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10 CFR 50.54(f)

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

SUBJECT:
Beaver Valley Power Station, Unit Nos. 1 and 2
BVPS-1 Docket No. 50-334, License No. DPR-66
BVPS-2 Docket No. 50-412, License No. NPF-73
Supplemental Response to Generic Letter 2004-02 (TAC Nos. MC4665 and MC4666)

This submittal provides a supplemental response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for Beaver Valley Power Station Unit Nos. 1 and 2. The supplemental response is provided in Attachment 1.

The Nuclear Regulatory Commission (NRC) Content Guide for Generic Letter 2004-02 Supplemental Response (Reference 1) was utilized in development of this submittal. Requests for additional information included in the NRC letter dated February 9, 2006, (Reference 2) are also addressed within the applicable sections of this submittal. The information in Attachment 1 is provided in accordance with 10 CFR 50.54(f).

A list of regulatory commitments made in this submittal is provided in Attachment 2. If there are any questions or if additional information is required, please contact Mr. Thomas A. Lentz, Manager – Fleet Licensing, at 330-761-6071.

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

Sincerely,

Peter P. Sena III

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NRR

Attachments:

1. Supplemental Response to Generic Letter 2004-02 for Beaver Valley Power Station Unit No. 1 and Unit No. 2
2. Regulatory Commitment List

References:

1. NRC Content Guide for Generic Letter 2004-02 Supplemental Response, dated August 15, 2007, and revised November 21, 2007.
2. NRC letter dated February 9, 2006, Beaver Valley Power Station, Unit Nos. 1 and 2 Request for Additional Information Re: Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors" (TAC Nos. MC4665 and MC4666).

cc: NRC Region I Administrator
NRC Resident Inspector
NRC Project Manager
Director BRP/DEP
Site BRP/DEP Representative

Executive Summary:

The Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2004-02 on September 13, 2004 (Reference 1). This GL required that addressees provide a description of and implementation schedule for corrective actions, including any plant modifications, identified while responding to the GL.

FirstEnergy Nuclear Operating Company (FENOC) provided the requested information for Beaver Valley Power Station Unit No. 1 (BVPS-1) and Unit No. 2 (BVPS-2) in letters dated March 4, July 22, and September 6, 2005 (References 2, 3 and 4). A supplemental response to GL 2004-02 was submitted to the NRC by a FENOC letter dated April 3, 2006 (Reference 5).

The NRC issued a request for additional information (RAI), dated February 9, 2006, related to GL 2004-02 (Reference 6). The Nuclear Energy Institute (NEI) Sump Task Force and the Pressurized Water Reactor (PWR) Owners Group initiated several projects to resolve the issues relative to post-Loss of Coolant Accident (LOCA) emergency sump strainers. Due to these efforts, the Staff extended the required due date for responding to the RAI through industry-wide communications.

A "Content Guide for Generic Letter 2004-02 Supplemental Responses" was issued by the NRC on August 15, 2007 (Reference 7). This guidance was clarified when the NRC issued a "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," (Revised Content Guide) to NEI in a letter dated November 21, 2007 (Reference 8). The NRC also issued draft guidance on chemical effects in a letter to NEI dated September 27, 2007 (Reference 9).

A supplemental response to GL 2004-02 was provided to the NRC in a FENOC letter dated February 29, 2008 (Reference 10). This response was superseded by another supplemental response dated October 29, 2008 (Reference 11). The Revised Content Guide was utilized in the development of these letters and the February 9, 2006 NRC RAI was addressed. Draft guidance on chemical effects from the September 27, 2007 NRC letter was also addressed in the response to Revised Content Guide Review Area 3.o.

The information provided in this attachment addresses each of the review areas listed in the Revised Content Guide and supersedes the response submitted on October 29, 2008. Where appropriate, a response to each question from the NRC's February 9, 2006 RAI has been appended to the relevant review area. The RAI number from the original NRC letter has been retained to aid in identifying the item being answered. Information on conservatism and margins is included within the appropriate response area.

The response in this attachment follows the final guidance issued by the NRC in a letter to NEI dated March 28, 2008 (Reference 12).

A considerable effort has been undertaken in order to bring BVPS-1 and BVPS-2 into full compliance with GL 2004-02. Strainers with a substantial increase in surface area have been installed at both units. A logic change for starting the recirculation spray system (RSS) pumps has been implemented at BVPS-1 and BVPS-2. This logic change ensures adequate water coverage over the new strainers by changing the start signal for the RSS pumps from a fixed time delay to an engineered safety feature actuation signal based on a refueling water storage tank level low coincident with a containment pressure high-high signal.

Head loss testing for BVPS-1 and BVPS-2 was completed. The results of the testing require corrective actions to be implemented. Insulation modifications are required to support the results of the successful BVPS-1 and BVPS-2 tests. The corrective actions for BVPS-1 were completed during the spring of 2009 refueling outage (1R19). However, during 1R19, fibrous insulating material (Temp-Mat™) was identified on the six reactor vessel inlet and outlet nozzles. The resulting additional fibrous loading is not bounded by the reactor coolant system (RCS) nozzle break scenario assumptions for the strainer testing and analysis that was performed. This supplemental response reflects the insulation modifications required to support the results of successful BVPS-1 tests, but does not address the newly identified issue with the fibrous insulation on the reactor vessel nozzles. This issue has been entered into the corrective action program. In a letter dated April 30, 2009 (Reference 13), FENOC requested an extension to address this newly identified issue and indicated that additional corrective actions are to be completed prior to startup from the next BVPS-1 refueling outage (1R20) scheduled to be completed in the fourth quarter of 2010. Mitigation of the additional fibrous insulation will be accomplished through removal, replacement, analysis or design modification (this is a commitment in the April 30, 2009 letter). The NRC subsequently approved this BVPS-1 extension request in a letter dated May 5, 2009 (Reference 14). A description of the proposed mitigation activities will be provided as a supplemental response to GL 2004-02 prior to the start of the fall 2010 refueling outage (1R20) (this is a regulatory commitment from the April 30, 2009 letter).

The corrective actions resulting from BVPS-2 retesting, including insulation modifications, will be completed prior to startup following the fall 2009 refueling outage (2R14) (this is a commitment in an August 28, 2008 FENOC letter, Reference 15).

Ex-vessel downstream effects analyses evaluate the effects of debris carried downstream of the containment sump screen on the function of the emergency core cooling system (ECCS) and containment spray system in terms of potential wear of components and blockage of flow streams. Ex-vessel downstream effects analyses were conducted for both BVPS-1 and BVPS-2 in accordance with WCAP-16406-P, Revision 0, "Evaluation of Downstream Debris Effects in Support of GSI-191." As a result, the high pressure safety injection cold leg throttle valves were replaced during the fall 2007 refueling outage (1R18) at BVPS-1. At BVPS-2, the high pressure safety injection throttle valves were modified during the spring 2008 refueling outage (2R13).

The revised guidance of WCAP-16406-P, Revision 1, was issued and required the previously developed analyses to be revised. The ex-vessel downstream effects analyses have been completed for BVPS-1 and BVPS-2. The evaluation results indicate that no unacceptable component wear of the ECCS and RSS flow paths will occur, and therefore inadequate core or containment cooling will not result due to the effects of the debris.

The NRC staff has not issued a safety evaluation for WCAP-16793-NP, Revision 1. Therefore, FENOC's evaluation for in-vessel downstream effects has not been finalized. The results of the BVPS-1 and BVPS-2 evaluations that were performed under WCAP-16793-NP, Revision 1, are provided within this response. Any additional actions required to address in-vessel downstream effects will be completed after issuance of the final NRC safety evaluation on WCAP-16793-NP, Revision 1.

Response Overview:

FENOC has completed most of the actions necessary to bring BVPS-1 and BVPS-2 into compliance with GL-2004-02. These activities include analysis, testing, and plant modifications. Completed activities and those scheduled to be completed will bring both units into full compliance with GL 2004-02. The primary means to achieve compliance are the containment sump screen modifications and comprehensive insulation replacement modifications. Both BVPS-1 and BVPS-2 utilize a single containment sump. The containment sump screen modifications for both plants increased the overall strainer size to ensure adequate Net Positive Suction Head (NPSH) for the ECCS and RSS pumps. The insulation modifications remove the majority of fibrous insulation and a large percentage of calcium-silicate (Cal-Sil) insulation potentially affected by line breaks. This insulation is to be replaced with reflective metal insulation (RMI). These insulation modifications yield a significant reduction in postulated debris at the sump, such that both BVPS-1 and BVPS-2 can be classified as low fiber plants.

Analysis and testing performed to attain compliance with GL 2004-02 included conservative approaches and included margins.

Testing to account for head loss attributed to chemical effects was originally conducted for BVPS-1 and BVPS-2 at the Vuez test facility. Due to issues related to the Vuez testing, FENOC restructured the testing and retested based on WCAP-16530-NP precipitate formation. The retest was performed in accordance with the March 28, 2008 Reviewers Guide (Reference 12). The testing protocol was established to test to success. Testing was performed by reducing debris quantities through a series of tests until an acceptable NPSH margin was established. The retests were comprehensive and extensive. Testing with various debris loads and chemical precipitants provided the information required to determine the type of plant modifications required to assure adequate NPSH margins. The testing was performed using conservative inputs to establish margins.

Modifications were implemented or are scheduled to be implemented to align both units with the successful tests performed. A significant quantity of aluminum has been removed from both units to lower chemical precipitant loading. As noted above, fibrous insulation and Cal-Sil has been replaced with RMI at BVPS-1 and is scheduled to be replaced at BVPS-2 during the fall 2009 refueling outage. These changes are a substantial undertaking; however FENOC has recognized that the path to success is to remove sufficient debris to be a low fiber plant with a reduced aluminum content. These changes result in additional margins for other aspects of GL 2004-02 including component wear from downstream effects.

Additional conservatisms were factored into the overall program. FENOC did not perform testing or credit specific industry testing to establish an alternate or reduced zone of influence (ZOI) for either BVPS-1 or BVPS-2. Debris and chemical precipitants generated during a postulated rupture were conservatively considered to arrive at the strainer at the time of recirculation initiation, for establishing minimum NPSH margins. In addition, the generated debris was conservatively considered to fully transport to the strainer for head loss testing. There was no credit for near field settling or dropout in inactive pools.

The design of the ECCS is such that the strainers are fully submerged at the start of the recirculation phase for both small and large break LOCAs. There are no vent paths that would allow air ingestion into the system. Testing has shown that the strainers are not subject to vortexing at twice the design flow.

FENOC's programs and processes are designed to ensure that latent debris remains within acceptable levels.

FENOC was proactive and fully engaged with Westinghouse prior to and during fuel nozzle testing for the evaluation of in-vessel downstream effects. FENOC has verified that BVPS-1 and BVPS-2 meet the requirements of the recently issued WCAP-16793-NP, Revision 1.

The detailed response to Review Area 3 highlights specific conservative methods, conservative inputs, and margins. The following is a summary of some of the more notable conservative aspects of FENOC's process.

Debris Generation / Zone of Influence

- No credit for leak-before-break was taken in the BVPS-1 or BVPS-2 sump analysis.
- The qualified epoxy coatings debris is conservatively based on a ZOI of 5D which is greater than the 4D recommended by WCAP-16568-P.

Latent Debris

- Latent debris was quantified for both BVPS-1 and BVPS-2. These quantities of latent debris were increased for head loss testing and conservatively taken as 200 pounds.
- The quantity of labels, tape, and miscellaneous debris that is predicted to result in a direct blockage of screen area was developed through walkdowns and reviews of component drawings.
    - No distinction was made regarding the type of tags and labels installed (qualified vs. unqualified).
    - If tags and labels are not metal and metal banded they were assumed to detach.
    - Tags and labels that detached were assumed to retain their original size.
    - Tags and labels that detached were assumed to fully transport to the strainer.
    - The resultant square footage was increased by 30 percent to account for uncertainty and to provide margin for both units.

Debris Transport

- The recirculation pool transport fractions for BVPS-2 were conservatively assumed to be 100 percent. Although a Computational Fluid Dynamic (CFD) analysis was applied for BVPS-1, the results also conservatively assume 100 percent transport of all fibrous and particulate debris to the sump screen.
- Design debris load is not time dependent. All transportable debris is assumed to be present at the containment sump screens at the time recirculation starts.
- Conservatively, no inactive pools are credited at BVPS-1 or BVPS-2.
- One hundred percent of fine fibrous debris and particulate is assumed to transport to the sump. This represents a significant conservatism as some fraction of debris would settle or be captured in stagnant areas of the containment.

Head Loss and Vortexing

- Since the quantity of fiber was predicted to be too low to fully cover the screens, the quantity of unqualified paint was introduced during head loss testing as both particulate and chips, effectively doubling the quantity of this debris source.
- In addition to the doubling of unqualified paint, the baseline unqualified inorganic zinc (IOZ) and epoxy coatings value was increased by an equivalent of 200 square feet for head loss testing.
- All unqualified coatings, labels, and other miscellaneous debris sources in containment are assumed to be at the containment sump screen at the initiation of recirculation when water level is at its lowest. These materials will require a substantial period of time for them to fail and be transported to the sump after which higher water levels would be available for additional NPSH.
- In order to quantify latent debris, containment walk downs were performed and included sampling. Reported latent debris values were increased for head loss testing at both units to establish margin. FENOC has also invoked a containment cleaning program at BVPS-1 and BVPS-2 to provide assurance that latent debris values will remain below the baseline levels in the head loss testing. Although the cleaning program is not designed to re-benchmark the latent debris, the program will result in a reduction of the debris quantity from that used in testing.
- Strainer head loss testing was performed with the tank agitated which prevented settling of debris in the vicinity of the strainers. It was verified during testing that the agitation did not disturb the debris bed.

NPSH

- A spectrum of RCS break sizes was examined to determine the minimum sump level. The minimum break sizes typically result in the minimum sump level since the contribution from the RCS inventory is small and the safety injection accumulators do not inject. This is a conservative approach since the normal progression for very small break sizes would not transition to recirculation mode. Emergency operating procedures direct the operators to use secondary heat removal to cool down the RCS and refill the system, and use the Residual Heat Removal System for long term cooling.
- The NPSH analyses consider both hot leg and pump suction breaks along with single active failure assumptions and utilize the most conservative combination of input parameters biased in a direction which yields the most limiting result.
- For BVPS-1 an additional volume of water (4,700 to 8,500 gallons) is injected from the chemical addition system. This volume is conservatively not credited for the purpose of calculating sump inventory and available NPSH.
- With the conservative inputs presented herein, the pumps at BVPS-1 all have an NPSH margin exceeding 19 percent and the pumps at BVPS-2 have an NPSH

margin exceeding 27 percent. The limiting point for NPSH margin is typically at or shortly following pump start and the NPSH margin increases quickly thereafter due to the increasing sump level and decreasing sump temperatures. Conservatively, the effects of chemical precipitates is applied to the containment sump strainer head loss at the onset of the accident.

- The NPSH available for small breaks is conservative as the head loss determined by the analysis is based on large break debris quantities.

Downstream Effects – Ex-vessel

- A significant portion of the ex-vessel downstream effects analyses were completed prior to establishing modifications for debris reduction and are based on larger debris quantities. Ex-vessel downstream analyses for BVPS-1 and BVPS-2 were performed with margins in the debris quantities.
- All fiber which is postulated to be transported to the sump screens is assumed to pass through the screens for ex-vessel downstream analysis. Plant specific bypass testing shows that a considerable quantity of fiber will remain on the screens.

Downstream Effects – In-vessel

- The in-vessel downstream analysis for core cooling included the use of conservative quantities of debris.
- The fuel bottom nozzle head loss tests were conducted using fibrous debris values that are based upon the BVPS strainer tests and include maximum particulate debris. It was conservatively assumed that 100 percent of the particulate debris that arrives at the strainer also arrives at the fuel bottom nozzle.
    - For BVPS-2, the bypass quantity used was conservatively based upon testing with the strainer top-hat integral debris eliminators removed. The debris eliminators are installed which lowers the bypass quantity.
- Margins for BVPS-1 and BVPS-2 fuel nozzle tests are shown in the response to Review Area 3.n.

Chemical Effects

- Chemical precipitate quantities introduced during head loss testing were based on calculated values, using the WCAP-16530 spreadsheet and increased by 10 percent.
- The thick aluminum input used to generate the chemical precipitates was increased by a minimum of 10 percent.

- An additional conservatism that exists for chemical effects is that the chemical precipitates will not readily form until containment pool temperature has decreased below the precipitate associated value. This will not occur until later in the event at which time the containment water level will be considerably higher, providing a greater available NPSH. Chemical precipitate loading was considered at initiation of recirculation. During BVPS chemical effects testing, chemical precipitates were added at the beginning of the test in accordance with WCAP-16530 methodology and the NRC guidance of March 28, 2008 (Reference 12).
- With the exception of aluminum paint protected by undamaged insulation, aluminum within the RSS area was not assessed for shielding from spray. All aluminum within the containment was included in the analysis for predicted chemical precipitates.
- Chemical precipitant quantities calculated for BVPS-2 were based on a sump water and spray pH based on use of a sodium hydroxide buffer. BVPS-2 will be changing buffers from sodium hydroxide to sodium tetraborate during the fall 2009 refueling outage. Since the predicted pH for sodium tetraborate is lower, the head loss test is conservative in regard to chemical precipitants.
- The containment sump water uses a conservative pH value for the full 30 day duration to determine the quantity of chemical precipitants developed. No assumption of acid generation is used to lower the pH of the water.

Strainer Structural Analysis

- The values of the margins for structural analysis are provided in FENOC's response to Review Area 3.

Conclusion

Significant margins and conservatisms have been established to resolve issues related to GL 2004-02 and GSI-191. FENOC has performed extensive analysis and testing, along with significant modifications to the plant, to ensure that the ECCS will meet the requirements of 10 CFR 50.46 following a LOCA.

Specific Guidance for Review Areas

1. ***Overall Compliance:***

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

GL 2004-02 Requested Information Item 2(a)
Confirmation that the ECCS and CSS recirculation functions under debris loading conditions are or will be in compliance with the regulatory requirements listed in

the Applicable Regulatory Requirements section of this generic letter. This submittal should address the configuration of the plant that will exist once all modifications required for regulatory compliance have been made and this licensing basis has been updated to reflect the results of the analysis described above.

FENOC Response

FENOC letter dated August, 28, 2008 (Reference 15) documented the required BVPS-1 and BVPS-2 corrective actions and schedule for achieving compliance to GL 2004-02. These corrective actions were identified from the results of FENOC's debris and chemical effects testing for BVPS-1 and BVPS-2. Upon completion of these activities and the additional BVPS-1 mitigation activities noted below, BVPS-1 and BVPS-2 will be in compliance with the regulatory requirements listed in GL 2004-02 with the exception of the industry open issues with in-vessel downstream analysis.

Fibrous insulating material (Temp-Mat™) was identified on the six reactor vessel inlet and outlet nozzles during the BVPS-1 refueling outage 1R19. The resulting additional fibrous loading is not bounded by the Reactor Coolant System (RCS) nozzle break scenario assumptions for strainer head loss testing and analysis that was performed. This issue has been entered into FENOC's corrective action program. A description of the additional BVPS-1 mitigation activities will be provided as a supplemental response to GL 2004-02 prior to the start of 1R20 (this is a commitment from the April 30, 2009 FENOC letter, Reference 13, and is documented in the NRC's extension request approval letter for BVPS-1, dated May 5, 2009, Reference 14).

FENOC has taken action in response to GL 2004-02 to ensure that the ECCS and RSS recirculation functions under debris loading conditions at BVPS-1 and BVPS-2 will continue to be in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of GL 2004-02. (At BVPS, the RSS provides the Containment Spray System [CSS] recirculation function.)

Compliance with the Applicable Regulatory Requirements section of GL 2004-02 is achieved through analysis, plant-specific testing, mechanistic evaluations, installation of new containment recirculation sump strainers, plant modifications to reduce debris to the containment sump, and programmatic changes to ensure continued compliance. Following implementation of the final plant modifications described in response to Review Area 2 below, the ECCS and CSS recirculation functions will continue to support the 10 CFR 50.46 requirement for the ECCS to provide long-term cooling of the reactor core following a design basis Loss Of Coolant Accident (LOCA), as well as the requirements of 10 CFR 50 Appendix A, General Design Criteria (GDC) 35 for ECCS, GDC 38 for containment heat removal systems, and GDC 41 for containment atmosphere cleanup systems.

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 not later than October 1, 2007.)

GL 2004-02 Requested Information Item 2(b)
A general description of and implementation schedule for all corrective actions, including any plant modifications, that you identified while responding to this generic letter. Efforts to implement the identified actions should be initiated no later than the first refueling outage starting after April 1, 2006. All actions should be completed by December 31, 2007. Provide justification for not implementing the identified actions during the first refueling outage starting after April 1, 2006. If all corrective actions will not be completed by December 31, 2007, describe how the regulatory requirements discussed in the Applicable Regulatory Requirements section will be met until the corrective actions are completed.

FENOC Response

Summary of Activities Already Completed:

- Strainer replacements have been installed at both units. At BVPS-2, the new replacement strainer, which increased the available surface area from approximately 150 square feet to 3300 square feet, was installed during the fall 2006 refueling outage (2R12). At BVPS-1, the new replacement strainer, which increased the available surface area from approximately 130 square feet to 3400 square feet, was installed during the fall 2007 refueling outage (1R18).
- Replacement of BVPS-1 and modification of BVPS-2 high pressure safety injection cold leg throttle valves have been completed to increase the throttle valve gap and thereby reduce flow restrictions.
- The BVPS-1 and BVPS-2 start signal for the RSS pumps has been changed from a fixed time delay to an Engineered Safety Features Actuation System (ESFAS) signal based on a refueling water storage tank (RWST) level low coincident with a containment pressure high-high signal to allow sufficient pool depth to cover the sump strainer before initiating recirculation flow.
- Borated Temp-Mat™ insulation encapsulated in Reflective Metal Insulation (RMI) on the BVPS-1 Reactor Vessel Closure Head has been replaced with RMI to reduce debris loading on the sump strainer.
- New RMI was installed on the BVPS-1 replacement steam generators (RSGs) and associated piping in the vicinity of the RSGs resulting in a reduced quantity of insulation that could contribute to debris loading on the sump strainer.

- Final strainer prototype debris and chemical effects testing of the new strainer designs were completed for BVPS-1 and BVPS-2.
- Borated Temp-Mat™ insulation encapsulated in RMI on the BVPS-2 Reactor Vessel Closure Head flange has been replaced with RMI, and Min-K™ insulation encapsulated in RMI on portions of the Reactor Coolant System piping has been replaced with Thermal Wrap insulation encapsulated in RMI. FENOC letter dated August 28, 2008 (Reference 15) stated that portions of the Safety Injection System piping insulation were also replaced with Thermal Wrap insulation encapsulated in RMI during the spring of 2008. However, inspection of the piping verified that no Min-K™ insulation was installed and therefore no actual insulation modification was necessary. This incorrect statement was entered into the FENOC corrective action program, and was communicated to the NRC Project Manager on October 6, 2008.
- A containment coatings inspection and assessment program and a containment cleaning program became effective for BVPS in April of 2008 and apply to BVPS refueling outages beginning with the BVPS-2 spring 2008 refueling outage (2R13).
- BVPS-1 and BVPS-2 reactor cavity drain cross bars that have the potential to collect debris and block water flow to the containment sump were removed.
- Temp-Mat™ insulation encapsulated in metal jacketing (Diamond Power Mirror®) on the BVPS-1 reactor coolant loop piping was replaced with RMI. This insulation extended within the reactor cavity penetrations as a transition between the reactor vessel nozzles and RMI on the reactor coolant system piping (hot and cold legs).
- Temp-Mat™ fibrous insulation or calcium-silicate (Cal-Sil) on select BVPS-1 piping was replaced with RMI.
- Iodine filters, containing a significant amount of thin aluminum that would have been submerged, were removed from the BVPS-1 and BVPS-2 containments.
- LOCADM analyses were conducted for both BVPS-1 and BVPS-2 in accordance with WCAP-16793-NP, Revision 1. Both BVPS-1 and BVPS-2 satisfy the maximum clad temperature and total deposition thickness limits of that WCAP. (See Table 3.n.1.)
- WCAP-16793-NP, Revision 1, and WCAP-17057-P, Revision 0, which describe the Westinghouse fuel nozzle tests, were reviewed. BVPS-1 and BVPS-2 were shown to be enveloped by the testing described within those WCAPs. The tests demonstrated adequate flow to assure core cooling with post LOCA debris and chemical amounts that bound BVPS-1 and BVPS-2. (See Table 3.n.2.) The available hot leg and cold leg driving heads of BVPS-1 and BVPS-2 were shown to be more than adequate to satisfy the WCAP requirements. Thus, BVPS-1 and

BVPS-2 will have flows in excess of those necessary to assure long term core cooling. (See Table 3.n.3.)

Provided that there are no technical issues identified during the NRC review process, long term cooling considering particulate, fibrous and chemical debris is assured.

- License Amendment No. 167 for BVPS-2, issued March 26, 2009 (Reference 16), authorized changes to the licensing basis as described in the BVPS-2 Updated Final Safety Analysis Report (UFSAR) regarding the method of calculating the net positive suction head available to the RSS pumps by crediting containment overpressure. The licensing basis was revised April 7, 2009.

Summary of Activities to be Completed for BVPS-1:

Fibrous insulating material (Temp-Mat™) was identified on the six reactor vessel inlet and outlet nozzles during the BVPS-1 refueling outage 1R19. The resulting additional fibrous loading is not bounded by the Reactor Coolant System (RCS) nozzle break scenario assumptions for strainer head loss testing and analysis that was performed (Reference 13). The information presented in this supplement for BVPS-1 reflects the absence of fibrous insulation on the reactor nozzles. Activities to be completed for BVPS-1 include the following items.

- A description of the proposed mitigation activities will be provided as a supplemental response to GL 2004-02 prior to the start of 1R20 (this is a commitment from the April 30, 2009 FENOC letter, Reference 13).
- Mitigation of the additional fibrous insulation will be accomplished through removal, replacement, analysis or design modification prior to startup from the next refueling outage (1R20), scheduled to be completed in the fourth quarter of 2010 (this is a commitment from the April 30, 2009 FENOC letter, Reference 13).
- Emergency operating procedures for BVPS-1 will be revised to enhance the steps that shut down two RSS pumps prior to the transfer to recirculation. This operator action is discussed in Sections 3.g.6 and 3.g.7. These procedure changes will be implemented by December 31, 2009.

It is recognized that the NRC is still reviewing WCAP-16793-NP, Revision 1. FENOC will address any limitations or conditions identified in the NRC SE within 90 days after the SE is issued.

Summary of Activities to be Completed for BVPS-2:

Activities to be completed include the following:

- Insulation modifications will be implemented prior to startup following the fall 2009 refueling outage (2R14). This commitment to modify insulation was made in a FENOC letter dated August 28, 2008 (Reference 15).

- Although not required to support closure of GSI-191 for BVPS-2, the sodium hydroxide buffer is scheduled to be replaced in the fall 2009 refueling outage. The replacement buffer is sodium tetraborate. This lowers the chemical loading and provides additional strainer head loss margin for BVPS-2.
- Emergency operating procedures for BVPS-2 will be revised to shut down one of the RSS pumps supplying the spray header when the containment pressure is reduced below a predetermined value. The change will be implemented prior to startup from the fall 2009 refueling outage (2R14).

It is recognized that the NRC is still reviewing WCAP-16793-NP, Revision 1. FENOC will address any limitations or conditions identified in the NRC SE within 90 days after the SE is issued.

3. *Specific Information Regarding Methodology for Demonstrating Compliance:*

3.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.***
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.***
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.***

FENOC Response

Break Selection Process

Break selection consists of determining the size and location of the High Energy Line Breaks (HELBs) that produce debris and potentially challenge the performance of the sump screen. The break selection process evaluated a number of break locations to identify the location that is likely to present the greatest challenge to post-accident sump performance. The debris inventory and the transport path were considered when making this determination.

Regulatory guidance recommends that a sufficient number of breaks bounding variations in debris size, quantity, and type be identified. BVPS-1 and BVPS-2 evaluated a number of break locations and piping systems, and considered breaks that rely on recirculation to mitigate the event. The following break locations were considered:

Break Criterion 1 - Breaks in the reactor coolant system (RCS) with the largest potential for debris

Break Criterion 2 - Large breaks with two or more different types of debris

Break Criterion 3 - Breaks in the most direct path to the sump

Break Criterion 4 - Medium and large breaks with the largest potential particulate debris to fibrous insulation ratio by weight

Break Criterion 5 - Breaks that generate an amount of fibrous debris that, after transport to the sump screen, could form a uniform thin bed (that is, usually 1/8 inch thick) that could subsequently filter sufficient particulate debris to create a relatively high head loss referred to as the "thin-bed effect."

This spectrum of breaks is consistent with that recommended in the NRC Safety Evaluation (SE); NEI 04-07, Volume 2 (Reference17), and is also consistent with regulatory position 1.3.2.3 of Regulatory Guide 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," Revision 3.

Locations were selected for the breaks that produce the maximum amount of debris and also the worst combination of debris mixes with the possibility of being transported to the sump screen. Section 3.3.5.2 of NEI 04-07, Volume 2 (Reference 17) advocates break selection at 5 foot intervals along a pipe in question but clarifies that "the concept of equal increments is only a reminder to be systematic and thorough." It further qualifies that recommendation by noting that a more discrete approach driven by the comparison of debris source term and transport potential can be effective at placing postulated breaks. The key difference between breaks (especially large breaks) is not the exact location along the pipe, but rather the envelope of containment material targets that is affected.

Small break LOCAs for piping within the secondary shield wall (inside crane wall) were evaluated in Class 1 piping to provide debris generation values associated with the lower water level postulated for certain small break events. Section 3.3.5.2 of NEI 04-07, Volume 2 stipulates that the need to evaluate breaks in RCS-attached piping beyond isolation points is contingent upon the determination that recirculation would not be required should a break occur in these sections. The decision whether to include piping segments beyond the isolation points considered possible failure of the isolation valves in a manner consistent with the licensing basis.

Analysis of Secondary Line Breaks

For both BVPS-1 and BVPS-2, secondary system line breaks do not require the plant to enter the recirculation phase for safe shutdown. As such, Main Steam System and Main Feedwater System line breaks are not required to be evaluated for debris generation.

Break Location Results

All phases of the plant-specific accident scenarios were evaluated to develop debris generation values in accordance with the criteria and process discussed above. Each break location was evaluated for the amount of debris generated and the resultant impact on sump performance. The break criterion have been evaluated based on the insulation modifications completed for BVPS-1 during the spring of 2009 refueling outage (1R19) and the planned insulation modifications for BVPS-2 in the fall of 2009 refueling outage (2R14). The breaks for BVPS-1 and BVPS-2 which meet the criterion are provided below. As previously identified, additional corrective actions will be required for BVPS-1. The additional BVPS-1 corrective actions were discussed in the FENOC extension request letter April 30, 2009 (Reference 13), and the NRC's extension request approval letter, dated May 5, 2009 (Reference 14).

Break Criterion 1 - Breaks in the RCS with the largest potential for debris

The RCS loop piping, reactor vessel nozzles, and pressurizer surge line, were evaluated for the generation of the greatest amount of fibrous debris and for the greatest amount of coatings and particulate debris.

For BVPS-1, there are two RCS piping breaks which have been identified as meeting Break Criterion 1. These include: 1) RCS loop piping breaks and 2) pressurizer surge line break.

For BVPS-2, there are three RCS piping breaks which have been identified as meeting Break Criterion 1. These include: 1) RCS loop piping breaks, 2) pressurizer surge line break, and 3) reactor vessel nozzle break.

Break Criterion 2 - Large breaks with two or more different types of debris

For BVPS-1, the breaks identified under Break Criterion 1 were also identified as the large breaks meeting Break Criterion 2.

For BVPS-2, the breaks identified under Break Criterion 1 were also identified as the large breaks meeting Break Criterion 2.

Break Criterion 3 - Breaks in the most direct path to the sump

For BVPS-1 and BVPS-2, all three RCS piping loops have a relatively unobstructed path to the ECCS recirculation sumps via an opening around the primary shield wall (surrounding the reactor vessel). Therefore, the RCS loop pipe breaks have the most direct path to the sump and were identified as breaks which meet Break Criterion 3.

In addition to the BVPS-1 and BVPS-2 RCS loop piping break, the reactor vessel nozzle break was also identified as meeting Break Criterion 3. The primary shield wall below the reactor vessel has an opening which allows water to drain from the cavity and provides a direct path to the sump.

Break Criterion 4 - Large breaks with the largest potential particulate debris to fibrous insulation ratio by weight

For BVPS-1, RCS piping loop breaks were identified as generating the largest mass quantities of fibrous debris and of particulate debris that results in having the largest impact in head loss. However, debris generation analysis concluded that the pressurizer surge line break generated the highest particulate to fibrous insulation mass ratio.

For BVPS-2, RCS piping loop breaks were identified as generating the largest mass quantities of fibrous debris and of particulate debris that results in having the largest impact in head loss. However, debris generation analysis concluded that the reactor cavity nozzle break generated the highest particulate to fibrous insulation mass ratio.

Break Criterion 5 - Breaks that generate a thin bed – high particulate with 1/8 inch fiber bed

The highest particulate to fibrous insulation ratio is generated by the pressurizer surge line break at BVPS-1 and the reactor nozzle break at BVPS-2 (as indicated under Break Criteria 4 above). However, the amount of fiber that the break generates, when applied uniformly across the screen, was found to be much less than 1/8 inch that is likely to result in available open screen area. Thus, the fiber debris bed that would form is not sufficiently thick to effectively capture particulate material and the potential impact on head loss is relatively insignificant.

As previously stated for both BVPS-1 and BVPS-2, the RCS loop piping breaks were found to have a greater amount of fibrous debris and particulate debris (even though the resultant ratio is small). The analysis of the debris sources for both units from an RCS loop piping break also concluded that the fibrous bed, when applied uniformly across the screen, will also result in a fiber bed being less than 1/8 inch. However, the total amount and resulting fiber bed thickness is greater than the thickness resulting from the pressurizer surge line break (for BVPS-1) and the reactor cavity nozzle break (for BVPS-2) and has a higher impact on head loss.

3.b. *Debris Generation / Zone of Influence (ZOI) (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; and (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 (GR)/safety***

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

2. ***Provide destruction ZOIs and the basis for the ZOIs for each applicable debris constituent.***
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).***
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.***
5. ***Provide total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment.***

FENOC Response

The debris generation analysis for BVPS-1 and BVPS-2 considers the ZOI based on the material with the lowest destruction pressure. Refinements include: debris-specific (insulation material specific), and non-spherical ZOIs. The debris-specific refinements endorsed in Section 4.2.2.1.1 of the NRC Safety Evaluation (SE) (Reference 17) provide relief as long as there are two or more distinct types of insulation within the break location.

Both BVPS-1 and BVPS-2 applied the ZOI refinement discussed in Section 4.2.2.1.1 of the SE (Reference 17), which allows the use of debris-specific spherical ZOIs. Using this approach, the amount of debris generated within each ZOI is calculated and the individual contributions from each debris type are summed to arrive at a total debris source term.

The sources of debris considered include insulation debris, coatings debris, and latent debris. The evaluation concluded that there are several types of insulation inside the containment that could potentially create debris following a LOCA. The assumptions utilized for each of these types are summarized as follows.

<u>*Diamond Power Mirror® RMI with Standard Bands*</u>:
Mirror® Reflective Metal Insulation (RMI), manufactured by Diamond Power, a subsidiary of Babcock and Wilcox, is installed throughout containment. The Mirror® cassettes include stainless steel foils encased in stainless steel sheaths secured with latches and strikes. In the absence of specific data for the various applications of Mirror® RMI, it was assumed that there are three layers of foil per inch of insulation. This assumption is based upon Mirror® insulation criteria used at other facilities. The guidance prescribes ZOIs between 11.7D (11.7 pipe diameters) and 28.6D for the RCS

loop insulating materials. This is conservative as a review of the containment configuration indicates that a ZOI of that size would be bounded by structural barriers surrounding the RCS (e.g., the reactor cavity, loop walls, secondary shield wall, and the floor slabs) and the 28.6D ZOI from Table 3-2 of the SE (Reference 17) (66 to 74 foot radius) specified for Mirror® RMI would be truncated significantly by the structural barriers.

Transco Products Inc. RMI:

Transco Products Inc. (Transco) RMI incorporates a stainless steel cassette design, secured with quick-release locking buckles, which encloses the foil liners. This design has been demonstrated to be more robust than the earlier Mirror® insulation and has a breakdown pressure of 114 pounds-force per square inch gauge (psig). As specified in Table 3-2 of the SE (Reference 17), a 2.0D ZOI is used.

NUKON®:

NUKON®, manufactured by Owens-Corning, is used for the Power Operated Relief Valve (PORV) piping. NUKON® is a composite fibrous glass insulation blanket material. As specified in Table 3-2 of the SE (Reference 17), a 17.0D ZOI is used.

Temp-Mat™ with SS wire retainer:

Temp-Mat™, originally supplied by Pittsburgh Corning Corporation, is a high density insulation manufactured with glass fibers needled into a felt mat. The 11.7D ZOI specified for Temp-Mat™ in Table 3-2 of the SE (Reference 17) is equivalent to a sphere with a radius approximately 27 to 30 feet, dependent upon the location of the particular pipe break.

Fiberglas® Thermal Insulating Wool (TIW):

Owens-Corning Thermal Insulating Wool (TIW) is low density fiberglass (LDFG) insulation. Two grades are specified in the insulation specification, Type I and Type II. For conservatism, all TIW insulation was assumed to have the higher manufactured density (2.4 pounds per cubic foot [lb/ft^3]) of Type II. Because the macroscopic density for TIW is similar to NUKON®, the material characteristics specified for NUKON® were assumed for this TIW. Thus, a 17.0D ZOI is used.

Fiberglass:

Three types of fiberglass insulation are specified for piping applications. In containment, use of these materials is limited to service water piping; a) Knauf full-range fiberglass insulation with All-Service Jacket (ASJ), b) Johns-Manville Micro-Lock 650 AD-T jacketing, and c) Heavy duty pipe covering with ASJ/SSL-II by Owens-Corning. Again, these materials are low density fiberglass with macroscopic (as-manufactured) density similar to NUKON®. Thus, a 17.0D ZOI is used.

Transco Thermal Wrap:
Transco Thermal Wrap has been used in BVPS-2 as a replacement for Min-K™ in the loop compartments. Transco Thermal Wrap is a LDFG insulation with a density of 2.4 lb/ft^3 that is equivalent to NUKON®. Therefore the material characteristics for NUKON® are assumed. Thus a 17.0D ZOI is used.

Calcium Silicate:
Calcium silicate (Cal-Sil) is a granular insulation consisting of fine particulate material that is chemically bonded and held together with a fine fibrous matrix. Two calcium silicate types are present: Johns-Manville Thermo-12 and Owens-Corning KAYLO. These are high strength, molded materials suitable for temperature up to 1200°F. The guidance specifies a ZOI equal to 5.45D for this material (assuming aluminum cladding with stainless steel banding). The smaller ZOI radius (12.5 feet to 14 feet) is small enough that the location within the loop compartment could have an impact on debris that is generated.

Encapsulated Min-K™:
Encapsulated Min-K™, originally manufactured by Johns-Manville, is a microporous insulation installed where insulation thickness is restricted. Min-K™ is a thermo-ceramic material (also referred to as a particulate insulation). Data supplied by the vendor was used to approximate a single, representative microscopic density by taking a mass-weighted average of the individual constituent particle densities. The guidance of the SE (Reference 17) prescribes ZOIs between 11.7D and 28.6D for this type of insulating material. The more conservative value of a 28.6D ZOI was used for Min-K™.

Benelex 401®:
Benelex 401® is a high density wood-based shielding material made by exploding clean wood chips. The resulting cellulose and lignin fibers are compressed into rigid panels with controlled densities, thicknesses and sizes. The structural integrity of Benelex® was evaluated for seismic forces and LOCA pressure loading. The evaluation concluded that the Benelex® could withstand a 120 psig pipe rupture without failure. The analyzed pressure exceeds the maximum destruction pressure listed in Table 3-2 of the SE (Reference 17) for any material. A ZOI of 2.0D (equivalent to a destruction pressure of 114 psig for Transco RMI) is considered conservative for Benelex® based upon comparison data in Table 3-2 of the SE (Reference 17).

Foamglas®:
FOAMGLAS® insulation is an inorganic, rigid and brittle cellular insulation manufactured by Pittsburgh Corning Corporation. The guidance of the SE (Reference 17) prescribes ZOIs between 11.7D and 28.6D for this type of insulating material. The more conservative value of a 28.6D ZOI was used for FOAMGLAS®.

Transite:
Transite is a fiber cement board material similar to Cal-Sil. The guidance of the SE (Reference 17) prescribes ZOIs between 11.7D and 28.6D for this type of insulating material. The more conservative value of a 28.6D ZOI was used for Transite.

Microtherm®:
Microtherm® is used within the reactor cavity for BVPS-2. Microtherm® is a microporous insulation material that is composed of filaments, fumed silica and titanium dioxide. The guidance of the SE (Reference 17) prescribes ZOIs between 11.7D and 28.6D for this type of insulating material.

The Microtherm® present in the BVPS-2 reactor cavity was supplied by Transco and is encapsulated in 24 gage cassettes ranging from 1 to 1.5 inches in thickness. The cassettes are seam welded at all vertical joints in the same manner as Transco RMI (RMI-T). Horizontal joints are spoked and both vertical and horizontal joints are lapped to adjacent panels around the reactor vessel using number 14 stainless steel screws. This encapsulation is similar to RMI-T, which has a destruction pressure of 114 psig and a ZOI of 2D. Although the ZOI for RMI is 2D, the encapsulated Microtherm® ZOI was conservatively increased by a factor of 2, resulting in a 4D ZOI for the Microtherm® application at BVPS-2. A destruction pressure of 40 psig was derived for this material through interpolation of destruction pressures within Table 3-2 of the SE, as a value equivalent to a 4D ZOI.

In addition to the stainless steel jacketing, the Microtherm® is fully surrounded by a reactor vessel supplemental neutron shielding. The supplemental neutron shielding structure consists of a silicon polymer material fully encased by 0.13 to 0.19 inch seam welded stainless steel plates. Total thickness of the shielding is 9 inches in the reactor vessel belt line region and 4 to 6 inches over the reactor vessel nozzles. This supplemental neutron shielding provides additional protection of the Microtherm® cassettes as a robust barrier although it is conservatively not factored into the Microtherm® debris generation ZOI determination value.

Table 3.b-1 lists the specific debris materials (common to both units, or as specified to only one of the units), the destruction pressure, and the ZOI.

Table 3.b-1
Damage Pressures and Corresponding Volume-Equivalent Spherical ZOI Radii

Insulation Types	Destruction Pressure (psig)	ZOI Radius / Break Diameter
Diamond Power Mirror® RMI with Standard Bands	2.4	28.6
Transco RMI	114	2.0
Temp-Mat™ with SS wire retainer	10.2	11.7
Fiberglas® Thermal Insulating Wool (TIW)	6	17.0
Fiberglass (2)	6	17.0
Transco Thermal Wrap (2)	6	17.0
Calcium Silicate (Aluminum cladding, SS bands)	24(3)	5.45
Encapsulated Min-K™	2.4	28.6
Encapsulated Microtherm® Insulation System(2)	40(6)	4.0(5)
Benelex 401® (1)	120	2.0(4)
Foamglas® (1)	N/A	28.6
Transite (1)	N/A	28.6

Notes:

(1) BVPS-1 only.

(2) BVPS-2 only.

(3) The destruction pressure provided is based upon use of aluminum cladding with stainless steel (SS) bands. The SS jacketing with SS wire/banding used at BVPS-1 and BVPS-2 is judged to provide protection at least equivalent to aluminum cladding.

(4) Equivalent ZOI utilized.

(5) The destruction pressure of the Microtherm® Insulation System provided in Table 3.b-1 is based upon a 4D spherical ZOI as assumed for encapsulated Microtherm®. A 1.68D ZOI size is utilized for this insulation which represents a confinement-adjusted ZOI and was determined using a ratio-based BWR URG approach for restrained breaks.

(6) Derived from interpolation of destruction pressures equivalent to a 4D ZOI in Table 3-2 of the SER.

Plant-specific destructive testing, as defined in the guidance report (GR)/safety evaluation (SE), was not performed to support the evaluation on either unit.

Debris quantities

The quantity of each debris type generated for the representative limiting break locations that were evaluated at BVPS-1 are summarized in Table 3.b-2.

Table 3.b-2
BVPS-1 Insulation Debris Quantities

Material Types	Loop LBLOCA(1)	RPV(2) Nozzle Break	Pressurizer Surge Line Break	6 Inch SIS(3) Injection Point
RMI	24,607 ft^2	16,689 ft^2	5,515 ft^2	18,716 ft^2
Temp-Mat™	4 ft^3	NA	NA	3.9 ft^3
Fiberglas® TIW	NA	NA	NA	NA
Calcium Silicate	63 lb.	NA	57.75 lb.	NA
Min-K™	NA	2.4 lb.	16 lb.	NA

Notes:

(1) Break locations were evaluated for hot leg, cold leg, and the cross-over leg; with the limiting values presented as Loop Large Break Loss of Coolant Accident (LBLOCA).

(2) Reactor Pressure Vessel (RPV)

(3) Safety Injection System (SIS)

The quantity of each debris type generated for the representative limiting break locations that were evaluated at BVPS-2 are summarized in Table 3.b-3. Note that the quantities provided for BVPS-2 are the quantities of debris remaining after insulation modification corrective actions are completed during the fall 2009 refueling outage (2R14).

Table 3.b-3
BVPS- 2 Insulation Debris Quantities
(With Insulation Remediation – post 2R14)

Material Types	Loop LBLOCA(1)	RPV(2) Nozzle Break	Pressurizer Surge Line Break	6 Inch SIS(3) Break(4)
RMI	35,806 ft^2	2,201.4 ft^2	2,390.4 ft^2	4,935.4 ft^2
Thermal Wrap	2. 3 ft^3	NA	NA	0.1 ft^3
Damming Material	0.1 ft^3	NA	NA	0.1 ft^3
Temp-Mat™	13.3 ft^3	NA	9.3 ft^3	5.9 ft^3
Calcium Silicate	96 lb.	NA	82.5 lb.	NA
Min-K™	0.8 lb.	NA	14.4 lb.	0.8 lb.
Microtherm®	NA	126.5 lb.	NA	NA

Notes:

(1) Break locations were evaluated for Hot Leg, Cold Leg, and the Cross-over Leg; with the limiting values presented as Loop Large Break Loss of Coolant Accident (LBLOCA).

(2) Reactor Pressure Vessel (RPV)

(3) Safety Injection System (SIS)

(4) Break is located at injection point.

The inherent design of the reactor coolant loop (piping, equipment, and equipment supports); along with the penetration of the hot / cold legs through the primary shield wall sleeves, provides limited offset displacements with the RPV nozzle breaks. Therefore, the quantity of Microtherm® generated from a nozzle break considered this limited displacement rupture configuration. A confinement-adjusted ZOI for the Microtherm® insulation was derived that also factored in a ratio of the restrained and unrestrained break ZOIs provided under Method 3, "Break Specific Analysis Using Break-Dependant Zone of Influence," of the Boiling Water Reactor Owners Group (BWROG) Utility Resolution Guide (URG). This ratio considers the applicable restrained break offset ZOI versus the unrestrained break ZOI. This ratio is factored against the 4D ZOI for the Microtherm® insulation, which provides an equivalent ZOI for a limited displacement rupture. The BWROG URG ratio-based ZOI has been derived to be 1.68D. When adjusted for confinement within the annular region between the reactor vessel and primary shield wall, the radius of the ZOI at the surface of the Microtherm® insulation on the reactor vessel was determined to be 49.35 inches.

A CAD model of the Microtherm® insulation was developed based on plant drawings. The percentage of Microtherm® affected by the 49.35 inch radius ZOI was determined for each of three regions in which the Microtherm® is installed on the reactor vessel. Using this information and the total quantity information provided by the BVPS-2 insulation walkdown report, the total volume of Microtherm® debris was determined to be 8.43 ft^3. This equates to the weight presented in Table 3.b-3 above.

Miscellaneous Solid Materials

The total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in the BVPS-1 and BVPS-2 containments were identified. Systematic walk-downs were performed and characteristic surface areas of the various metal, plastic, tape, stickers, and paper tags were identified at each level of the containment based upon application (identification tags, location tags, calibration tags). Cable tie-wraps were estimated based upon lengths of cable trays within containment and an assumption of one tie every 4 linear feet. A total surface area of each category of tag was estimated and a 30 percent uncertainty factor on total surface area was applied to address uncertainties in the walk-down initiative. The results of this evaluation indicate that BVPS-1 has approximately 540 square feet of miscellaneous materials and BVPS-2 has approximately 750 square feet of miscellaneous materials. These are bounding quantities. The uses of miscellaneous solid materials inside containment are controlled as discussed in FENOC's response to Review Area 3.i.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. FENOC responses for BVPS-1 and BVPS-2 related to debris generation are presented below. The format for the response includes the request itself, followed by the specific FENOC response.

RAI #1 (from Reference 6)

Identify the name and bounding quantity of each insulation material generated by a large-break loss-of coolant accident (LBLOCA). Include the amount of these materials transported to the containment pool. State any assumptions used to provide this response.

FENOC Response

The insulation material types and quantities of insulation debris generated by the limiting break locations, including LBLOCA, have been provided within response area 3.b, "Debris Generation / Zone of Influence (ZOI) (excluding coatings)." The amounts of insulation material transported to the containment pool for the limiting break locations have been provided within response area 3.e, "Debris Transport." Any key assumptions utilized in the analyses are discussed within the applicable response area 3.b or 3.e.

RAI #26 (from Reference 6)

Provide test methodology and data used to support a zone of influence (ZOI) of 5.0 L/D. Provide justification regarding how the test conditions simulate or correlate to actual plant conditions and will ensure representative or conservative treatment in the amounts of coatings debris generated by the interaction of coatings and a two-phase jet. Identify all instances where the testing or specimens used deviate from actual plant conditions (i.e., irradiation of actual coatings vice samples, aging differences, etc.). Provide justification regarding how these deviations are accounted for with the test demonstrating the proposed ZOI.

FENOC Response

Both BVPS-1 and BVPS-2 HELB debris generation calculations determined the amount of debris generated by the interaction of coatings and a two-phase jet using a ZOI of 5D. The NRC has provided guidance on the use of the 5D ZOI for coatings in Enclosure 2 of Reference 12. Specifically, the NRC's response to Item 3 in Reference 12 indicates that Licensees may use WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings," as the basis for using a ZOI of 4D or greater for qualified epoxy coatings, and a ZOI of 5D or greater for qualified untopcoated inorganic zinc coatings. The strainer testing for BVPS-1 and BVPS-2 was performed with consideration to the 5D ZOI for qualified coatings debris; therefore, the 5D ZOI has been selected as the basis for the strainer head loss results.

For BVPS-1 and BVPS-2, FENOC has assumed 100 percent failure of unqualified coatings, both inside and outside the ZOI. The amount of debris calculated from this was added to the amount generated for qualified coatings and the total used in the subsequent calculations and testing. In addition, FENOC assumes that unqualified coatings that are under intact insulation are not considered to fail. Unqualified coatings that are under insulation that becomes debris (that is, insulation within the ZOI) are assumed to fail.

3.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.***
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.***

3. ***Provide assumed specific surface areas for fibrous and particulate debris.***
4. ***Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance.***

FENOC Response

The debris sources for BVPS-1 and BVPS-2 include insulation, coatings, and latent debris. The insulation debris includes fibrous materials (Temp-Mat™, NUKON®, Knauf Fiberglass, Fiberglas® TIW, Transco Thermal Wrap), stainless steel reflective metallic insulation (RMI), and other materials (calcium silicate, Microtherm®, and Min-K™). Also categorized under the insulation debris is the penetration damming material (Kaowool and Cerawool). The characteristics of the insulation debris materials are discussed in this section and the characteristics of the other debris types (e.g., coatings and latent) are included elsewhere.

Debris Size Distribution

High Density Fiberglass (HDFG)

Proprietary analysis developed by Alion Science & Technology Corporation (Alion) for low density fiberglass (LDFG) and high density fiberglass (HDFG) insulating materials demonstrates that the fraction of fines and small pieces decreases with increasing distance from the break jet, and the fraction of large pieces and intact blankets increases with increasing distance. The results of this analysis support use of a four size distribution for Temp-Mat™. The table below (Table 3.c-1) provides the four size debris distribution values for Temp-Mat™ implemented for both BVPS-1 and BVPS-2.

Table 3.c-1
TEMP-MAT™ (HDFG) Four Size Debris Distribution

SIZE	45.0 psi ZOI (3.7 L/D)	10.2 to 45.0 psi ZOI (11.7 to 3.7 L/D)
Fines (Individual Fibers)	20%	7%
Small Pieces (Less than 6 inches on a side)	80%	27%
Large Exposed (Uncovered) Pieces	0%	32%
Intact (Covered) Blankets	0%	34%

psi Pounds per square inch
ZOI Zone of influence
L Distance from break to target
D Diameter of broken pipe

HDFG debris has a different macroscopic density than the original material. HDFG fines and small piece debris have been shown to be very similar to LDFG debris. The HDFG debris loses its felt type characteristics when it breaks down into individual fibers or clumps of fibers (see NUREG/CR-6224, size classes 1 through 4). As such, use of the HDFG as-manufactured density underestimates the volume of debris generated since the density of HDFG fines and small pieces is significantly less than the density of the original felted material.

The volume of transportable HDFG debris is estimated by multiplying the volume of HDFG fines and small pieces generated within the ZOI by the ratio of HDFG as-manufactured density to LDFG as-manufactured density. The properties of NUKON® are commonly used as representative of LDFG. The volume of Temp-Mat™ debris categorized as either fines or small pieces, therefore, are estimated as the nominal volume of Temp-Mat™ multiplied by the as-manufactured density ratio of Temp-Mat™ to NUKON®.

Low Density Fiberglass (LDFG)

A size distribution of 100 percent small fines for LDFG at BVPS-1 was taken from Table 3-3 of the SE (Reference 17).

The previously mentioned proprietary analysis also supports use of a four size distribution of NUKON®, Knauf Fiberglass and, by similitude, Fiberglas® TIW and Thermal Wrap at BVPS-2, for utilization in a debris transport analysis. The table below (Table 3.c-2) provides the four size debris distribution values for these materials.

Table 3.c-2
LDFG Four Size Debris Distribution (BVPS-2)

SIZE	18.6 psi ZOI (7.0 L/D)	10.0 to 18.6 psi ZOI (11.9 to 7.0 L/D)	6.0 to 10.0 psi ZOI (17.0 to 11.9 L/D)
Fines (Individual Fibers)	20%	13%	8%
Small Pieces (Less than 6 inches on a side)	80%	54%	7%
Large Pieces (Greater than 6 inches on a side)	0%	16%	41%
Intact (covered) Blankets	0%	17%	44%

psi Pounds per square inch — L Distance from break to target

ZOI Zone of influence — D Diameter of broken pipe

RMI

Debris size distribution for RMI is based upon the 1995 NRC testing intended to generate representative RMI debris for application in US plants and documented within NUREG/CR-6808, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," LA-UR-03-0880, 2003. The table below (Table 3.c-3) provides a summary of the size distribution of the RMI debris generated for both BVPS-1 and BVPS-2. Pieces smaller than 4 inches were treated as small piece debris, and the pieces that were 4 inches and 6 inches were treated as large pieces for purposes of the debris transport analysis.

Table 3.c-3
RMI Debris Size Distribution

DEBRIS SIZE (in.)	PERCENTAGE OF TOTAL RECOVERED
¼	4.3%
½	20.2%
1	20.9%
2	25.6%
4	16.8%
6	12.2%

Calcium Silicate (Cal-Sil)

Although Volumes 1 and 2 of NEI 04-07 recommend the assumption that 100 percent of Cal-Sil insulation within a 5.45D ZOI is destroyed as particulate, the amount of insulation debris generated in the Ontario Power Generation (OPG) tests ranged from 21 to 47 percent (that is, destruction, in all cases, was less than 50 percent of the target material). Based upon the results of the NRC-sponsored OPG tests, a reduction factor of 50 percent was applied to debris generated within a 5.45D ZOI.

Cal-Sil insulation installed in the containments of the BVPS plants (Thermo-12/Blue) was manufactured in the same manufacturing plants using the same manufacturing processes as the Cal-Sil (Thermo-12/Gold) used in the destructive jet destruction testing conducted by Ontario Power Generation. Other than pigment, the only difference between the two types of insulation is a corrosion inhibitor treatment applied to the inner surface of the Thermo-12/Gold insulation to reduce piping corrosion. Since this treatment is only on the inner surface of the Cal-Sil, it would have no effect on the Cal-Sil's resistance to erosion or jet impingement. With regard to resistance to erosion or jet impingement, the Cal-Sil present in the BVPS containments is equivalent to the Cal-Sil used in the jet destruction testing conducted by Ontario Power Generation.

Remaining debris types

The following table (Table 3.c-4) summarizes the potential insulation and coatings debris sources in the BVPS-1 and BVPS-2 containments, other than those previously addressed above. The following debris size distributions are taken from Table 3-3 of the SE (Reference 17).

Table 3.c-4
Debris Size Distributions

Material	Percentage Small Fines	Percentage Large Pieces
Within the ZOI		
Encapsulated Min-K™	100	0
Microtherm® (BVPS-2)	100	0
Benelex® (BVPS-1)	100	0
Foamglas® (BVPS-1)	100	0
Coatings	100	0
Outside the ZOI		
Qualified Coatings	0	0
Unqualified Coatings (Exposed)	100	0
Unqualified Coatings (Protected by Insulation)	0	0

Debris Characteristics

The following tables (Table 3.c-5 and 3.c-6) provide a summary of the as-fabricated densities, microscopic densities, and dimensions for applicable debris types at both BVPS-1 and BVPS-2. Characteristics associated with coatings and latent debris are discussed in other areas of this response but are also included here for convenience.

Table 3.c-5
Fibrous Material Characteristics

Debris Material	As-Fabricated Density (lb/ft^3)	Microscopic Density (lb/ft^3)	Characteristic Diameter (μm)
Temp-Mat™	11.8 (1)	162	9.0
NUKON®f	2.4	175	7
Thermal Wrap	2.4	175	7
Fiberglass	3.3	159	7
Fiberglas® TIW	2.4	159	7
Latent Fiber	2.4	94	7
Kaowool	12	161	3.2
Cerawool	12	158	3.2

Note:

(1) The Temp-Mat™ as fabricated density is 11.8 lb/ft^3. As discussed, the transportable fines and small pieces of Temp-Mat™ debris are treated as LDFG with a density of 2.4 lb/ft^3.

Table 3.c-6
Particulate Debris Characteristics

Debris Material	As-Fabricated Density (lb/ft^3)	Microscopic Density (lb/ft^3)	Characteristic Diameter (μm)
Cal-Sil	15	144	2.1
Microtherm®	15	187	2.5
Min-K™	16	162	2.5
Latent Particulate (dirt/dust)	N/A	169	17.3
Carboline Carbozinc® 11 IOZ	N/A	220	10
Carboline 191 HB Epoxy	N/A	103.6	10
Nutec 11S Epoxy	N/A	144.2	10
Nutec 1201 Epoxy	N/A	120.5	10
Unspecified Epoxy Coatings	N/A	103.6	10
Galvanox Cold Galvanizing	N/A	390	10
Cold Galvanizing	N/A	442	10
Alkyd	N/A	98	10
Foamglas®	7.5	156	10
Benelex®	86.9	86.9	10
Dupont Corlar 823 Epoxy	N/A	90	10
High Temp. Aluminum	N/A	90	10
Vi-Cryl CP-10	N/A	55	10
Unspecified IOZ Primer	N/A	220	10
Carboline 4674	N/A	109.4	10

Specific Surface Areas for Debris (S_v)

The specific surface area (S_v) was only used for preliminary analytically determined head loss values across a debris laden sump screen using the correlation given in NUREG/CR-6224. Since the head loss across the installed sump screen is determined via testing, these values are not used in the design basis for BVPS-1 and BVPS-2. Therefore, these values are not provided as part of this response.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. A response is presented below pertaining to debris characteristics at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed by the specific response.

RAI #30 (from Reference 6)

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

FENOC Response

In the staff evaluation of Section 3.4.3.6 of the SE states, "For plants that substantiate a thin bed, use of the basic material constituent (10 micron sphere) to size coating debris is acceptable. For those plants that can substantiate no formation of a thin bed that can collect particulate debris, the staff finds that coating debris should be based on plant-specific analyses for debris..., or that a default area equivalent to the area of the sump screen openings should be used."

FENOC interprets this to mean that for those HELB scenarios where there is not adequate fibrous debris generated to form a uniform thin bed (that is, particulate material would pass freely through the screen openings, generating little or no head loss), then in the absence of plant-specific analysis, modeling should assume a chip size that could potentially block the screen openings to ensure that the chips could not block enough of the screen area to cause a significant head loss to develop. For those scenarios where the fibrous debris quantity is adequate to form a filtering bed, the use of 10 micron spheres is conservative because the 10 micron spheres are more transportable and will produce higher head loss in a fiber bed than an equivalent quantity of chips.

The retesting for BVPS-1 included a series of tests, stepping through a reduction of Temp-Mat^{TM} and Cal-Sil insulation, until acceptable head loss results were achieved. The final retesting results for BVPS-2 also represent reductions in Temp-Mat^{TM} and Cal-Sil to achieve acceptable head loss results. The tests for BVPS-1 and BVPS-2, which represent the final configuration after targeted removal of the Cal-Sil, Temp-Mat^{TM} and Fiberglas$^{®}$ - TIW, included an amount of fibrous debris which was less than the quantity considered necessary to form a thin bed. For qualified coatings inside the ZOI, the test was performed using representative 10 micron spheres as the particulate size. For unqualified coatings outside the ZOI, the test was performed using both representative 10 micron spheres as the particulate size, and 1/8-inch or 1/4-inch paint chips (ensuring that they would not pass through the 1/16-inch [BVPS-1] or the 3/32-inch [BVPS-2] perforations in the strainer) as the particulate size. This approach is considered conservative in that the quantity of unqualified coatings introduced in the test was doubled.

3.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 quantity and composition of latent debris.***
2. ***Provide the basis for assumptions used in the evaluation.***
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.***
4. ***Provide amount of sacrificial strainer surface area allotted to miscellaneous latent debris.***

FENOC Response

Latent debris has been evaluated via containment condition assessments. Containment walkdowns were completed for BVPS-1 during the fall 2004 refueling outage (1R16). A supplementary walkdown was performed for BVPS-1 in the spring 2006 refueling outage (1R17) to assess containment conditions with consideration of the guidelines in the NRC SE for NEI 04-07 (Reference 17). Containment walkdowns for BVPS-2 were completed during the spring 2005, 2R11 outage. The walkdowns were performed using guidance provided in NEI 02-01, "Condition Assessment Guidelines, Debris Sources Inside Containment," Revision 1, dated September 2002. The quantity and composition of the latent debris was evaluated by extensive sampling for latent debris considering guidance in the SE (Reference 17).

The latent debris sources include NEI 02-01 "Foreign Materials" and other fibrous debris sources that were not system-specific, or appeared in small quantities. The following NEI 02-01 categories were considered:

- Dirt, dust, and lint
- Tape and equipment labels
- Construction and maintenance debris
- Temporary equipment

Dirt, Dust, and Lint

The following activities suggested by NEI guidance were performed to quantify the amount of latent debris inside containment.

- Calculate the surface areas inside containment
- Evaluate the resident debris buildup (determine density)
- Calculate the total quantity and composition of debris

Contributors to the debris include failed paint coatings, dust and normal debris due to personnel, construction and maintenance activities. Samples were taken to determine the latent debris mass distribution per unit area, referred to as latent debris density (for example, lbm/1000 ft^2) of representative surfaces throughout containment including walls, equipment, floors and grating. Forty-five (45) samples were taken for BVPS-1 and forty-two (42) samples were taken for BVPS-2. Prior to collection of samples, the containment was evaluated to locate desirable sample locations.

The latent debris density was estimated by weighing sample bags before and after sampling, dividing the net weight increase by the sampled surface area, adjusting the result based on an estimated sample efficiency, and converting the result to a density.

The total mass of dirt, dust, and debris was calculated using the estimated surface areas and the average sample density (except for the cable trays which were assigned the maximum density from the equipment area samples due to safety concerns associated with contacting potentially energized wiring). The following tables (Tables 3.d-1 and 3.d-2) summarize the surface areas sampled at BVPS-1 and BVPS-2.

BVPS-1

Table 3.d-1

BVPS-1	Surface Area Sampled (ft^2)				
Elevation	Horizontal Surface Equipment	Wall	Vertical Surface Equipment	Floor	Grating
692' - 11"	2.63	3.83	2.97	7.32	N/A
718' - 6"	3.96	4.00	2.00	3.72	0.66
738' - 10"	5.44	5.60	2.33	1.50	0.66
767' - 10"	3.91	5.44	3.25	6.22	0.66

BVPS-2

Table 3.d-2

BVPS-2	Surface Area Sampled (ft^2)			
Elevation	Horizontal Surface Equipment	Vertical Wall Surface	Floor	Grating
692' - 11"	6.18	29.41	17.91	N/A
718' - 6" & 738' - 10"	7.38	7.57	17.80	0.30
767' - 10"	7.40	33.44	15.32	0.15

In lieu of analysis of samples, conservative values for debris composition properties were assumed as recommended by the SE (Reference 17). This results in a very conservative estimate of fiber content. The particulate / fiber mix of the latent debris is assumed to be 15 percent fiber. The latent fiber debris is assumed to have a mean density of 94 lb/ft^3 and the latent particulate debris a microscopic density of 169 lb/ft^3. The latent particulate size is assumed to have a specific surface area of 106,000 ft^{-1}.

Tape and Equipment Labels

Foreign materials such as tape, stickers, paper/plastic tags, signs and placards were included in the scope of the containment walkdown. These were tabulated using walkdown data and photographs. A standard size was chosen for each basic type of foreign material based on the average size of each item. If a material appeared to be larger than this size, it was counted as two or more, as appropriate, to match the standard area size. This approach allowed for a conservative accounting of the surface area for each item. Additional discussion on Tape and Equipment labels has been provided, as requested, in response area 3b, Debris Generation / Zone of Influence (ZOI) (excluding coatings). An assessment was also made of the number of plastic tie-wraps throughout containment.

BVPS-1

The number of miscellaneous tags counted during the detailed containment walkdown of the basement annulus was used as the value for the miscellaneous tag counts in each of the intermediate annulus elevations. However, cable tray and conduit labels, as well as junction box and terminal box tags, were counted for the annulus on the intermediate elevations using plant drawings. It was assumed that each cable tray has two labels and each conduit has two labels. One label was attributed to each junction box and terminal box. This method was used for these items since they are sometimes located in areas (such as the overhead) that are difficult to access and see during a walkdown. To determine the amount of tape debris in the annulus, the total amount of tape counted in the basement was multiplied by the ratio of the annulus floor area to the total basement floor area. The 'B' loop compartment was counted in detail and the subsequent data was used for the 'A' and 'C' loop compartments, as well as the incore instrumentation area and the pressurizer room (including pressurizer relief tank room). All three loop compartments are similar enough in size and arrangement that any small discrepancies would be within the uncertainty of the final results. This practice is in accordance with NEI guidance. For increased conservatism, it was assumed that the count did not capture every item. Thus, a 30 percent increase is judged to be appropriate for the final square footage.

BVPS-2

A count for each compartment was carried out during the containment walkdown. The three loop compartments were reviewed and the largest count was multiplied by three. All three loop compartments are similar in size and arrangement such that any small discrepancies would be within the uncertainty of the final results. For increased conservatism, it is assumed that the count did not capture every item. Thus a 30 percent increase was judged to be appropriate for the final square footage.

The basis for assumptions used in the evaluation is provided below.

BVPS-1 & BVPS-2

1. Cable trays were observed to have slightly higher concentrations of dirt and dust compared to floor surfaces but consisted mostly of lint. However, due to the safety concerns associated with contacting potentially energized wiring, no cable trays were sampled. Therefore, for conservatism, the cable tray area will be assigned the maximum density from the equipment area samples. The reason for this derives from the observation that equipment tops that were easily accessible tended to be relatively clean, while equipment tops that were generally inaccessible tended to be much dirtier. Since cable trays tend to be inaccessible, they can reasonably be equated to the dirtier equipment samples taken.

2. For increased conservatism, the walkdown to count tape and equipment labels was not assumed to capture every item. Thus, a 30 percent increase is judged to be appropriate for the final square footage.

3. The characterization of latent debris typical of a pressurized-water-reactor nuclear power plant has been defined in a study initiated by the NRC and conducted through Los Alamos National Laboratory and the University of New Mexico. The NRC's recommendation (Reference 17) is to assume that 15 percent of transportable latent debris is fiber and that 85 percent is particulate. BVPS adopted this guidance.

4. The post containment closeout inspection verifies that all debris and unauthorized, non-permanent mounted equipment or material has been removed from containment.

5. There was no temporary equipment identified that would lead to a debris source.

Construction and Maintenance Debris

No construction or maintenance debris is allowed to remain in containment during operation. The post-outage containment close-out inspection described in section 3.i.1 insures that construction and maintenance debris is removed from containment prior to start-up.

Temporary Equipment

No temporary equipment was included in the sump debris loading because procedure controls are in place to verify that only authorized nonpermanent mounted equipment and materials are left in containment and only when restrained and located as evaluated.

The results of the latent debris evaluation are provided below in Tables 3.d-3 and 3.d-4, including amount of latent debris types and physical data for latent debris as requested for other debris.

For strainer head loss testing, 200 pounds of dirt was conservatively used at both units.

BVPS-1

Amount of Tape and Equipment Labels: 543 square feet (with 30 percent increase)

Table 3.d-3
Amount of Dirt, Dust, and Lint – BVPS-1

Description	Area (ft^2)	Area Density ($lb/1000\ ft^2$) (Average)	Dirt, Dust and Lint (lb)
Horizontal Concrete Floor	23,426	1.49	35.0
Grating	17,404	0.40	6.9
Vertical Surfaces (Equip & Walls)	206,211	0.12	24.6
Cable Tray	9,555	6.09 *	58.2
Equipment Horizontal	18,460	1.83	33.9
		Total	**158.6**

* The cable tray area density is based on the maximum area density identified in the containment walkdown for equipment horizontal surfaces.

BVPS-2

Amount of Tape and Equipment Labels: 750 square feet (with 30 percent increase)

Table 3.d-4
Amount of Dirt, Dust, and Lint – BVPS-2

Description	Area (ft^2)	Area Density ($lb/1000\ ft^2$) (Average)	Dirt, Dust and Lint (lb)
Horizontal Concrete Floor	23,173	0.63	15
Grating	15,196	4.38	67
Vertical Wall Surfaces	173,893	0.43	75
Cable Tray	6,678	2.19(1)	15
Equipment Horizontal	15,141	0.76	12
		Total	**184**

Note:

(1) The cable tray area density is based on the maximum area density identified in the containment walkdown for equipment horizontal surfaces.

The amount of sacrificial surface strainer area allotted to miscellaneous latent debris is provided below.

The debris transport fraction for miscellaneous debris (tape, tags, and labels) is assumed to be 100 percent. Miscellaneous debris is modeled as a reduction in effective screen area. The effective area of the screen was reduced by an area equivalent to 75 percent of the total of the surface area of the miscellaneous debris source term, consistent with the guidance provided in the NRC SE (Reference 17). This was accomplished by using a 75 percent debris transport fraction to imitate the stacking fraction.

BVPS-1

The sacrificial strainer surface area allotted to miscellaneous debris is 407 square feet. This value represents 75 percent of the total 543 square feet accounted for in the containment walkdown.

BVPS-2

The sacrificial strainer surface area allotted to miscellaneous debris is 563 square feet. This value represents 75 percent of the total 750 square feet accounted for in the containment walkdown.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. Responses are presented below pertaining to latent debris at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed by the specific response.

RAI #32 (from Reference 6)

Your submittal indicated that you had taken samples for latent debris in your containment, but did not provide any details regarding the number, type, and location of samples. Please provide these details.

FENOC Response

The requested information in this RAI has been included within the response to Review Area 3.d, Latent Debris.

RAI #33 (from Reference 6)

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

FENOC Response

The requested information in this RAI has been included within the response to Review Area 3.d, Latent Debris.

3.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 the blowdown, washdown, pool-fill-up, and recirculation phases of an accident.***
2. ***Provide the technical basis for assumptions and methods used in the analysis that deviate from the approved guidance.***
3. ***Identify any computational fluid dynamics codes used to compute debris transport fractions during recirculation and summarize the methodology, modeling assumptions, and results.***
4. ***Provide a summary of, and supporting basis for, any credit taken for debris interceptors.***
5. ***State whether fine debris was assumed to settle and provide basis for any settling credited.***
6. ***Provide the calculated debris transport fractions and the total quantities of each type of debris transported to the strainers.***

FENOC Response

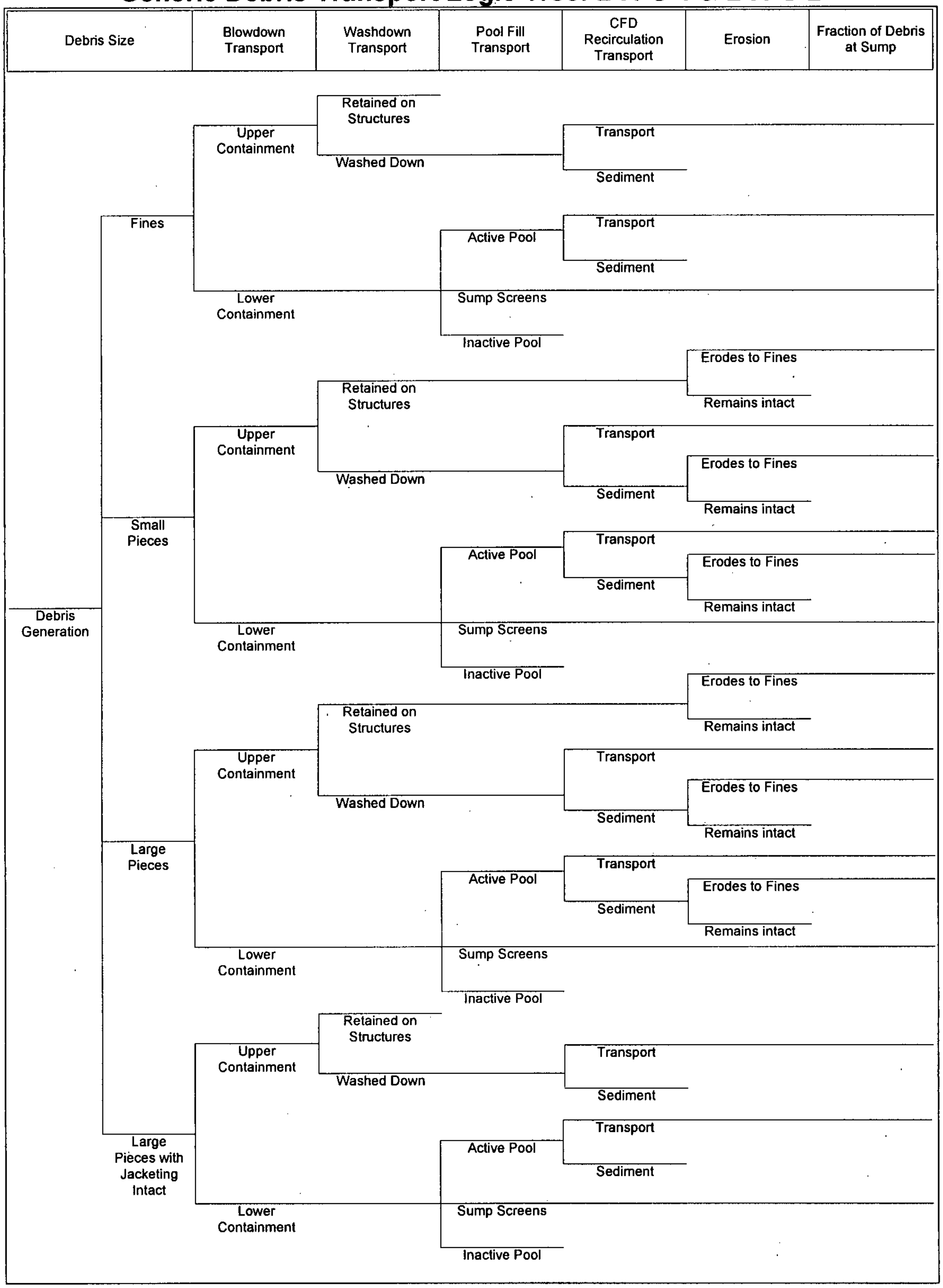
Description of Methodology

The methodology used in the transport analysis is based on the NEI 04-07 guidance report (GR) for refined analyses as modified by the NRC's SE (Reference 17), as well as the refined methodologies suggested by the SE in Appendices III, IV, and VI. The specific effect of each of four modes of transport was analyzed 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 and break flow.
- *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 then applied for each type of debris determined from the debris generation calculation. The logic tree shown in the following figure (Figure 3.e-1) is somewhat different than the baseline logic tree provided in the GR. This departure was made to account for certain non-conservative assumptions identified by the SE (Reference 17) 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. Also, the generic logic tree was expanded to account for a more refined debris size distribution. Some branches of the logic tree were not required for certain debris types. Also, for BVPS-1 and BVPS-2, the logic trees for containment were separated into three (3) compartments; upper, lower and steam generator compartments.

Figure 3.e-1
Generic Debris Transport Logic Tree: BVPS-1 & BVPS-2



The basic methodology used for the BVPS-1 and BVPS-2 transport analyses is shown below:

1. Based on containment building drawings, a three-dimensional model was built using computer aided drafting (CAD) software.
2. A review was made of the drawings and CAD model along with a containment flow path walkdown to determine transport flow paths. Potential upstream blockage points including screens, fences, grating, drains, etc., that could lead to water holdup were addressed.
3. Debris types and size distributions were gathered from the debris generation calculation for each postulated break location.
4. The fraction of debris blown into upper containment was determined based on the relative volumes of upper and lower containment.
5. The quantity of debris washed down by spray flow was conservatively determined based on relevant test data.
6. The quantity of debris transported to inactive areas was determined to be negligible.
7. Using conservative assumptions, the locations of each type/size of debris at the beginning of recirculation was determined.
8. A Computational Fluid Dynamic (CFD) model was developed to simulate the flow patterns that would occur during recirculation.
9. A graphical determination of the BVPS-1 recirculation transport fraction for 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. The recirculation transport fractions for BVPS-2 were assumed to be 100 percent.
10. The recirculation transport fractions from the CFD analysis (for BVPS-1) were gathered to input into the logic trees. Although the CFD analysis was developed for BVPS-1, the results conservatively show 100 percent transport of all fibrous and particulate debris to the sump screen.
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 of debris was determined by combining each of the previous steps in logic trees.

BLOWDOWN TRANSPORT

The fraction of blowdown flow to various regions was estimated using the relative volumes of containment. Fine debris can be easily suspended and carried by the blowdown flow. Small and large piece debris can also be easily carried by the high velocity blowdown flow in the vicinity of the break. However, in areas farther away from the break that are not directly affected by the blowdown, this debris would likely fall to the floor.

The volumes for the upper containment (including the refueling canal and areas above the operating deck) and for lower containment (including the steam generator and pump enclosures, the reactor cavity, the volume inside the crane wall, and all volume between the crane wall and the outer containment wall below the operating deck) were determined from the CAD model. Because the debris was assumed to be carried with the blowdown flow, the flow split is then proportional to the containment volumes. This resulted in a transport fraction for the fine debris to upper containment of 61 percent.

The drywell debris transport study (DDTS) testing provides debris holdup values for blowdown occurring in wetted and highly congested areas. Values associated with grating being present in the blowdown flow path were utilized in the BVPS-2 blowdown analysis. The DDTS also presents values for holdup when blowdown travels a flow path with 90 degree turn(s). Although 90 degree turns might not have to be negotiated by debris blown to upper containment at BVPS-2, significant bends would have to be made. Therefore, it was estimated that 5 percent (versus the 17 percent value in the study) of the small fiberglass debris blown upward would be trapped due to changes in flow direction. The BVPS-1 blowdown transport analysis did not utilize any holdup values associated with this DDTS. Although the BVPS-2 transport analysis did account for small fibrous debris holdup, the strainer testing was conservatively performed assuming full transport. The downstream effects review also conservatively considered full transport.

Additional guidance was incorporated into the analysis through use of the Boiling Water Reactor (BWR) Utility Resolution Guide (URG). The guidance from this document indicates that grating would trap approximately 65 percent of the small RMI debris blown toward it.

The following tables (Tables 3.e-1a, 3.e-1b and 3.e-2) show the transport fractions for each type/size of debris to upper containment, steam generator compartment and containment pool due to the blowdown forces for the LBLOCA breaks inside the bioshield wall. Note that debris outside the ZOI (including latent dirt/dust and fibers) is not affected by the blowdown, and therefore the transport fraction for this debris would be 0 percent.

Table 3.e-1a
Blowdown Transport Fractions of Debris to Upper Containment (BVPS-1/BVPS-2)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
RMI	NA	14% / 13%	14% / 0%	NA
Thermal Wrap™	NA / 61%	NA / 33%	NA	NA
Temp-Mat™	0% / 61%	0% / 33%	0% / NA	0% / NA
Cal-Sil	61% / 61%	NA	NA	NA
Min-K™	61% / NA	NA	NA	NA
Qualified Coatings (Inside ZOI)	61% / 61%	NA	NA	NA
Unqualified Coatings (Outside ZOI)	0% / 0%	NA	NA	NA
Dirt/Dust	0% / 0%	NA	NA	NA
Latent Fiber	0% / 0%	NA	NA	NA

Table 3.e-1b
Blowdown Transport Fractions of Debris to Steam Generator Compartment (BVPS-1/BVPS-2)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
RMI	NA	72% /48%	86% / 61%	NA
Thermal Wrap™	NA /0%	NA / 34%	NA	NA
Temp-Mat™	0% / 0%	0% /34%	0% / NA	0% / NA
Cal-Sil	0% / 0%	NA	NA	NA
Min-K™	0% / NA	NA	NA	NA
Qualified Coatings (Inside ZOI)	0% / 0%	NA	NA	NA
Unqualified Coatings (Outside ZOI)	0% / 0%	NA	NA	NA
Dirt/Dust	0% / 0%	NA	NA	NA
Latent Fiber	0% / 0%	NA	NA	NA

Table 3.e-2
Blowdown Transport Fractions of Debris to Containment Pool (BVPS-1/BVPS-2)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
RMI	NA	14% / 39%	0% / 39%	NA
Thermal Wrap™	NA / 39%	NA / 33%	NA	NA
Temp-Mat™	100% / 39%	100% / 33%	100% / NA	100% / NA
Cal-Sil	39% / 39%	NA	NA	NA
Min-K™	39% / NA	NA	NA	NA
Qualified Coatings (Inside ZOI)	39% / 39%	NA	NA	NA
Unqualified Coatings (Outside ZOI)	0% / 0%	NA	NA	NA
Dirt/Dust	0% / 0%	NA	NA	NA
Latent Fiber	0% / 0%	NA	NA	NA

WASHDOWN TRANSPORT

During the washdown phase, debris in upper containment could be washed down by the containment sprays. With the exception of small piece fibrous debris in BVPS-2, all debris blown to upper containment was conservatively assumed for both BVPS-1 and BVPS-2 to be washed back down into lower containment.

The debris blown to upper containment was assumed to be scattered around, and a reasonable approximation of the washdown locations was made based on the spray flow split in upper containment. This resulted in the following washdown split for both BVPS-1 and BVPS-2 of 89 percent to the pool inside the secondary shield wall (further broken down to identify percentages to areas such as the steam generator and pressurizer compartments as well as the reactor cavity and other openings), and the remaining 11 percent of the sprays were estimated to flow into the annulus.

Multiple levels of grating are present in the BVPS-1 and BVPS-2 Containments. The results of the DDTS testing showed that approximately 40 to 50 percent of small fiberglass debris landing on grating would be washed through the grating due to spray flows. (Note that the spray flow at BVPS-2 is on the lower end of the 1 to 12 gpm/ft^2 spray flow used in the testing.) Holdup of small pieces of fibrous debris was credited at each level of grating that washdown flow passed through for BVPS-2. Although the BVPS-2 transport analysis did account for small fibrous debris holdup, the strainer testing was conservatively performed assuming full transport. The downstream effects review also conservatively considered full transport.

Credit was taken for holdup of small pieces of RMI on grating based on the BWR URG which indicates that the retention of small RMI debris on grating is approximately 29 percent.

The following tables (Table 3.e-3 and 3.e-4) provide the washdown transport fractions from the upper containment into the annulus and inside the secondary shield wall for BVPS-1 and BVPS-2.

Table 3.e-3
Washdown Transport Fractions of Debris in the Annulus (BVPS-1 / BVPS-2)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
RMI	NA	4% / 4%	NA	NA
Thermal Wrap™	NA / 11%	NA / 1%	NA	NA
Temp-Mat™	NA / 11%	NA / 1%	NA	NA
Cal-Sil	11% / 11%	NA	NA	NA
Min-K™	11% / NA	NA	NA	NA
Qualified Coatings (Inside ZOI)	11% / 11%	NA	NA	NA
Unqualified Coatings (Outside ZOI)	0% / 0%	NA	NA	NA
Dirt/Dust	0% / 0%	NA	NA	NA
Latent Fiber	0% / 0%	NA	NA	NA

Table 3.e-4
Washdown Transport Fractions of Debris to Inside the Secondary Shield Wall (BVPS-1 / BVPS-2)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
RMI	NA	63% / 60%	20% / NA	NA
Thermal Wrap™	NA / 89%	NA / 43%	NA	NA
Temp-Mat™	NA / 89%	NA / 43%	NA	NA
Cal-Sil	89% / 89%	NA	NA	NA
Min-K™	89% / NA	NA	NA	NA
Qualified Coatings (Inside ZOI)	89% / 89%	NA	NA	NA
Unqualified Coatings (Outside ZOI)	0% / 0%	NA	NA	NA
Dirt/Dust	0% / 0%	NA	NA	NA
Latent Fiber	0% / 0%	NA	NA	NA

The following table (Table 3.e-5) provides the washdown transport fraction of debris from the steam generator compartment for BVPS-1 and BVPS-2.

Table 3.e-5
Washdown Transport Fractions of Debris from Steam Generator Compartment (BVPS-1 / BVPS-2)

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
RMI	NA	71% / 100%	0% / 100%	NA
Thermal Wrap™	NA / 100%	NA / 100%	NA	NA
Temp-Mat™	NA / 100%	NA / 100%	NA	NA
Cal-Sil	100% / 100%	NA	NA	NA
Min-K™	100% / NA	NA	NA	NA
Qualified Coatings (Inside ZOI)	100% / 100%	NA	NA	NA
Unqualified Coatings (Outside ZOI)	0% / 0%	NA	NA	NA
Dirt/Dust	0% / 0%	NA	NA	NA
Latent Fiber	0% / 0%	NA	NA	NA

POOL FILL-UP TRANSPORT

For BVPS-1, the new sump strainer is approximately 2 inches above the floor and does not have a sump pit. Because the volume of the strainer plenum and sump trench is relatively small, it would be filled with water almost immediately. Therefore, preferential flow to the strainer during pool fill-up would be very short, and would result in negligible debris transport.

For BVPS-2, the new sump strainer is at least 1 foot above the depressed floor section, and no large pieces of debris were determined to collect on the strainer during pool fill. The normal sump and trench around the primary shield wall and leading to the normal sump are the only inactive volumes in the containment floor. Since this volume is small, it was conservatively neglected as holdup volume for debris. Therefore, all of the debris is assumed to be in the active portion of the recirculation pool.

RECIRCULATION TRANSPORT USING CFD

The use of CFD to determine the debris transport fractions in the recirculation pool was applied to BVPS-1 only, as the recirculation pool transport fractions for BVPS-2 were conservatively assumed to be 100 percent. Therefore, the following discussion applies to BVPS-1. Although the CFD analysis was applied for BVPS-1, the results conservatively assume 100 percent transport of all fibrous and particulate debris to the sump screen.

The recirculation pool debris transport fractions were determined through CFD modeling. To accomplish this, a three-dimensional CAD model was imported into the CFD model, flows into and out of the pool were defined, and the CFD simulation was run until steady-state conditions were reached. The result of the CFD analysis is a three-dimensional model showing the turbulence and fluid velocities within the pool. By comparing the direction of pool flow, the magnitude of the turbulence and velocity, the initial location of debris, and the specific debris transport metrics (that is, the minimum velocity or turbulence required to transport a particular type/size of debris), the recirculation transport of each type/size of debris to the sump screens was determined.

Flow-3D® Version 9.0 developed by Flow Sciences, Incorporated was used for the CFD modeling. 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 prohibitively long to run. A 6-inch cell length was chosen as the largest cell size that could reasonably resolve the concrete structures that compose the containment floor. 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. To further define specific objects, node planes were placed at the edges of key structures including the top of the sump curb, and the edges of the break and spray mass source obstacles.

Modeling of Containment Spray Flows:

From consideration of various plan and section drawings, as well as the containment building CAD model, it was judged that spray water would drain to the pool through numerous pathways. Some of these pathways included; through the steam generator compartments via the open area above the steam generators, through the reactor head storage grating directly to the pool, and through other grating and a stairwell. The sprays were introduced near the surface of the pool.

Assuming that spray flow is uniform across containment, the fraction of spray landing on any given area was calculated using the ratio of that area to the overall area. Also, for sprays landing on a solid surface, such as the operating deck, the runoff flow split to different regions, such as the annulus, was approximated using the ratios of open perimeters where water could drain off.

Modeling of Break Flow:

Breaks were modeled at the break location which was not directly above the recirculation pool and consideration of the additional free fall energy was not necessary. The break flow falls onto the floor at the associated elevation and then drains through various paths to the recirculation pool. This break flow was combined with the spray flow and introduced to each region where flow occurs near the surface of the pool.

Containment Sump:

The containment sump consists of a single sump cavity. The mass sink used to pull flow from the CFD model was defined within the sump. A negative flow rate was set for the sump mass sink, which tells the CFD model to draw the specified amount of water from the pool over the entire exposed surface area of the mass sink obstacle.

Turbulence Modeling:

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

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

The RNG turbulence model was judged to be the most appropriate for this CFD analysis due to the 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 turbulent kinetic energy 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 with the pool depth at the level present when recirculation begins, and run to simulate a total of five minutes real time. To ensure that the CFD model achieved steady state conditions before the end of the CFD runs, a plot of mean kinetic energy was used. 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:

Metrics for predicting debris transport have been adopted or derived from data. The specific metrics are the turbulent kinetic energy (TKE) necessary to keep debris suspended, and the flow velocity necessary to tumble sunken debris along a floor. The metrics utilized in the BVPS-1 and BVPS-2 transport analyses originate from either:

1) NUREG/CR-6772 Tables 3.1, 3.2 and 3.5;
2) NUREG/CR-6808 Figure 5-2, Table 3.2;
3) NUREG/CR-2982 Section 3.2; or
4) Calculated using Stokes' Law using saturated water properties at 215°F.

Graphical Determination of Debris Transport Fractions

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.

- Colored contour velocity and TKE maps indicating regions of the pool through which a particular type of debris could be expected to transport were generated from the Flow-3D® results in the form of bitmap files.
- The bitmap files 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.
- For the uniformly distributed debris, closed polylines were drawn around the contiguous areas where velocity or TKE was high enough that debris could be carried in suspension or tumbled along the floor to the sump screens.

- The areas within the closed polylines were determined utilizing an AutoCAD® querying feature.
- The combined area within the polylines was compared to the debris distribution area.
- The percentage of a particular debris type that would transport to the sump screens was estimated 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. Regions where the debris would be suspended were specifically identified in the plots as well as regions where the debris would be tumbled along the floor. Color coding TKE portions of the plots is a three-dimensional representation of the TKE. 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 screens or transported to quieter regions of the pool where it could settle to the floor.

It was also necessary to determine the distribution of debris prior to the event as well as prior to the beginning of recirculation. Since the various types and sizes of debris transport differently during the blowdown, washdown, and pool fill-up phases, the initial distribution of this debris at the start of recirculation can vary widely. Insulation debris on the pool floor would be scattered around by the break flow as the pool fills, and debris in upper containment would be washed down at various locations by the spray flow. It was assumed that the debris washed down by containment sprays would remain in the general vicinity of the washdown locations until recirculation starts. Other key considerations for the debris types include:

- Latent debris in containment (dirt/dust and fibers) was assumed to be uniformly distributed on the containment floor at the beginning of recirculation.
- Unqualified coatings in lower containment were assumed to be uniformly distributed in the recirculation pool.
- It was assumed that the fine debris in lower containment at the end of the blowdown would be uniformly distributed in the pool at the beginning of recirculation.
- Small pieces of insulation debris not blown to upper containment were conservatively assumed to be distributed between the locations where it would be destroyed and the sump screens.
- Fine and small piece debris washed down from upper containment was assumed to be in the vicinity of the locations where spray water would reach the pool.

The following figures (Figure 3.e-2, 3.e-3, 3.e-4, and 3.e-5) and discussion are presented as an example of how the transport analysis was performed for a single debris type at BVPS-1 – Small Piece Stainless Steel RMI. This same approach was utilized for other debris types analyzed at BVPS-1.

Figure 3.e-3 shows that the turbulence in the pool is not high enough to suspend small RMI debris essentially anywhere in the pool. Therefore, the tumbling velocity is considered to be the predominant means of transport. The small RMI debris not blown to upper containment was assumed initially to be uniformly distributed between the location where it was destroyed and the sump screen, as shown in Figure 3.e-4. This area was overlaid on top of the plot showing the tumbling velocity and flow vectors to determine the recirculation transport fraction. The area where small pieces of RMI would transport within the initial distribution area is 3,196 square feet as shown in Figure 3.e-5. Since the initial distribution area was determined to be 7,115 square feet, the recirculation transport fraction for small pieces of RMI is 45 percent.

Figure 3.e-2

Vectors Showing Break Location, Sump Location and Pool Flow Direction

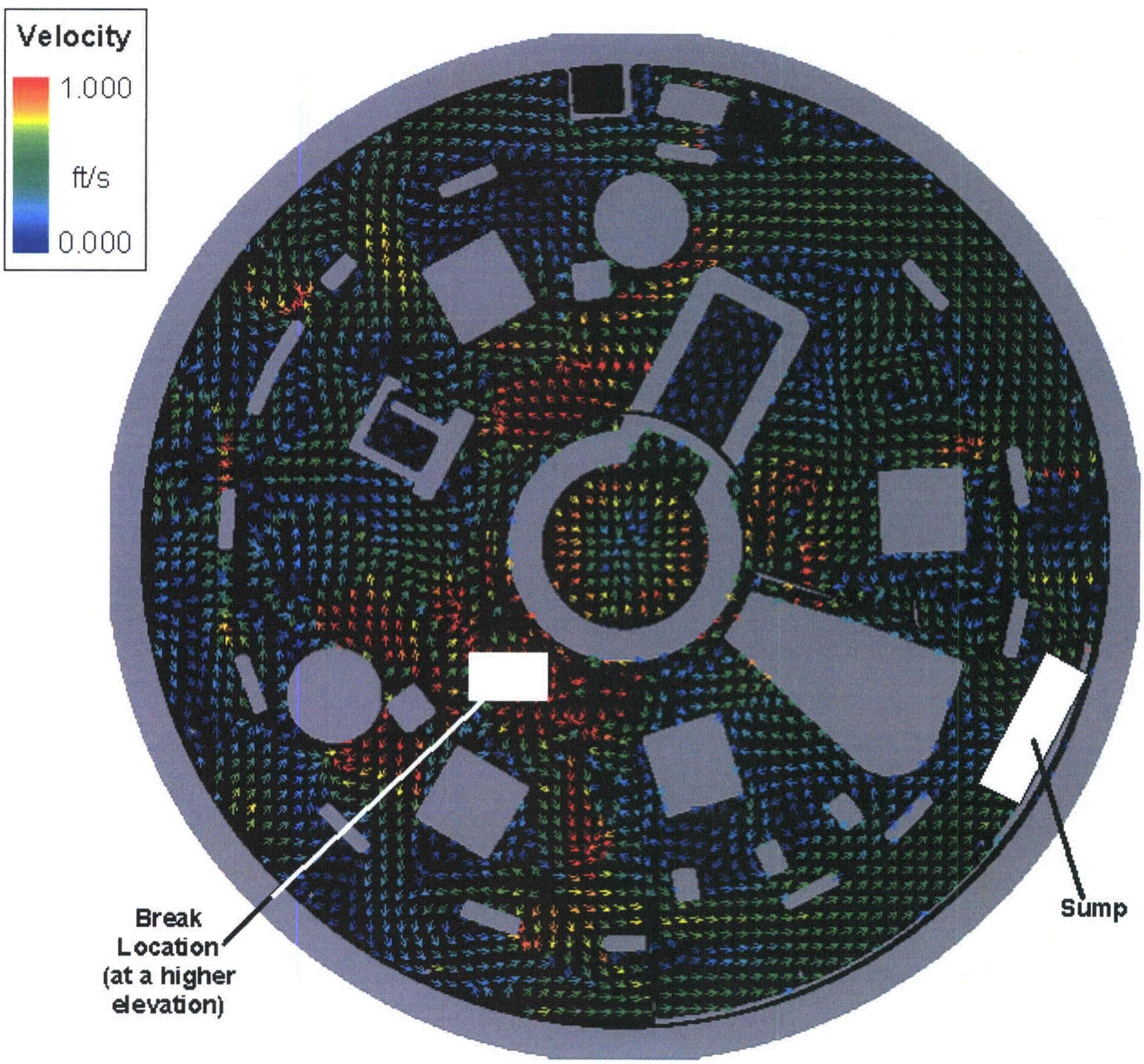


Figure 3.e-3

View of TKE and Velocity with Limits Set at Suspension/Tumbling of Small Pieces of Stainless Steel RMI

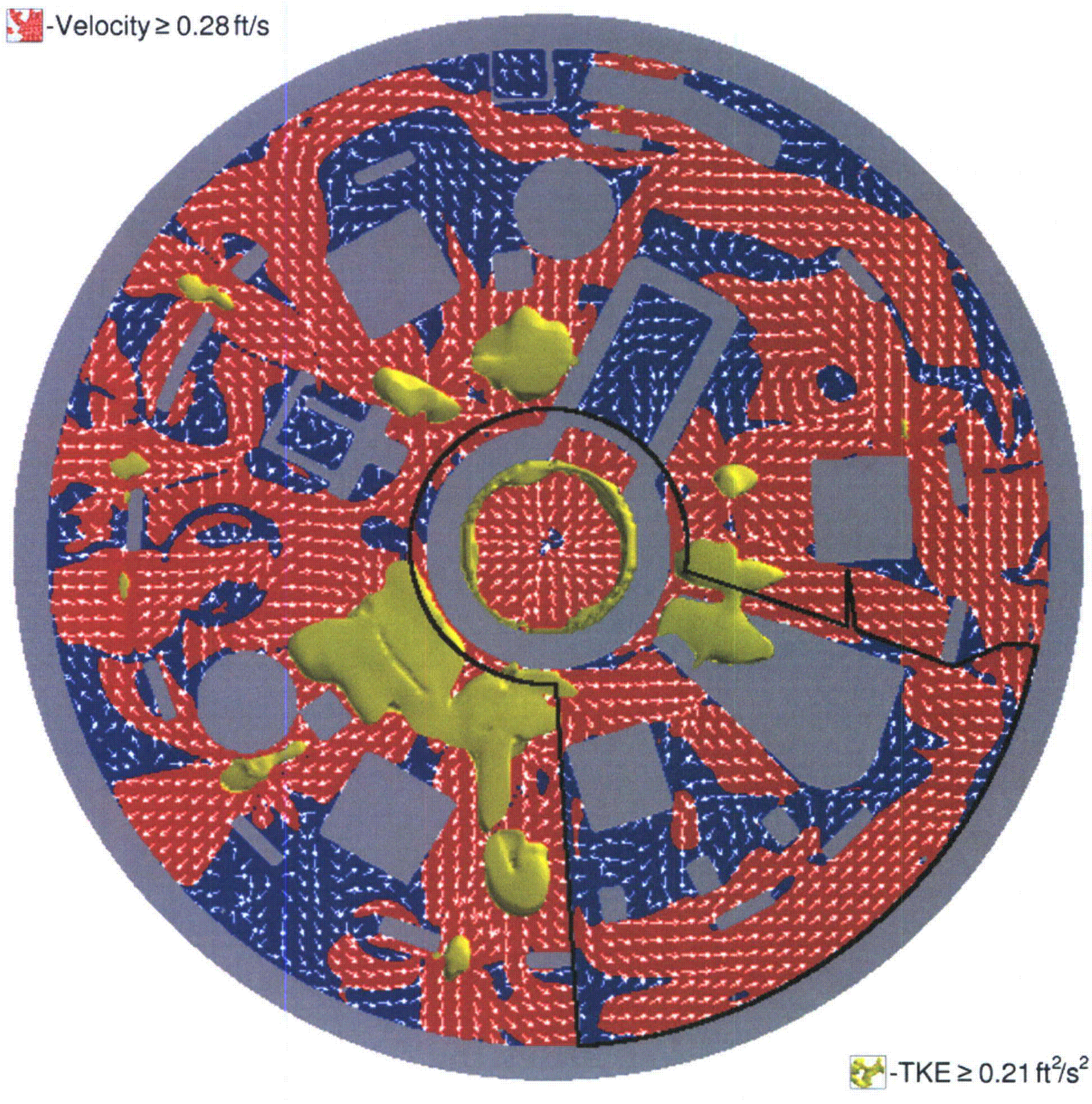


Figure 3.e-4

Distribution of Small and Large Pieces of Debris in Lower Containment

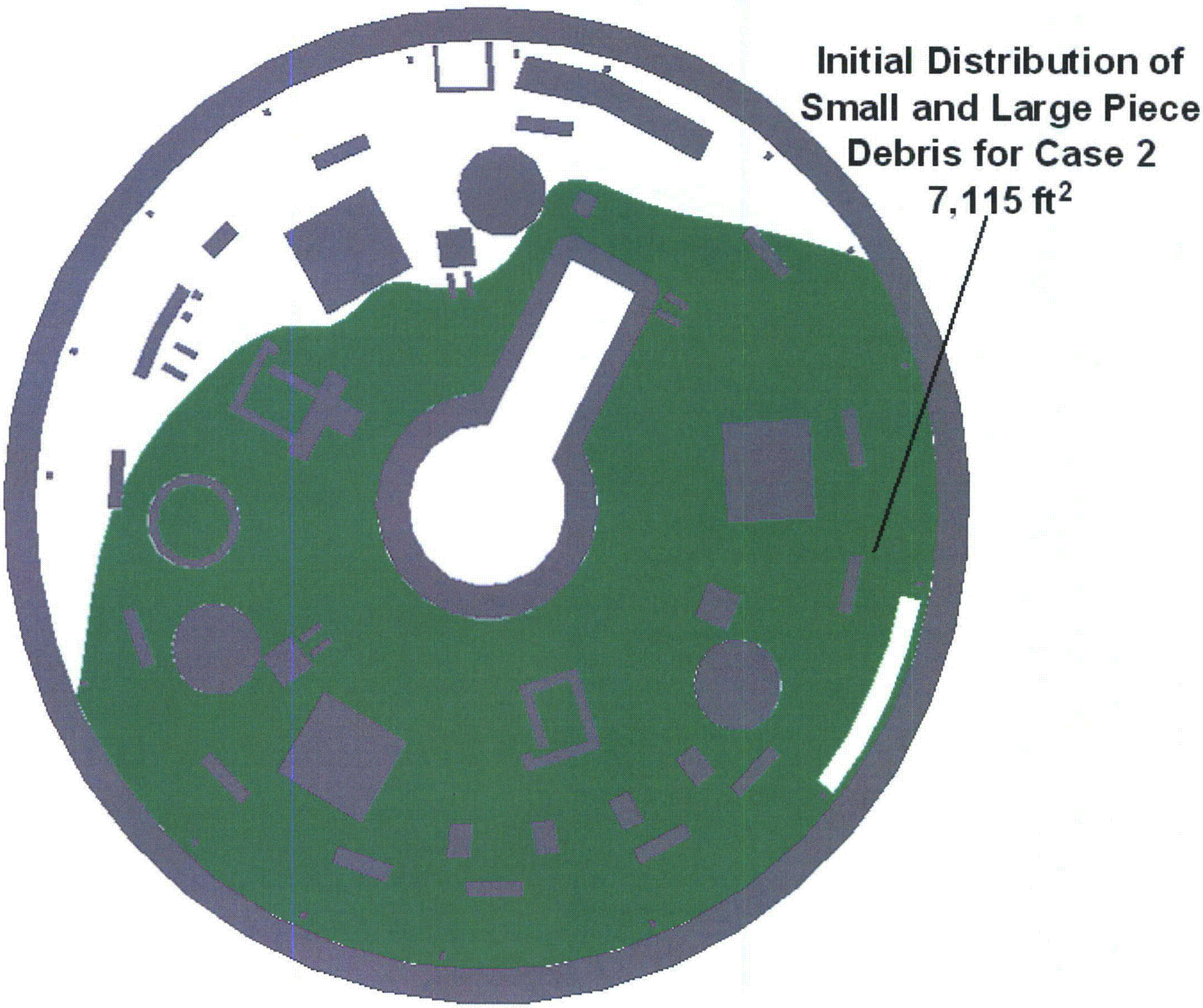
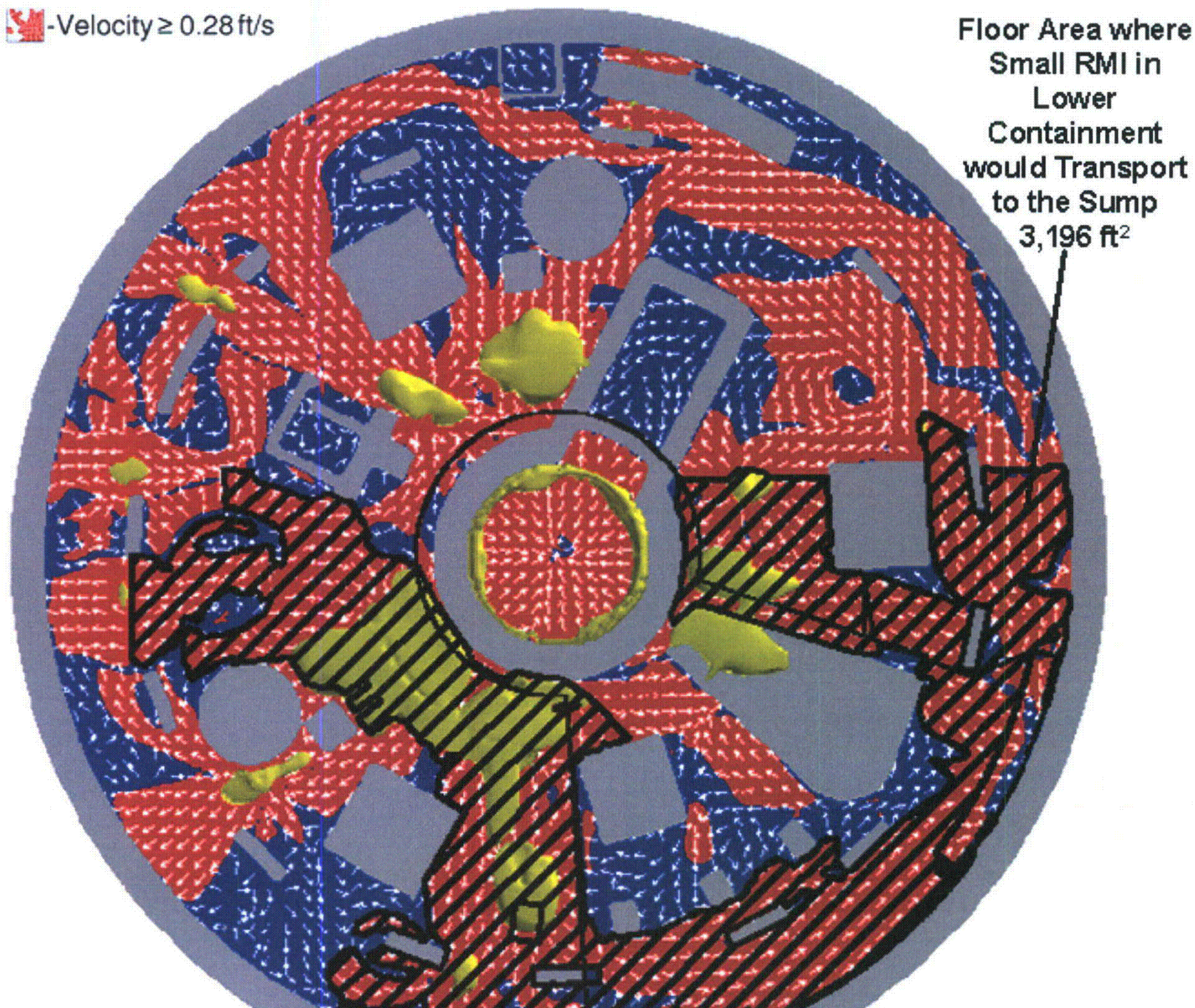


Figure 3.e-5
Floor Area Where Small RMI Would Transport to the Sump



The washdown distribution area was overlaid on top of the plot showing tumbling velocity and flow vectors to determine the recirculation transport fraction. The area where small pieces of RMI washed down in the annulus would transport to the sump and the area where small pieces of RMI washed down inside the secondary shield wall are 1,880 square feet and 968 square feet, respectively. The initial distribution areas were determined to be 4,844 square feet for washdown inside the secondary shield wall and 2,510 square feet for washdown in the annulus (not pictured), the recirculation transport fractions for small pieces washed down inside the secondary shield wall would be 39 percent, and 39 percent for small pieces washed down in the annulus.

Recirculation pool transport fractions were identified for each debris type associated with the location of its original distribution. This includes a transport fraction for debris: 1) not originally blown into upper containment, 2) washed down inside the secondary shield wall, and 3) washed down into the annulus.

Erosion of Fibrous Insulation Debris

The limiting LOCA breaks for BVPS-1 only generate Temp-Mat™ fiberglass as fibrous insulation debris. The debris generation analysis results reflect a size distribution of 20 percent fines and 80 percent small pieces for this insulation debris. The debris transport analysis has conservatively considered full transport of the fibrous insulation debris to the sump screen; therefore, erosion was not considered. The prototypical testing of the sump screen for the final BVPS-1 configuration conservatively considered all of the Temp-Mat™ fibrous insulation being 100 percent fines.

The limiting LOCA breaks for BVPS-2 generate Temp-Mat™ and Thermal Wrap™ fiberglass as fibrous insulation debris. The debris generation analysis results reflect a size distribution of 20 percent fines and 80 percent small pieces for this insulation debris. The debris transport analysis shows that 18 percent of the small pieces of fibrous insulation is held up in the upper containment and would be subjected to containment spray flows. The remaining small pieces were conservatively considered to transport to the sump screen. The small pieces being held up were considered to be susceptible to an erosion fraction of 1 percent, which is based on tests performed as part of the drywell debris transport study (DDTS). This is consistent with the approach taken with the pilot plant in the SER (Appendix VI). Although the BVPS-2 debris transport analysis did account for small pieces of fibrous debris holdup, the strainer prototypical testing was conservatively performed assuming full transport of the fibrous debris to the sump screen. The fiberglass insulation debris was conservatively prepared for testing as 50 percent fines and 50 percent small pieces. The small pieces were shredded and inspected to meet the size distribution requirements (small fiber clusters, Class 4 or smaller) as defined in NUREG/CR-6808.

The downstream effects reviews for BVPS-1 and BVPS-2 have also been conservatively performed with respect to fibrous debris loading as detailed in the response to Review Area 3.m.

DEVIATIONS FROM REGULATORY GUIDANCE

There were no deviations from regulatory guidance.

FENOC letter dated February 29, 2008, identified one area where the debris transport analysis deviated from regulatory guidance. Erosion fractions were previously provided based on the DDTS, which deviated from regulatory guidance. This deviation is no longer used in either BVPS-1 or BVPS-2 as discussed in the response to Review Area 3.e above under the heading Erosion of Fibrous Insulation Debris.

USE OF DEBRIS INTERCEPTORS AND CREDIT FOR SETTLING

Debris interceptors are not integrated into the BVPS-1 and BVPS-2 debris transport analyses.

Debris settling is not credited for the BVPS-1 and BVPS-2 debris transport analyses. The following tables depict the resultant transport data, showing that 100 percent of debris fines are transported.

FINAL DEBRIS TRANSPORT DATA

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 screen in each of the postulated cases.

BVPS-1

The postulated cases for BVPS-1 include the RCS loop breaks (hot leg, cold leg and crossover leg), a break on the pressurizer surge line, a break on a safety injection line, and a break in a reactor vessel nozzle. Transport data for these cases are presented in the following tables:

Table 3.e-6, Overall Debris Transport (Bounding RCS Loop Break) – BVPS-1

Table 3.e-7, Overall Debris Transport (Pressurizer Surge Line Break) – BVPS-1

Table 3.e-8, Overall Debris Transport (Reactor Vessel Nozzle Break) – BVPS-1

Table 3.e-9, Overall Debris Transport (6 Inch SIS Line Break) – BVPS-1

The coatings debris quantities have been revised based on refined analyses of the installed coating systems.

Table 3.e-6
Overall Debris Transport (Bounding RCS Loop Break) – BVPS-1

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	17,471 ft^2	42%	7,338 ft^2
	Large Pieces (>4")	7,136 ft^2	2%	143 ft^2
	Total	**24,607 ft^2**	**30%**	**7,481 ft^2**
Temp-Mat™	Fines	0.8 ft^3	100%	0.8 ft^3
	Small Pieces (<6")	3.2 ft^3	100%	3.2 ft^3
	Large Pieces (>6")	0 ft^3	10%	0 ft^3
	Intact Pieces (>6")	0 ft^3	0%	0 ft^3
	Total	**4.0 ft^3**	**100%**	**4.0 ft^3**
Cal-Sil (Reduced)	Total (Fines)	63 lbm	100%	63 lbm
IOZ Coatings (inside ZOI)	Total (Fines)	93.5 lbm	100%	93.5 lbm
Epoxy (inside ZOI)	Total (Fines)	111.1 lbm	100%	111.1 lbm
High Temp Al (inside ZOI)	Total (Fines)	0.0 lbm	100%	0.0 lbm
Vi Cryl CP-10 (inside ZOI)	Total (Fines)	104.5 lbm	100%	104.5 lbm
IOZ Coatings (outside ZOI)	Total (Fines)	8.6 lbm	100%	8.6 lbm
Epoxy (outside ZOI)	Total (Fines)	5.4 lbm	100%	5.4 lbm
Alkyd Enamel (outside ZOI)	Total (Fines)	30.7 lbm	100%	30.7 lbm
Cold Galvanizing (outside ZOI)	Total (Fines)	11.1 lbm	100%	11.1 lbm
Dirt/Dust	Total (Fines)	134.7 lbm	100%	134.7 lbm
Latent Fiber	Total (Fines)	0.25 ft^3	100%	0.25 ft^3
Misc. Debris	Total	543 ft^2	100%	543 ft^2

Table 3.e-7

Overall Debris Transport (Pressurizer Surge Line Break) – BVPS-1

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	3,916 ft^2	100%	3,916 ft^2
	Large Pieces (>4")	1,599 ft^2	100%	1,599 ft^2
	Total	**5,515 ft^2**	**100%**	**5,515 ft^2**
Cal-Sil	Total (Fines)	57.75 lbm	100%	57.75 lbm
Min-K™	Total (Fines)	16.0 lbm	100%	16.0 lbm
IOZ Coatings (inside ZOI)	Total (Fines)	0.1 lbm	100%	0.1 lbm
Epoxy (inside ZOI)	Total (Fines)	14.1 lbm	100%	14.1 lbm
High Temp Al (inside ZOI)	Total (Fines)	0.9 lbm	100%	0.9 lbm
Vi Cryl CP-10 (inside ZOI)	Total (Fines)	22.0 lbm	100%	22.0 lbm
IOZ Coatings (outside ZOI)	Total (Fines)	8.6 lbm	100%	8.6 lbm
Epoxy (outside ZOI)	Total (Fines)	5.4 lbm	100%	5.4 lbm
Alkyd Enamel (outside ZOI)	Total (Fines)	30.7 lbm	100%	30.7 lbm
Cold Galvanizing (outside ZOI)	Total (Fines)	11.1 lbm	100%	11.1 lbm
Dirt/Dust	Total (Fines)	134.7 lbm	100%	134.7 lbm
Latent Fiber	Total (Fines)	0.25 ft^3	100%	0.25 ft^3
Misc. Debris	Total	543 ft^2	100%	543 ft^2

Table 3.e-8
Overall Debris Transport (Reactor Vessel Nozzle Break) – BVPS-1

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	11,849 ft^2	100%	11,849 ft^2
	Large Pieces (>4")	4,840 ft^2	100%	4,840 ft^2
	Total	**16,689 ft^2**	**100%**	**16,689 ft^2**
Temp-Mat™	Fines	0 ft^3	100%	0 ft^3
	Small Pieces (<6")	0 ft^3	100%	0 ft^3
	Large Pieces (>6")	0 ft^3	100%	0 ft^3
	Intact Pieces (>6")	0 ft^3	100%	0 ft^3
	Total	**0 ft^3**	**100%**	**0 ft^3**
Cal-Sil	Total (Fines)	0 lbm	100%	0 lbm
Min-K™	Total (Fines)	2.4 lbm	100%	2.4 lbm
IOZ Coatings (inside ZOI)	Total (Fines)	0 lbm	100%	0 lbm
Epoxy (inside ZOI)	Total (Fines)	45.4 lbm	100%	45.4 lbm
High Temp Al (inside ZOI)	Total (Fines)	5.9 lbm	100%	5.9 lbm
Vi Cryl CP-10 (inside ZOI)	Total (Fines)	0 lbm	100%	0 lbm
IOZ Coatings (outside ZOI)	Total (Fines)	8.6 lbm	100%	8.6 lbm
Epoxy (outside ZOI)	Total (Fines)	5.4 lbm	100%	5.4 lbm
Alkyd Enamel (outside ZOI)	Total (Fines)	30.7 lbm	100%	30.7 lbm
Cold Galvanizing (outside ZOI)	Total (Fines)	11.1 lbm	100%	11.1 lbm
Dirt/Dust	Total (Fines)	134.7 lbm	100%	134.7 lbm
Latent Fiber	Total (Fines)	0.25 ft^3	100%	0.25 ft^3
Misc. Debris	Total	543 ft^2	100%	543 ft^2

Table 3.e-9
Overall Debris Transport (6 Inch SIS Line Break) – BVPS-1

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	13,288 ft^2	100%	13,288 ft^2
	Large Pieces (>4")	5,428 ft^2	100%	5,428 ft^2
	Total	**18,716 ft^2**	**100%**	**18,716 ft^2**
Temp-Mat™	Fines	0.8 ft^3	100%	0.8 ft^3
	Small Pieces (<6")	3.1 ft^3	100%	3.1 ft^3
	Large Pieces (>6")	0 ft^3	100%	0 ft^3
	Intact Pieces (>6")	0 ft^3	100%	0 ft^3
	Total	**3.9 ft^3**	**100%**	**3.9 ft^3**
Cal-Sil	Total (Fines)	0 lbm	100%	0 lbm
Min-K™	Total (Fines)	0 lbm	100%	0 lbm
IOZ Coatings (inside ZOI)	Total (Fines)	3.3 lbm	100%	3.3 lbm
Epoxy (inside ZOI)	Total (Fines)	8.2 lbm	100%	8.2 lbm
High Temp Al (inside ZOI)	Total (Fines)	0 lbm	100%	0 lbm
Vi Cryl CP-10 (inside ZOI)	Total (Fines)	93.5 lbm	100%	93.5 lbm
IOZ Coatings (outside ZOI)	Total (Fines)	8.6 lbm	100%	8.6 lbm
Epoxy (outside ZOI)	Total (Fines)	5.4 lbm	100%	5.4 lbm
Alkyd Enamel (outside ZOI)	Total (Fines)	30.7 lbm	100%	30.7 lbm
Cold Galvanizing (outside ZOI)	Total (Fines)	11.1 lbm	100%	11.1 lbm
Dirt/Dust	Total (Fines)	134.7 lbm	100%	134.7 lbm
Latent Fiber	Total (Fines)	0.25 ft^3	100%	0.25 ft^3
Misc. Debris	Total	543 ft^2	100%	543 ft^2

BVPS-2

The postulated cases for BVPS-2 also include the RCS loop breaks (hot leg, cold leg and crossover leg), a break on the pressurizer surge line, a break on a safety injection line, and a break in a reactor vessel nozzle. Transport data for these cases are presented in the following tables:

Table 3.e-10, Overall Debris Transport (Bounding RCS Loop Break) – BVPS-2

Table 3.e-11, Overall Debris Transport (Pressurizer Surge Line Break) – BVPS-2

Table 3.e-12, Overall Debris Transport (Reactor Vessel Nozzle Break) – BVPS-2

Table 3.e-13, Overall Debris Transport (6 Inch SIS Line Break) – BVPS-2

Table 3.e-10
Overall Debris Transport (Bounding RCS Loop Break) – BVPS-2

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	25,422.3 ft^2	95%	24,151.2 ft^2
	Large Pieces (>4")	10,383.7 ft^2	100%	10,383.7 ft^2
	Total	**35,806.0 ft^2**	**96%**	**34,534.9 ft^2**
Temp-Mat™	Fines	2.7 ft^3	100%	2.7 ft^3
	Small Pieces (<6")	10.6 ft^3	82%	8.7 ft^3
	Large Pieces (>6")	0 ft^3	0%	0 ft^3
	Intact Pieces (>6")	0 ft^3	0%	0 ft^3
	Total	**13.3 ft^3**	**86%**	**11.4 ft^3**
Thermal Wrap	Fines	0.5 ft^3	100%	0.5 ft^3
	Small Pieces (<6")	1.8 ft^3	82%	1.5 ft^3
	Large Pieces (>6")	0 ft^3	NA	0 ft^3
	Intact Pieces (>6")	0 ft^3	NA	0 ft^3
	Total	**2.3 ft^3**	**87%**	**2.0 ft^3**
Min-K™	Total (Fines)	0.8 lbm	100%	0.8 lbm
Damming Material	Total (Fines)	0.1 ft^3	100%	0.1ft^3
Cal-Sil	Total (Fines)	96.0 lb	100%	96.0 lb
Qualified IOZ Coatings (5D)	Total (Fines)	196.3 lb	100%	196.3 lb
Qualified Carboline 191 HB (5D)	Total (Fines)	66.8 lb	100%	66.8 lb
Qualified Nutec 11S Epoxy (5D)	Total (Fines)	44.1 lb	100%	44.1 lb
Qualified Nutec 1201 Epoxy (5D)	Total (Fines)	36.9 lb	100%	36.9 lb
Unqualified Carboline 4674	Total (Fines)	12.6 lb	100%	12.6 lb
Unqualified IOZ Coatings	Total (Fines)	4.4 lb	100%	4.4 lb
Unqualified Carboline 191 HB	Total (Fines)	39.5 lb	100%	39.5 lb
Unqualified Alkyd	Total (Fines)	117.3 lb	100%	117.3 lb
Unqualified Cold Galvanizing	Total (Fines)	19.5 lb	100%	19.5 lb
Dirt/Dust	Total (Fines)	156.4 lb	100%	156.4 lb
Latent Fiber	Total (Fines)	11.3 ft^3	100%	11.3 ft^3
Misc. Debris	Total	750.8 ft^2	100%	750.8 ft^2

Table 3.e-11

Overall Debris Transport (Pressurizer Surge Line Break) – BVPS-2

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	1,697.2 ft^2	100%	1,697.2 ft^2
	Large Pieces (>4")	693.2 ft^2	100%	693.2 ft^2
	Total	**2,390.4 ft^2**	**100%**	**2,390.4 ft^2**
Temp-Mat™	Fines	1.8 ft^3	100%	1.8 ft^3
	Small Pieces (<6")	7.0 ft^3	100%	7.0 ft^3
	Large Pieces (>6")	0.26 ft^3	100%	0.26 ft^3
	Intact Pieces (>6")	0.27 ft^3	100%	0.27 ft^3
	Total	**9.3 ft^3**	**100%**	**9.3 ft^3**
Cal-Sil	Total (Fines)	82.5 lb	100%	82.5 lb
Min-K™	Total (Fines)	14.4 lb	100%	14.4 lb
Qualified IOZ Coatings (5D)	Total (Fines)	0.7 lb	100%	0.7 lb
Qualified Carboline 191 HB (5D)	Total (Fines)	0.3 lb	100%	0.3 lb
Qualified Nutec 11S Epoxy (5D)	Total (Fines)	4.7 lb	100%	4.7 lb
Qualified Nutec 1201 Epoxy (5D)	Total (Fines)	4.1 lb	100%	4.1 lb
Unqualified Carboline 4674	Total (Fines)	2.2 lb	100%	2.2 lb
Unqualified IOZ Coatings	Total (Fines)	4.4 lb	100%	4.4 lb
Unqualified Carboline 191 HB	Total (Fines)	39.5 lb	100%	39.5 lb
Unqualified Alkyd	Total (Fines)	117.3 lb	100%	117.3 lb
Unqualified Cold Galvanizing	Total (Fines)	19.5 lb	100%	19.5 lb
Dirt/Dust	Total (Fines)	156.4 lb	100%	156.4 lb
Latent Fiber	Total (Fines)	11.3 ft^3	100%	11.3 ft^3
Misc. Debris	Total	750.8 ft^2	100%	750.8 ft^2

Table 3.e-12

Overall Debris Transport (Reactor Vessel Nozzle Break) – BVPS-2

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	1,563.0 ft^2	100%	1,563.0 ft^2
	Large Pieces (>4")	638.4 ft^2	100%	638.4 ft^2
	Total	**2,201.4 ft^2**	**100%**	**2,201.4 ft^2**
Microtherm®	Total (Fines)	126.5 lb	100%	126.5 lb
Qualified Nutec 11S Epoxy (5D)	Total (Fines)	36.3 lb	100%	36.3 lb
Qualified Nutec 1201 Epoxy (5D)	Total (Fines)	30.4 lb	100%	30.4 lb
Unqualified Carboline 4674	Total (Fines)	8.0 lb	100%	8.0 lb
Unqualified IOZ Coatings	Total (Fines)	4.4 lb	100%	4.4 lb
Unqualified Carboline 191 HB	Total (Fines)	39.5 lb	100%	39.5 lb
Unqualified Alkyd	Total (Fines)	117.3 lb	100%	117.3 lb
Unqualified Cold Galvanizing	Total (Fines)	19.5 lb	100%	19.5 lb
Dirt/Dust	Total (Fines)	156.4 lb	100%	156.4 lb
Latent Fiber	Total (Fines)	11.3 ft^3	100%	11.3 ft^3
Misc. Debris	Total	750.8 ft^2	100%	750.8 ft^2

Table 3.e-13

Overall Debris Transport (6 Inch SIS Line Break) – BVPS- 2

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	3,504.2 ft^2	100%	3,504.2 ft^2
	Large Pieces (>4")	1,431.2 ft^2	100%	1,431.2 ft^2
	Total	**4,935.4 ft^2**	**100%**	**4,935.4 ft^2**
Temp-Mat™	Fines	5.9 ft^3	100%	5.9 ft^3
	Small Pieces (<6")	0 ft^3	100%	0 ft^3
	Large Pieces (>6")	0 ft^3	100%	0 ft^3
	Intact Pieces (>6")	0 ft^3	100%	0 ft^3
	Total	**5.9 ft^3**	**100%**	**5.9 ft^3**
Min-K™	Total (Fines)	0.8 lbm	100%	0.8 lbm
Damming Material	Total (Fines)	0.1 ft^3	100%	0.1 ft^3
Thermal Wrap™	Total (Fines)	0.1 ft^3	100%	0.1 ft^3
Qualified IOZ Coatings	Total (Fines)	8.0 lb	100%	8.0 lb
Qualified Carboline 191 HB	Total (Fines)	3.8 lb	100%	3.8 lb
Qualified Nutec 11S Epoxy	Total (Fines)	5.3 lb	100%	5.3 lb
Qualified Nutec 1201 Epoxy	Total (Fines)	4.4 lb	100%	4.4 lb
Unqualified Carboline 4674	Total (Fines)	0 lb	NA	0 lb
Unqualified IOZ Coatings	Total (Fines)	4.4 lb	100%	4.4 lb
Unqualified Carboline 191 HB	Total (Fines)	39.5 lb	100%	39.5 lb
Unqualified Alkyd	Total (Fines)	117.3 lb	100%	117.3 lb
Unqualified Cold Galvanizing	Total (Fines)	19.5 lb	100%	19.5 lb
Dirt/Dust	Total (Fines)	156.4 lb	100%	156.4 lb
Latent Fiber	Total (Fines)	11.3 ft^3	100%	11.3 ft^3
Misc. Debris	Total	750.8 ft^2	100%	750.8 ft^2

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. Responses are presented below pertaining to the debris transport analysis at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed by the specific response.

RAI #36 (from Reference 6)

Your submittal indicated that you plan to use a debris interceptor as a method to impede transport of debris to the ECCS sump screen. What is the amount (in either volume or percentage) of debris that is expected to be captured by the interceptor? Is there an evaluation for the potential to overload the debris interceptor?

FENOC Response

Use of debris interceptors was discussed as a possible option in the September 6, 2005 response to GL 2004-02 (Reference 4). However, this option was not implemented as subsequent debris transport analyses for both BVPS-1 and BVPS-2 did not indicate a need for debris interceptors.

RAI #39 (from Reference 6)

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

FENOC Response

The BVPS-1 and BVPS-2 debris transport analyses did not credit settling for fine debris. The debris transport analyses have conservatively shown that all (100 percent) of the fine fibrous and particulate debris have been transported to the sump itself, and the information contained in responses provided for Review Area 3.e shows these results for this debris transport. As stated in responses to Review Area 3.f, head loss testing used mechanical and manual stirring to assure that essentially 100 percent of the transported debris was deposited on the strainer. The holdup of small and large pieces of debris through transport has been described in response to Review Area 3.e.

RAI #41 (from Reference 6)

What is the basis for concluding that the refueling cavity drain(s) would not become blocked with debris? What are the potential types and characteristics of debris that could reach these drains? In particular, could large pieces of debris

be blown into the upper containment by pipe breaks occurring in the lower containment, and subsequently drop into the cavity? In the case that large pieces of debris could reach the cavity, are trash racks or interceptors present to prevent drain blockage? In the case that partial/total blockage of the drains might occur, do water hold-up calculations used in the computation of NPSH margin account for lost or held-up water resulting from debris blockage?

FENOC Response

The debris transport analysis for both BVPS-1 and BVPS-2 assessed the potential for debris blockage. One potential upstream blockage point was evaluated for spray water draining down from the refueling cavity through the reactor cavity keyway and out the reactor cavity drain to the containment general floor area. This analysis is included in the response to upstream effects. It is repeated for convenience in addressing the answers specific to the RAI.

All spray water entering the refueling cavity drains to the keyway through the annular seal region between the reactor vessel and the refueling cavity floor. The permanent seal has several openings through the seal for reactor cavity ventilation that are uncovered during power operation to allow adequate water drainage to the cavity. The BVPS-2 ventilation openings have a coarse grating mesh over the opening during plant operation. There is no grating over the BVPS-1 ventilation openings. These openings, in both units, are sufficiently large to prevent any credible debris that may be generated as a result of the break from blocking this flow path.

The drain opening from the reactor cavity to the containment general floor area was identified to contain a cross-bar (acting as a personnel exclusion device), at both BVPS-1 and BVPS-2. The cross bars have subsequently been removed from the reactor cavity drain openings, for BVPS-1 and BVPS-2, to alleviate the potential for debris from being lodged against them and restricting flow out of the drain.

The types of debris determined to be blown to upper containment are identified in response to Review Area 3.e, Debris Transport. Large pieces of RMI (BVPS-1) were identified to be blown to upper containment and assumed to be evenly distributed in upper containment and available for washdown transport because of the containment sprays. The amount of debris determined to be washed to the reactor cavity would be exposed to approximately 11 percent of the total containment spray flow. So, though the debris with the potential to be in the reactor cavity was assumed to transport to the containment pool, the amount of large pieces of debris is small.

RAI #44 (from Reference 6)

The September 2005 GL response stated that the FirstEnergy Nuclear Operating Company is in the process of performing debris transport analysis. Please supplement your response after completing the analysis.

FENOC Response

The response to Review Area 3.e provides a summary of the methodology and results obtained for the debris transport analysis for BVPS-1 and BVPS-2.

3.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).***
2. ***Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.***
3. ***Provide a summary of the methodology, assumptions and results of the vortexing evaluation. Provide bases for key assumptions.***
4. ***Provide a summary of the methodology, assumptions, and results of prototypical head loss testing for the strainer, including chemical effects. Provide bases for key assumptions.***
5. ***Address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen.***
6. ***Address the ability of the screen to resist the formation of a "thin bed" or to accommodate partial thin bed formation.***
7. ***Provide the basis for the strainer design maximum head loss.***
8. ***Describe significant margins and conservatisms used in the head loss and vortexing calculations.***
9. ***Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the clean strainer head loss calculation.***
10. ***Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the debris head loss analysis.***
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.***
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.***

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

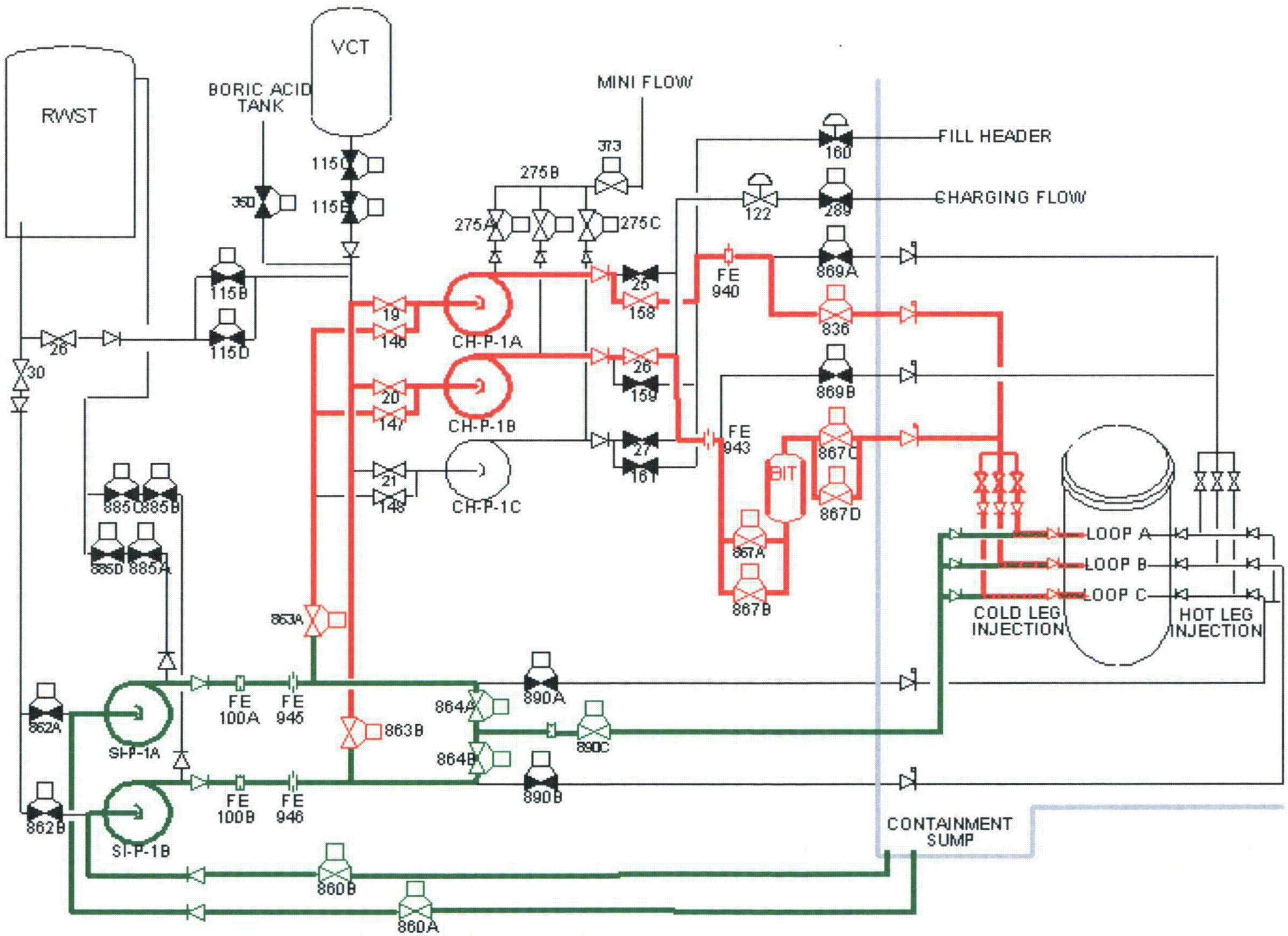
14. ***State whether containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface, and if so, summarize the methodology used to determine the available containment pressure.***

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

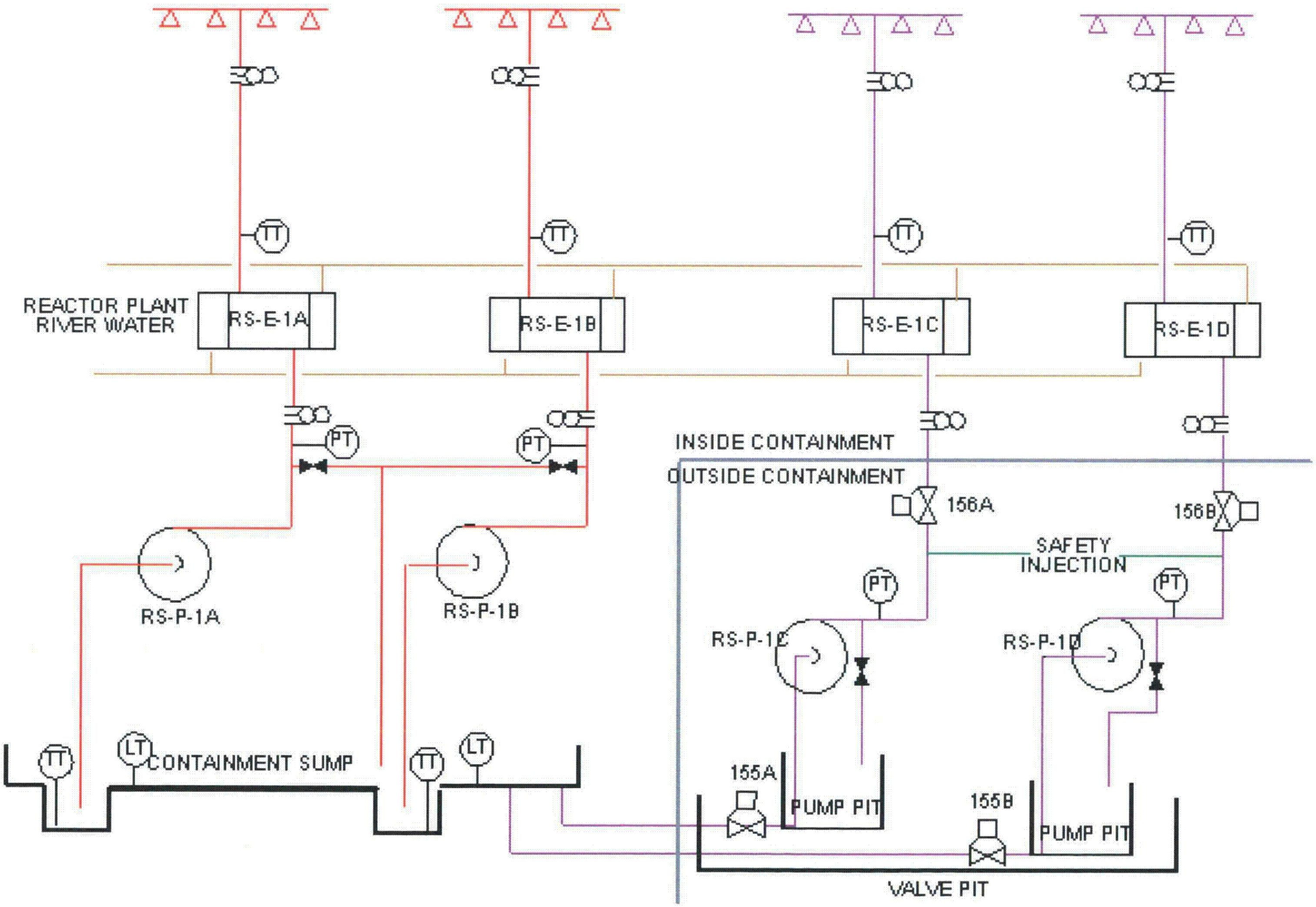
FENOC Response

Schematics for the BVPS-1 and BVPS-2 ECCS and CSS are provided below.

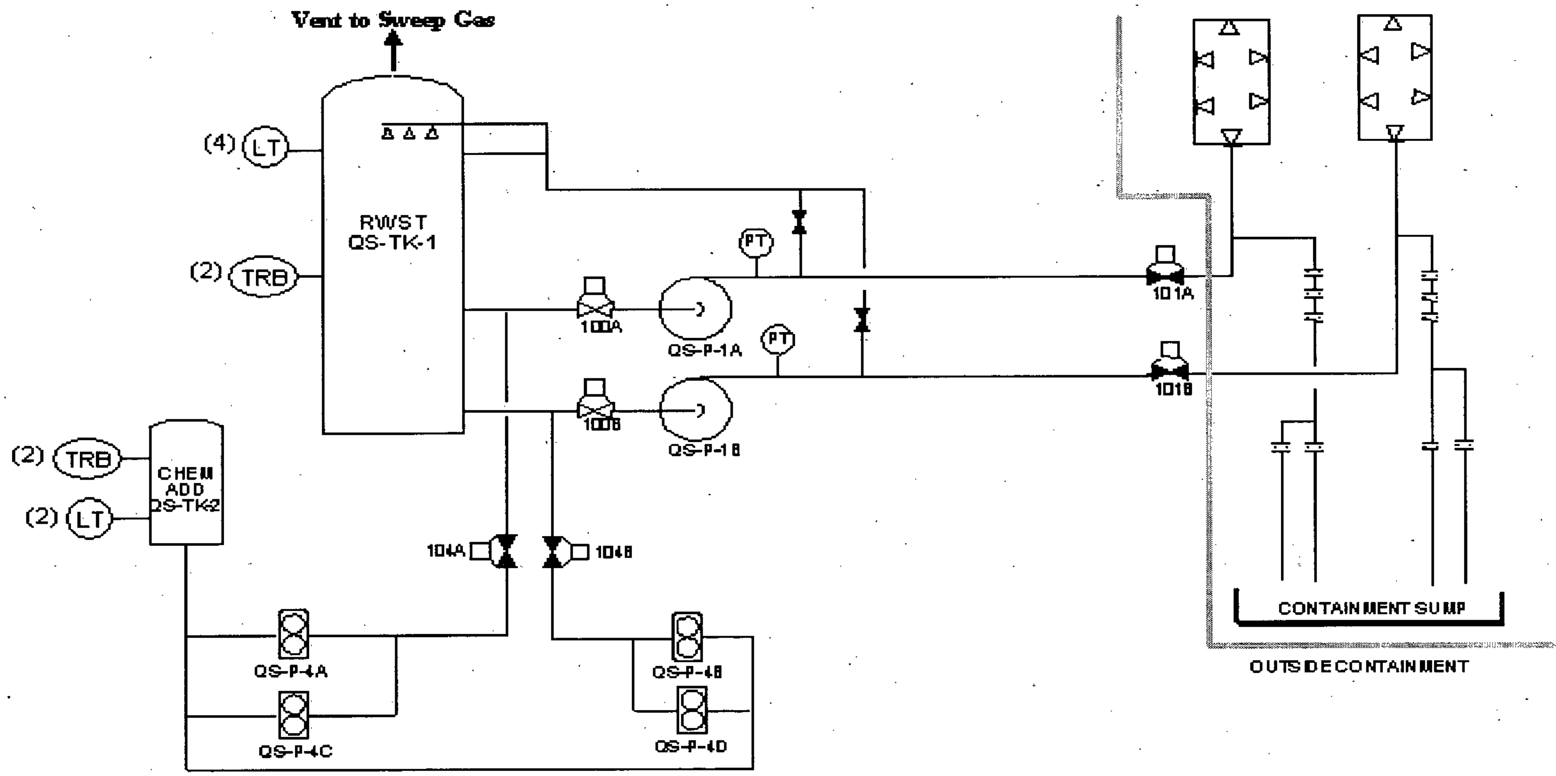
BVPS-1 Safety Injection System Cold Leg Recirc Phase



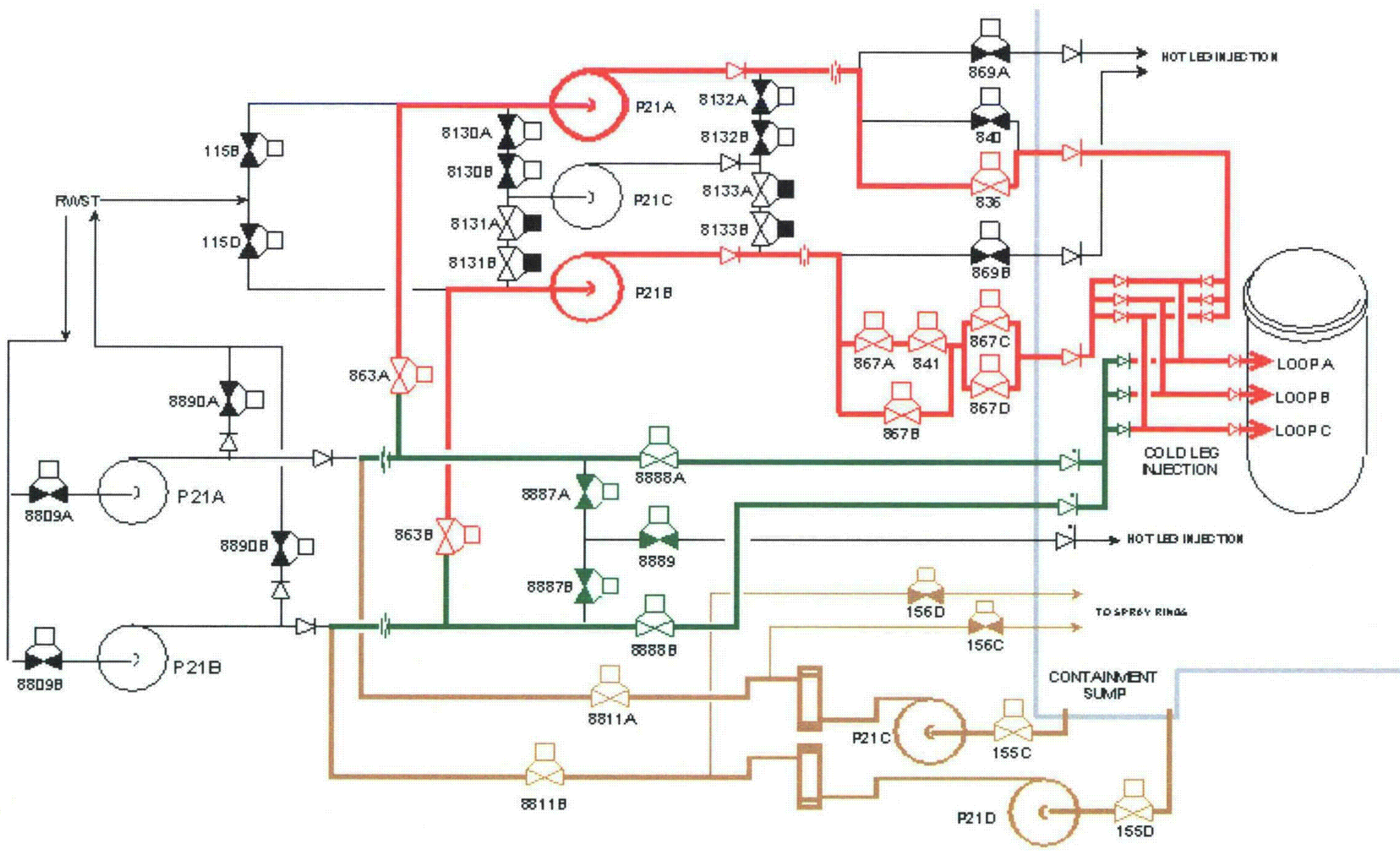
BVPS-1 Recirculation Spray System



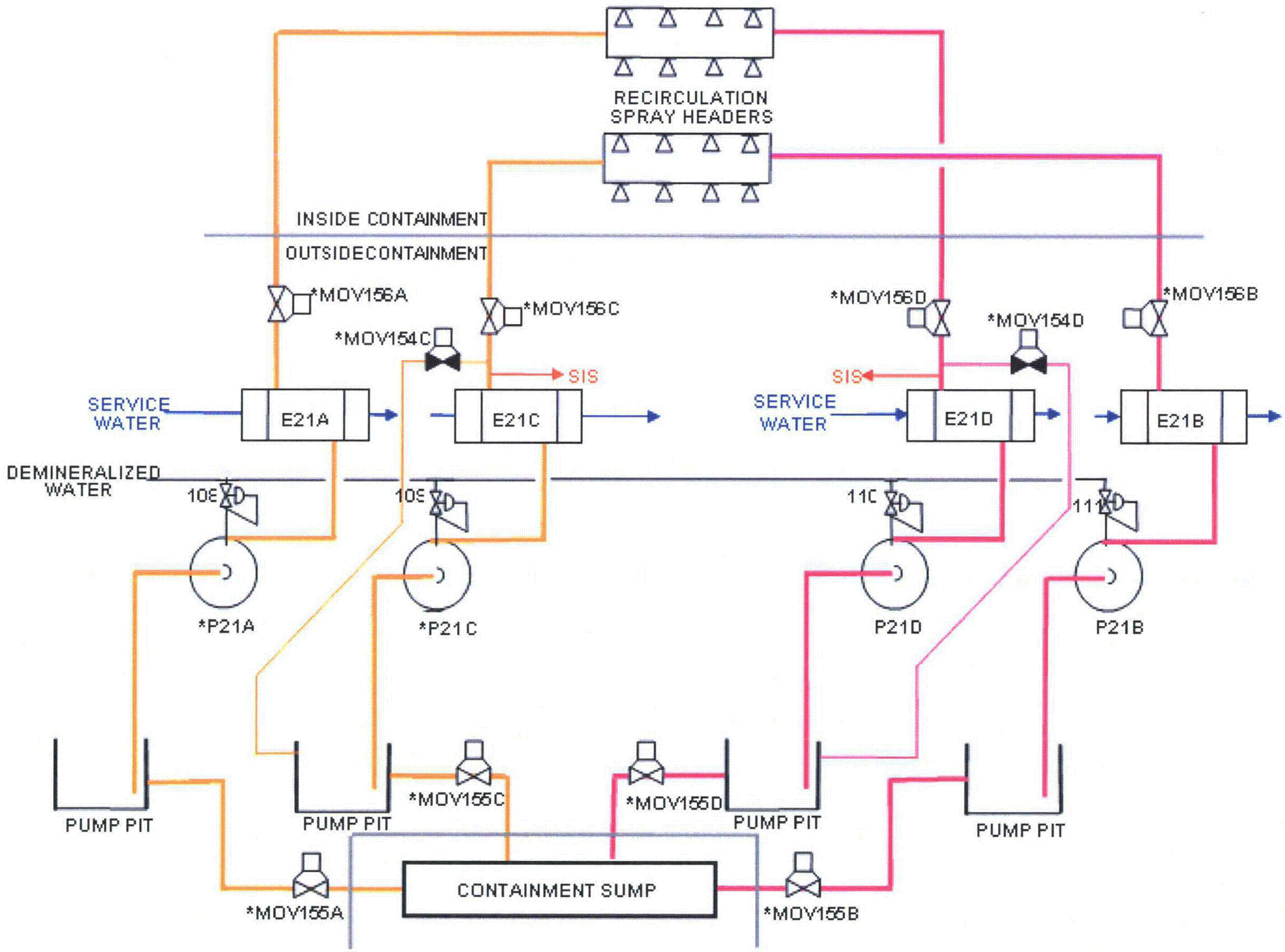
BVPS-1 Quench Spray System



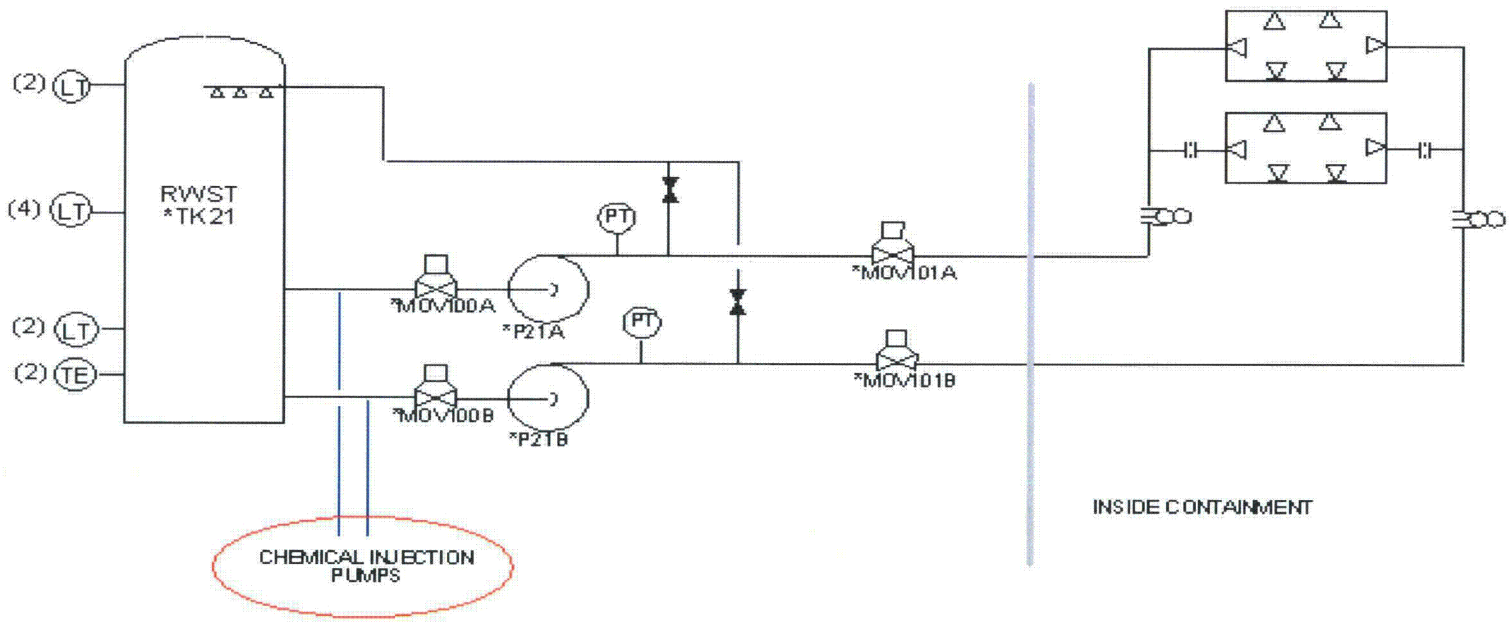
BVPS-2 Safety Injection System Cold Leg Recirc Phase



BVPS-2 Recirculation Spray System



BVPS-2 Quench Spray System



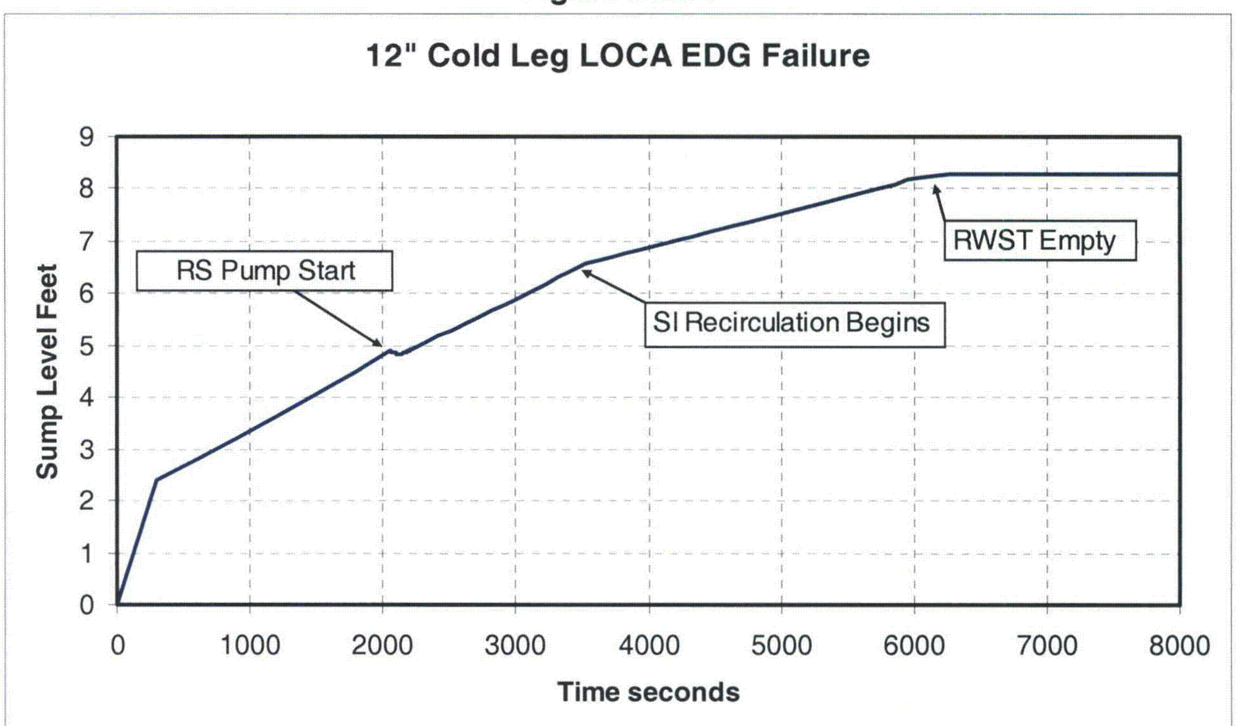
Scheduled to be retired during Fall 2009 Refueling Outage (2R14)

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

FENOC Response

The minimum submergence of the strainers at BVPS-1 and BVPS-2 occurs shortly following start of the RSS pumps. After the pumps start on a Refueling Water Storage Tank (RWST) level low coincident with a containment pressure high-high signal, water is drawn from the containment sump to fill the RSS piping. During this period, no water is discharged from the RSS spray headers so the sump experiences a net decrease in inventory. Within a few minutes following pump start, the spray from the RSS starts to reach the sump and the sump level increases from that point until the RWST is empty (i.e., when the entire usable inventory of the RWST is delivered), at which time the sump level stabilizes and the maximum submergence is reached. The following plot (Figure 3.f.2-1) shows the typical BVPS-1 sump level response for an intermediate break size LOCA. All break sizes exhibit similar trends; however, the timing is dependent on the break size and single failure assumptions.

Figure 3.f.2-1



The minimum submergence in the following table (Table 3.f.2-1) is calculated as the height of water above the highest strainer opening at the minimum level following RSS pump start. In all cases, submergence will increase from that point until the RWST is empty.

Table 3.f.2-1

Minimum Strainer Submergence (inches)

	BVPS-1	BVPS-2
SBLOCA	2.2	16.6
LBLOCA	7.0	22.6

After the entire usable inventory of the RWST is delivered to the containment building, the final submergence level is achieved. This occurs within the first several hours following accident initiation. Table 3.f.2-2 shows the minimum final submergence values for each unit for the limiting small break LOCA case.

Table 3.f.2-2

Minimum Final Strainer Submergence (inches)

	BVPS-1	BVPS-2
SBLOCA	44.1	100.6

The strainers are designed and located within containment such that there will be no significant splashing at the containment pool surface that could lead to unacceptable air entrainment through the strainer surface. The BVPS-1 and BVPS-2 containments were evaluated for locations where sheeting flow would enter the containment pool from upper levels of the containment. The containment levels above the strainers consist of floor grating. Therefore, the strainers would have spray droplets falling on them. No sheeting flow would cascade down on the strainers. In addition, cover plates above the strainers at both units protect the strainers from falling water. As discussed in response to Review Area 3.j.1, these cover plates prevent water from falling directly on the strainer top surface.

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

FENOC Response

Testing has shown that vortexes are not formed with the BVPS sump strainers.

The BVPS-1 containment sump strainer is designed and supplied by Control Components Incorporated (CCI), which has performed vortex testing for their strainer design with both perforated and un-perforated top plates. The BVPS-1 design uses un-perforated top plates. All testing performed by CCI for un-perforated top plates show no vortex formation. Testing included stopping and restarting the test pump verifying that localized clean screen windows with high velocities do not result in vortexing. The CCI strainer design is within the design and operating ranges where no air vortex formations occurred during testing.

In addition to the CCI testing, the strainers on both BVPS-1 and BVPS-2 have been tested for vortex formation during the retesting done for chemical effects head loss by Alion. These tests verified that no vortex formation occurred.

Both of the BVPS containment sump strainers have less than the 9 feet of submergence recommended in Regulatory Guide 1.82, Revision 3. The above-described testing has shown that the new strainers ensure that there is no air ingestion into the pump intakes.

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

FENOC Response

In order to maintain operability of the sump with the predicted debris loads from the Debris Generation and Debris Transport analyses, new strainers were designed. To qualify these strainers for the predicted debris loads, head loss testing was performed using a prototypical strainer array.

The purpose of the testing was to collect and record differential pressure (dp), temperature, and flow rate data while building a bed of a specific quantity and mixture of debris across a prototypical strainer array representative of a portion of the larger arrays that are installed at BVPS-1 and BVPS-2. The specific mixture used includes fibrous insulation debris, particulate debris, and chemical precipitates.

The BVPS-1 and 2 retesting was designed and performed in accordance with the March 2008 NRC staff's review guidance (Reference 12).

The prototypical head loss testing performed for BVPS-1 was originally conducted by CCI. The CCI tests have been completely superseded by tests that have been conducted by Alion. A total of nine tests were performed for the BVPS-1 strainer array. The specific debris mixture used included fibrous insulation debris, particulate debris, and chemical precipitates. The retesting performed for BVPS-1 included a series of tests, stepping through a reduction of Temp-Mat™ and Cal-Sil insulation, until acceptable head loss results were achieved. The final test represents the final configuration for BVPS-1, which included an amount of debris that was less than the quantity required to form a complete thin bed.

Table 3.f.4-1 below provides a summary of the BVPS-1 retesting.

Table 3.f.4-1

Test No.	Test Description	Break
All tests	Clean Screen Head Loss Test	Not Applicable
1, 1A, 1B, 1C	Full Load Test Debris (current debris loads)	BVPS-1 Loop Break
2	Full Load Test Debris (current debris loads)	BVPS-1 Reactor Vessel Nozzle Break
3	Assumed targeted removal of Temp-Mat™ from the Reactor Coolant piping penetrations through the primary shield wall	BVPS-1 Loop and Reactor Vessel Nozzle Break
4	Latent Fiber Test Debris (assumed removal of all Temp-Mat™ and Cal-Sil)	BVPS-1 Loop and Reactor Vessel Nozzle Break
5	Reduced Cal-Sil and TempMat™ (assumed targeted removal of Temp-Mat™ and Cal-Sil)	BVPS-1 Loop and Reactor Vessel Nozzle Break
6	Reduced Cal-Sil and TempMat™ (assumed targeted removal of Temp-Mat™ and Cal-Sil)	BVPS-1 Loop and Reactor Vessel Nozzle Break and Surge Line

Prototypical head loss testing for BVPS-2 was originally conducted by Alion Science & Technology. A total of seven tests were performed for the BVPS-2 strainer array. The specific debris mixture used included fibrous insulation debris, particulate debris, and chemical precipitates. The retesting performed for BVPS-2 included a test for the predicted debris from a loop break and a series of tests for a reactor nozzle break, stepping through a reduction of Microtherm®, until acceptable head loss results were achieved. The final tests, which represent the final configuration for BVPS-2 after planned insulation modifications, included an amount of debris which was less than the quantity required to form a complete thin bed.

Table 3.f.4-2 below provides a summary of the BVPS-2 retesting.

Table 3.f.4-2

Test No.	Test Description	Break
All tests	Clean Screen Head Loss Test	Not Applicable
1A, 1N	Scaled Load Assuming reduced Cal-Sil and Temp-Mat™ (Test 1N without Bypass Eliminator)	BVPS-2 Loop Break and Surge Line Break
2	Scaled Load Test Debris 100% Microtherm® (with Bypass Eliminator)	BVPS-2 Reactor Vessel Nozzle Break
3, 3N	Scaled Load Test Debris 50% Microtherm® (Test 3N without Bypass Eliminator)	BVPS-2 Reactor Vessel Nozzle Break
4	Scaled Load Test Debris 25% Microtherm® (with Bypass Eliminator)	BVPS-2 Reactor Vessel Nozzle Break
5	Scaled Load Test Debris 15% Microtherm® (with Bypass Eliminator)	BVPS-2 Reactor Vessel Nozzle Break

The debris mix used was a scaled version of the quantity and debris mix developed in the debris generation and debris transport analyses performed for BVPS-1 and BVPS-2.

The methodology, assumptions, and results of chemical effects are discussed in the response to Review Area 3.o. "Chemical Effects." The chemical precipitant loads were obtained from a chemical product generation calculation.

The debris type and quantity used for each case is listed in Tables 3.f.4-3 (BVPS-1) and 3.f.4-4 (BVPS-2) below.

Table 3.f.4-3

Test No.	NUKON® Fines (lbm)	Temp-Mat™ Fines (lbm)	Temp-Mat™ Small Pieces (lbm)	Min-K™ (lbm)	Ground Silica (lbm)	Paint Chips Surrogate (lbm)	Cal-Sil (lbm)	Dirt/Dust (lbm)
1	0.87	1.97	5.48	N/A	28.88	N/A	6.44	4.93
1A	0.87	1.97	5.48	N/A	28.88	N/A	6.44	4.93
1B	0.87	1.97	5.48	N/A	28.88	N/A	6.44	4.93
1C	0.75	1.70	4.72	N/A	24.89	N/A	5.55	4.25
2	0.75	3.48	13.87	N/A	23.81	N/A	0	4.25
3	0.75	0.85	0.85	N/A	24.89	6.9	5.55	4.25
4	0.75	0	0	N/A	24.89	7.0	0	4.25
5	0.75	0.3	0	N/A	24.89	7.0	1.73	4.25
6	0.75	0.3	0	0.4	24.89	7.0	2.63	4.25

Table 3.f.4-4

Test No.	NUKON® Fines (lbm)	NUKON® Small Pieces (lbm)	Temp-Mat™ Fines (lbm)	Temp-Mat™ Small Pieces (lbm)	Cal-Sil (lbm)	Min-K™ (lbm)	Micro-therm® (lbm)	Ground Silica (lbm)	Paint Chips Surrogate (lbm)	Dirt/ Dust (lbm)
1A, 1N	1.76	0.09	0.92	0.92	5.34	0.89	0	59.5	17.0	9.5
2	1.67	0	0	0	0	0	51.0	39.7	15.9	9.5
3, 3N	1.67	0	0	0	0	0	25.5	39.7	15.9	9.5
4	1.67	0	0	0	0	0	12.8	39.7	15.9	9.5
5	1.67	0	0	0	0	0	7.7	39.7	15.9	9.5

SIL-CO-SIL™ 53 Ground Silica was used as a surrogate for both the qualified and unqualified coatings. The surrogate material volume was adjusted to match the volume of the coatings particulate. The particle size for coatings is 10 microns spherical particle diameter. The ground silica is a spherical particulate ranging in size from just under 1 micron to 100 microns.

Chips Unlimited paint chips were also used as a surrogate material for unqualified coatings. The paint chips were 4 to 6 mils thick with a 1/8 inch or 1/4 inch nominal size distribution.

BVPS-1 Test Configuration

The prototype strainer array consisted of four cartridges, arranged two on each side. Each cartridge contains 16 pockets (2 wide x 8 high), so the array contains 64 pockets overall.

The prototype strainer array was placed in a large test tank approximately 6 feet tall, 6 feet wide, and 10 feet long. The array was located near the middle of the tank. Flow was routed from the tank sparger inlet, through the strainer/plenum assembly, and out through the bottom flow outlet channel (bottom suction). The flow rate through the array was controlled by throttling of the control valve on the return line to the tank or through the adjustment of a variable frequency drive on the pump motor.

The cartridges used in testing are equivalent to the cartridges that are installed in the replacement strainer modules at BVPS-1. The prototype strainer array included perforated seal plates, that is, side plates. However, for Test 1C through Test 6, the side plates were blocked off. Tests 1, 1A, and 1B were performed with the side plates open to flow and resulted in significant clean screen area on the side plates. Therefore, for subsequent testing, the side plates were blocked off to force all debris through the ends of the pockets of the array. The 1/16 inch screen opening size represented the full scale size.

Omega pressure transmitters were used for head loss measurements of water. The same type of transmitters were used for pressure measurement across the orifice plate as well as the plenum and strainers, but each system is completely separated. Two ranges for each system overlap to ensure the differential pressure signal is uninterrupted during testing of low and high differential pressure. Omega quick disconnect temperature transducers were used. A Hach turbidity meter was installed in-line on the return side of the pump to monitor the water that had already flowed through the strainers (downstream of the sump). Monitoring the downstream turbidity aids in observing the filtering effects of the debris bed. This monitoring was for information purposes only. Two sets of strainer pressure transmitters, orifice plate pressure transmitters, and thermocouples were used during the testing to obtain redundant measurements. A pH meter and probe were used to measure the pH of the water in the tank throughout testing. The pH was recorded but not controlled. The data collected by the electronic transducers was recorded by an automatic data acquisition system controlled by LabVIEW Version 7.0 software. Time history plots of differential pressure, flow rate (and approach velocity based on the strainer effective screen area), temperature, and turbidity were visible on the monitor of the computer that supported the LabVIEW software.

The required maximum flow rate was 360 gallons per minute through the 76.60 square foot prototype strainer array. The water temperature was maintained above 80°F during the course of the tests.

BVPS-2 Test Configuration

The prototype top-hats used in testing were double top-hats 33 inches in length with a 17.5 inch square base plate arranged in a 2 by 3 array. The screen opening size, 3/32 inch, represented the full scale size. Walls were installed on three sides of the array to simulate adjacent top-hats next to the array. The front of the array was located in close proximity to the tank wall which is representative of a fourth wall. All top-hats (with the exception of Test 1N and Test 3N) that were tested were equipped with the Debris Bypass Eliminator designed to capture fibrous debris that is not captured on the surface of the strainer and minimize potential downstream effects.

The prototype array was placed in a large test tank approximately 6 feet tall, 6 feet wide, and 10 feet long. Flow was routed from the tank sparger inlet, through the strainer/plenum assembly, and out through the side flow outlet channel (side suction). The flow rate through the strainer array was controlled by throttling of the control valve on the return line to the tank or through the adjustment of a variable frequency drive (VFD) on the pump motor.

Omega pressure transmitters were used for head loss measurements of water. The same type of transmitters were used for pressure measurement across the orifice plate as well as the plenum and strainers, but each system is completely separated. Two ranges for each system overlap to ensure the differential pressure signal is uninterrupted during testing of low and high differential pressure. Omega quick disconnect temperature transducers were used. A Hach turbidity meter was installed in-line on the return side of the pump to monitor the water that had already flowed through the strainers (downstream of the sump). Monitoring the downstream turbidity aids in observing the filtering effects of the debris bed. This monitoring was for information purposes only. Two sets of strainer pressure transmitters, orifice plate pressure transmitters, and thermocouples were used during the testing to obtain redundant measurements. The data collected by the electronic transducers was recorded by an automatic data acquisition system controlled by LabVIEW Version 7.0 software. Time history plots of differential pressure, flow rate (and approach velocity based on the strainer effective screen area), temperature, and turbidity were visible on the monitor of the computer that supported the LabVIEW software.

The required maximum flow rate for the 2 by 3 array was 762 gallons per minute through the 157.5 square foot prototype array. The water temperature was maintained above 80°F during the course of the tests.

Debris Preparation

The debris for BVPS-1 and BVPS-2 testing was prepared as follows:

NUKON®

Although the following discussion applies to the preparation of NUKON® debris at both BVPS-1 and BVPS-2, a separate size distribution was applied to BVPS-2 since the debris generation calculation identifies a distribution of 20 percent fines and 80 percent small pieces. The distribution in the BVPS-2 testing assumed 50 percent fines and 50 percent small pieces which adequately bounds the size distribution contained in the debris generation calculation.

NUKON® fiberglass sheets were shredded. The shredded fiber was inspected to ensure that it met the size distribution requirements that are defined in NUREG/CR-6808 and then weighed out. Batches of shredded fiber were wetted, placed in a blender, and mixed for at least one minute. Then, the fiber was boiled in water for at least 10 minutes to remove binder. The boiled fiber was put into a bucket with water at a temperature within plus or minus 10°F of the water used for testing. Prior to adding to the test tank, the fiber was mixed thoroughly, with a paint mixer attached to an electric drill, to form a homogeneous slurry. The small pieces were boiled directly after being weighed and were not blended.

Temp-Mat™

As was done for NUKON®, a size distribution more conservative than what was contained in the BVPS-1 and BVPS-2 debris generation calculations was applied. For BVPS-1, the debris generation calculation identified a size distribution of 20 percent fines and 80 percent small pieces while the testing assumed 100 percent fines. For BVPS-2, the debris generation calculation also identified a size distribution of 20 percent fines and 80 percent small pieces while the testing applied a 50 percent fines and 50 percent small piece size distribution.

Temp-Mat™ fiberglass sheets were shredded. The shredded fiber was inspected to ensure that it met the size distribution requirements that are defined in NUREG/CR-6808 and then weighed out. Batches of shredded fiber were wetted, placed in a blender, and mixed for at least one minute. Then, the fiber was boiled in water for at least 10 minutes to remove binder. The boiled fiber was put into a bucket with water at a temperature within plus or minus 10°F of the water used for testing. Prior to adding to the test tank, the fiber was mixed thoroughly, with a paint mixer attached to an electric drill, to form a homogeneous slurry. The small pieces were boiled directly after being weighed and were not blended.

Calcium Silicate Insulation

Cal-Sil material used for testing was IIG Thermo Gold (received in powdered form). The required amount of particulate was weighed out and placed in a bucket of water at a temperature within plus or minus 10°F of the temperature of the water used for testing. This particulate was then mixed thoroughly, with a paint mixer attached to an electric drill, to form a homogeneous slurry.

Min-K™

Min-K™ manufactured by Thermal Ceramics was used for testing. The Min-K™ was in powder form. The required amount of particulate was weighed out and placed in a bucket of water at a temperature within plus or minus 10°F of the temperature of the water used for testing. This particulate was then mixed thoroughly, with a paint mixer attached to an electric drill, to form a homogeneous slurry.

Silica Sand

Silica sand prepared by Performance Contracting, Inc. was used as a surrogate material for latent dirt and dust debris. The size distribution of the silica sand was prepared to be consistent with the latent dirt/dust size distribution provided in the SE (Reference 17).

Testing was designed and performed (including the preparation of chemical precipitates) in accordance with WCAP-16530-NP and March 2008 NRC Staff Review Guidance. Additional criteria of "PWR Owners Group, New Settling Rate Criteria for Precipitates Generated in Accordance with WCAP-16530-NP (PA-SEE-0275)," (OG-07-270) was utilized in the BVPS-1 testing. Additional information on chemical effects testing can be found in the response to Review Area 3.o, "Chemical Effects," of this response write-up.

BVPS-1 Head Loss Results

Test 6 represents the final configuration for BVPS-1, based on planned insulation modifications, and bounds the BVPS-1 loop break, BVPS-1 reactor vessel nozzle break and surge line break debris loads plus WCAP predicted chemical precipitates.

The head loss test results for this case at an approach velocity of 0.0105 ft/sec, corrected for the temperatures, are shown in Table 3.f.4-5.

Table 3.f.4-5

Correction Temperature (°F)	Temperature Corrected Head Loss (ft-water)
65	3.26
100	2.91
150	2.66
180	2.55
212	2.46

Note: The above table reports head loss values at test termination.

BVPS-2 Head Loss Results

The final configuration for BVPS-2 is represented by two tests, based on planned insulation modifications. Test 1A represents the loads from a BVPS-2 loop break and a surge line break. Test 5 represents the head loss for the reactor vessel nozzle break and bounds the maximum allowable Microtherm® debris load. Both tests include the predicted chemical precipitates.

The head loss test results for Test 1A at an approach velocity of 0.0108 ft/sec, corrected for the temperatures, are shown in Table 3.f.4-6.

Table 3.f.4-6

Correction Temperature (°F)	Temperature Corrected Head Loss (ft-water)
65	7.44
100	6.19
150	5.32
180	4.98
212	4.71

The head loss test results for Test 5 at an approach velocity of 0.0104 ft/sec, corrected for the temperatures, are shown in Table 3.f.4-7.

Table 3.f.4-7

Correction Temperature (°F)	Temperature Corrected Head Loss (ft-water)
65	8.41
100	5.68
150	3.85
180	3.18
212	2.68

Note: The above tables report head loss values at test termination.

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

FENOC Response

As discussed in the response to Review Area 3.f.4, BVPS-1 and BVPS-2 were tested to find a debris load that resulted in acceptable head losses. Insulation will be replaced to achieve this acceptable debris load.

Test 6 represents the final configuration for BVPS-1 and bounds the BVPS-1 loop break, BVPS-1 reactor vessel nozzle break and surge line break debris loads plus WCAP predicted chemical precipitants (that also bounds the BVPS-1 loop and the BVPS-1 reactor vessel nozzle breaks).

The final configuration for BVPS-2 is represented by two tests and assumes the completion of insulation modifications. Test 1A represents the loads from a BVPS-2 loop break and a surge line break. Test 5 represents the head loss for the reactor vessel nozzle break and bounds the maximum allowable Microtherm® debris load.

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

FENOC Response

For BVPS-1, the final tested configuration (Test 6) represents the assumed plant condition following planned insulation modifications. The resultant head loss and the high stable turbidity indicated that the amount of material was likely not enough to completely coat the strainer. The associated flow sweep data indicated that the flow was not adequate to cause a collapse of the thin amount of debris on the strainer. Therefore, testing demonstrated that the debris loads from this final configuration (Test 6) are small enough that a thin bed will not form.

For BVPS-2, the final tested configuration was represented through two tests, Test 1A and Test 5. These tests also represent the assumed plant conditions following planned insulation modifications. The resultant head loss values indicate that a partial thin bed was potentially formed, resulting from the additional contribution of the particulates and chemical precipitates. However, these head loss values were low enough to accommodate this potential partial thin bed formation.

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

FENOC Response

The debris head loss, including chemical effects head loss, is added to the strainer flow head loss to determine the total head loss across the sump strainers due to post-LOCA debris. The response to Review Area 3.f.10 contains further discussion of the BVPS-1 and BVPS-2 strainer head loss.

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

FENOC Response

Head loss calculations for BVPS-1 are based upon test data for the maximum head loss from the breaks selected, and use the NEI 04-07 methodology for determining the maximum sump debris load.

The BVPS-1 testing was done to conservatively represent the maximum possible head loss associated with the tested debris loads. As recommended by NRC staff review guidance (March 2008), all particulate debris (Cal-Sil, Min-K™, coatings surrogates, dirt/dust) was added first. NUKON® and Temp-Mat™ fiber fines were prepared using a blender in order to create very fine pieces of debris. The percentage of Temp-Mat™ fiber fines versus Temp-Mat™ fiber small pieces bounded what is expected at BVPS-1. For the final bounding test, 100 percent of the unqualified/chips coatings load was added as both ground silica and paint chips. In the WCAP Chemical Product Formation Report, it was assumed that 100 percent of the aluminum paint will combine with other materials to create the maximum precipitate possible. Since the final ratio of sodium aluminum silicate to aluminum oxyhydroxide is not known, both precipitates were assumed to be the maximum which can be generated by the specified amount of aluminum paint. These values were conservatively combined with the precipitates predicted by the spreadsheet which was run without the aluminum paint. Extra quantities of sodium aluminum silicate and aluminum oxyhydroxide, equivalent to an additional 10 percent each, were added to allow for increased margin.

Testing was performed for the purpose of determining the susceptibility of the BVPS-1 strainer array to vortexing. The tank was filled with water to 1 inch above the top of the strainer (33.5 inches). The approach velocity was set to 0.01 ft/s (approximately 360 gallons per minute). The approach velocity was increased in 0.005 ft/s increments, up to approximately 600 gallons per minute. At each velocity, a minimum of 10 minutes was allowed for a vortex to form. Visual observations were noted for each flow and recorded in the test log. No vortexing at any of the velocities was observed. There are more possibilities of vortexing when the surface of water is closer to the top of the strainer. A similar process was then used to test a reduced water level at the top of the strainer (32.5 inches) to explore any possible vortexing. However, other than dimples on the surface of water, no vortexing was observed. At BVPS-1, the maximum approach velocity is 0.01 ft/s and the minimum submergence above the strainer modules is 2.2 inches. Therefore, the vortex testing bounded worst case plant conditions. Additionally, during the prototype testing, visual observations to ensure that no significant vortices are formed during the clean screen strainer test and flow sweeps, as well as throughout the testing, were performed. None were observed.

As with BVPS-1, head loss calculations for BVPS-2 are based upon test data for the maximum head loss from the breaks selected, and use the NEI 04-07 methodology for determining the maximum sump debris load.

The BVPS-2 testing was done to conservatively represent the maximum possible head loss associated with the tested debris loads. As recommended by NRC staff review guidance (Reference 12), all particulate debris (Cal-Sil, Min-K™, Microtherm® coatings surrogates, dirt/dust) was added first. NUKON® and Temp-Mat™ fiber fines were prepared using a blender in order to create very fine pieces of debris. The percentage of Temp-Mat™ fiber fines versus Temp-Mat™ fiber small pieces bounded what is expected at BVPS-2. For all testing, 100 percent of the unqualified/chips coatings load was added as both ground silica and paint chips. Extra quantities of sodium aluminum silicate and aluminum oxyhydroxide, equivalent to an additional 10 percent each, were added to allow for increased margin.

Testing was performed for the purpose of determining the susceptibility of the BVPS-2 strainer array to vortexing. The test was conservatively perfomed without the vortex suppression grating that is installed above the top-hats. A 2 by 1 strainer array was used for the test. The tank was filled with water to 2.5 inches above the top of the strainer. The approach velocity was set to 0.01 ft/s (approximately 254 gallons per minute). The approach velocity was increased in 0.005 ft/s increments, up to an approach velocity of 0.020 ft/s. At each velocity, a minimum of 10 minutes was allowed for a vortex to form. Visual observations were noted for each flow and recorded in the test log. No vortexing at any of the velocities was observed. There are more possibilities of vortexing when the surface of water is closer to the top of the strainer. A similar process was then used to test a reduced water level at the top of the strainer (1.5 and 0 inches above the top-hat) to explore any possible vortexing. However, other than slight dimples on the surface of water, no vortexing was observed. At BVPS-2, the maximum approach velocity is 0.0108 ft/s and the minimum submergence above the strainer modules is approximately 16.6 inches. Therefore, the vortex testing bounded worst case plant conditions. Additionally, during the prototype testing, visual observations to ensure that no significant vortices are formed during the clean screen strainer test and flow sweeps, as well as throughout the testing, were performed. None were observed.

Microtherm® loading was an additional consideration for BVPS-2. Testing demonstrated that the Microtherm® particulate load combined with the sodium aluminum silicate and aluminum oxyhydroxide chemical precipitates can result in high head loss. However, the testing protocol assumed that the entire amount of Microtherm® insulation that was destroyed by the break was transported to the screen, which contributes to the non-chemical debris bed head loss. Additionally, the WCAP Chemical Product Formation Report assumes that the silica dissolves from the entire amount of Microtherm® insulation that was destroyed by the break and is available to produce sodium aluminum silicate, which contributes to the chemical debris bed head loss. In reality, both phenomena cannot happen at the same time.

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

FENOC Response

BVPS-1

The clean strainer head losses are calculated utilizing standard industry flow resistance coefficients. For BVPS-1 the head loss in the connection duct between the strainer rows and the suction box and the head loss in the suction box itself are determined by Computational Fluid Dynamic (CFD) calculation.

The internal flow in the inside strainer structure has four main head loss regions: the head loss in the axial flow channel between the cartridges, the head loss in the duct between strainer sections, the head loss in the connection duct between the strainer rows and the suction box, and the head loss in the suction box itself.

The axial flow channel head loss is calculated in four parts:

- Head loss due to inflow from the side (that is, from the cartridges)
- Friction drag head loss
- Head loss due to constrictions of the flow path

- Head loss caused by obstructions in the flow channel (stabilizer plates)

The assumptions made include:

- The clean head loss of the cartridges themselves is negligible because the velocities in the screen holes and the cartridge channels are comparatively very low.
- The density of water for these head losses is taken at the low (conservative) temperature of 25°C (77°F); density of water equal to 997 kg/m^3 (62.2 lbm/ft^3).
- Coefficient of friction of 0.025 is used as a conservative value for high Reynolds numbers, and a relative roughness of 0.001 was applied for the smooth stainless steel surfaces.

As stated above, since the head loss in the duct between the strainer rows and the suction box and in the suction box itself cannot be easily evaluated by hand calculations, a CFD calculation has been performed. The CFD calculation program utilized was ANSYS CFX.

The clean strainer head loss for BVPS-1 is 1.800 feet of water at a flow rate and temperature of 14,500 gallons per minute and 100°F.

BVPS-2

The clean strainer head loss is calculated based upon steady, incompressible flow using standard industry flow resistance coefficients.

The internal flow in the strainer structure has two main head loss regions: the head loss in the top-hat strainers, and the head loss through the flow channels that direct flow from the strainers to the sump area containing the pump suction pipes. Head loss testing includes the head loss from the top-hat strainers and debris bypass eliminator.

Flow is directed to the sump area in channels separated from each other by perforated plate. The flow channel head loss is calculated for each node of the flow channel in three parts:

- Friction drag head loss
- Head loss due to constrictions and expansions of the flow path
- Head loss caused by obstructions in the flow channel

The friction factor is calculated for each section of the strainer assembly based upon the flow in each section. The average channel head loss is used as the strainer head loss.

The assumptions made include:

- The density of water for these head losses is taken at the low (conservative) temperature of 60°F; density of water equal to 62.4 lbm/ft^3.
- The effective roughness of commercial steel pipe is used for the all-stainless steel portions of the strainer and an average of commercial steel and concrete is used for flow channels bounded by the containment floor.
- Flow through the strainer is assumed to be uniform and normalized over each of the top-hats.
- The flow resistance for flat perforated plate is assumed to be applicable to the curved perforated plate on the strainers, as the curvature is small relative to the hole size.

The clean strainer head loss for BVPS-2 is 0.756 feet of water at a flow rate of 13,636 gallons per minute.

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

FENOC Response

To determine the BVPS-1 sump strainer head loss, two separate factors are considered:

- Strainer inlet plenum head loss
- Debris bed/strainer module head loss

These factors are developed in a single calculation. The factors are developed and established as inputs to the Modular Accident Analysis Program - Design Basis Accidents (MAAP-DBA) integrated containment analysis code, where the head loss is dynamically calculated based on the changing flow rate and temperature of the water flowing through the RSS.

The factors used in the MAAP-DBA code to develop the debris bed/strainer module head loss are calculated in the BVPS-1 Reactor Building Sump Strainers Head Loss Calculation. This calculation develops head loss based upon strainer flow and temperature.

The flow dependent head loss correlation is based on the maximum head loss from the several debris mixes tested in the prototype strainer. These debris loads were tested at the maximum sump flow rate. The flow in the debris bed is mostly turbulent. The flow within the strainer channels is turbulent. The mixture porosity and the actual packing density are assumed to be constant; this is conservative for scaling to higher temperatures. So, the tested head loss is scaled proportionally to the temperature-dependent viscosity and density of the water. The debris bed head loss was added to the internal strainer losses.

The following table shows the resulting head loss at the maximum expected sump flow rate for various temperatures:

Table 3.f.10-1
Total Debris and Strainer Head Loss
BVPS-1

Temperature (°F)	Head Loss (ft.)
65	5.08
100	4.72
150	4.46
180	4.34
212	4.25

Note: Head loss values presented in Table 3.f.10-1 include the debris head loss and clean screen head loss.

To determine the BVPS-2 sump strainer head loss, two separate factors are considered:

- Strainer manifold head loss and,
- Debris bed/strainer top-hat head loss

These factors are developed in separate calculations. The manifold head loss is calculated using standard engineering techniques and quantifies the expected head loss through the manifold which holds the strainer top-hats. The calculated value represents the expected head loss from the discharge of the top-hats to the pump suction inlet pipes. This value is adjusted for the actual sump flow in the MAAP-DBA code to determine the run specific manifold head loss.

The top-hat and debris head loss is added to this manifold head loss to arrive at the total head loss upstream of the pump suction inlet piping. The top-hat and debris head loss is based on prototype testing with the plant specific debris loading including chemical effects.

The following table lists the head loss at the maximum expected sump flow rates for various temperatures. These values represent the composite maximum head loss from both the loop break and the nozzle break. The head loss for a specific case is adjusted on a transient basis for the actual sump strainer flow and temperature in the MAAP-DBA code for use in calculating available NPSH.

Table 3.f.10-2
Total Debris and Strainer Head Loss
BVPS-2

Temperature (°F)	Head Loss (ft.)
65	12.26
100	8.53
150	6.48
180	5.90
212	5. 45

Note: Head loss values presented in Table 3.f.10-2 are extrapolated values to 30 days and include the clean screen head loss. Method of extrapolation is discussed in in the response to Review Area 3.o.2.17. The reported values are for all four RSS pumps running. One of the pumps will be shutdown to lower the flow (and head loss) when lower containment pressure occurs and colder temperatures occur in the sump. This is due to structural considerations of the strainer.

3.f.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.***

FENOC Response

The new BVPS-1 and BVPS-2 sump strainers will be fully submerged for all LOCA scenarios. On BVPS-1, a potential vent path was identified in the quench spray piping to the suctions of the pumps drawing from the containment sump. To ensure that this did not provide a vent path to the sump, a design modification was implemented to ensure that a water-filled loop seal prevented the introduction of air. Because the strainers are fully submerged, no additional failure criteria other than NPSH margin was needed. There were no potential vent paths identified for BVPS-2.

3.f.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.***

FENOC Response

No near-field settling effects were credited for BVPS-1 or BVPS-2 head-loss testing.

3.f.13 ***State whether temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. If scaling was used, provide the basis for concluding that boreholes or other differential-pressure induced effects did not affect morphology of the test debris bed.***

FENOC Response

Regarding BVPS-1, based on the approximately 3 foot of water head loss that occurred during testing, and the high and stable turbidity, it is reasonable to assume that the 0.05 inches of fibrous debris, along with the paint chips and chemical precipitates, was most likely not enough material to completely coat the strainer. Such a thin bed cannot compress very much, and the flow increase was not adequate to cause a collapse from the low to high flow rates. Such uniform behavior suggests that the strainer was not completely covered with a debris bed. Given the small amount of fibrous debris, a lack of complete debris bed coverage is a reasonable conclusion.

The theoretical equivalent bed thickness of the fibrous debris in BVPS-2 was found to be 0.07 inches for Test 1A and 0.05 inches for Test 5. Visual observation of the debris beds indicated that this theoretical equivalent bed thickness is not enough to completely coat the strainer with fibrous debris. Given the small amount of fibrous debris used in testing, a lack of complete debris bed coverage is a reasonable conclusion.

Temperature corrections were performed for the final representative test configurations for both BVPS-1 and BVPS-2. These corrections were performed at 65°F, 100°F, 150°F, 180°F and 212°F using laminar and turbulent ratios. Curves were then fitted to the data points for each temperature, in order to prove an equation for calculation of the head loss at a specific approach velocity.

3.f.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.***

FENOC Response

Containment accident pressure has been credited in evaluating whether flashing would occur across the strainer. Analyses have been performed for BVPS to evaluate the potential for flashing and air evolution throughout the system. For each large break LOCA case, a minimum of four points in time are evaluated. These are at RSS pump start, at the point of minimum sump sub-cooling, after transfer to safety injection recirculation, and when containment pressure is at a minimum. These have been established as the critical times based on the sensitivity of the analysis. Small break LOCA scenarios which have minimum submergence have been evaluated. These evaluations have been completed for BVPS-1 and BVPS-2, and show acceptable results, i.e, no flashing is expected and air void fraction is less than 2 percent.

The containment pressure is determined using the MAAP-DBA code as part of the NPSH evaluations. The methodology utilized to minimize sump sub-cooling by maximizing sump temperature while minimizing containment pressure is described in the response to 3.g.14.

The BVPS-1 analyses predict a potential for some minor flashing to occur across the strainer for a brief period of time shortly after the RSS pumps start. However, the analyses conservatively use the strainer head loss considering the full debris bed and the effect of chemical precipitates. Since it is unlikely that a full debris bed will be established within minutes following pump start and the chemical precipitates are a longer term process, no flashing is expected to occur. Additionally the RSS pumps are provided with cooling flow from the Quench Spray system in the suction lines which will condense any steam bubbles formed in the strainer. The BVPS-2 analysis predicts no flashing will occur.

A void fraction of less than 2 percent at the pump inlet is considered acceptable. The maximum void fraction calculated for a BVPS-1 break is 0.21 percent, while the maximum void fraction calculated for a BVPS-2 break is 0.23 percent. Both cases are acceptable and provide adequate margin. In both cases, this voiding occurs as the flow passes through the debris bed and inner channels. The maximum void fraction predicted at the actual pump inlet connection is 0.03 percent. The reduction is due to a higher static pressure at this location resulting from a decrease in the flow velocity and an increase in the static head. Applying the correction factor from Regulatory Guide 1.82 Revision 3 with this low void fraction will result in an insignificant change in required NPSH (< 2 percent).

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. Responses are presented below pertaining to strainer debris head loss at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed by the specific response.

RAI #42 (from Reference 6)

What is the minimum strainer submergence during the postulated LOCA? At the time that the re-circulation starts, most of the strainer surface is expected to be clean, and the strainer surface close to the pump suction line may experience higher fluid flow than the rest of the strainer. Has any analysis been done to evaluate the possibility of vortex formation close to the pump suction line and possible air ingestion into the ECCS pumps? In addition, has any analysis or test been performed to evaluate the possible accumulation of buoyant debris on top of the strainer, which may cause the formation of an air flow path directly through the strainer surface and reduce the effectiveness of the strainer?

FENOC Response

The minimum strainer submergence during the postulated LOCA is discussed in response to Review Area 3.f.2.

No specific analyses were developed for vortexing. The BVPS-1 and BVPS-2 strainers have been tested to prove that no vortexes will compromise the performance of the strainers. All testing showed no vortex formation. The strainer testing conditions were defined to bound the design and operating ranges (high flow and low submergence). A discussion of the testing for vortexing is included in response to Review Area 3.f.8. No vortex formations were observed.

No analysis or test has been performed to evaluate the effects of possible accumulation of buoyant debris on top of the BVPS-1 and BVPS-2 sump strainers. This accumulation is not a concern with the Beaver Valley strainer designs. The Beaver Valley strainers draw from the sides and are fully submerged when recirculation begins. Water will not be drawn down from the top of the strainers because they are covered by solid plate. On BVPS-2, there is a gap of about five inches between the bottom of the cover and the top of the top-hat strainer units. This allows the straining surfaces on the interior of the top-hats to draw flow. However, since the water level reaches the cover plate before the strainer begins to draw water, any floating debris will be prevented from reaching the internal portions of the top-hat strainers. Therefore, floating debris, even if it were to settle on the strainer covers will not be drawn into the active strainer surfaces.

RAI #43 (from Reference 6)

As stated in the GL response, NUREG-CR/6224 correlation is considered by the licensee to be applicable to the Nukon-Calcium Silicate debris bed and is conservative.

In addition, the correlation will be used if the prototype testing indicates the possible uniform debris distribution. As stated in the NRC SE, the staff indicated that the correlation could only be used for scoping analysis for the Nukon-CalSil debris bed. Therefore, please provide justification for why the correlation can be directly applied to the new strainer design.

FENOC Response

Strainer debris head losses for BVPS-1 and BVPS-2 are based upon head loss testing with several limiting break debris mixtures. The NUREG-CR/6224 correlation was only used for scoping analyses and is not used for the strainer design basis.

3.g. Net Positive Suction Head (NPSH)

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

1. ***Provide applicable pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level.***
2. ***Describe the assumptions used in the calculations for the above parameters and the sources/bases of the assumptions.***
3. ***Provide the basis for the required NPSH values, e.g., three percent head drop or other criterion***
4. ***Describe how friction and other flow losses are accounted for.***
5. ***Describe the system response scenarios for LBLOCA and SBLOCAs.***
6. ***Describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation.***
7. ***Describe the single failure assumptions relevant to pump operation and sump performance.***
8. ***Describe how the containment sump water level is determined.***
9. ***Provide assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin.***
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.

11. ***Provide assumptions (and their bases) as to what equipment will displace water resulting in higher pool level.***
12. ***Provide assumptions (and their bases) as to what water sources provide pool volume and how much volume is from each source.***
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.***
14. ***Provide assumptions made which minimize the containment accident pressure and maximize the sump water temperature.***
15. ***Specify whether the containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature.***
16. ***Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode.***

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

FENOC Response

Tables 3.g.1-1 and 3.g.1-2 list the maximum pump flow rates, total sump flow rate, maximum sump temperatures and containment water level at RS pump start and at initiation of safety injection recirculation for each unit. Note that the limiting values are provided for each parameter; however, these values do not necessarily occur for the same set of conditions. For example, the minimum water level typically occurs for small break Loss of Coolant Accident (LOCA) events, whereas the maximum sump temperature occurs during a large break LOCA.

Table 3.g.1-1(1)

BVPS-1				
Start of Recirculation Spray Pumps				
Maximum RSS pump Flow (gpm)	Maximum LHSI Pump Flow (gpm)	Maximum Sump Flow(2) (gpm)	Max Sump Temperature (°F)	Minimum Sump Water Level(3) (Ft)
3637	Note (4)	14476	235	4.0
Safety Injection Recirculation				
Maximum RSS pump Flow (gpm)	Maximum LHSI Pump Flow (gpm)	Maximum Sump Flow(2) (gpm)	Max Sump Temperature (°F)	Minimum Sump Water Level(3) (Ft)
3637	3072	12318	207	5.0

Table 3.g.1-2(1)

BVPS-2				
Start of Recirculation Spray Pumps				
Maximum RSS pump Flow (gpm)	Maximum LHSI Pump Flow (gpm)	Maximum Sump Flow(2) (gpm)	Max Sump Temperature (°F)	Minimum Sump Water Level(3) (Ft)
3751	Note (4)	10470	217.5	6.6
Safety Injection Recirculation				
Maximum RSS pump Flow (gpm)	Maximum LHSI (RSS) Pump Flow(5) (gpm)	Maximum Sump Flow(2) (gpm)	Max Sump Temperature (°F)	Minimum Sump Water Level(3) (Ft)
3761	3685	13640	217	6.9

Notes for Tables 3.g.1-1 and 3.g.1-2:

(1) Abbreviations include gallon per minute (gpm), degrees Fahrenheit (°F), feet (Ft), recirculation spray (RS), and low head safety injection (LHSI).

(2) Total flow through containment sump strainer in gallons per minute.

(3) Level above bottom of containment sump in feet.

(4) Low Head Safety Injection pumps take suction from the RWST prior to safety injection recirculation.

(5) BVPS-2 uses 2 of 4 (1 of 2 for single train) RSS pumps for LHSI function following initiation of safety injection recirculation

At BVPS-1, two sets of pumps draw from the sump (low head safety injection and RSS). All of the pumps start automatically. An operator action is required to stop two RSS pumps prior to transfer to recirculation as discussed in the response to Review Area 3.g.6. This compensates for the increase in sump flow that takes place when the low head safety injection pumps shift to recirculation mode. The low head safety injection pump flow is limited by cavitating venturis on the pump discharge, and the recirculation pump flow is limited by the system configuration, as discussed in the response to Review Area 3.g.2.

At BVPS-2, only the RSS pumps draw from the sump. These pumps start automatically and shift to recirculation automatically. No operator action is required to set up the systems for recirculation post-LOCA or to throttle flow. The RSS pump flow is limited by the system configuration, as discussed in the response to Review Area 3.g.2, below.

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

Pump and total sump flow rate:

System schematics are provided in response to Review Area 3.f.1. The pump flow and corresponding total sump flow rates are calculated using the MAAP-DBA model based on containment and RCS conditions. System hydraulic models are used to develop response curves which define pump flow as a function of boundary conditions and system alignment. For the RSS pumps which take suction from the containment sump and deliver flow to spray headers, the boundary conditions are only dependent on the sump water level since containment pressure is the same at the suction and discharge. At BVPS-1, the four pumps have individual spray headers such that the flow per pump is not influenced by the number of pumps running. At BVPS-2, the spray headers are shared on each train such that the number of pumps running influences the flow per pump. The quench spray (QS) pumps are similarly aligned for each unit; individual spray headers are used at BVPS-1 and shared spray headers are used at BVPS-2.

For the spray systems, performance models are established to represent the maximum and minimum flow conditions. The minimum performance conditions are based on either single or two train operation with degraded pump performance and conservative system loss factors. In some cases, it is more conservative to use maximum system performance. One example is when calculating the available NPSH for the RSS pumps. Maximizing the system flow increases the suction head loss for the pumps and increases the NPSH required. Increased RS flow also increases the rate of containment de-pressurization which minimizes the containment over-pressure contribution to the available NPSH. To establish conservative maximum performance conditions, pump performance is assumed to meet the nominal reference performance curve and the system loss factors are reduced by 20 percent. This reduction applies to all form and friction losses calculated for the system including piping, fittings, and valves.

For BVPS-1, all RSS pump flow is conservatively assumed to pass through the sump strainer, though a portion of the flow that is supplied directly from the RWST via the QS system to the pump suctions bypasses the strainer.

Sump Temperature:

Containment analysis inputs are biased, which results in a conservative sump temperature. This includes parameters such as RWST temperature, accumulator temperature, containment initial temperature, pressure, volume, and relative humidity, ranges of pump flow rates based on spray and safety injection pump performance and single failures, thermal conductance properties of coatings on heat sinks, heat transfer coefficients, system start delays and initiation setpoints, RS heat exchanger performance, and service water temperature.

Because the NPSH analyses credit containment overpressure, the sump vapor pressure is important in establishing the available net positive suction head ($NPSH_a$) and higher containment sump temperatures are limiting. In addition to input biasing, the sump temperature is maximized by assuming the release streams from the double-ended RCS break are mixed. Mixing the streams directs higher enthalpy water to the sump resulting in higher sump water temperatures and lower containment pressure.

Minimum sump water level:

There are no specific assumptions associated with the calculation of the containment sump level. The level is calculated using the MAAP-DBA containment model. The containment is modeled as 17 (BVPS-2) or 18 (BVPS-1) nodes each characterizing specific containment sub-volumes. The noding is generally based on physical boundaries such as walls and floors. Some open volumes in the upper dome region are separated to capture stratification effects. The nodes are interconnected by junctions, which can pass flow from node to connected nodes. If a node is capable of capturing spray flow, this effect is included. An example of this is the refueling cavity (including the fuel transfer canal), which will hold up water from reaching the containment sump until the level in this node is high enough to overflow into openings in the refueling seal ring, which drains to the reactor cavity and then to the sump through a port in the cavity wall. The model tracks water hold up and inventory in each node throughout the transient, including the node containing the sump. The sump level is calculated using a volume versus height curve, which is derived from the physical layout of the containment floor, the sump volume, and the equipment and structures in this node which occupy space.

A distribution of spray flow which biases higher spray flow toward the center of the containment is used. This spray flow distribution is conservative since more opportunities for hold up of spray water exist in the center of containment. Spray that reaches the area outside the inner shield/crane wall can fall directly to the bottom elevations. The spray distribution is based on test data from the Carolina Virginia Tube Reactor experiments.

A spectrum of RCS break sizes was examined to capture the minimum sump level. Break sizes from 1 inch equivalent diameter to full double-ended ruptures are considered. The minimum break sizes typically result in the minimum sump level since the contribution from the RCS inventory is small and the safety injection accumulators do not inject. This is a conservative approach since the normal progression for very small break sizes would not transition to recirculation mode since the emergency operating procedures direct the operators to use secondary heat removal to cool down the RCS, refill the system and use the residual heat removal system for long term cooling.

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

FENOC Response

The required net positive suction head ($NPSH_r$) values for all pumps are based on a 3 percent reduction in head. The $NPSH_r$ values for the BVPS-1 RSS pumps and LHSI pumps are based on tests which were performed at North Anna Power Station using pumps that are hydraulically identical in design. The required NPSH values at maximum flow conditions for the pumps were determined to be 10.4 feet for the RSS pumps and 10.6 feet for the LHSI pumps. These tests also included operating the pumps at reduced NPSH conditions as low as 4 feet available NPSH. The tests concluded that the pumps were capable of operating under cavitation conditions without damage for at least one hour. The $NPSH_r$ value used for the BVPS-2 RSS pumps is 15.9 feet and is based on the original manufacturers testing. However, the BVPS-2 pumps are almost identical to the RSS pump that was tested at North Anna Power Station. The pumps use the same impeller patterns with slight variations in the diameter. BVPS-2 conservatively does not credit the reduced NPSH requirement based on the North Anna Power Station testing or operation under cavitation conditions.

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

FENOC Response

The available NPSH calculations take into account the friction and form losses in the pump suction piping. The total pump suction head loss accounts for the head loss across the debris built up on the strainer surface, the head loss through the strainer perforated plates, head loss in the ductwork which connects the individual strainer assemblies (cassettes or top-hats), head loss through the suction box covering the sump, piping losses from the sump to the pump suction well, and internal pump losses.

The head loss through the debris and strainer perforated plates is based on the results of prototypical testing. Scaled testing was performed to determine the head loss based on the plant specific debris mixture (including the effect of chemical precipitates) over a range of flows. The results are presented in the form of head loss as a function of flow and sump temperature. The head loss associated with temperatures which are different than the test medium are derived based on correcting the head loss for viscosity and density as appropriate.

The data provides input to the MAAP-DBA program in the form of correlations so that head loss can be calculated on a transient basis using the actual flow and sump temperature for a particular case.

The head loss associated with the ductwork and waterbox that connect the strainer modules to the containment sump and pump suction lines is based on conservatively calculated friction and form losses. For BVPS-1, the ductwork and waterbox were modeled using the ANSYS CFX10 CFD program to determine the head loss as a function of strainer flow. For BVPS-2, the head loss through the suction manifold was calculated using standard engineering techniques.

The head loss through the suction piping for each pump was calculated based on the actual piping layout using standard engineering techniques (for example, Crane Technical Paper 410 and the Handbook of Hydraulic Resistances). In some cases where available, pump internal losses were based on hydraulic test data, otherwise the head loss was conservatively calculated based on the pump internal configuration. The most conservative head loss is used to represent pumps that serve the same purpose. For example, at BVPS-2 the highest suction piping head loss value among the system pumps is used for all RSS pumps.

For each pump, the total head loss is calculated based on the pump and total sump flow and sump temperature. This is used along with other parameters such as sump level to calculate the available NPSH for each particular case evaluated. The minimum available NPSH is then determined based on the time dependent results for all cases.

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

FENOC Response

The containment system response to large and small break LOCAs is slightly different between the two BVPS units due to differences in the engineered safety features. For a small break LOCA, the rate of RCS depressurization will be slow and create a delay between high head safety injection (HHSI), low head safety injection (LHSI) and quench spray (QS) actuations. For a large break LOCA, rapid RCS depressurization, and concurrent containment pressurization will cause HHSI, LHSI and QS actuation early in the event. The HHSI and LHSI pumps are actuated when RCS pressure decreases to the pressurizer pressure - low setpoint. For the LHSI pumps to deliver flow to the RCS, the RCS pressure must decrease to approximately 200 psia.

At BVPS-1, the QS system (consisting of two trains) is actuated on a Containment Isolation Phase B (CIB) signal and starts injecting cool water from the RWST to dedicated quench spray ring headers in containment. The QS pumps operate only until RWST depletion, at which time the QS pumps are shut down. During QS injection, roughly 415 gallons per minute per train is diverted from the QS pump flow directly to the RSS pump suctions to provide enhancement (cooling) flow to both the inside-containment recirculation spray (IRS) pumps and the outside-containment recirculation spray (ORS) pumps. The flow split is nominally 140 gallons per minute to the IRS pumps and 275 gallons per minute to the ORS pumps. BVPS-1 possesses two IRS pumps and two ORS pumps, each with its own dedicated heat exchanger. It is the IRS and ORS system that provides containment heat removal via the IRS and ORS heat exchangers. The IRS and ORS pumps receive an initiation signal based on an RWST level low coincident with a containment pressure high-high signal and begin injecting water into a dedicated spray ring header in containment. The IRS and ORS pumps will continue to operate throughout an accident until the operators take manual actions to control the system based on containment conditions.

The safety injection system consists of two trains of pumps that initially take suction from the RWST upon receipt of a safety injection (SI) signal. Upon transfer to recirculation, the BVPS-1 LHSI pumps can inject directly into the cold legs and provide suction to HHSI pumps.

At BVPS-2, the containment and primary system responses are similar, except for the following distinctions:

1. At BVPS-2, the RSS pumps and heat exchangers are located outside containment.
2. The BVPS-2 QS system does not provide enhancement flow to the RSS pumps.
3. At BVPS-2, the LHSI pumps do not function in recirculation mode. Instead, one of the two RS systems is re-aligned to serve the low head safety injection function during hot and cold leg recirculation modes.

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

FENOC Response

The ECCS and CSS pumps for each unit consist of two QS pumps, four RSS pumps, two LHSI pumps and two out of three HHSI pumps. The pumps are arranged in two independently powered trains. The flow schematics are provided in response to Review Area 3.f.1.

Prior to initiation of safety injection (SI) recirculation:

QS pumps are operating after the containment pressure high-high setpoint has been reached and draw water from the RWST.

RSS pumps are operating after the containment pressure high-high setpoint has been reached and the RWST level low setpoint has actuated. This level setpoint is reached before actuation of the transfer to SI recirculation setpoint. The pumps can only take suction from the containment sump.

The LHSI pumps will be operating following the SI actuation signal and drawing flow from the RWST. The pumps provide injection if the RCS pressure is below the shutoff head of the pumps. Otherwise the pumps will recirculate flow back to the RWST.

The HHSI pumps will be operating following SI actuation and drawing flow from the RWST.

Following initiation of recirculation:

The QS pumps continue to operate drawing flow from the RWST until the tank is nearly empty at which time the pumps are manually shut down by the operator in accordance with the emergency operating procedures.

The BVPS-1 RSS pumps will continue to operate to provide spray flow to the RS spray headers and remove heat via the RS heat exchangers. At SI recirculation, the LHSI pumps are realigned from the RWST to the containment sump. If all four RSS pumps are operating, two of the four pumps will be shut down prior to reaching the recirculation initiation setpoint. This reduces the total strainer flow during recirculation to minimize head loss. This is a proceduralized operator action. The Emergency Operating Procedures (EOPs) for BVPS-1 will be revised to enhance the steps that shut down two RSS pumps prior to the transfer to recirculation.

The BVPS-2 RSS pumps continue to operate drawing flow from the containment sump. Two of the four RSS pumps re-align the discharge path at initiation of SI recirculation to supply flow to the LHSI header and the HHSI pump suction. The remaining pump(s) continues to supply flow to the RS spray header(s). Emergency Operating Procedures for BVPS-2 will be revised to shut down one of the RSS pumps supplying the spray headers when the containment pressure is reduced below a predetermined value. The purpose of the operator action is to reduce flow through the strainer in order to prevent head losses from exceeding the strainer structural limit at low temperatures. This is not a time critical action since it is associated with a long term action.

The BVPS-1 LHSI pumps realign the suction to draw water from the containment sump following initiation of SI recirculation. The pump discharge is also re-aligned to supply HHSI suction flow in addition to the LHSI injection path.

The BVPS-2 LHSI pumps automatically shut down following transfer to SI recirculation mode. LHSI flow is provided as described above by the RSS pumps.

The HHSI pumps at both BVPS-1 and BVPS-2 automatically realign the suction supply to receive flow from the LHSI system. The pumps continue to supply flow to the cold leg injection paths until manual switchover to hot leg injection is called for by the procedures.

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

FENOC Response

Single active failures (SAFs) were identified and analyzed for BVPS-1 and BVPS-2. The list of these SAFs is shown in Table 3.g.7-1.

Table 3.g.7-1

Single Active Failure	BVPS -1	BVPS-2
♦ CIB	X	X
♦ LHSI / SI	X	X
♦ QS	X	X
♦ EDG	X	X
♦ RELAY	X	X
CIB	One train each, QSS, RSS	
LHSI	One LHSI train or SI Train	
QS	One train of QSS	
EDG	One train each, SI, QSS, RSS, and service water failure	
RELAY	One train of RSS fails due to pump start relay failure	
X	Single active failure assumed in analysis	

The above single active failures were considered in conjunction with the containment analysis employing mass and energy release information for both hot leg and pump suction break locations.

Both BVPS units employ a single sump and a single sump strainer. The strainer is a passive device with no moving parts. There are no internal sources of failures (i.e. active failures). Passive failure of the sump / strainer also need not be considered. The replacement strainers are designed to withstand design basis earthquake loading and hydraulic loading. No pipe whip or jet impingement concerns exist in the vicinity of the strainer. There is no credible passive structural failure of the sump strainer.

The strainers were also assessed from a clogging perspective. As a consequence of a LOCA, the debris generated and transported to the sump will not impede flow to the recirculation pumps. Head loss testing conducted on the strainers, demonstrated that the head loss is low enough to meet NPSH requirements. For BVPS-2, this accounts for the proposed 2R14 insulation modifications. In addition, the BVPS-2 strainer employs an internal perforated plate which allows communication between the two channels of strainers. This perforated plate is not subject to clogging as discussed in section 3.j-1.

Single failures relevant to pump operation and sump performance were reviewed and are discussed below.

In the case of BVPS-1, the four RSS pumps automatically start following containment pressure high-high setpoint actuation and when an RWST level low (approximately 28 feet) has been reached. Two of the four RSS pumps are required to be manually shut down prior to transfer to SI recirculation. This provides for a total of four pumps drawing off of the sump strainer (two RSS pumps and the two LHSI pumps). Single failures could occur that would render the inability to shut down one or two RSS pumps from the benchboard. For example, if a control switch were to fail, one pump would not be able to be shut down from the control room. Under a failure of CIB to reset or a DC bus failure, two pumps associated with one train of RSS would not be able to be shut down from the control room. Under these conditions, operators would be required to take additional action to secure one or two of the other operating pumps. The EOPs for BVPS-1 will be revised to enhance the steps that shut down two RSS pumps prior to the transfer to recirculation.

In the case of BVPS-2, the four RS pumps automatically start following containment pressure high-high setpoint actuation and when an RWST level low (approximately 33 feet) has been reached. For BVPS-2, the LHSI system is arranged differently. The LHSI pumps draw water from the RWST and are not designed to realign to the sump following transfer to recirculation. At transfer to recirculation, and with all four RSS pumps operating, two of the RSS pumps will be automatically realigned to supply the LHSI header. The other two RSS pumps will continue to provide flow to the spray headers. Following progression of the event, and when the containment pressure is reduced below a predetermined value (and sump temperature has cooled significantly), one of the two RSS pumps supplying the spray header will be shut down.

Single failure considerations related to pump operation and sump performance for BVPS-2 were also reviewed. A single failure of the LHSI pumps to stop upon transfer to recirculation does not impact sump performance. The pumps would continue to operate, but by design, do not draw water from the sump. Sump performance therefore is not impacted.

The other single failure considered for BVPS-2 is if one of the pumps supplying the spray header cannot be shut down from the control room. The operators would be directed to take other action to secure the pump or could secure the other operating pump. This is not a time critical action since it is associated with a long term action.

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

FENOC RESPONSE

The calculation of the sump level is integral with the transient NPSH analysis. This is done using the MAAP-DBA multiple node model, which tracks the distribution and holdup of water in all containment nodes where this can occur. The volume of water in the containment sump is determined from the net mass of water in the lower containment node. The net mass is calculated from the mass of water flowing into the containment sump minus the mass of water that is pumped out of the sump following startup of the RSS pumps. From the predominant pressure and temperature of water in the containment sump, the mass of water in the sump is converted into volume. A volume versus height lookup function is then used to calculate the level in the sump, which is then used in the available NPSH calculation.

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

FENOC Response

The available NPSH calculations were performed using the following assumptions to ensure a minimum containment sump water level is used in determining NPSH margin:

1. The NPSH calculations use the minimum mass of RWST water that must be injected prior to RS initiation and safety injection recirculation.
2. Inventory from the chemical addition system is not included in the sump inventory.
3. The NPSH calculations use a multi-node containment model with non-uniform spray distribution to allow additional spray water to be collected and held up in the refueling canal, reactor cavity, and on various horizontal platforms inside the containment.

3.g.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.***

FENOC Response

Containment spray is the major source of water supplied to the containment sump. Of spray water exiting the spray header in the containment dome, 11 percent is intercepted by the annulus outside the crane wall and 89 percent is intercepted by the crane wall and everything inside it (e.g., the refueling canal and platforms or floors at various elevations). The 11 percent portion that falls through the annulus is allowed to directly fall into the lower containment sump. Only 5 percent of the 89 percent portion that falls within the crane wall is allowed to fall directly to the lower containment sump without being intercepted by any platforms.

For BVPS-1, the major hold-up of spray water is in the refueling canal, which can hold water up to 1818 cubic feet before it overflows through open hatches in the refueling ring seal and then accumulates in the reactor cavity from which it can flow through a drain to the lower containment where the ECCS recirculation sump is located. Up to 139,000 pounds of water can be trapped in the reactor cavity before overflow to the lower containment can occur. The refueling canal holds about 33,700 pounds of water at the time of RS initiation for a limiting single active failure emergency diesel generator (EDG) case. The operating deck floor holds about 12,600 pounds of water at this time. About 9,230 pounds of water are held up on various platforms in the loop compartments. BVPS-2 results are similar.

The hold-up in the RS piping between the pump suction piping and the spray header is accounted for and embedded mechanistically in the calculations. The hold-up mass of 70,160 pounds for BVPS-1 is estimated from a fill time of 73 seconds at a flow rate of 3.46×10^6 pounds per hour (lbs/hr). For BVPS-2, the hold-up water mass is 80,170 pounds.

The calculations do not account for the following water hold-up:

- Water hold-up in the airborne spray droplets for paths that provide no water hold-up prior to reaching the containment sump.
- Water hold-up in the condensate films on containment wall and containment dome.
- Water required to fill the empty spray pipe and spray header for the quench spray system.

The combined effect of water hold-up that is not accounted for in the sump level and NPSH calculations is a net decrease of approximately 0.35 inches for both BVPS-1 and

BVPS-2. This small change is not significant in terms of the overall accuracy of the analyses which establish the available NPSH or sump strainer submergence levels.

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

FENOC Response

The containment sump water level is calculated using a height versus net free volume table that characterizes in detail the relationship between the heights measured from the bottom of the containment sump and its corresponding net free volume in the containment sump which extends from elevation 690 feet 11 inches to elevation 692 feet 11 inches. The height versus net free volume table also includes volume of the lower containment from elevation 692 feet 11 inches to elevation 718 feet 6 inches so that a continuous water level above the containment sump is calculated. The height versus net free volume look-up table for the containment sump takes into account the displacement by miscellaneous equipment present in the sump depending on its size and location. For the lower containment above the sump, the displacement by the following objects are taken into account in calculating the net free volume at various heights by subtracting these object volumes from the gross volume: reactor cavity (modeled as a separate node), keyway, keyway wall, cavity wall, floor support columns, crane wall support columns, miscellaneous concrete walls, accumulators and miscellaneous equipment, Containment Air Recirculation fans and duct work, containment purge vents, containment elevator, structural steel, piping, and supports. The inclusion of equipment volumes that displace sump water is based on the physical location and makeup of the equipment. Equipment such as tanks, fans and ducts are only credited if it can be demonstrated that integrity will be maintained such that no sump water can occupy the interior volume.

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

FENOC Response

For both small and large break LOCAs, the water sources available to participate in the NPSH calculations outside of the primary system inventory released via the LOCA comes from only two other sources: the RWST and the cold leg accumulators.

For the available NPSH calculations, the volume of water in the RWST and the accumulators are skewed to their minimum values (Technical Specification minimums) in order to minimize water volume in the containment sump. These volumes are shown in Table 3.g.12-1.

Table 3.g.12-1

WATER SOURCE	BVPS-1 (Gallons)	BVPS-2 (Gallons)
Accumulators water volume (Minimum)	20,043	20,694
RWST total usable volume (Minimum)	430,500	859,248
RWST volume Injected at RSS pump start (Minimum)	179,900	369,648
RWST volume Injected at SI switchover (Minimum)	317,000	411,500
RWST usable volume for QS after SI switchover	113,500	447,748

An additional inventory (4700 to 8500 gallons) is also injected from the chemical addition system. This volume is conservatively not credited for the purpose of calculating sump inventory and available NPSH. FENOC intends to retire the existing BVPS-2 chemical addition system when the sodium tetraborate system becomes operable.

Table 3.g.12-2 shows how the sources of water contribute to the sump inventory for BVPS-2 for a range of break sizes. The BVPS-1 distribution would be similar except that the RWST water source is smaller. The final condition represents the time when all inventories from the water sources have either been depleted or reached a steady state value. Typically this occurs following depletion of the RWST, which occurs over the first several hours for large breaks and longer periods for small breaks due to the lower safety injection rate. The results show that full accumulator discharge does not occur until a break size of 6 inches is reached. For the smallest breaks considered, the RCS has an increase in mass. This is due to the fact that the RCS refills following safety injection actuation and the temperature of the water is reduced from the initial condition. Capturing these effects is important in establishing the minimum sump level and containment sump strainer submergence for small break LOCA scenarios. This table lists the mass of water in pounds (lbs).

Table 3.g.12-2 Water Distribution

Break Size	Initial Mass of water in RWST	Initial mass of water in accumulators	Initial mass of water in RCS	Final mass of water in containment sump	Final mass of water in RCS	Final mass of water held up in containment volumes	Final mass of water in accumulators
Inches	lbs	lbs	lbs	lbs	lbs	lbs	lbs
1	7180000	172200	381983	6726793	464154	281000	172200
4	7180000	172200	381983	7020498	222929	282016	117438
5	7180000	172200	381983	7059667	223136	282071	83470
6	7180000	172200	381983	7115676	224162	282086	0
12	7180000	172200	381983	7100372	236769	284201	0

3.g.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.***

FENOC Response

Credit is taken for containment accident pressure in determining the available NPSH. A fully mechanistic, multi-node containment model is used to predict containment pressure.

The source of steam is from the break. Condensation to all structural heat sinks, condensation on spray droplets, and sensible heat transfer to structural heat sinks and water pools are considered in the model. A heat and mass transfer analogy based on natural convection correlations is used in the calculation. The pressure within a containment node is the sum of the partial pressures of the gas constituents, which includes both non-condensable and condensable (steam) constituents. Non-condensable gases are modeled as ideal gases. Steam is modeled as a real gas that can exist throughout the full spectrum of thermodynamic regimes: superheated, saturated, and condensing. Steam is always in thermal equilibrium with the other gas constituents since each containment node has a single freeboard gas temperature.

The gas constituents are in thermodynamic non-equilibrium with surrounding water in the containment node, which includes:

- Airborne containment spray droplets
- Film condensate on walls and structures
- Water pools (particularly in the containment sump)

Although the model is non-equilibrium, from a practical standpoint, the sprays readily achieve thermal and thermodynamic equilibrium with the local atmosphere in a containment node. This results in a steam partial pressure that corresponds to saturation pressure at the local gas temperature.

The calculated containment pressure is used along with the RS suction fluid vapor pressure, the sump level and friction losses to dynamically calculate available NPSH for each set of case inputs and single failure assumptions. This allows for capturing the minimum available NPSH, which occurs when the containment overpressure (containment absolute pressure minus sump vapor pressure) is at a minimum value.

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

FENOC Response

The following assumptions were used in the calculations to minimize pressure and maximize sump water temperature:

1. The pipe break location can have an impact on sump water temperature. For a double-ended break LOCA, different pipe break locations give different mass and energy releases. Among three postulated double-ended pipe break locations, hot leg (DEHL), cold log (DECL), and pump suction (DEPS), the DEPS break maximizes the sump water temperature because more energy is released from a DEPS break than from a DEHL break. For a DEHL break, the majority of fluid that passes through the core vents directly to the containment, bypassing the steam generators. For a DEPS break, stored energy from steam generators is also released. A DECL break is least limiting because most injected water is diverted to the break and out into the containment bypassing the core. This results in more mass release, but a considerably lower energy release into the containment.
2. The largest degree of water-steam mixing in the break flow can have an impact that minimizes containment pressure and maximizes sump water temperature. For a double-ended break where two streams of mass and energy, one from each side of the break, are discharged into the containment, a complete mixing of mass and energy between injected cold water and hot steam from the two streams before entering the containment will maximize mass and temperature of the liquid phase and minimize the amount of steam released. This approach is used for the BVPS NPSH calculations.
3. There are several plant initial containment conditions that can vary over a range of values and plant parameters that are subject to uncertainty over a range of possible values. Values of these initial conditions and plant parameters are skewed toward a maximum or minimum value of their possible ranges that result in minimizing available NPSH by minimizing containment pressure and maximizing sump water temperature. The direction of conservatism has been established by sensitivity studies. These initial conditions and plant parameters are listed in Table 3.g.14-1.

Table 3.g.14-1

BVPS-1 and BVPS-2 Input Biasing for NPSH Analysis			
Design Input Parameter	**BVPS-1 RS NPSH**	**BVPS-1 LHSI NPSH**	**BVPS-2 RS NPSH**
Containment Configuration and Initial Conditions			
Containment volume	Minimum	Maximum	Maximum
Initial containment pressure	Minimum	Minimum	Minimum
Initial containment temperature	Maximum	Maximum	Maximum
Initial containment relative humidity	Maximum	Maximum	Maximum
Steel liner to concrete gap effective heat transfer coefficient	Minimum	Minimum	Minimum
Paint thickness on carbon steel heat sinks	Maximum	Maximum	Maximum
Effective heat transfer coefficient for the paint on the carbon steel	Minimum	Minimum	Minimum
Paint thickness on concrete heat sinks	Maximum	Maximum	Maximum
Effective heat transfer coefficient for the paint on the concrete heat sinks	Minimum	Minimum	Minimum
Zinc thickness on carbon steel	Maximum	Maximum	Maximum
RWST temperature	Maximum	Maximum	Maximum

Table 3.g.14-1 (Continued)
BVPS-1 and BVPS-2 Input Biasing for NPSH Analysis

Design Input Parameter	BVPS-1 RS NPSH	BVPS-1 LHSI NPSH	BVPS-2 RS NPSH
Engineering Safeguards Actuation			
Containment high-high quench spray setpoint	Maximum	Minimum	Minimum
Start delay for quench spray	Maximum	Maximum	Maximum
Quench spray flow rate	Minimum	Maximum	Minimum
RWST mass injected prior to RS initiation	Minimum	Minimum	Minimum
Recirculation spray heat exchanger UA (BTU/hr/°F)	Maximum	Minimum	Maximum
Recirculating spray flow rate	Maximum	Minimum	Maximum
Recirculation spray heat exchanger cooling water temperature	Minimum	Minimum	Minimum
Recirculation spray heat exchanger cooling water flow rate	Maximum	Minimum	Maximum
Range of usable RWST volume prior to switchover	Minimum	Minimum	Minimum
Nitrogen gas mass (accumulator gas volume/initial pressure/initial temperature)	Minimum (Minimum/ Minimum/ Maximum)	Minimum (Minimum/ Minimum/ Maximum)	Minimum (Minimum/ Minimum/ Maximum)
MAAP-DBA Model Parameters			
Quench spray droplet diameter	Minimum	Minimum	Minimum

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

FENOC Response

Credit is taken for containment accident pressure in determining the available NPSH as discussed in response to Review Area 3.g.13.

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

FENOC Response

The NPSH Margins for the BVPS-1 large break LOCA cases analyzed, are shown below.

Table 3.g.16-1
Minimum Recirculation Spray NPSH Margins

RS Case	Single Failure	Minimum IRS NPSHa[1]	Minimum ORS NPSHa[1]	Strainer HL	NPSHr	Minimum IRS Margin[2]	Minimum ORS Margin[2]
		Feet	Feet	Feet	Feet	Feet	Feet
1L-DEHL MIN SI	EDG	24.4	23.1	1.52	10.4	12.5	11.2
1L1-DEHL MIN SI	LHSI	19.6	18.1	4.26	10.4	4.9	3.5
2L-DEHL MAX SI	None	19.4	18.1	4.27	10.4	4.8	3.4
3L-DEHL MIN SI	EDG	24.0	22.9	1.52	10.4	12.1	11.0
4L-DEHL MAX SI	None	18.9	17.8	4.27	10.4	4.2	3.1
4L1-DEHL MAX SI	QS	21.7	21.5	4.22	10.4	7.0	6.9
6L-DEPS MIN SI	EDG	18.8	19.3	1.5	10.4	6.9	7.4
6L1-DEPS MIN SI	LHSI	17.8	16.6	4.28	10.4	3.1	2.0
7L-DEPS MAX SI	CIB	17.4	16.9	1.51	10.4	5.5	5.0
7L1-DEPS MAX SI	QS	17.1	17.0	4.23	10.4	2.5	2.4
7L2-DEPS MAX SI	RELAY	19.6	18.5	1.51	10.4	7.7	6.6
7L3-DEPS MAX SI	None	18.0	17.2	4.25	10.4	3.4	2.6

Table 3.g.16-2
Minimum Low Head Safety Injection NPSH Margin

LHSI Case	Single Failure	Minimum LHSI NPSHa[1]	Strainer HL	NPSHr[3]	Minimum LHSI Margin[2]
		Feet	Feet	Feet	Feet
6L-DEPS MIN SI	EDG	16.2	2.21	10.6	3.4
6L1-DEPS MIN SI	LHSI	22.4	2.27	10.6	9.5
7L-DEPS MAX SI	CIB	21.5	2.96	8.3	10.2
7L1-DEPS MAX SI	QS	23.1	2.98	8.3	11.8
7L2-DEPS MAX SI	RELAY	18.0	2.97	8.3	6.7
7L3-DEPS MAX SI	None	23.5	3.01	8.3	12.2

Notes

1. Calculated NPSHa does not include strainer head loss
2. NPSH margin = NPSHa – Strainer HL – NPSHr
3. The NSPHr value is reduced to 8.3 feet when two LHSI pumps are operating in parallel due to a reduced flow of approximately 2500 gpm per pump

As can be seen from these tables, the limiting cases result in NPSH margins of 2.5 feet for the IRS pumps, 2.0 feet for the ORS pumps, and 3.4 feet for the LHSI pump. These margins are conservative since it is assumed that the full effect of chemical precipitates is present when the pumps initially take suction from the containment sump. As can be seen from the following figures, the minimum margin condition lasts only for a short period of time and margins increase as the containment sump level increases and the sump temperature decreases thereby increasing subcooling.

Figure 3.g.16-1 BVPS-1 RSS pump Margin and Strainer Head Loss

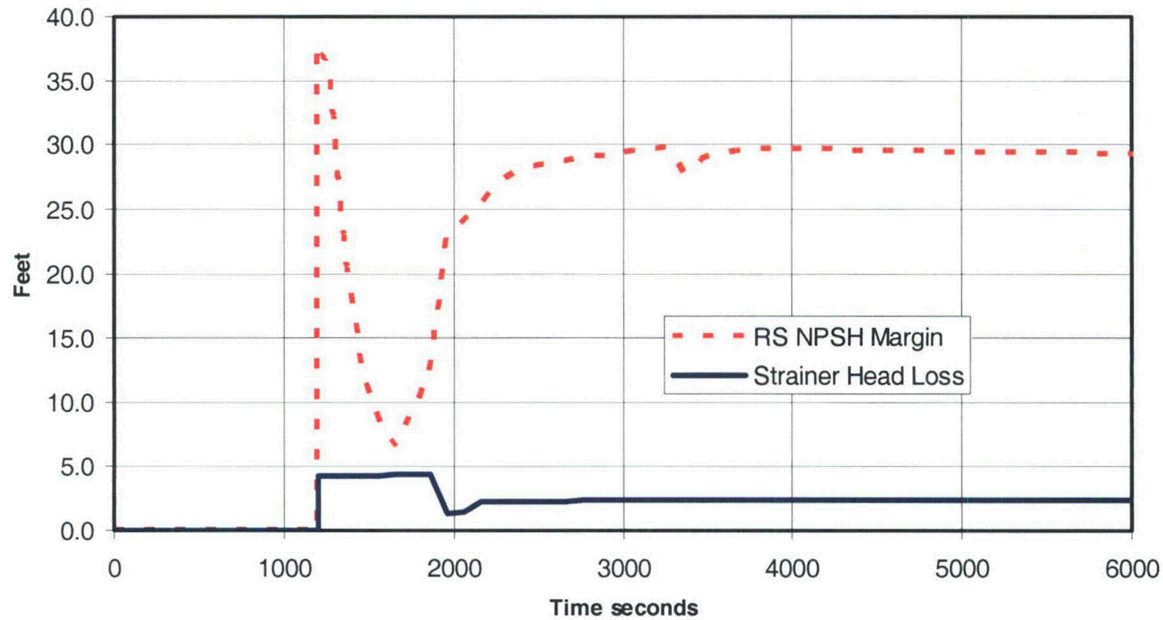
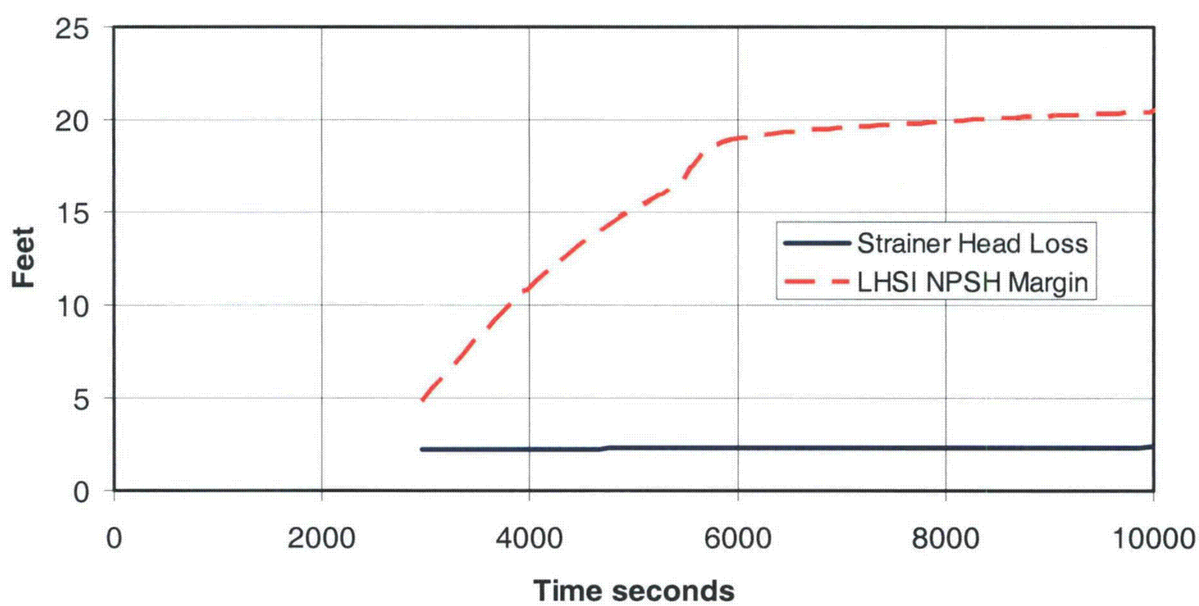


Figure 3.g.16-2 BVPS-1 LHSI Pump Margin and Strainer Head Loss



The NPSH for the BVPS-2 large break LOCA cases analyzed are shown below.

**Table 3.g.16-3:
Minimum Recirculation Spray Pump Margin**

Case	Single Failure	Minimum NPSHa[1]	Strainer HL	NPSHr	NPSH Margin[2]
		Feet	Feet	Feet	Feet
1L-DEPS MIN SI	EDG	22.0	1.83	15.9	4.3
1L1-DEPS MIN SI	SI	25.2	3.95	15.9	5.3
2L-DEPS MAX SI	CIB	26.9	1.88	15.9	9.1
2L1-DEPS-MAX SI	QS	27.0	5.81	15.9	5.3
2L2-DEPS MAX SI	RELAY	25.9	1.88	15.9	8.1
2L3-DEPS MAX SI	NONE	26.9	5.81	15.9	5.2
3L-DEHL	NONE	33.1	5.60	15.9	11.6
3L1-DEHL	QS	27.0	4.00	15.9	7.1
3L2-DEHL	RELAY	30.9	1.95	15.9	13.0
3L3-DEHL	CIB	27.8	1.87	15.9	10.0

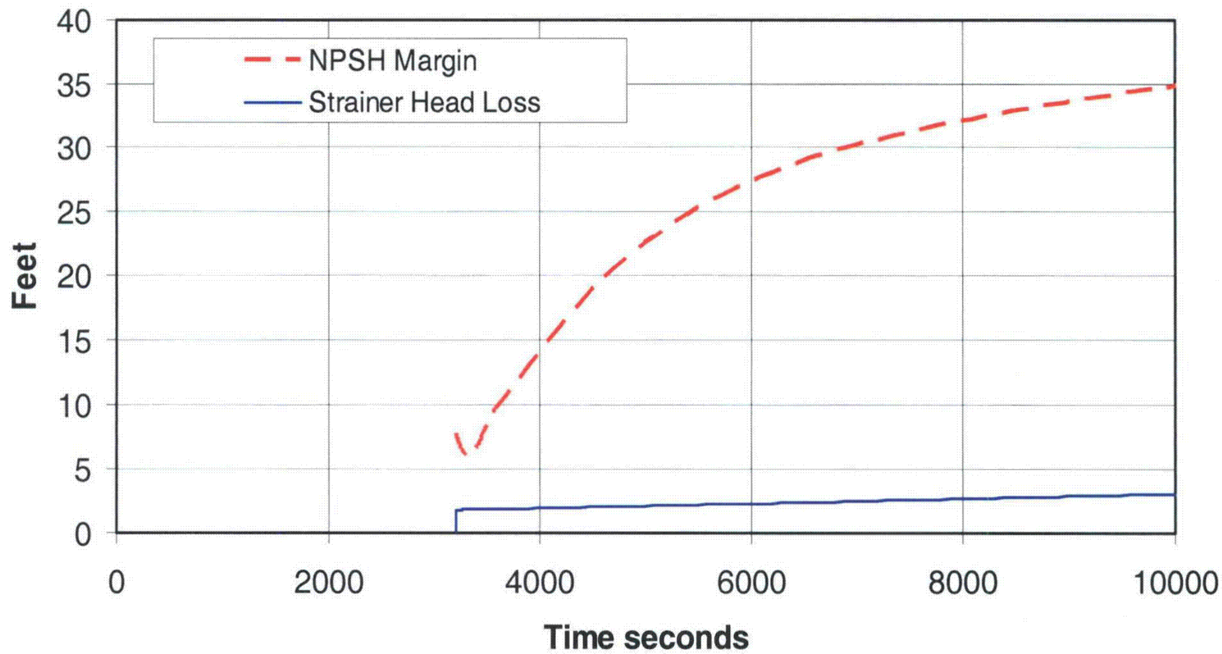
Notes

1. Calculated NPSHa does not include strainer head loss

2. NPSH margin = NPSHa – Strainer HL - NPSHr

As shown in the table above, the minimum margin for the most limiting case is 4.3 feet for the BVPS-2 RSS pumps. Again this is a conservative value since the effects of chemical precipitates is applied at the onset of the accident. The trend of NPSH margin is shown in the following plot along with the strainer head loss for the limiting margin case.

Figure 3.g.16-3 BVPS-2 RSS pump Margin and Strainer Head Loss



NPSH margins have also been analyzed for a spectrum of small break LOCA cases for BVPS-1 and 2 with the same set of single failure assumptions. The results of these analyses are bounded by the large break results.

Additionally, no explicit NPSH calculations are required for the hot leg injection mode for BVPS-1 and BVPS-2. At BVPS-1, the flows through the LHSI pump from the containment sump are limited by a cavitating venturi and the increase in flow due to a reduction in sump temperature is insignificant relative to the increase in sub-cooling. Therefore, the cold leg injection analyses bound the hot leg injection alignment. At BVPS-2, the flow from the sump will be reduced in the hot leg injection alignment due to the system design and therefore the cold leg injection analyses are bounding.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. A response pertaining to NPSH margin at BVPS-1 and BVPS-2 is presented below. The format for the response first includes the request itself, followed by FENOC's response.

RAI #7 (from Reference 6)

For a LBLOCA, provide the time until ECCS external recirculation initiation and the associated pool temperature and pool volume. Provide estimated pool temperature and pool volume 24 hours after a LBLOCA. Identify the assumptions used for these estimates.

FENOC Response

The times associated with recirculation flow from the containment sump at BVPS-1 and BVPS-2 include the time at which the RSS pumps start and the time when switchover to safety injection recirculation occurs. Since both of these automatic features are actuated by a level signal from the RWST, the time at which they occur is dependent on the drawdown rate, which is dependent primarily on single failure assumptions for a LBLOCA. For all LOCAs, the drawdown rate is also break size dependent. Table RAI 7-1 provides the results from the limiting large break LOCA case for NPSH except for the sump temperature at 24 hours. This value is based on a maximum sump temperature case, which assumes that the service water temperature is at the maximum value.

Table RAI 7-1

BVPS-1								
Case	Single Failure	Time of RS Start	Temp at RS Start	Time of CL Recirc	Temp at CL Recirc	Volume at CL Recirc	Temp at 24 hours	Volume at 24 hours
		seconds	°F	seconds	°F	gallons	°F	gallons
Case6L1-rs	LHSI	1,308	222.5	2,088	171.7	273,470	124	380,710

BVPS-2								
Case	Single Failure	Time of RS Start	Temp at RS Start	Time of CL Recirc	Temp at CL Recirc	Volume at CL Recirc	Temp at 24 hours	Volume at 24 hours
		seconds	°F	seconds	°F	gallons	°F	gallons
Case1L-NPSH	EDG	3,106	211.9	3,450	203.5	350,440	115	761,390

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

3. ***Discuss suction strainer head loss testing performed as it relates to both qualified and unqualified coatings and what surrogate material was used to simulate coatings debris.***
4. ***Provide bases for the choice of surrogates.***
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.***
6. ***Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.***
7. ***Describe any ongoing containment coating condition assessment program.***

3.h.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.***

FENOC Response

BVPS-1

The primary original coating systems in containment for BVPS-1 are Carboline CZ-11 primer and DuPont Corlar Epoxy for steel surfaces and DuPont Corlar Epoxy for concrete surfaces. A limited area of the containment steel liner was coated with Keeler & Long 6548/7107 epoxy primer with D-1 Epoxy topcoat.

In addition, the following qualified coatings have been used for steel maintenance coating work: Carboline 193LF Epoxy Primer and 191HB topcoat, Carboline 801, Carboline 890, Keeler & Long 6548/7107 epoxy primer and Keeler & Long 9600N epoxy topcoat.

For concrete surfaces, the following qualified coatings have been used for maintenance coating work: Carboline Nutec 1201 and Keeler & Long 9600N.

BVPS-2

The primary original coating systems in containment for BVPS-2 are Carboline CZ-11 primer and Carboline 191HB Epoxy for steel, and Imperial Nutec 11S/11 surfacer with Nutec 1201 topcoat for concrete.

In addition, the following qualified coatings have been used for steel maintenance coating work: Carboline 193LF Epoxy Primer and 191HB topcoat, Carboline 801, Carboline 890, Keeler & Long 6548/7107 epoxy primer and Keeler & Long 9600N Epoxy topcoat.

For concrete surfaces, the following qualified coatings have also been used for maintenance coating work: Carboline 801 / 890.

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

FENOC Response

Responses provided for Review Area 3.e "Debris Transport" describe the methodology utilized for the BVPS-1 and BVPS-2 debris transport analyses. In addition to the methodology described in response to Review Area 3.e, the following key attributes apply and are intended to describe and provide the bases for assumptions made in post-LOCA paint debris transport analyses.

1. The unqualified coatings are assumed to be uniformly distributed in the recirculation pool. This is a reasonable assumption since the unqualified coatings are scattered around containment in small quantities.
2. Both the qualified coatings (inside the ZOI) and the unqualified coatings were conservatively assumed to fail as 10 micron particulate in the debris generation analysis. This assumption follows the guidance of the NRC SE, section 3.4.3.6. Therefore, the transport of paint chips is not required to be considered. However, head loss testing conservatively included both particulates and chips, effectively doubling the quantity of unqualified coatings.
3. The transport metrics for IOZ, epoxy, alkyd, aluminum, cold galvanizing and Vi-Cryl coatings are all bounded by the metric for individual fibers (that is, they are more readily suspended). Therefore, since 100 percent of the individual fibers were shown to transport to the sump, the recirculation transport fraction for the paint is also 100 percent.

The results of debris transport are included in response to Review Area 3.e "Debris Transport" and include the associated values for the transport of coatings debris both within and outside the ZOI. A review of Tables 3.e-6 through 3.e-9 identify that for the bounding LOCA analyses, coating debris transports as fines and 100 percent are transported to the screen.

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

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

FENOC Response

The following provides the key attributes of the suction strainer head loss testing performed for both BVPS-1 and BVPS-2 as it relates to both qualified and unqualified coatings and what surrogate material was used to simulate coatings debris. Additional detail with regard to the overall head loss testing was provided in response to Review Area 3.f.

Also provided are the assumed debris characteristics, including: chips, particulate, size distribution and bases for these assumptions, and the bases for the choice of surrogates used in the testing.

1. SIL-CO-SIL™ 53 Ground Silica manufactured by U.S. Silica Company was used as a surrogate for both the qualified and unqualified coatings. Coatings densities at BVPS-1 and BVPS-2 range from 55 lb/ft^3 to 442 lb/ft^3. The ground silica surrogate used has a material specific gravity of 2.65, which corresponds to a microscopic density of 165 lb/ft^3. The critical parameter for selecting the surrogate material is the volume of the material in the debris mix. The particulate material occupies a certain volume in the fibrous debris space that results in increasing resistance to flow and higher head loss. The surrogate material volume was adjusted to match the volume of the coatings particulate. The particle size for coatings is 10 microns spherical particle diameter. The ground silica is a spherical particulate ranging in size from just under 1 micro-meter to approximately 100 micro-meters (taken from the product data sheet for the particle size distribution).
2. In addition to the ground silica being used for the coatings surrogate, using paint chips for the unqualified chips load introduced additional conservatism.
3. Coatings Chips Unlimited paint chips were also used as a surrogate material for unqualified coatings. The paint chips were 4 to 6 mils thick with a 1/8 inch or 1/4 inch nominal size distribution. The paint chips consist of a mixture of resins and other materials.
4. The entire particulate debris load, including coatings, surrogates, fines, and chips, were added prior to the fiber debris load, which was introduced in batches. This approach was done as recommended by the March 2008 NRC Staff Review Guide (Reference 12).

3.h.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.***

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

FENOC Response

Responses provided for Review Areas 3.a, 3.b, and 3.c describe the methodology utilized for the BVPS-1 and BVPS-2 debris generation analyses. In addition to the methodology described in these review areas, the following key attributes apply and are intended to describe and provide the bases for coatings debris generation assumptions for both BVPS-1 and BVPS-2, and describe how the quantity of paint debris was determined based on ZOI size for qualified and unqualified coatings.

1. A 5D ZOI was used as the basis for debris generation for qualified coatings for BVPS-1 and BVPS-2. The NRC has provided guidance on the use of the 5D ZOI for coatings in Enclosure 2 of Reference 12. Specifically the NRC's response to Item 3 in Reference 12 indicates that licensees may use WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence for DBA-Qualified/ Acceptable Coatings," as the basis for using a ZOI of 4D or greater for qualified epoxy coatings, and a ZOI of 5D or greater for qualified untopcoated inorganic zinc coatings.
2. Qualified coatings outside the ZOI are considered to remain intact consistent with Section 3.4.2.1 of NEI 04-07, Volume 2.
3. In the Baseline Analysis, both topcoat and primer coatings materials within the ZOI are assumed to fail as 10-micron-diameter spherical particles, which is approximately equivalent to the basic constituent or pigment sizes. Based on NEI 04-07 Volume 1 and Section 3.4.3.6, Item 2 of NEI 04-07, Volume 2, unqualified coatings are also considered to fail as 10-micron particles for the Baseline Analysis.
4. Although the SE does not specifically address the presence of insulation on top of coatings, the analysis assumes that unqualified coatings under intact insulation are not considered to fail as discussed in the NEI Guidance Report. However, unqualified coatings that are under insulation that becomes debris (that is, insulation within the ZOI) are assumed to fail.
5. All unqualified coatings not covered by insulation and outside the ZOI are assumed to fail and add to the debris load.

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

FENOC Response

Coatings inside containment are assessed as part of containment walkdowns, maintenance activities and the Containment Structural Integrity Test. The containment liner is inspected in accordance with the Containment Structural Integrity Test approximately every three years or every other refueling outage. Observed deficiencies in coatings are captured in the corrective action program.

A new containment coatings inspection and assessment program was implemented during the BVPS-2 spring 2008 refueling outage. The coatings inspection program was implemented for BVPS-1 beginning with the spring 2009 refueling outage. Containment coatings inspections are a scheduled activity to be conducted during refueling outages at both BVPS-1 and BVPS-2 (refer to FENOC letter dated December 20, 2007; Reference 18).

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. Responses are presented below pertaining to the coatings evaluation at BVPS-1 and BVPS-2. The format for the response first includes the request itself, followed by FENOC's response.

RAI #2 (from Reference 6)

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

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

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

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

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

FENOC Response

This response has been revised from that provided to the NRC in FENOC letter dated October 29, 2008 (Reference 11), to:

1. Reflect that the aluminum portions of BVPS-1 containment iodine filters have been removed during refueling outage 1R19. This change reduces the amount of BVPS-1 aluminum shown in Table RAI 2-1 from the previous 12,457 ft^2 to the current 10,373 ft^2.
2. Reflect the updated aluminum surface area of the BVPS-2 equipment hatch trolley hoists.

The following table (Table RAI 2-1) provides the quantity of materials either submerged or exposed to the containment spray following a LOCA for BVPS-1 and BVPS-2:

Table RAI 2-1

	BVPS-1 ft^2	BVPS-2 ft^2
Aluminum	10,373$^{(1)}$	1,539$^{(1)}$
Zinc in Galvanized Steel	150,000$^{(2)}$	177,166$^{(2)}$
Inorganic Zinc Coatings	90,000$^{(2)}$	295,573$^{(2)}$
Total Zinc	240,000$^{(2)}$	472,739$^{(2)}$
Copper	NA$^{(3)}$	NA$^{(3)}$
Carbon Steel not Coated	NA$^{(4)}$	NA$^{(4)}$
Uncoated Concrete	811$^{(5)}$	811$^{(5)}$

Notes:

(1) Includes a 10 percent margin on existing submerged and unsubmerged thick aluminum

(2) Maximum allowable amounts by plant zinc/aluminum inventory control standard

(3) Copper is not listed based on WCAP-16530, Revision 0, page 46, which states that Integrated Chemical Effects testing and Oak Ridge testing concluded the corrosion rate of copper is low enough in alkaline borate solution to be of no practical concern.

(4) Uncoated carbon steel is not used in BVPS-1 or BVPS-2 containments.

(5) Uncoated concrete is not used in BVPS-1 or BVPS-2 containments. The uncoated concrete areas listed represent the concrete area that is assumed to be stripped of coatings by a break (611 ft^2) plus a 200 square foot margin (611 ft^2 stripped + 200 ft^2 margin = 811 ft^2).

A comparison of the amounts of these materials in the submerged and spray zones at BVPS relative to the scaled amounts of these materials used in the NRC nuclear industry jointly-sponsored Integrated Chemical Effects Tests (ICET) is provided in Table RAI 2-2 below.

Table RAI 2-2

Material	ICET Ratio Value	Units (1)	Ratio Value BVPS-1 (2)	Ratio Value BVPS-2 (3)
Zinc in Galvanized Steel	8	SF/CF	3.46	1.75
Inorganic Zinc Coatings	4.6	SF/CF	2.08	2.92
Aluminum	3.5	SF/CF	0.24	0.02
Copper	6	SF/CF	NA	NA
Carbon Steel not Coated	0.15	SF/CF	NA	NA
Uncoated Concrete	0.045	SF/CF	0.02	0.01

Notes:

(1) Ratio = Material Square Footage Quantity (SF) divided by the Sump Water Volume in cubic feet (CF).

(2) BVPS-1 Sump Water Volume = 324,080 gallons (43,323.19 cubic feet)

(3) BVPS-2 Sump Water Volume = 756,050 gallons (101,069.18 cubic feet)

RAI #3 (from Reference 6)

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

BVPS-1

Scaffold poles and connecting knuckles are stored at various elevations in containment. The scaffold poles and knuckles are carbon steel. The scaffold poles are hot dipped galvanized. The knuckles are carbon steel coated by hot dipped galvanize or electroplated zinc.

The estimated amount of zinc from the galvanized scaffold components, based on the amount of scaffold materials currently permitted to be stored in BVPS-1 containment, is 2030 square feet and 190 pounds mass.

No scaffold materials are stored on the lowest containment elevation. Scaffold materials are stored at elevations higher than the pool level in containment following a LOCA. Therefore no scaffold material is submerged during a LOCA event.

BVPS-2

Scaffold poles and connecting knuckles are stored at various elevations in containment. The scaffold poles and knuckles are carbon steel. The scaffold poles are hot dipped galvanized. The knuckles are carbon steel coated by hot dipped galvanize or electroplated zinc.

The estimated amount of zinc from the galvanized scaffold components, based on the amount of scaffold materials currently permitted to be stored in BVPS-2 containment, is 817 square feet and 76 pounds mass.

No scaffold materials are stored on the lowest containment elevation. Scaffold materials are stored at elevations higher than the pool level in containment following a LOCA. Therefore no scaffold material is submerged during a LOCA event.

Scaffolding material was included in the response to Question 2 for both BVPS-1 and BVPS-2.

RAI #4 (from Reference 6)

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

FENOC Response:

Insulation Jacketing:

BVPS-1

Original thermal insulation was installed per Stone and Webster Specification No. BVS-465, "Thermal Insulation for In-Service Inspection," or No. BVS-466, "Thermal Insulation," which specified that all metallic insulation jacketing inside the reactor containment is made of stainless steel.

Plant modifications to insulation have been installed in accordance with standard specifications and procedures which specify that all metallic jacketing inside the reactor containment is made of stainless steel.

BVPS-2

Original thermal insulation was installed per Stone and Webster Specification No. 2BVS-60, "Thermal Insulation," which specified that all insulation jacketing inside the reactor containment is made of stainless steel.

Plant modifications to insulation have been installed in accordance with standard specifications and procedures which specify that all jacketing inside the reactor containment is stainless steel.

In conclusion, there is no non-stainless steel insulation jacketing inside the Reactor Containment for BVPS-1 and BVPS-2.

Metallic Paints:

BVPS-1

In addition to the inorganic zinc coatings identified in the response to RAI #2, two metallic paints have been used for BVPS-1: 1) High temperature aluminum and 2) Galvanox Type I or Type III "Cold Galvanizing."

The high temperature aluminum paint was used on the pressurizer and reactor vessel of BVPS-1. Neither would be submerged or subjected to containment spray during a LOCA. Both are above the post LOCA containment water level. The pressurizer would not be subjected to containment spray because it is in an area outside the spray zone and is protected by insulation. The reactor vessel would not be subjected to direct containment spray because it is in an area protected from containment spray by the reactor cavity wall, and the neutron shield tank. It is also protected by insulation.

The Galvanox would be exposed to containment spray. Galvanox is a touchup product for galvanized ventilation ducts. The estimated amount of Galvanox is 200 square feet and 11.1 pound-mass.

BVPS-2

In addition to the inorganic zinc coatings identified in the response to RAI #2, one metallic paint was used for BVPS-2: Galvanox Type I or Type III "Cold Galvanizing."

The Galvanox would be exposed to containment spray. Galvanox is a touchup product for galvanized ventilation ducts and electrical conduit. The estimated amount of Galvanox is 400 square feet and 19.5 pound-mass.

RAI #25 (from Reference 6)

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

qualified/acceptable coatings continue to meet DBA performance requirements. Alternately, assume all containment coatings fail and describe the potential for this debris to transport to the sump.

FENOC Response

In support of the GSI-191 closeout and the new ECCS suction strainer designs for BVPS-1 and BVPS-2, detailed containment coating condition assessment walkdowns were conducted at BVPS-1 and BVPS-2. These walkdowns were performed by an industry expert to identify existing coatings within the containment that might fail under normal or accident conditions (DB-LOCA) and contribute to the containment emergency sump debris source term. The results of the containment coating condition walkdowns indicate that DBA-qualified coatings in the BVPS-1 and BVPS-2 continue to perform satisfactorily and serve as the baseline for ongoing containment coatings configuration control activities.

As originally discussed in FENOC letter dated November 11, 1998, (Reference 19), controls have been implemented at BVPS-1 and BVPS-2 for the procurement, application, and maintenance of protective coatings used inside containment in a manner consistent with the applicable licensing basis and regulatory requirements. The procedures associated with these controls require the generation of data that is used to schedule coating maintenance. Coating maintenance ensures that qualified/acceptable primary containment coatings will not fail (detach) during normal and accident conditions and thus will not contribute to the ECCS debris source term.

A new coatings assessment program was implemented for BVPS. The initial coatings assessment for BVPS-2 was performed during the spring 2008 refueling outage. The initial coatings assessment for BVPS-1 was performed during the spring 2009 refueling outage. These assessments and associated coating repair and replacement activities assure that the amount of coatings which may be susceptible to detachment from the substrate during a LOCA event is minimized.

3.i. Debris Source Term Refinements

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

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

    GL 2004-02 Requested Information Item 2(f).
    A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduced into containment (e.g.

insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions. Addressees may reference their responses to GL 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident because of Construction and Protective Coating Deficiencies and Foreign Material in Containment", to the extent that their responses address these specific foreign material control issues.

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

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.*
2. *A summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the 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.*
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.*
5. *If any or all of the five suggested design and operational refinements given in the guidance report (GR, Section 5) and safety evaluation (SE, Section 5.1) were used, summarize the application of the refinements.*
6. *Recent or planned insulation change-outs in the containment which will reduce the debris burden at the sump strainers.*
7. *Any actions taken to modify existing insulation (e.g. jacketing or banding) to reduce debris burden at the sump strainers.*
8. *Modifications to equipment or systems conducted to reduce the debris burden at the sump strainers.*
9. *Actions taken to modify or improve the containment coatings program.*

FENOC Response

The following describes the BVPS design and operational measures to control the plant debris source term to prevent potential adverse effects on the ECCS and Containment Spray recirculation functions.

3.i.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.***

FENOC Response

To assure that the BVPS containment buildings are maintained in a clean condition the BVPS-1 and BVPS-2 Licensing Requirements Manuals include surveillance requirements.

Prior to establishing containment OPERABILITY (unless affected areas of the containment have been inspected at the completion of each containment entry per surveillance requirements), a visual inspection of all accessible areas of the containment for loose debris is performed. This surveillance is performed by procedures. Personnel verify by visual inspection that no loose debris (rags, trash, clothing, etc.) is present in the containment that could be transported to the containment sump and cause restriction of the ECCS pump suctions during LOCA conditions.

In addition, a visual inspection of the accessible regions of the ECCS containment sump suction inlets is performed to verify that they are not restricted by debris and that the accessible regions of the strainers show no signs of structural distress or abnormal corrosion. These procedures are performed on an 18 month frequency in accordance with Technical Specification surveillance requirements.

The periodic containment debris inspections described above provide sufficient monitoring of the containment cleanliness. However, to further reduce the latent debris burden on the sump, FENOC has developed a periodic containment cleaning program. This program was implemented at BVPS-2 during the spring 2008 refueling outage (2R13) and at BVPS-1 during the spring 2009 refueling outage (1R19). This enhancement program directs an initial containment cleaning by vacuuming in conjunction with wiping, mopping and /or low pressure water washing. Following the initial cleaning on each unit, focused cleaning will be conducted each refueling outage on rotating containment quadrants.

The above controls provide sufficient assurance that the BVPS-1 and BVPS-2 containments remain below the baseline latent debris levels in the sump performance calculations and testing.

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

FENOC Response

Plant labels and signs are controlled by procedure 1/2-ADM-0700, "Plant Labeling and Tagging." This procedure was revised in 2004 to stipulate that new labels, signs and placards to be installed inside containment at BVPS-1 and BVPS-2 are required to meet the post-LOCA environment requirements.

Foreign material exclusion (FME) is controlled by procedures. Prior to establishing containment operability (e.g. following an outage), visual inspection is conducted on all accessible areas of the containment to confirm there is no loose debris (rags, trash, clothing, etc.). If a containment entry is made during operating Modes 1 through 4, containment foreign material control is also addressed by procedure. The procedure ensures that an inspection of the affected area is performed and all debris is removed at the conclusion of work in containment.

3.i.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.***

FENOC Response

Design control procedures have been revised to ensure that plant changes will be reviewed for any potential impact on the performance of the containment sump. Design Interface Review Checklist for Nuclear Operating Procedure, "Design Interface Reviews and Evaluations," has been revised to ensure changes that could affect the containment sump performance (including insulation, flow paths to the sump, water hold-up volumes, unqualified paint and material being added to the containment that could add to the sump debris load) are evaluated. In addition, the BVPS-1 and BVPS-2 specifications for the procurement, installation and replacement of thermal and sound insulation have been revised to identify that the amount and type of insulation damaged in a DBA is an input to the sump design and that all insulation changes inside the containment must be approved by Design Engineering.

3.i.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.***

FENOC Response

Maintenance activities, including temporary changes, are subject to the provision of 10 CFR 50.65(a)(4) as well as the Technical Specifications. Procedures provide guidance on the following areas:

- the work management processes establish the administrative controls for maintenance of systems, structure, and components to enhance overall plant safety and reliability
- temporary modifications are controlled under the engineering change process, which establishes the overall requirements for such changes
- a 10 CFR 50.59 review is performed for any temporary alterations in support of maintenance that will be in place more than 90 days.
- Maintenance Rule condition monitoring has been established to focus on the condition of the containment sump in an effort to preclude functional failure.

3.i.5 ***If any or all of the five suggested design and operational refinements given in the guidance report (GR, Section 5) and safety evaluation (SE, Section 5.1) were used, summarize the application of the refinements.***

FENOC Response

The safety evaluation (SE, Section 5.1), lists the following five categories:

1. Housekeeping and FME Programs
2. Change-Out of Insulation
3. Modify Existing Insulation
4. Modify Other Equipment or Systems
5. Modify or Improve Coatings Program

These items are addressed sequentially below:

1. Housekeeping and FME Programs

Housekeeping and FME is discussed in response to Review Areas 3.i.1 and 3.i.2.

2. Change-Out of Insulation

Insulation changes were made and additional changes will be made as discussed in the response to Review Area 3.i.6.

3. Modify Existing Insulation

Other than the insulation replacement discussed above, the existing insulation remains as is (no banding was added or additional layers of cladding added).

4. Modify Other Equipment or Systems

Containment iodine filters were removed from BVPS-1 and BVPS-2 to reduce the amount of aluminum submerged in the containment pool.

5. Modify or Improve Coatings Program

The containment coatings inspection program was improved, as discussed in response to Review Area 3.h.7.

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

FENOC Response

At BVPS-1, the following insulation modifications reduced the debris burden of the sump strainers.

- New RMI was installed on the BVPS-1 replacement steam generators (RSG) and associated piping in the vicinity of the RSG during the spring 2006 refueling outage (1R17). The associated piping included the Reactor Coolant System cross-over leg elbow, the Main Steam piping between RSG Main Steam nozzle and the first pipe rupture restraint, Feedwater piping between the RSG Feedwater nozzle and the first rupture restraint, and the existing Blowdown and Shell Drain piping between the RSG nozzles and the point where the two Blowdown lines and the Shell drain merge into a common header.
- New RMI was also installed on the BVPS-1 reactor vessel closure head during the spring 2006 refueling outage (1R17).
- Selected portions of calcium-silicate and fiberglass piping insulation inside of the BVPS-1 reactor coolant loop compartments were replaced during the spring 2009 refueling outage (1R19). These replaced sections of insulation were selected to reduce the amount of calcium-silicate and fiberglass insulation debris at the sump to less than that tested for post-accident head loss.

At BVPS-2, to reduce the debris head loss across the containment sump strainer, two different insulation replacement activities were completed during the spring 2008 refueling outage (2R13).

- The fibrous Temp-Mat™ insulation included in the insulation panels over the reactor vessel head closure studs was replaced with reflective metal insulation.

- Min-K^{TM} insulation in selected portions of the reactor coolant system piping that could add to the break debris was replaced with Thermal-Wrap insulation.

In addition, insulation will be replaced with RMI during the fall 2009 refueling outage.

- Selected portions of calcium-silicate and fiberglass piping insulation inside of the BVPS-2 reactor coolant loop compartments and on the steam generator will be replaced with RMI. These sections of insulation to be replaced were selected to reduce the amount of calcium-silicate and fiberglass insulation debris at the sump to less than that tested for post-accident head loss.

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

FENOC Response

Other than the insulation replacement discussed above, the existing insulation remains as is (no banding was added or additional layers of cladding added).

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

FENOC Response

Containment iodine filters have been removed from both BVPS-1 and BVPS-2 as discussed in the response to Review Area 3.i.5, and insulation modifications have been completed at BVPS-1 and will be completed at BVPS-2 as discussed in the response to Review Area 3.i.6.

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

FENOC Response

Containment coatings are controlled by procedures "Painting for Containment Interior," and "Procurement, Receipt, Storage, and Handling of Coating Materials – BVPS#1 and #2."

As discussed in the response to Review Area 3.h, BVPS did not previously have a formalized painting assessment program. However, the containment liner coatings were periodically inspected during the performance of the "Containment Structural Integrity Test." These procedures are performed approximately every three years or every other refueling outage. Coating discrepancies discovered during these inspections were entered into the corrective action program.

A new containment coatings inspection and assessment program was implemented starting with the BVPS-2 spring 2008 refueling outage. The first BVPS-1 containment coatings inspection under this program was performed during the spring 2009 refueling outage. Containment coatings inspections are a scheduled activity to be conducted during refueling outages at both BVPS-1 and BVPS-2 (refer to Regulatory Commitment in FENOC letter dated December 20, 2007; Reference 18).

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. Responses are presented below pertaining to the debris source term refinements at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed by the specific response.

RAI #34 (from Reference 6)

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

FENOC Response

FENOC's response to Review Areas 3.i.1 and 3.i.2 describe how containment cleanliness and FME programs assure that latent debris in containment will be controlled and monitored. The new containment cleaning program addressed in the response to Review Area 3.i.1 provides for using scaffolds constructed in containment in support of other activities, to provide access for cleaning inaccessible areas. By using this strategy, some otherwise inaccessible areas will be able to be cleaned each outage.

RAI #35 (from Reference 6)

Will latent debris sampling become an ongoing program?

FENOC Response

No. The new containment cleaning program requires cleaning of the containment on a regularly scheduled basis rather than ongoing sampling to determine if cleaning is required. The sampling that was performed to establish the baseline used in the debris calculations was performed prior to implementation of the containment cleaning program following 17 operating cycles at Unit 1 and 11 operating cycles at Unit 2. The initial cleaning of the Unit 1 and Unit 2 containments was completed after the baseline sampling. The containment cleaning program requirement to clean a containment quadrant during each refueling outage following the initial cleaning will assure that the amount of latent debris will remain below the baseline levels.

3.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.***
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.***

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

FENOC Response

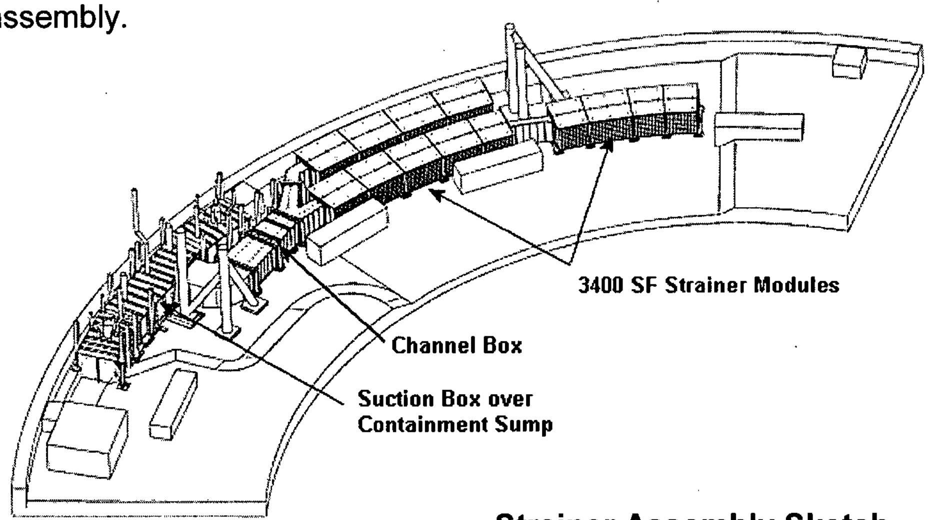
BVPS-1

The modification performed hardware changes required to bring BVPS-1 into compliance with NRC GSI-191. This modification replaced the existing BVPS-1 sump screens located outside the crane wall and adjacent to the containment wall, on the basement floor of the BVPS-1 containment building.

Containment sump screens were replaced by a passive, safety-related strainer assembly engineered and manufactured by CCI. The strainer design does not include an active approach or use a reverse flow back-flushing strategy. The new containment sump strainer provides approximately 3400 square feet of strainer area. Flow velocity through the screens is 0.01 feet per second based on 14,500 gallons per minute maximum flow and 3,086 square feet effective flow area. The strainer configuration is designed to a differential pressure of 5.78 pounds per square inch (psi).

The new strainer assembly for BVPS-1 consists of strings of strainer modules, connected to a channel box, which is in turn connected to a common sump suction box. The common sump suction box is designed to form a suction chamber in the existing sump trench. Containment water passes through the cassettes that make up the cartridges on either side of the modules and flows to the module duct (clean side). Strainer modules are connected to each other so that debris will not enter the system between modules. The strainer module strings are connected to a channel box, which forms a plenum that routes the strained containment water to the sump suction box. The modifications were installed in BVPS-1 during the 2007 refueling outage.

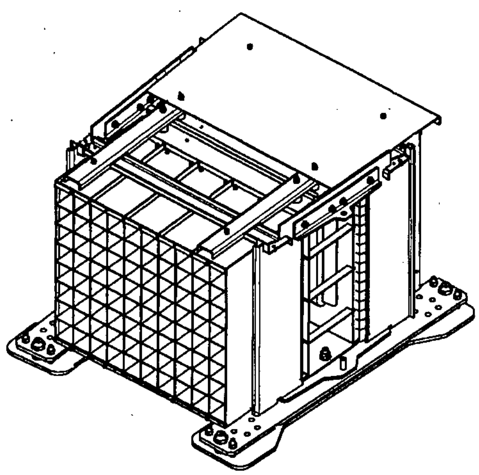
The sketch below shows the primary components for the new containment sump strainer assembly.



Strainer Assembly Sketch

The strainer assembly has 13 strainer modules. A strainer module is comprised of cassettes consisting of perforated plate boxes approximately 3 inches by 3 inches by 16 inches deep. The perforations are 1/16 inch in diameter. Cassettes, two wide and eight deep, comprise a cartridge. A central core duct supports the cartridges. Duct retaining structures, supports and cover plates complete each module. Modules come in three sizes of either 5, 7 or 8 cartridges on a side. Each module is independently supported. Modules are connected with flexible closure plates that permit thermal expansion in the axial direction while preventing debris from entering the system between adjacent modules. One end of a module is fixed to a support plate and the other end is free to expand through slotted holes in another support plate. The tops of the modules are covered with diamond plate to protect the modules from falling objects or debris and to provide a work platform for access to the overhead pipe racks.

The sketch below shows a typical strainer module.



Module Assembly Sketch

A channel box connects the strainer modules to the suction box. The channel box is comprised of individual segments that are independently supported. Like the strainer modules, individual segments are connected with flexible closure plates that permit thermal expansion in the axial direction while preventing debris from entering the system between adjacent modules. Similar to the strainer modules, one end of a channel box is fixed to a support plate and the other end is free to expand through slotted holes in another support plate. One channel box segment has removable panels to facilitate installation of a temporary test dike used for RSS pump testing.

The sump is totally enclosed by the strainer suction box to prevent debris laden water from directly entering the sump without passing through the strainer assembly. The suction box is comprised of three segments connected with flexible closure plates that permit axial thermal expansion while preventing debris from entering the system between adjacent segments. The suction box is attached to the containment floor with bearing type concrete anchors in base plates. Gaps between the base plates and the concrete were closed with woven stainless steel wire mesh. Gaps between base plates were closed with flexible closure plates. Penetrations through the top of the suction box were closed with flexible closure escutcheons and plates.

The modules, channel box, suction box, and fasteners are all constructed of corrosion resistant stainless steel alloys. The bolted strainer assembly design allows for disassembly, cartridge replacement or addition of future modules as needed.

Removable plates on top of the suction box at four locations provide access for remote inspections of the pump suction inlets and the sump trench area in general. Additionally, removable panels are provided on the top of the suction box to allow access to the inside of the suction box to facilitate calibration of level instruments located in the stilling wells. Removable covers on the duct boxes around the stilling well bases provides access to the stilling well internals, or because they are of bolted construction the boxes themselves may be disassembled.

There are no vents or components penetrating the strainer suction box to connect the suction box water volume to the containment atmosphere above the containment minimum LOCA water level. Strainer cassettes, channel boxes and the suction box are fully submerged at initiation of RSS pump start. Loop seals are provided for open Quench Spray piping which penetrates the suction box. Other pipes that penetrate the suction box are in closed systems. The stilling wells that penetrate the suction box remain unchanged except that now the water inlet at the base of the stilling wells will be ducted in from outside the suction box. Therefore, the stilling wells are isolated from the suction box water volume. The design of the BVPS-1 containment sump strainer ensures that there is no open vent path between the strainer assembly and the containment atmosphere. Therefore, the strainer is considered fully submerged.

BVPS-2

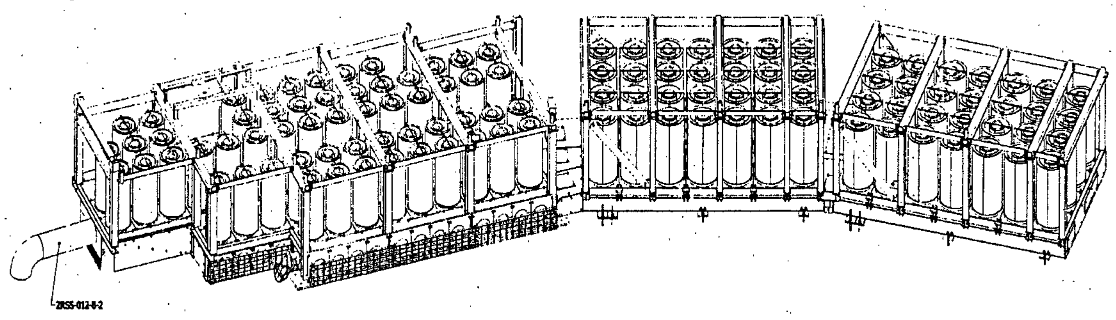
A modification was performed to bring BVPS-2 into compliance with NRC GSI-191. The modification replaced the existing containment sump screens located outside the crane wall and adjacent to the containment wall, on the basement floor of the BVPS-2 containment building.

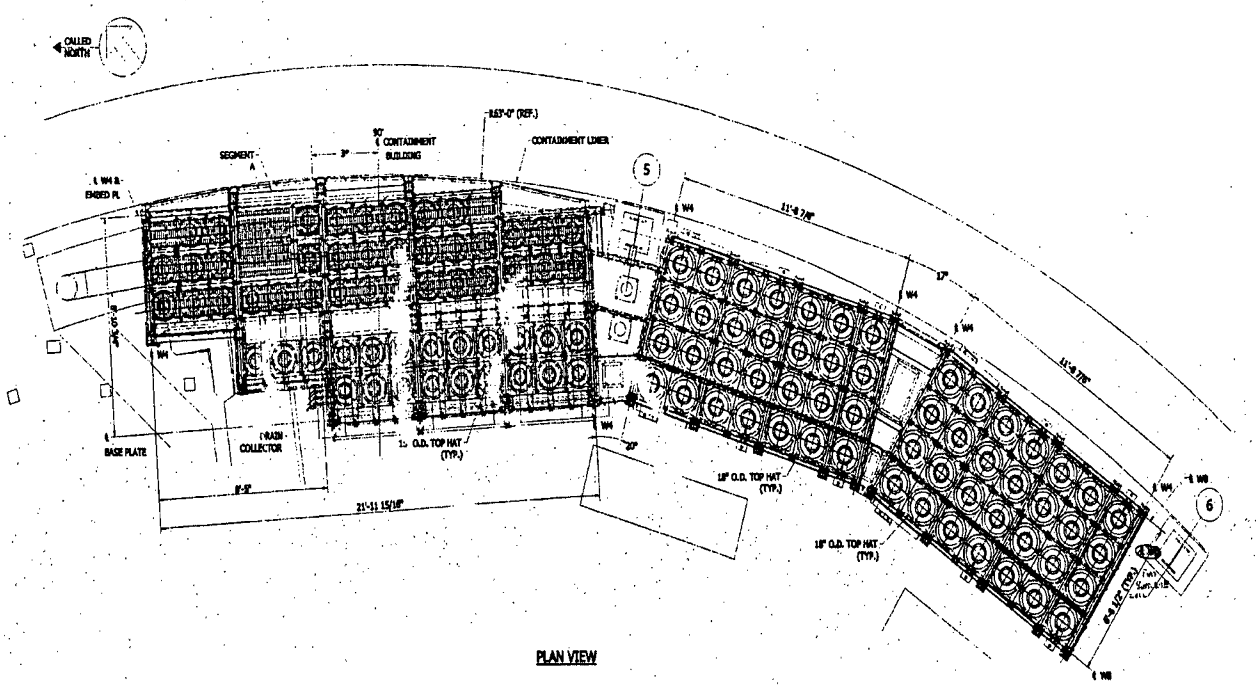
Containment sump screens were replaced by a passive, safety-related strainer assembly engineered by Enercon and fabricated by Transco. The strainer design does not include an active approach or use a reverse flow back-flushing strategy. The new containment sump strainer provides approximately 3,300 square feet of strainer area. Flow velocity through the screens is 0.0108 feet per second based on 13,700 gallons per minute maximum flow and 3,396 square feet effective flow area. The strainer configuration is designed to a differential pressure of 5.0 psi.

The new strainer arrangement for BVPS-2 consists of three segments, A, B, and C, with connectors between segments. Segment A is located over the existing sump trench. Each segment has vertically orientated, cylindrical top-hat style strainer assemblies supported on structural frames. Each top-hat is approximately 3 feet long and consists of four perforated plate tubes of different diameters stacked one inside the other. The perforated plates are made from 14 gage stainless steel plates with 3/32 inch diameter holes. A bypass eliminator material made of woven stainless steel wire is sandwiched between the tubes. Top-hats have a square flange at the bottom for attachment to the supporting frames. A cruciform near the flange acts as a vortex suppressor. Additionally, in segment A, vortex suppression grating is installed between the top-hats and the RSS pump inlets. There are water boxes below each of the three separate segments to collect and channel recirculated containment water to the sump trench. The modifications were installed in BVPS-2 during the 2006 refueling outage.

Strainer segment A has fifty-seven (57) of the top-hat modules, which consists of an outer perforated tube with a diameter of 15 inches and inner perforated tubes with diameters of 13, 8, and 6 inches. Strainer segments B and C each have 28 (56 total) top-hat modules which consists of an outer perforated tube with a diameter of 18 inches and inner perforated tubes with diameters of 15, 9, and 7 inches. Containment water enters the top-hats through either the inner or outer perforated tubes and then flows downward through the bypass eliminator material, in the annulus region between the tubes, into the water boxes below.

The sketch below shows the primary components for the new containment sump assembly.





The three strainer segments are independently supported. Segment A frame support members are welded to the existing embedded floor plates. The support frame is divided into five separate bays. The support frame members between and within the bays have slotted bolt holes to allow for thermal expansion. Strainer segments B and C are attached to the containment floor with expansion type concrete anchors. One end of segment B is fixed and is allowed to grow thermally toward Segment C. One end of segment C is fixed and is allowed to grow thermally away from Segment B. The connection between segments B and C has slotted holes to accommodate thermal expansion. The support frame members within segments B and C have slotted bolt holes to allow for thermal expansion.

All three segments are divided into two channels. Perforated and solid plates divide the two channels After the scheduled insulation modifications are completed during the fall 2009 refueling outage, BVPS-2 will be a low fiber plant. The debris eliminators contained within each top-hat strainer assembly prohibit a significant amount of strainer bypass. Since the overall amount of fiber is low, bypass testing resulted in only a 4.2 percent fiber bypass. The perforations in the divider plates are the same diameter as in the strainer top-hats permitting debris that may have bypassed the top-hats to pass through from one channel to the other. The debris eliminators will capture the larger debris sizes passing through the top-hat perforations. Divider plates will not prohibit flow from one channel to the other.

Grout and welded shims were used to close gaps between the two channels as well as the exterior of the water boxes to prevent debris laden water from directly entering the sump without first passing through the top-hat strainers.

The top-hats, debris eliminator mesh, supporting structural steel, shims, and fasteners are constructed of corrosion resistant stainless steel alloys. The top-hat flanges are bolted to the supporting structural steel to allow the top-hat to be removed or replaced as needed. There are removable plates on, or between, all three segments to provide access for inspections.

Nonsafety-related trash racks constructed of 1 inch by 1/8 inch grating are installed directly over the top-hat strainer assemblies. The trash rack is seismically supported for passive integrity following a seismic event. The trash rack does not perform any safety-functions, but is only provided for general protection of the top-hat assemblies. The grating above the top-hat assemblies is covered with 18 gage solid steel plate to divert any containment leakage water (from the floor above) from raining down directly on top of the top-hat assemblies.

There were 16 temporary horizontal, tubular screens installed in the water box area of the strainer segment A. These strainer sections were installed to serve as the operable portion of the strainer until the RSS pump start logic was changed, which provides a greater volume of water at pump start. These temporary screens were removed during 2R13 in the spring of 2008, after the RSS pump start on low RWST level logic change was implemented.

Vertical trash racks are placed in front of the segment A strainer's horizontal screens. These vertical trash racks reduce the possibility that large debris could clog the 16 horizontal top-hats. These trash racks were removed in the spring of 2008 (2R13) when the temporary horizontal screens discussed above were removed. The sketch above shows the layout of the segment A horizontal screens and vertical trash racks.

There are no vents or components penetrating the strainer suction box to connect the suction box water volume to the containment atmosphere above the containment minimum water level. All top-hats are fully submerged at initiation of RSS pump start. The RS test piping that penetrates the strainer segment A is installed with a blind flange. The RS test piping that penetrates the connection box between segments A and B is removed after testing and the holes are covered with plates. Pipes for boroscope inspection have screwed caps on their ends. The design of the BVPS-2 containment strainer ensures that there is no open vent path between the strainer assembly and the containment atmosphere. Therefore, the strainer is considered fully submerged.

3.j.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.***

FENOC Response

Several component modifications were required to eliminate interferences with the installation of the new containment sump strainer. The modifications were local configuration changes or local relocations. Additional whip restraints or missile shields were not required. These modifications included:

BVPS-1

- Bell-mouth flanges were added in the sump trench at the pump suction inlets for the outside RSS pumps and the Low Head Safety Injection pumps. The flanges reduce the suction head loss.
- Temperature sensors, used to provide containment water temperature post LOCA, were relocated.
- Pipe supports were locally modified.
- Flow transmitters were relocated locally.
- Support columns for the existing sump screens' frame were deleted or relocated.
- Quench spray loop seals were modified.
- Recirculation spray test return pipe and support were modified.
- Recirculation spray pump test dike was modified.

BVPS-2

- Bell-mouth flanges were added in the sump trench at the pump suction inlets for the outside RSS pumps. Grating is attached to these flanges for vortex suppression. The flanges reduce the suction head loss.

- Modifications were performed to shorten a QS line and to relocate a QS support.
- Modifications to the RS system test return lines and supports were implemented.
- Conduits to containment sump level instruments were modified.
- Containment sump level transmitters and containment sump level switches were relocated locally within the sump.
- Conduits to containment sump level switches were modified.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. A response is presented below pertaining to the screen modifications at BVPS-1 and BVPS-2. The format for the response first includes the request itself, followed by the FENOC response.

RAI #40 (from Reference 6)

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

FENOC Response

The information presented in response to Review Area 3.j "Screen Modification Package" provides the required information for the response to this RAI.

3.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 GL 2004-02 Requested Information 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.***
2. ***Provide a summary of the structural qualification results and design margins for the various components of the sump strainer structural assembly.***
3. ***Provide a summary of evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high energy line breaks (as applicable).***
4. ***If a backflushing strategy is credited, provide a summary statement regarding the sump strainer structural analysis considering reverse flow.***

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

FENOC Response

BVPS-1

The design inputs used in the BVPS-1 strainer structural analyses are:

1. Beaver Valley Power Station Engineering Specification No. 8700-DMS-0501-3
2. Seismic Data, Amplified Response Spectra, Unit 1 Thursday, December 07, 2006
3. ASME Boiler and Pressure Vessel Code, Section III, Division 1-Subsection NF Supports, Edition 2004, including Addenda 2005
4. ASME Boiler and Pressure Vessel Code, Section II, Part D – Properties (Metric), Edition 2004, including Addenda 2005
5. T. Kirk Patton, Tables for Hydrodynamic Mass Factors for the Translational Motion, ASME-Publication 65-WA/UNT-2
6. R. J. Fritz, The Effect of Liquids on the Dynamic Motions of Immersed Solids Journal of Engineering for Industry, February 1972

7. G. W. Housner, Dynamic Pressures on Accelerated Fluid Containers, Bulletin of the Seismological Society of America 47 (1957)
8. J. M. Biggs, Introduction to Structural Dynamics, McGraw Hill 1964, ISBN 07-005255-7
9. Design Input Transmittals, DIT-SUMP-0001-00, 0002-00, 0003-00, 0004-00
10. Reduced Allowables for Drillco Bolts, 12241-NS (B)-214, Rev. 5, 8-7-87
11. CCI Report, Head Loss Calculation, Beaver Valley Unit 1, Reactor Building Emergency Sump Strainers, (8700-DMC-1654)
12. CCI Drawings (Vendor Technical Information 8700-06.060 Series Drawings)
13. Drawing 8700-RV-1K, Rev. 4, "Reactor Containment Liner Details - Sh 5"
14. Drawing 8700-RV-1L, Rev. 4, "Reactor Containment Liner Details - Sh 6"
15. Analysis 13387.65-S-0150, Rev. 0, Add. A1, "Recirculating Pump Frame Analysis"
16. BVPS-1 Analysis NP(B)-00256-Z-021, Rev. 2, "Pipe Support Reanalysis of Problem No. 256, Support No. H-1 (Anchor)"
17. Condition Report (CR) 07-28102, October 8, 2007, "BV1 Containment Sump Project: Drillco Minimum Embedment Violation"
18. CR 07-28180, October 9, 2007, "QC ID: Drillco Spacing and Embedment Violations ECP 05-0361 RCB Sump"
19. CR 07-28564, October 15, 2007, "QC ID: Drillco Embedment Depth Violation ECP 05-0361 RCB Sump"

The code used for the design of the BVPS-1 containment strainer is the ASME Boiler and Pressure Vessel Code, Section III, Division 1-Subsection NF Supports, Edition 2004 including Addenda 2005. The material properties, allowable stresses, and formulas used have been reconciled against the 1998 Edition of the ASME Code. Evaluations of field modifications for welding, anchorages and fasteners used the American Institute of Steel Construction (AISC) Manual of Steel Construction, Eighth Edition.

The critical components of the strainer assembly, fasteners and anchorages are analyzed using manual calculations and finite element methods based on ANSYS modeling. Installation modifications were analyzed using manual calculations and "Preparation and Revision of Pipe Support Analyses" (PC-PREPS) computer modeling. The standard strainer module of 8 cartridges per side was used in the analysis and was assumed to envelop modules of 7 and 5 cartridges per side. Debris weight per cartridge was based on assumed uniform debris spreading over the strainer area. Table 3.k.1-1 provides the load combinations used for the analysis.

Table 3.k.1-1

Load Combination Number	Temperature		Load Combination	ASME Service Level
	(°F)	(°C)		
1	280	137.8	DL (pool dry)	A
2	280	137.8	DL + OBE (pool dry)	B
3	280	137.8	DL + SSE (pool dry)	C
4	280	137.8	DL +OBE (pool filled)	B
5	280	137.8	DL + SSE (pool filled)	C
6	100 (212)	37.8 (100)	DL + WD + OBE (pool filled) + DP	C
7	100 (212)	37.8 (100)	DL + WD + SSE (pool filled) + DP	C
8	100	37.8	DL + LL (pool dry)	A

Stress limits at 100 degrees Celsius (°C) are used for the load combinations 6 and 7 in the analysis for the support structure.

Loads:
DL Dead Load (Weight of strainers and supporting structures)
WD Weight of debris
DP Pressure difference
OBE Operating Basis Earthquake
SSE Safe shutdown earthquake
LL Live Load

Hydrodynamic masses as well as loads due to sloshing are taken into account for submerged strainers exposed to earthquake loads.

BVPS-2

The design inputs used in the analyses are:

1. 12241-NP(N)-2000, "Reactor Ctmt. Bldg. ARS Calculation," Revision 1
2. Engineering Change Package No. 05-0362-01, "Replacement of Containment Sump Strainer"
3. Calculation No. 10080-DSC-0282, "Analysis of Top Hat Assembly"
4. Calculation No. 12241-SM-035, "Analysis and Design of Containment Sump Screens (Trash Rack)," Rev. 2
5. Specification No. 2BVS-634, "Specification for Level Switches," April 13, 1987

6. Containment Screen Drawings (Vendor Technical Information 2003.191 Series Drawings)
7. Designers, Specifiers and Buyers Handbook for Perforated Metals, Industrial Perforators Association, 1993
8. Final Report on Strainer-Model Tests and Force-Calculation Methodology, Dr. T. Sarpkaya, prepared for Enercon
9. Diamond Manufacturing Company, Perforated Metal Specialists Catalog, 2003
10. Crane, "Flow of Fluids Through Valves, Fittings and Pipe," Technical Paper No. 410, Crane Engineering Co., 1985
11. Specification 2BVS-939A, "Stone & Webster Pipe Classes," Revision 6 through Addendum 4
12. Specification 2BVS-15, "Recirculation Pumps," August 3, 1987
13. ASME Steam Tables, Fifth Edition, 1983

The code used to design the BVPS-2 containment sump strainer assembly is the AISC Specification for the Design, Fabrication, and Erection of Structural Steel - Seventh Edition. The AISC code does not provide reduction in strength due to elevated temperatures. Therefore the material property values used at elevated temperatures are from ASME Section III, 1971 and 1974 Editions. Stud material properties for the top-hats are from ASME Section III, 1984.

The design loads used in the analyses are:

1. Dead Load (DL)
2. Faulted Seismic (SSE)(including hydrodynamic effects)
3. Live Load (LL)
4. Pressure Differential
5. Jet Impingement (loads are from a water jet discharging from the RSS test line as it strikes the strainer under pump testing)

The loading combination consider in the analysis include:

DL + Seismic (SSE) + Differential Pressure

DL + Seismic (SSE) + LL

DL + Jet Impingement

The combinations were computed for Normal and Faulted conditions (SSE). The Upset condition = DL + Seismic OBE is qualified by comparison to the Faulted load case = DL + Seismic SSE + LL

The live load on the overhead grating is considered to be 75 pounds per square foot.

The pressure load on the channel separation grating is considered to be 734 pounds per square foot.

The BVPS-2 strainer top-hats are bolted to supporting structures. The top-hats were analyzed by hand calculations. The strainer supporting structures were designed as space frames using GTSTRUDL dynamic analysis and hand calculations. Modifications to the strainer supporting structure during installation were evaluated using PC-PREPS static analyses.

3.k.2 ***Provide a summary of the structural qualification results and design margins for the various components of the sump strainer structural assembly.***

BVPS-1

The following table (Table 3.k.2-1) provides a listing of major components with their design margins. In some cases (e.g., anchor bolts or welds) the margin listed is the smallest margin presented in the analysis for the same type of component.

Table 3.k.2-1

Component	Actual Value (1)	Allowable Value (1)	Margin
Strainer Modules			
Side Wall	91.6 MPa	296.6 MPa	69%
Upper Cover Plate	108.3 MPa	168.5 MPa	35%
Lower Cover Plate	171.6 MPa	206.8 MPa	17%
Perforated Sheet	263.5 MPa	296.6 MPa	11%
Support Structure	96 MPa	115.1 MPa	16%
Duct Plate	154 MPa	259 MPa	40%
Anchor Plate	64 MPa	172.7 MPa	63%
Anchor Bolts(3)	0.849	1.0	15%
Anchor Bolts – End Plate(3)	0.973	1.0	2.7%
Channel Box			
Connection Duct Plates	250.4 MPa	258.8 MPa	3.2%
Suction duct	243.6 MPa	258.8 MPa	5.8%
Suction duct Anchor Bolts(3)	0.652	1.0	35%

Table 3.k.2-1 (Continued)

Component	Actual Value[1]	Allowable Value[1]	Margin
Suction Box			
Suction Box support Element	14.817 MPa	43.407 MPa	65%
Anchor Plates	107.642 MPa	296.55 MPa	63%
Back Side Plates	208 MPa	296.6 MPa	30%
Front Side Plates	198 MPa	296.6 MPa	33%
Top Plates	165 MPa	296.6 MPa	44%
Anchor Bolts	4.976 kN	5.525 kN	10%
Sheet	165 MPa	296.6 MPa	44%
Side Plate – Sheet	198 MPa	296.6 MPa	33%
Field Modifications			
Anchor bolt tension	870 lb	1940 lb	55%
Anchor bolt shear	1360 lb	1440 lb	5.5%
Brace Weld	Small	8580 lb	[2]
Threaded Rod	23.826 MPa	326.1 MPa	86%
Stilling Well Box Weld	0.0066 in	0.125 in	94%
Sump Liner Plate	4552.41 psi	22500 psi	79%
Vertical Brace Weld	0.173 in	0.1875 in	7.7%
Base Anchor[3]	0.375	1.0	62%
Base Stress	22281.6 psi	22500 psi	1%

Notes:

(1) 1 MPa = 145 psi, 1kN = 224.809 lb

(2) Margin is not quantified due to use of engineering judgment.

(3) Interaction Ratio

BVPS-2

Table 3.k.2-2 provides a listing of major components with their design margins. In some cases (e.g, anchor bolts or welds) the margin listed is the smallest margin presented in the analysis for the same type components. The majority of components have a substantial margin of safety.

Table 3.k.2-2

Component	Actual Value	Allowable Value	Margin
MAIN FRAME			
Member	0.83	1.0	17%
Cover Plate	7149 psi	17250 psi	59%
Vertical Plate	3488 psi	3974 psi	12%
Horizontal Plate	8843 psi	17250 psi	49%
Connection Plate	13521 psi	17250 psi	22%
Embedment Plate (studs)	0.99	1.0	1 %
Weld	0.97	1.0	3%
EXTENSION FRAME			
Member	0.77	1.0	23%
Base Plate (Anchor Bolt)	1.015	1.0	(1)
Weld	0.85	1.0	15%
Side Seal Plate	9038 psi	17250 psi	48%
Connector Plates	18070 psi	20700psi	13%
TOP-HATS			
Top-Hat	600 psi	1498 psi	60 %
Studs	0.2	1.0	80 %
Cover Plate	8019 psi	16875 psi	52 %
Welds	202 lb/in	563 lb/in	64%

Note:

(1) Margin is not quantified due to use of engineering judgment.

3.k.3 ***Provide a summary of evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high energy line breaks (as applicable).***

FENOC Response

BVPS-1

Reviews were performed and documented within the engineering change package to determine the dynamic effects of missiles and pipe whip and jet impingement on the new BVPS-1 strainer.

The new sump strainer is located on elevation 692 feet 11 inches of the containment, on the bottom floor of the containment and entirely outside of the crane wall adjacent to the containment liner. High energy systems, such as Feedwater, Main Steam, Steam Generator Blowdown and Reactor Coolant piping, are isolated from the sump by major structural features such as walls and floors. These structural features will act as barriers that will withstand loadings caused by missile impact, jet forces and pipe whip impact forces. This protection from the dynamic effects of pipe breaks is discussed in Section 5.2.6 of the BVPS-1 Updated Final Safety Analysis Report (UFSAR). The protection from dynamic effects provided for the original sump screens will be the same for the new containment sump strainer assembly.

Therefore, there is no potential for loads from high energy pipe whip, jet impingement, or internally generated missiles.

BVPS-2

Reviews were performed and documented within the engineering change package and top-hat qualification calculation that determined the effects of missiles, high energy lines or associated dynamic effects due to pipe whip and jet impingement on the new BVPS-2 strainer. The new sump strainer is located on elevation 692 feet 11 inches of the containment, on the bottom floor of the containment and entirely outside of the crane wall adjacent to the containment liner.

There are no high energy lines in proximity to the containment sump strainer. High energy systems, such as Feedwater, Main Steam, Steam Generator Blowdown and Reactor Coolant piping, are isolated from the sump by major structural features such as walls and floors. These structural features will act as barriers that will withstand loadings caused by missile impact, jet forces and pipe whip impact forces. This protection from the dynamic effects of pipe breaks is included in Section 3.6B.2.1.1, "Criteria for Inside the Containment," of the BVPS-2 UFSAR. All breaks postulated are systematically analyzed to determine what potential damage may occur, due to pipe whip and jet impingement to systems and structures required for safe shutdown. The protection criteria are provided in Sections 3.6B.1 and 3.6N.2.2.3. The protection from dynamic effects provided for the original sump screens will be the same for the new containment sump strainer assembly. Therefore there is no potential for loads from high energy pipe whip, jet impingement, or internally generated missiles.

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

FENOC Response

The new containment sump strainers for BVPS-1 and BVPS-2 are designed as passive components. There is no backflushing in the design. No structural analysis is required for active components or for backflushing.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. A response is presented below pertaining to the sump structural analysis at BVPS-1 and BVPS-2. The format for the response first includes the request itself, followed by FENOC's response.

RAI #38 (from Reference 6)

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

FENOC Response

As stated in the response to Review Area 3.k, "Sump Structural Analysis," no active approach such as backflushing is used for either BVPS-1 or BVPS-2 strainer design. An active approach was not considered as a potential strategy or backup for addressing any issues.

3.l. 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 Requested Information 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 flow paths from the postulated break locations and containment spray washdown to identify potential choke points in the flow field upstream of the sump.***
2. ***Summarize measures taken to mitigate potential choke points.***
3. ***Summarize the evaluation of water holdup at installed curbs and/or debris interceptors.***
4. ***Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.***

FENOC Response

As part of the containment walkdown report and debris transport analyses, an evaluation of flowpaths necessary to return water to the recirculation sump strainer was performed. This evaluation was performed in accordance with the recommendations contained within NEI 04-07 to identify those flowpaths that could result in the holdup of water not previously considered. These flowpaths included areas that would allow containment spray and RCS break flow to enter. This evaluation determined that, with the exception of the fuel transfer canal, all other water return flowpaths have sufficiently large openings to prevent the holdup of significant quantities of water that could challenge the containment sump minimum water level analysis.

Containment water level is determined dynamically as part of the integrated containment response analyses. In these analyses, hold-up volumes are calculated for all spray return pathways that due to recessed areas such as the fuel transfer canal, would function to reduce the quantity of water available in the containment sump pool. The water holdup assumptions in the dynamic containment analyses were also compared against the BVPS-1 and BVPS-2 Debris Generation and Debris Transport analyses to ensure that no new hold-up volumes were created as a result of debris blockage of the required flowpaths. One potential holdup point was identified. The new drainage hole for the reactor cavity was designed with a cruciform personnel exclusion device. Due to the location of this device and the turbulence in the vicinity of the drain hole, it is possible that large pieces of debris could be transported into the bore hole and trapped by the exclusion device. The design has been enhanced such that the device was removed from BVPS-1 during the fall 2007 refueling outage (1R18) and was removed from BVPS-2 during the spring 2008 refueling outage (2R13).

The required flowpaths for return of water to the containment sump pool include the refueling cavity drains via the reactor vessel flange seal, the stairwells connecting the various elevations of containment, and the openings (doorways) within the bioshield. These pathways were walked down to ensure that no significant holdup locations exist. All gates and doors that could trap debris have a large enough opening at the bottom to preclude debris blockage. For all areas with doorways containing curbs, either the curbs are below the minimum water level for recirculation or an alternate drain path is available to prevent hold-up. Neither BVPS-1 nor BVPS-2 has any installed debris interceptors or flow diversion devices that could lead to potential water holdup points.

The refueling cavity drains to the reactor cavity via the reactor vessel flange seal area. A permanent seal is installed in this area. The permanent seal has several openings through the seal for reactor cavity ventilation that are uncovered during power operation to allow adequate water drainage to the cavity. A possible upstream blockage point was identified at BVPS-2, that is not present at BVPS-1. The potential blockage point results from the presence of access port safety covers for the reactor cavity seal ring. The safety covers have a coarse mesh, but since the debris washed into the cavity would be mainly fine debris, with some small and large pieces of RMI, this was judged not to be a significant blockage concern. At BVPS-1, shielding below the permanent seal was identified in the Debris Transport analysis as a potential blockage point. However, the analysis determined that the gaps on either side of the shielding were adequate to pass debris as most of the debris would be fines with some small and large RMI. Therefore, blocking of the gaps is not a significant concern. The fuel transfer canal (housing the fuel assembly upender) is located in the refueling cavity, does not drain in an accident, and as discussed above (Review Area 3.g.2), is accounted for as a water holdup location in the dynamic containment analysis.

3.m. Downstream effects - Components and Systems

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

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

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

GL 2004-02 Requested Information Item 2(d)(vi)
Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

1. ***If NRC-approved methods were used (e.g., WCAP-16406-P with accompanying NRC SE), briefly summarize the application of the methods. Indicate where the approved methods were not used or exceptions were taken, and summarize the evaluation of those areas.***
2. ***Provide a summary and conclusions of downstream evaluations.***
3. ***Provide a summary of design or operational changes made as a result of downstream evaluations.***

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

FENOC RESPONSE

The downstream impact of containment sump debris on the performance of the BVPS-1 and BVPS-2 ECCS and the RSS flow path components was evaluated using the guidance of Westinghouse WCAP-16406-P-A, Evaluation of Downstream Effects in Support of GSI-191 Revision 1.

The methodology for the BVPS evaluation of downstream effects started with determining the flow paths of the ECCS and RSS that are used in response to various design basis accidents. The flow paths considered normal system lineup for a large break Loss of Coolant Accident (LOCA) and a small break LOCA. These flow paths were used in determining the system components that would be evaluated for blockage and wear during the accident and a 30-day post accident period. The determination of the debris that could either block flow through the ECCS or RSS components or contribute to internal wear of the components is based on the quantities of insulating material, coatings and latent debris in containment. These materials were then assessed to determine if they would be dislodged or destroyed during various accidents. Once the quantities of loose debris that would be generated during various accident scenarios was predicted, an evaluation was done to show what percentage of the loose debris would be transported under each accident scenario to the containment recirculation sump by blowdown, washdown, pool fill-up or recirculation flow. These analyses were discussed in the response to Review Areas 3.a through 3.e. Specific bounding debris concentrations were established and were then used in the assessment of component blockage and wear.

The sump strainer screens at both BVPS-1 and BVPS-2 have a series of circular openings. The BVPS-1 screens are constructed of perforated plate that has 1/16 inch diameter holes. BVPS-2 screens have 3/32 inch diameter holes. During installation, gaps or openings between connected parts of the strainer were verified to be less than 1/16 inch for BVPS-1 and 3/32 inch for BVPS-2. The calculations conservatively assume that 100 percent of fibrous and particulate debris that reaches the screen goes through the screen.

All of the debris assumed to pass through the sump screens is assumed to have the potential to cause blockage and or wear at downstream locations.

A list of components for each unit that would be in the recirculating flow path during postulated LOCAs was developed. These components are in the following flow paths:

1) Low Head Safety Injection (LHSI) – Recirculation Mode (BVPS-1 only)
2) Charging / High Head Safety Injection (HHSI) – Recirculation Mode
3) Recirculation Spray System (RSS)

These components were reviewed for exposure to debris laden flow and hence the possibility of component blockage and abrasive or erosive wear. Each of the potentially susceptible pumps, valves, orifices, nozzles, heat exchangers and pipe segments was assessed for blockage and wear using the guidance of WCAP-16406-P-A, Revision 1.

The recirculating fluid volumes, debris quantities, debris concentrations and debris mass fractions form the basis for evaluating each of the components susceptible to blockage and abrasive or erosive wear. Blockage evaluations and calculations of wear rates and total mission wear used component and system parameters such as material of construction, material parameters such as hardness, component internal dimensions, fluid mass flows and velocities through the components, pump clearances, valve openings and code allowable stresses and wall thicknesses. Debris depletion, as described in the WCAP, is credited in these evaluations.

With the exception of the RSS pumps for both units and the LHSI pumps for BVPS-1, the quantity of debris used in the downstream effects analysis is based on the debris values prior to insulation modifications. BVPS-1 has completed previously identified insulation modifications during the spring of 2009 refueling outage (1R19) and BVPS-2 is scheduled to complete insulation modifications in the fall of 2009. These modifications will result in less debris transported to the containment sump. Additional margin for the HHSI pumps will be realized after the insulation modifications are completed. The RSS pumps for both units and the LHSI pumps for BVPS-1 were evaluated based on the debris concentration that will be realized after the insulation modifications are completed.

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

The blockage evaluations revealed that the BVPS-1 and BVPS-2 high pressure safety injection throttle valves had gaps that were smaller than the size of the opening in the new strainers. High pressure safety injection throttle valves were replaced at BVPS-1 during the fall 2007 refueling outage (1R18) and were modified at BVPS-2 during the spring 2008 refueling outage (2R13). Debris potentially passing through the strainers at BVPS-1 and BVPS-2 would not block other components.

Wear analysis for the valves, orifices, nozzles, heat exchangers and pipe segments evaluated were found to meet the acceptance criteria of WCAP-16406-P-A, Revision 1, with the exception of the high pressure safety injection throttle valves discussed above.

Detailed analyses were performed for the BVPS-1 and BVPS-2 high head safety injection pump performance under post accident containment sump downstream debris laden conditions. The analyses were performed by MPR Associates Incorporated, with input provided by the pump and mechanical seal manufacturers. The analyses included: a hydraulic performance assessment, mechanical seals performance analysis, and a rotor dynamic analysis. The hydraulic performance assessment was performed in accordance with the screening criteria in WCAP-16406-P-A, and the associated SE. The mechanical seal performance was also assessed. The mechanical seal backup seal bushings for the HHSI pumps are manufactured from stainless steel with a Grafoil insert. An analysis was included to conservatively assess pump leakage considering a passive failure of a mechanical seal in conjunction with destruction of the Grafoil insert. The seal leakage was found to be bounded by the current design basis. A cyclone separator is not used in the seal injection system for the HHSI pumps. The analyses for hydraulic performance and mechanical seal performance were determined to be acceptable per the WCAP requirements. The rotor dynamic analysis followed the methodology described in the WCAP and included the following:

Calculation of the wear rate and clearances at the wear rings, and pressure reducing sleeve as a function of time for the 30 day mission time was performed.

Calculation of the differential pressures across the wear rings and pressure reducing sleeve as a function of pump flow and clearance to determine the stiffness and damping coefficients was performed.

Calculation of the journal bearing pedestal stiffness and journal bearing stiffness and damping coefficients was performed.

A rotor dynamic analysis of the HHSI pump with as-built and worn clearances was performed considering multiple flow rates and operating times through the 30 day mission time.

The results of the rotor dynamic analysis were compared to the acceptance criteria in American Petroleum Institute Standard API 610, as referred to in the WCAP. The results of the analysis shows that the pump remains stable under the predicted wear rates and will maintain its design functions throughout its 30 day mission time.

The wear analysis for the BVPS-1 and BVPS-2 RSS pumps and the BVPS-1 LHSI pumps were developed in accordance with the requirements of WCAP-16406-P-A, Revision 1. Debris concentration inputs were based on the final predicted debris transported to the sump after insulation modifications that were completed for BVPS-1 during the spring 2009 refueling outage (1R19) and are scheduled for BVPS-2 during the fall 2009 refueling outage (2R14). The wear results for all components evaluated were found to be within the wear acceptance criteria in the WCAP. With the relatively low wear, the hydraulic performance of the pumps was evaluated as acceptable.

The WCAP SE requires the licensee to evaluate seal leakage in the context of room habitability, room equipment operation, and environmental qualification if the calculated leakage is outside that which has been previously assumed. Seal leakage has been evaluated for the HHSI pumps for both units. The postulated leakage has been determined to be bounded by both BVPS-1 and BVPS-2 design bases.

The BVPS-1 RSS pumps consist of two pumps inside the containment and 2 pumps outside the containment. The BVPS-2 RSS pumps are all located outside of the containment. The seals for these pumps are not exposed to debris laden fluid. Seal leakage for the pumps inside the containment has no impact on room habitability, equipment operation, and environmental qualification since any leakage is contained. The RSS pumps for both BVPS-1 and BVPS-2 that are located outside of the containment and the BVPS-1 LHSI pumps also located outside of the containment, are fitted with a tandem mechanical seal arrangement and have no cyclone separators in their shaft seal assemblies. The tandem mechanical seal arrangement provides a positive seal against leakage of radioactive fluid from the seals of these pumps. The space between the seal faces is maintained at a pressure greater than the recirculation water with demineralized water as seal fluid, thus preventing leakage of the recirculation sump water. This will also eliminate debris-laden fluid from entering the seal.

In summary, the BVPS-1 and BVPS-2 ex-vessel downstream analyses have been completed and demonstrate that no unacceptable component wear or plugging of the ECCS and RSS flow paths will occur, and therefore inadequate core or containment cooling will not result due to the effects of the debris. Review area 3.n discusses the BVPS in-vessel downstream analysis.

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

The changes made to the plants as a result of the downstream analysis included the following:

BVPS-1

High pressure safety injection cold leg throttle valves were replaced to increase the throttle valve gap and eliminate potential blockage by debris that passes through the strainer.

Insulation modifications which replace fibrous and Cal-Sil insulation with RMI were completed during the spring 2009 refueling outage (1R19). These modifications are targeted to achieve head loss margin, but have a positive impact on downstream effects as well.

BVPS-2

High pressure safety injection throttle valves were modified to increase the throttle valve gap to eliminate potential blockage by debris that passes through the strainer.

Insulation modifications which replace fibrous and Cal-Sil insulation with RMI are scheduled to be implemented during the fall of 2009 refueling outage (2R14). These modifications are targeted to achieve head loss margin but have a positive impact on downstream effects as well.

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

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. A response is presented below pertaining to downstream effects at BVPS-1 and BVPS-2. The format for the response first includes the request itself, followed by FENOC's response.

RAI #37 (from Reference 6)

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

ee. Wear rates of pump-wetted materials and the effect of wear on component operation

ff. Settling of debris in low flow areas downstream of the strainer or credit for filtering leading to a change in fluid composition

gg. Volume of debris injected into the reactor vessel and core region

hh. Debris types and properties

ii. Contribution of in-vessel velocity profile to the formation of a debris bed or clog

jj. Fluid and metal component temperature impact

kk. Gravitational and temperature gradients

ll. Debris and boron precipitation effects

mm. ECCS injection paths

nn. Core bypass design features

oo. Radiation and chemical considerations

pp. Debris adhesion to solid surfaces

qq. Thermodynamic properties of coolant

FENOC Response

At the time that this RAI was written, both the ex-vessel and in-vessel downstream analyses methodologies were still under development. The ex-vessel methodology is now defined by WCAP-16406-P-A, Revision 1, which includes the NRC staff's safety evaluation.

As noted in this response, the BVPS analysis has been conducted following the guidance of WCAP-16406-P-A, Revision 1 and WCAP-16793-NP, Revision 1. The issues related to WCAP-16406-P identified in this RAI have been resolved. See Review Area 3.n below for additional discussion of the fuel and vessel evaluation utilizing WCAP-16793-NP, Revision 1. Any additional actions required to address in-vessel downstream effects will be completed after issuance of the final NRC safety evaluation on WCAP-16793-NP, Revision 1.

3.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 screen and into the reactor vessel has on core cooling.

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

FENOC Response

Beaver Valley Units 1 and 2 have followed and satisfied the requirements of the PWROG program which provides reasonable assurance that sufficient long term core cooling (LTCC) is achieved to satisfy the requirements of 10 CFR 50.46 as listed in

WCAP-16793-NP, Revision 1. This includes both LOCADM analysis and fuel nozzle testing. Details follow.

The program consists of:

1. Unit specific analysis of the core (LOCADM) to confirm that:
   A. The maximum clad temperature will not exceed 800°F and
   B. The thickness of the cladding oxide and the fuel deposits will not exceed an average of 0.050 inches (50 mils) in any region.
2. Prototypical fuel assembly testing to justify the mass of debris that can reach the RCS and not impede long term core cooling.

Details of the PWROG program are provided in:

1. WCAP-16793-NP, Revision 1, "Evaluation of Long Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," dated April 2009 and
2. WCAP-17057-P, "GSI-191 Fuel Assembly Test Report for PWROG," dated March 2009

<u>BVPS Specific LOCADM Analysis</u>

A LOCADM analysis using the WCAP-16793-NP, Revision 1, methodology was performed by Westinghouse for BVPS-1. Plant specific particulate, fibrous, aluminum, and sump pH values were used in the analysis as inputs for calculating chemical debris consistent with WCAP-16530-NP-A. The fibrous debris loading used as input was based on the results of BVPS-1 sump strainer bypass tests.

Analysis results showed that the BVPS-1 maximum clad temperature and total fuel deposits are within the above acceptance criteria. The calculated maximum clad temperature is 359.18°F, which is less than 800°F, and the calculated total deposition thickness is 12.5 mils, which is less than 50 mils.

A LOCADM analysis using the WCAP-16793-NP, Revision 1, methodology was also performed by Westinghouse for BVPS-2. Plant specific particulate, fibrous, aluminum, and sump pH values were used in the analysis as input for calculating chemical debris consistent with WCAP-16530-NP-A. The fibrous debris loading was based on the results of sump strainer bypass tests conservatively performed with the debris eliminators removed. BVPS-2 presently uses a NaOH buffer and is planning to convert to a sodium tetraborate (NATB) buffer. Both were evaluated.

The results determined that the BVPS-2 maximum clad temperature and total fuel deposits are within the above acceptance criteria for both buffers. The calculated maximum clad temperature is 316.38°F, which is less than 800°F and the calculated total deposition thickness is 11.9 mils, which is less than 50 mils.

A comparison of BVPS clad temperature and total fuel deposition thickness to WCAP-16793-NP, Revision 1, acceptance criteria is provided in Table 3.n.1.

Table 3.n.1

Comparison of BVPS Clad Temperature and Total Fuel Deposit to WCAP-16793-NP, Revision 1

	BVPS-1	BVPS-2	WCAP-16793-NP Revision 1, LTCC Acceptance Bases	Does BVPS Satisfy LTCC Acceptance Bases?
Max Clad Temperature	359.18°F	316.38°F	Less than 800°F	Yes – Both BVPS 1 and BVPS-2 Are Acceptable and Satisfy LTCC
Total Deposition Thickness	12.5 mils	11.9 mils	Less than 50 mils	Yes – Both BVPS 1 and BVPS-2 Are Acceptable and Satisfy LTCC

Fuel Assembly Testing:

BVPS-1 and BVPS-2 both are covered by the PWROG GSI-191 fuel assembly tests as described in WCAP-16793-NP, Revision 1, dated April 2009 and WCAP-17057-P, dated March 2009. Both satisfy the WCAP requirements and acceptance criteria as described below.

WCAP-16793-NP, Revision 1, requires each unit to verify the following in order for its conclusions to apply to that unit:

1. Debris amounts must be less than the amounts shown in WCAP-16793-NP, Revision 1, Table 10-1.

2. Hot leg and cold leg driving heads must be greater than those adhered to in the Westinghouse fuel assembly tests reported in WCAP-17057-P, dated March 2009.
3. A unit specific LOCADM analysis must be performed (addressed above).

Unit specific particulate, fibrous and chemical debris satisfy the limits provided in Table 10-1 of WCAP-16793-NP, Revision 1 (See Table 3.n.2 below). Both BVPS-1 and BVPS-2 have available driving heads (for both hot leg and cold leg) that are more than adequate to satisfy the stop test limits and the maximum measured differential pressures reported in WCAP-17057-P, dated March 2009 (See Table 3.n.3 below). Thus, reasonable assurance is provided that both BVPS-1 and BVPS-2 will achieve LTCC.

Table 3.n.2

Comparison of BVPS-1 and BVPS-2
to Limits of WCAP-16793-NP, Revision 1, Table 10-1

Debris Type	WCAP-16793-NP Revision 1, Table 10-1 Limit (per FA, in lbs.)	BVPS-1 Amount (per FA, in lbs.)	BVPS-2 Amount (per FA, in lbs.)	Do BVPS-1 and BVPS-2 Satisfy the WCAP-16793-NP Revision 1 Limits?
Fiber	< 0.33	0.02	0.10	Yes, Both BVPS-1 and BVPS-2
Particulate	< 29	5.35	6.99	Yes, Both BVPS-1 and BVPS-2
Chemical	< 13	2.09	1.55	Yes, Both BVPS-1 and BVPS-2
Calcium Silicate	< 6	0.67	0.61	Yes, Both BVPS-1 and BVPS-2
Microporous Insulation	< 3.2	0	2.92	Yes, Both BVPS-1 and BVPS-2

FA = Fuel Assembly

Table 3.n-3

BVPS Available Driving Heads vs. Fuel Nozzle Tests

	Fuel Nozzle Test WCAP-17057 Stop Test Criteria	Fuel Nozzle Test WCAP-17057 Max Differential Measured For BV Plant- Groups		BVPS-1 Available Driving Head	BVPS-2 Available Driving Head	Does BVPS Satisfy WCAP-16793 & WCAP-17057
Hot Leg	13 psid	3.85 psid		16.41 psid	16.58 psid	Yes, BVPS Available Driving Heads are more than adequate to satisfy both Stop Test Limits and Max. Measured Differential of Fuel Nozzle Tests
Cold Leg	1.5 psid	1.5 psid		3.90 psid	3.87 psid	Yes, BVPS Available Driving Heads are more than adequate to satisfy both Stop Test Limits and Max. Measured Differential of Fuel Nozzle Tests

WCAP Status

It is recognized that the NRC review of WCAP-16793-NP, Revision 1, has not been completed. Any additional actions required to address NRC questions will be addressed within 90 days after issuance of the final NRC safety evaluation on WCAP-16793-NP, Revision 1.

3.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.***
2. ***Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425).***

   2.1 Sufficient 'Clean' Strainer Area

   i. 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.

   2.2 Debris Bed Formation

   i. 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 was based on break location 2.

   2.3 Plant Specific Materials and Buffers

   i. 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.

   2.4 Approach to Determine Chemical Source Term (Decision Point)

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

2.5 Separate Effects Decision (Decision Point)

i. State which method of addressing plant-specific chemical effects is used.

2.6 AECL Model

i. Since the NRC USNRC is not currently aware of the testing approach, the NRC USNRC expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results.

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

2.7 WCAP Base Model

i. For licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart [in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425)], justify any deviations from the WCAP base model spreadsheet (i.e., any plant specific refinements) and describe how any exceptions to the base model spreadsheet affected the amount of chemical precipitate predicted.

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

2.8 WCAP Refinements: State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

2.9 Solubility of Phosphates, Silicates and Al Alloys

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

ii. For crediting inhibition of aluminum that is not submerged, licensees should provide the substantiation for the following: (1) the threshold concentration of silica or phosphate needed to passivate aluminum, (2) the time needed to reach a phosphate or silicate level in the pool that would result in aluminum passivation, and (3) the amount of containment spray time (following the achieved threshold of chemicals) before aluminum that is sprayed is assumed to be passivated.

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

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

2.10 Precipitate Generation (Decision Point)

i. State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.

2.11 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.

ii. For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminum), the percentage that precipitates, and the percentage that remains dissolved during testing.

iii. Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100 percent 140 percent).

2.12 Pre-Mix in Tank

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

2.13 Technical Approach to Debris Transport (Decision Point)

i. State whether near-field settlement is credited or not.

2.14 Integrated Head Loss Test with Near-Field Settlement Credit

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

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

2.15 Head Loss Testing Without Near Field Settlement Credit

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.

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).

2.16 Test Termination Criteria

i. Provide the test termination criteria.

2.17 Data Analysis:

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

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

2.18 Integral Generation (Alion)

i. A sufficient technical basis is developed to support selecting plant-specific test parameters that produce a conservative chemical effects test

ii. Inability to reach peak sump temperatures is offset by extended testing at highest loop temperatures.

2.19 Tank Scaling / Bed Formation

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

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.

2.20 Tank Transport

i. 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.

2.21 30-Day Integrated Head Loss Test

i. Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.

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

2.22 Data Analysis Bump Up Factor

i. Licensees should provide the details and the technical basis that show why the bump-up factor from the particular debris bed in the test is appropriate for application to other debris beds.

3.o.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.*

FENOC Response

Integrated chemical effects testing for BVPS-1 was completed in the spring of 2008 by Alion Science and Technology Corporation at Alion's Warrenville, Illinois, facility. This testing included incorporation of target debris load reductions. The testing also included WCAP-16530-NP chemical precipitates. The testing that was conducted kept chemical and nonchemical debris in suspension, and thus, debris was available for deposition on the prototype strainer tested. As discussed in the response to Review Area 3.f.4, Test 6 was determined to be the target test in regards to planned insulation modifications. This test case bounded the debris and chemical quantities for all breaks including BVPS-1 loop, reactor nozzle, and surge line breaks. The results from the test were explained in the response to Review Area 3.f, and acceptable results were achieved with deposition of chemical product on the sump strainer for BVPS-1. The response to Review Area 3.n provides information regarding chemical effects on core cooling.

Similar to BVPS-1, integrated chemical effects testing for BVPS-2 was completed in the fall of 2008. The testing also used WCAP-16530-NP chemical precipitates. Test 1A and Test 5 were determined to be the target tests for BVPS-2, with regard to planned insulation modifications. Test 1A bounds the debris and chemical quantities for BVPS-2 loop break and surge line break. Test 5 bounds the debris and chemical quantities for the BVPS-2 reactor vessel nozzle break, and identifies the maximum allowable Microtherm® load.

3.o.2 ***Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425).***

2.1 Sufficient 'Clean' Strainer Area

i. 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.

FENOC Response

FENOC did not perform a simplified chemical effects analysis for BVPS-1 or BVPS-2. Beaver Valley debris loads are sufficiently large to preclude the use of a simplified chemical effects analysis.

2.2 Debris Bed Formation

i. 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 was based on break location 2.

FENOC Response

Testing was performed for BVPS-1 and BVPS-2 based on the configuration after planned insulation modifications and addressed all breaks including the loop, reactor vessel nozzle, and surge line break loads for both units. The testing included latent and coating debris plus WCAP-16530-NP predicted chemical precipitants. Other tests were performed, which looked at other types of breaks, and it was determined that insulation modifications would be required.

Test 6 was performed for the purpose of determining the head loss of the final insulation configuration for BVPS-1 and bounds all breaks. However, during the spring 2009 refueling outage (1R19), fibrous insulation material (Temp-Mat™) was identified on the six reactor vessel inlet and outlet nozzles. The resulting additional fibrous loading is not bounded by the RCS nozzle break scenario assumptions for strainer testing and analysis that was performed. This issue has been entered into the corrective action program. A description of the proposed mitigation activities will be provided as a supplemental response to GL 2004-02 prior to the start of the fall 2010 refueling outage (1R20) as committed to in the April 30, 2009 FENOC letter, Reference 13. Test 1A was performed for the purpose of determining the head loss of the final configuration for BVPS-2 and bounds the loop break and surge line break. Additionally, Test 5 was performed for the purpose of determining the head loss for the BVPS-2 reactor vessel nozzle break and to identify the maximum allowable Microtherm® load.

For BVPS-1 Test 6 and BVPS-2 Test 1A and Test 5, additional quantities of sodium aluminum silicate and aluminum oxyhydroxide, equivalent to at least an additional 10 percent each, were added to allow for increased margin in head loss testing. Therefore, the debris for head loss testing with chemical effects was determined to be bounding for the final insulation configuration. The WCAP-16530-NP chemical testing methodology was used for BVPS-1 and BVPS-2 testing. Several cases were evaluated for the chemical effects head loss testing and adjusted as mentioned above for margin. The calculated amounts of precipitants for BVPS-1 and BVPS-2 testing are documented below in response to Review Area 3.o.2.7.

2.3 Plant Specific Materials and Buffers

i. 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.

FENOC Response

BVPS-1 (Utilizing WCAP-16530-NP Chemical Precipitates)

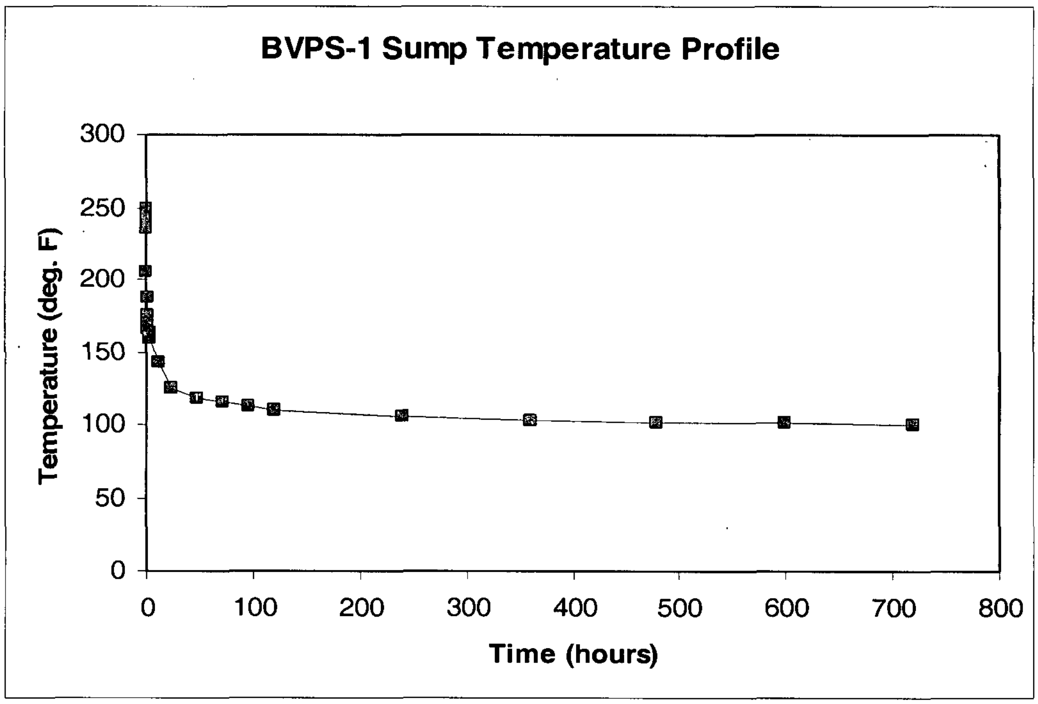
pH Range

A pH range from 8.79 to 10.1 was utilized. The initial pH of the spray was 10.1 (maximum expected spray pH), and then upon recirculation with mixing, a pH of 8.79 (maximum expected sump pH) was used. The sump pH was modeled as 8.79 throughout the event. This pH profile corresponds to a buffer of sodium hydroxide.

Temperature Profile

The BVPS-1 sump temperature profile used for WCAP-16530 predictions over 30 days is shown in Figure 3.o.2.3-1. The temperature profile provided is the maximum expected sump temperature.

Figure 3.o.2.3-1



Duration of Spray for BVPS-1

The duration of the containment spray was assumed to be for a full 30 days of operation.

Materials Expected to Contribute to Chemical Precipitate Formation

For BVPS-1 the following materials were evaluated in a WCAP-16530-NP spreadsheet calculation:

Aluminum (submerged/not submerged)

Calcium Silicate

Fiberglass Insulation (latent fiber)

Temp-Mat^{TM}

Min-K^{TM}

Concrete

BVPS-2 (Utilizing WCAP-16530-NP Chemical Precipitates)

pH Range

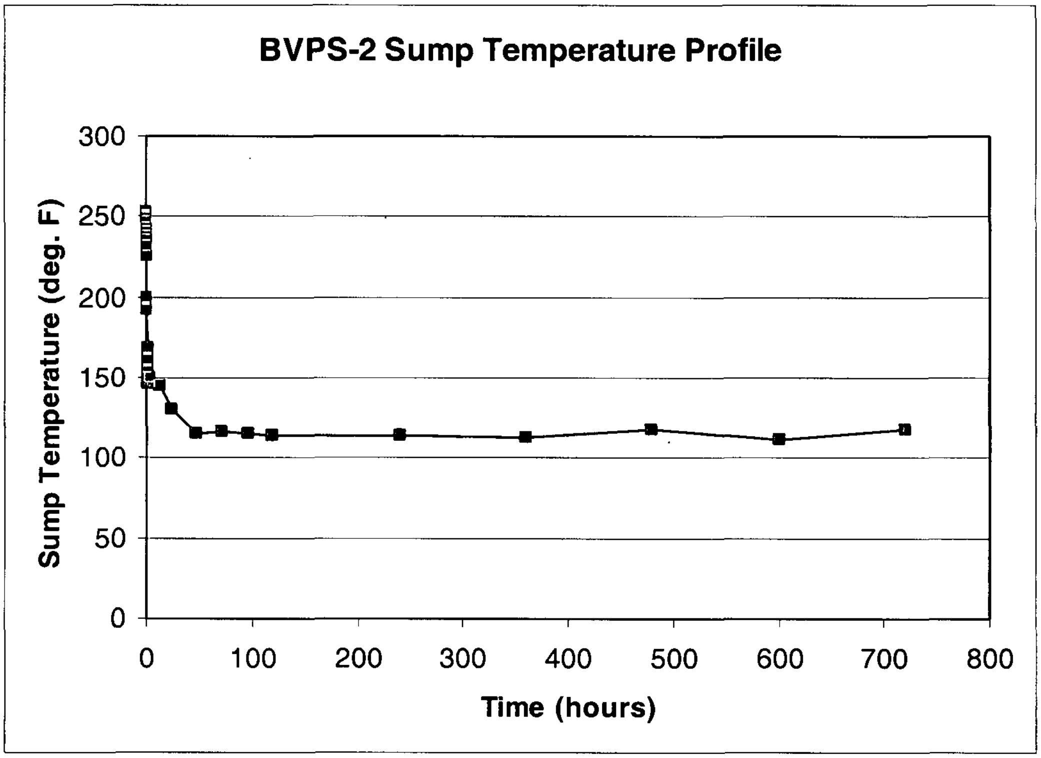
A pH range from 9.93 to 9.03 was used. The initial pH of the spray is 9.93, and then upon the start of RSS, the spray pH decreases to 9.48, and then upon quench spray termination, the spray pH decreases to 9.03. The sump pH was modeled as 9.03 throughout the event.

BVPS-2 is also planning to implement a buffer change during the next refueling outage. This was also evaluated. For sodium tetraborate, the pH ranges from 4.64 to 8.27. Therefore the sodium hydroxide loads are bounding.

Temperature Profile

The BVPS-2 sump temperature profile used for WCAP-16530 predictions over 30 days is shown in Figure 3.o.2.3-2. The temperature profile provided is the maximum expected sump temperature.

Figure 3.o.2.3-2



Duration of Spray for BVPS-2

The duration of the containment spray was assumed to be for a full 30 days of operation.

Materials Expected to Contribute to Chemical Precipitate Formation

For BVPS-2 the following materials were evaluated in a WCAP-16530-NP spreadsheet calculation:

Aluminum (submerged/not submerged)

Calcium Silicate

Fiberglass Insulation (latent fiber)

Temp-Mat™

Thermal Wrap

Min-K™

Microtherm®

Concrete

2.4 Approach to Determine Chemical Source Term (Decision Point)

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

FENOC Response

BVPS-1 and BVPS-2 testing was completed in 2008 by Alion Science and Technology at its Warrenville, Illinois, facility using the WCAP-16530 base model.

2.5 Separate Effects Decision (Decision Point)

i. State which method of addressing plant-specific chemical effects is used.

FENOC Response

Both BVPS-1 and BVPS-2 used the WCAP-16530 base model to conduct chemical effects testing at the Alion Warrenville facility.

2.6 AECL Model

i. Since the NRC USNRC is not currently aware of the testing approach, the NRC USNRC expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results.

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

FENOC Response

Requested response is not applicable to either BVPS unit because WCAP-16530 base model testing is used.

2.7 WCAP Base Model

i. For licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart [in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425)], justify any deviations from the WCAP base model spreadsheet (i.e., any plant specific refinements) and describe how any exceptions to the base model spreadsheet affected the amount of chemical precipitate predicted.

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

FENOC Response

i. The WCAP-16530-NP methodology was utilized for BVPS-1 and BVPS-2 chemical product generation predictions. No deviations were taken from the base model spreadsheet. Various combinations of cases were run to determine a bounding chemical debris load for head loss testing.

ii. The type and amount of predicted WCAP-16530-NP plant specific BVPS-1 and BVPS-2 precipitates for bounding tests are shown (before scaling amounts) in Tables 3.o.2.7-1 and 3.o.2.7-2 respectively.

Table 3.o.2.7-1

BVPS-1

Precipitate	Test 6 (lbs)
Sodium Aluminum Silicate	83
Aluminum Oxyhydroxide	245

Table 3.o.2.7-2

BVPS-2

Precipitate	Test 1A (lbs)	Test 5 (lbs)
Sodium Aluminum Silicate	130	77
Aluminum Oxyhydroxide	76	80

2.8 WCAP Refinements: State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

FENOC Response

The refinements to WCAP-16530-NP were not utilized for BVPS-1 or BVPS-2 predictions of chemical precipitates.

2.9 Solubility of Phosphates, Silicates and Al Alloys

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

ii. For crediting inhibition of aluminum that is not submerged, licensees should provide the substantiation for the following: (1) the threshold concentration of silica or phosphate needed to passivate aluminum, (2) the time needed to reach a phosphate or silicate level in the pool

that would result in aluminum passivation, and (3) the amount of containment spray time (following the achieved threshold of chemicals) before aluminum that is sprayed is assumed to be passivated.

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

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

FENOC Response

Refinements to WCAP-16530-NP were not utilized for BVPS-1 or BVPS-2 chemical product generation predictions.

2.10 Precipitate Generation (Decision Point)

i. State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.

FENOC Response

For the BVPS-1 and BVPS-2 testing, the chemical precipitates were prepared in accordance with WCAP-16530-NP in a separate mixing tank. Extra quantities of sodium aluminum silicate and aluminum oxyhydroxide equivalent to at least an additional 10 percent each, were added for increased margin.

2.11 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.

ii. For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminum), the percentage that precipitates, and the percentage that remains dissolved during testing.

iii. Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100 percent 140 percent).

FENOC Response

The in-situ chemical injection method was not used in BVPS-1 or BVPS-2 prototype testing.

2.12 Pre-Mix in Tank

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

FENOC Response

No exceptions to the procedure recommended for surrogate precipitate formation were taken for BVPS-1 or BVPS-2 testing. The chemical precipitates were not premixed in the test tank. They were added in batches to provide chemical loads corresponding to the precipitant generation cases identified in the test plans.

2.13 Technical Approach to Debris Transport (Decision Point)

i. State whether near-field settlement is credited or not.

FENOC Response

Near-field settlement was not credited in the BVPS-1 and BVPS-2 testing. All debris loads were added over a sparger in the tank. This was performed in two locations to maximize uniformity in debris distribution. A sparger system was used on the return line to aid in the suspension of debris within the water. Two mechanical mixers were also installed inside the tank opposite the sparger. These methods of debris agitation were sufficient in keeping the debris suspended in the water, and hence near-field settling was not credited.

2.14 Integrated Head Loss Test with Near-Field Settlement Credit

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

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

FENOC Response

As previously stated, near-field settlement was not credited; thus, this is not applicable to BVPS-1 and BVPS-2 testing.

2.15 Head Loss Testing Without Near Field Settlement Credit

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.

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).

FENOC Response

i. There was no insulation or chemical precipitate observed to have settled on the tank/flume floor for the BVPS-1 and BVPS-2 prototype testing. The only materials evidenced to have settled to the floor were some paint chips and dirt/dust. Due to the high average approach velocity utilized in the testing, and the sparger systems, the insulation and chemical debris remained suspended and deposited on the strainer array based on reported observations.

For both BVPS-1 and BVPS-2 prototype testing, a sparger system was installed on the return line and two mechanical mixers were installed inside the tank opposite the sparger to keep the debris suspended in the fluid and prevent non-prototypical settling on the tank floor. The hydraulics of the test tank were designed such that the sparger system and mechanical mixers did not result in washing debris from the strainer screen surfaces based on reported observations and post test debris bed photographs. The sparger system and mechanical mixers may have resulted in the transport of debris that otherwise would not transport. Given the high particulate to fiber ratio and very low fiber load for both BVPS-1 and BVPS-2, the transport of additional debris would result in increased head loss.

ii. The chemical precipitate settling was measured within 24 hours of the time the surrogate was used. The one-hour settled volume was required to be 6 ml (sodium aluminum silicate and aluminum oxyhydroxide) or greater and within 1.5 milliliters of the freshly prepared surrogate. These measurements were recorded during testing. The precipitate retest guidance provided under OG-07-270 noted that if chemicals were made within seven days of use, they did not need to be retested 24 hours before use. This guidance was implemented for testing associated with BVPS-1 only. Testing for BVPS-2 included retesting the chemicals 24 hours before use.

The lowest averaged measurement recorded for the bounding BVPS-1 testing was 8.6 milliliters for sodium aluminum silicate and 6.8 milliliters for aluminum oxyhydroxide and thus, was greater than the 6 milliliter settled criterion.

For BVPS-2, the lowest averaged measurement recorded for the bounding BVPS-2 testing was 7.9 milliliters for sodium aluminum silicate and

6.5 milliliters for aluminum oxyhydroxide and thus, was greater than the 6 milliliter settled criterion.

2.16 Test Termination Criteria

i. Provide the test termination criteria.

FENOC Response

The head loss measurements for each BVPS-1 and BVPS-2 test were recorded continuously throughout the test. The final head loss value was achieved when a stable differential pressure was achieved. The head loss was considered stable when the differential pressure across the debris bed changed by less than or equal to 1 percent over a one-hour period. In addition, the rate of head loss increase was required to be significantly decreasing, or the head loss was required to be consistently steady at termination of the test.

The stabilization criteria for intermediate loads varied. After the particulate debris load was added, a minimum of five pool turnovers was required. After each fibrous debris load batch was added, a minimum of 10 pool turnovers was required. In addition, the rate of head loss increase was required to be significantly decreasing, or the head loss was required to be consistently steady at termination of the test. In some cases due to debris bed formation the head loss was declared stable if the peak head loss was not increasing over a period of three hours or after eight hours had passed. A successful test was terminated based on stable head loss results.

Since the test termination criterion allowed for an increase of less than 1 percent over a one-hour interval at the completion of the test, an extrapolation of the head loss test results from the last value measured at the end of the test to the anticipated head loss at the end of the ECCS mission, that is, 30 days was required. The methodology for this extrapolation is discussed in the Review Area 3.o.2.17ii response.

2.17 Data Analysis:

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

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

FENOC Response

i. The curves in Figures 3.o.2.17-1 through 3.o.2.17-8 below illustrate the pressure drop as a function of time (uncorrected temperature) for the BVPS-1 and BVPS-2 bounding test configurations.

Figure 3.o.2.17-1

BVPS-1 Test 6 Differential Pressure and Velocity Versus Time

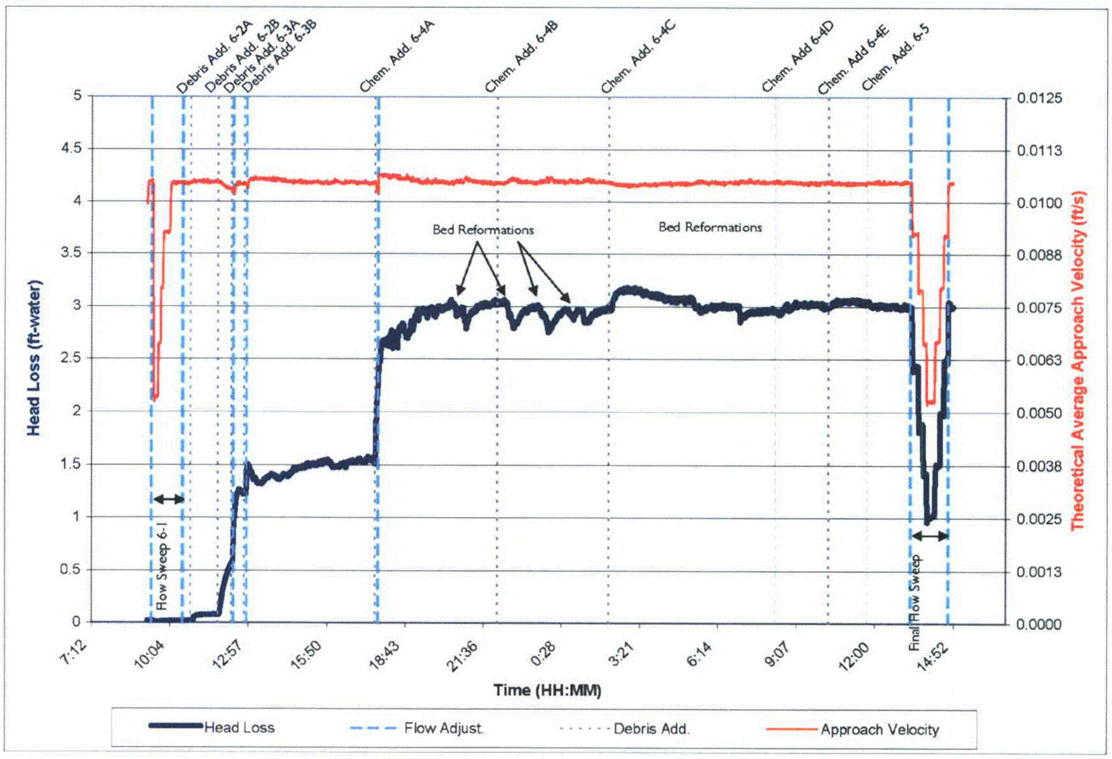


Figure 3.o.2.17-2

BVPS-2 Test 1A Differential Pressure and Velocity Versus Time, Part 1

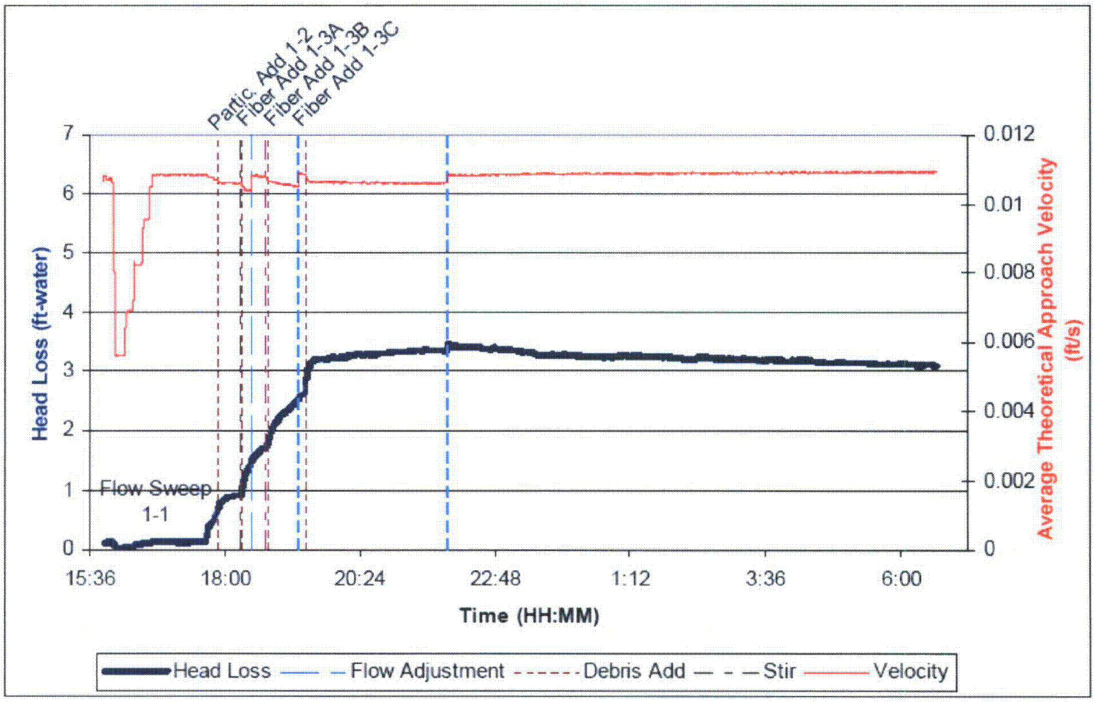


Figure 3.o.2.17-3

BVPS-2 Test 1A Differential Pressure and Velocity Versus Time, Part 2

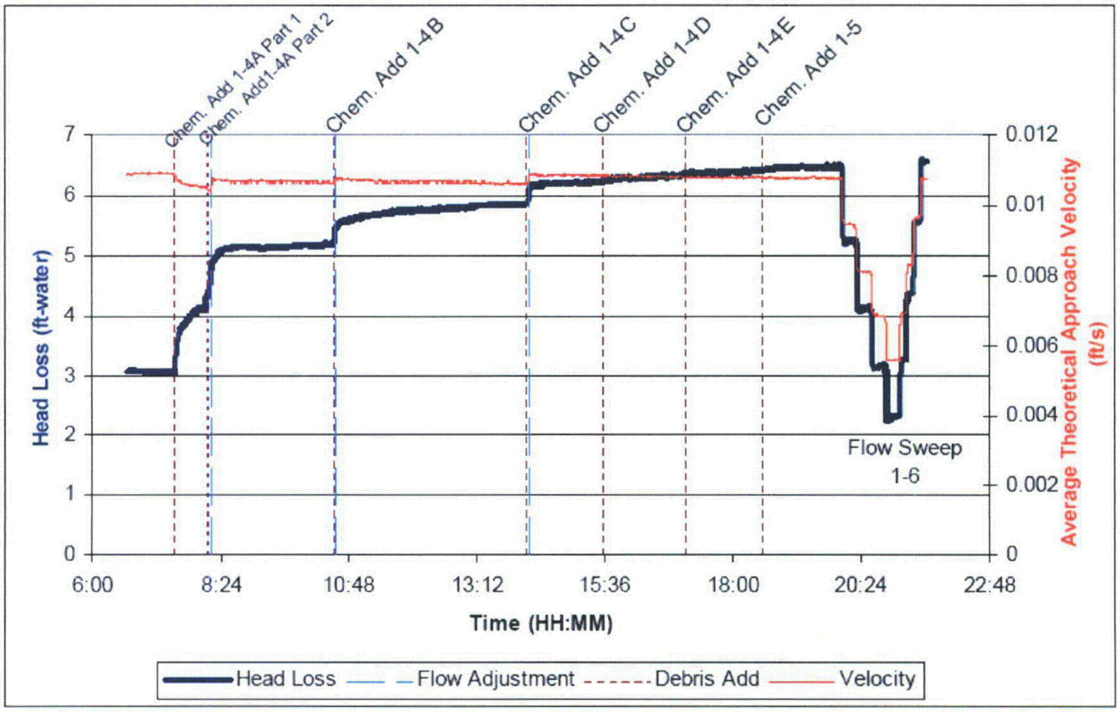


Figure 3.o.2.17-4

BVPS-2 Test 5 Differential Pressure and Velocity Versus Time, Part 1

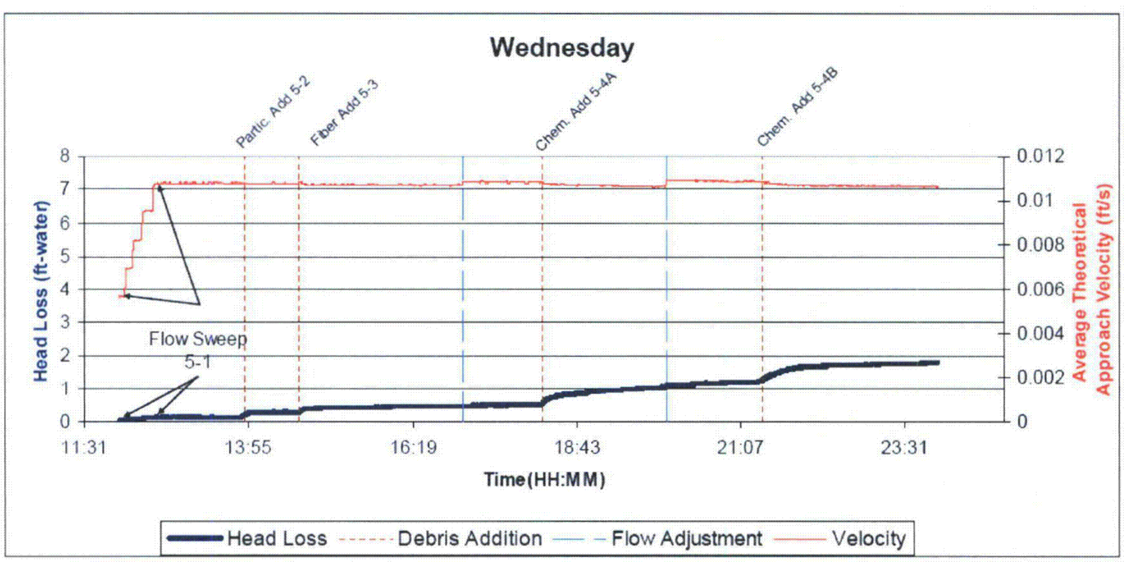


Figure 3.o.2.17-5

BVPS-2 Test 5 Differential Pressure and Velocity Versus Time, Part 2

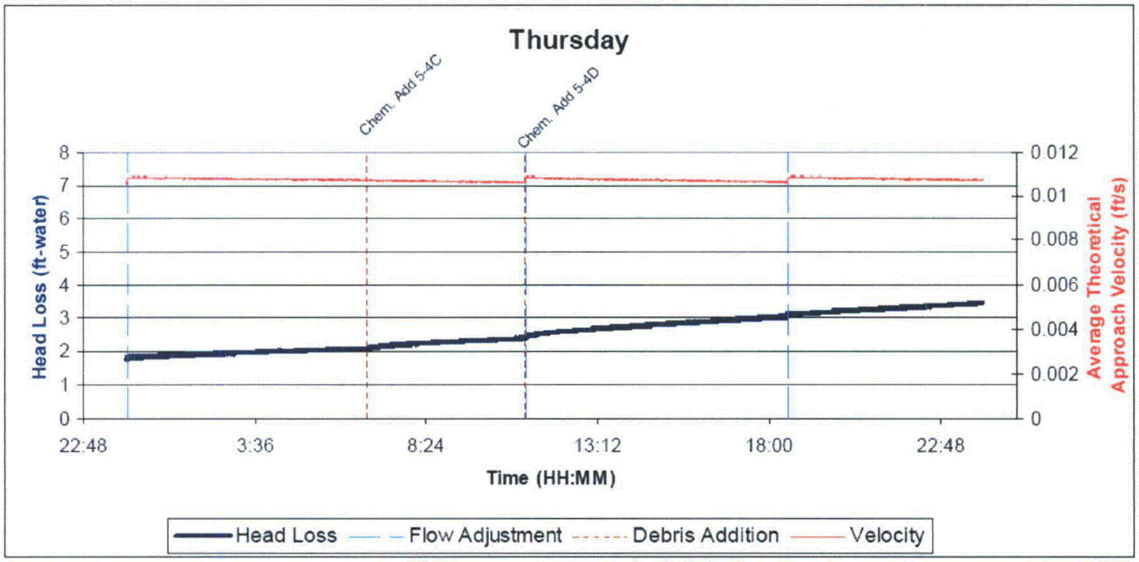


Figure 3.o.2.17-6

BVPS-2 Test 5 Differential Pressure and Velocity Versus Time, Part 3

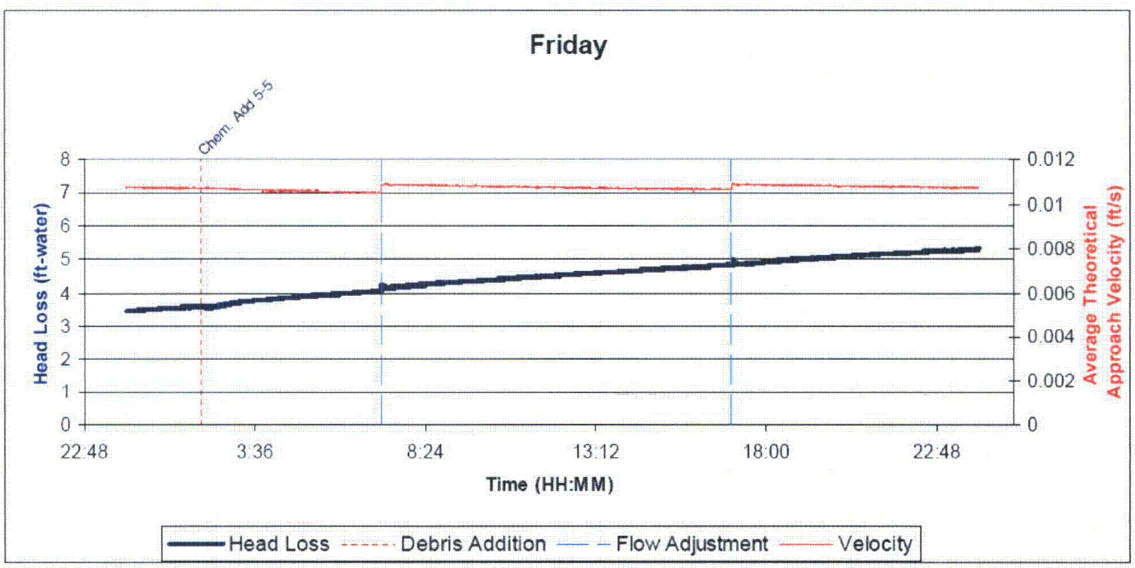


Figure 3.o.2.17-7

BVPS-2 Test 5 Differential Pressure and Velocity Versus Time, Part 4

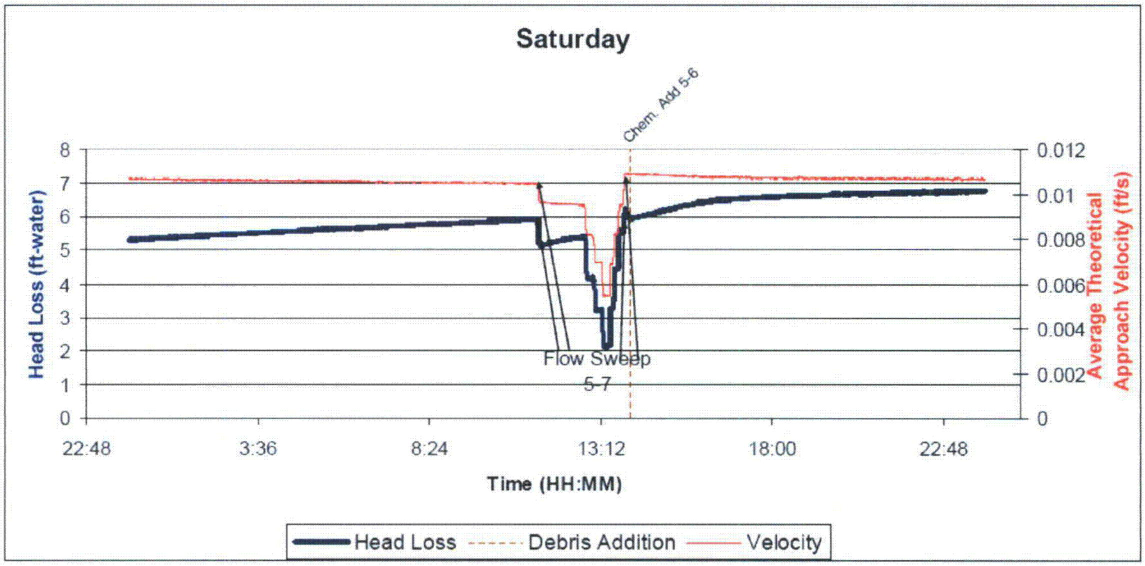
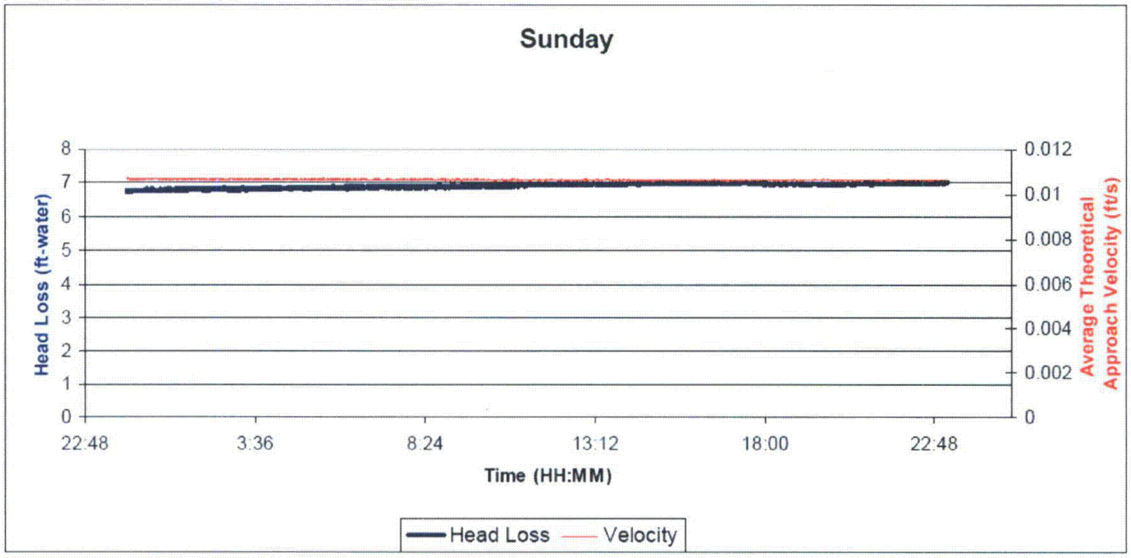


Figure 3.o.2.17-8

BVPS-2 Test 5 Differential Pressure and Velocity Versus Time, Part 5



ii. Temperature corrections were applied to the head loss data analysis.

Additionally, since the test termination criterion allowed for an increase of less than 1 percent over a one hour interval at the completion of the test, an extrapolation of the head loss test results from the last value measured at the end of the test to the anticipated head loss at the end of the ECCS mission (30 days) was required. For BVPS-1 Test 6 the head loss actually started to decrease towards the end of the test; therefore, no extrapolation was performed. For BVPS-2 Tests 1A and 5 an extrapolation was performed to determine the head loss at the 30 day mission time.

The raw test data for Tests 1A and 5 was analyzed in order to determine a bounding head loss value expected at the end of the 30 day mission time, using the following methodology. For each test the raw data starting from the last chemical addition point and ending when the final head loss value was declared stable was analyzed. The data is curve fit using a weighted 10 percent smoothing algorithm, which uses the locally weighted least-squared error method with an applied smoothing factor of 10 percent controlling the fraction of the data population considered during smoothing. In comparison to other smoothing methods, this technique is less sensitive to outliers. This provides a continuous representation of the data to allow further numerical analysis to be performed. While the data smoothing is useful for visualization, it does not affect the final result. A first order derivative is calculated using the data from the smooth curve fit. The first derivative results are reviewed to ensure that the slope of the smoothed data is trending towards zero, suggesting that the head loss profile is stabilizing. The smoothed head loss data beginning at the last chemical debris addition point (which is treated as time t = 0) is then curve fit to a simple logarithmic expression. This numerical expression allows for a curve fit that visually appears to match well with the data and also provides a curve whose slope never goes completely to zero. The head loss at 720 hours is then estimated from the resulting log curve fit expression.

The increase in head loss for Test 1A, from test termination and extrapolated to 30 days, at the test temperature was 0.11 feet. The increase in head loss for Test 5 was 0.64 feet.

2.18 Integral Generation (Alion)

i. A sufficient technical basis is developed to support selecting plant-specific test parameters that produce a conservative chemical effects test

ii. Inability to reach peak sump temperatures is offset by extended testing at highest loop temperatures.

FENOC Response

i. The requested response is not applicable to BVPS-1 or BVPS-2 because WCAP-16530 base model testing is used.

ii. The requested response is not applicable to BVPS-1 or BVPS-2 because WCAP-16530 base model testing is used.

2.19 Tank Scaling / Bed Formation

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

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.

FENOC Response

i. The requested response is not applicable to BVPS-1 or BVPS-2 because WCAP-16530 base model testing is used.

ii. The requested response is not applicable to BVPS-1 or BVPS-2 because WCAP-16530 base model testing is used.

2.20 Tank Transport

i. 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.

FENOC Response

i. The requested response is not applicable to BVPS-1 or BVPS-2 because WCAP-16530 base model testing is used.

2.21 30-Day Integrated Head Loss Test

i. Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.

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

FENOC Response

i. The requested response is not applicable to BVPS-1 or BVPS-2 because WCAP-16530 base model testing is used.

ii. The requested response is not applicable to BVPS-1 or BVPS-2 because WCAP-16530 base model testing is used.

2.22 Data Analysis Bump Up Factor

i. Licensees should provide the details and the technical basis that show why the bump-up factor from the particular debris bed in the test is appropriate for application to other debris beds.

FENOC Response

i. The requested response is not applicable to BVPS-1 or BVPS-2 because WCAP-16530 base model testing is used.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 6), requested additional information relative to Generic Letter 2004-02. Responses are presented below pertaining to chemical effects at BVPS-1 and BVPS-2. The format for the response first includes the request itself, followed by FENOC's response.

RAI #5 (from Reference 6)
Provide the expected containment pool pH during the emergency core cooling system (ECCS) recirculation mission time following a LOCA at the beginning of the fuel cycle and at the end of the fuel cycle. Identify any key assumptions.

FENOC Response

At the beginning of the fuel cycle, RCS boron will be at its maximum value. If a LOCA were to occur at this time, the sump pH would be lower than at any other time in the fuel cycle. To ensure that the lowest sump pH possible is calculated to obtain the pH range for the sump during a LOCA, the RWST, and accumulators are all assumed to be at their maximum boron concentration and maximum delivered volume; the Chemical Addition Tank is assumed to be at its minimum sodium hydroxide concentration and minimum delivered volume.

At the end of the fuel cycle, RCS boron will be at its minimum value. If a LOCA were to occur at this time, the sump pH would be higher than at any other time in the fuel cycle. To ensure that the highest sump pH possible is calculated to obtain the pH range for the sump during a LOCA, the RWST, and accumulators are all assumed to be at their minimum boron concentration and minimum delivered volume; the Chemical Addition Tank is assumed to be at its maximum sodium hydroxide concentration and maximum delivered volume.

BVPS-1

Minimum sump pH at beginning of life (BOL)	7.80
Maximum sump pH at end of life (EOL)	8.79

For BVPS-2

Minimum sump pH (BOL)	8.14
Maximum sump pH (EOL)	9.03

The NRC issued License Amendment No. 168 by letter dated April 16, 2009 (Reference 20) to change the pH buffer from sodium hydroxide to sodium tetraborate prior to achieving Mode 4 during startup from the BVPS-2 fall 2009 refueling outage (2R14). The BVPS-2 long term containment sump range with sodium tetraborate would be as follows:

Minimum sump pH (BOL)	7.09
Maximum sump pH (EOL)	7.58

The lower pH values will result in additional margin for the quantity of chemical precipitants tested for BVPS-2.

RAI #6 (from Reference 6)

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

FENOC Response

As shown in Table RAI 6-1, BVPS-1 and BVPS-2 are most closely represented by the conditions in ICET #4 – fiberglass and calcium silicate insulation, and sodium hydroxide (NaOH) pH buffer.

Table RAI 6-1

CHEMICAL	ICET #4	BVPS-1			BVPS-2		
	VALUE			MIDPOINT			MIDPOINT
pH	9.80	7.80 (MIN)	8.79 (MAX)	8.30	8.14 (MIN)	9.03 (MAX)	8.59
Corresponding BORIC ACID (as ppm Boron)	2800	2567	2126	2347	2585	2244	2415
Corresponding NaOH (ppm)	9572	890	2540	1715	1520	3390	2455

There were two other major differences between ICET #4 and the Beaver Valley Power Station containment sump chemistries. The ICET chemistry insulation content was 80 percent calcium silicate (Cal-Sil) and 20 percent fiberglass. BVPS-1 ranges from 100 percent fiberglass, 0 percent Cal-Sil to 79 percent fiberglass, and 21 percent Cal-Sil, depending on the break location. BVPS-2 ranges from 100 percent fiberglass, 0 percent Cal-Sil to 94 percent fiberglass, and 6 percent Cal-Sil, depending on the break location. The other major difference was temperature. ICET #4 was performed at 60°C (140 °F), and after 30 days, was dropped to room temperature. Following a LOCA, both Beaver Valley sumps quickly reach a peak temperature of approximately 250 °F, and then slowly decrease over a 30 day period.

The NRC issued License Amendment No. 168 by letter dated April 16, 2009 (Reference 20) to change the pH buffer from sodium hydroxide to sodium tetraborate prior to achieving Mode 4 during startup from the BVPS-2 fall 2009 refueling outage (2R14). Following the buffer change, BVPS-2 will be most closely represented by the conditions in ICET #5 - fiberglass insulation and sodium tetraborate buffer as shown in Table RAI 6-2.

Table RAI 6-2

CHEMICAL	ICET #5	BVPS-2 CYCLE 15		
	VALUE			MIDPOINT
pH	8.0 – 8.5	7.2 (MIN)	7.4 (MAX)	7.3
Corresponding BORIC ACID (as ppm Boron)	2800	2588.2	2269	2428.6
Corresponding SODIUM TETRABORATE (ppm)	5574.5	1205.4	1219.3	1212.4

RAI #8 (from Reference 6)
Discuss your overall strategy to evaluate potential chemical effects including demonstrating that, with chemical effects considered, there is sufficient net positive suction head (NPSH) margin available during the ECCS mission time. Provide an estimated date with milestones for the completion of all chemical effects evaluations.

FENOC Response

The responses to Review Area 3.o above provide the overall strategy to evaluate chemical effects for BVPS-1. Chemical effects testing has resulted in corrective actions required to reduce the fiber and chemical loading by insulation remediation. Planned insulation modifications were completed during the spring 2009 refueling outage (1R19).

A similar strategy was followed for BVPS-2 as described in response to Review Area 3.o above. Chemical effects testing has resulted in corrective actions required to reduce the fiber and chemical loading by insulation remediation. Insulation modifications are currently scheduled to take place during the fall 2009 refueling outage (2R14).

RAI #9 (from Reference 6)
Identify, if applicable, any plans to remove certain materials from the containment building and/or to make a change from the existing chemicals that buffer containment pool pH following a LOCA.

FENOC Response

Based on chemical effects testing performed for BVPS-1, approximately 370 linear feet of existing Temp-Mat™ and Cal-Sil insulation were removed from containment. Additionally at BVPS-1, 27 pounds of aluminum contained in the iodine removal filters have been removed in order to maximize margin by minimizing post-LOCA chemical effects. These materials were removed from the BVPS-1 containment during the spring 2009 refueling outage (1R19).

The following materials were removed from the BVPS-2 containment during the spring 2008 refueling outage (2R13):

1. The existing Borated Temp-Mat encapsulated RMI on the reactor vessel closure head flange was replaced with RMI insulation.
2. The existing Min-K™ encapsulated in RMI in portions of the RCS piping was replaced with Thermal Wrap insulation encapsulated in RMI.
3. The 211 pounds of aluminum in the containment iodine removal filters were removed.

Based on the chemical effects testing performed for BVPS-2, FENOC plans to replace insulation on approximately 1270 linear feet of piping in containment. Additionally, the insulation on all three steam generators including the transition cones will be removed from containment and replaced with RMI. The required insulation modifications will be performed during the fall 2009 refueling outage (2R14).

The NRC issued License Amendment No. 168 by letter dated April 16, 2009 (Reference 20) to change the pH buffer from sodium hydroxide to sodium tetraborate prior to achieving Mode 4 during startup from the fall 2009 refueling outage (2R14). However, this change is not being credited with reducing the precipitant loading on the Containment Sump Strainers during a LOCA, but is being performed to eliminate active components of the spray additive system, reduce testing and maintenance, and reduce the potential for inadvertent discharge as well as personnel injury from hazardous chemicals.

RAI #10 (from Reference 6)

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

FENOC Response

The benchtop testing for BVPS-1 and BVPS-2 was performed for informational purposes only. Plant specific head loss testing was performed in accordance with WCAP-16530-NP.

The objective of the benchtop testing performed for BVPS is to test for the dissolution and corrosion of aluminum, zinc, Temp-Mat^{TM}, calcium silicate, dirt/dust, concrete, and alkyd paint, in sodium hydroxide (NaOH) or sodium tetraborate (NaTB) containing solutions, and observe the potential formation of chemical precipitates from these reactions at elevated temperature and chemical conditions that simulate post-LOCA conditions for the BVPS units. The materials that were selected for testing (aluminum, zinc, Temp-Mat^{TM} (fiberglass), Cal-Sil, concrete, alkyd paint, and dirt/dust) are what would be expected to enter the containment sump pool following a LOCA at BVPS-1 or BVPS-2. The material amounts added are representative of typical exposed area and mass per sump volume ratio based on an industry survey conducted by the Westinghouse Owners Group and summarized in Table 5.1-4 of WCAP-16530-NP.

Five separate benchtop tests were carried out. The two tests using NaOH buffer were identical, except that one test contained Cal-Sil, while the second test did not (to see the impact of Cal-Sil on the aluminum corrosion rate). These tests consisted of the materials being placed in a solution consisting of 2,800 ppm boron (from boric acid) and 0.7 ppm lithium (from lithium hydroxide). The solutions were then brought to a pH of 8.8 to 9.1 using NaOH. The solution was maintained at 200°F for seven hours, and then cooled to 140°F, where the temperature was kept for the duration of the 30 day test. The test with Cal-Sil was representative of Beaver Valley post-LOCA conditions, except that, due to the limitations of an open beaker test, the maximum expected temperature of 250°F at the beginning of the accident could not be duplicated.

One test was carried out in an autoclave without a buffer to simulate the corrosion of materials and precipitate formation for the first 76 minutes after a LOCA in acidic spray at 280°F. All seven materials were added to a solution consisting of 2,800 ppm boron (from boric acid) and 0.7 ppm lithium (from lithium hydroxide); the resultant solution pH was 5.2. This test was also representative of Beaver Valley Power Station conditions immediately following a LOCA, except that there was no air exposure or exposure to spray due to the limitations of using an autoclave.

The remaining two tests were carried out using NaTB as a buffer, and were representative of BVPS-2 as it will be configured following the implementation of License Amendment No. 168 (Reference 20). The tests were designed to see the impact of changing the buffer from NaOH to NaTB on corrosion product formation. As expected, the testing showed that reducing the sump pH by switching the buffer to NaTB reduced the amount of corrosion products formed; however, switching the buffer from NaOH to NaTB was not necessary to comply with the requirements of the Generic Letter. The buffer change to NaTB will be performed to increase operating margins, reduce costs, and improve personnel safety.

The principle means to address uncertainties related to head loss from chemical effects is the conservative design of the WCAP-16530 testing protocol. Chemical effects testing conducted for BVPS-1 and BVPS-2 use the WCAP-16530 base model testing protocol without exception or refinement. The NRC staff concluded that WCAP-16530 provides an acceptable technical justification for the evaluation of plant specific chemical effects related to GSI-191, subject to the conditions and limitations in the NRC safety evaluation of WCAP-16530, dated December 21, 2007. The testing protocol for both BVPS-1 and BVPS-2 also conformed to the March 2008 NRC staff review guidance for chemical effects testing.

RAI #11 (from Reference 6)

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

Discuss the criteria that will be used to demonstrate that chemical surrogates produced for testing (e.g., head loss, flume) behave in a similar manner physically and chemically as in the ICET environment and plant containment pool environment.

FENOC Response

BVPS-1 and BVPS-2 chemical effects testing was performed in the Alion hydraulics test loop in the late spring of 2008 and the fall of 2008, respectively. The WCAP-16530-NP method of producing chemical precipitates was utilized for this testing. The WCAP refinements were not utilized for prediction of chemical precipitates. The testing was performed for the purpose of determining the head loss of the final desired insulation configuration after maximum feasible fiber replacement and targeted Cal-Sil replacement for each unit. Prototypical strainer array testing was performed to collect and record differential pressure (dp), temperature, and flow rate data while building a bed of a specific quantity and mixture of debris across a strainer array representative of a portion of the larger arrays. The specific debris mixture used included fibrous insulation debris, particulate debris, and chemical precipitates. Detailed discussions about the prototype testing, debris loads, and chemical precipitates used are provided in response to Review Areas 3.f and 3.o.

The prototype testing was performed at temperatures that were considerably lower than the early temperature phases of the sump pool environment (maintained above 80°F). However, results from the prototype testing were scaled to various temperatures and at 212°F approach plant environmental sump temperatures. These results were then presented in the test report documenting the various tests performed. The test tank setup was controlled for flow rate to match the average approach velocity across each Beaver Valley Power Station unit's prototype strainer array. Debris scaling was utilized to match against various break considerations. Chemical precipitant loads were obtained based on WCAP-16530-NP predictions for maximum temperature (containment/sump) conditions. The test was performed utilizing normal tap water. If testing were to occur at higher temperatures, the chemical precipitates would probably remain in solution rather than being in precipitate form. The test temperatures are considered to be more conservative from a standpoint of precipitate retention on the debris bed. At higher temperatures there could be a propensity based on solution kinetics that the materials would go into solution and hence not be deposited on a strainer bed (potential reduction in head loss). Also with testing in untreated water without other buffers or pH controlling materials, the impact of potential chemical inhibition or reduction in material solubility is controlled. If a chemical compound is apt to remain as a precipitate in water at a certain temperature, then having another chemical compound present in the water could interfere with that precipitation process. Testing in water isolates the precipitate to a known standardized condition without having to account for or credit a material remaining soluble, thereby minimizing the impact on the hydraulic head loss testing results.

The chemical precipitates utilized for testing were produced with an NRC acceptable method, WCAP-16530-NP. Settling criteria was applied to the chemical precipitates prior to making any chemical additions to the test facility. Also the chemical materials were added over a sparger and added in two locations to maximize uniformity in chemical debris distribution between the two sides of the prototype array. A sparger system was installed on the return line to aid in the suspension of the chemical debris within the water. These methods of chemical debris agitation were sufficient in keeping the debris suspended in the water. Specific chemical and physical properties of the chemical precipitates were not compared against the ICET environment, as an approved methodology was used for formation of the chemical debris for each planned test. Additionally, the debris, fiber, and precipitates were introduced to the test tank in accordance with the instructions provided in the March 2008 "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Plant-Specific Chemical Evaluations," Enclosure 1.

RAI #12 (from Reference 6)

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

FENOC Response

Based on head loss testing of a prototypical BVPS-1 strainer array, the temperature corrected maximum head loss for Test 6 was 2.46 feet-water (maximum predicted average approach velocity and 212°F). This was based on a predicted 30 day WCAP-16530-NP chemical precipitate load with additional equivalent 10 percent margin added. Therefore, this value also bounds the head loss expected within the first day. See Table 3.f.4-5 in the response to Review Area 3.f.4 for temperature corrected head loss values.

Based on head loss testing of a prototypical BVPS-2 strainer array the temperature corrected maximum head loss extrapolated out to 30 days for Test 1A was 4.78 feet of water and 3.56 feet of water for Test 5 (maximum predicted average approach velocity and 212°F). This was based on a predicted 30 day WCAP-16530-NP chemical precipitate load with additional equivalent 10 percent margin added. Therefore, this value also bounds the head loss expected within the first day. See Tables 3.f.4-6 (Test 1A) and 3.f.4-7 (Test 5) in the response to Review Area 3.f.4 for temperature corrected head loss values.

RAI #17 (from Reference 6)

The aluminum and other submerged metallic coupons in ICET #4 experienced little corrosion. In this test, the calcium silicate appeared to produce a beneficial effect by contributing to the protective film that formed on the submerged samples. Given that individual plants have less calcium silicate insulation than was represented by the ICET and that a given plant LOCA could result in little or no calcium silicate in the containment pool, discuss how you are confirming your plant materials will behave similar to ICET #4 for your plant-specific conditions.

FENOC Response

As shown in Table RAI 17-1, BVPS-1 and BVPS-2 are most closely represented by the conditions in ICET #4 – fiberglass and calcium silicate insulation, and sodium hydroxide (NaOH) pH buffer.

Table RAI 17-1

	ICET #4	BVPS-1			BVPS-2		
	VALUE	MIN (pH)	MAX (pH)	MIDPOINT (pH)	MIN (pH)	MAX (pH)	MIDPOINT (pH)
pH	9.80	7.80	8.79	8.30	8.14	9.03	8.59

Notes:

(1) MAX = Maximum

(2) MIN = Minimum

The ICET #4 pH was 1.01 pH units higher than the highest expected sump pH at BVPS-1, and 0.77 pH units higher than the highest expected sump pH at BVPS-2. This pH difference should result in significantly less corrosion of aluminum sources in the Beaver Valley containments than would be expected from the ICET #4 results. However, the insulation differences between ICET #4 and the BVPS-1 and BVPS-2 must also be considered. The ICET chemistry insulation content was 80 percent calcium silicate (Cal-Sil) and 20 percent fiberglass. BVPS-1 insulation content ranges from 100 percent fiberglass, 0 percent Cal-Sil to 79 percent fiberglass, and 21 percent Cal-Sil, depending on the break location. BVPS-2 insulation content ranges from 100 percent fiberglass, 0 percent Cal-Sil to 94 percent fiberglass, and 6 percent Cal-Sil, depending on break location. Silicates inhibit aluminum corrosion; there are fewer silicates available at the BVPS-1 and BVPS-2 than were present in the ICET #4 test to inhibit aluminum corrosion. However, benchtop testing of aluminum dissolution conducted for Beaver Valley units showed that pH was far more important than silica concentration in the rate of aluminum dissolution. From an aluminum dissolution standpoint, the Beaver Valley units will be bounded by ICET #4.

Since other materials were not significantly attacked by the pH conditions in ICET #4, the lower pH conditions at BVPS-1 and BVPS-2 will not allow greater amounts of corrosion than were experienced during ICET #4.

The NRC has issued License Amendment No. 168 by letter dated April 16, 2009 (Reference 20) to change the pH buffer from sodium hydroxide to sodium tetraborate prior to achieving Mode 4 during startup from the BVPS-2 fall 2009 refueling outage (2R14). Following the buffer change, BVPS-2 will be most closely represented by the conditions in ICET #5 - fiberglass insulation and sodium tetraborate buffer. The buffer change will result in a lower pH range than was reported in the ICET #4 testing. However, since benchtop testing of aluminum dissolution conducted for Beaver Valley showed that pH was the most important factor in the rate of aluminum dissolution, and that other materials were not significantly attacked by the pH conditions in ICET #4, the lower sump pH resulting from the change of sump buffer to NaTB will not change the finding that ICET #4 remains the bounding test result for aluminum dissolution, and resulting chemical precipitate formation, at BVPS-2.

3.p. Licensing Basis

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

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

GL 2004-02 Requested Information Item 2(e)

A general description of and planned schedule for any changes to the plant licensing bases resulting from any analysis or plant modifications made to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter. Any licensing actions or exemption requests needed to support changes to the plant licensing basis should be included.

FENOC Response

New sump strainers were installed during the fall 2006 refueling outage (2R12) at BVPS-2, and the fall 2007 refueling outage (1R18) at BVPS-1. The new sump strainers increased the available surface area and are designed to reduce both head loss and the ingestion of debris which could affect downstream components.

To achieve sufficient water level to cover the containment sump strainers following a containment pressurization event, the start signal for the RSS pumps was changed. License Amendment Nos. 280 (dated October 5, 2007) and 164 (dated March 11, 2008), that change Technical Specifications to reflect the new RSS pump start signal, have been implemented for BVPS-1 and BVPS-2 respectively. Plant modifications associated with changing the RSS pump start signal were completed during the fall 2007 refueling outage (1R18) at BVPS-1 and during the spring 2008 refueling outage (2R13) at BVPS-2.

The BVPS-1 licensing basis presently credits containment overpressure to meet NPSH requirements. This methodology provides benefits in maintaining NPSH margins. License Amendment No. 167 for BVPS-2, issued March 26, 2009 (Reference 16) authorized changes to the licensing basis as described in the BVPS-2 UFSAR regarding the method of calculating the net positive suction head available to the RSS pumps by crediting containment over pressure. The BVPS-2 licensing basis was revised April 7, 2009 and also credits containment overpressure to meet RSS pump NPSH requirements.

The BVPS-2 presently uses sodium hydroxide as the buffer for sump water pH control. FENOC plans to retire the sodium hydroxide additive system and replace it with a passive sodium tetraborate system. While not required to meet the head loss margins described in this response, this change will result in a lower sump water pH and reduce the quantity of chemical precipitates. The installation of sodium tetraborate is scheduled for the fall 2009 refueling outage. The NRC issued License Amendment No. 168 by letter dated April 16, 2009 (Reference 20) to change the pH buffer from sodium hydroxide to sodium tetraborate prior to achieving Mode 4 during startup from the BVPS-2 fall 2009 refueling outage (2R14).

The BVPS-1 and BVPS-2 UFSARs have been updated to reflect installation of the new sump strainers and the new RSS pump start signal. Other facility and procedure changes made to support compliance with GL 2004-02 requirements will be incorporated into the BVPS-1 or BVPS-2 UFSAR, as appropriate, in accordance with 10 CFR 50.71(e). FENOC intends to develop and issue other licensing bases changes following NRC review and approval of the response to GL 2004-02.

List of References

1. NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004.
2. FENOC Letter L-05-034, "Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors'," ADAMS Accession No. ML050680211, dated March 4, 2005.
3. FENOC Letter L-05-123, "Response to Request for Additional Information on Generic Letter 2004-02 (TAC Nos. MC4665 and MC4666)," ADAMS Accession No. ML052080167, dated July 22, 2005.
4. FENOC Letter L-05-146, "Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors'," ADAMS Accession No. ML052510411, dated September 6, 2005.
5. FENOC Letter L-06-020, "Supplemental Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors'," ADAMS Accession No. ML060960442, dated April 3, 2006.
6. NRC letter, Beaver Valley Power Station, Unit Nos. 1 and 2, "Request for Additional Information Re: Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors' (TAC Nos. MC4665 and MC4666)," ADAMS Accession No. ML060380342, dated February 9, 2006.
7. Mr. W. H. Ruland, NRC Division of Safety Systems Director, letter to Mr. Anthony Pietrangelo, Vice President, Nuclear Energy Institute, Subject: Content Guide for Generic Letter 2004-02 Supplemental Responses, dated August 15, 2007.
8. Mr. W. H. Ruland, NRC Division of Safety Systems Director, letter to Mr. Anthony Pietrangelo, Vice President, Nuclear Energy Institute, Subject: Revised Content Guide for Generic Letter 2004-02 Supplemental Responses, dated November 21, 2007.
9. Mr. W. H. Ruland, NRC Division of Safety Systems Director, letter to Mr. Anthony R. Pietrangelo, of the Nuclear Energy Institute, Subject: Draft Guidance for Review of Final Licensee Responses to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 27, 2007.
10. FENOC Letter L-08-035, Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design

Basis Accidents at Pressurized-Water Reactors" (TAC Nos. MC4665 and MC4666), ADAMS Accession No. ML080660597, dated February 29, 2008

11. FENOC Letter L-08-321, "Supplemental Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,' (TAC Nos. MC4665 and MC4666)," ADAMS Accession No. ML083080094, dated October 29, 2008.
12. Mr. W. H. Ruland, NRC Division of Safety Systems Director, letter to Mr. Anthony R. Pietrangelo, of the Nuclear Energy Institute, Subject: Revised Guidance for Review of Final Licensee Responses to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated March 28, 2008.
13. FENOC letter L-09-131, "Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors' - Request for Extension of Completion Date for Additional Corrective Actions (TAC Nos. MC4665)," ADAMS Accession No. ML091250180, dated April 30, 2009.
14. NRC Letter, Beaver Valley Power Station, Unit No. 1 - "Extension Request Approval Letter Re: Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors'," (TAC No. MC4665), ADAMS Accession No. ML091240030, dated May 5, 2009.
15. FENOC Letter L-08-257, "Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors' Request for Extension of Completion Date for Corrective Actions (TAC Nos. MC4665 and MC4666)," ADAMS Accession No. ML082480045, dated August 28, 2008.
16. NRC Letter, Beaver Valley Power Station, Unit No. 2 - "Issuance of Amendment Re: The Use of Containment Accident Pressure in Determining Available Net Positive Suction Head of Recirculation Spray Pumps, (TAC No. ME0098)," ADAMS Accession No. ML090270068, dated March 26, 2009.
17. NEI 04-07 Pressurized Water Reactor Sump Performance Evaluation Methodology (Volume 1– "Pressurized Water Reactor Sump Performance Evaluation Methodology," and Volume 2 – "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Revision 0, December 6, 2004"), Revision 0 of both volumes, dated December 2004.
18. FENOC Letter L-07-519, "Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,' – Request for Extension of Completion Date for Corrective Actions," ADAMS Accession No. ML073620201, dated December 20, 2007.

19. FENOC letter L-98-217 “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,” dated November 11, 1998.

20. NRC letter, "Beaver Valley Power Station, Unit Nos. 1 and 2, Issuance of Amendment Nos. 283 and 168 Re: Spray Additive System By Containment Sump pH Control, (TAC Nos. MD9734 AND MD9735)," dated April 16, 2009.

ATTACHMENT 2
L-09-152

Regulatory Commitment List
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The following list identifies those actions committed to by FirstEnergy Nuclear Operating Company (FENOC) for Beaver Valley Power Station Unit No. 1 (BVPS-1) and Unit No. 2 (BVPS-2) in this document. Any other actions discussed in the submittal represent intended or planned actions by FENOC. They are described only as information and are not Regulatory Commitments. Please notify Mr. Thomas A. Lentz, Manager - Fleet Licensing, at (330) 761-6071 of any questions regarding this document or associated Regulatory Commitments.

Regulatory Commitment	Due Date
1. It is recognized that the NRC review of WCAP-16793-NP, Revision 1, has not been completed. Any additional actions required to address NRC questions will be addressed.	1. Within 90 days after issuance of the final NRC safety evaluation on WCAP-16793-NP, Revision 1.
2. Emergency Operating Procedures for BVPS-1 will be revised to enhance the steps that shut down two recirculation spray pumps prior to the transfer to recirculation.	2. By December 31, 2009.
3. Emergency Operating Procedures for BVPS-2 will be revised to shut down one of the recirculation spray system pumps supplying the spray header when the containment pressure is reduced below a predetermined value.	3. Prior to startup from the fall 2009 refueling outage (2R14).