FENOC
FirstEnergy Nuclear Operating Company

Beaver Valley Power Station
P.O. Box 4
Shippingport, PA 15077

Peter P. Sena III
Site Vice President

724-682-5234
Fax: 724-643-8069

October 29, 2008
L-08-321

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

SUBJECT:
Beaver Valley Power Station, Unit Nos. 1 and 2
BV-1 Docket No. 50-334, License No. DPR-66
BV-2 Docket No. 50-412, License No. NPF-73
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)

This letter provides supplemental information, in Attachment 1, regarding the FirstEnergy Nuclear Operating Company (FENOC) response to Generic Letter 2004-02 (Reference 1) for Beaver Valley Power Station Unit Nos. 1 (BVPS-1) and 2 (BVPS-2).

The NRC Content Guide for Generic Letter 2004-02 Supplemental Response (Reference 2) was utilized in development of this submittal. Requests for additional information included in the NRC letter dated February 9, 2006 (Reference 3) are also addressed within the applicable sections of this submittal. The response to the content guide review areas for BVPS-2 that are dependent on scheduled head loss testing will be provided in the BVPS-2 supplemental response to Generic Letter 2004-02 described in FENOC's August 28, 2008 corrective action extension request letter. The information in Attachment 1 is provided in accordance with 10 CFR 50.54(f).

The response to Review Area 3.m in Attachment 1 discusses the need for additional evaluation of downstream effects for the BVPS-1 recirculation spray system and low head safety injection system pumps. Attachment 2 includes a commitment for completion of this evaluation.

If there are any questions, or if additional information is required, please contact Mr. Thomas A. Lentz, Manager – Fleet Licensing, at 330-761-6071.

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NRR

I declare under penalty of perjury that the foregoing is true and correct. Executed on October 29, 2008.

Sincerely,

Peter P. Sena III

Attachment:

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 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. NRC Content Guide for Generic Letter 2004-02 Supplemental Response, dated August 15, 2007 and revised November 21, 2007.
3. 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: Mr. S. J. Collins, NRC Region I Administrator
Mr. D. L. Werkheiser, NRC Senior Resident Inspector
Ms. N. S. Morgan, NRR Project Manager
Mr. D. J. Allard, Director BRP/DEP
Mr. L. E. Ryan (BRP/DEP)

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 Generic Letter 2004-02 (Reference 6). The Nuclear Energy Institute (NEI) Sump Task Force and the 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). The Revised Content Guide was utilized in the development of this letter 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 our response submitted on February 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 for easy identification of 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 11).

With the exception of the additional downstream effects evaluation that is described in response to Review Areas 3.m and 3.n, this submittal is a complete response for BVPS-1. Since additional BVPS-2 testing is scheduled for the Fall of 2008, portions of the BVPS-2 responses are not complete.

An extension request was submitted for implementing the BVPS-1 and BVPS-2 corrective actions in a FENOC letter dated August 28, 2008 (Reference 12). The extension request provided in the August 28, 2008 letter commits to a supplemental BVPS-2 response by April 30, 2009.

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 the start of 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. Debris evaluations and prototype testing have been performed as well as chemical effects testing.

Head loss testing for BVPS-1 has been completed. The results of the testing require corrective actions to be implemented. Fibrous and calcium silicate (Cal-Sil) insulation will be modified to the extent required to support the results of the successful test. This corrective action will be completed in the Spring of 2009 during the BVPS-1 refueling outage (1R19).

Based on test results from BVPS-1 and the open issues presently unresolved with chemical effects testing performed at the Vuez test facility, FENOC had made a decision to change the BVPS-2 test protocol from that used at Vuez to the same as that used for BVPS-1. Corrective actions for BVPS-2 include retesting, insulation modifications to be implemented during the Fall 2009 refueling outage (2R14), and submittal of a license amendment request for a methodology change to credit containment overpressure.

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 have been 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. As identified in a FENOC letter dated February 14, 2008 (Reference 13), FENOC had committed to complete the final downstream effects analyses with the results to be provided in our supplemental response.

The ex-vessel downstream effects analysis has been completed for BVPS-1 with the exception of finalizing the evaluations for the recirculation spray and low head safety injection pumps. The final results for BVPS-2 downstream effects analysis will be provided in our follow-up supplemental response as committed to in FENOC letter dated August 28, 2008.

It is recognized that the NRC staff has not issued a final safety evaluation for WCAP-16793-NP. Therefore, our evaluation for in-vessel downstream effects has not been finalized. The results of the BVPS-1 evaluations that were performed under WCAP 16793-NP, Revision 0, are provided within this response. The BVPS-2 in-vessel downstream effects evaluation is pending completion of the BVPS-2 testing. 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.

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 12) 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 our retesting for debris and chemical effects for Unit 1 and our scheduled retesting for Unit 2. The response to Review Area 3.m discusses additional evaluation of the BVPS-1 recirculation spray and low head safety injection pumps. Upon completion of these activities, BVPS Units 1 and 2 will be in compliance with the regulatory requirements listed in GL 2004-02.

FENOC is taking appropriate actions in response to GL 2004-02 to ensure that the Emergency Core Cooling System (ECCS) and Recirculation Spray System (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 being 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 the implementation of testing, analysis, and 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 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. BVPS-2 strainer prototype debris and chemical effects retesting is scheduled for the Fall of 2008.
- 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 stated that portions of the Safety Injection System piping insulation was 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.
- 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.

Summary of Activities to be Completed for BVPS-1:

FENOC plans to complete insulation modification corrective actions during the Spring 2009 refueling outage (1R19). Both fibrous and Cal-Sil insulation modifications will result in the remaining insulation exposed to pipe breaks and subsequent transport to the containment sump being bounded by the testing performed .

Additional evaluation of downstream effects for the BVPS-1 recirculation spray and low head safety injection pumps is presently being conducted as described in the response to Review Area 3.m. The final results of the evaluation will be provided by March 20, 2009.

Summary of Activities to be Completed for BVPS-2:

Additional testing will be performed for BVPS Unit 2. The testing protocol is to be changed from that used at Vuez to that successfully used for BVPS-1.

The corrective actions planned for BVPS-2 are identified within the FENOC extension request letter dated August 28, 2008 and include the following:

- Additional required corrective actions resulting from the BVPS-2 retesting, including insulation modifications will be implemented prior to startup following the Fall 2009 refueling outage (2R14).
- FENOC committed to submit a license amendment request for NRC approval, to credit containment overpressure when calculating available NPSH for BVPS-2, by November 9, 2008. The BVPS licensing basis will be revised to credit containment overpressure upon NRC approval of the requested change.

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 (i.e., 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 (Reference 14), 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 14) 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 many 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 and 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. As previously discussed in the Executive Summary, additional sump screen debris load testing will be performed for BVPS-2. The breaks for BVPS-1, which meet the criterion, are provided below. BVPS-2 breaks selected to match the criterion will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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

RCS loop piping, including the reactor pressure vessel nozzles, and the 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. The planned Spring 2009 refueling outage (1R19) insulation modifications will result in the RCS Loop piping break and the pressurizer surge line break being the breaks with the largest potential for debris.

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.

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

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 pressure vessel).

In addition to the BVPS-1 RCS piping loop, FENOC identified the BVPS-1 reactor vessel nozzle break as meeting Break Criterion 3.

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 which 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.

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

For BVPS-1, the pressurizer surge line break generates the highest particulate to fibrous insulation ratio (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 which 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, 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 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 and has a higher impact on head loss. Therefore, none of the breaks at BVPS-1 were found to generate a 1/8 inch thick fiber bed.

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 baseline debris generation analysis for BVPS-1 and BVPS-2 considers the ZOI to be defined 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 14) provide relief as long as there are two or more distinct types of insulation within the break location.

Both units applied the ZOI refinement discussed in Section 4.2.2.1.1 of the SE (Reference 14), 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.

Diamond Power Mirror® RMI with Standard Bands:
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 14) (66 to 74 foot radius) specified for Mirror RMI would be truncated significantly by the structural barriers.

Transco RMI:
Transco Products Inc. (TPI) 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 substantially 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 14), 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. Material characteristics specified for NUKON™ were assumed for Fiberglass and Fiberglas® Thermal Insulating Wool (TIW). As specified in Table 3-2 of the SE (Reference 14), 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 14) is equivalent to a sphere with 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 a low density fiberglass 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 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. Material characteristics specified for NUKON™ were assumed for Fiberglass. Again, these materials are low density fiberglass with macroscopic (as-manufactured) density equivalent to NUKON™. Thus a 17.0D ZOI is used.

Calcium Silicate (Aluminum cladding, Stainless Steel (SS) bands):
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 14) 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™.

Microtherm®:
Microtherm® is used within the reactor cavity. Microtherm® is a microporous insulation material that is composed of filaments, fumed silica and titanium dioxide. The guidance of the SE (Reference 14) 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 Microtherm® .

Benelex 401®:
The description of Benelex 401® has been updated from that previously provided under FENOC letter dated February 29, 2008 to reflect the debris generation evaluation of this material.

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 14) 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 14).

Foamglas®:
FOAMGLAS® insulation is an inorganic, rigid and brittle cellular insulation manufactured by Pittsburgh Corning Corporation. The guidance of the SE (Reference 14) 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 14) 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.

The following table (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 (5)	114	2.0
NUKON™ (2)	6	17.0
Temp-Mat with SS wire retainer	10.2	11.7
Fiberglas® Thermal Insulating Wool (TIW)	6	17.0
Fiberglass (2)	6	17.0
Calcium Silicate (Aluminum cladding, SS bands)	24 (3)	5.45
Encapsulated Min-K™	2.4	28.6
Microtherm® (2)	2.4	28.6
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 SS bands. The SS jacketing with SS wire/banding used at BVPS-2 is judged to provide protection at least equivalent to aluminum cladding.

(4) Equivalent ZOI utilized.

(5) Currently BVPS-1 only. Projected for future use on BVPS-2.

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. Note that the quantities provided for Unit 1 are the quantities of debris remaining after insulation modification corrective actions are completed during the Spring 2009 refueling outage (1R19).

The insulation debris quantities for BVPS-2 will be re-assessed upon completion of additional debris load head loss testing and evaluation of insulation remediation requirements, as discussed in the Executive Summary. Since insulation modification requirements have not yet been established, BVPS-2 debris quantities are not provided.

Table 3.b-2
BVPS-1 Insulation Debris Quantities
(With Insulation Remediation – post 1R19)

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			3.9 ft^3
Fiberglas TIW				
Calcium Silicate	63 lb.		57.75 lb.	
Min-K™			16 lb.	

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)

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 effort. The results of this evaluation indicate that BVPS-1 has 543 square feet of miscellaneous materials and BVPS-2 has 750.8 square feet of miscellaneous materials. These are bounding quantities. The uses of miscellaneous solid materials inside containment are controlled as discussed in Section 3.i.

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 debris generation 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 #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 -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 9. Specifically, the NRC's response to Item 3 in Reference 9 indicates that Licensees may use WCAP-16568-P (WCAP), "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 was performed with consideration to the 5D ZOI for coatings debris; therefore, the 5D ZOI has been selected for the basis for the strainer head loss results. As discussed in the Executive Summary, additional debris load head loss testing will be performed for BVPS-2. This new testing will include coatings debris with consideration given to the 5D ZOI.

BVPS has assumed that there is a 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, BVPS assumes that unqualified coatings that are under intact insulation are not considered to fail. Unqualified coatings that are under insulation that becomes debris (i.e., 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, and Fiberglas® TIW), 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 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 has been shown to be very similar to LDFG debris. The HDFG debris loses its "felt" type characteristics when it breaks down to 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 14).

The previously mentioned proprietary analysis also supports use of a four size distribution for NUKON™, Knauf Fiberglass and, by similitude, Fiberglas® TIW 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%

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 (i.e., destruction, in all cases, was less than 50 percent of the target material). Based upon the results of the NRC-sponsored OPG tests and with the following exception, a reduction factor of 50 percent was applied to debris generated within a 5.45D ZOI. A 50 percent reduction was not applied when a breach (split rupture) is assumed to occur beneath the insulation and, thus, the source of the jet and the target are assumed to be the same line.

Remaining debris types

The following table (Table 3.c-4) summarizes the potential 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 14).

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
Coatings	100	0
Outside the ZOI		
Covered Undamaged Insulation	0	0
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™	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 previously, 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 (BVPS-1)	N/A	442	10
High Temp. Silicone Aluminum	N/A	150	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

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."

This is interpreted to mean that for those HELB scenarios where there is not adequate fibrous debris generated to form a uniform thin bed (i.e., 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 performed for Unit 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, which represents the final configuration for BV-1 after targeted removal of the Cal-Sil and Temp-Mat, included an amount of debris which was less than the quantity required to form a thin bed. For coatings inside the ZOI, i.e. qualified coatings, the test was performed using 10 micron spheres as the particulate size. For coatings outside the ZOI, i.e. unqualified coatings, in order to assure the approach was conservative, the test was performed using both 10 micron spheres as the particulate size and ¼ inch paint chips (ensuring that they would not pass through the 1/16 inch 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.

As previously discussed in the Executive Summary, insulation remediation and additional sump screen debris load testing will be performed for BVPS-2. The testing will be performed with consideration to the new NRC Guidelines (March 28, 2008, Reference 11). Upon completion of the testing and associated evaluations this supplemental response will be revised to address how the coatings debris characteristics are modeled to account for the plant specific bed.

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, 1R16 outage. A supplementary walkdown was performed for BVPS-1 in the Spring 2006, 1R17 outage, to assess containment conditions with consideration of the guidelines in the NRC SE for NEI 04-07 (Reference 14). 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 14).

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 (e.g., 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	Grating	Vertical Wall Surface	Floor
692' - 11"	6.18	N/A	29.41	17.91
718' - 6" & 738' - 10"	7.38	0.30	7.57	17.80
767' - 10"	7.40	0.15	33.44	15.32

In lieu of analysis of samples, conservative values for debris composition properties were assumed as recommended by the SE (Reference 14). 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, it is assumed that the walkdown to count tape and equipment labels did not 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 USNRC and conducted through Los Alamos National Laboratory and the University of New Mexico. The USNRC's recommendation (Reference 14) is to assume that 15 percent of transportable latent debris is fiber and that 85 percent is particulate.

4. There was a small amount of construction and maintenance debris observed during the walkdown that appeared to have been placed recently, but none that appeared to have remained from the previous outage. Therefore, it is assumed that no construction and maintenance debris sources would be present after containment closeout. The post containment closeout inspection assures that no significant construction or maintenance equipment remains in containment.

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

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.

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: 750.8 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 14). 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 563.1 square feet. This value represents 75 percent of the total 750.8 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 Item 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 Item 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

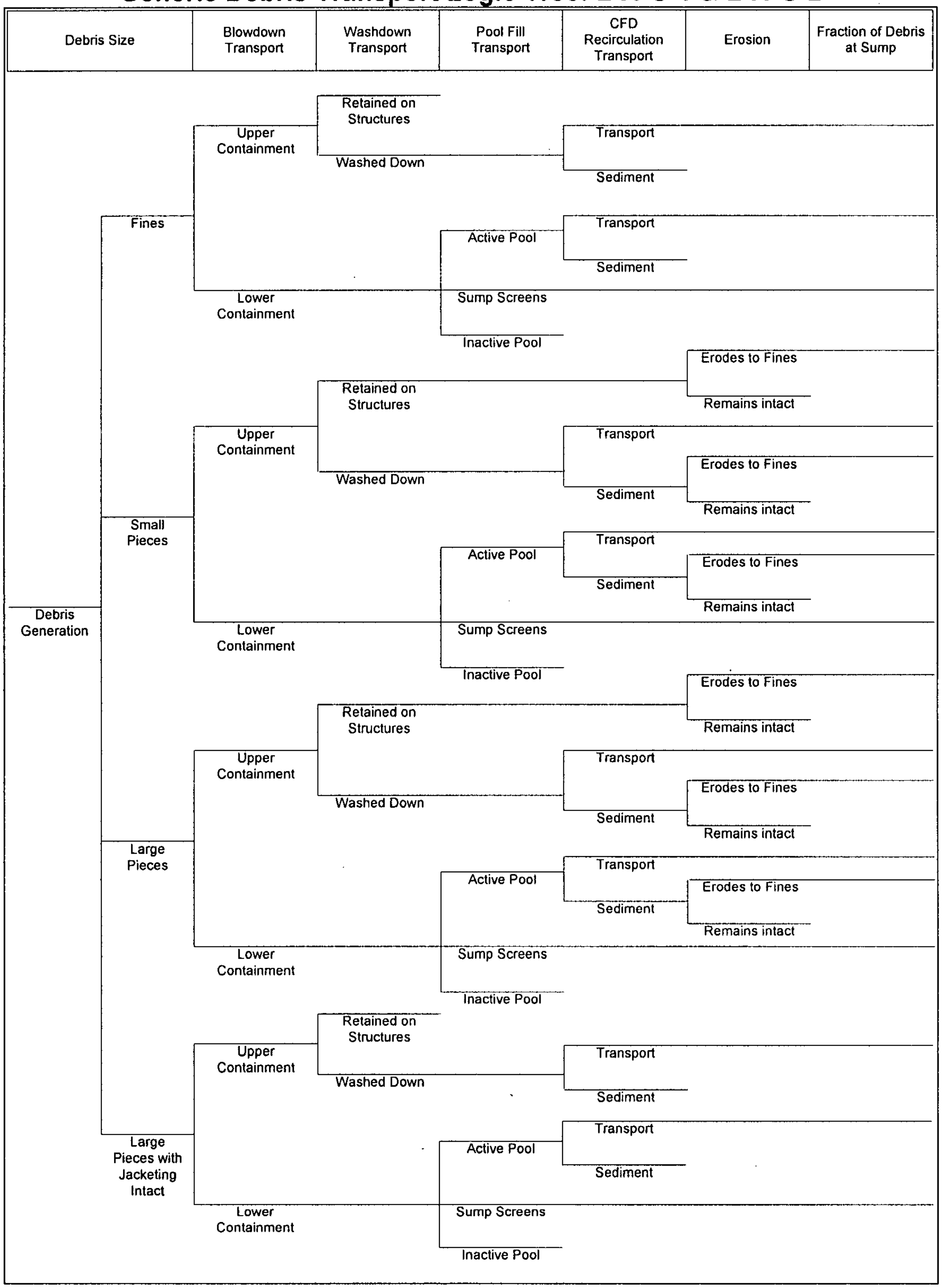
Description of Methodology

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 14), 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 Refueling Water Storage Tank (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 emergency core cooling system (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 14) 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. (Note that some branches of the logic tree were not required for certain debris types.)

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 transport fraction of each type of debris was made using the velocity and Turbulent Kinetic Energy (TKE) profiles from the CFD model output, along with the determined initial distribution of debris.
10. The recirculation transport fractions from the CFD analysis were gathered to input into the logic trees.
11. The quantity of debris that could experience erosion due to the break flow or spray flow was determined.
12. The overall transport fraction for each type 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 a wetted and highly congested area. 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 analyses did not utilize any holdup values associated with this study.

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 (Table 3.e-1 and 3.e-2) show the transport fractions for each type/size of debris to upper containment 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-1
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
TIW	NA / 61%	NA / 44%	NA / 21%	NA / 21%
Temp-Mat™	0% / 61%	0% / 33%	0% / 0%	0% / 0%
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-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
TIW	NA / 39%	NA / 25%	NA / 0%	NA / 0%
Temp-Mat™	100% / 39%	100% / 33%	100% / 0%	100% / 0%
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. For BVPS-2, large pieces of Thermal Insulating Wool (TIW) as well as small pieces of debris would be held up by grating.

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 fiberglass debris was credited at each level of grating that washdown flow passed through for BVPS-2. 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 fractions of debris in 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
TIW	NA / 11%	NA / 1%	NA / 0%	NA / 0%
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
TIW	NA / 89%	NA / 43%	NA / 17%	NA / 17%
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
TIW	NA / 100%	NA / 50%	NA / 0%	NA / 0%
Temp-Mat™	NA / 100%	NA / 100%	NA / 100%	NA / 100%
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 replacement screens are at least 1 foot above the depressed floor section, and no large pieces of debris were determined to collect on the screens during pool fill. The normal sump and trench around the primary shield 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 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 (i.e., 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 theory (RNG) 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 5 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 & 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 and at BVPS-2.

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

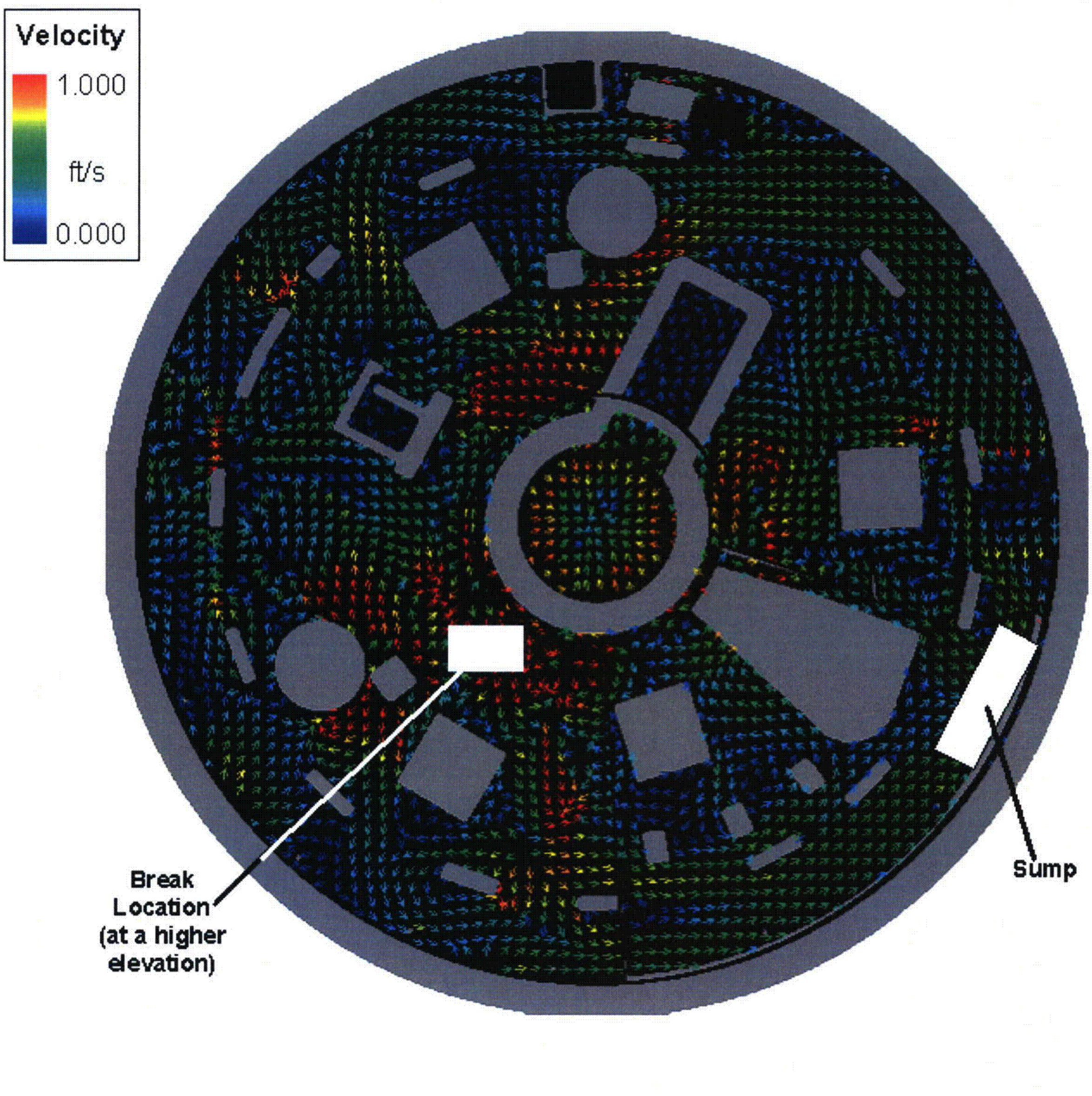


Figure 3.e-3

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

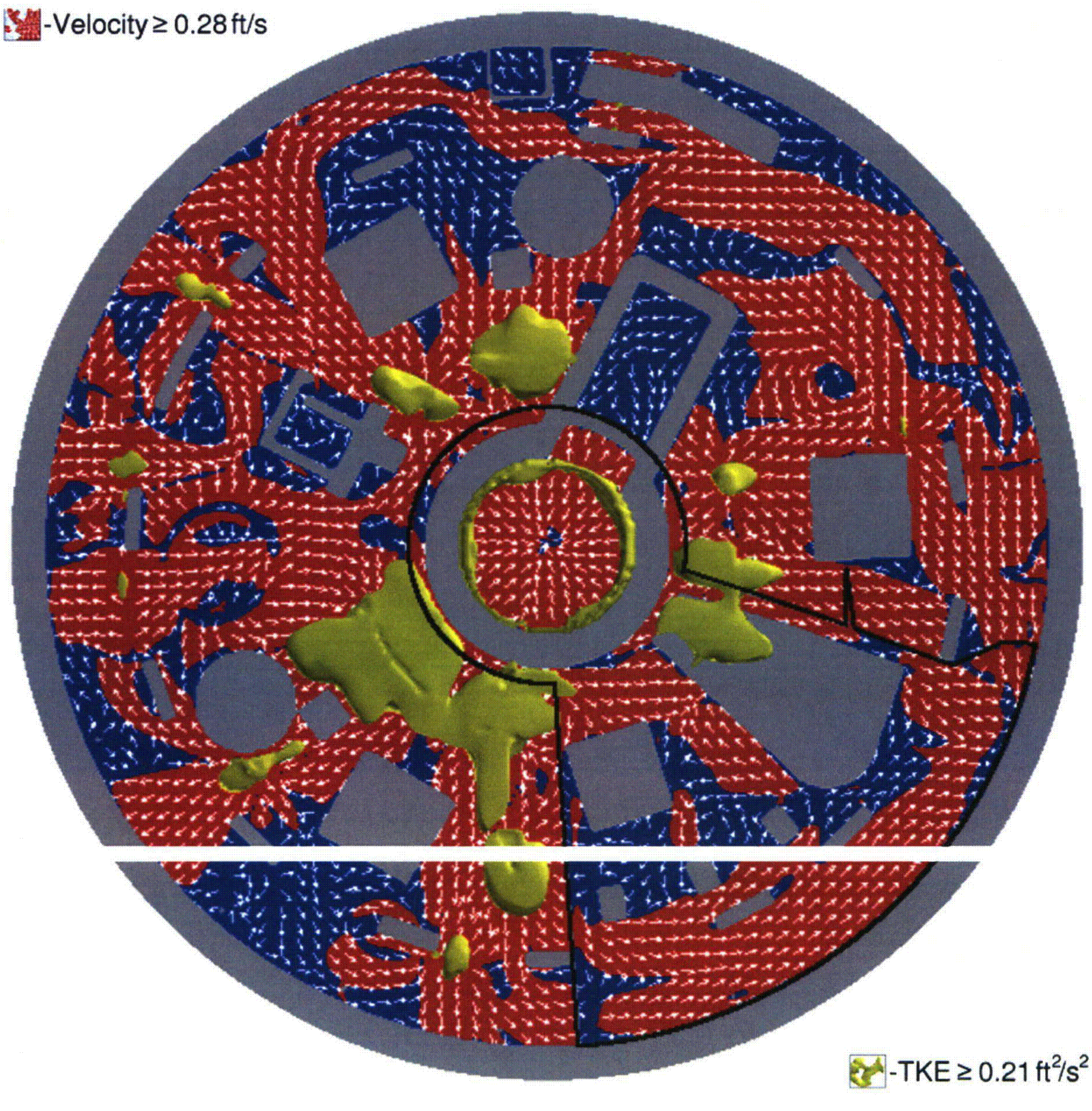


Figure 3.e-4

Distribution of Small and Large Pieces of Debris in Lower Containment

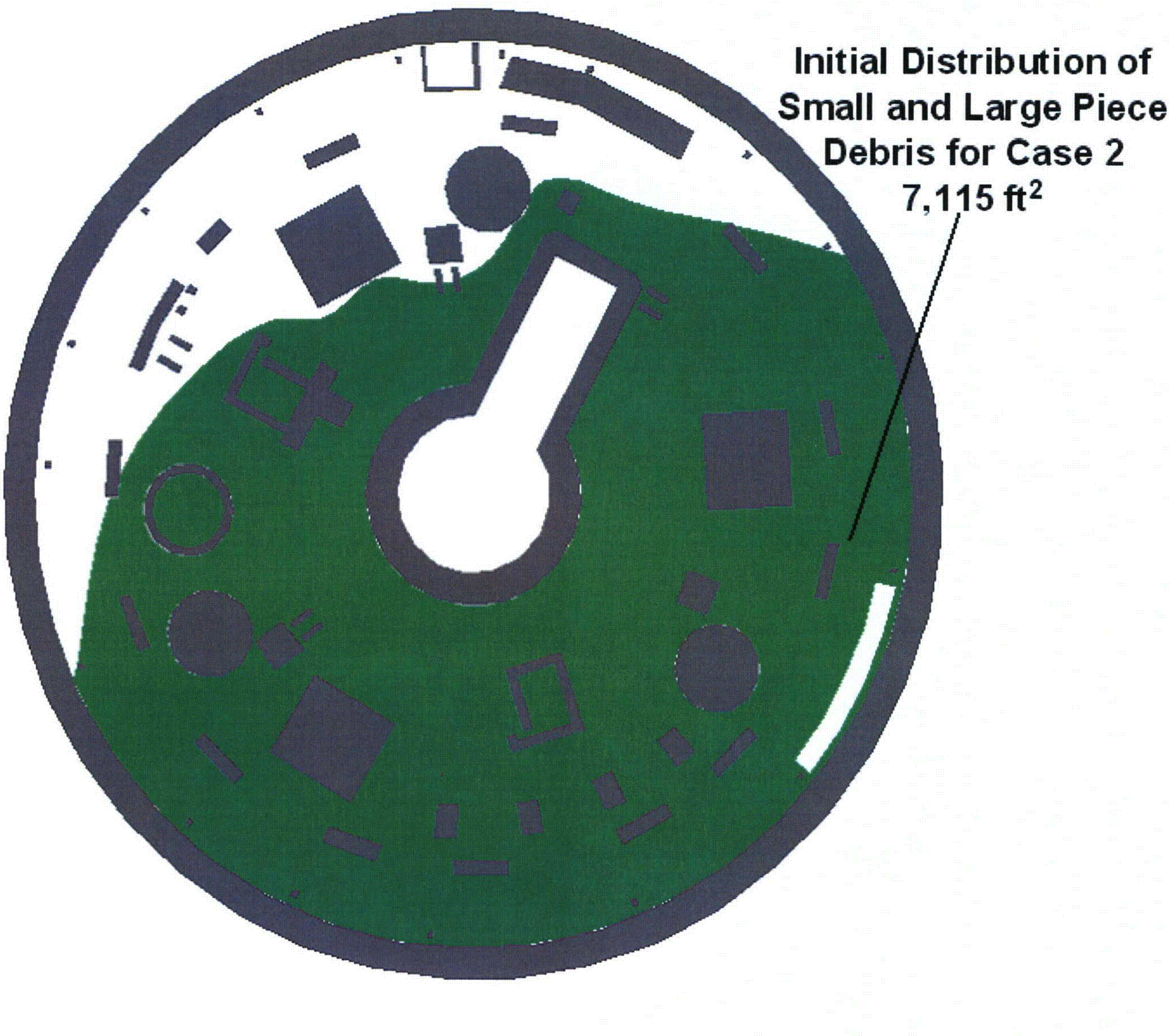
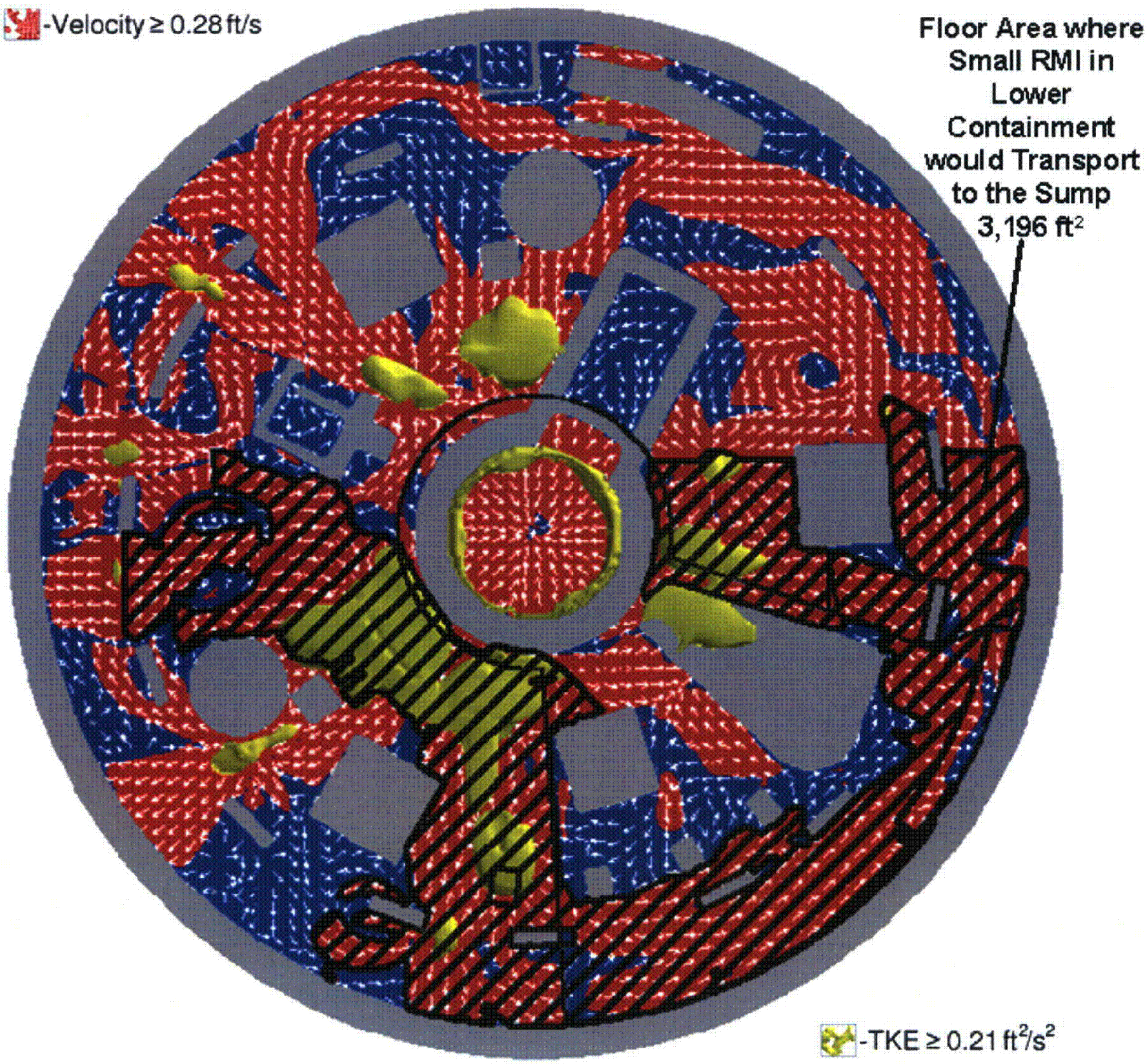


Figure 3.e-5
Floor Area Where Small RMI Would Transport to the Sump



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 distributions 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 coincidentally 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.

DEVIATIONS FROM REGULATORY GUIDANCE

There were no deviations from Regulatory Guidance.

Our previous response, provided in FENOC letter dated February 29, 2008, identified one area where our analysis deviated from regulatory guidance. Erosion fractions were previously provided based on the Drywell Debris Transport Study (DDTS) which deviated from regulatory guidance. This deviation is no longer used in our BVPS-1 debris transport analysis. Any deviations from regulatory guidance for BVPS-2 will be addressed in our follow-up supplemental response.

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. As can be seen from the following tables, 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. 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 quantities of debris transported to the BVPS-2 containment sump have not been re-evaluated and are therefore not included in this supplemental response. New quantity values will be provided upon completion of future prototype sump screen debris load testing and quantification of the insulation remediation, as previously discussed in the Executive Summary.

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™ (Reduced)	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)	83.6 lbm	100%	83.6 lbm
Epoxy (inside ZOI)	Total (Fines)	101.1 lbm	100%	101.1 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)	248.4 lbm	100%	248.4 lbm
Alkyd Enamel (outside ZOI)	Total (Fines)	50.3 lbm	100%	50.3 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 (Reduced)	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)	248.4 lbm	100%	248.4 lbm
Alkyd Enamel (outside ZOI)	Total (Fines)	50.3 lbm	100%	50.3 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™ (Reduced)	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)	0 lbm	100%	0 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)	248.4 lbm	100%	248.4 lbm
Alkyd Enamel (outside ZOI)	Total (Fines)	50.3 lbm	100%	50.3 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™ (Reduced)	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)	248.4 lbm	100%	248.4 lbm
Alkyd Enamel (outside ZOI)	Total (Fines)	50.3 lbm	100%	50.3 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

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 because 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 item 3.e shows these results for this debris transport. Also, as stated in responses to item 3.f, head loss testing was carried out in such a manner, i.e., use of mechanical and manual stirring, as 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 section 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 again 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 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. Additional assessment of the potential blockage that the cross-bar can result in was included in the transport analyses.

The types of debris determined to be blown to upper containment are identified in this section (Debris Transport). Large pieces of RMI (BVPS-1) and TIW (BVPS-2) 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 see 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.

While unlikely that the small amount of large piece debris could transport through the drain opening and lodge against the cross-bar, restricting flow out the drain, the cross-bars in BVPS-1 and in BVPS-2 have been removed.

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

Section 3.e of this response provides a complete 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.

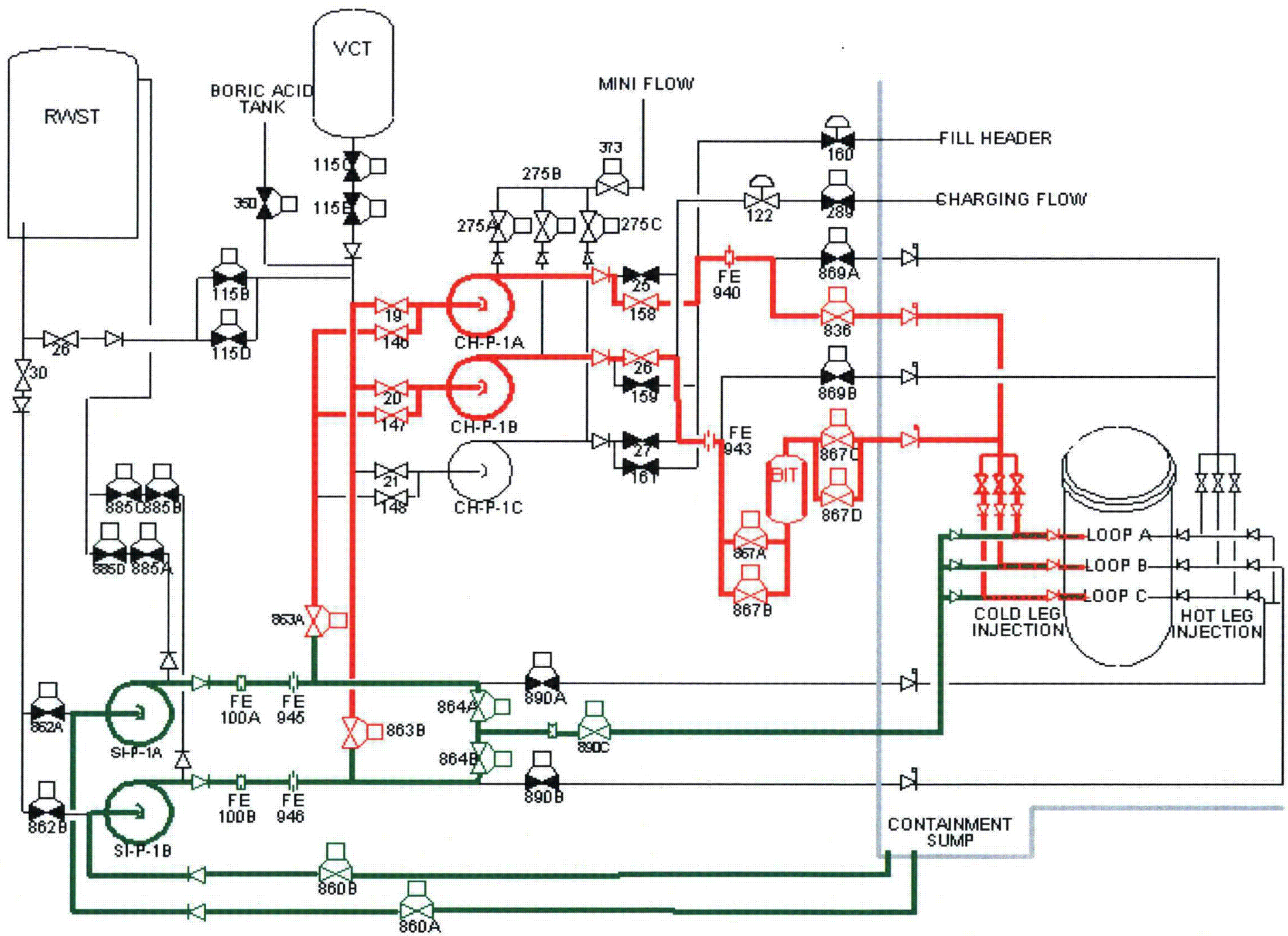
12. *State whether near-field settling was credited for the head-loss testing and, if so, provide a description of the scaling analysis used to justify near-field credit.*
13. *State whether temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. If scaling 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).

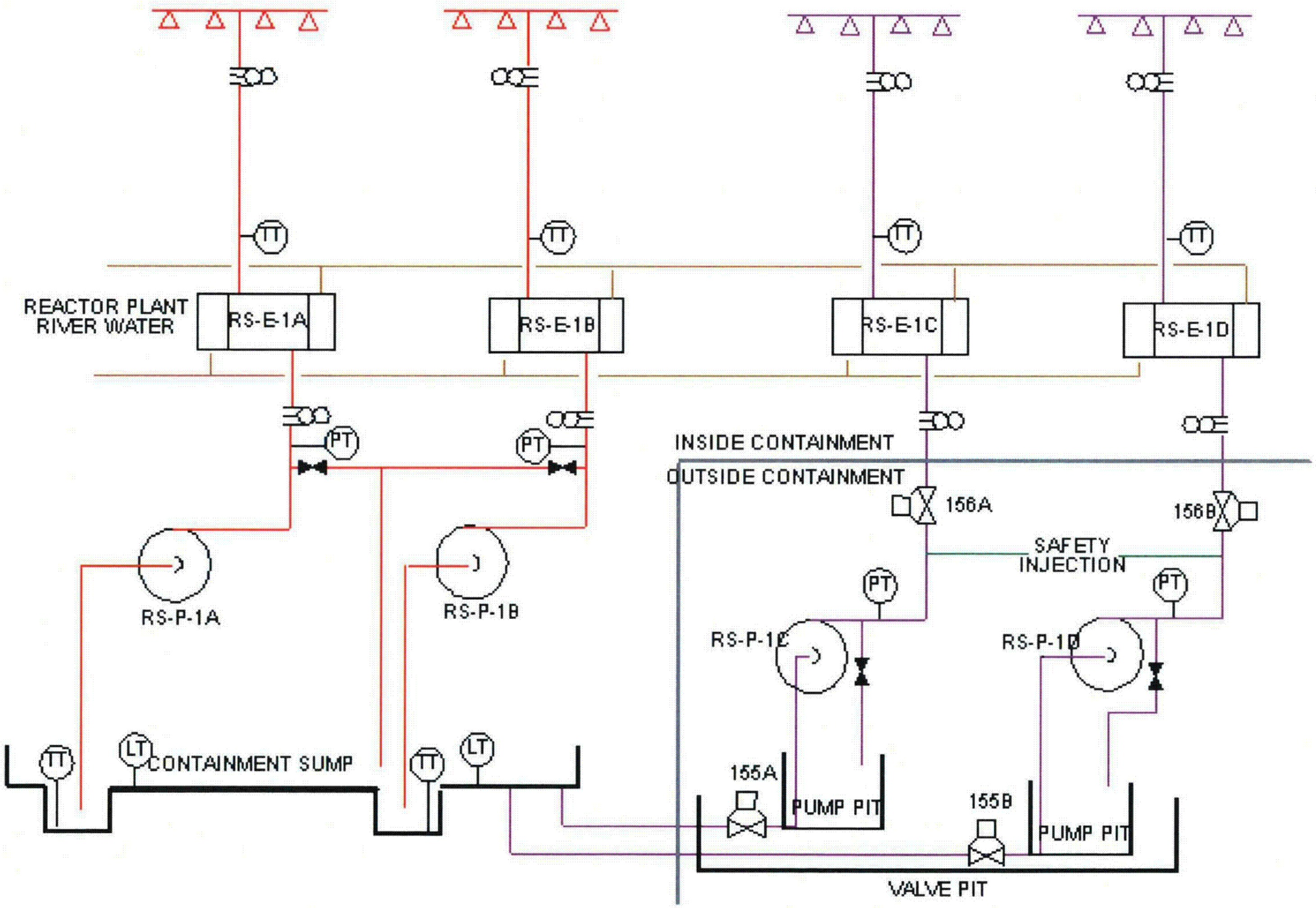
FENOC Response

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

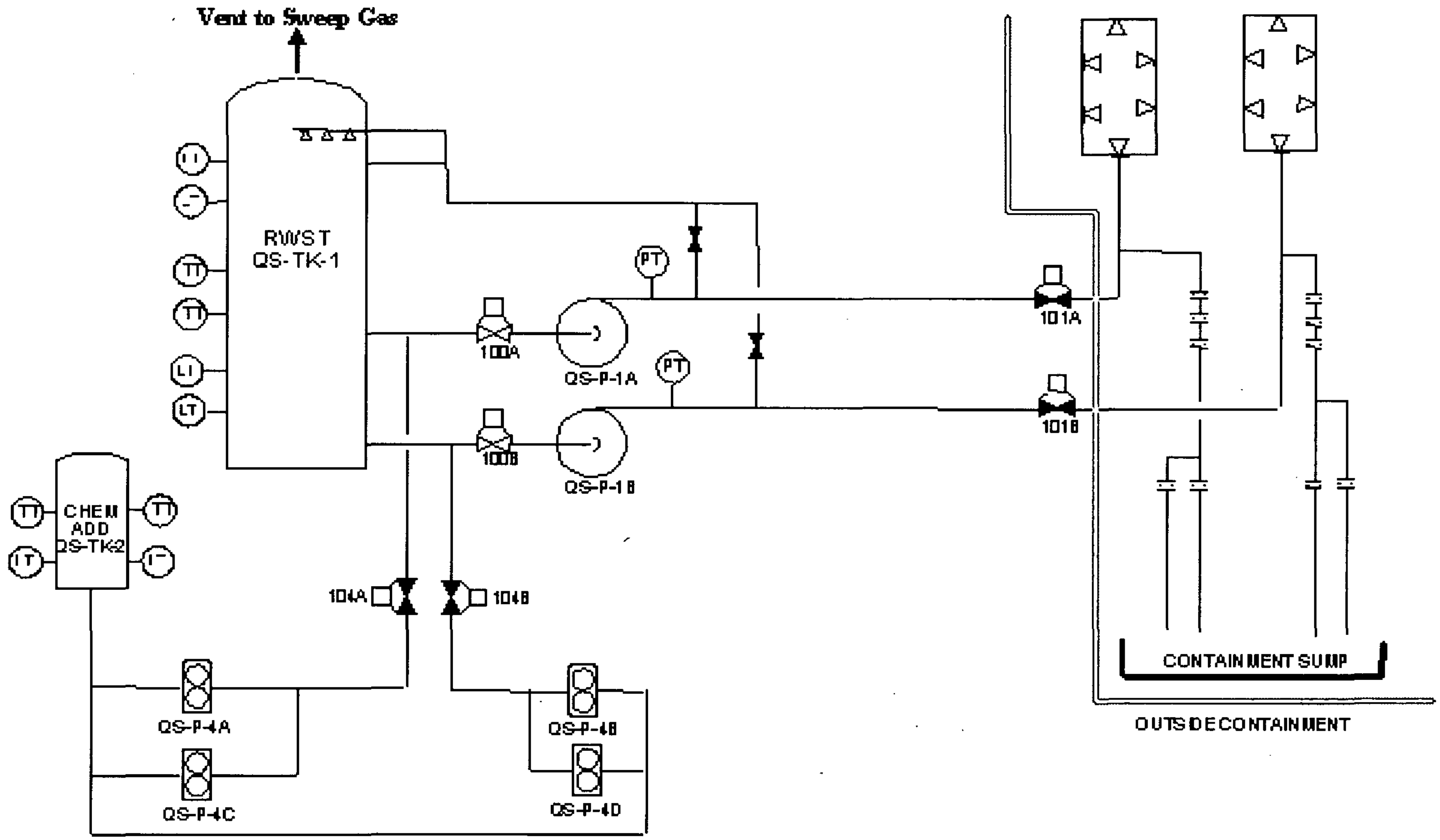
BVPS-1 Safety Injection System Cold Leg Recirc Phase



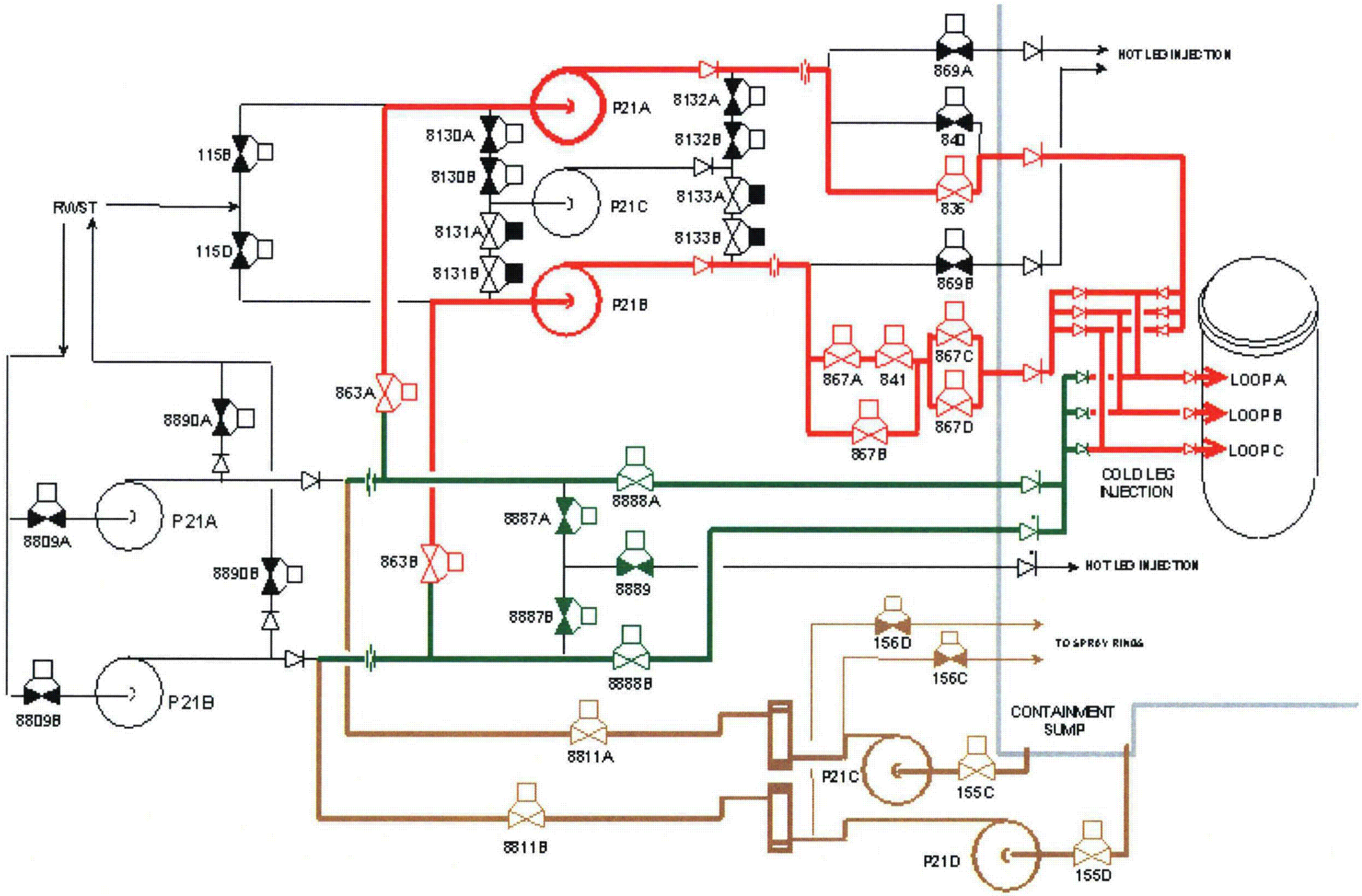
BVPS-1 Recirculation Spray System



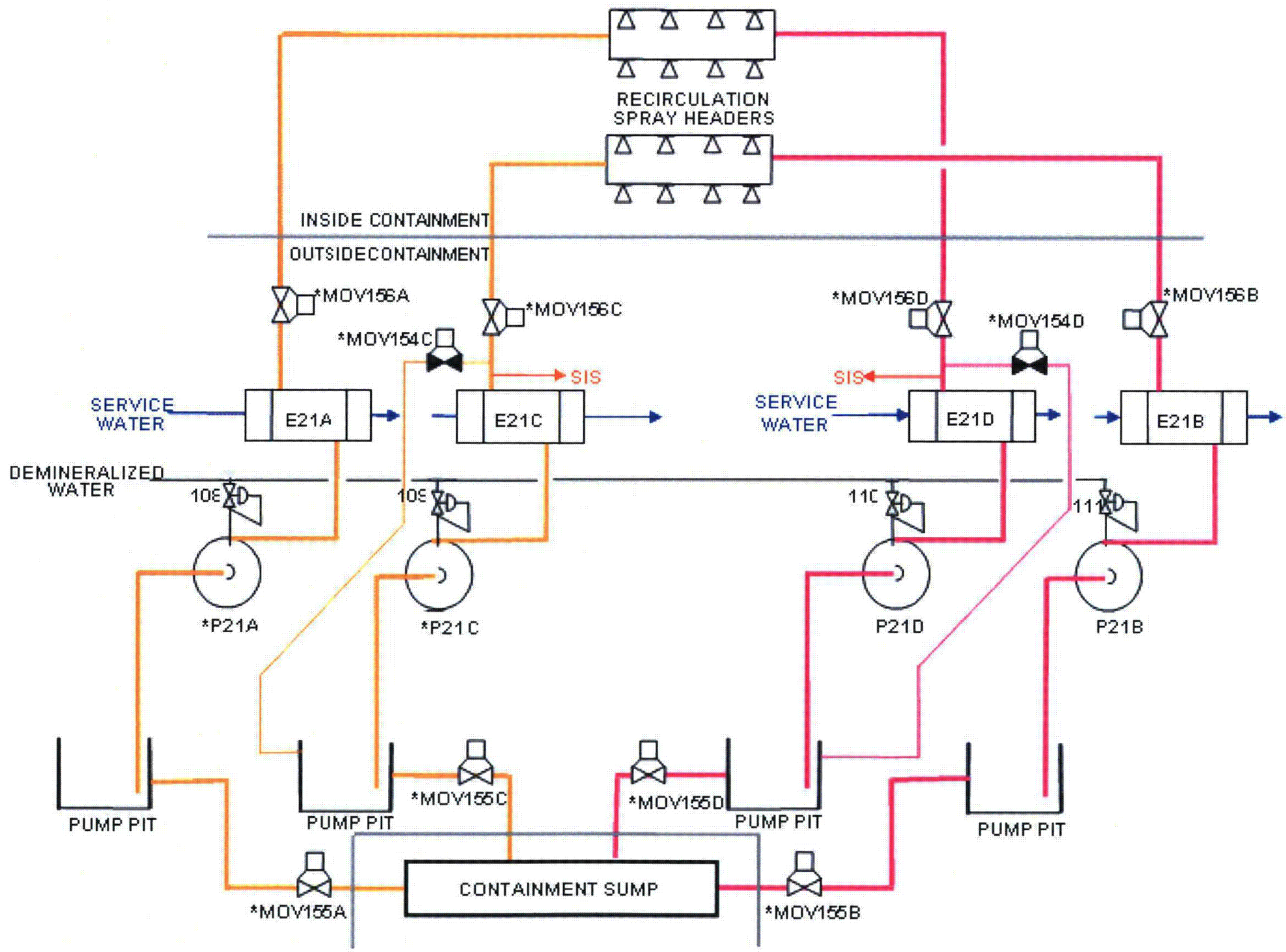
BVPS-1 Quench Spray System



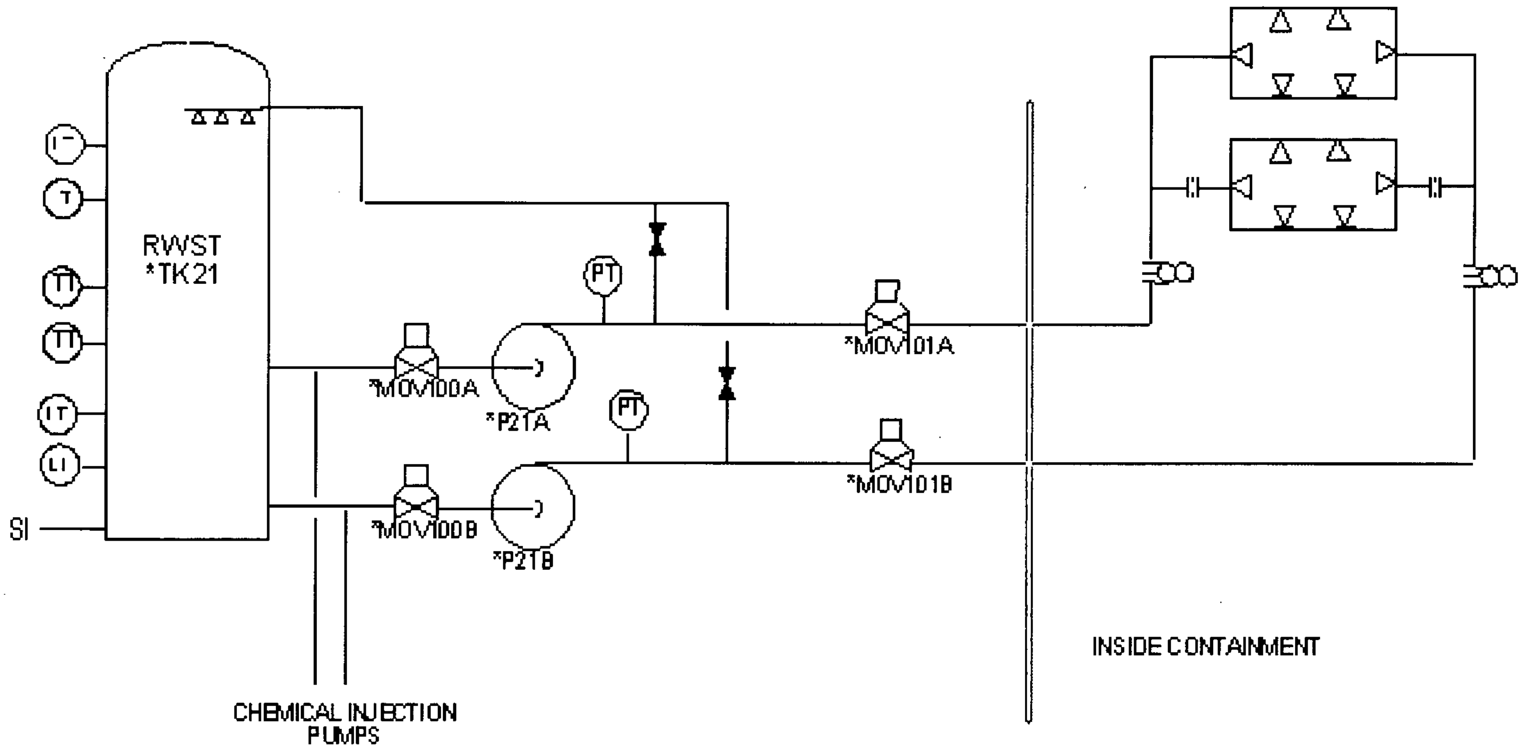
BVPS-2 Safety Injection System Cold Leg Recirc Phase



BVPS-2 Recirculation Spray System



BVPS-2 Quench Spray System

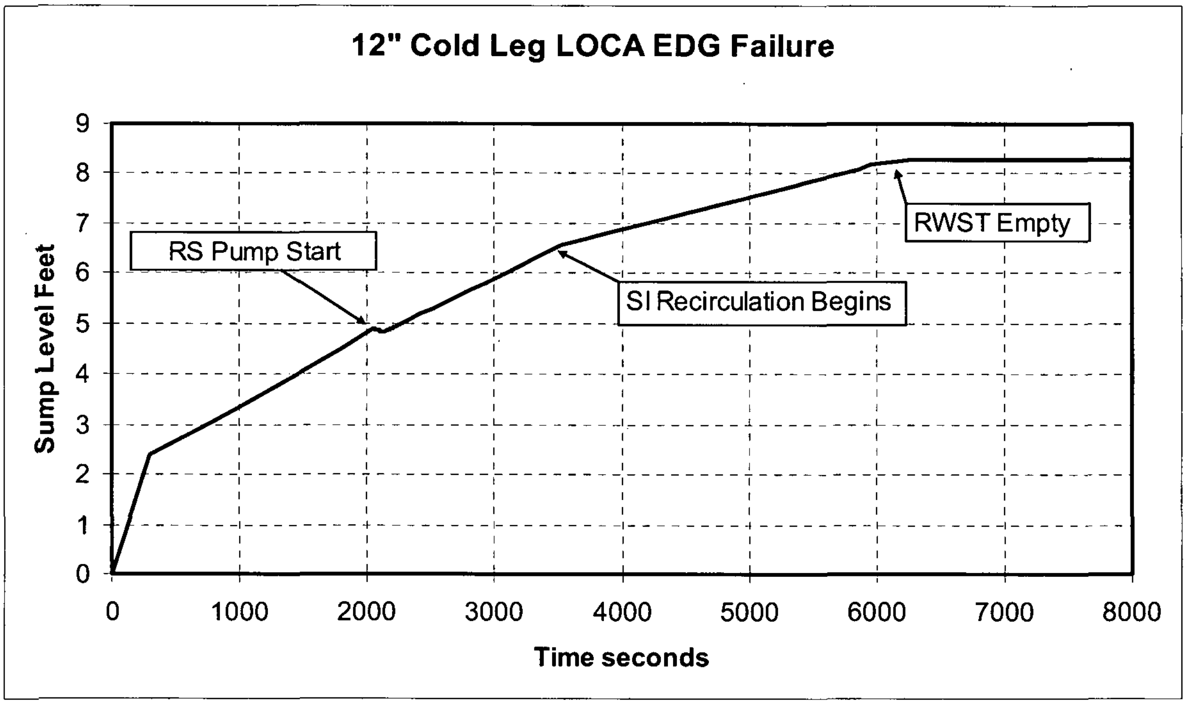


3.f.2 *Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.*

FENOC Response

The minimum submergence of the strainers at BVPS-1 and BVPS-2 occurs shortly following start of the Recirculation Spray (RS) pumps. After the pumps start on a Refueling Water Storage Tank (RWST) level signal coincident with a high containment pressure (CIB) signal, water is drawn from the containment sump to fill the RS piping. During this period, no water is discharged from the RS spray headers so the sump experiences a net decrease in inventory. Within a few minutes following pump start, the spray from the RS system starts to reach the sump and the sump level increases from that point until the RWST is empty 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 RS 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

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

FENOC Response

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 under testing.

The recent retesting for BVPS-1 included verification of no vortexing. This test verified that no vortex formation occurred.

During all BVPS-2 strainer head loss testing, the water surface was observed with no indications of a vortex formation noted. The BVPS-2 headloss testing is scheduled to be re-performed in the Fall 2008 and confirmation of no vortex formation will form a part of the test protocol.

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

BVPS-1

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 Science. 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, which represents the final configuration for BVPS-1 after planned insulation modifications, included an amount of debris which was less than the quantity required to form a thin bed.

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

Table 3.f.4-1

Test #	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

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

The methodology, assumptions, and results of chemical effects are discussed under Section 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 Table 3.f.4-2 below.

Table 3.f.4-2

Test #	NUKON® (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

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 ¼ inch nominal size distribution.

The prototype strainer module consisted of 4 cartridges, arranged two on each side. Each cartridge contains 16 pockets (2 wide x 8 high), so the module contains 64 pockets overall.

The prototype 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 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.

The cartridges used in testing are equivalent to the cartridges that are installed in the replacement strainer modules at BVPS-1. The prototype included perforated seal plates, i.e. 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 module. The prototype screen opening size, 1/16 inch, 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 turbidity meter (Hach) was installed in-line on the return side of the pump, thus monitoring 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 array. The water temperature was maintained above 80 °F during the course of the tests. The debris for BVPS-1 testing was prepared as follows:

NUKON®

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 +/- 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.

Temp-Mat

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 +/- 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 and 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 +/- 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 +/- 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 14).

The chemical precipitates were prepared in accordance with WCAP-16530-NP and "PWR Owners Group, New Settling Rate Criteria for Precipitates Generated in Accordance with WCAP-16530-NP (PA-SEE-0275)," (OG-07-270). Additionally surrogate settling criteria was employed to ensure that the precipitates did not exceed settling thresholds prior to being used in testing.

The testing was executed using the following procedural steps:

1. For Tests 1 and 2 (full load tests with current debris loads), the entire particulate debris load was added.
2. Then the fiber debris load (latent, Temp-Mat) was added in batches.
3. Subsequently, the chemical batches were added.
4. For Test 3 the entire particulate debris load was added except for paint chips.
5. Then the fiber debris load was added in batches.
6. Then the paint chips were added
7. Subsequently the chemical batches were added.

8. For Test 4 (latent fiber test), Test 5 (target insulation replacement test), and Test 6 (surge line bounding test) the entire particulate debris load was added.
9. Then the entire fiber debris load was added in batches.
10. Subsequently the chemical batches were added.
11. For Test 1 and 2 all coatings were added as ground silica.
12. For Tests 3, 4, 5 and 6, all coatings were added as ground silica, and for conservatism, the unqualified chips load was also added as paint chips.
13. All debris loads were added over the sparger. A sparger system was installed on the return line to aid in the suspension of the debris within the water.
14. All debris loads were added in two locations to maximize uniformity in debris distribution between the two sides of the strainer assembly. (For Tests 1 and 1A, debris was added in only one location.)
15. Two mechanical mixers were also installed inside the tank opposite the sparger; these methods of debris agitation were sufficient in keeping debris suspended in water.
16. Clean strainer head loss was depicted for each test by plotting the differential pressures across the clean strainer array versus fluid theoretical average approach velocity.
17. Head loss versus time was monitored for all tests.
18. The stabilization criteria varied. For instance 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. After the final fibrous debris load batch and after each chemical precipitate batch was added, the subtest 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 1-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.
19. Calibrated instruments were used to continuously measure all key parameters, including debris quantity, strainer assembly differential pressure, flow rate and tank temperature.
20. Observations for vortexing were also performed.

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 precipitants.

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.4-3.

Table 3.f.4-3

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

BVPS-2

The BVPS-2 strainer will be retested for head loss, including chemical effects, as discussed in the executive summary. BVPS-2 head loss data will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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 section 3.f.4, BVPS-1 was 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 (assuming 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 precipitants (that also bound the BVPS-1 Loop and the BVPS-1 Reactor Vessel Nozzle breaks).

The BVPS-2 strainer will be retested for head loss, including chemical effects, as discussed in the executive summary. It is anticipated that this testing will result in the need to remove fibrous and particulate insulation. The testing will demonstrate the BVPS-2 strainer capability to accommodate the maximum volume of debris with the new insulation configuration.

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.

The BVPS-2 strainer will be retested for thin bed effects using the methodology described in the NRC reviewer's guide, as was done on BVPS-1. BVPS-2 thin bed test results will be provided after that testing has been completed.

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 ability to sustain this head loss is then assessed through fulfillment of the acceptance criteria as determined by the NPSH margins and structural loading requirements. See the response to Review Area 3.f.10 for further discussion of the strainer head loss.

The BVPS-2 strainer will be retested for head loss, including chemical effects, as discussed in the executive summary. BVPS-2 maximum head loss basis will be provided after that testing has been completed.

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 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, for the aluminum paint it was assumed that 100 percent of the 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. These values were conservatively combined with the precipitates predicted by the spreadsheet which was run without the Al 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 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 (~360 gallons per minute). The approach velocity was increased in 0.005 ft/s increments, up to ~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.

The BVPS-2 strainer will be retested for head loss, including chemical effects, as discussed in the executive summary. BVPS-2 head loss data will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

For BVPS-2, there were no specific analyses performed to assess the potential for vortexing. The potential for vortexing was evaluated for BVPS-2 and is discussed within Section 3.f.3, and the response to RAI #42 (at the end of this section). Vortex testing will be performed during BVPS-2 retesting.

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 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 rows, 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 (i.e., 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 5383 Pascal (1.8 feet) at an actual 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 and prototype test results for the debris bypass eliminator internal to the top-hat strainers.

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.

Flow though the strainers is normalized over all of the top-hat strainers in a train. Head loss through the perforated plate is calculated using the flow resistance coefficient and the head loss through the top-hat debris bypass eliminator wire mesh is calculated based upon proto-type testing results.

Flow then proceeds to the sump area in train-specific channels separated from each other by perforated plate. The flow channel head loss is calculated for each node of the flow channel in four parts:

- Head loss due to inflow from the top (i.e., from the top-hat strainers)
- 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 largest head loss experienced by a top hat and manifold train is summed to produce the most conservative head loss. No credit is taken for flow equalization between the channels. The higher train head loss is used as the strainer head loss. To account for any uncertainty in the flow model, 10 percent is added to the results of the clean strainer head loss models.

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 0.923 foot-of water at a flow rate and temperature of 12,600 gallons per minute and 60°F.

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 recirculation spray system.

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

The BVPS-2 strainer will be retested for head loss, including chemical effects, as discussed in the executive summary. BVPS-2 debris head loss analysis will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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 the BVPS-1 testing.

Head loss retesting is scheduled for BVPS-2. A BVPS-2 response to this issue of near-field settling will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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. Therefore, testing demonstrated that the debris loads (Test 6) are small enough such that a thin bed will not form.

Temperature corrections were performed for the final representative test configuration (Test 6). 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.

The BVPS-2 strainer will be retested for head loss, including chemical effects, as discussed in the executive summary. Information on boreholes or other differential-pressure induced effects will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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-1 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 RS 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 show acceptable results. These evaluations cannot be completed for BVPS-2 until the containment analyses are complete and the head loss including chemical effects is established.

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 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 under section 3.f.2.

All testing, including the recent retesting, performed for BVPS-1 showed no vortex formations. The strainer testing conditions bounded the design and operating ranges with no vortex formations observed.

For BVPS-2, there have been no analyses performed to evaluate the possibility of vortex formation. Performance of the strainer testing required that observations be made to confirm no presence of a vortex formation. No vortex formations were observed to occur under testing conditions which bounded the strainer design and operating ranges. This will be reconfirmed by further strainer testing, planned to commence in the Fall of 2008.

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 loss for BVPS-1 is based upon head loss testing with several limiting break debris mixtures. The NUREG-CR/6224 correlation was only used for scoping analyses. The scheduled testing for BVPS-2 will follow the same protocol as that used for BVPS-1.

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 Recirculation Spray (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

BVPS-1				
Start of Recirculation Spray Pumps				
Maximum RS Pump Flow (GPM)	Maximum LHSI Pump Flow (GPM)	Maximum Sump Flow(1) (GPM)	Max Sump Temperature (°F)	Minimum Sump Water Level(2) (Ft)
3637	Note (3)	14472	235	4.0
Safety Injection Recirculation				
Maximum RS Pump Flow (GPM)	Maximum LHSI Pump Flow (GPM)	Maximum Sump Flow(1) (GPM)	Max Sump Temperature (°F)	Minimum Sump Water Level(2) (Ft)
3637	3072	12318	206	5.0

Table 3.g.1-2

BVPS-2				
Start of Recirculation Spray Pumps				
Maximum RS Pump Flow (GPM)	Maximum LHSI Pump Flow (GPM)	Maximum Sump Flow(1) (GPM)	Max Sump Temperature (°F)	Minimum Sump Water Level(2) (Ft)
3740	Note (3)	10470	212	6.6
Safety Injection Recirculation				
Maximum RS Pump Flow (GPM)	Maximum LHSI (RSS) Pump Flow(4) (GPM)	Maximum Sump Flow(1) (GPM)	Max Sump Temperature (°F)	Minimum Sump Water Level(2) (Ft)
3761	3685	13640	209	6.9

Notes:

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

(2) Level above bottom of containment sump in feet (Ft).

(3) Low Head Safety Injection (LHSI) pumps take suction from the RWST prior to Safety Injection Recirculation.

(4) BVPS-2 uses 2 of 4 (1 of 2 for single train) RSS pumps for LHSI function following initiation of Safety Injection Recirculation

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 section 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 recirculation spray (RS) 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 influences the flow per pump. The quench spray (QS) pumps are similarly aligned for each unit, i.e., 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 RS 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, it is also assumed that all RS pump flow passes through the sump strainer. In reality, a portion of the flow which is supplied directly from the QS system to the pump suctions bypasses the strainer.

Sump Temperature:

Containment analysis inputs are biased in a manner which results in the most 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 for BVPS-1 and will credit containment overpressure for BVPS-2 (pending LAR approval), the sump vapor pressure is important in establishing that the available NPSH 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 broken up 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. A good example of this is the refueling cavity 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 is 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 NPSH values for all pumps are based on a 3 percent reduction in head. The required NPSH values for the BVPS-1 RS pumps and LHSI pumps are based on tests which were performed at North Anna Power Station using pumps which are hydraulically identical in design. The required NPSH values for the pumps were determined to be 9.8 feet for the RS 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 required NPSH value used for the BVPS-2 RS pumps is 15 feet and is based on the original manufacturers testing. However, the BVPS-2 pumps are almost identical to the pump which 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 in 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 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 a 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. 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 which serve the same purpose, e.g., 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 pumps are actuated when RCS pressure decreases to 1760 pounds-force per square inch absolute (psia). 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 RS pump suctions to provide enhancement 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/ORS system that provides containment heat removal via the IRS/ORS heat exchangers. The IRS/ORS pumps receive an initiation signal based on an RWST low level coincident with CIB and begin injecting water into a dedicated spray ring header in containment. The IRS/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 RS pumps and heat exchangers are located outside containment.

2. The BVPS-2 QS system does not provide enhancement flow to the RS pumps.
3. At BVPS-2, the LHSI pumps do not function in recirculation mode. Instead, one of the two recirculation spray (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 CS pumps for each unit consist of two QS pumps, four RS 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 section 3.f.1.

Prior to initiation of SI recirculation:

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

RS pumps are operating after the CIB setpoint has been reached and the RWST low level 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 RS pumps will continue to operate to provide spray flow to the RS spray headers and remove heat via the RS heat exchangers. If all four RS pumps are operating, two of the four pumps will be shut down just prior to reaching the recirculation initiation setpoint. This reduces the total strainer flow during SI recirculation to minimize head loss.

The BVPS-2 RS pumps continue to operate drawing flow from the containment sump. Two of the four (or one of two for single train operation) RS 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.

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 RS pumps.

The HHSI pumps at both BVPS-1 and BVPS-2 automatically realign the suction supply to receive flow from the LHSI system in a "piggy-back" arrangement. 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	X	
♦ QS	X	X
♦ EDG	X	X
♦ RELAY		X
CIB	One train each, QSS, RSS	
LHSI	One LHSI 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	

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 recirculation spray 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) Use of the minimum mass of RWST that must be injected prior to RS initiation and safety injection recirculation.

(2) Volumes of water from the chemical addition system are not included in contributing to the sump inventory.

(3) Use of 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.

The major hold-up of spray water is in the refueling canal which can hold water up to 1818 cubic feet (for BVPS-1) 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. Water of up to 139,000 pounds 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 DG case. The operating deck floor holds about 12,600 pounds at this time. About 9,230 pounds of water are held up on various platforms in the loop compartments. It is noted that the amounts of water cited here are for BVPS-1. 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 3.46E6 lbs/hr. For BVPS-2, the hold-up water mass is 80,170 pounds.

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

- Water hold-up in the air-borne spray droplets for paths which 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 which 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 foot 11 inches to elevation 692 foot 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 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

	BVPS -1	BVPS-2
Accumulator Water Volume (Minimum)	20,042 gal	20,692 gal
RWST Total Useable Volume (Minimum)	430,500 gal	859,248 gal
RWST volume Injected @ RS pump start (Minimum)	179,900 gal	369,648 gal
RWST volume Injected @SI switchover (Minimum)	317,000 gal	411,500 gal
RWST Usable Volume for QS after SI Switchover	113,500 gal	447,748 gal

An additional volume of water (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.

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

At BVPS-1, credit is taken for containment accident pressure in determining the available NPSH. As noted in FENOC letter dated August 28, 2008 (Reference 12), this methodology will also be implemented at BVPS-2 following approval of a License Amendment to change the methodology. 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.

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

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

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

The preceding discussion applies to the current methodology in use at BVPS-1. As noted in FENOC letter dated August 28, 2008 (Reference 12), it is intended that this methodology will also be applied at BVPS-2 following approval of a LAR to change the methodology. Separate sensitivity analyses will be completed as part of the analysis to establish the direction of limiting bias for BVPS-2 containment inputs.

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

FENOC Response

At BVPS-1, credit is taken for containment accident pressure in determining the available NPSH as discussed in Section 3.g.13.

The current BVPS-2 calculations for available NPSH assume that the containment pressure is equal to the vapor pressure corresponding to the sump liquid temperature. This is in accordance with the current licensing basis for BVPS-2. While this assumption is conservative for conditions where the vapor pressure of the sump liquid is above the initial containment pressure, it is unrealistic and overly conservative for conditions where the sump liquid vapor pressure is below the initial containment pressure. Since the sump strainer head loss increases with lower sump liquid temperatures, this assumption artificially drives the available NPSH results to minimum values for low sump temperature conditions such as those that occur during smaller break LOCA scenarios. As noted in FENOC letter dated August 28, 2008 (Reference 12), a LAR will be submitted for BVPS-2 to change the methodology for calculating available NPSH. The LAR will request that BVPS-2 use the same methodology as currently approved and in use at BVPS-1.

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

FENOC Response

The NPSH Margins for BVPS-1 are as follows:

	NPSH Required (feet)	NPSH Available (feet)	Margin (feet)
Inside Recirculation Pumps	9.8	14.2	4.4
Outside Recirculation Pumps	9.8	13.9	4.1
Low Head Safety Injection Pump	10.6	15.4	4.8

FENOC has submitted an extension request in letter dated August 28, 2008 (Reference 12) for specified corrective actions for BVPS-2. Additional testing is required for BVPS-2. These tests need to be completed before the final calculation of NPSH margins. The changes for BVPS-2 require the completion of testing, analysis and the submittal of a LAR for crediting containment overpressure in calculating available NPSH. The response to this request will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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 NPSH margin 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 #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 include the time at which the RS pumps start and the time at which 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
Case6L-rs	EDG	1805.7	233.4	2955.7	188.3	291,940	124	376,200

FENOC has submitted an extension request in letter dated August 28, 2008 (Reference 12) for specified corrective actions for BVPS-2 which requires additional testing and subsequent analysis. The BVPS-2 response to this RAI will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008).

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 / DuPont Corlar Epoxy for steel surfaces and DuPont Corlar Epoxy for concrete surfaces. 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 & 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 concrete 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 / 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 & 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 concrete 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 item 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 responses to item 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. It was assumed that the settling velocity of fine debris (insulation, dirt/dust, and paint particulate) can be calculated using Stokes' Law. This is a reasonable assumption since the particulate debris is generally spherical and would settle slowly (within the applicability of Stokes' Law).
2. It was assumed that the unqualified coatings would be uniformly distributed in the recirculation pool. This is a reasonable assumption since the unqualified coatings are scattered around containment in small quantities.
3. 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 considered. However, head loss testing conservatively included both particulates and chips effectively doubling the quantity of unqualified coatings.
4. The transport metrics for IOZ, epoxy, alkyd, aluminum, cold galvanizing and Vi-Cryl coatings are all bounded by the metric for individual fibers (i.e., 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 item 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 BVPS-1 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 responses for item 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. Though multiple tests were performed, the discussion below, as it applies to BVPS-1, relates primarily to the final and bounding test.

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 range from 55 lb/ft^3 to 442 lb/ft^3. The ground silica surrogate to be used has a material specific gravity of 2.65, that 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-meter (taken from the Product Data Sheet for the particle size distribution).
2. In addition to the ground silica being used for the coatings surrogate for BVPS-1, the utilization of 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 1/8 inch chips were sifted using 1/16 inch perforated plate (similar to the strainer perforated plate) to ensure that only chips larger than 1/16 inch were used in the testing so that none would pass through the strainer plate. The 1/4 inch chips were not sifted since the nominal size distribution is significantly greater than the 1/16 inch strainer perforated plate. 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 11).

As discussed in the executive summary, suction strainer head loss re-testing for BVPS-2 will be conducted using the same test protocol used for BVPS-1. A discussion of coatings and surrogate material used to simulate coatings for BVPS-2 will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, 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 items 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 sections, 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 2. The NRC has provided guidance on the use of the 5D ZOI for coatings in Enclosure 2 of Reference 9. Specifically the NRC's response to Item 3 in Reference 9 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 GR. However, unqualified coatings that are under insulation that becomes debris (i.e., insulation within the ZOI) are assumed to fail.
5. With the exception of unqualified coatings under insulation discussed in item 4 above, all unqualified coatings are assumed to fail and add to the debris load.

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

FENOC Response

Service Level 1 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 starting with the BVPS-2 Spring 2008 refueling outage. The coatings inspection program will be implemented for BVPS-1 beginning with the Spring 2009 refueling outage. Containment coatings inspections will be 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 15).

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 and is then followed by the specific 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

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	12,457(1)	3,549(1)
Zinc in Galvanized Steel	150000(2)	177166(2)
Inorganic Zinc Coatings	90000(2)	295573(2)
Total Zinc	240000(2)	472739(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) No quantity is provided because sufficient records are not available to determine the amount of copper surface area in the containment spray zone or submerged in the containment pool following a LOCA and because WCAP 16530, Revision 0, page 46, states that ICE testing & 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 of the Beaver Valley 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) 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	0.29	0.04
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 hot carbon steel coated by 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 hot 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 RAI #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 plant 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 insulation jacketing inside the reactor containment is made of stainless steel.

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

BVPS-2

Original plant 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.

Subsequently, all 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:

The response to this portion of the RAI has been revised from that previously provided under FENOC Letter dated February 29, 2008. This response is updated to: a) reflect the high temperature aluminum coating used on the BVPS-1 reactor vessel, b) to update the metallic coatings information for other nuclear steam supply system (NSSS) component coatings - based on site specific information received from the supplier, c) to include information on the limited use of Galvanox paint, and d) to develop the discussion that the NSSS components coated with a metallic paint are not subjected to containment spray.

BVPS-1

In addition to the inorganic zinc coatings identified in the response to RAI #2, Two (2) 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 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 was used as touchup 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 (1) metallic paint was used for BVPS-2: Galvanox Type I or Type III "Cold Galvanizing."

The Galvanox would be exposed to containment spray. Galvanox was used as touchup 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 Emergency Core Cooling System (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 experienced outside 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 16), 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 Emergency Core Cooling System (ECCS) debris source term.

A new coatings assessment program was implemented for BVPS. The initial coatings assessment for BVPS Unit 2 was performed during the Spring 2008 refueling outage. The initial coatings assessment for BVPS Unit 1 will be conducted during the Spring 2009 refueling outage. These assessments and associated coating repair/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.

Design Control

Design control procedures revisions have been made 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 NOP-CC-2004, "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.

Containment Labels and Signs

Plant labels and signs are controlled by procedure "Guidelines for 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.

Containment Coatings

Containment coatings are controlled by procedures 1/2-PIP-S11 "Painting for Containment Interior" and 1/2-PIP-S15 "Procurement, Receipt, Storage, and Handling of Coating Materials – BVPS#1 and #2."

As discussed in section 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 and identified as requiring resolution prior to plant heatup.

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 will be performed during the Spring 2009 refueling outage. Containment coatings inspections will be a scheduled activity to be conducted during refueling outages at both BVPS-1 and BVPS-2 (refer to Regulatory Commitment No. 3 of FENOC letter dated December 20, 2007; Reference 15).

Containment Cleanliness

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. These procedures verify by visual inspection that no loose debris (rags, trash, clothing, etc.) is present in the containment which could be transported to the containment sump and cause restriction of the Emergency Core Cooling System pump suctions during LOCA conditions.

During Operating Modes 1 through 4, containment foreign material control is 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.

In addition, by procedure a visual inspection of the accessible regions of the ECCS containment sump suction inlets are 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, BVPS has developed a periodic containment cleaning program. This program was implemented at BVPS-2 during the Spring 2008 refueling outage (2R13) and will be implemented during the next refueling outage (Spring 2009) at BVPS-1. 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 implementing procedure includes provisions for obtaining some limited periodic debris samples using methods consistent with those initially used for sample collection and calculation of the baseline latent debris load. The results of the initial BVPS-2 periodic sample plan performed during 2R13 indicated that the calculated debris load is lower than that calculated from the baseline samples. Inspection and cleaning of inaccessible areas of the containment will be done when access to these areas is available from scaffolding constructed to support other outage activities inside containment.

With the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the containment it is not expected that routine maintenance activities could significantly impact the plant debris source term. For non-routine maintenance activities and temporary changes to the containment sump, the activities would be addressed for their risk impact on a case-by-case basis and managed in accordance with the Maintenance Rule, 10 CFR 50.65.

In addition to the design and operational refinements already discussed within this response area, the following suggested design and operational refinements given in the NEI guidance report (Section 5) and SE (Section 5.1) have been applied to BVPS-1:

1. At BVPS-1, new Reflective Metal Insulation (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 includes 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.
2. New RMI was also installed on the new BVPS-1 reactor vessel closure head (RVCH) during the Spring 2006 refueling outage (1R17).

Because of this, the insulation mix for a postulated Reactor Coolant System (RCS) loop pipe break would have less particulate and much less fibrous insulation than it would have had prior to the up-grades noted above. Additional insulation modifications are planned for BVPS-1 during the Spring 2009 refueling outage.

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

1. The fibrous Temp-Mat insulation included in the insulation panels over the reactor vessel head closure studs was replaced with reflective metal insulation.
2. 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.

Additional insulation modifications are anticipated for BVPS-2 during the Fall 2009 refueling outage.

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 item 3i "Debris Source Term Refinements" Under "Containment Cleanliness" provides the response to this RAI.

RAI #35 (from Reference 6)

Will latent debris sampling become an ongoing program?

FENOC Response

FENOC's response to item 3i "Debris Source Term Refinements" Under "Containment Cleanliness" provides the response to this RAI.

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

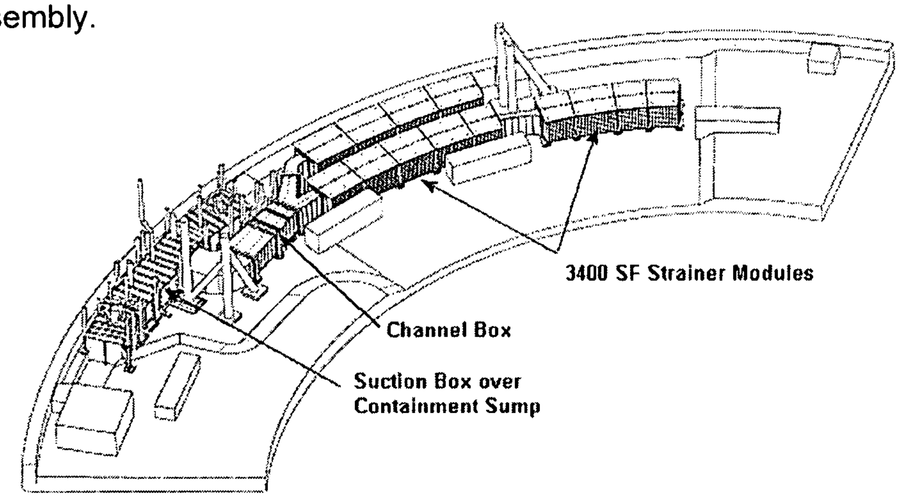
BVPS-1

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

The modification installed a passive, safety-related strainer assembly engineered and manufactured by CCI. The design does not include an active approach for the strainer. Reverse flow back flushing strategy was not used. The new containment sump strainer provides approximately 3400 square feet of strainer area. The 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 arrangement for BVPS-1 consists of strings of strainer modules, connecting to a channel box which is connected to a common sump suction box, which 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 to the module duct (clean side). The 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.

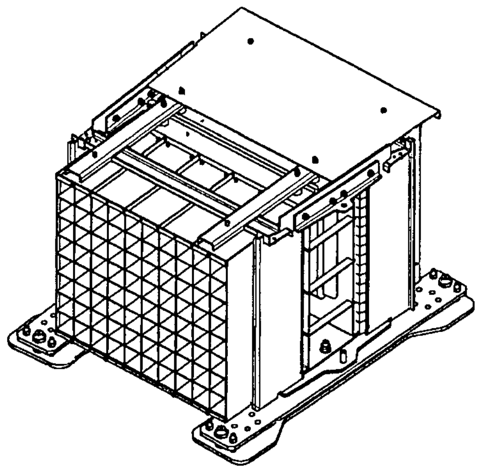
The sketch below shows the primary components for the new containment sump assembly.



Strainer Assembly Sketch

The strainer assembly has 13 strainer modules. A strainer module is comprised of cassettes consisting of a 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 / 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. Also like 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 Recirculation Spray 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 assemblies. 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, which connects 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 all fully submerged at initiation of Recirculation Spray pump start. Loop seals are provided for open Quench Spray piping which penetrates the suction box. All 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 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

The intent of the modification was to perform the hardware changes required to bring BVPS-2 into compliance with NRC GSI-191. This modification replaced the existing screens for BVPS-2 containment sump located outside the crane wall adjacent to the containment wall on the basement floor of the BVPS-2 Containment building.

The modification installed a passive, safety related strainer assembly engineered and supplied by Enercon. The new containment sump strainer provides approximately 3300 square feet of strainer area.

The original containment sump screen assembly was composed of a structural steel frame that supported trash racks, two layers of vertical screening that comprised approximately 150 square feet of strainer surface area and anti vortex grating located inside the sump screens adjacent to the pump inlets. The top of the frame was covered with steel deck plate.

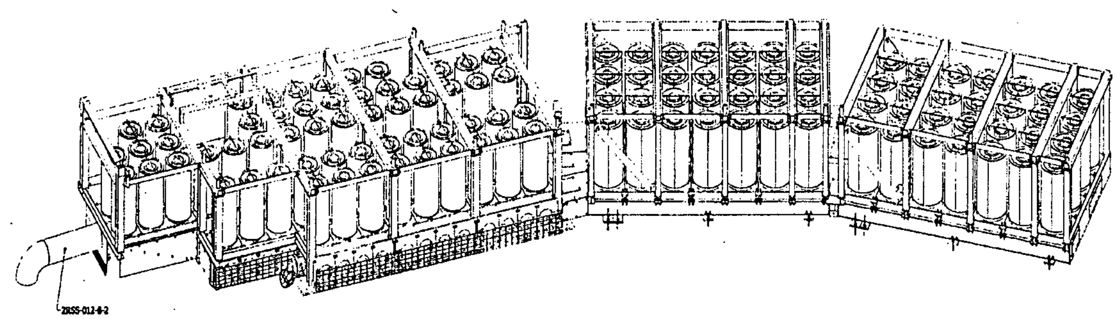
The frame's vertical columns were welded to embedded plates in the floor. The trash racks were made of vertical 1 inch by 1/8 inch galvanized carbon steel grating. Inside the trash racks were vertical screens composed of outer screens with 3/4 inch square openings of 0.192 inch diameter wire, 304 stainless steel, and inner wire cloth screens, 3/32 inch square openings, 0.063 inch diameter wire, 304 stainless steel. Inside the screens, above the pump suction inlets, was a horizontal layer of 1 by 1/8 inch antivortex grating. The frame members and rash racks adjacent to the screens, the vertical screens, and antivortex grating were all removed and discarded. Because it supports numerous pipes, pumps and equipment, original framing and decking at the normal sump area remains as originally installed.

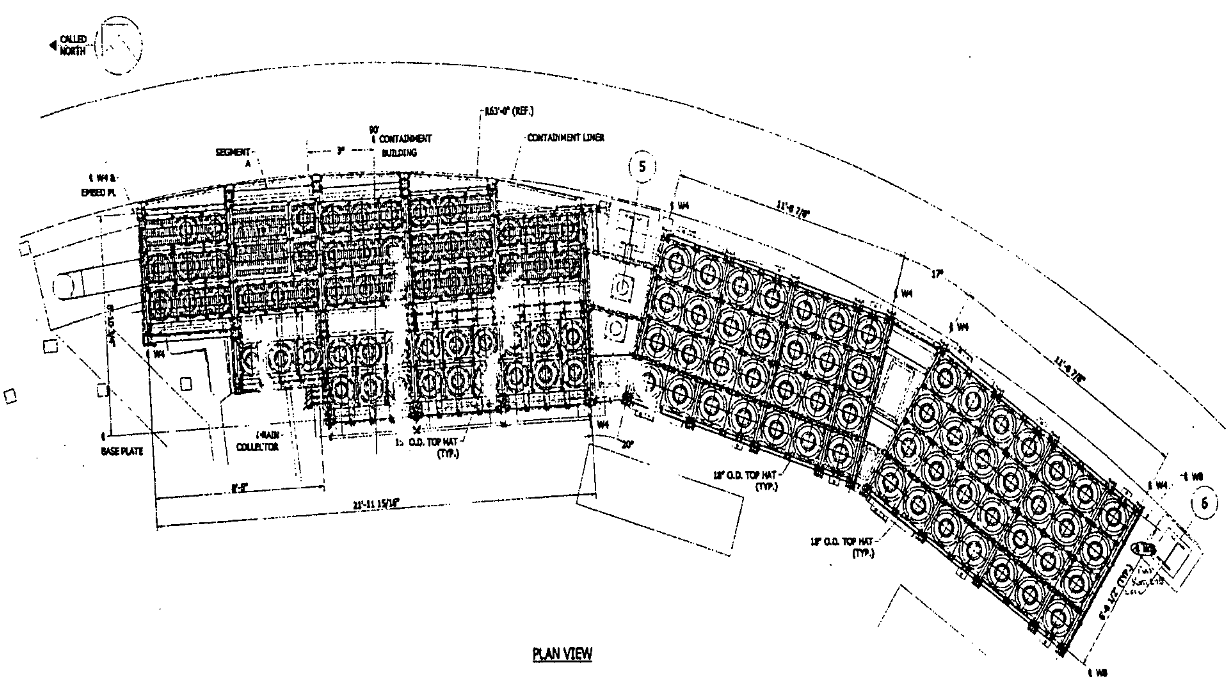
The modification installed a passive, safety-related strainer assembly engineered by Enercon and fabricated by Transco. The design does not include an active approach for the strainer. Reverse flow back flushing strategy was not used. The new containment sump strainer provides approximately 3300 square feet of strainer area. The flow velocity through the screens is 0.009 feet per second based on upon 12,600 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, & 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 Recirculation Spray 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, of the 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.





PLAN VIEW

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 & 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 & C has slotted holes to accommodate thermal expansion. The support frame members within segments B & C have slotted bolt holes to allow for thermal expansion.

All three segments are divided into sump trains A & B. Perforated and solid plates divide the two trains. Grout and welded shims were used to close gaps between the two trains 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.

Non-safety-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. This 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 recirculation spray 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, since the recirculation spray 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). 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 which connects the suction box water volume to the containment atmosphere above the containment minimum water level. All top-hats are fully submerged at initiation of Recirculation Spray pump start. The Recirculation Spray test piping which penetrates the strainer segment A is installed with a blind flange. The Recirculation Spray test piping which penetrates the connection box between segments A & 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 insures 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.*

BVPS-1

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:

- Bell-mouth flanges were added in the sump trench at the pump suction inlets for the outside Recirculation Spray pumps and the outside Low Head Safety Injection pumps. The flanges increase the Net Positive Suction Head (NPSH).
- Temperature sensors used to provide containment water temperature post LOCA, were relocated.
- The reactor cavity drain barrier was removed.
- Pipe supports were locally modified.
- Flow transmitters were relocated locally.
- Support columns for the existing sump screens' frame were deleted or relocated.
- RWST Level Interlock was modified to change RS Pump start.
- High Head Safety Injection throttle valves were replaced.
- Quench Spray loop seals were modified.
- Recirculation Spray test return pipe and support were modified.

BVPS-2

- Bell-mouth flanges were added in the sump trench at the pump suction inlets for the outside Recirculation Spray pumps. Grating is attached to these flanges for vortex suppression. The flanges increase the Net Positive Suction Head (NPSH).
- Modifications were performed to shorten a Quench Spray Line and to relocate a Quench Spray Support.

- Modifications to the Recirculation Spray 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 reactor cavity drain barrier was removed during 2R13.
- RWST Level Interlock was modified to change RS Pump start.

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 and is then followed by the specific 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 item 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 NPP Engineering Specification, Spec. 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 incl. Addenda 2005
4. ASME Boiler and Pressure Vessel Code, Section II, Part D – Properties (Metric), Edition 2004 incl. 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 Bull. Seismolog. Soc. Amer. 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, Rev. 1
12. CCI Drawings (VTI 8700-06.060 Series Drawings)
13. 8700-RV-1K, Rev. 4, "Reactor Containment Liner Details - Sh 5"
14. 8700-RV-1L, Rev. 4, "Reactor Containment Liner Details - Sh 6"
15. 13387.65-S-0150, Rev. 0, Add. A1, "Recirculating Pump Frame Analysis"
16. Unit 1 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, Oct. 8, 2007, "BV1 Containment Sump Project: Drillco Minimum Embedment Violation"
18. CR 07-28180, Oct. 9, 2007, "QC ID: Drillco Spacing and Embedment Violations ECP 05-0361 RCB Sump"
19. CR 07-28564, Oct. 15, 2007, "QC ID: Drillco Embedment Depth Violation ECP 05-0361 RCB Sump"

The Design 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 AISC Manual of Steel Construction, 8th 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. As noted in Table 3.k.1-1, 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

Load Comb Nr.	Temperature (°F)	Temperature (°C)	Load Combination	ASME Service Level
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 °C are used for the load combinations 6 and 7 in the analysis for the support structure.

<u>Loads:</u>
DL 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. ECP No. 05-0362-01, “Replacement of Containment Sump Strainer”
3. Calc. No. 10080-DSC-0282, “Analysis of Top Hat Assembly”
4. Calc. 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. IDCN and VTI References for Containment Screen 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, 5th Edition, 1983

The Design Code used to design the BVPS-2 containment sump strainer assembly is the AISC Specification for the Design, Fabrication, and Erection of Structural Steel - 7th 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)
3. Live Load (LL)
4. Pressure Differential
5. Jet Impingement

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 train 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 presented is the smallest margin presented in the analysis for the same type of component.

Table 3.k.2-1

Component	Actual Value *	Allowable Value *	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	0.849	1.0	15%
Anchor Bolts – End Plate	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	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	1.0	1.16	14%
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	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.

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 presented 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%

Table 3.k.2-2 (Continued)

Component	Actual Value	Allowable Value	Margin
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 foot 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 included 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 foot 11 inches of the containment; on the bottom floor of the containment and entirely outside of the crane wall adjacent to the containment liner.

It has been verified that 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 and is then followed by the specific 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 item 3.k, "Sump Structural Analysis," no active approach such as backflushing is used for either BVPS-1 or BVPS-2 strainer design.

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 those areas into which Containment Spray and RCS break flow would 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. The report identified the need for a plant modification to core bore a 12 inch drain hole at the bottom of the reactor cavity to ensure that water draining into the reactor cavity from the refueling cavity can transit freely to the outside of the primary shield wall. The plant modification has subsequently been completed at both units.

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. 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 are sufficiently large to prevent any credible debris that may be generated as a result of the break from blocking this flow path. 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 the small pieces of insulation that could be present in upper containment, and that not enough large pieces would be present to cause a blockage concern. The fuel transfer canal (housing the fuel assembly upender), located in the refueling cavity does not drain in an accident, and as discussed above, 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.

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

<u>GL 2004-02 Requested Information Item 2(d)(vi)</u>
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 Emergency Core Cooling System (ECCS) and the Recirculation Spray System (RSS) flow path components is performed using the guidance of Westinghouse WCAP-16406-P, Evaluation of Downstream Effects in Support of GSI-191 Revision 1.

The methodology for the Beaver Valley 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 / or 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 paragraphs 3.a – e above. Specific bounding debris concentrations were established, and were then used in the assessment of component blockage and wear.

The sump strainer screens at BVPS-1 have a series of circular openings. The screens are constructed of perforated plate that have 1/16 inch (0.0625 inch) diameter holes. During installation, gaps or openings between connected parts of the strainer were verified to be less than 1/16 inch. The downstream effects calculation conservatively assumed that the openings in the screens were 1/8 inch (0.125 inch) in diameter. Using guidance in Westinghouse WCAP-16406-P, the calculation conservatively assumes the following:

1) All fibrous and particulate debris with a diameter up to 0.14 inch (0.125 inch plus 10 percent then rounded upward) will pass through the screen into the downstream recirculation water
2) Loose fibrous debris regardless of length will pass through the screen into the downstream recirculation water.

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
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 / or abrasive or erosive wear. Each of the potentially susceptible pumps, valves, orifices, nozzles, heat exchangers and pipe segments is assessed for blockage and wear using the guidance of WCAP-16406-P, 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 / or 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.

The quantity of debris used in the downstream effects analysis is based on the presently installed conditions. BVPS-1 is scheduled to complete insulation modifications in the Spring of 2009 which will result in less debris transported to the containment sump. Additional margin for downstream effects will be realized after the insulation modifications are completed.

BVPS-2 is scheduled for retesting in the Fall of 2008 and insulation modification in the Fall of 2009. The final results of downstream effects will be provided for BVPS-2 in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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

The blockage evaluations revealed that the BVPS-1 high pressure safety injection throttle valves had gaps that are smaller than the size of the opening in the new strainer. High pressure safety injection throttle valves were replaced at BVPS-1 during the Fall 2007 refueling outage (1R18). Debris potentially passing through the strainers at BVPS-1 has been determined to 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, Revision 1, with the exception of the high pressure safety injection throttle valves discussed above.

Detailed analyses were performed for the 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, and the associated SE. The mechanical seal performance was also assessed considering the WCAP screening criteria. The mechanical seal backup seal bushing for the BVPS-1 HHSI pumps is manufactured from stainless steel with a Grafoil insert. An analysis was included to conservatively assess pump leakage considering a passive failure with 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 need for additional evaluation was identified for the recirculation spray and low head safety injection pump wear analysis during the final review of the downstream analysis, while this submittal was being developed. This additional evaluation of downstream effects on the BVPS-1 recirculation spray and low head safety injection pumps is presently being conducted. The final results of the evaluation will be provided by March 20, 2009. This issue has been identified and tracked through our corrective action program.

In summary, with the exception of the evaluation required for the pumps addressed above, the BVPS-1 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.

BVPS-2 is scheduled for retesting and insulation modification in the Fall of 2009. The final results of downstream effects will be provided for BVPS-2 in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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 Unit 1

Replacement of BVPS-1 High Pressure Safety Injection Cold Leg Throttle Valves to increase the throttle valve gap and eliminate potential blockage by debris that passes through the strainer.

BVPS Unit 2

Modification of the BVPS-2 High Pressure Safety Injection Throttle Valves to increase the throttle valve gap to eliminate potential blockage by debris that passes through the strainer.

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 and is then followed by the specific 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. Since then the ex-vessel methodology has been defined by WCAP-16406-P, Evaluation of Downstream Sump Debris Effects in Support of GSI-191. The safety evaluation on this was transmitted by Ho K. Neih's letter of December 20, 2007. WCAP-16793-NP, Evaluation of Long-Term

Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid, has been developed and submitted to the NRC.

As noted in this response, the Beaver Valley analysis has been conducted following the guidance of WCAP-16406-P, Revision 1 and WCAP-16793-NP, Revision 0. The issues related to WCAP-16406-P identified in this RAI have been resolved. As noted below in response to Item 3.n, the WCAP-16793-NP approach is still under discussion. 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.

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

WCAP-16793-NP, Revision 0, "Evaluation of Long Term Core Cooling Associated with Sump Debris Effects," section 7 states that assurance of long term core cooling is demonstrated by satisfying five statements. The first four statements are generically met by all PWRs, while the fifth requirement is to either demonstrate that the sample calculation bounds plant-specific chemistry or complete a plant specific calculation using the method in the WCAP.

A plant specific calculation has been completed for BVPS-1 using the methodology and acceptance criteria of WCAP-16793-NP, Revision 0. The plant specific calculation satisfies the acceptance criteria of the WCAP and together with the four generic evaluations of the WCAP demonstrate adequate core cooling at BVPS-1.

The in-vessel evaluation for BVPS-2 is pending completion of the BVPS-2 specific chemical effects testing.

It is recognized that the NRC review of WCAP-16793-NP has not been completed. 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.

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.

FENOC Response

3.o.1. Beaver Valley Integrated Chemical Effects testing for BVPS-1 was completed in the Spring of 2008 by Alion Science and Technology at Alion's Warrenville facility. This testing included incorporation of target debris load reductions. The testing also included utilizing 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. Test 6 (section 3.f.4) 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 section 3.f, and acceptable results were achieved with deposition of chemical product on the sump strainer for BVPS-1. Section 3.n provides information regarding chemical effects on core cooling.

Integrated chemical effects testing for BVPS-2 is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. Results will be provided in the follow-up supplemental response FENOC committed to provide in a letter dated August 28, 2008 (Reference 12).

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 based on the final configuration after planned insulation modifications and bounds all breaks including the BVPS-1 loop, reactor vessel nozzle, and surge line break loads. The testing included latent and coating debris plus WCAP 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. Additional quantities of sodium aluminum silicate and aluminum oxyhydroxide equivalent to an additional 10 percent each were also 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 as previously discussed for BVPS-1 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 testing are documented later in response to 3.o.2.7.

The limiting break location for BVPS-2 will be selected and confirmed based on testing currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. Results will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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 Testing (Utilizing WCAP-16530-NP Chemical Precipitates)

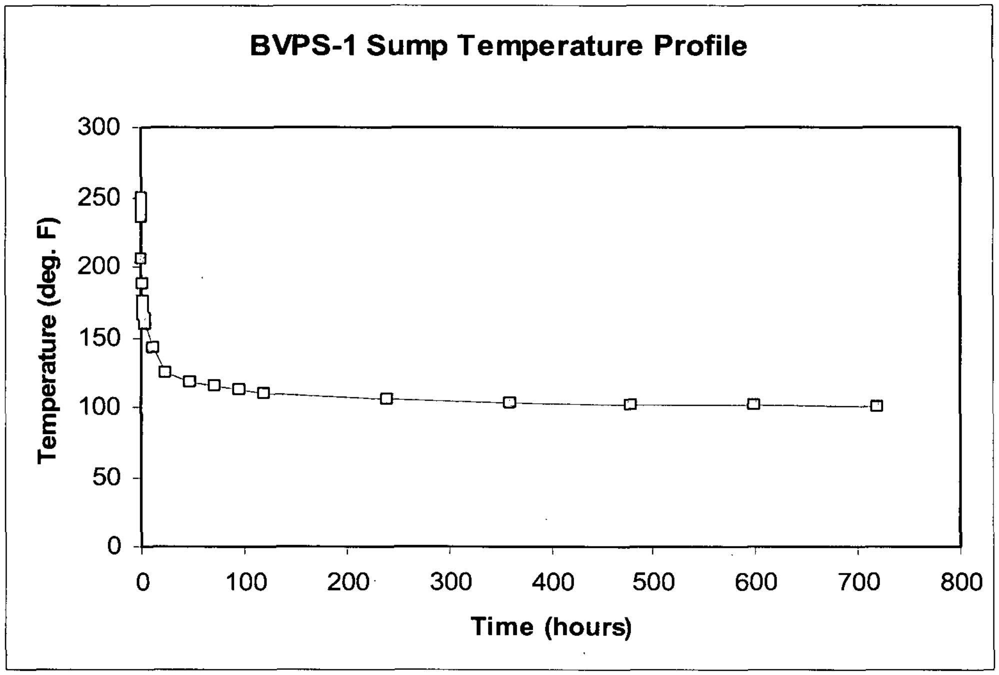
pH Range

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 to be 8.79 throughout the event.

Temperature Profile

The temperature profile that was used for the BVPS-1 sump temperatures 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

Nukon®

Temp-Mat

Concrete

BVPS-2 Testing

BVPS-2 testing will also be performed utilizing WCAP-16530-NP chemical precipitates. The pH range, temperature profile, spray duration, and materials expected to contribute to precipitates will be determined prior to the initiation of the testing, which is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. Results will be provided in the follow-up supplemental response

FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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 testing was completed in the Spring of 2008 by Alion Science and Technology at its Warrenville facility using the WCAP-16530 Base Model.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed 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

BVPS-1 used the WCAP-16530 Base Model to conduct Chemical Effects testing at the Alion Warrenville facility.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed using the WCAP-16530 Base Model.

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 chemical product generation predictions. No deviations were taken from the WCAP base model spreadsheet. Various combinations of cases were run to determine a bounding chemical debris load for BVPS-1 head loss testing.

ii. The type and amount of predicted WCAP-16530-NP plant specific BVPS-1 precipitates for Test 6 are shown in the following Table (before scaling amounts). All cases for Test 6 resulted in acceptable head loss margins. The results for Test 6 are used for the head loss analysis.

Table 3.o.2.7-1

BVPS-1 Test 6

Precipitate	Test 6 (Pounds)
Sodium Aluminum Silicate	449
Aluminum Oxyhydroxide	691

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed using the WCAP-16530 Base Model.

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 predictions of chemical precipitates.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed using the WCAP-16530 Base Model. Use of refinements to the WCAP is not expected at this time.

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.

FENOC Response

Refinements to WCAP-16530-NP were not utilized for BVPS-1 chemical product generation predictions.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed using the WCAP-16530 Base Model. Use of refinements to the WCAP is not expected at this time.

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 testing, the chemical precipitates were prepared in accordance with WCAP-16530-NP and OG-07-270 in a separate mixing tank. Batches of chemical precipitates were produced and then checked against settling criteria prior to use in a head loss test. Extra quantities of sodium aluminum silicate and aluminum oxyhydroxide equivalent to an additional 10 percent each, were added for increased margin.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. It is currently anticipated that the precipitates will be formed in a separate mixing tank in accordance with the WCAP-16530 Base Model.

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

i. In-situ chemical injection method was not utilized for BVPS-1 prototype testing. Thus, this question is not applicable. The settling criteria for pre-prepared chemical precipitates as documented in OG-07-270 was utilized for the BVPS-1 testing.

ii. The injected chemical method was not used for BVPS-1 prototype testing. Thus, this is not applicable.

iii. T he amount of chemical precipitant that was added to the BVPS-1 head loss test of record was equivalent to 110 percent of the quantities calculated in the WCAP-16530-NP spreadsheet.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008.

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 were taken in regards to the procedure recommended for surrogate precipitate formation for the BVPS-1 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 BVPS-1 test plan.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. As at BVPS-1, no exceptions to the surrogate precipitation formation procedure in WCAP-16530 are expected.

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 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.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. A credit for near-field settlement is not expected to be taken.

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

For BVPS-1 near-field settlement was not credited thus, this is not applicable to BVPS-1 testing.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. A credit for near-field settlement is not expected to be taken.

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 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.

ii. The chemical precipitate settling was measured within 24 hours of the time the surrogate was used. The 1-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. Note that if chemicals were made within 7 days of use, they did not need to be re-tested 24 hours before use. These measurements were recorded during testing. The lowest averaged measurement recorded for the BVPS-1 testing was 8.6 milliliters and thus, was greater than the 6 milliliter settled criterion.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008.

2.16 Test Termination Criteria

i. Provide the test termination criteria.

FENOC Response

The head loss measurements for each BVPS-1 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 1-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 3 hours or after 8 hours had passed. A successful test (Test 6) was terminated based on stable head loss results.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008.

2.17 Data Analysis:

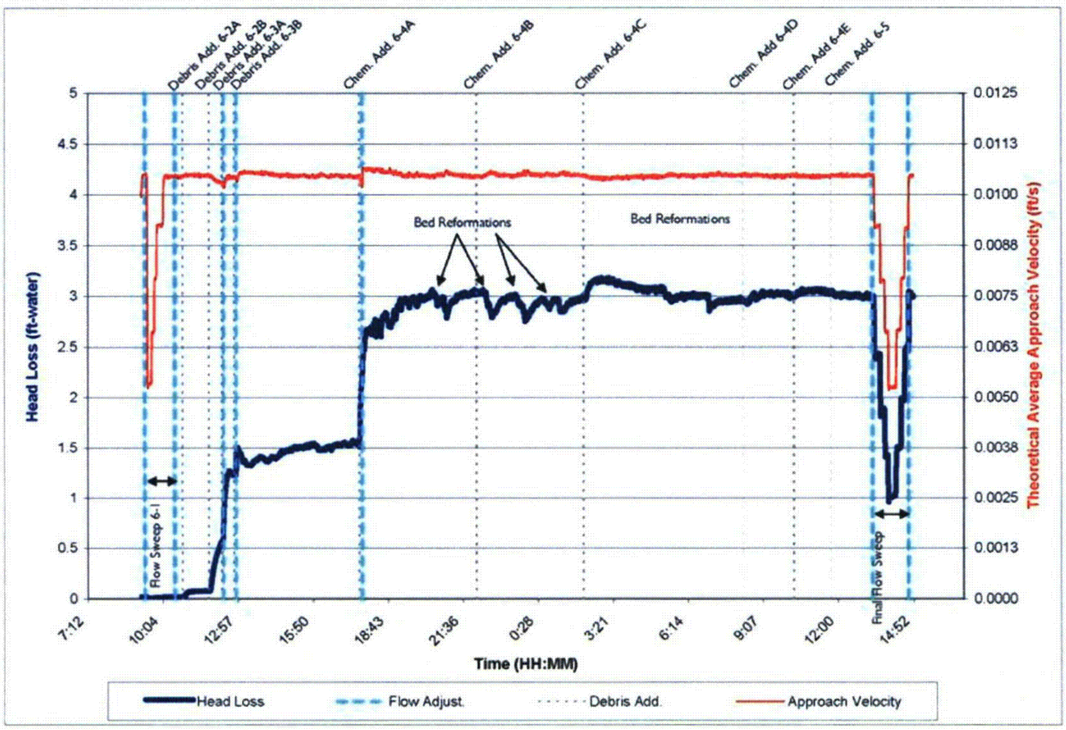
i. Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.

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

FENOC Response

i. The curve in Figure 2.17-1 below illustrates the pressure drop as a function of time (uncorrected temperature) for the BVPS-1 Test 6 configuration.

Figure 2.17-1 Test 6 Differential Pressure and Velocity Versus Time



ii. Only temperature corrections were applied to the head loss data analysis. No other extrapolations were utilized for BVPS-1 testing.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008.

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. Requested response is not applicable to BVPS-1 because WCAP-16530 Base Model Testing is used.

ii. Requested response is not applicable to BVPS-1 because WCAP-16530 Base Model Testing is used.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed using the WCAP-16530 Base Model. Therefore, the requested responses to this section are not applicable.

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. Requested response is not applicable to BVPS-1 because WCAP-16530 Base Model Testing is used.

ii. Requested response is not applicable to BVPS-1 because WCAP-16530 Base Model Testing is used.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed using the WCAP-16530 Base Model. Therefore, the requested responses to this section are not applicable.

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. Requested response is not applicable to BVPS-1 because WCAP-16530 Base Model Testing is used.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed using the WCAP-16530 Base Model. Therefore, the requested response to this section is not applicable.

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. Requested response is not applicable to BVPS-1 because WCAP-16530 Base Model Testing is used.

ii. Requested response is not applicable to BVPS-1 because WCAP-16530 Base Model Testing is used.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed using the WCAP-16530 Base Model. Therefore, the requested responses to this section are not applicable.

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. Requested response is not applicable to BVPS-1 because WCAP-16530 Base Model Testing is used.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008. The testing will be performed using the WCAP-16530 Base Model. Therefore, the requested response to this section is not applicable.

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 and is then followed by the specific 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 NaOH concentration and minimum delivered volume.

Likewise, 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 NaOH concentration and maximum delivered volume.

BVPS-1

Minimum Sump pH (BOL)	7.80
Maximum Sump pH (EOL)	8.79

For BVPS-2

Minimum Sump pH (BOL)	8.14
Maximum Sump pH (EOL)	9.03

BVPS-2 has submitted a License Amendment Request (FENOC letter dated September 24, 2008) to change the pH buffer from sodium hydroxide to sodium tetraborate during the 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

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 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, 21 percent Cal-Sil, depending on the break location. BVPS-2 ranges from 100 percent fiberglass, 0 percent Cal-Sil to 94 percent fiberglass, 6 percent Cal-Sil, depending on the break location. The other major difference was temperature. ICET #4 was carried out 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.

BVPS-2 testing is currently scheduled to begin at Alion's Warrenville facility in the Fall of 2008 to experimentally determine the insulation changes necessary to meet the requirements of GSI-191.

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 in section 3.o above provide the BVPS-1 overall strategy to evaluate chemical effects. 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 Spring 2009 refueling outage (1R19).

BVPS-2 will follow a similar strategy as BVPS-1. BVPS-2 Chemical Effects testing is scheduled to begin in the Fall of 2008, using the WCAP-16530 Base Model as the testing protocol. Iterative testing will continue until a scaled amount of debris/fiber/chemical precipitates is determined that results in sufficient NPSH margin. Based on the testing results, the scope of containment insulation modifications required to produce this scaled amount will be calculated, planned and engineered, and will be performed during the Fall of 2009 scheduled 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 the Chemical Effects testing performed for BVPS-1, it will be necessary to remediate existing Temp-Mat and Cal-Sil insulation.

Additionally at BVPS-1, it is planned to remove the aluminum contained in the iodine removal filters in order to maximize margin by minimizing post-LOCA chemical effects.

These materials will be 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 Reflective Metal Insulation (RMI) on the Reactor Vessel Closure head (RVCH) flange was replaced with RMI insulation.
2) The existing "Min-K™" encapsulated in RMI in portions of the Reactor Coolant System (RCS) piping was replaced with "Thermal Wrap" insulation encapsulated in RMI.
3) The aluminum in the containment iodine removal filters was removed.

Based on BVPS-1 Chemical Effects testing results, it is anticipated that additional insulation modifications will be required at BVPS-2. The scope of insulation modifications required will be determined by results of the BVPS-2 Chemical Effects testing, which is scheduled to begin in the Fall of 2008.

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 objective of the benchtop testing performed for Beaver Valley is to test for the dissolution and corrosion of aluminum, zinc, Temp Mat, 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 Beaver Valley units. The materials that were selected for testing (aluminum, zinc, Temp Mat (fiberglass), Cal-Sil, concrete, alkyd paint, and dirt/dust) are what would be expected to enter the Beaver Valley containment sump pool following a LOCA. 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 2800 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 7 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 very 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 2800 ppm boron (from boric acid) and 0.7 ppm lithium (from lithium hydroxide); the resultant solution pH was 5.2. This test was also very representative of Beaver Valley 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; while they are not representative of either BVPS-1 or BVPS-2 as they are currently configured, the tests were designed to see the impact of changing the buffer from NaOH to NaTB on corrosion product formation.

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 planned for 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.

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 Chemical effects testing was performed in the Alion hydraulics test loop in the late Spring of 2008. 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. Prototypical strainer array testing was performed for BVPS-1 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 installed at BVPS-1. 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 section 3.f and 3.o of the revised supplemental response.

The prototype testing was performed at temperatures that were considerably lower than the early temperature phases of the BVPS-1 sump pool environment (maintained above 80°F). However, results from the prototype testing were scaled to various temperatures and at 212°F to approach plant environmental sump temperatures. These results were then presented in the test report documenting the various tests performed for BVPS-1. The test tank setup was controlled for flow rate to match the average approach velocity across the BVPS-1 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. pH was monitored throughout the test for information only. If testing were to occur at higher temperature, it is probable that the chemical precipitates would 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 thé 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 (i.e., without other buffers or pH controlling materials), the impact of potential chemical inhibition or reduction in material solubility is controlled. In other words, 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 and inhibit its formation. 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, i.e., WCAP-16530-NP and OG-07-270 "PWR Owners Group, New Settling Rate Criteria for Precipitates Generated in Accordance with WCAP-16530-NP (PA-SEE-0275)." 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 the planned BVPS-1 configuration (related to buffer and insulation changes). 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.

BVPS-2 Integrated Chemical Effects Testing, scheduled to begin in the Fall of 2008, will be conducted in a manner similar to the completed BVPS-1 testing.

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). 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.4-3, in the response to Review Area 3.f.4, for temperature corrected head loss values.

BVPS-2 Chemical Effects testing is scheduled to start in the Fall of 2008. A BVPS-2 response to this RAI will be provided in the follow-up supplemental response FENOC committed to submit (FENOC letter dated August 28, 2008, Reference 12).

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 73 percent fiberglass, 27 percent Cal-Sil, depending on the break location. BVPS-2 insulation content ranges from 100 percent fiberglass, 0 percent Cal-Sil to 97 percent fiberglass, 3 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. Therefore, 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.

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 Recirculation Spray System (RSS) pumps was changed. License Amendments 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 Net Positive Suction Head (NPSH) requirements. This methodology provides benefits in maintaining NPSH margins. First Energy Nuclear Operating Company (FENOC) plans to credit containment overpressure for BVPS-2 consistent with the current BVPS-1 methodology. In a letter dated August 28, 2008 (Reference 12) FENOC committed to submit a license amendment request by November 9, 2008 for NRC approval of the BVPS-2 change to credit containment overpressure. The change will be implemented in accordance with the license amendment upon NRC approval.

The BVPS-1 and BVPS-2 UFSARs have been updated to reflect installation of the new sump strainers, and the BVPS-1 UFSAR has been updated to reflect installation of the new RSS pump start signal. The BVPS-2 UFSAR will be updated in accordance with the requirements of 10 CFR 50.71 to reflect the new RSS pump start signal change and methodology change to credit containment overpressure.

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," 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), 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," 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," 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), 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), dated February 29, 2008

11. 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.

12. 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), dated August 28, 2008.

13. FENOC Letter L-08-054, 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 Dated February 14, 2008

14. 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.

15. 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, dated December 20, 2007.

16. 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.

Regulatory Commitment List
Page 1 of 1

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 - Licensing, at (330) 761-6071 of any questions regarding this document or associated Regulatory Commitments.

Regulatory Commitment	Due Date
Additional evaluation of downstream effects for the BVPS-1 recirculation spray and low head safety injection pumps is presently being conducted. The final results of the evaluation will be provided by March 20, 2009.	March 20, 2009