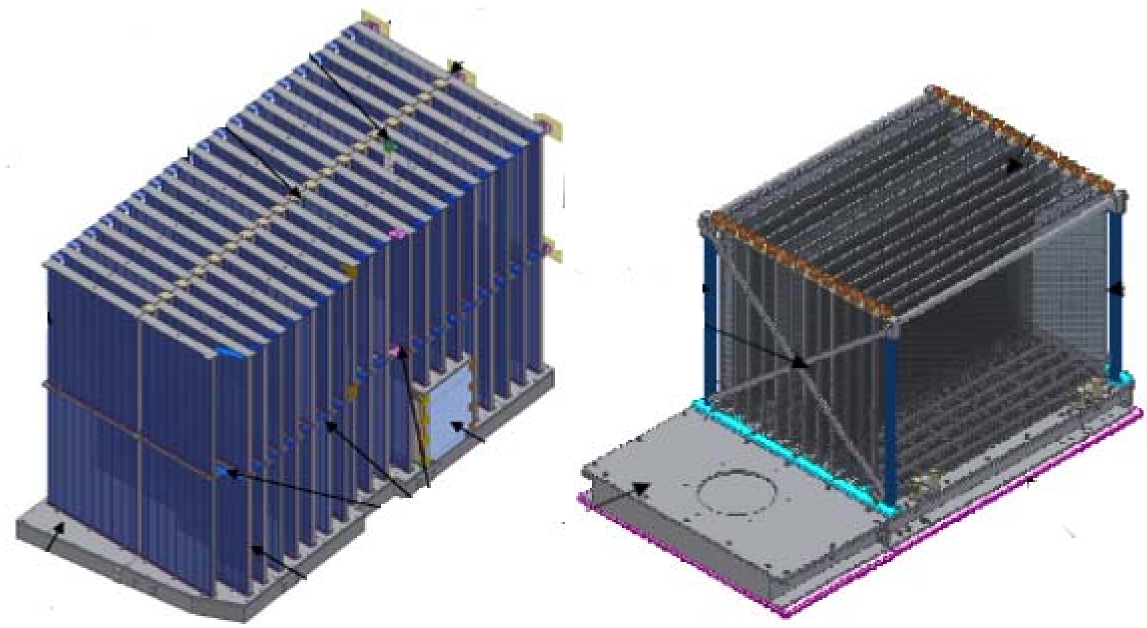

Figure 3.n.1-1 Seabrook (left) and PSL1 (right) Strainer Modules

The Seabrook and PSL1 strainer disks also have similar construction, consisting of a disk frame, perforated plates, and a wire cloth. The disk frame for both disks has an upper and lower bar connected by vertical bars that are sandwiched by the perforated plates and serve to create vertical flow channels down into the plenum. The Seabrook and PSL1 strainer disk frames are shown in Figure 3.n.1-2.

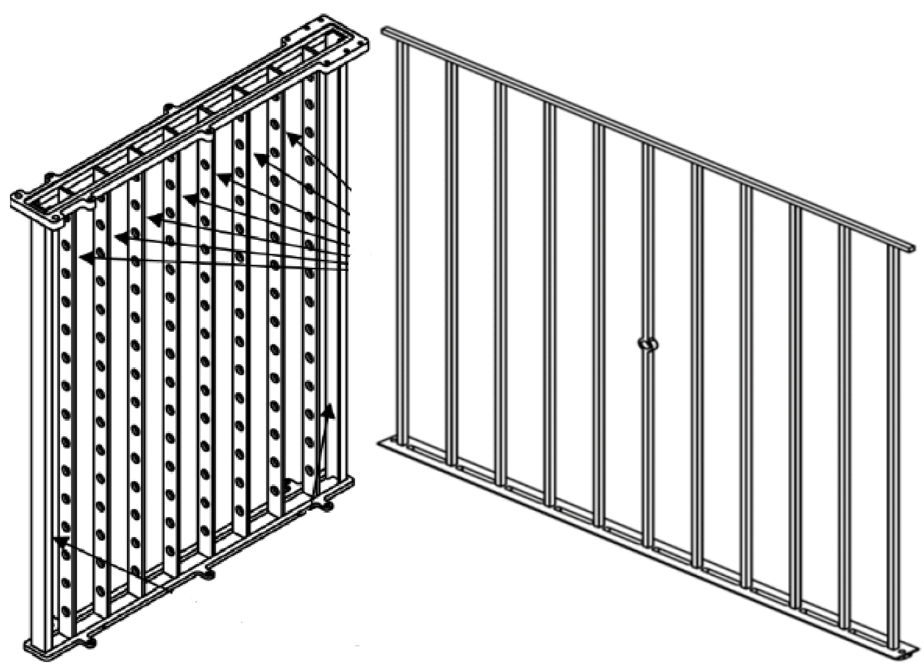

Figure 3.n.1-2: Seabrook (left) and PSL1 (right) Strainer Disk Frames

The perforated plates that are mounted on either side of the disk frames for Seabrook and PSL1 have identical characteristics, as shown in Table 3.n.1-1.

Table 3.n.1-1: Seabrook and PSL1 Strainer Perforated Plate Comparison

Parameter	Seabrook	PSL1
Strainer Perforated Plate Hole Diameter	1/16 inch	1/16 inch
Strainer Perforated Plate Hole Pitch	0.109 inch	0.109 inch
Strainer Perforated Plate Thickness	0.048 inch	0.048 inch
Strainer Perforated Plate Open Area	30%	30%
Wire Cloth Open Area	57.8%	57.8%

Because of the high level of similarity between the strainers, it is expected that, for common flow conditions, the fiber loading patterns and penetration rates would be very similar. Additionally, as mentioned above, neither the PSL1 nor Seabrook strainer is flow controlled. Therefore, the majority of the strainer flow travels through the portion of the strainer disks close to the connection to the plenums. As a result, the difference in size between the PSL1 and Seabrook strainer disks has no significant impact on fiber penetration.

The spacing between two adjacent strainer disks for the Seabrook strainer, 7.25” is greater than that of the PSL1 test strainer, 4.9” . This difference in spacing has no impact on the fiber penetration. Note that the actual PSL1 sump strainer has a smaller gap width between two adjacent disks, 1.874” . When performing fiber penetration testing, every other disk was removed to increase the gap width. This modification allowed the fiber to reach the perforated disk surfaces without bridging over the gaps between disks, which could cause non-conservative fiber penetration results. The larger gaps for Seabrook would also be effective in preventing fiber bridging.

Therefore, PSL1 penetration testing was performed with a plant strainer module that is representative of the Seabrook sump strainers.

Strainer Approach Velocity, Fiber Debris Type, and Sump Water Chemistry

The approach velocities, fibrous debris type, maximum fiber bed thickness, and sump water chemistry are compared between PSL1 and Seabrook in Table 3.n.1-2. Note that debris concentration is not compared in the table because debris concentration was shown to have insignificant effect on fiber penetration.

Table 3.n.1-2. Seabrook and PSL1 Plant Recirculation Condition Comparison

Parameter	Seabrook	PSL1	Testing Evaluation
Average Approach Velocity	0.0055 ft/s	0.0023 ft/s	PSL1 penetration tests were conducted at 0.0096 and 0.0024 ft/s, which encompass the average approach velocity for Seabrook. Although the maximum module approach velocity (0.0217 ft/s) exceeds the velocity used for the high flow test, this maximum approach velocity is only applicable for the clean strainer conditions. As soon as debris starts to accumulate on the strainer, the flow distribution on the strainer becomes more uniform and the peak module approach velocity decreases rapidly. Therefore, the Seabrook strainer approach velocities are adequately represented by PSL1 testing conditions.
Max Disk/Module Approach Velocity	0.0217 ft/s (Disk)	0.0096 ft/s (Disk)	
Fiber Debris Composition	Nukon/LDFG	Nukon/LDFG (>90%), Temp-Mat	The PSL1 tested fiber composition consisted of >90% Nukon. The fiber composition is therefore reasonably representative of Seabrook plant conditions.
Max Fiber Bed Thickness	0.65 inches	0.41 inches	The tested fiber bed thickness was 0.41 inches. This allows sufficient data to establish a reliable penetration trend that can be conservatively extrapolated for Seabrook.
Buffer Type/ Concentration	NaOH/ 0.11 mol/L	NaOH/ 0.083 mol/L	The tested chemistry condition was a boron concentration of 0.142 mol/L and an NaOH concentration of 0.083 mol/L. The tested condition is similar to Seabrook water chemistry conditions.
Boron Concentration	0.186 mol/L	0.142 mol/L	
Max pH	9.4	9.66	

As shown in Table 3.n.1-2, the PSL1 penetration testing conditions are similar to the Seabrook plant recirculation conditions. Therefore, it is acceptable to use PSL1 fiber penetration data to address in-vessel effects for Seabrook. PSL1 penetration testing is discussed below.

Fiber Penetration Testing

Two large-scale fiber penetration tests were conducted with test parameters selected to be representative of conservative conditions (temperature, flow rate, and water chemistry). The test results were used to derive a model to quantify fiber penetration for the plant strainer at its respective plant conditions. This model may be applied to the Seabrook strainer because of the similarity between plant conditions relevant to fiber penetration. The penetration test is described in the sections below.

Test Loop Design

The test loop used for penetration testing included a metal test tank that housed a test strainer, a fiber filtration system, a heating system, and a debris introduction system. A schematic piping diagram of the test loop is provided in Figure 3.n.1-3. A test loop recirculation pump was used, which took suction from the test strainer plenum and returned the water back into the test tank. Water was circulated through the test strainer, a fiber filtering system, and various piping components. The return flow exits into the tank were located such that the turbulence from the flow did not affect the debris bed on the test strainer, but allowed for thorough mixing of debris in the water column as it was introduced into the test tank.

The filtration system consisted of two parallel in-line filter housings with filter bags installed. The arrangement allowed for the online filter housing to be switched mid-test in order for clean bags to be brought online while providing continuous filtration. The filter bags were verified to have fiber capture rates of >97%.

Flow elements were used to measure the flow rate through the test loop and the flow split between the front and rear of the strainer. Flow control valves, and heating and cooling loops were used to control the test flow rate and water temperature.

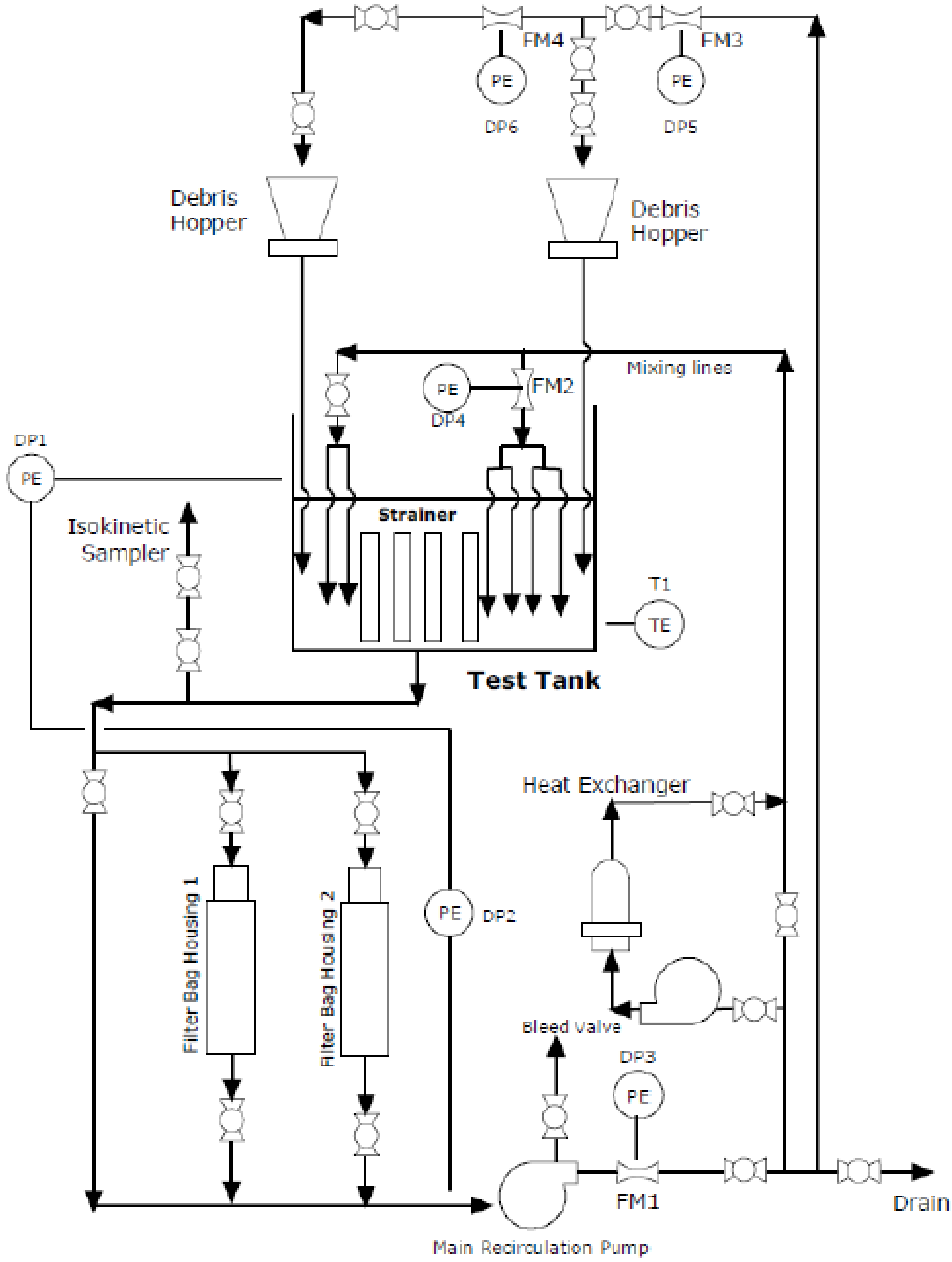

Figure 3.n.1-3: Piping Diagram of Head Loss Test Loop

The test tank was rectangular, as shown in Figure 3.n.1-4. Debris was introduced in the high-agitation regions on both sides of the strainer. These regions were equipped with hydraulic mixing lines to create adequate mixing and prevent the debris from settling. This mixing motion kept fiber in suspension without disturbing the fiber bed on the strainer.

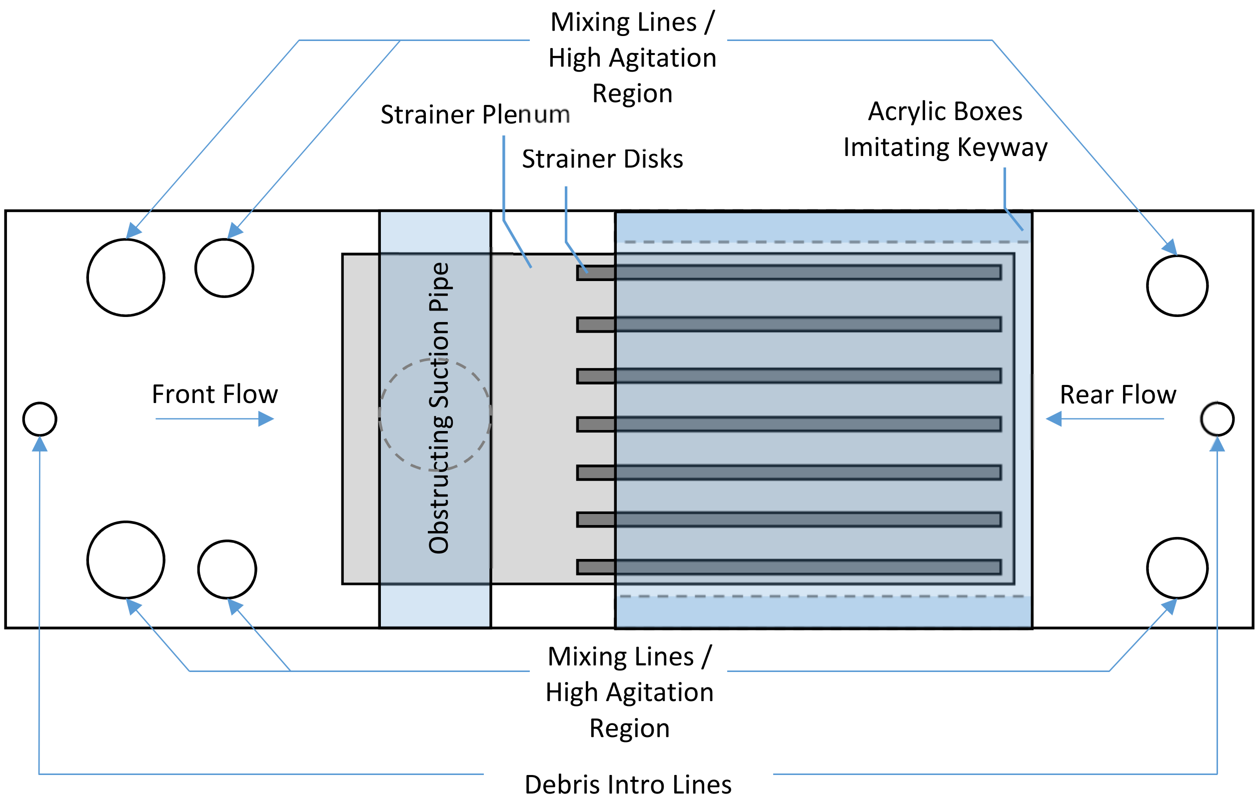

Figure 3.n.1-4: General Arrangement of PSL1 Fiber Penetration Test Tank

The effectiveness of the agitation regions is displayed in Table 3.n.1-3, which documents the quantity of fiber that did not transport to the strainer and was collected from the high agitation or transport regions after the conclusion of each test.

Table 3.n.1-3: Summary of PSL1 Fiber Transport

Test[1]	Fiber Size	Gross Fiber Added (g)	Non-Transported Fiber (g)	Net Fiber Added (g)	% of Fiber Transport
Low Flow	Fines	7,287.70	3.05	7,284.65	99.96%
High Flow	Fines	7,287.44	0.84	7,286.60	99.99%

[1] The test shown corresponds to the name assigned to each test in the PSL1 fiber penetration test report.

<u>PSL1 Test Strainer</u>

The test strainer for penetration testing was a prototypical strainer module. The strainer module was modified with every other disk removed, such that only 7 of the

13 disks were installed on the module. This modification more than doubled the gap between adjacent disks to prevent a fiber bridge from developing across adjacent disks. This promoted fiber penetration by preserving penetrable strainer area. The plenum slots corresponding to the removed disks were capped to prevent a path for flow to bypass the remaining perforated strainer disks.

PSL1 Debris Types and Preparation

Nukon and Temp-Mat fines were used in testing. All fiber fines were prepared according to the NEI protocol (Reference 24). Preparation of Nukon and Temp-Mat debris was performed separately. Nukon sheets, with an overall thickness of 2 inches, were baked single-sided until the binder burnout reached into approximately half the thickness. The heat-treated sheets were then cut up into approximately 2” x 2” cubes and weighed out according to batch size. Nukon was then pressure-washed with test water following the NEI protocol.

To pressure-wash the debris, the debris was placed inside a debris preparation vessel that included a manifold with three high pressure nozzles. Test water was added to the vessel using a low-pressure water spray until the fiber debris was completely wetted and a slurry was formed. The debris was then sprayed with test water pressurized to 1500 psi. The initial amount of water, the high-pressure spray nozzle position within the vessel, and the duration that the high-pressure spray was applied were controlled during debris preparation so that fine fiber batches had similar characteristics. Acceptable debris characteristics were documented by photographing each batch of prepared debris over a light table. Fiber fines were acceptable once their composition was predominantly Class 2 fibers as defined in NUREG/CR-6224 (Reference 25 Table B-3), consisting mainly of individual fibers with lesser quantities of fiber shards and small clumps.

Temp-Mat was pre-shredded by the debris vendor and heat treated at the test vendor’s facility. Temp-Mat batches were prepared with equal parts of heat-treated and un-treated Temp-Mat. Temp-Mat was then pressure-washed in the same manner as the Nukon debris. Figure 3.n.1-5 shows the prepared Nukon and Temp-Mat fines after pressure washing.

Figure 3.n.1-5: Nukon Fines (Left) and Temp-Mat Fines (Right) Prepared for PSL1 Penetration Testing

After each debris type was separately pressure-washed, the Nukon and Temp-Mat prepared for each batch were combined in a barrel and stirred to form a homogeneous mixture before introduction.

<u>PSL1 Debris Introduction</u>

Fine fiber debris was introduced in four separate batches. The first and fourth batches resulted in theoretical uniform bed thicknesses of 0.067” and 0.41”, respectively. The final fiber bed is shown on a disk removed from the strainer assembly after the completion of testing in Figure 3.n.1-6 below.

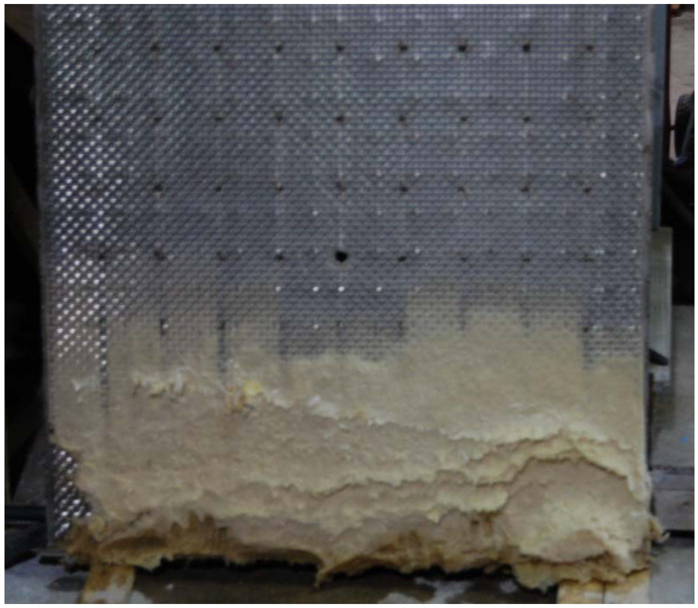

Figure 3.n.1-6: Final Fiber Bed from PSL1 Penetration Testing

The first batch consisted only of Nukon. Temp-Mat was added in the remaining batches to achieve a final fine fiber composition of approximately 10% Temp-Mat.

Fine fiber debris was introduced to the front and rear sides of the test tank via a front and rear debris hopper, respectively. Each batch introduction was split evenly between the two sides of the strainer.

Debris was added to the hopper by using 5 gallon buckets to transfer the debris slurry from the barrel to the debris hopper. During this process, the debris slurry was stirred to promote a homogeneous mixture in the barrel. Additionally, the debris added to the hopper and transported into the tank was stirred, as necessary to break up any agglomeration of fibers that formed.

For each batch, the debris introduction rate was controlled to maintain a prototypical debris concentration in the test tank.

PSL1 Debris Capture

Fiber can penetrate through the strainer by two different mechanisms: prompt penetration and shedding. Prompt penetration occurs when fiber reaching the strainer travels through the strainer immediately. Shedding occurs when fiber that already accumulated on the strainer migrates through the bed and ultimately travels through the strainer. Both mechanisms were considered during testing.

Fibers that passed through the strainer were collected by the in-line filters downstream of the test strainer and upstream of the pump. All of the flow downstream of the strainer traveled through the 5-micron filter bags before returning to the test tank. The capture efficiency of the filter bags was verified to be above 97%. The filtering system allowed the installation of sets of filter bags in parallel lines such that one set of filter bags could be left online at all times, even during periods in which filter bags were swapped.

Before and after each test, all of the filter bags required for the test were uniquely marked and dried, and their weights were recorded. The weight gain of the filter bags during testing was used to quantify fiber penetration. After testing, the debris-laden filter bags were rinsed with deionized (DI) water to remove residual chemicals before being dried and weighed. When processing the filter bags, in either a clean or debris laden state, the bags were placed in an oven for at least an hour before being cooled and weighed inside a humidity-controlled chamber. This process was repeated for each bag until two consecutive bag weights were within 0.05 g of each other.

A clean set of filter bags was placed online before a debris batch was introduced to the test tank, and was left online for a minimum of three pool turnovers (PTOs) to capture the prompt fiber penetration. For each batch, at least one additional filter bag was used to capture the fiber penetration due to shedding. For batches 3 and 4, an additional filter bag set was used to capture long-term shedding data. At the time that the final batch 4 shedding filter bag was taken offline, the test duration exceeded the minimum amount of time required after an accident for PSL1 operators to switch to simultaneous cold and hot leg recirculation injection in the plant. Note that the test duration also exceeded the amount of time required after an accident for Seabrook operators to switch to simultaneous cold and hot leg injection. This approach allowed the testing to capture time-dependent fiber penetration data, which was used to develop a model for the rate of fiber penetration as a function of fiber quantity on the strainer. Before each debris addition, the test tank and debris hoppers were visually checked to verify that all introduced debris had transported to the strainer.

PSL1 Test Parameters

The chemistry condition selected for testing had a boron concentration of 0.1424 mol/l and a buffer (NaOH) concentration of 0.0830 mol/l. This water chemistry corresponds to the maximum PSL1 pH condition at the sump (which is shown above to bound the maximum Seabrook pH condition at the sump) and was chosen based on small scale testing results that showed more bypass at a higher pH. Test water was prepared by adding pre-weighed chemicals to DI water per the prescribed concentrations.

Two different strainer approach velocities, 0.0024 ft/s and 0.0096 ft/s, were used for the PSL1 fiber penetration testing. As described above, these tested velocities encompass the Seabrook average approach velocity although not the maximum. Each of the two approach velocities was used for the entire duration of a single test. All other test parameters were constant between the two tests.

PSL1 Strainer Penetration Model Development

Data gathered from the PSL1 fiber penetration tests were used to develop a model for quantifying the strainer fiber penetration under plant conditions. The model was developed per the following steps:

- General governing equations were developed to describe both the prompt fiber penetration and shedding through the strainer as a function of time and fiber quantity on the strainer. The equations contain coefficients whose values were determined separately for each test based on the individual test results.
- The results for each test were fit to the governing equations using various optimization techniques to refine the coefficient values. This produced a unique set of equations, and thus a unique penetration model for each test. Figure 3.n.1-7 compares the fiber penetration results of the high flow test (shown as circles) with the fiber penetration quantities determined by applying the high flow model to the test conditions (shown as blue solid line). As Figure 3.n.1-7 shows, the model results adequately represent the test data. A model of similar quality was achieved for the low flow test.

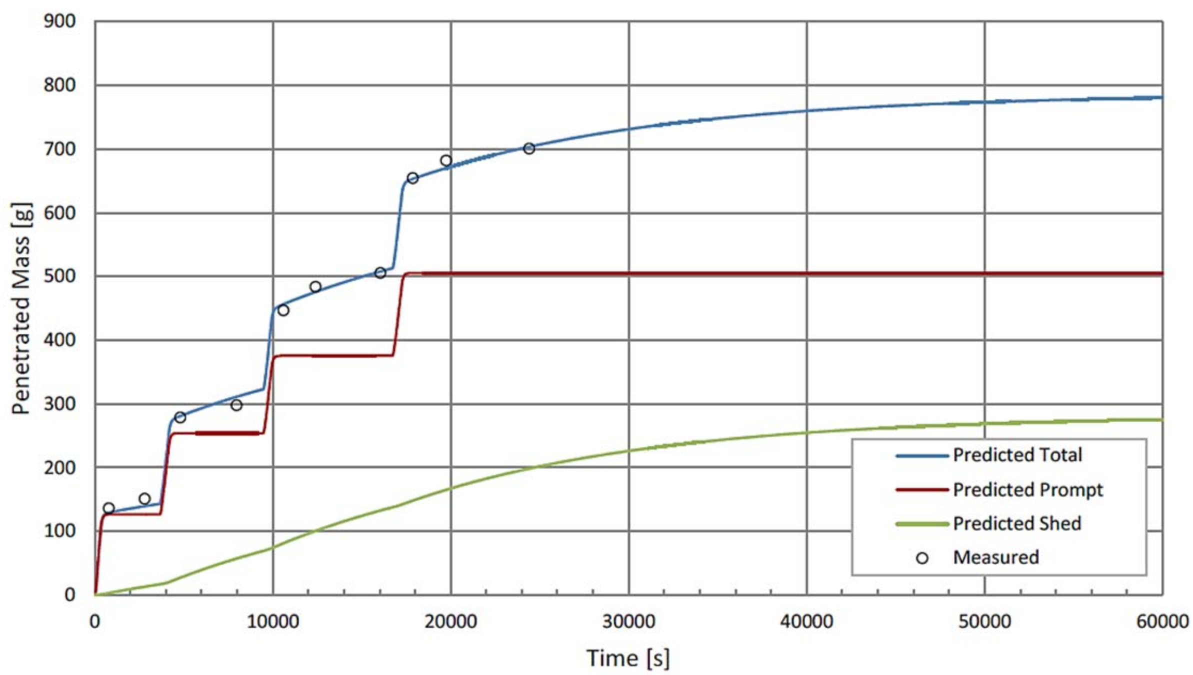

Figure 3.n.1-7: PSL1 High Flow Test Penetration Model Fit

The penetration models from the previous step can then be used to determine the prompt fiber penetration fraction and shedding fraction for a given time and amount of fiber accumulated on the strainer. Coupled with a fiber transport model, a time-dependent evaluation can be performed to quantify the total amount of fiber that could pass through the strainer under certain plant conditions.

Example applications of the low flow and high flow models on PSL1 plant conditions are shown below. For the time-dependent analysis, the recirculation duration was divided into smaller time steps. For each time step, the fiber penetration rates and quantities were calculated. Figure 3.n.1-8 and Figure 3.n.1-9 show the resulting cumulative fiber penetration through the strainer over time at plant conditions.

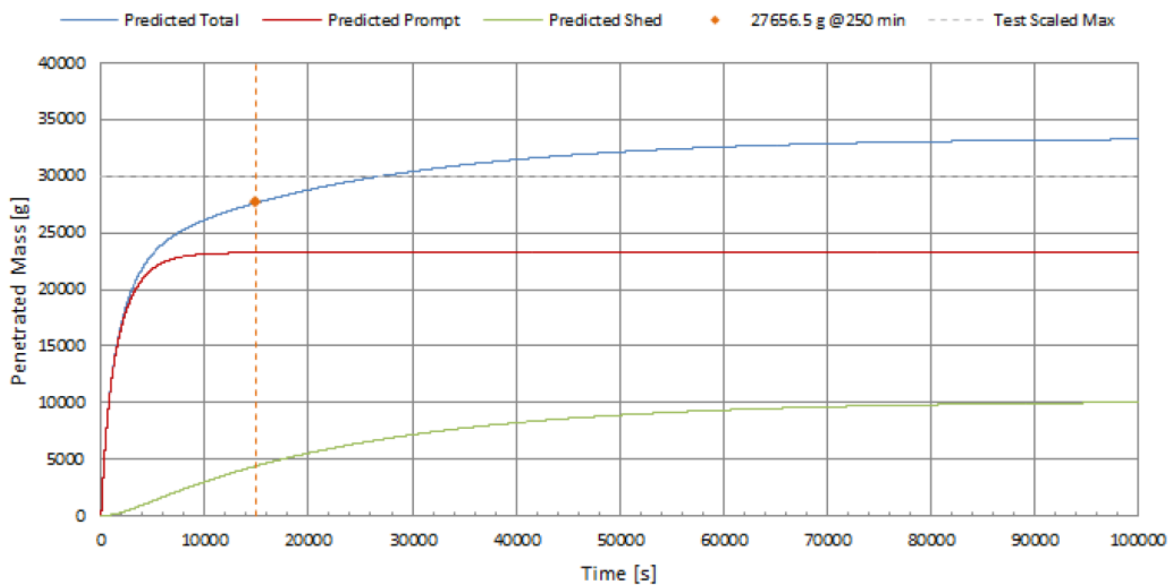

Figure 3.n.1-8: PSL1 Low Flow Penetration Model at Plant Scale

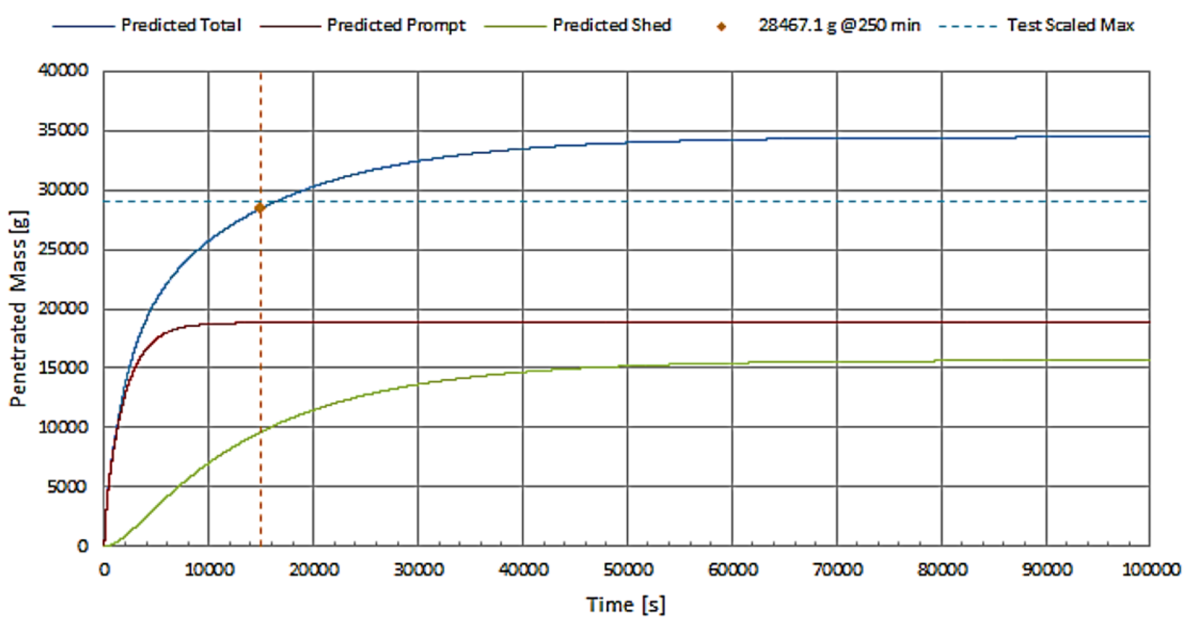

Figure 3.n.1-9: PSL1 High Flow Penetration Model at Plant Scale

As the figures show, the high flow model shows slightly higher penetration than the low flow model when applied to plant conditions. Therefore, the high flow model was used to determine the total fiber penetration quantity for resolution of in-vessel effects.

Figure 3.n.1-10 shows the prompt fiber penetration fraction as a function of fiber quantity on the strainer derived using the high flow fiber penetration model. As expected, the prompt penetration fraction decreases as a fiber debris bed forms on the strainer.

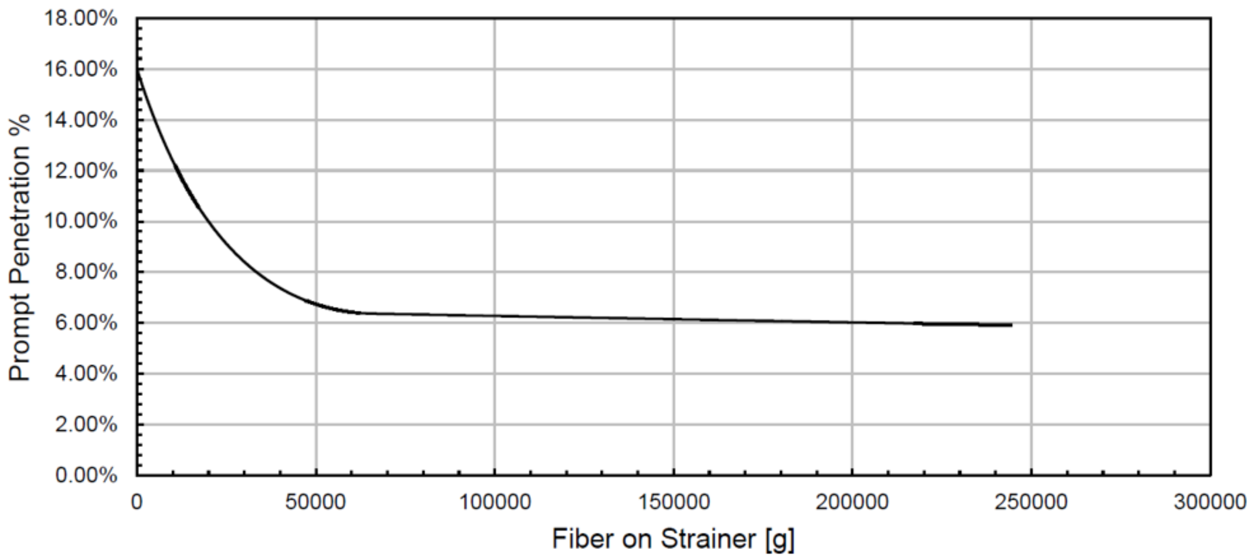

Figure 3.n.1-10: PSL1 Prompt Fiber Penetration Fraction Strainer Model

Figure 3.n.1-11 shows the shedding rate calculated from the high flow model as a function of time. Note that shedding penetration depends on the fiber quantity on the strainer and time. As shown in the figure, the shedding rate decreases over time for a given amount of fiber on the strainer.

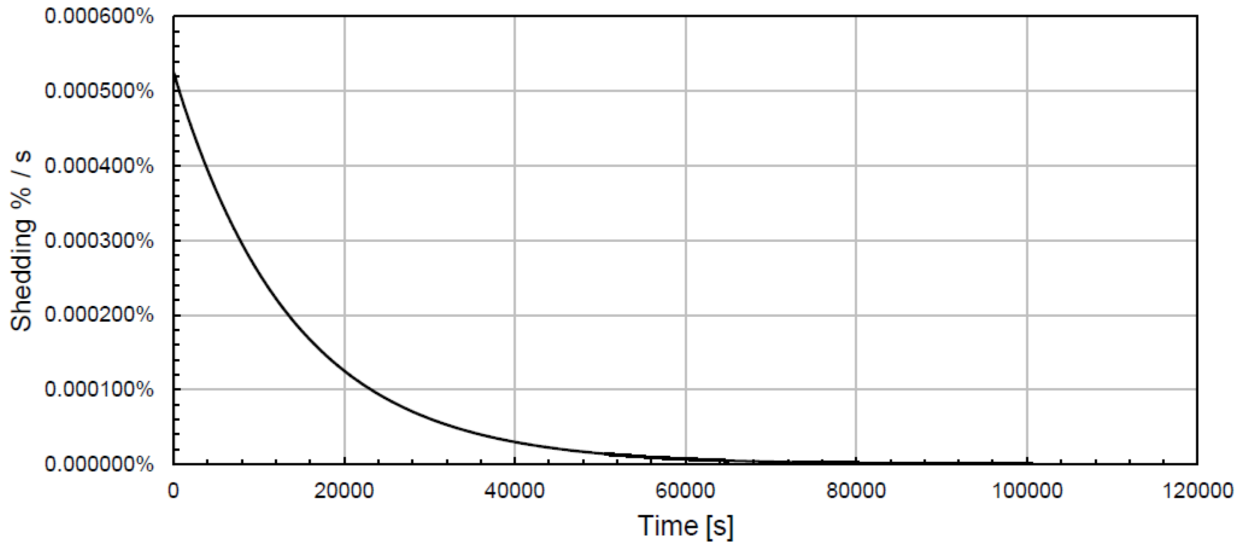

Figure 3.n.1-11: PSL1 Shedding Rate Calculated from High Flow Correlation

Peak Cladding Temperature (PCT) and Deposition Thickness (DT)

The LOCA deposition model (LOCADM), which is contained as part of WCAP-16793-NP (Revision 2) (Reference 26), was used to determine the scale thickness due to deposition of debris that passes through the strainer on the fuel rod surfaces and the resulting PCT. The calculated scale thickness was then combined with the thickness of existing fuel cladding oxidation and crud build-up to determine the total DT. The calculated total DT and PCT were compared with the acceptance criteria provided in WCAP-16793-NP. Note that the evaluation also considered the applicable requirements and recommendations from the following Pressurized Water Reactor Owners Group (PWROG) letters: OG-07-419, OG-07-534, OG-08-64, and OG-10-253 (Reference 27; 28; 29; 30). The limitations and conditions (LACs) identified in the NRC's SE of this WCAP were also addressed (Reference 31).

The inputs (such as pH values, temperature profiles, debris quantities, etc.) used in the Seabrook LOCADM analysis conservative, and thus, the results are applicable for all breaks at Seabrook. The bump-up factor used to account for the impact of fibrous debris that passes through the strainer was calculated based upon an assumed 100 grams of fiber bypass per fuel assembly. This value conservatively bounds the in-vessel fiber load determined for Seabrook, as shown later in this submittal. Table 3.n.1-4 summarizes the PCT and DT.

Table 3.n.1-4: Summary of PCT and DT

PCT (°F)		DT (mils)	
Results	**Acceptance Criteria**	**Results**	**Acceptance Criteria**
408.7	< 800	16.13	< 50

The PCT is much lower than the acceptance criterion of 800 °F, and the DT value is well within the acceptance criterion of 50 mils. Therefore, deposition of post-LOCA debris and chemical precipitate product on the fuel rods will not block the LTCC flow through the core or create unacceptable local hot spots on the fuel cladding surfaces.

The 15 grams per fuel assembly (g/FA) fiber limit at the reactor core inlet given in WCAP-16793-NP (Reference 26 p. 10−3) was not used. Instead, accumulation of fiber on the reactor core inlet and inside the reactor vessel was evaluated using the WCAP-17788-P methodology, as discussed later in this section.

The NRC Safety Evaluation of WCAP-16793-NP provided analysis and recommendations on the use of Westinghouse's WCAP-16793-NP, Revision 2 methodology and identified 14 LACs that must be addressed. The responses to these LACs are summarized below.

1. Assure the plant fuel type, inlet filter configuration, and ECCS flow rate are bounded by those used in the FA testing outlined in Appendix G of the WCAP. If the 15 g/FA acceptance criterion is used, determine the available driving head for an HL break and compare it to the debris head loss measured during the FA testing. Compare the fiber bypass amounts with the acceptance criterion given in the WCAP.

   Response:

   This LAC is associated with the 15 g/FA limit established in WCAP-16793-NP, and is not being used for Seabrook. Therefore, this LAC is not applicable.

2. Each licensee's GL 2004-02 submittal to the NRC should state the available driving head for an HL break, ECCS flow rates, LOCADM results, type of fuel and inlet filter, and amount of fiber bypass.

   Response:

   This LAC is associated with the 15 g/FA limit established in WCAP-16793-NP, and is not being used for Seabrook. Therefore, this LAC is not applicable.

3. If a licensee credits alternate flow paths in the reactor vessel in their LTCC evaluations, justification is required through testing or analysis.

   Response:

   This LAC is associated with the 15 g/FA limit established in WCAP-16793-NP, and is not being used for Seabrook. Therefore, this LAC is not applicable.

4. The numerical analyses discussed in Sections 3.2 and 3.3 of the WCAP should not be relied upon to demonstrate adequate LTCC.

   Response:

   The fuel blockage modeling concerns discussed in Sections 3.2 and 3.3 of WCAP-16793-NP are not applicable to the LOCADM analysis for Seabrook. Therefore, this LAC is not applicable.

5. The SE requires that a plant must maintain its debris load within the limits defined by the testing (e.g., 15 g/FA), and any debris amounts greater than those justified by generic testing in the WCAP must be justified on a plant-specific basis.

   Response:

   This LAC is associated with the 15 g/FA limit established in WCAP-16793-NP, and is not being used for Seabrook. Therefore, this LAC is not applicable.

6. The debris acceptance criterion can only be applied to fuel types and inlet filter configurations evaluated in the WCAP FA testing.

   Response:

   This LAC is associated with the 15 g/FA limit established in WCAP-16793-NP, and is not being used for Seabrook. Therefore, this LAC is not applicable.

7. Each licensee's GL 2004-02 submittal to the NRC should compare the PCT from LOCADM with the acceptance criterion of 800°F.

   Response:

   The bounding PCTs are well within the acceptance criterion of 800°F.

8. When utilizing LOCADM to determine PCT and DT, the aluminum release rate must be doubled to more accurately predict aluminum concentrations in the sump pool in the initial days following a LOCA.

   Response:

   The appropriate methodology was followed with regard to increasing the aluminum release rate in the LOCADM analysis.

9. If refinements specific to the plant are made to the LOCADM to reduce conservatisms, the licensee should demonstrate that the results still adequately bound chemical product generation.

   Response:

   The LOCADM runs for Seabrook do not employ any conservative-reducing refinements specific to the plant. Therefore, no additional justification is required.

10. The recommended value for scale thermal conductivity of 0.11 BTU/(h-ft-°F) should be used for LTCC evaluations.

   Response:

   As stated in Appendix E of WCAP-16793-NP (Ref. 2.1. Page E-16), the recommended thermal conductivity of 0.11 BTU/(h-ft-°F) can be converted to 0.2 W/m-K, which was used in the evaluation for Seabrook.

11. The licensee's submittals should include the means used to determine the amount of debris that bypasses the ECCS sump strainer and the fiber loading at the fuel inlet expected for the HL and CL break scenarios. Licensees should provide the debris loads, calculated on a fuel assembly basis, for both the HL and CL break cases in their GL 2004-02 responses.

   Response:

   This LAC is associated with the 15 g/FA limit established in WCAP-16793-NP, and is not being used for Seabrook. Therefore, this LAC is not applicable.

12. Plants that can qualify a higher fiber load based on the absence of chemical deposits should ensure that tests for their conditions determine limiting head losses using particulate and fiber loads that maximize the head loss with no chemical precipitates included in the tests. In this case, licensees must also evaluate the other considerations discussed in the first LAC.

   Response:

   This LAC is associated with the 15 g/FA limit established in WCAP-16793-NP, and is not being used for Seabrook. Therefore, this LAC is not applicable.

13. The size distribution of the debris used in the FA testing must represent the size distribution of fibrous debris expected to pass through the ECCS sump strainer at the plant.

   Response:

   This LAC is associated with the 15 g/FA limit established in WCAP-16793-NP, and is not being used for Seabrook. Therefore, this LAC is not applicable.

14. Each licensee's GL 2004-02 submittal to the NRC should not utilize the "Margin Calculator" as it has not been reviewed by the NRC.

    Response:

    The evaluation for Seabrook does not use the "Margin Calculator".

In summary, the evaluation showed that the PCT and total DT due to accumulation of debris on the fuel rods met the acceptance criteria and will not challenge the LTCC.

Accumulation of Fiber inside Reactor Vessel

During the post-LOCA sump recirculation phase, debris that passes through the strainer could accumulate at the reactor core inlet or inside the reactor vessel and challenge LTCC. This effect was evaluated for both hot leg break (HLB) and cold leg break (CLB) scenarios using the methodology of WCAP-17788-P (Reference 9) The evaluation used time-dependent fiber penetration fractions obtained from PSL1 testing, as described earlier in this response. The penetration fraction varies with the amount of fiber on the strainer and the amount of time passed since the onset of recirculation.

A bounding evaluation for the Region I and Region II breaks was performed. The Region I breaks were defined in the Response to 3.a.3 as the breaks of 17" and smaller. The Region II breaks were defined as the larger than 17" breaks up to the DEGBs on the main loop piping. For the analysis for both regions, the worst-case combination of input parameters, identified by sensitivity runs, were selected. Region I and II evaluations are identical except for the number of ECCS and CSS trains in operation and the transportable fiber fines quantities. For the Region I breaks, the HLB analysis assumed that two ECCS trains and one CBS train were in service, while for CLBs, one ECCS and one CBS train were in service. For the Region II breaks, the modeling for both HLBs and CLBs assumed that two ECCS and two CBS trains were in service. Note that a single failure is not assumed for Region II breaks. A CBS pump failure would divert flow and fiber to the core rather than to the spray header. For all of the breaks, the evaluation used the full surface area of the strainer, conservatively neglecting the reduction in strainer surface area due to blockage by miscellaneous debris. The uncertainty of the fiber penetration model was added to the calculated fiber quantities. The worst case in-vessel results of the hand calculation are summarized in the table below.

Table 3.n.1-5: Bounding In-vessel Fiber Loads for HLB and CLB Scenarios

HLB	Maximum Core Inlet Fiber Load (g/FA)	Region I	34.40
		Region II	43.68
	Maximum Total Reactor Vessel Fiber Load (g/FA)	Region I	64.41
		Region II	89.60
CLB	Maximum Core Inlet Fiber Load at Hot Leg Switchover (g/FA)	Region I	10.75
		Region II	13.96

The HLB and CLB results were compared to the limits contained in the version of WCAP-17788, which is currently in NRC review, and were found to be acceptable. Therefore, in-vessel fiber loads will not challenge Seabrook's ability to maintain long-term core cooling.

o. Chemical Effects

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

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

Response to 3.o.1:

The chemical effects strategy for Seabrook includes:

- Quantification of maximum chemical precipitates using the WCAP-16530-NP-A methodology. The limitations and conditions of this WCAP were addressed as part of the evaluation and it was shown that the WCAP-16530-NP-A methods and values were appropriate to use for Seabrook.
- Introduction of those pre-prepared precipitates in prototypical strainer testing.
- Application of head loss due to aluminum precipitates at 212°F, where NPSH margin is at a minimum. Note that an aluminum solubility correlation was used to determine that the maximum precipitation temperature would, in reality, be much lower.

As discussed in the Response to 3.a.1, Seabrook has determined the debris generated at all ISI welds on the primary RCS piping inside containment. The amount/mass of chemical precipitate was quantified for bounding quantities of LOCA generated debris. Other plant-specific inputs such as pH, temperature, aluminum quantity, and spray times were selected to maximize the generated amount of precipitates. The precipitate amount was scaled by the ratio of the test strainer area to the plant strainer surface area and was compared with the chemical debris quantities used in the prototypical strainer tests to determine the resulting head loss across the strainers. Before the chemical debris portions of the tests were conducted, the AlOOH was prepared according to the WCAP-16530-NP-A recipe and was verified to meet the settling criteria described in the Response to 3.o.2.12. During the test, a fiber and particulate debris bed was established on the strainer surfaces, the stabilization criteria was satisfied, and the pre-prepared precipitates were added to the test tank in batches. See the Response to 3.f.4 for further details on the head loss measured after introduction of chemical precipitates.

See the in-vessel effects evaluations in the Response to 3.n.1 for the evaluation of chemical precipitate deposition on the fuel rod surfaces.

2. *Content guidance for chemical effects is provided in Enclosure 3 dated March 2008 to a letter from the NRC to NEI* (Reference 5)*.*

Response to 3.o.2:

The NRC identified evaluation steps in "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Plant-Specific Chemical Effect Evaluations" in March of 2008 (Reference 5). Seabrook's responses to the GL supplemental content evaluation steps are summarized below. The numbering of the following subsections to the Response to 3.o.2 follow the numbering scheme provided in Section 3 and Figure 1 of the March 2008 guidance (Reference 5 pp. 8-23). Figure 3.o-1 (provided at the end of the Response to 3.o) highlights the Seabrook chemical effects evaluation process using the flow chart in Figure 1 of the March 2008 guidance (Reference 5 p. 8).

1. *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.*

   Response to 3.o.2.1:

   Seabrook is not crediting clean strainer area to perform a simplified chemical effects analysis. See Figure 3.o-1.

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.*

   Response to 3.o.2.2:

   Three head loss tests were completed for Seabrook using the thin bed test protocol. These tests were used to develop the head loss contributions from conventional debris and aluminum precipitates. For these tests, plant-specific conventional debris was first added, followed by chemical precipitates, as described in the Response to 3.f.4. The tested debris loads bound the Region I and Region II breaks (see the Response to 3.f.7). The highest debris head loss of the three tests was used in the analyses, as shown in the Responses to 3.f.4 and 3.f.10.

3. *<u>Plant-Specific Materials and Buffers</u>: 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.*

Response to 3.o.2.3:

The chemical model requires a number of plant-specific inputs. Each input was chosen to maximize the calculated quantity and minimize the solubility (aluminum only) of the chemical precipitates.

Seabrook uses sodium hydroxide (NaOH) to buffer the post-LOCA containment sump pool to a final pH between 8.8 and 9.4. The injection spray delivers the NaOH to the containment sump pool and is buffered to a maximum pH of 9.6. The pH value used for chemical release was conservatively high, and the pH value used for aluminum solubility was conservatively low. Different pH values for release and solubility were combined in a non-physical way, bounding the effects of all potential pH profile variations.

The pH values are summarized in Table 3.o.2.3-1:

Table 3.o.2.3-1: Seabrook pH Values

Injection Spray pH Used To Determine Chemical Release Rates	9.6
Sump and Recirculation Spray pH Used To Determine Chemical Release Rates	9.4
Sump pH Used To Determine Aluminum Solubility	8.8

The containment building sprays are initiated at 65 s (1.08 min) post-LOCA during the injection phase. The recirculation phase starts at 2755 s (45.92 min) for the minimum ECCS case, after which, the containment spray pH will be the same as the containment sump pool pH. The containment sprays were assumed to be active to the end of the 30-day post-LOCA event.

Conservative containment sump pool and containment temperature profiles were used to maximize chemical release rates. The temperature profiles are shown in Table 3.o.2.3-2.

Table 3.o.2.3-2: Sump Pool and Containment Temperature Profiles used to Determine Chemical Release Rates

Time (min)	Sump Pool Temperature (°F)	Containment Temperature (°F)
0.1	223	240
0.5	230	250
1	216	250

2	218	252
3	222	255
3.33	224	256
6.67	236	260
10	243	265
13.33	248	265
16.67	252	265
20	253	265
23.33	254	265
26.67	254	265
30	245	265
53.33	237	270
76.67	232	265
100	230	265
123.33	220	260
146.67	218	260
170	213	250
193.33	209	250
216.67	204	250
240	204	245
773.33	176	225
1440	162	185
2880	150	130
4320	150	130
5760	150	130
7200	150	130
14400	150	130
21600	150	130
28800	150	130
36000	150	130
43200	150	130

The total amount of concrete assumed to be exposed and submerged in the containment sump pool was 10,000 ft^2. The quantity of chemical precipitates was negligibly impacted by this large assumed surface area of exposed concrete. Therefore, exposed concrete is not a significant impact to chemical product generation in the Seabrook post-LOCA containment sump pool and is not tracked for this purpose.

The containment sump pool was assumed to be well mixed. This assumption conservatively maximized aluminum release by not considering the concentration gradient that will form around submerged source materials at low pool velocity conditions.

At Seabrook, the total amount of unsubmerged aluminum exposed to containment sprays is 776.2 ft^2 (including contingency). The total amount of submerged aluminum exposed to the containment sump fluid at Seabrook is 190.1 ft^2 (including contingency). The mass of these unsubmerged and submerged aluminum metals was in excess of the total aluminum that would be released into the containment sump pool, and therefore, no limit was set on the quantity released from these sources.

At Seabrook, the maximum containment sump pool mass that is available for chemical dissolution is 4,367,000 lbm. The maximum containment sump pool mass was used to conservatively maximize the mass of aluminum released from sources with concentration dependent release rates. The minimum containment sump pool mass that is available for chemical dissolution is 3,692,000 lbm. Given the conservatively maximized amount of aluminum released, the minimum containment sump pool mass was conservatively used to determine the concentration of aluminum for the solubility equation. Consistent with the WCAP-16530-NP-A methodology, the total mass was assumed to be present immediately post-LOCA.

The maximum amount of Nukon destroyed by the LOCA and assumed to be submerged was 2,809 ft^3 (including contingency) with an as-fabricated bulk density of 2.4 lbm/ft^3. The amount of latent fiberglass insulation in containment is 15 lbm.

4. *<u>Approach to Determine Chemical Source Term (Decision Point)</u>: Licensees should identify the vendor who performed plant-specific chemical effects testing.*

Response to 3.o.2.4:

Seabrook is using the separate chemical effects approach to determine the chemical source term. CDI performed the testing in their test lab in Ewing, NJ.

5. *<u>Separate Effects Decision (Decision Point)</u>: Within this part of the process flow chart, two different methods of assessing the plant-specific chemical effects have been proposed. The WCAP-16530-NP-A study (Box 7 WCAP Base Model) uses predominantly single-variable test measurements. This provides baseline information for one material acting independently with one pH-adjusting chemical at an elevated temperature. Thus, one type of insulation is tested at each individual pH, or one metal alloy is tested at one pH. These separate effects are used to formulate a calculational model, which linearly sums all of the individual effects. A second method for determining plant-specific chemical effects that may rely on single-effects bench testing is currently being developed by one of the strainer vendors (Box 6, AECL).*

Response to 3.o.2.5:

Seabrook is using the WCAP-16530-NP-A chemical effects base model to determine the chemical source term. The application of an aluminum solubility correlation to determine a maximum precipitate formation temperature is discussed in the Responses to 3.o.2.8 and 3.o.2.9.i.

6. *<u>AECL Model</u>:*

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

   Response to 3.o.2.6.i:

   This question is not applicable because Seabrook is not using the AECL model. See Figure 3.o-1.

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

   Response to 3.o.2.6.ii:

   This question is not applicable because Seabrook is not using the AECL model. See Figure 3.o-1.

7. *<u>WCAP Base Model</u>:*

   i. *Licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart [in Enclosure 3 dated March 2008 to a letter from the NRC to NEI* (Reference 5 p. 8)*] 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.*

   Response to 3.o.2.7.i:

   The Seabrook chemical model quantifies chemical precipitates using the WCAP-16530-NP-A (Reference 32) methodology with the following two deviations:

   1. The application of an aluminum solubility correlation to determine a maximum precipitate formation temperature (see the Response to 3.o.2.9.i).
   2. The use of a new base model spreadsheet that follows the WCAP-16530-NP-A methodology

   An aluminum solubility correlation was used to determine a maximum precipitate formation temperature, which effectively delays the onset of aluminum precipitation. Therefore, to allow for time-based head loss acceptance criteria, a new spreadsheet was developed to include the requirement in the SE to double the aluminum release rate from aluminum metal over the initial 15 days. Additionally, the aluminum solubility was used to conservatively decrease the aluminum concentration after precipitation occurs, which increases the rate of release from insulation materials and concrete post-precipitation. As shown in Figures 3.o.2.7-1 and 3.o.2.7-2, the ICET 1 test results were simulated using the new spreadsheet and compared with the measured aluminum concentrations. The results verify that the new spreadsheet accurately predicts ICET 1 aluminum release and, therefore, can be used for time-based acceptance criteria in accordance with the WCAP-16530-NP-A SE.

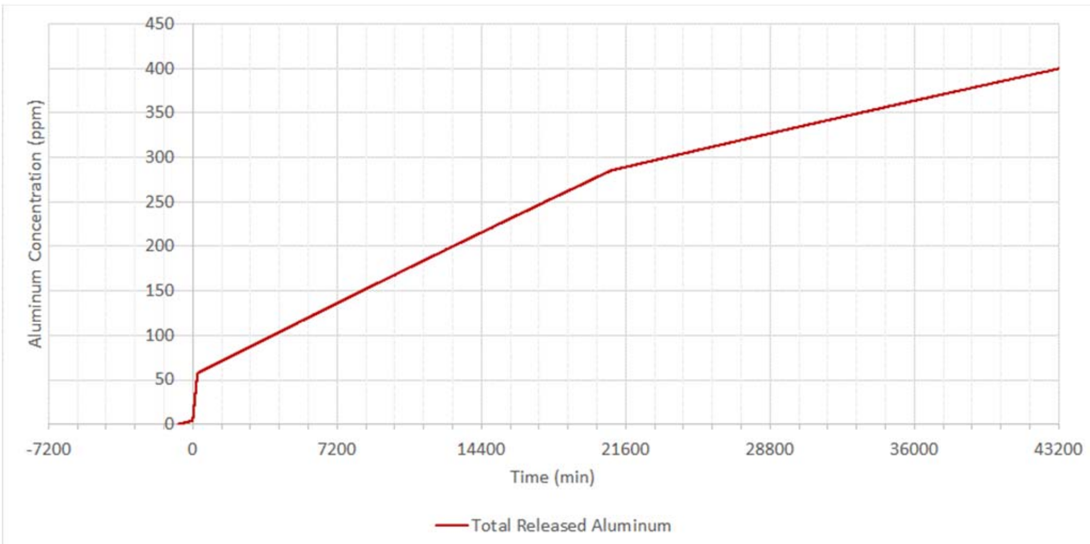

Figure 3.o.2.7-1: Simulation of ICET 1 Al Concentration

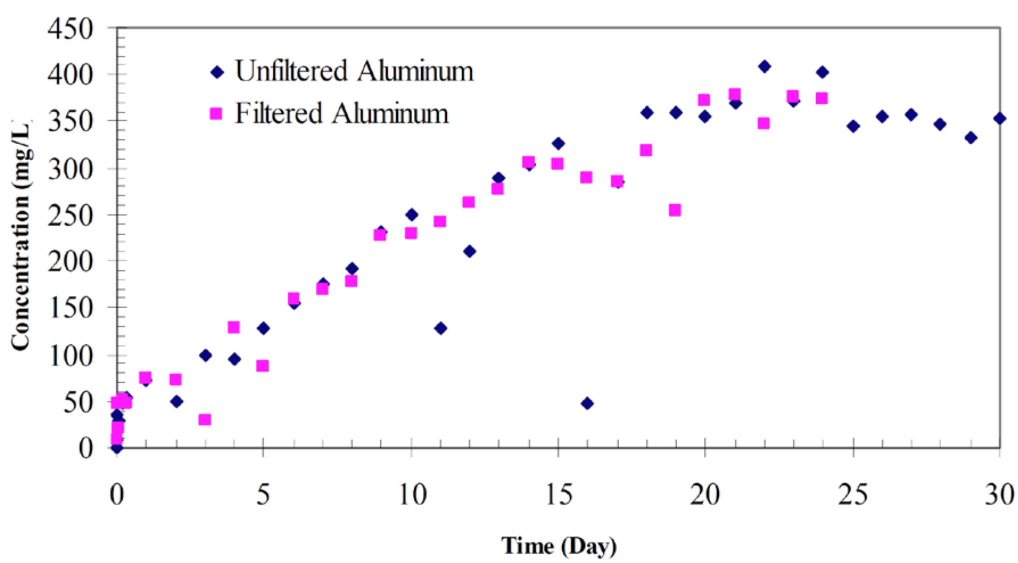

Figure 3.o.2.7-2: Measured Aluminum Concentrations in ICET 1

The chemical precipitates assumed by the WCAP-16530-NP-A methodology for plants that use NaOH buffer are AlOOH and sodium aluminum silicate ($NaAlSi_3O_8$). Per the WCAP-16530-NP-A SE, both aluminum precipitates are acceptable surrogates for aluminum precipitate in head loss testing. Therefore, to simplify head loss testing, only AlOOH is predicted to form by the new spreadsheet.

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

Response to 3.o.2.7.ii:

A bounding AlOOH precipitate mass of 174 kg was calculated for Seabrook. The maximum temperature where aluminum precipitation could occur in the containment sump pool is 116.8°F.

The design contingency applied to the Nukon and aluminum quantities (discussed in the Response to 3.o.2.3) results in an AlOOH precipitate mass margin of 17 kg.

8. *<u>WCAP Refinements</u>: State whether refinements to WCAP-16530-NP-A were utilized in the chemical effects analysis.*

Response to 3.o.2.8:

Refinement to the model for aluminum solubility is discussed in the Response to 3.o.2.9.i. No other refinements to the WCAP-16530-NP-A methodology were used.

9. *<u>Solubility of Phosphates, Silicates and Al Alloys</u>:*

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

Response to 3.o.2.9.i:

The base WCAP-16530-NP-A model assumes that aluminum precipitates form immediately upon the release of aluminum into solution. However, as justified in the Response to 3.o.2.7.i, the Seabrook chemical model includes the following application of an aluminum solubility correlation to determine formation temperature and timing.

The aluminum solubility limit was determined using Equation 3.o.2.9-1, developed by Argonne National Laboratory (ANL).

$$C_{Al,sol} = \begin{cases} 26980 \cdot 10^{(pH+\Delta pH)-14.4+0.0243T}, & \text{if } T \leq 175\ °F \\ 26980 \cdot 10^{(pH+\Delta pH)-10.41+0.00148T}, & \text{if } T > 175\ °F \end{cases} \quad \text{(Equation 3.o.2.9-1)}$$

Nomenclature:

ΔpH = pH change due to radiolysis acids
T = solution temperature, °F

The aluminum solubility limit equation was used to determine the temperature and timing of aluminum precipitation and to determine the aluminum concentration in solution for use in the aluminum release equations for concrete and insulation. When precipitation was predicted by this equation, the full amount of aluminum released was assumed to precipitate. The aluminum solubility limit equation was not used to reduce the predicted quantity of precipitate by crediting the amount remaining in solution.

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.

Response to 3.o.2.9.ii:

Silicon and phosphate inhibition of aluminum release were not credited. See the Response to 3.o.2.9.i.

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.

Response to 3.o.2.9.iii:

Reductions in precipitate quantity due to residual solubility of aluminum after precipitation occurs was not credited. See the Response to 3.o.2.9.i.

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

Response to 3.o.2.9.iv:

The type and amount of plant-specific precipitates are provided in the Response to 3.o.2.7.ii.

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

Response to 3.o.2.10:

As discussed in the Response to 3.o.2.12, Seabrook pre-mixed surrogate chemical precipitates in a separate mixing tank for chemical head loss testing. The direct chemical injection method was not used in head loss testing.

11. *Chemical Injection into the Loop:*

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.*

Response to 3.o.2.11.i:

The direct chemical injection method was not used in head loss testing for Seabrook. See Figure 3.o-1.

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.*

Response to 3.o.2.11.ii:

The direct chemical injection method was not used in head loss testing for Seabrook. See Figure 3.o-1.

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).*

Response to 3.o.2.11.iii:

The direct chemical injection method was not used in head loss testing for Seabrook. See Figure 3.o-1.

12. *<u>Pre-Mix in Tank</u>: Licensees should discuss any exceptions taken to the procedure recommended for surrogate precipitate formation in WCAP-16530-NP-A.*

Response to 3.o.2.12:

Chemical effects debris was simulated with AlOOH. The AlOOH was fabricated and tested based on the WCAP-16530-NP-A methodology.

The AlOOH was mixed for a minimum of 60 minutes prior to use. To determine if the chemical debris was suitable for use in testing, two samples were taken. The first sample of AlOOH was tested by diluting the sample to 9.7 g/L and allowing the precipitate to settle for 60 minutes. If the turbid portion was more than 90% of the total height in a graduated cylinder, the simulated debris was suitable for use in testing. The second sample was tested by diluting the sample to 2.2 g/L and allowing the precipitate to settle for 60 minutes. For the simulated debris to be used in testing, the turbid portion could not be less than 40% of the total height in a graduated cylinder. If the debris did not pass both tests, it was stirred and retested.

The AlOOH settling test acceptance criteria used for head loss testing by CDI is an exception to the WCAP-16530-NP-A methodology, which indicates that the minimum one-hour settlement rate for aluminum oxyhydroxide diluted to a 2.2 g/l concentration is greater than 60% turbid for tests that ensure the precipitate is transported to the test strainer (Reference 32 pp. 10,17). The turbid fraction criteria used by CDI (40% at 2.2 g/L or 90% at 9.7 g/L) are judged to be acceptable based on complete transport to the test article (no settling). The prepared AlOOH suspension was continuously agitated with a motor driven mixer for 60 minutes prior to adding the AlOOH into the test, and the mixing tank (where the AlOOH was added) was continuously agitated during the test. All of the debris was transported to the strainer (after the mixing tank all flow goes directly to the test article). After testing was completed, the agitators and pumps were shut off, the test tank and mixing tank were drained, and the test tank and mixing tank were examined for residual debris. The only debris remaining in the mixing tank was an essentially uniform coating of particulate on the bottom of the mixing tank that was deposited from the particulate that was still in suspension at the termination of the test. All of the chemical precipitate reached the test article. The test facility consisted of the mixing tank, test article (including a bottom plenum), and the return piping (including pump).

The photographs below show the water draining from the mixing tank after Test S3-1S (left) and after the water was drained prior to cleaning (right). The other tests were similar.

Figure 3.o.2.12-1: S3-1S Test Tank During and After Drain Down

The photograph on the left is looking toward the test article as the tank is being drained. The two agitators can be seen as well as the top part of the test article. The photograph on the right is looking away from the test article and shows the back of the tank, after the water was drained completely. Note that the perforated plate ring in the corner was used for cleaning and was not part of the test. No debris remained in the mixing tank, other than a reasonably uniform film. Note that the flow entered from the bottom of the tank and was covered by a plate to direct the flow along the floor to prevent debris settling. The hole in the back wall of the tank was plugged (an alternate flow return that was not used). Additionally, as discussed in the Response to 3.f.7, the scaled AlOOH quantity used in head loss testing was more than double the quantity predicted for Seabrook. Therefore, it is certain that a quantity of AlOOH greater than the scaled Seabrook quantity transported to the strainers during head loss testing.

13. *<u>Technical Approach to Debris Transport (Decision Point)</u>: State whether near-field settlement is credited or not.*

Response to 3.o.2.13:

Seabrook chemical effects testing used hydraulic and manual agitation and turbulence in the test tank to ensure that essentially all debris analyzed to reach the strainer in the plant reached the strainer in head loss testing. Seabrook did not credit any near field settlement in head loss testing. Refer also to the Response to 3.f.4.

14. *<u>Integrated Head Loss Test with Near-Field Settlement Credit</u>:*

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

   Response to 3.o.2.14.i:

   Seabrook is not crediting near field settlement of chemical precipitate in chemical head loss testing. See Figure 3.o-1.

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

   Response to 3.o.2.14.ii:

   Seabrook is not crediting near field settlement of chemical precipitate in chemical head loss testing. See Figure 3.o-1.

15. *<u>Head Loss Testing Without Near Field Settlement Credit</u>:*

   i. *Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable.*

   Response to 3.o.2.15.i:

   As described in the Response to 3.f.12, measures were taken during the test to keep debris suspended and transportable to the test strainer, preventing notable settling of debris or precipitate.

   ii. *Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).*

   Response to 3.o.2.15.ii:

   See the Response to 3.o.2.12.

16. *<u>Test Termination Criteria</u>: Licensees should provide the test termination criteria.*

Response to 3.o.2.16:

The head-loss tests were terminated upon stabilization after the final chemical addition or pump restart, as applicable. The stabilization criterion was a head loss increase of less than or equal to 1% or 0.1 inch of water, whichever was greater, over a 30-minute period. See the Response to 3.f.4 for details on the test termination criteria.

17. *Data Analysis:*

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

Response to 3.o.2.17.i:

The pressure drop curves as a function of time for Tests S3-1S, S3-2S, and S3-3S are shown in Figure 3.f.4-8, Figure 3.f.4-9, and Figure 3.f.4-10, respectively.

ii. *Licensees should explain any extrapolation methods used for data analysis.*

Response to 3.o.2.17.ii:

In order to calculate the projected 30-day head loss from the head loss at the termination of testing, a 5% termination factor was applied.

The 5% termination factor was calculated by analyzing a conventional debris only head loss test performed for Seabrook (see description below) as well as tests from several other plants that used the same test termination criterion as Seabrook (a 1% change or less in head loss in 30 minutes). In order to develop a relationship between the final test head loss and the maximum expected head loss, the test data were fit to an exponential of the form:

$$HL = A\left(1 - e^{-\frac{\alpha}{\tau}t}\right),$$

Where:

HL = Measured test head loss
A = Maximum projected head loss
t = time
α/τ = effective turnover time

The result of the series of curve fits showed that tests that met the termination criterion had an HL/A ratio of greater than 0.98. Therefore, dividing the measured final test head loss by 0.95 (i.e., applying a 5% termination factor) produces a conservative estimate of the maximum head loss.

The bounding tested head loss is the maximum aluminum precipitate head loss of 3.4” for Test S3-1S, as presented in Table 3.f.4-3. After applying the conservative 5% termination factor, a head loss of 3.6” was used to evaluate pump NPSH, void fraction, flashing, and strainer integrity. Note also, as discussed in the Response to 3.f.7, the scaled AlOOH quantity used in head loss testing was more than double the quantity predicted for Seabrook.

18. *<u>Integral Generation (Alion)</u>: Licensees should explain why the test parameters (e.g., temperature, pH) provide for a conservative chemical effects test.*

Response to 3.o.2.18:

Seabrook is using the separate chemical effects approach to determine the chemical source term. This section is not applicable to the Seabrook chemical effects analysis. See Figure 3.o-1.

19. *<u>Tank Scaling / Bed Formation</u>:*

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

Response to 3.o.2.19.i:

Seabrook is using the separate chemical effects approach to determine the chemical source term. This section is not applicable to the Seabrook chemical effects analysis. See Figure 3.o-1.

ii. *Explain how bed formation is representative of that expected for the size of materials and debris that is formed in the plant specific evaluation.*

Response to 3.o.2.19.ii:

Seabrook is using the separate chemical effects approach to determine the chemical source term. This section is not applicable to the Seabrook chemical effects analysis. See Figure 3.o-1.

20. *<u>Tank Transport</u>: Explain how the transport of chemicals and debris in the testing facility is representative or conservative with regard to the expected flow and transport in the plant-specific conditions.*

Response to 3.o.2.20:

Seabrook is using the separate chemical effects approach to determine the chemical source term. This section is not applicable to the Seabrook chemical effects analysis. See Figure 3.o-1.

21. *<u>30-Day Integrated Head Loss Test</u>: 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.*

Response to 3.o.2.21:

Seabrook is using the separate chemical effects approach to determine the chemical source term. This section is not applicable to the Seabrook chemical effects analysis. See Figure 3.o-1.

22. *<u>Data Analysis Bump Up Factor</u>: 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.*

Response to 3.o.2.22:

Seabrook is using the separate chemical effects approach to determine the chemical source term. This section is not applicable to the Seabrook chemical effects analysis. See Figure 3.o-1.

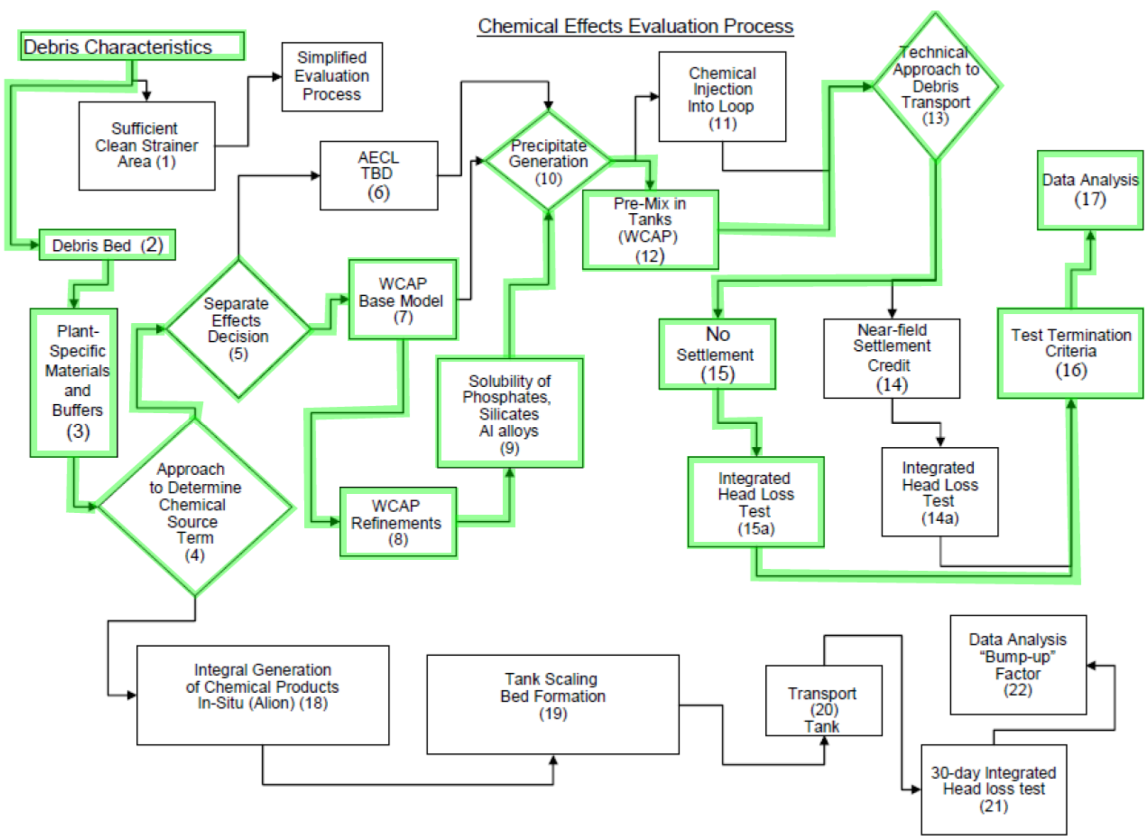

Figure 3.o-1: Chemical Effects Evaluation Process for Seabrook
(Reference 5 p. 8)

p. Licensing Basis

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

1. *Provide the information requested in GL 2004-02 Requested Information Item 2(e) regarding changes to the plant-licensing basis. The effective date for changes to the licensing basis should be specified. This date should correspond to that specified in the 10 CFR 50.59 evaluation for the change to the licensing basis.*

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

Response to 3.p.1:

As discussed in other sections of this response, physical plant changes and procedural changes have been made at Seabrook to resolve GL 2004-02 and GSI-191 concerns.

The Seabrook UFSAR has previously been updated to incorporate the effects of plant modifications and evaluations performed in accordance with the requirements of 10 CFR 50.59. The UFSAR will be reviewed after approval of the Seabrook-specific exemption request and receipt of the final closeout letter from the NRC to determine if any further changes are necessary. If changes are determined to be necessary, then the UFSAR updates will occur after receipt of the final closeout letter from the NRC.

The TS surveillance procedure was updated to expand the recirculation sump inspection requirements to include the entire sump strainer system. This change ensures that the entire system will come under the TS requirements for sump inspection and control. No further revision of the technical specifications or bases is anticipated.

The existing SR 4.5.2.d.2 mentions trash racks as potential sump components that should be included in the sump inspection. Although the new strainers installed at Seabrook do not include trash racks, in the context of TS surveillance, the debris interceptors are viewed as “trash racks”. To ensure that the debris interceptors are available during Modes 1-4, the surveillance procedure was revised to include inspections of the debris interceptors in accordance with SR 4.5.2.d.2. Seabrook has no current plans to revise the TS surveillance requirement since it ensures that the current design is in a condition ready to support operation of the ECCS recirculation sumps.

4. References

1. **NRC Generic Letter 2004-02 (ML042360586).** Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors. September 13, 2004.
2. **NRC Revised Content Guide (ML073110278).** Revised Content Guide for Generic Letter 2004-02 Supplemental Responses. November 2007.
3. **NRC Staff Review Guidance (ML080230038).** NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing. March 2008.
4. **NRC Staff Review Guidance (ML080230462).** NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Coatings Evaluation. March 2008.
5. **NRC Staff Review Guidance (ML080380214).** *NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Plant-Specific Chemical Effects Evaluation.* March 2008.
6. **NEI Guidance Report NEI 04-07 Volume 1.** Pressurized Water Reactor Sump Performance Evaluation Methodology 'Volume 1 - Pressurized Water Reactor Sump Performance Evaluation Methodology'. December 2004. Revision 0.
7. **NEI Guidance Report NEI 04-07 Volume 2.** Pressurized Water Reactor Sump Performance Evaluation Methodology 'Volume 2 - Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02'. December 2004. Revision 0.
8. **NRC Revised Guidance Regarding Coatings Zone of Influence for Review of Final Licensee Responses to Generic Letter 2004-02 (ML100960495).** NRC Revised Guidance Regarding Coatings Zone of Influence 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".
9. **Westinghouse WCAP-17788-P, Volume 1.** Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090). July 2015.
10. **NUREG-1829 Volume 1.** Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process. April 2008.
11. **Regulatory Guide 1.174.** An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis. May 2011. Revision 2.
12. **Correspondance ML120730654.** Defense-In-Depth Measures in Support of GSI-191 Resolution Options. March 5, 2012.
13. **Correspondance ML120730660.** Example Pressurized Water Reactor Defense-in-Depth Measures for GSI-191, PWR Sump Performance.

14. **Correspondance ML16214A244.** NextEra Energy Seabrook, LLC Status of Required Actions for EA-12-049 Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events. July 26, 2016.
15. **ASME Boiler and Pressure Vessel (B&PV) Code.** ASME Boiler and Pressure Vessel Code. *Section III, Subsection NC, Class 2 Components and Subsection NF Supports.*
16. **Correspondence SBK-L-08136.** Final Response and Notice of Completion for NRC Generic Letter 2004-02. August 4, 2008.
17. **NUREG/CR-6772.** *GSI-191: Separate Effects Characterization of Debris Transport in Water.* Aubust 2002.
18. **NUREG/CR-6808.** *Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency CDore Cooling Sump Performance.* February 2003.
19. **Crane Paper 410.** Flow of Fluids through Valves, Fittings, and Pipe. December 2001.
20. **ASME Steam Tables.** Thermodynamic and Transport Properties of Steam. Vol. Fourth Addition.
21. **Correspondence ML070950240.** San Onofre Nuclear Generating Station Unit 2 and Unit 3 GSI-191 Generic Letter 2004-02 Corrective Actions Audit Report.
22. **Correspondence ML082050433.** Indian Point Energy Center Corrective Actions for Generic Letter 2004-02.
23. **Westinghouse WCAP-16406-P-A.** Evaluation of Downstream Sump Debris Effects in Support of GSI-191. March 2008. Revision 1.
24. **Nuclear Energy Institute.** *ZOI Fibrous Debris Penetration: Processing, Storage and Handling.* Revision 1 : January 2012.
25. **NUREG/CR-6224 (ML083290498).** *Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris.* October 1995.
26. **Westinghouse WCAP-16793-NP.** Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid. October 2011. Revision 2.
27. **Correspondance OG-07-419.** Transmittal of LOCADM Software in Support of WCAP-16793-P, Evaluation of Long-Term Cooling Associated with Sump Debris Effects (PA-SEE-0312). September 18, 2007.
28. **Correspondance OG-07-534.** Transmittal of Additional Guidance for Modeling Post-LOCA Core Deposition with LOCADM Document for WCAP-16793-NP (PA-SEE-0312). December 14, 2007.
29. **Correspondance OG-08-64.** Additional Guidance for LOCADM for Modification to Aluminum Release for Westinghouse Topical Report WCAP-16793-NP. February 28, 2008.

30. **Correspondance OG-10-253.** PWROG Response to Request for Additional Information Regarding PWROG Topicla Report WCAP-16793-NP, Revision 1. August 9, 2010.

31. **NRC Final Safety Evaluation of WCAP-16793-NP.** Final Safety Evaluation by the Office of Nuclear Reactor Regulation – Topical Report WCAP-16793-NP, Revision 2 – “Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid"-PWROG-Project No. 694. April, 2013.

32. **Westinghouse WCAP-16530-NP-A.** Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191. March 2008.