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February 29, 2008
L-08-035

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 regarding the FirstEnergy Nuclear Operating Company (FENOC) response to Generic Letter 2004-02 (Reference 1) for Beaver Valley Power Station (BVPS) Unit Nos. 1 and 2.

Attachment 1 of this submittal provides the BVPS Unit Nos. 1 and 2 supplemental response to Generic Letter 2004-02. The NRC Content Guide for Generic Letter 2004-02 Supplemental Response (Reference 2) was utilized in development of this submittal, and the Request for Additional Information (RAI) provided by the NRC in letter dated February 9, 2006 (Reference 3) is also addressed within the applicable sections of this submittal. This information is being provided in accordance with 10 CFR 50.54(f).

There are no regulatory commitments contained in this letter. If there are any questions, or if additional information is required, please contact Mr. Thomas A. Lentz, Manager – FENOC Fleet Licensing, at 330-761-6071.

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

Sincerely,

Peter P. Sena III

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NRR

Attachments:

1. Supplemental Response to Generic Letter 2004-02 for Beaver Valley Power Station Unit 1 (BVPS-1) and Unit 2 (BVPS-2)

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:

Generic Letter (GL) 2004-02 (Reference 1) required that addressees provide a description of and implementation schedule for all corrective actions, including any plant modifications, that are identified while responding to the GL. FirstEnergy Nuclear Operating Company (FENOC) provided the requested information for Beaver Valley Power Station (BVPS) 1 and 2 in References 3, 4 and 5. In subsequent letters dated April 3, 2006 (Reference 2) and September 6, 2005 (Reference 6), FENOC requested an extension for BVPS-2 to permit the completion of the installation of the Recirculation Spray System (RSS) pumps start signal and the High Pressure Safety Injection Throttle Valve gap sizing modifications during the spring 2008 refueling outage (2R13). The NRC approved the BVPS-2 extension request in their letter dated May 18, 2006 (Reference 7).

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 Request for Additional Information (RAI) through industry wide communications. Additionally, a Content Guide for Generic Letter 2004-02 Supplemental Responses was issued by the NRC on August 15, 2007. This guidance was revised by NRC letter to NEI dated November 21, 2007.

In FENOC letter dated December 20, 2007 (Reference 10), an extension was requested for BVPS-1 and BVPS-2 to complete the remaining technical evaluations as well as to determine what additional corrective actions would be necessary based on the results of these evaluations. The extension was required to fully assess the chemical effects testing and downstream effects analyses, and develop required corrective actions by February 29, 2008. The NRC approved the BVPS-1 & 2 extension request in their letter dated December 27, 2007 (Reference 17).

FENOC has completed the assessment of the chemical effects testing and has developed an action plan to address the potential uncertainties related to head loss from chemical effects and identified corrective actions necessary to come into full compliance with GL 2004-02. Based on the results of the testing, corrective actions will be required in the form of additional testing for BVPS-1 and licensing changes and modifications for BVPS-2, which were documented in FENOC letter L-08-054 dated February 14, 2008 (Reference 20). By letter dated February 29, 2008, the NRC approved an extension request for BVPS-1 and BVPS-2. Corrective actions for BVPS-2 include plans for a buffer change from sodium hydroxide to sodium tetraborate coupled with crediting available NPSH with containment overpressure. A License Amendment Request will be submitted for both the buffer change and use of containment overpressure for BVPS-2.

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. The logic change for the start of the RSS pumps has been implemented at BVPS-1 and is scheduled to be implemented in BVPS-2 during the spring 2008 Refueling Outage (2R13). This logic change ensures adequate water coverage over the new strainers. Debris evaluations and prototype testing has been performed as well as chemical effects testing.

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 will be modified during the spring 2008 Refueling Outage (2R13). The recently issued guidance on downstream effects, both in-vessel and ex-vessel, required the previously developed analyses to be revised. As identified in FENOC letter L-08-054 dated February 14, 2008 (Reference 20), the final downstream effects analyses will be completed and the results provided by August 30, 2008.

The information provided in this attachment addresses each of the specific Review Areas listed in the Revised Content Guide. In addition, 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 NRC also issued separate guidance on Chemical Effects in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (Reference 19). The response to Review Area 3.o of the Revised Content Guide includes the specific details from this guidance.

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 L-08-054 dated February 14, 2008 (Reference 20) documented the BVPS-1 and BVPS-2 corrective actions and schedule for achieving compliance to 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 as 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 analyses, evaluations 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); GDC 35 for ECCS design, GDC 38 for containment heat removal systems, and GDC 41 for containment atmosphere cleanup.

A general description of the actions taken and planned actions at BVPS-1 and BVPS-2 is provided in response to Review Area 2 below. Upon completion of all required actions, the licensing basis for BVPS-1 and BVPS-2 will be updated to reflect the results of the analyses and plant modifications performed to demonstrate compliance with the regulatory requirements and the UFSAR will be updated in accordance with 10 CFR 50.71(e).

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 was installed during the Fall 2006 refueling outage (2R12) which increased the available surface area from approximately 150 sq. ft. to 3300 sq. ft. At BVPS-1, the new replacement strainer was installed during the Fall 2007 refueling outage (1R18) which increased the available surface area from approximately 130 sq. ft. to 3400 sq. ft.
- Replacement of BVPS-1 High Pressure Safety Injection Cold Leg Throttle Valves to increase the throttle valve gap during the Fall 2007 refueling outage (1R18).
- Changing the BVPS-1 start signal for the RSS pumps 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 during the Fall 2007 refueling outage (1R18).
- Replacement of Borated Temp Mat insulation encapsulated in Reflective Metal Insulation (RMI) on the BVPS-1 Reactor Vessel Closure Head with RMI during the Spring 2006 refueling outage (1R17) 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 during the Spring 2006 refueling outage (1R17).
- Prototype testing of the new strainer designs were completed for BVPS-1 and BVPS-2.
- Chemical effects testing has been performed for BVPS-1 and BVPS-2.

Summary of Activities to be Completed During the BVPS-2 Spring 2008 Refueling Outage (2R13):

- Modification of the BVPS-2 High Pressure Safety Injection Throttle Valves to increase the throttle valve gap.
- Changing the BVPS-2 start signal for the RSS pumps from a fixed time delay to an ESFAS signal based on a 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.
- Replacement of Borated Temp Mat insulation encapsulated in RMI on the BVPS-2 Reactor Vessel Closure Head flange with RMI, and replacement of Min-K^{TM} insulation encapsulated in RMI on portions of the Reactor Coolant System and Safety Injection System piping with Thermal Wrap insulation encapsulated in RMI.
- A containment coatings inspection and evaluation program will be implemented starting with the BVPS-2 Spring 2008 refueling outage (2R13).
- Installation of baskets to support the BVPS-2 buffer change from sodium hydroxide to sodium tetraborate.
- Removal of reactor cavity drain cross bars.

Summary of Activities to be Completed for BVPS-1 and BVPS-2 by August 30, 2008:

- Additional BVPS-1 chemical effects testing will be performed using the BVPS-1 specific debris mix and the results will be provided by August 30, 2008.
- At BVPS-2, develop and complete analyses required to support the buffer replacement, presently sodium hydroxide with sodium tetraborate. This buffer change will require physical configuration changes as well as supporting analyses. A License Amendment Request (LAR) will be submitted to the NRC for this change by August 30, 2008.
- At BVPS-2, develop and complete analyses required to support the use of containment overpressure to credit available NPSH. The proposed LAR submitted for the buffer change will also include this change and be submitted by August 30, 2008.
- The downstream effects analyses (both in-vessel and ex-vessel) are being developed for BVPS-1 and BVPS-2. The documentation is progressing but will not be finalized by February 29, 2008. The downstream effects analyses will be completed with results provided in the follow-up supplemental response by August 30, 2008.

Additional Planned Action for BVPS-2:

The BVPS-2 buffer change will be implemented within 60 days from receipt of NRC approval of the LAR or by Spring (March 31) 2009, whichever is sooner. Implementation is contingent on NRC approval of the LAR.

The details of how the regulatory requirements will be met and the schedule for implementation of the planned corrective actions are included in FENOC letter L-08-054 dated February 14, 2008 (Reference 20).

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

The response previously provided to the NRC under FENOC Letter L-05-146, dated September 6, 2005 (Reference 6), for BVPS-1 and BVPS-2 continues to apply as it relates to the subject of break selection.

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 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" 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 18), 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 18) advocates break selection at 5-ft 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 I 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.

Large main steam and feedwater line breaks were not evaluated for debris generation since recirculation is not required under the plant licensing basis for BVPS-1 and BVPS-2. A small main steam line break (less than 0.2 ft^2, or less than 6" diameter) was originally included as a postulated accident condition where safety injection recirculation from the sump may be required. In further review, it has been determined that there are no main steam or feedwater line break accident conditions where recirculation from the containment sump is required to mitigate the accident condition. The small main steam line break debris generation condition considered in the analyses was determined to be a limiting condition break for Break Criterion 5 (for uniform thin-bed effects), and has therefore been left in the debris generation analyses. This condition bounds all other cases for thin-bed effects and is therefore conservative. As part of the FENOC corrective actions, additional testing will be performed for BVPS-1. The following discussions on break criteria refer to main steam line breaks. The use of the main steam line break as a basis for break criteria is subject to change to be more representative of debris from postulated breaks which require recirculation.

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

A large break LOCA in any RCS loop piping would generate significant fibrous debris, with Cal-Sil microporous particulate debris and RMI, as well as coatings and latent particulate debris. All three loops have a direct path to the ECCS recirculation sumps via an opening around the primary shield wall (surrounding the reactor pressure vessel). The three RCS legs have the largest break cross-sectional areas and therefore generate the highest particulate to fiber debris ratio (by weight).

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

Of the break cases evaluated, the break with the largest potential for multiple debris types again originates from the RCS loop piping breaks described for Break Criterion 1. However, for BVPS-2 a Surge Line Break was also identified as generating several types of debris and was included in the debris generation analysis. Since the RCS loop breaks were identified as meeting Break Selection Criteria 1 and 3, the Surge Line Break best represents Break Criterion 2. For BVPS-1, the main steam line split (small break) also met this criterion as a potential limiting break.

Breaks in the most direct path to the sump (Break Criterion 3)

All three RCS piping loops have a direct path to the ECCS recirculation sumps via an opening around the primary shield wall.

Calcium silicate (Cal-Sil) is used extensively within the loop areas. Since Cal-Sil debris has the potential to impact the sump screen head loss significantly, breaks at each of the RCS legs (i.e., hot leg, cross-over leg, and cold leg) were evaluated for Cal-Sil debris generation.

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

The RCS loop breaks (LBLOCA) would generate significant fibrous debris, with Cal-Sil microporous particulate debris and RMI, as well as coatings and latent particulate debris, and have the potential to generate the largest particulate to fibrous insulation ratio (by weight). For BVPS-1, the small main steam line break also produces high particulate debris to fibrous insulation ratios.

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

The main steam lines are insulated with Cal-Sil with small amounts of Min-K™. Although the concept of a thin bed generally refers to a 1/8" fiber bed with high particulate, there is experimental data indicating that Cal-Sil is capable of forming a thin bed without supporting fibers. The MSLB, unlike other break scenarios, would generate significant Cal-Sil without fiber resulting in potential thin bed conditions at the sump screen. For BVPS-1 the RCS cross-over leg break has also been identified as a potential limiting break for this Criterion. As part of the BVPS corrective actions, additional testing will be performed for BVPS-1. The use of the main steam line break as a basis for a thin bed is subject to change to be more representative of debris from postulated breaks which require recirculation.

Analysis of secondary line breaks

As previously discussed, the main steam lines were included in the evaluation because of the amount of Cal-Sil and its ability to form a thin bed; thereby meeting Break Criterion 5 of the regulatory guidance. The analysis was based upon a 6" break in one of the 32" main steam lines. This break is intended to envelope the amount of Cal-Sil debris for any small break outside the secondary shield wall.

Break location conclusion

In summary, BVPS-1 and BVPS-2 determined that a postulated LBLOCA within the Loop 1, 2 or 3 steam generator compartments generates the largest quantities of RMI, Low Density Fiberglass, High Density Fiberglass and Calcium Silicate debris. A break near the reactor vessel nozzle generates a large amount of RMI and Microtherm® or Temp-Mat debris. A break at the 14 inch Pressurizer Surge Line is considered for multiple types of debris, generating Low Density Fiberglass, Cal-Sil, Min-K™ and Reflective Metal Insulation (RMI) debris which will likely transport to the containment emergency sump. A Main Steam Line Break will generate the largest amount of Cal-Sil, with enough fiber to develop a thin bed if a secondary line break resulted in recirculation from the containment sump. It was concluded that the reactor coolant system loop breaks generate the largest amount of debris, and also the worst combination of debris with the possibility of being transported to the containment emergency sump strainer.

All phases of the plant-specific accident scenarios were evaluated to develop debris generation values for the breaks listed in the previous summary paragraph. The accident scenario cases that meet the SE Break Criterion are:

1. Limiting Break for SE Break Criterion 1 – For BVPS-1 the RCS cross-over leg breaks and the reactor pressure vessel nozzle breaks meet Criterion 1 as potential limiting breaks. For BVPS-2 the RCS loop breaks meet Criterion 1 as the limiting breaks.

2. Limiting Break for SE Break Criterion 2 – For BVPS-1 the RCS cross-over leg breaks, reactor pressure vessel nozzle breaks, and small main steam line breaks meet Criterion 2 as potential limiting breaks. For BVPS-2 the RCS loop breaks as well as the surge line break meet Criterion 2 as the limiting breaks.

3. Limiting Break for SE Break Criterion 3 – For BVPS-1 the RCS loop breaks, reactor pressure vessel nozzle breaks and the small main steam line break have been

identified to be potential limiting breaks. For BVPS-2 the RCS loop breaks meet Criterion 3 as the limiting breaks.

4. Limiting Break for SE Break Criterion 4 – For BVPS-1 the RCS cross-over leg breaks and the small main steam line break meet Criterion 4 as potential limiting breaks. For BVPS-2 the RCS loop breaks meet Criterion 4 as the limiting breaks.
5. Limiting Break for SE Break Criterion 5 – For BVPS-1 the RCS cross-over leg breaks and the small main steam line break meet Criterion 5 as potential limiting breaks. For BVPS-2 the small main steam line break meets Criterion 5 as the limiting break.

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 response previously provided to NRC under FENOC Letter L-05-146, dated September 6, 2005 (Reference 6), for BVPS-1 and BVPS-2 continues to apply as it relates to the subject of debris generation and determination of Zones of Influence (ZOIs).

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 SE (Reference 18) 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 18), 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 below.

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 3 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 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 18) (66 to 74 ft 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 psig. As specified in Table 3-2 of the SE (Reference 18), a 2.0D ZOI is used.

NUKON™:
NUKON™, manufactured by Owens-Corning, is specified 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® TIW. As specified in Table 3-2 of the SE (Reference 18), a 17.0D ZOI is used.

Temp-Mat with SS wire retainer:
Temp-Mat, originally supplied by Pittsburgh Corning, 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 18), is equivalent to a sphere with radius approximately 27 to 30 ft, 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/ft3) 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 and Fiberglas® TIW. Again, these materials are low density fiberglass with macroscopic (as-manufactured) density equivalent to NUKON™. The destruction pressure and associate ZOI specified for NUKON™ was assumed for Fiberglas® TIW. 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 ft to 14 ft) 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 18) 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 18) 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®:
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 guidance of the SE (Reference 18) 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 Benelex 401®.

Foamglas®:
FOAMGLAS® insulation is an inorganic, rigid and brittle cellular insulation manufactured by Pittsburgh Corning Corp. The guidance of the SE (Reference 18) 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 18) 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 (1)	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)	2.0(4)	28.6
Foamglas® (1)	N/A	28.6
Transite (1)	N/A	28.6

(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.

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 and BVPS-2 are summarized in Tables 3.b-2 and 3.b-3.

Table 3.b-2
BVPS-1 (As-Installed) Insulation Debris Quantities

Material Types	Loop 2 LBLOCA	RPV Nozzle Break	Pressurizer Surge Line Break	MSLB
RMI	18,183 ft^2	18,958 ft^2	11,042 ft^2	
TPI RMI	1,275 ft^2			
Temp-Mat	133.0 ft^3	289.1 ft^3		
Fiberglas TIW				44.0 ft^3
Calcium Silicate	222 lb.		49.5 lb.	325.5 lb.
Min-K™			16 lb.	3.5 lb.

Table 3.b-3
BVPS-2 (As-Installed) Insulation Debris Quantities

Material Types	Loop 1 LBLOCA	RPV Nozzle Break	Pressurizer Surge Line Break	MSLB
RMI	23,184 ft^2	1630.8 ft^2	1483.2 ft^2	
TIW	517 ft^3			
Temp-Mat	332.4 ft^3		9.3 ft^3	
Thermal Wrap	1.4 ft^3			
Damming Material	0.1 ft^3			
Calcium Silicate	498 lb.		177.0 lb.	532.5 lb.
Min-K™			8.4 lb.	6.4 lb.
Microtherm®		459 lb.		

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% 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 approximately 543.9 ft^2 of miscellaneous materials and BVPS-2 has 750.8 ft^2 of miscellaneous materials.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAI's pertaining to debris generation at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed up by the specific response.

RAI #1 (from Reference 14)

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 14)

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

BVPS-1 HELB Debris Generation Calculation determined the amount of debris generated by the interaction of coatings and a two phase jet using a ZOI of 10D. This debris amount was utilized in subsequent debris transport and head loss calculations. The strainer testing was performed with consideration to the 10D ZOI for coatings debris.

The BVPS-2 HELB debris generation calculation determined the amount of debris generated by the interaction of coatings and a two phase jet using a ZOI of both 5D and

10D. The 5D debris amount was considered, alternatively to the 10D ZOI, in subsequent debris transport and head loss calculations. The strainer testing 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.

The NRC has provided guidance on the use of the 5D ZOI for coatings in Enclosure 2 of Reference 19. Specifically the NRC's response to Item 3 in Reference 19 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.

In the calculations identified above, BVPS has assumed that there is a 100% 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 response previously provided to NRC under FENOC Letter L-05-146, dated September 6, 2005 (Reference 6), for BVPS-1 and BVPS-2 continues to apply as it relates to subject of debris characterization. Except when described below, debris characterization followed approved regulatory guidance and therefore, the following information supplements the previous submittal by providing the requested additional information.

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 as 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™ HDFG at BVPS-2 for utilization in a debris transport analysis. 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 (< 6" on a Side)	80%	27%
Large Exposed (Uncovered) Pieces	0%	32%
Intact (Covered) Blankets	0%	34%

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% small fines for LDFG at BVPS-1 was taken from Table 3-3 of the SE (Reference 18).

The previously mentioned proprietary analysis also supports use of a four size distributions 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 (<6" on a side)	80%	54%	7%
Large Pieces (>6" on a side)	0%	16%	41%
Intact (covered) Blankets	0%	17%	44%

RMI

Debris size distribution for RMI is based upon the testing conducted by the NRC in 1995 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" were treated as small piece debris, and the pieces that were 4" and 6" 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% 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% (i.e., destruction, in all cases, was less than 50% of the target material). Based upon the results of the NRC-sponsored OPG tests and with the following exception, a reduction factor of 50% was applied to debris generated within a 5.45D ZOI. A 50% 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 18).

Table 3.c-4
Default 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 completeness.

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 (1.5 g/cm^3)	7
Kaowool	12	161	3.2
Cerawool	12	158	3.2

(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®	75	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 (Sv)

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 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAI pertaining to debris characteristics at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed up by the specific response.

RAI #30 (from Reference 14)

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 response 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. It should be noted that for scenarios where there is less than the amount of fiberglass debris necessary to form a thin bed (MSLB and RV nozzle break), the insulation materials that are present (cal-sil and microtherm®) contain fibrous material and were considered to be capable of forming a thin bed without the presence of other fibrous debris. BVPS-1 and 2 cannot substantiate any HELB scenarios where a potential formation of a thin bed would not occur. Therefore, all head loss analysis and testing conservatively used 10 micron spheres as the particle size for all coatings debris.

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

The response previously provided to NRC under FENOC letter L-05-146, dated September 6, 2005 (Reference 6) for BVPS-1 and BVPS-2 continues to apply. The purpose of this submittal response is to supplement the previous responses for this item. It should be noted that the previous commitment to conduct a follow-up walkdown of the BVPS-1 containment to validate the assumed debris quantity and re-evaluate the latent debris quantity based upon the results of the walkdown has been completed. A walkdown was performed during 1R17 to incorporate the guidance of the NRC SE for NEI 04-07 (Reference 18) with respect to latent debris. As a result of this walkdown and subsequent evaluations, the BVPS-1 assessments are independent of the BVPS-2 evaluation assessments for latent debris.

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 18). 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 18).

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) (Factored)			
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

These surface areas have been factored. The factor reduces the sampled surface based on an estimated percentage of the debris removed from the area.

In lieu of analysis of samples, conservative values for debris composition properties were assumed as recommended by the SE (Reference 18). This results in a very conservative estimate of fiber content. The particulate / fiber mix of the latent debris is assumed to be 15% fiber. The latent fiber debris is assumed to have a mean density of 94 lbm/ft^3 (1.5 g/cm^3) and the latent particulate debris a nominal density of 169 lbm/ft^3 (2.7 g/cm3). The latent particulate size is assumed to have a specific surface area of 106,000 ft^{-1}. The latent fiber debris characteristic diameter is assumed to be 7 μm.

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% 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% increase is 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% increases 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 18) is to assume that 15% of transportable latent debris is fiber and that 85% 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 4.d-3 and 4.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: 543.9 ft^2 (w/ 30% increase)

Table 4.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 ft^2 (w/ 30% increase)

Table 4.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 *	15
Equipment Horizontal	15,141	0.76	12
		Total	**184**

* 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%. 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% of the total of the surface area of the miscellaneous debris source term, consistent with the guidance provided in the NRC SE (Reference 18). This will be accomplished by using a 75% debris transport fraction to imitate the "stacking" fraction.

BVPS-1

The sacrificial strainer surface area allotted to Miscellaneous Debris is 407.9 ft^2. This value represents 75% of the total 543.9 ft^2 accounted for in the containment walkdown.

BVPS-2

The sacrificial strainer surface area allotted to Miscellaneous Debris is 563.1 ft^2. This value represents 75% of the total 750.8 ft^2 accounted for in the containment walkdown.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 14), requested licensees to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAIs pertaining to latent debris at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed up by the specific response.

RAI #32 (from Reference 14)

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 14)

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 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

The response previously provided to NRC under FENOC Letter L-05-146, dated September 6, 2005 (Reference 6), for BVPS-1 and BVPS-2 indicated that the debris transport analysis was in progress at the time of the response. This discussion provides the necessary information to describe the methodology and associated results. Additionally, the previous response indicated that the use of debris interceptors would be considered. Debris interceptors were not utilized in the debris transport analyses for BVPS-1 and BVPS-2.

Description of Methodology

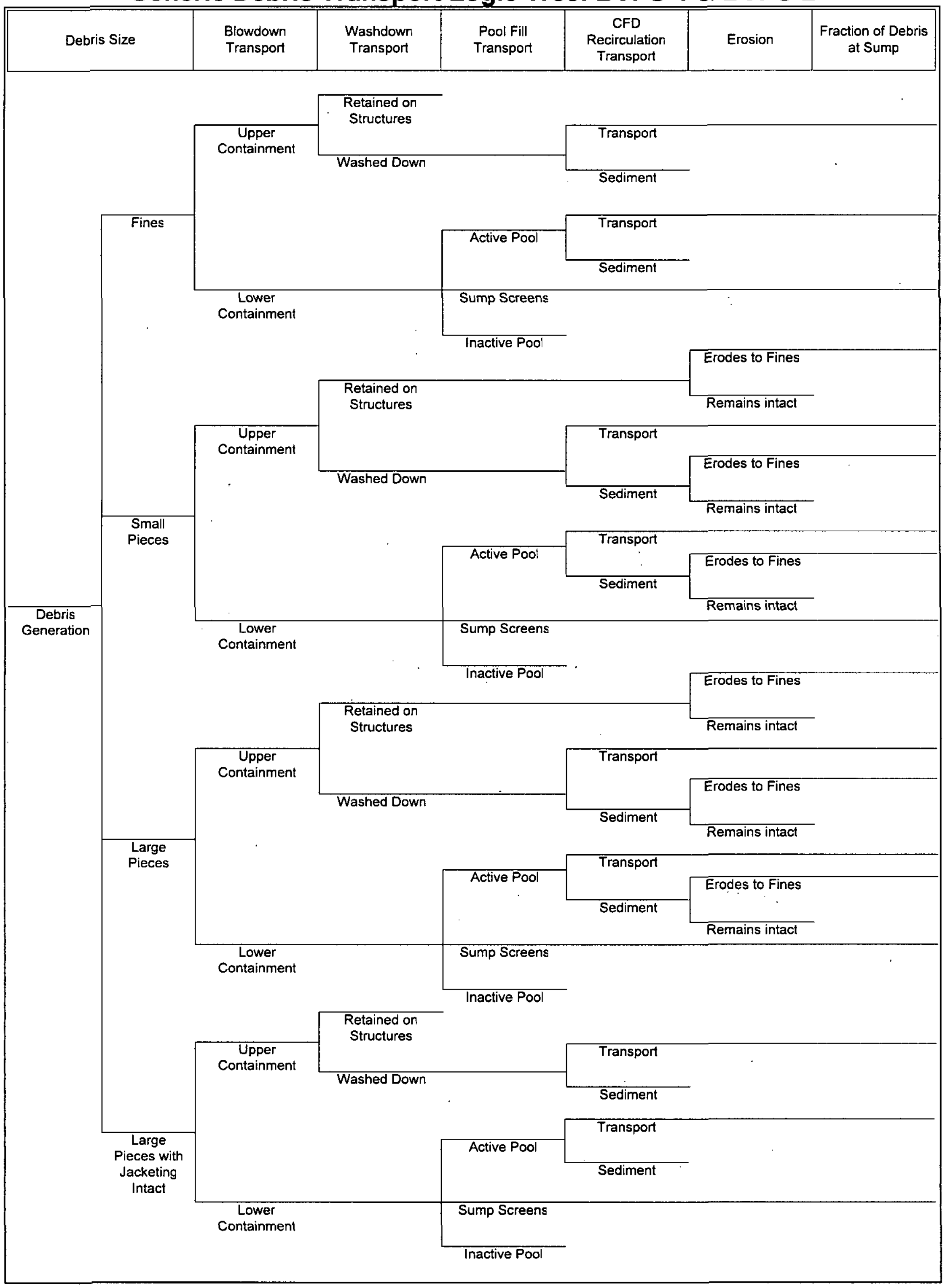
The methodology used in the transport analysis is based on the NEI 04-07 guidance report (GR) for refined analyses as modified by the NRC's SE (Reference 18), as well as the refined methodologies suggested by the SE in Appendices III, IV, and VI. The specific effect of each of four modes of transport 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 coolant 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 18) 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%.

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 flowpath were utilized in the BVPS-2 blowdown analysis. The DDTS also presents values for holdup when blowdown travels a flow path with 90° turn(s). Although 90° 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% (versus the 17% value in the study) of the small fiberglass debris blown upward would be trapped due to changes in flow direction.

Additional guidance was incorporated into the anaylsis through use of the Boiling Water Reactor (BWR) Utility Resolution Guide (URG). The guidance from this document indicates that grating would trap approximately 65% 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 (cross-over legs) 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%.

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% 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% 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 40-50% 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%.

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™	100% / 89%	100% / 43%	100% / 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 at a pool depth of 4.0 ft, and run for a total of 5 minutes real time. A plot of mean kinetic energy was used to determine when steady-state conditions were reached. Checks were also made of the velocity and turbulent energy patterns in the pool to verify that steady-state conditions were reached.

Debris Transport Metrics:

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 Table 5-2;
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-2 – 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 139 ft^2 as shown in Figure 3.e-5. Since the initial distribution area was determined to be 6,903 ft^2, the recirculation transport fraction for small pieces of RMI is 2%.

Figure 3.e-2

Vectors Showing Break Location, Sump Location and Pool Flow Direction

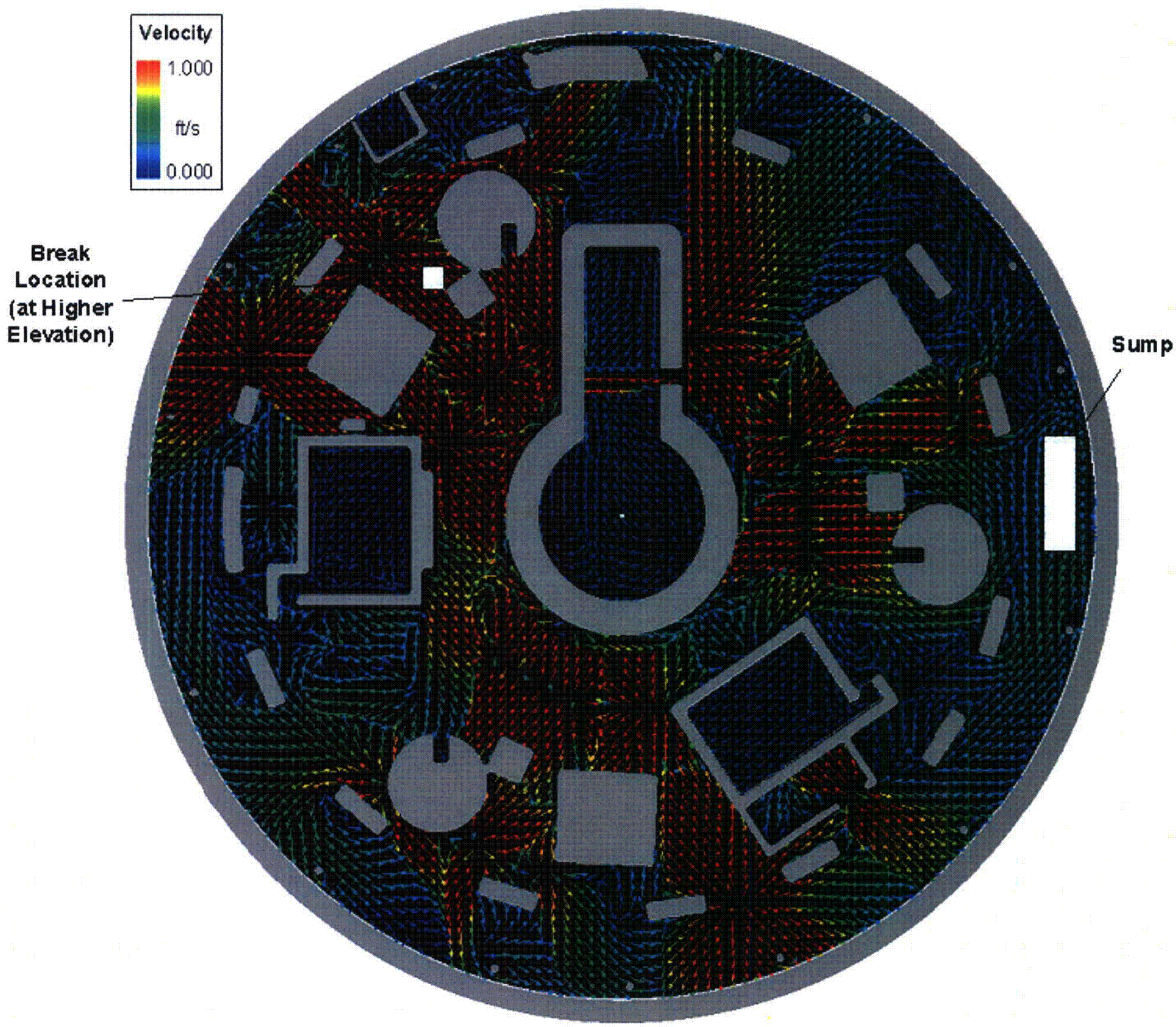


Figure 3.e-3

3D 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

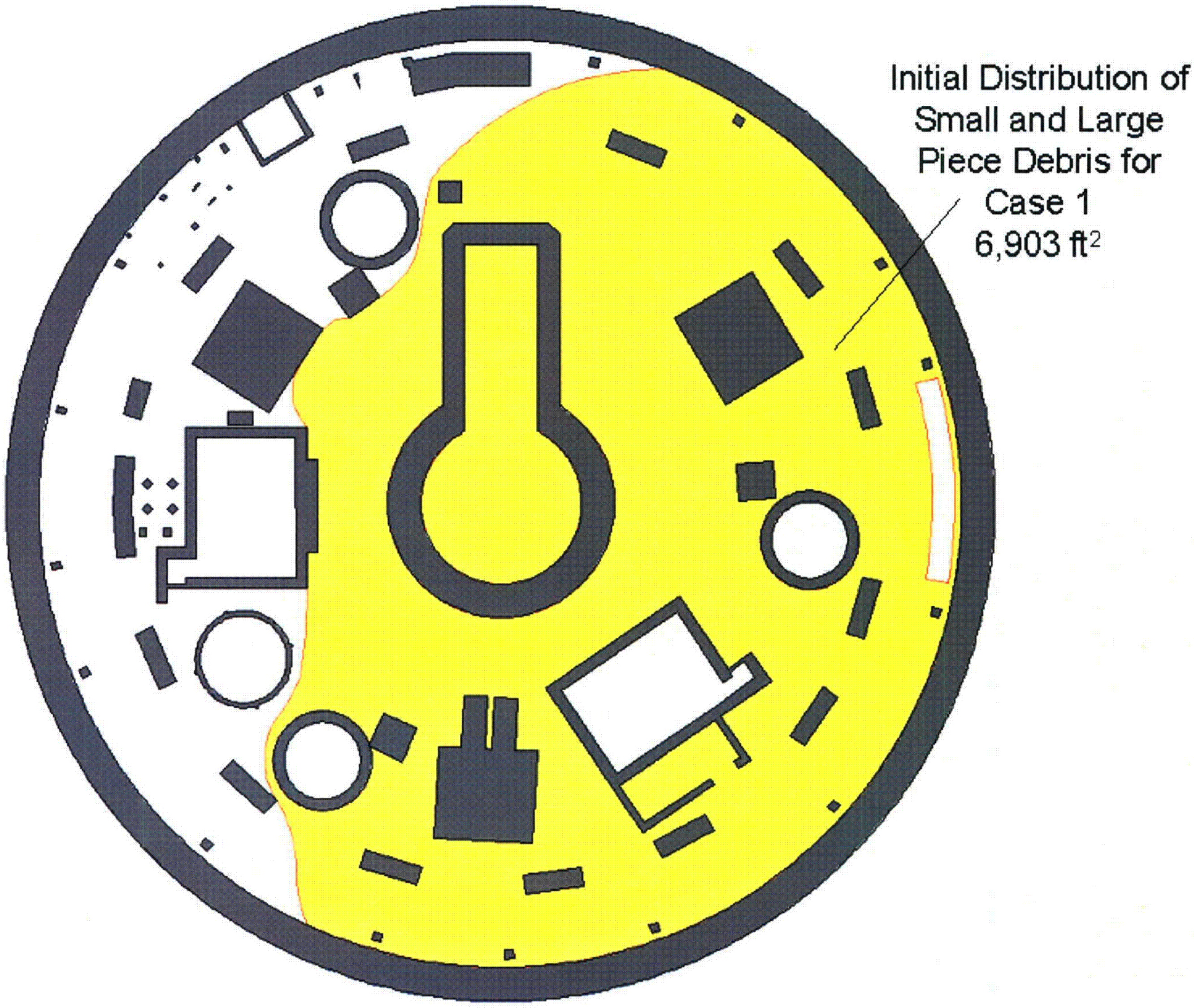
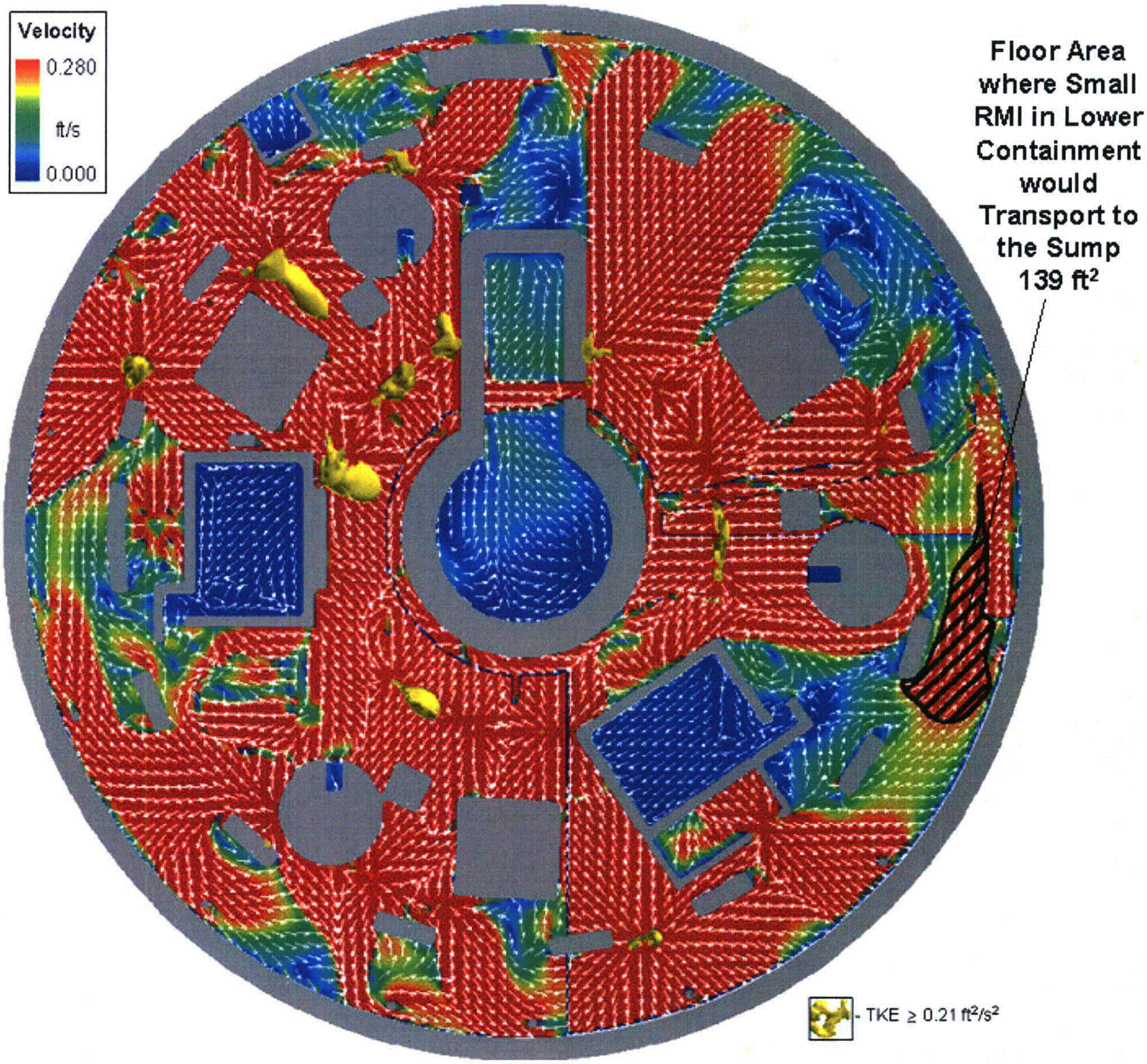


Figure 3.e-5
Floor Area Where Small RMI Would Transport to the Sump



The washdown distribution area was overlaid on top of the plot showing tumbling velocity and flow vectors to determine the recirculation transport fraction. The recirculation transport fraction for small RMI washed down inside the secondary shield wall would be 0%. The area where small pieces of RMI washed down in the annulus would transport is 139 ft^2. Since the initial distribution area was determined to be

2,544 ft^2 for washdown outside the secondary shield wall, the recirculation transport fraction for small pieces washed down in the annulus would be 5% for this case.

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

Debris erosion is the only area where the debris transport analysis deviates from the regulatory guidance. The guidance specifies that an erosion fraction of 90% should be used for fiberglass debris. However, as described in the SE (Reference 18) and the justification below, an erosion fraction of 10% was used for fiberglass debris in the recirculation pool.

The only insulation debris types with the potential for erosion at BVPS-1 and BVPS-2 are TIW and Temp-Mat™ fiberglass. The individual fibers would not be subject to further erosion, and by definition, intact blankets are still covered by the original jacketing and therefore would also not be subject to erosion. This leaves the small and large pieces of TIW and Temp-Mat™.

Tests performed as a part of the drywell debris transport study (DDTS) have indicated that the erosion of fibrous debris is significantly different for debris directly impacted by containment sprays versus debris directly impacted by break flow. The erosion of large pieces of fibrous debris by containment sprays was found to be less than 1%, whereas the erosion due to the break flow was much higher. Due to differences in the design of PWR nuclear plants compared to the boiling water reactor (BWR) nuclear plants, the results of the erosion testing in the DDTS are only partially applicable. In a BWR plant, a LOCA accident would generate debris that would be held up below the break location on grating above the suppression pool. In the BVPS-1 and BVPS-2 plants, however, the break would generate debris that would either be blown to upper containment or blown out away from the break. Most of the debris would not be hung up directly below the break flow where it would undergo the high erosion rates suggested by the DDTS. Any debris blown to upper containment that is not washed back down, however, would be subject to erosion by the sprays. Based on the results of the DDTS testing, a 1% erosion factor was applied for small and large piece fibrous debris held up in upper containment. This is consistent with the approach taken for the pilot plant in the SE (Appendix VI). The erosion mechanism for debris in the pool is somewhat different than what was tested in the DDTS. The SE (Appendix III) describes erosion tests that indicated that the erosion rate of fibrous debris could be on the order of 0.3 percent of the current debris per hour for a pool with a 16-inch depth (compared to 2 percent per hour for a pool with a 9-inch depth).

Using the following equation from Appendix III of the SE, this gives a total erosion of 7% after 24 hours, and 89% after 30 days.

$$f_{eroded} = 1 - (1 - rate)^{NumberOfHours}$$

where:

f_{eroded} = total fraction of debris eroded
rate = erosion rate of current debris per hour
Number of Hours = Number of hours debris is subject to erosion

The SE (Reference 18) points out substantial uncertainties associated with the erosion testing including the following:

- The integral debris transport tests lasted 3 to 5 hours. Therefore, the question remains whether the erosion rate tapers off with time. In addition, it is not certain that all of the end-of-test debris accumulation was the result of erosion products.
- The test results include the usual variances in test data, such as flow and depth control and debris collection.
- Although the test series was designed to approximate the flow and turbulence characteristics of the volunteer-plant sump pool, the tank characteristics may have been significantly different than those at the plant. The difference in the erosion rates between the 9-inch and 16-inch pool depths in the integrated tests clearly illustrates the effect of pool turbulence on fibrous debris erosion.
- The geometry of the volunteer-plant sump pool is larger and more complex than that of the test tank used in the integrated tests.
- The long-term tests did not study large-piece debris.

Since the test data showed in general that the erosion consisted primarily of small, loosely attached pieces of fiber breaking off from larger pieces, it is considered reasonable to assume that erosion would taper off after 24 hours. To be conservative, however, the 24 hour erosion was rounded up to 10%. This erosion fraction was applied for both small and unjacketed large fiberglass pieces in the containment pool.

USE OF DEBRIS INTERCEPTORS AND CREDIT FOR SETTLING

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

Debris settling is not credited for the BVPS-1 and BVPS-2 debris transport analyses. The analyses are a model of transport to the sump. As can be seen from the following tables, 100% 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 include 3 cross-over leg breaks, a break on the pressurizer surge line, one safety injection line, a break in the main steam line and a break in a reactor vessel nozzle. Transport data for the limiting cases including RCS Cross-over Leg Break and the Reactor Vessel Nozzle Break at BVPS-1 and BVPS-2 are presented in the following tables (Tables 3.e-6, 3.e-7, 3.e-8 and 3.e-9).

Table 3.e-6
Overall Debris Transport (Limiting RCS Cross-over Leg Break) – BVPS-1

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	13,815 ft^2	42%	5,802 ft^2
	Large Pieces (>4")	5,643 ft^2	2%	113 ft^2
	Total	**19,458 ft^2**	**30%**	**5,915 ft^2**
Temp-Mat™	Fines	20.2 ft^3	100%	20.2 ft^3
	Small Pieces (<6")	78.6 ft^3	100%	78.6 ft^3
	Large Pieces (>6")	16.6 ft^3	10%	1.7 ft^3
	Intact Pieces (>6")	17.6 ft^3	0%	0 ft^3
	Total	**133.0 ft^3**	**76%**	**100.5 ft^3**
Cal-Sil	Total (Fines)	222 lb	100%	222 lb
Qualified IOZ Coatings	Total (Fines)	147.0 lb	100%	147.0 lb
Qualified DuPont Corlar 823	Total (Fines)	798.3 lb	100%	798.3 lb
Qualified High Temp Al	Total (Fines)	3.0 lb	100%	3.0 lb
Qualified Vi Cryl CP-10	Total (Fines)	66.0 lb	100%	66.0 lb
Unqualified IOZ Coatings	Total (Fines)	8.6 lb	100%	8.6 lb
Unqualified DuPont Corlar 823	Total (Fines)	149.4 lb	100%	149.4 lb
Unqualified Alkyd Enamel	Total (Fines)	50.3 lb	100%	50.3 lb
Unqualified Cold Galvanizing	Total (Fines)	11.1 lb	100%	11.1 lb
Dirt/Dust	Total (Fines)	360.0 lb	100%	360.0 lb
Latent Fiber	Total (Fines)	0.67 ft^3	100%	0.67 ft^3
Misc. Debris	Total	543.0 ft^2	100%	543.0 ft^2

Table 3.e-7
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")	13,460ft^2	100%	13,460ft^2
	Large Pieces (>4")	5,498 ft^2	100%	5,498 ft^2
	Total	**18,958 ft^2**	**100%**	**18,958 ft^2**
Temp-Mat™	Fines	58.0 ft^3	100%	58.0 ft^3
	Small Pieces (<6")	231.1 ft^3	100%	231.1 ft^3
	Large Pieces (>6")	0 ft^3	100%	0 ft^3
	Intact Pieces (>6")	0 ft^3	100%	0 ft^3
	Total	**289.1 ft^3**	**100%**	**289.1 ft^3**
Cal-Sil	Total (Fines)	0 lb	100%	0 lb
Min-K™	Total (Fines)	0 lb	100%	0 lb
Qualified IOZ Coatings	Total (Fines)	0 lb	100%	0 lb
Qualified DuPont Corlar 823	Total (Fines)	181.8 lb	100%	181.8 lb
Qualified High Temp Al	Total (Fines)	22.7 lb	100%	22.7 lb
Qualified Vi Cryl CP-10	Total (Fines)	0 lb	100%	0 lb
Unqualified IOZ Coatings	Total (Fines)	8.6 lb	100%	8.6 lb
Unqualified DuPont Corlar 823	Total (Fines)	149.4 lb	100%	149.4 lb
Unqualified Alkyd Enamel	Total (Fines)	50.3 lb	100%	50.3 lb
Unqualified Cold Galvanizing	Total (Fines)	11.1 lb	100%	11.1 lb
Dirt/Dust	Total (Fines)	360.0 lb	100%	360.0 lb
Latent Fiber	Total (Fines)	0.67 lb	100%	0.67 lb
Misc. Debris	Total	543.0 ft^2	100%	543.0 ft^2

Table 3.e-8
Overall Debris Transport (Enveloped RCS Cross-over Leg Break) – BVPS-2

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	15,281.9 ft^2	23%	3,514.8 ft^2
	Large Pieces (>4")	6,241.9 ft^2	25%	1,560.5 ft^2
	Total	**21,523.8 ft^2**	**24%**	**5,075.3 ft^2**
TIW	Fines	66.8 ft^3	100%	66.8 ft^3
	Small Pieces (<6")	216.9 ft^3	60%	130.1 ft^3
	Large Pieces (>6")	112.8 ft^3	1%	1.1 ft^3
	Intact Pieces (>6")	120.8 ft^3	0%	0 ft^3
	Total	**517.3 ft^3**	**38%**	**198.0 ft^3**
Temp-Mat™	Fines	66.4 ft^3	100%	66.4 ft^3
	Small Pieces (<6")	226.0 ft^3	82%	218.1 ft^3
	Large Pieces (>6")	0 ft^3	10%	0 ft^3
	Intact Pieces (>6")	0 ft^3	0%	0 ft^3
	Total	**332.4 ft^3**	**86%**	**284.5 ft^3**
Damming Material	Total (Fines)	0.1 ft^3	100%	0.1 ft^3
Cal-Sil	Total (Fines)	517.5 lb	100%	517.5 lb
Thermal Wrap	Fines	0.5 ft^3	100%	0.5 ft^3
	Small Pieces (<6")	1.8 ft^3	100%	1.8 ft^3
	Large Pieces (>6")	0 ft^3	100%	0 ft^3
	Intact Pieces (>6")	0 ft^3	100%	0 ft^3
	Total	**2.3 ft^3**	**100%**	**2.3 ft^3**

Table 3.e-8 (Continued)
Overall Debris Transport (Enveloped RCS Cross-over Leg Break) – BVPS-2

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
Qualified IOZ Coatings (10D / 5D High / 5D Low)[Note 1]	Total (Fines)	294.1 / 167.0 / 112.6 lb	100%	294.1 / 167.0 / 112.6 lb
Qualified Carboline 191 HB (10D / 5D High / 5D Low)[Note 1]	Total (Fines)	169.6 / 78.6 / 53.0 lb	100%	169.6 / 78.6 / 53.0 lb
Qualified Nutec 11S Epoxy (10D / 5D High / 5D Low)[Note 1]	Total (Fines)	543.2 / 0.7 / 44.1 lb	100%	543.2 / 0.7 / 44.1 lb
Qualified Nutec 1201 Epoxy (10D / 5D High / 5D Low)[Note 1]	Total (Fines)	453.9 / 0.6 / 36.9 lb	100%	453.9 / 0.6 / 36.9 lb
Qualified High Temp Si Al (10D / 5D High / 5D Low)[Note 1]	Total (Fines)	39.3 / 39.3 / 39.3 lb	100%	39.3 / 39.3 / 39.3 lb
Unqualified IOZ Coatings	Total (Fines)	59.6 lb	100%	59.6 lb
Unqualified Carboline 191 HB	Total (Fines)	15.7 lb	100%	15.7 lb
Unqualified Alkyd	Total (Fines)	102 lb	100%	102 lb
Unqualified Cold Galvanizing	Total (Fines)	19.5 lb	100%	19.5 lb
Dirt/Dust	Total (Fines)	156.4 lb	100%	156.4 lb
Latent Fiber	Total (Fines)	11.3 ft^3	100%	11.3 ft^3
Misc. Debris	Total	750.8 ft^2	100%	750.8 ft^2

Note 1: High/Low indicate debris quantities generated from breaks at higher and lower elevations.

Table 3.e-9
Overall Debris Transport (Reactor Vessel Nozzle Break) – BVPS-2

Debris Type	Debris Size	Debris Quantity Generated	Debris Transport Fraction	Debris Quantity at Sump
RMI	Small Pieces (<4")	1157.8 ft^2	100%	1157.8 ft^2
	Large Pieces (>4")	473.0 ft^2	100%	473.0 ft^2
	Total	**1630.8 ft^2**	**100%**	**1630.8 ft^2**
Microtherm®	Total (Fines)	459 lb	100%	459 lb
Qualified Nutec 11S Epoxy (10D / 5D)	Total (Fines)	145.5 / 36.3 lb	100%	145.5 / 36.3 lb
Qualified Nutec 1201 Epoxy (10D / 5D)	Total (Fines)	121.6 / 30.4 lb	100%	121.6 / 30.4 lb
Qualified High Temp Si Al (10D / 5D)	Total (Fines)	37.8 / 9.5 lb	100%	37.8 / 9.5 lb
Unqualified IOZ Coatings	Total (Fines)	59.6 lb	100%	59.6 lb
Unqualified Carboline 191 HB	Total (Fines)	15.7 lb	100%	15.7 lb
Unqualified Alkyd	Total (Fines)	102 lb	100%	102 lb
Unqualified Cold Galvanizing	Total (Fines)	19.5 lb	100%	19.5 lb
Dirt/Dust	Total (Fines)	156.4 lb	100%	156.4 lb
Latent Fiber	Total (Fines)	11.3 ft^3	100%	11.3 ft^3
Misc. Debris	Total	750.8 ft^2	100%	750.8 ft^2

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 14), requested licensees to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAIs 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 up by the specific response.

RAI #36 (from Reference 14)

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 6). However, this option was not implemented because subsequent debris transport analyses for both BVPS-1 and BVPS-2 did not indicate a need.

RAI #39 (from Reference 14)

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%) 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% 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 14)

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 here for completeness in addressing the answers specific to the RAI.

All spray water drains from the refueling cavity 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% 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-bar in BVPS-1 was removed. This same device will be removed at BVPS-2 in its upcoming spring 2008 refueling outage (2R13).

RAI #44 (from Reference 14)

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.*

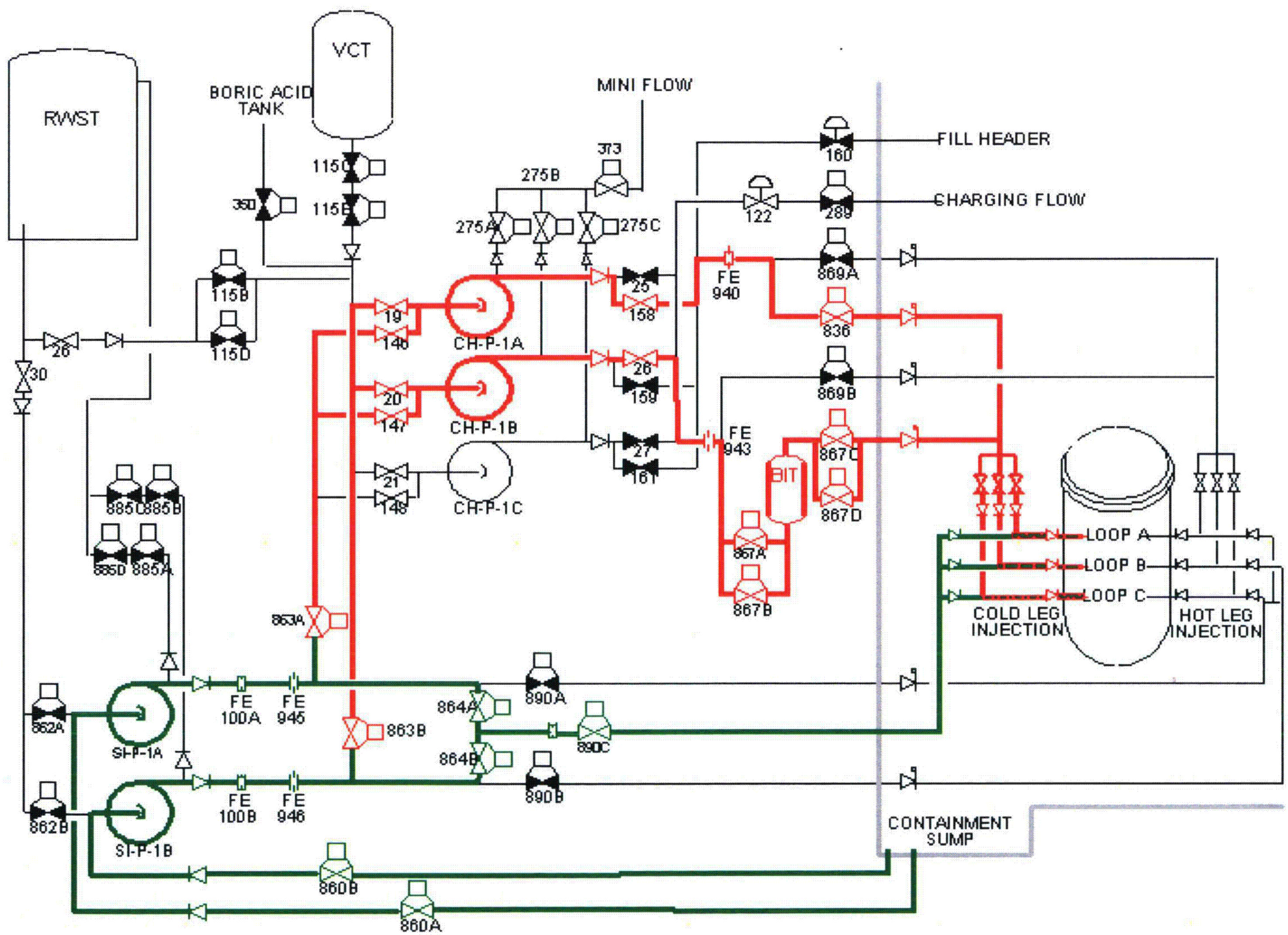
14. *State whether containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface, and if so, summarize the methodology used to determine the available containment pressure.*

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

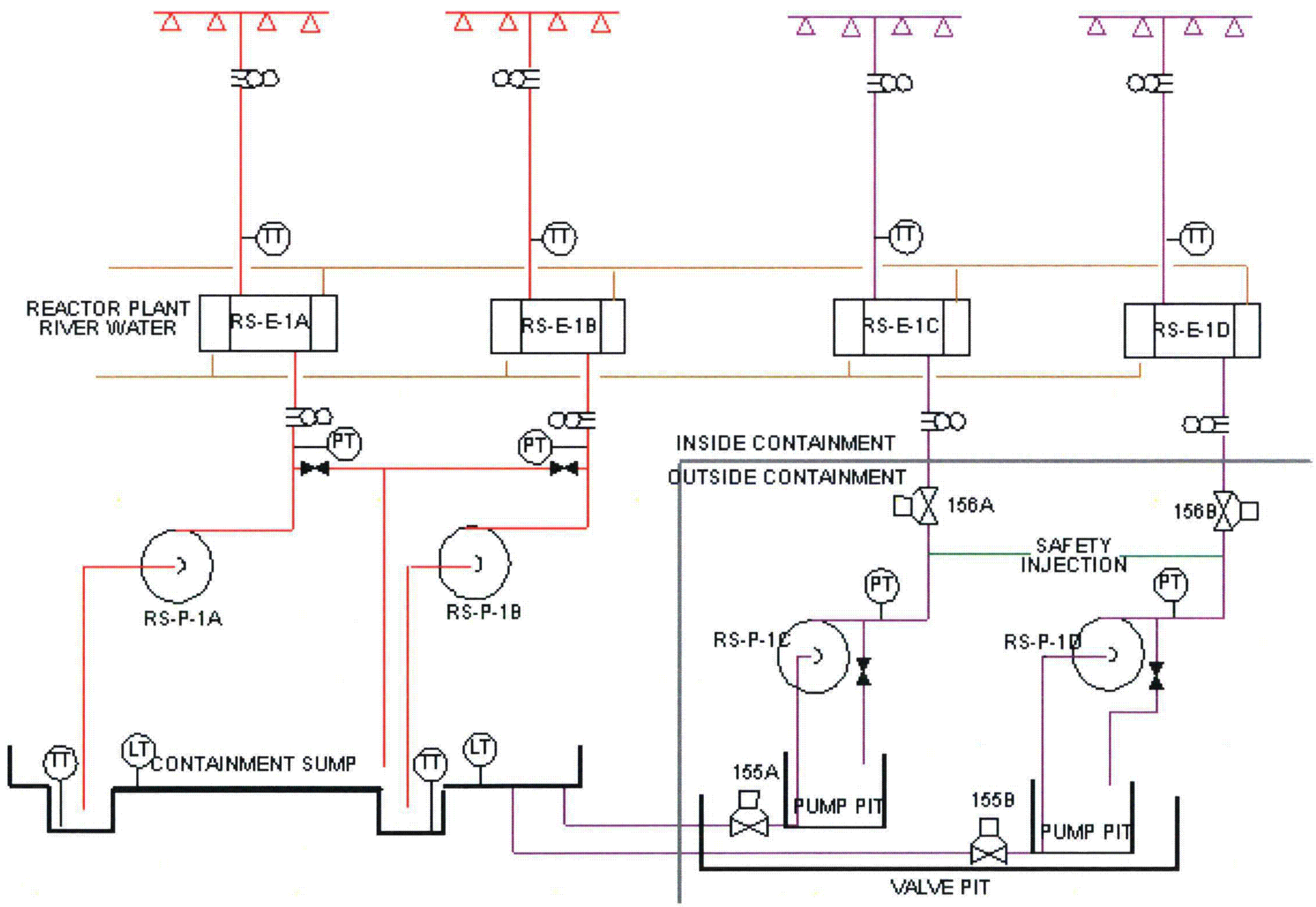
FENOC Response

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

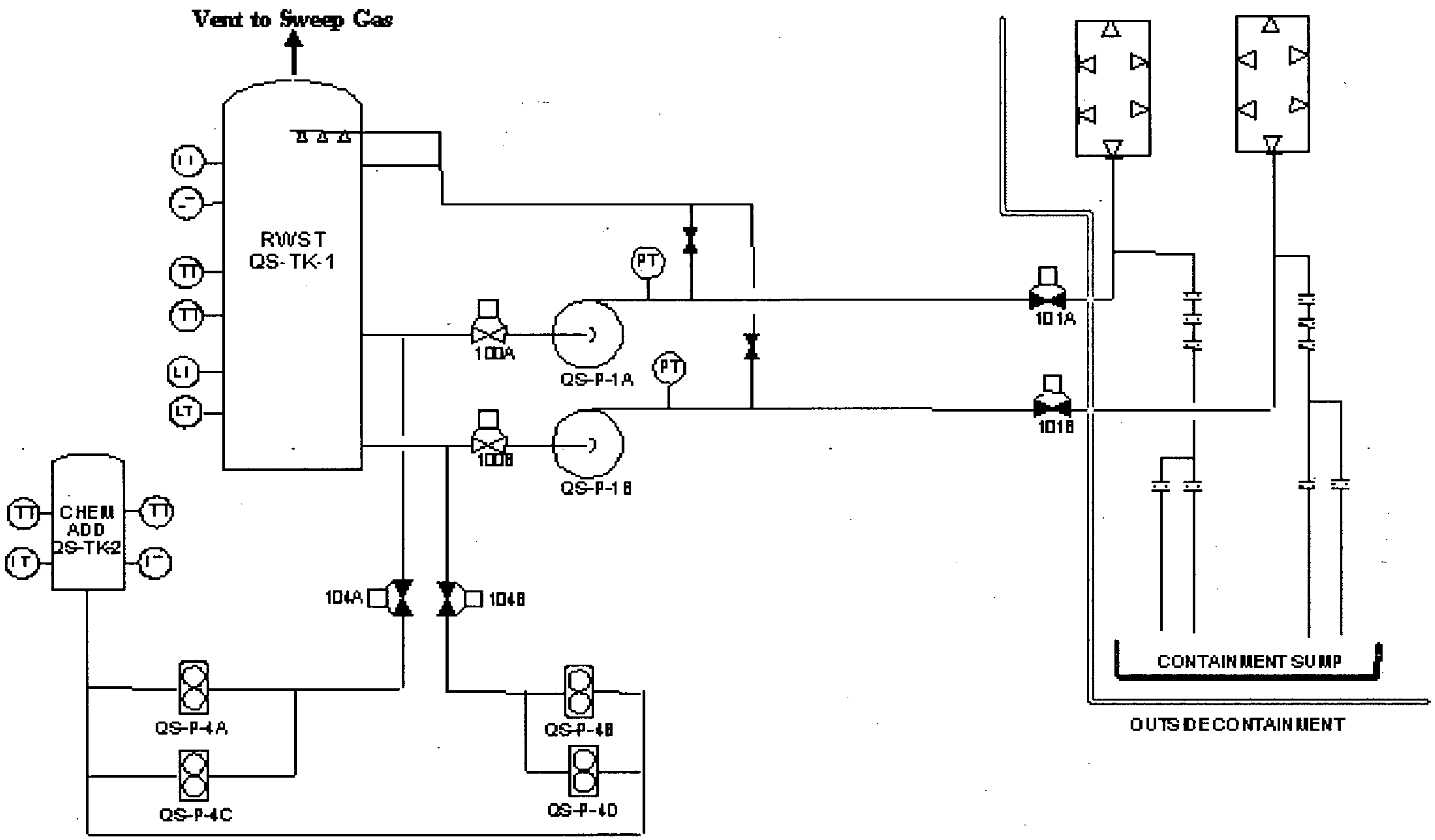
BVPS-1 Safety Injection System Cold Leg Recirc Phase



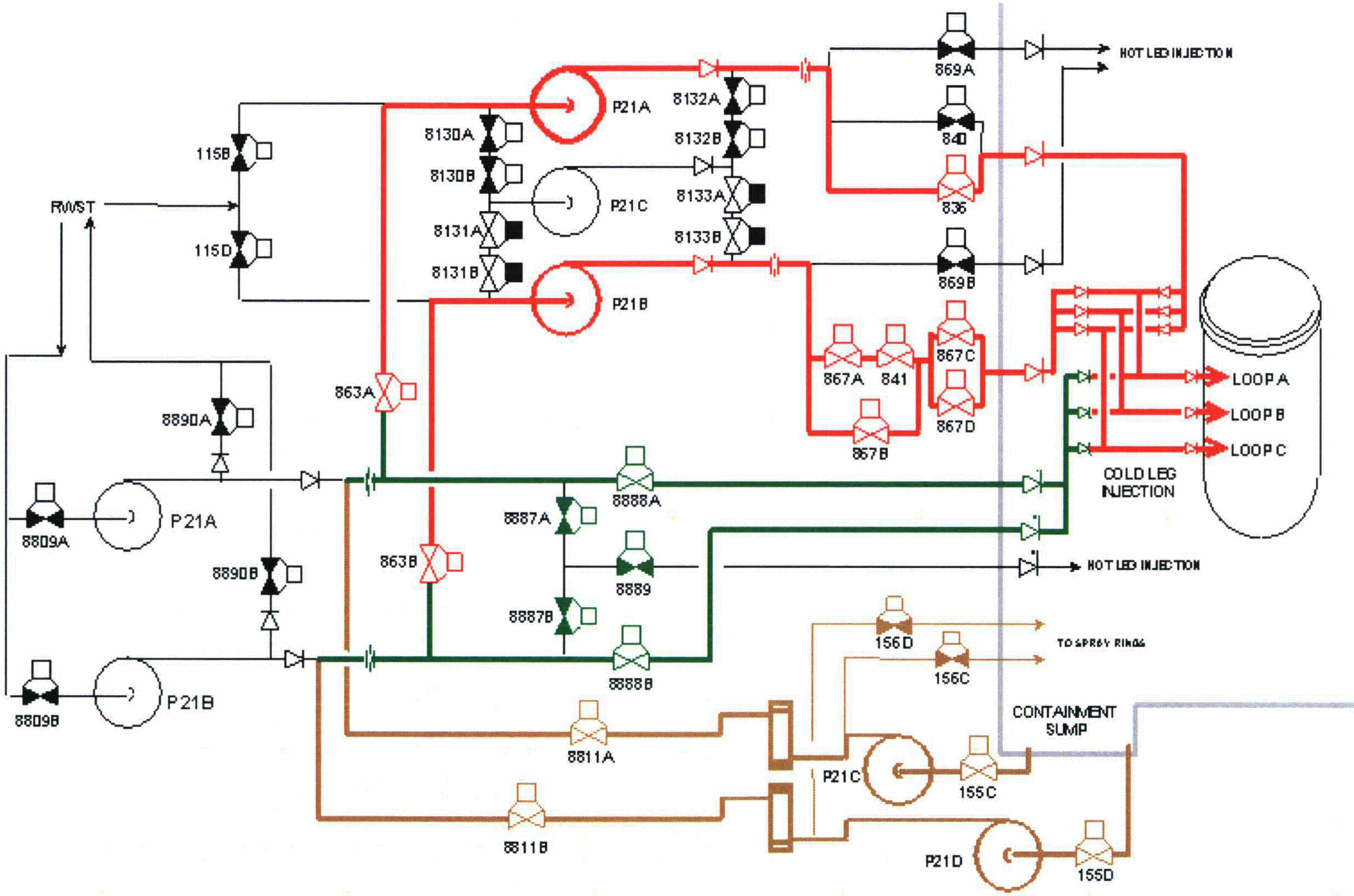
BVPS-1 Recirculation Spray System



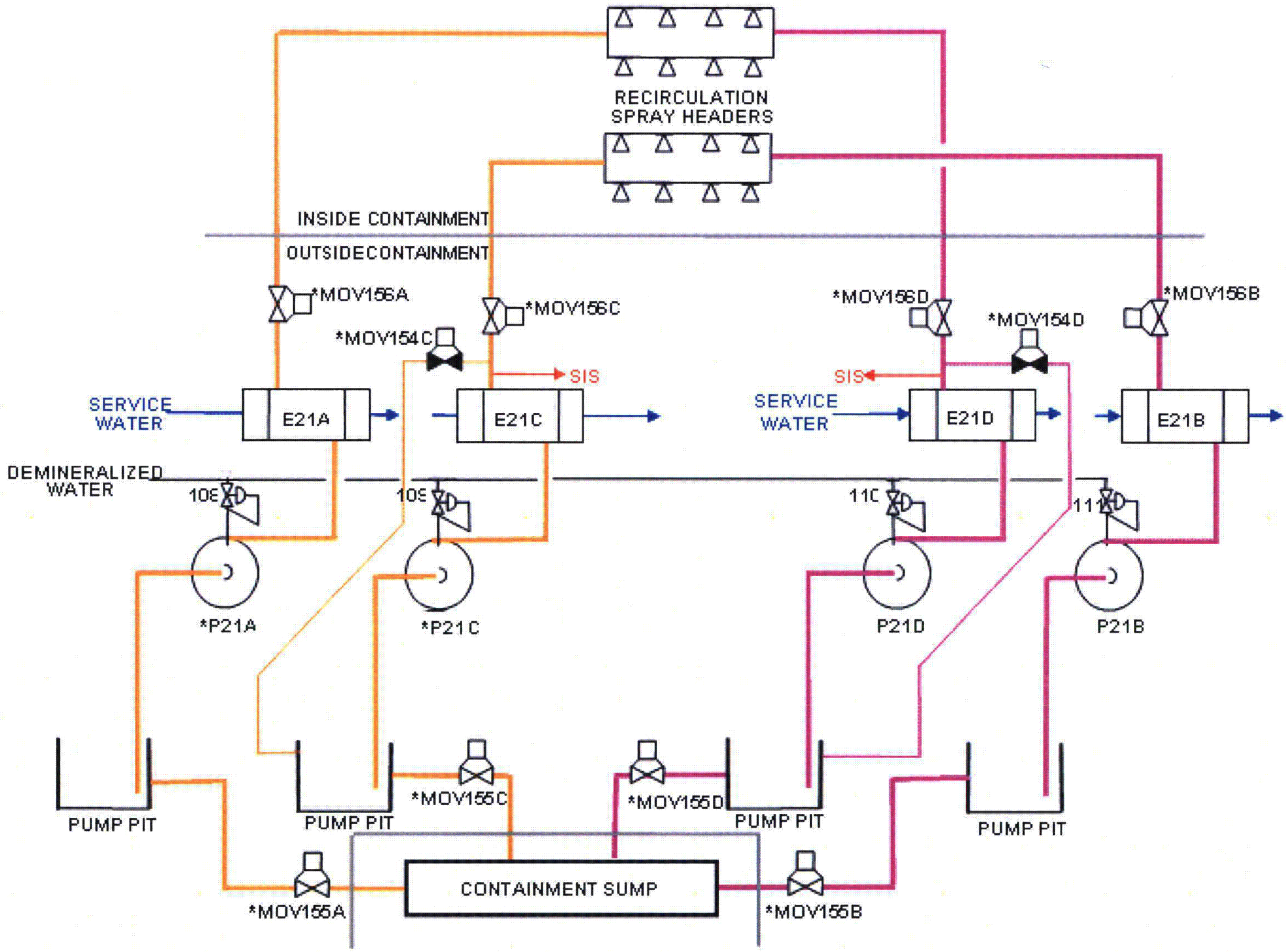
BVPS-1 Quench Spray System



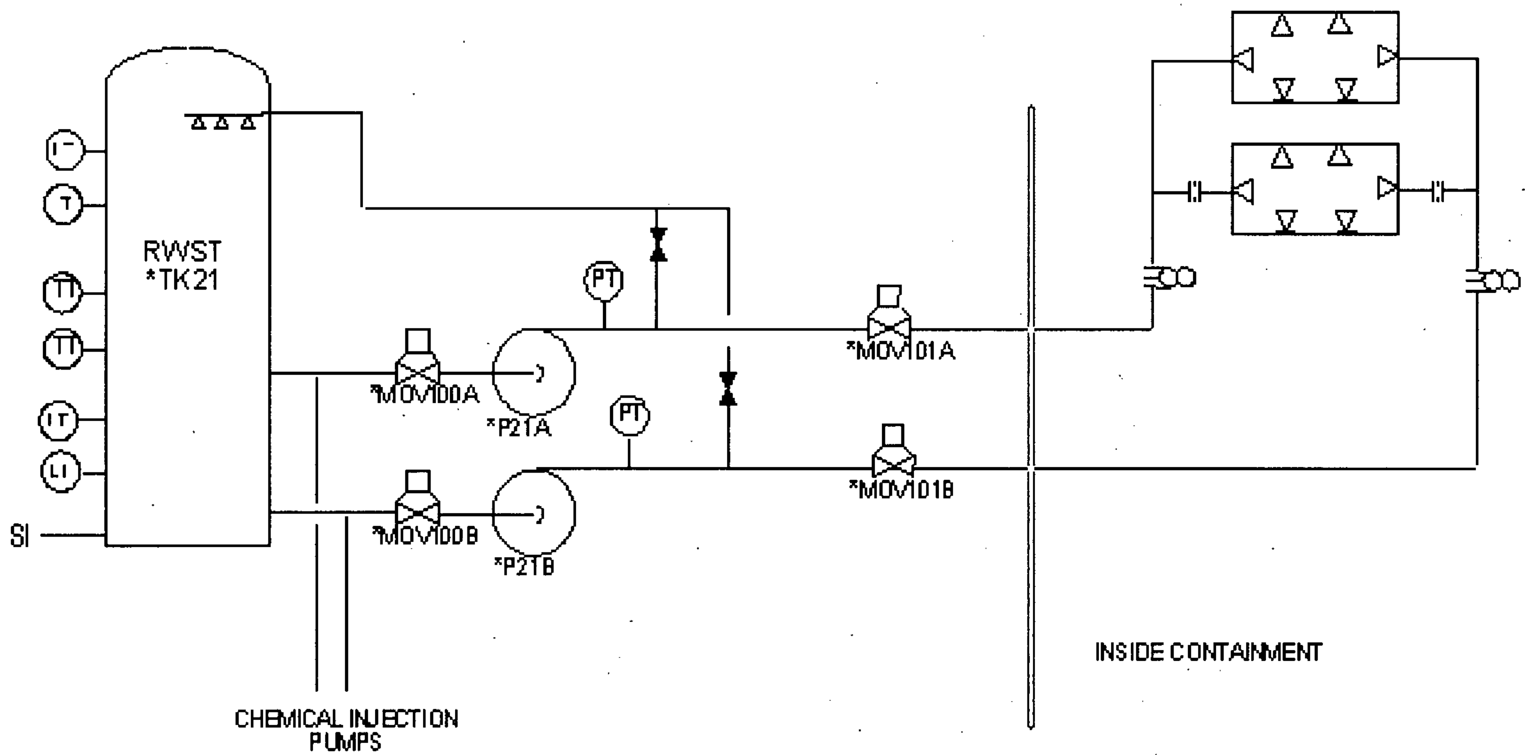
BVPS-2 Safety Injection System Cold Leg Recirc Phase



BVPS-2 Recirculation Spray System



BVPS-2 Quench Spray System

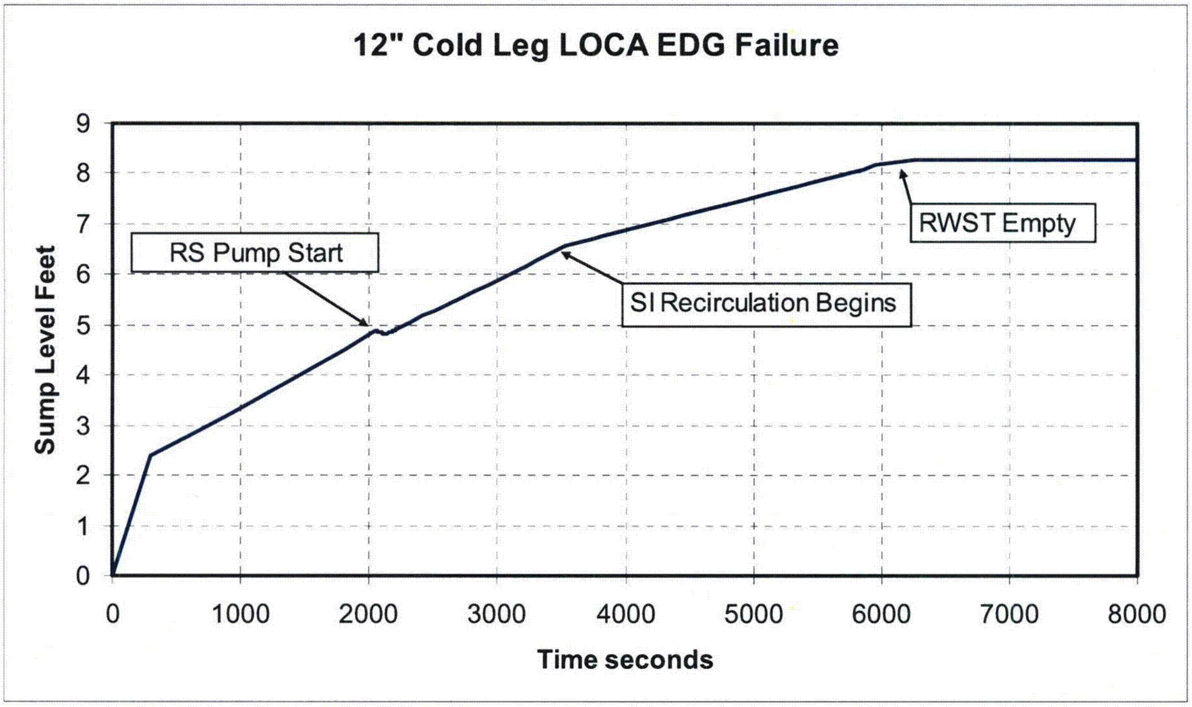


3.f.2 *Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.*

FENOC Response

The minimum submergence of the strainers at BVPS-1 and BVPS-2 occurs shortly following start of the Recirculation Spray pumps. After the pumps start on a 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	22.6
LBLOCA	7.0	27.4

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-2 containment sump strainer design was developed with consideration to the guidelines of Regulatory Guide 1.82, Revision 3. Regulatory Guide 1.82, Revision 3, provides criteria for ensuring zero air ingestion into the sump intakes. One of these criteria is maintaining a minimum submergence of 9 ft above the inlet pipe. For BVPS-2, the submergence is less than 9 ft. Thus, vortex suppressors are installed. Regulatory Guide 1.82 provides guidelines for installing grating to act as a vortex suppressor. The primary goal of the vortex suppressors is to reduce the circulation of the fluid near the intake, thus preventing vortex formation. They operate on the principle of providing swirl suppressing shear to the liquid. A vortex suppressor is installed to prevent vortex formation above the top hat strainer assemblies. This vortex suppressor provides assurance that the recirculating spray pump suction lines will not be susceptible to air ingestion caused by air core vortex formation from the post-LOCA containment building water surface.

In addition, it is postulated that the support frame and perforated top hats will provide similar resistance to swirl in the pool as grating does. Since the percent open area for the sump screen modules is smaller than the percent open area for the floor grating, the perforated sump screens are expected to be more effective in breaking up a vortex than standard floor grating. In addition, even if a vortex was to form at the water surface, it would need to travel through the top hat perforated plate, through the annulus of the top hat which is filled with steel wire mesh (debris bypass eliminator material), and past the exit of the top hat which is fitted with a steel cruciform. Each of these design features would break up or minimize any vortex that would travel through the length of the sump screen modules. Therefore, it would be incredible for a vortex to make its way through this torturous path to the recirculating spray intakes at the bottom of the sump.

During all BVPS-2 strainer head loss testing, the water surface was observed with no indications of a vortex formation noted.

The BVPS-1 containment sump strainer is designed and supplied by CCI. CCI has performed vortex testing for their strainer design with both perforated and unperforated top plates. The BVPS-1 design uses unperforated top plates. All testing performed by CCI for unperforated top plates show no vortex formations. 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 supplied by CCI is within the design and operating ranges where no air vortex formations occurred under testing.

During all BVPS-1 strainer head loss testing the water surface was observed with no indications of a vortex formation noted.

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-2

The predicted head loss for the BVPS-2 Recirculation Sump Top-Hat array is based on test data obtained for a prototypical Top-Hat array utilizing the debris loads from several break locations postulated to transport to the sump. This data is then adjusted for containment chemical effects. The methodology, assumptions, and results of chemical effects are discussed under "3.o. Chemical Effects".

The prototype testing was performed at the Alion Science and Technology Hydraulics Testing Laboratory in Warrenville, Illinois. The strainer modules that were tested are a double Top-Hat design developed by Enercon Services, Inc. The Top-Hat modules that were tested are identical to a portion of the modules that are installed at BVPS-2. For the tests, the Top-Hat strainers were mounted to a plenum assembly and arranged vertically in a 3×3 array. The vertical orientation is consistent with the way the strainers are mounted in the plant. The Top-Hat array was placed in a test tank capable of flow circulation. The Test Tank is approximately 6 ft tall, 6 ft wide, and 10 ft long. The water in the tank is circulated by a variable speed pump capable of providing the flow rates necessary to achieve the required strainer bulk fluid approach velocity. A total of four tests were used to establish the strainer and debris head loss characteristics.

The maximum debris loads for four postulated HELB scenarios were obtained from the Debris Transport calculation and scaled to the strainer surface area represented by the prototype array. The debris loads represented various characteristics that could potentially produce a limiting head loss. Key characteristics included:

- Varying debris constituents to ensure all significant possible combinations were tested,
- Maximum bed thickness to ensure proper representation of potential filling of interstitial volume
- High particulate to fiber ratio with maximum particulate quantities to ensure proper representation of any thin bed effects

The test plan established the scaling factor used for scaling a full size array to the test array. The scaling factor is a direct ratio of the full size array surface area to the test array surface area. For thin bed and maximum debris bed tests, the scaling factor is based on the net surface area of the strainer. The net surface area is defined as the perforated plate free surface area unrestricted to flow. Although it is possible that for the full load tests, the debris bed would bridge the solid portions of the strainer surface, thus allowing the use of gross strainer area for scaling, the net surface area was conservatively used for all tests. The scaling factor for debris on the 3 X 3 array was determined to be 0.083. Debris bed thickness, fiber volume and fiber mass were then determined for each test. Debris quantities used as the basis for the testing and the scaled quantities established by the test plan are shown in the following tables (Tables 3.f.4-1 thru 3.f.4-5).

Table 3.f.4-1

Fibrous Debris Quantities

Bed Thickness (inch)	Fiber Volume - Scaled (ft^3)	Fiber Mass (lb)
0.05	0.94	2.25
0.38	7.38	17.7
0.50	9.83	23.6
1.00	19.7	47.2
1.50	29.5	70.8
2.06	40.5	97.3

Table 3.f.4-2
Particulate Debris Quantities
for the Loop Break

Particulate Debris Type	Mass (lb)	Scaled Mass (lb)
Cal-Sil	517.5	43.0
Coatings Surrogate	521.9	43.3
Dirt/Dust	156.4	13.0

Table 3.f.4-3
Particulate Debris Quantities for the MSLB

Particulate Debris Type	Mass (lb)	Scaled Mass (lb)
Cal-Sil	532.5	44.2
Min-K™	6.4	0.53
Coatings Surrogate	287.1	23.8
Dirt/Dust	156.4	13.0

Table 3.f.4-4
Particulate Debris Quantities for the RV Nozzle Break

Particulate Debris Type	Mass (lb)	Scaled Mass (lb)
Microtherm®	459	38.1
Coatings Surrogate	343.4	28.5
Dirt/Dust	156.4	13.0

Table 3.f.4-5
Particulate Debris Quantities for the Surge Line Break

BV2 Particulate Debris Type	Mass (lb)	Scaled Mass (lb)
Cal-Sil	33.0	2.74
Min-K™	14.4	1.20
Coatings Surrogate	386.9	32.1
Dirt/Dust	156.4	13.0

Testing was performed to conservatively represent the maximum possible head loss associated with the tested debris loads. All fibrous debris was reduced to small pieces and fines prior to introduction into the tank. Where surrogate materials were used, their characteristics were evaluated to ensure that their hydraulic characteristics were conservative with respect to the debris material they were intended to represent. The prototype array was surrounded with walls on three sides to simulate the presence of additional strainer modules and ensure that the potential for filling the strainer's interstitial volume was maximized. A homogeneous mixture of debris was added to the tank in a manner that promoted transport to the strainer, and the use of mechanical and manual stirring was employed actively to minimize the potential for settling of the debris. Essentially 100% of the debris was deposited on the strainer, and no near-field settling effects were accommodated or credited in the testing.

Calibrated instruments were used to continuously measure all key parameters, including debris quantity, strainer assembly differential pressure, flow rate and tank temperature. The flow rate through the strainer was controlled to conservatively maintain a constant bulk fluid approach velocity to the strainer and flow was varied at controlled points in the test to ensure that the flow regime of the water (laminar vs turbulent) flowing through the debris bed could be clearly understood.

Water level was established and maintained at approximately 6 inches above the top of the prototype strainer assembly, which is conservative with respect to the actual minimum coverage expected at BVPS-2. During the testing, the pool surface was monitored for signs of vortexing. None was observed.

The controlling BVPS-2 test was the "Full Load Test for Loop Break". The head loss test results for this case at an approach velocity of 0.009 ft/sec, corrected for the temperatures, are shown in Table 3.f.4-6 as follows:

Table 3.f.4-6

Correction Temperature (°F)	Temperature Corrected Head Loss (ft-water)
65	9.7
100	6.3
135	4.5
162	3.7
191	3.0

BVPS-1

The prototypical head loss testing performed for BVPS-1 was conducted by CCI. The head loss testing included a series of 4 specific tests with different quantity and mix of debris. The tests included:

Clean Screen Head Loss Test
Full Load Test Debris Case 1-3 (Loop 1, 2, 3 Cross-over Loop Break)
Full Load Test Debris Case 5 (Reactor Vessel Nozzle Break)
Full Load Test Debris Case 8 (Main Steam Line Break)

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".

A "Thin Bed Effect Test" was performed with reduced amount of fiber and a full amount of particulate corresponding to a layer thickness of least ⅛" which followed the requirements of NUREG CR/6224. This thickness guarantees a closed filter screen surface and is used as support for the particulate. The test for "Debris Case 8" corresponds to the definition of a thin bed effect test.

The debris type and quantity used for each case is listed in Table 3.f.4-7 below.

Table 3.f.4-7

Debris Name	Case 1, 2, 3	Case 5	Case 8
RMI (kg)	3.309	10.607	0.000
Temp-Mat (kg)	8.072	23.221	0.000
TIW (kg)	0.162	0.162	0.881
CalSil (kg)	1.511	0.000	2.216
Min-K™ (kg)	0.010	0.000	0.024
Stone Flour (kg)	16.364	6.679	4.297

The stone flour was used as a surrogate for qualified and unqualified inorganic zinc (IOZ) coatings, DuPont Corlar 823 paint, qualified High Temp AL, qualified Vi Cryl CP-10, unqualified Alkyd Enamel and cold galvanizing as well as dirt/dust. The size spectrum analysis (Sv value) is 0.776 m^2/cm^3, corresponding to a sphere diameter of 7.7 μm.

A representative strainer specimen consisting of two cartridges was installed in the CCI large test loop with a horizontal flow orientation into the pockets to correlate with the actual installation at BVPS-1.

The test loop used was a closed recirculation loop with a test pool, piping, pump and instrumentation. The "active" volume was approximately 1096 gal (4.15m^3) for BVPS-1 testing. The scaling of the test tank volume to containment volume was approximately 1/130.

The 2 strainer cartridges with the 32 pockets were placed in a pool of water. The hole diameter used was 1.6 mm (1/16") and the plate thickness of the test module was 1.25 mm.

The water recirculation in the loop was by means of centrifugal pump with flow rates capacity up to 90 m^3/h (396 GPM). The test temperature was controlled to be between 50°F to 86°F. The flow rate could be adjusted by controlling the rpm of the pump motor and by a throttle valve in the circuit. Water flow rate was measured using an Annubar within the suction pipe. The temperature of the water was measured by using thermocouples in the pool and in the piping after the pump. The head loss through the strainer was measured using a calibrated differential pressure transducer with range of 0 - 360 mbar (5.08 psi). All measuring data was monitored and stored on a data logger. Additionally, turbidity measurements were taken downstream of the strainer with a Hach SS6 Surface Scatter Turbidimeter. Measurements were taken online with this device.

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

Fibers (TIW, Temp- Mat, latent fibers)

- TIW was used as a surrogate for the latent fiber specified for each debris mix.
- The fibers are freed from the jacketing and hand cut into pieces of approx. 50 x 50 mm.
- The dry material was weighed.
- The fibers were split in batches of 0.1 to 0.14 ft^3.
- Each batch was soaked in 2 liters of water (½ gal).
- Their adherence was decomposed by a high pressure water jet, for approximately 4 minutes for each batch.
- It was verified visually that the insulation was decomposed into the water in suspended fiber pieces smaller than 10 mm (⅜").

Calcium Silicate Insulation

Calcium Silicate was prepared by reducing the material to fines using a rasp. It was finely shredded into powder with some larger particles. The Cal-Sil was mixed together with the fibers in a water bucket after decomposition of the fibers.

Min-K™

The Type of insulation used was Flex BL21811-16, F182 with a density of 16 lb/ft^3. The Min-K™ was reduced to a powder form by hand crushing. The Min-K™ was mixed together with the fibers in the water bucket after decomposition of the fibers.

Reflective Metal Insulation (RMI)

Pre-shredded stainless steel foils were used. The foils were prepared by a commercial shredding company which tore and crumpled the RMI foils using a mechanical process.

Particulate (Stone Flour)

For BVPS-1 testing, stone flour was used as a surrogate for qualified and unqualified IOZ coatings, DuPont Corlar 823 paint, qualified High Temp AL, qualified Vi Cryl CP-10, unqualified Alkyd Enamel and cold galvanizing as well dirt/ dust.

The size spectrum analysis (Sv value) was 0.776 m2/cm3, corresponding to a sphere diameter of 7.7 µm.

The particulates are mixed together with the fibers in the water bucket after decomposition of the fibers. They do not need decomposition, since they already come in a form of flour and distribute instantly.

The testing was executed using the following procedural steps:

1. The required amounts of debris were converted from volumes to weights.
2. The masses of the debris components were determined by weight and used for the mixture batches according to the description of the debris preparation. The batches of particulates and fibers were mixed in the water buckets.
3. After filling the pool with approximately 1.0 m of water the flow doors between compartments were closed and recirculation started. The flow rate was adjusted according to the required value of the test parameter.
4. A clean head loss measurement was taken (recording of water temperature, head loss, turbidity).
5. The debris was introduced directly at the surface of the strainer with 50% of the debris composition being introduced on each side of the strainer.
6. The head loss was monitored until the trend curve levels off (saturation of value). As general guidance, if the head loss changed less than 3% in 30 minutes, then stabilization was determined to have occurred.
7. The same procedure was repeated with increased debris amount until all debris was added.
8. The final head loss measurement was taken.

9. After the full insertion of debris (120%) and 100% flow rate, the flow rate was increased to 120% to take an additional measuring point.

10. Each test concluded with turning the test pump off for 2 minutes, and then re-establish design flow. Head loss was recorded and observations for vortexing were performed.

11. The amount of total debris which was added for each test was recorded. Also, the amount of settled debris in the tank was quantified visually.

12. After all testing for a particular debris recipe was done, the test loop was drained, the test cartridges were disassembled and the whole test loop was cleaned.

The "raw" results of the head loss test corresponding to recirculating water test temperatures are as follows:

Clean	0.34 mbar	(0.005 psi)	(test water temp 11.7 C)
Case 1, 2, 3	142.15 mbar	(2.062 psi)	(test water temp 13.5 C)
Case 5	27.63 mbar	(0.400 psi)	(test water temp 12.7 C)
Case 8	202.27 mbar	(2.934 psi)	(test water temp 13.1 C)

For the total head loss through a debris laden strainer the raw testing head loss values are scaled for temperature and additional losses through the strainer components are included. The resulting head loss is presented as a family of curves for different water temperatures.

For the design case with a flow rate of 14500 gpm, the total head loss (including duct and water box head losses) at selected temperatures is as follows:

100°F – 4.518 ft
150°F – 3.466 ft
180°F – 3.105 ft
212°F – 2.835 ft

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

The BVPS-2 prototypical Top-Hat array testing demonstrated that the maximum debris head loss was obtained from the maximum debris load. The maximum debris load conservatively uses the bounding debris quantity for constituent material from the cross-over leg break on each of the three RCS loops. It was shown that the maximum debris quantity did not fill the strainer's interstitial volume.

For BVPS-1, the debris generation calculation and debris transportation calculation determine the type and quantity of debris which has the potential to reach the BVPS-1 containment sump strainer. The debris evaluated for the strainer was the predicted values from the following breaks:

Cases 1 and 2	Loops 1 or 2 cross-over leg breaks
Case 3	Loop 3 cross-over leg break
Case 4	14" pressurizer surge line break
Case 5	Reactor vessel nozzle break
Case 6	6" SIS line break
Case 7	6" break in the 14" pressurizer surge line
Case 8	Main steam line break

From theoretical head loss calculations, Cases 4, 6, and 7 have been determined not to be bounding. The other cases have been tested in the prototypical head loss test which has verified that the design of the BVPS-1 strainer will accommodate the type and quantity of debris predicted to be transported to the screen.

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

The testing demonstrated that the BVPS-2 strainer is not susceptible to the "thin bed effect". Varying fiber loads produced progressively higher head losses, indicating that non-uniform debris deposition effectively prevented the development of high head loss when maximum particulate loads were applied to a fiber quantity that would have been adequate to form a thin filtering bed.

Results of the testing showed that for those debris loads that effectively cover the strainer surface, the head loss response is linear with respect to flow rate, indicating a laminar flow regime through the debris bed; thus validating the use of the change in water viscosity in determining temperature correction factors.

Head loss testing for BVPS-1 included the use of a debris mix which has both fiber content and a high particulate content. This debris mix is predicted from the debris generation and transport evaluation for a Main Steam Line Break.

This debris load gives a debris bed thickness of 0.25" (based on a planned surface area of 2,592 ft^2 and 2.4 ppcf for TIW & latent fiber from NEI 04-07). This is within the thin bed region.

The head loss realized under this test was 202.3 mbar with a water temperature of 13.1 C.

This test confirms that the BVPS-1 containment sump strainer will provide acceptable head losses when presented with the predicted debris mix with a high particulate to fiber debris content.

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

FENOC Response

The BVPS-2 prototypical Top-Hat array testing provides the basis for the strainer design maximum head loss. The testing demonstrated that the maximum debris head loss was obtained from the maximum debris load. The maximum debris load conservatively uses the bounding debris quantity for constituent material from the cross-over leg break on each of the three RCS loops.

The BVPS-1 containment sump strainer was specified to be designed with a maximum head loss of 4.6 feet @ 14,500 gpm and 212 °F. The 4.6 ft head loss was specified to insure the pumps maintained adequate NPSH margin. The actual headloss achieved for these flow and temperature conditions, not considering chemical effects was 2.835 ft. The actual headloss is derived through debris head loss testing and the use of standard analytical techniques and CFD modeling to develop losses through the clean side of the strainer flow areas.

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

FENOC Response

Testing was performed for BVPS-2 to conservatively represent the maximum possible head loss associated with the tested debris loads. All fibrous debris was reduced to small pieces and fines prior to introduction into the tank. Where surrogate materials were used, their characteristics were evaluated to ensure that their hydraulic characteristics were conservative with respect to the debris material they were intended to represent. The prototype array was surrounded with walls on three sides to simulate the presence of additional strainer modules and ensure that the potential for filling the strainer's interstitial volume was maximized. A homogeneous mixture of debris was added to the tank in a manner that promoted transport to the strainer, and the use of mechanical and manual stirring was employed actively to minimize the potential for settling of the debris. Essentially 100% of the debris was deposited on the strainer, and no near-field settling effects were accommodated or credited in the testing. Because testing forms the basis of the debris bed head loss calculation, these conservatisms are directly applied to the debris bed head loss correlation that is used in the containment analysis.

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).

Head loss calculations for BVPS-1 are based upon test data for the maximum head loss from the breaks selected using 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. All fibrous debris was reduced to small pieces and fines prior to introduction into the tank. Where surrogate materials were used, their characteristics were evaluated to ensure that their hydraulic characteristics were conservative with respect to the debris material they were intended to represent. Barriers in the test tank restrained the debris on both sides of the test module to ensure that the potential for filling the strainers interstitial volume was maximized. A homogeneous mixture of debris was slowly added to the tank at the face of the strainer. Essentially 100% of the debris was deposited on the strainer, and no near-field settling effects were credited in the testing.

The potential for vortexing for the BVPS-1 strainer was evaluated against systematic tests done by CCI to understand the vortexing phenomenon. During that testing, strainers with solid top plates, as are used at BVPS-1 and BVPS-2, were never observed to display vortexing phenomenon. The strainer post-accident flow, submergence, and head loss were compared with the data from the systematic testing that had shown vortex formation through strainers with perforated top plates by comparing the Froude numbers for the two conditions. The Beaver Valley data showed Froude numbers that were less than half of those present in the tests showing vortex formation.

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 module 5 and 6 of train 2 and 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); ρ_w = 997 kg/m^3 (62.2 lbm/ft^3).
- Coefficient of friction "lambda" 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 Pa (1.8 feet) at an actual flow rate and temperature of 14,500 gpm 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% 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; ρ_w = 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 ft-of water at a flow rate and temperature of 12,600 gpm 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-2 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 two separate calculations. In both cases, the factors are developed and established as inputs to the 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-2 Recirculation Sump Top Hat Strainer Qualification calculation. This calculation establishes two correlations:

- A flow dependent head loss correlation
- A temperature correction factor.

The flow dependent head loss correlation is based directly on the prototypical strainer head loss test results. The limiting strainer debris load was tested over a range of flow rates corresponding to the range expected for various operating configurations evaluated in the containment response analysis. The test results were input to a spreadsheet and graphed; then a regression calculation was performed to establish the flow dependent head loss correlation. As discussed earlier, the characteristics of the head loss vs flow rate curve also allow the determination of the flow regime of the water as it travels through the debris bed. This, in turn, allows the development of a temperature compensation factor based on the hydraulic properties of the recirculating water. The results of the testing show the flow through the debris bed for the limiting case and all other significant debris loads to be 100% laminar. Therefore, the temperature compensation is based on the difference between the viscosity of the test water and the temperature and the viscosity of the water in the dynamic containment response analysis. The flow correlation is applied at test temperature, and then adjusted by the temperature correlation to produce the corrected head loss for any given set of sump flow and temperature conditions.

Testing was performed to conservatively represent the maximum possible head loss associated with the tested debris loads for BVPS-2. Because testing forms the basis of the debris bed head loss calculation, these conservatisms are directly applied to the debris bed head loss correlation that is used in the containment analysis.

A summary of the most limiting debris head loss values was provided in section 3.f.4 (Table 3.f.4-6).

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 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 laminar. However, flow within in 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 of the water. The debris bed head loss was added to the internal strainer losses.

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 have been designed to be fully submerged for all LOCA accident scenarios. On BVPS-1, a potential vent path was identified in the quench spray piping to 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

For BVPS-2 a homogeneous mixture of debris was added to the tank in a manner that promoted transport to the strainer, and the use of mechanical and manual stirring was employed actively to minimize the potential for settling of the debris. Essentially 100% of the debris was deposited on the strainer, and no near-field settling effects were accommodated or credited in the testing.

For BVPS-1, the testing was done to conservatively represent the maximum possible head loss associated with the tested debris loads. All fibrous debris was reduced to small pieces and fines prior to introduction into the tank. Barriers in the test tank restrained the debris on both sides of the test module to ensure that the potential for filling the strainers interstitial volume was maximized. A homogeneous mixture of debris was slowly added to the tank at the face of the strainer. Essentially 100% of the debris was deposited on the strainer, and no near-field settling effects were credited in the testing.

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

FENOC Response

Temperature/viscosity was used to scale head loss test results to actual plant conditions. Head loss testing was performed at a range of temperatures from approximately 50° F to 90° F. These results are adjusted up to actual plant conditions. For head loss results which exhibit a linear relationship with flow indicating a laminar flow regime, the head loss is adjusted by applying the ratio of the viscosity at the actual plant condition to the test condition. In cases where some non-linearity is indicated in the relationship between head loss and flow indicating some turbulent flow is present, a density correction is also made based on the ratio of the density at the test condition to the actual plant condition for that percentage of flow which is determined to be in the turbulent flow regime.

The Beaver Valley strainer surface area is completely covered with fiber during the debris head loss testing. At BVPS-2, end-of-test data showed linear differential pressure response throughout the tested flow ranges demonstrating laminar flow characteristics. This is characteristic of a strainer whose surface is completely covered with fiber and indicates that morphology is not affected. Similar data was not collected at BVPS-1, but flow through the debris bed is considered to be laminar since the strainer surface is completely covered with debris.

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

As noted in FENOC letter L-08-054 (Reference 20), a LAR will be processed for crediting available NPSH with containment overpressure at BVPS-2. Containment accident pressure will be credited in evaluating whether flashing would occur across the strainer. Analyses will be performed to evaluate the potential for flashing and air evolution throughout the system. For each large break LOCA case, a minimum of four points will be evaluated. These will be 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 will also be evaluated. These evaluations cannot be completed until the containment analyses are complete for BVPS-2 and the head loss including chemical effects is established for BVPS-1.

The containment pressure will be 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 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAI 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 up by the specific response.

RAI #42 (from Reference 14)

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.

For BVPS-2, there have been no analyses performed to evaluate the possibility of vortex formation close to the pump suction line and air ingestion into the ECCS pumps for BVPS-2. 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.

For BVPS-1, CCI has performed vortex testing for their strainer design with both perforated and unperforated top plates. The BVPS-1 design uses unperforated top plates. All testing performed by CCI for unperforated top plates show no vortex formations. 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 supplied by CCI is within the design and operating ranges where no vortex formations occurred under testing.

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 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 14)

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 the BVPS-1 and BVPS-2 is based upon head loss testing with several limiting break debris mixtures. The NUREG-CR/6224 correlation was only used for scoping analyses.

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 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 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 GPM Note 1	Max Sump Temperature F	Minimum Sump Water Level Ft Note 2
3637	Note 3	14472	235	4.0
Safety Injection Recirculation				
Maximum RS Pump Flow GPM	Maximum LHSI Pump Flow GPM	Maximum Sump Flow GPM Note 1	Max Sump Temperature F	Minimum Sump Water Level Feet Note 2
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 GPM Note 1	Max Sump Temperature F	Minimum Sump Water Level Feet Note 2
3740	Note 3	10470	210	7.1
Safety Injection Recirculation				
Maximum RS Pump Flow GPM	Maximum LHSI (RSS) Pump Flow GPM Note 4	Maximum Sump Flow GPM Note 1	Max Sump Temperature F	Minimum Sump Water Level Feet Note 2
3761	3685	13640	210	7.2

Notes:
1. Total flow through containment sump strainer
2. Level above bottom of containment sump
3. LHSI pumps take suction from 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 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 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%. 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(pending LAR approval for BVPS-2), the sump vapor pressure is important in establishing the available NPSH and higher containment sump temperatures are limiting. In addition to input biasing, the sump temperature is also maximized by assuming the release streams from the double-ended RCS break are mixed. By mixing the streams, higher enthalpy water is directed 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 is this node is high enough to overflow into openings in the refueling seal ring which then 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 which 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" 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% 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 ductwork and waterbox which 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 was 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., the B RSS pump at BVPS-2 has the highest suction piping head loss and this value 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 small break LOCA, the rate of RCS depressurization will be slow and create a delay between HHSI, LHSI and 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 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 a 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 450 gpm per train is diverted from the QS pump flow directly to the RS pump suctions to provide enhancement flow to both the in-containment recirculation spray (IRS) pumps and the ex-containment recirculation spray (ORS) pumps. The flow split is nominally 140 gpm to the IRS pumps and 275 gpm 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 pump does 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 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 CIB setpoint has been reached and the RWST low level has actuated (following 2R13 for BVPS-2). 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 SI actuation signal and drawing flow from the RWST. The pumps provide injection if 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

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% is intercepted by the annulus outside the crane wall and 89% is intercepted by the crane wall and everything inside it (e.g., the refueling canal and platforms or floors at various elevations). The 11% portion that falls through the annulus is allowed to directly fall into the lower containment sump. Only 5% of the 89% 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 cu. ft. (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 lbs can be trapped in the reactor cavity before overflow to the lower containment can occur. The refueling canal holds about 33,700 lbs of water at the time of RS initiation for a limiting single active failure DG case. The operating deck floor holds about 12,600 lbs at this time. About 9,230 lbs 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 lbs 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 lbs.

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 inch for both BVPS-1 and BVPS-2. This small change is not significant in terms of the overall accuracy of the analyses which establishes 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 vs. 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 690'11" to elevation 692'11". The height vs. net free volume table also includes volume of the lower containment from elevation 692'11' to elevation 718' 6" so that a continuous water level above the containment sump is calculated. The height vs. 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 which 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	401,227 gal
RWST volume Injected @SI switchover (Minimum)	317,000 gal	415,915 gal
RWST Usable Volume for QS after SI Switchover	113,500 gal	443,333 gal

An additional volume of water (4700 – 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 L-08-054 (Reference 20), 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 (DE) pipe break locations, i.e., hot leg (HL), cold log (CL), and pump suction (PS), the double-ended pump suction (DEPS) break maximizes the sump water temperature. This is because more energy is released from DEPS break than from 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 considerably a 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	Min	Max
Initial containment pressure	Min	Min
Initial containment temperature	Max	Max
Initial containment relative humidity	Max	Max
Steel liner to concrete gap effective heat transfer coefficient	Min	Min
Paint thickness on carbon steel heat sinks	Max	Max
Effective heat transfer coefficient for the paint on the carbon steel	Min	Min
Paint thickness on concrete heat sinks	Max	Max
Effective heat transfer coefficient for the paint on the concrete heat sinks	Min	Min
Zinc thickness on carbon steel	Max	Max
RWST temperature	Max	Max

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	Max	Min
Start delay for quench spray	Min	Min
Quench spray flow rate	Max	Max
RWST mass injected prior to RS initiation	Min	Min
Recirculation spray HX UA (BTU/hr/°F)	Max	Min
Recirculating spray flow rate	Max	Min
Recirculation HX cooling water temperature	Min	Max
Recirculation spray HX cooling water flow rate	Max	Min
Range of usable RWST volume prior to switchover	Min	Min
Nitrogen gas mass (accumulator gas volume/initial pressure/initial temperature)	Min (Min/Min/Max)	Min (Min/Min/Max)
MAAP-DBA Model Parameters		
Quench spray droplet diameter	Min	Min

The preceding discussion applies to the current methodology in use at BVPS-1. As noted in FENOC letter L-08-054 (Reference 20), 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

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. It is noted that 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 L-08-054 (Reference 20), 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

FENOC has submitted an extension request in letter L-08-054 (Reference 20) for specified corrective actions for both BVPS-1 and BVPS-2. Additional testing is required for BVPS-1 as the chemical effects tests were inconclusive. These tests need to be completed before the final calculation of NPSH margins. The extension request for BVPS-2 is for a buffer change to sodium tetraborate and crediting containment overpressure in calculating available NPSH. The changes for BVPS-2 require the completion of analysis and the submittal of a LAR. These analysis need to be completed before specifying the NPSH margins for BVPS-2. FENOC's extension letter committed to providing a supplemental response by August 30, 2008 which will include the response to this request.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAI pertaining to NPSH margin at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed up by the specific response.

RAI # 7 (from Reference 14)

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 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 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	380,260
BVPS-2								
Case	Single Failure	Time of RS Start	Temp at RS Start	Time of CL Recirc	Temp at CL Recirc	Volume at CL recirc	Temp at 24 hours	Volume at 24 hours
		seconds	F	seconds	F	gallons	F	gallons
Case1L-npsh	EDG	3271.9	208.1	3392.0	207.1	361,540	115	768,090

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.
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% of the individual fibers were shown to transport to the sump, the recirculation transport fraction for the paint is also 100%.

The results of debris transport are included in response to item 3.3 "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% 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 and BVPS-2 as it relates to both qualified and unqualified coatings and what surrogate material was used to simulate coatings debris. Additional detail with regard to the overall head loss testing was provided in 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.

BVPS-1

1. Stone Flour was used as a surrogate for coatings for the BVPS-1 prototype strainer head loss test. The density of the surrogate used is specified as 167.4 lb/ft^3. The size spectrum analysis for the stone flour resulted in a sphere size of 7.7 μm. As with BVPS-2, the use of this surrogate would tend to produce a debris bed with a lower porosity and higher surface to volume ratio than a debris bed comprised of coating material with a sphere size of 10 μm. The use of stone flour as a surrogate for coating is therefore considered conservative.
2. The volume of coating surrogate used for testing was determined by weight, adjusting for the surrogate density of 167.4 lb/ft^3. The test scaling factor was applied for final determination of surrogate quantities.
3. The coating surrogate was received in flour form therefore no preparation was required. After the fiber had been decomposed, the surrogate was mixed in buckets with the fiber. The fiber and particulate mix was added in batches directly at the surface of the strainer with 50% of the batch applied at each side of the strainer during the prototype test.

BVPS-2

1. For prototype strainer head loss testing, the particulate debris (coatings) surrogate material is selected based on a comparison of the microscopic densities of the material. Epoxy and alkyd coatings densities at plants range from 94 lb/ft3 to 98 lb/ft^3 per the NEI GR (Guidance Report). Inorganic zinc coatings have a density on the order of 220 lb/ft^3. The microscopic density of the surrogate that was used, ground silica is on the order of 165 lb/ft^3. Based on average density for the combinations of coatings, the ground silica material would be an appropriate surrogate material and was used in the testing. The volume of the silica material was adjusted to match the volume of the coatings material. Ground silica surrogate material was sized as 10 micron particulate.

2. SIL-CO-SIL™ 53 Ground Silica manufactured by U.S. Silica Company was used as a surrogate for both the IOZ and non-IOZ coatings. The ground silica is a spherical particulate ranging in size from just under 1 μm to approximately 100 μm. The ground silica material specific gravity is 2.65 which corresponds to a density of 165 lbm/ft^3. Non-IOZ (mostly epoxy) coatings density is typically on the order of 94 lb/ft^3. An adjustment is made to compensate for the difference in the volume of the material such that an equivalent volume of the surrogate material used. The majority of the coatings are on the order of 10 μm in size or greater. Since a significant portion of the ground silica material is less than 10 μm, the ground silica would tend to produce a debris bed with a lower porosity and higher surface-to-volume ratio than a debris bed comprised of coating material. Thus, the use of ground silica as a surrogate for coating material is conservative.
3. Coatings surrogate debris quantities used for testing were determined by multiplying the total volume of qualified and unqualified coatings by the density of coatings surrogate (165 lbm/ft^3) to get the total mass of coatings surrogate and then multiplying by the test screen scaling factor to get the scaled mass.
4. The coating surrogate was prepared for testing as follows: The particulate debris was received in a 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. The particulate was then mixed thoroughly with a paint mixer attached to an electric drill until a homogeneous slurry was formed.
5. For all tests, the fiber and particulate was added in batches with the test tank pump and mechanical mixer in operation per the test plans. The fiber and particulate were mixed in separate buckets. For most tests the particulate and fiber were kept in their separated buckets but added to the tank at the same time, but in some cases the particulate and fibrous debris were mixed together into the same bucket before adding them to the tank.

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.

A 10D ZOI was used as the basis for debris generation for qualified coatings for BVPS-1. The following provides a justification for use of the 10D ZOI:

1. The NRC guidance for the use of a 5D ZOI for coatings in Enclosure 2 of Reference 19 was not available during the development of the BVPS-1 evaluations, therefore a 10D ZOI was assumed for coatings consistent with Section 3.4.2.1 of NEI 04-07, Volume 2.
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. With the exception of coatings protected by intact insulation, all unqualified coatings outside of the ZOI are assumed to fail as 10μm particulate, equivalent in size to the average zinc particle in inorganic zinc (IOZ) coatings or the pigment used in epoxy coatings [NEI 04-07, Volume 2, section 3.4.2.1]
4. 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 (unless plant-specific information is available).
5. In accordance with the NEI GR, unqualified coatings that are under intact insulation are not considered to fail. Unqualified coatings that are under insulation that become debris (i.e. insulation within the ZOI) are assumed to fail. This is included as an assumption since the SE does not address this GR position.

For BVPS-2, the amount of coating debris generated was determined for a 5D ZOI as an alternative to the 10D ZOI. The coatings debris associated with the 5D ZOI was integrated into subsequent transport and head loss analyses. The basis for the use of the 5D ZOI is further explained within the response to RAI #26.

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

FENOC Response

BVPS-1 and 2 do not have a formalized painting assessment program. 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 is to be implemented starting with the BVPS-2 Spring 2008 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 L-07-519; Reference 10).

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAIs 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 up by the specific response.

RAI #2 (from Reference 14)

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	28800*	20087*
Zinc in Galvanized Steel	150000*	177166*
Inorganic Zinc Coatings	90000*	295573*
Total Zinc	240000*	472739*
Copper	NA	NA
Carbon Steel not Coated	NA	NA
Uncoated Concrete	7533	7533

Notes:

*Maximum Allowable Limits
- Uncoated concrete is based on a 10D ZOI break.
- Copper is not used based on WCAP 16530.
- A small amount of aluminum is submerged at each unit. (36 SF at BVPS-1, and 64.7 SF at BVPS-2).

The comparison to the materials used in the Integrated Chemical Effects Tests is provided in Table RAI 2-2, as follows:

Table RAI 2-2

Material	ICET Ratio Value	Units (1)	Ratio Value BVPS-1	Ratio Value BVPS 2
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	0.66	0.20
Copper	6	SF/CF	NA	NA
Carbon Steel not Coated	0.15	SF/CF	NA	NA
Uncoated Concrete	0.045	SF/CF	0.17	0.075

BVPS-1 Sump Water Volume = 324080 gal (43323.19 CF)
BVPS-2 Sump Water Volume = 756050 gal (101069.18 CF)

Note 1 – Ratio is the Material Square Footage Quantity divided by the Sump Water Volume.

RAI #3 (from Reference 14)

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 maximum amount of scaffold materials permitted to be stored in BVPS-1 containment is 2030 sq ft and 190 pounds mass. These values are based on the maximum amount of scaffold permitted to be stored in containment and rounded upward.

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 stored in BVPS-2 containment is 817 sq ft and 76 pounds mass. These values are based on the maximum amount of scaffold permitted to be stored in containment and rounded upward.

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 14)

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.

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 are no non-stainless steel insulation jacketing inside the Reactor Containment for BVPS-1 and BVPS-2.

Metallic Paints:

With exception to painting identified within the response for RAI #2, metallic paints were not used in containment at BVPS for field painting activities during construction or operation phases.

The pressurizer and reactor coolant pumps for BVPS-1, and the steam generators and reactor coolant pumps for BVPS-2, were coated with a high temperature aluminum paint. None of these components are submerged during a LOCA; although, may be subjected to containment spray.

The amount of high temperature aluminum paint in the BVPS-1 containment is estimated at 1900 square feet. The dry film thickness (DFT) is assumed as 1.5 mils that results in a volume of 0.24 cubic feet. The amount of high temperature aluminum paint in the BVPS-2 containment is estimated at 9400 square feet. The DFT is assumed as 1.5 mils that results in a volume of 1.18 cubic feet.

RAI #25 (from Reference 14)

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

The containment coatings assessments that have been performed and that are currently in effect at BVPS-1 and BVPS-2 have been used to identify degraded qualified/acceptable coatings and to determine the amount of debris that will result from these coatings. These assessments also ensure that qualified/acceptable coatings remain in compliance with current plant licensing basis requirements for design-basis accident (DBA) performance.

As originally discussed in FENOC letter L-98-217 dated November 11, 1998 (Reference 21), 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 requires the generation of data which is used to schedule coating maintenance to ensure that qualified/acceptable primary containment coatings will not fail (detach) during normal and accident conditions and thus not contribute to the Emergency Core Cooling System (ECCS) debris source term.

Coatings inside containment at BVPS-1 and BVPS-2 are currently assessed as part of containment walkdowns, maintenance activities, and the "Containment Structural Integrity Test" (BVPS-1 – 1BVT 1.47.1; BVPS-2 – 2BVT 1.47.1). As localized areas of degraded coatings are identified, those areas are evaluated and scheduled for repair or replacement as necessary. This assessment 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.

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 which 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 which will continue in the Spring of 2008 outage for BVPS-2 (2R13) as described below.

An expanded coating condition assessment program for BVPS-1 and BVPS-2 is being developed as committed in FENOC letter L-07-519 (Reference 10). Under the planned program for the containment coating condition assessment protocol for BVPS-1 and BVPS-2, when degraded coatings are visually identified, the affected areas will continue to be documented in accordance with plant procedures.

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 responses previously provided to the NRC for BVPS-1 and BVPS-2 continue to apply as they relate to this response area. The information contained herein supplements the previous response information.

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 1-PIP-M10 and 2-PIP-M10 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 1/2-ADM-0700, 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 does not have a formalized painting assessment program. However, the containment liner coatings are periodically inspected during the performance of the "Containment Structural Integrity Test" (1BVT 1.47.1 and 2BVT 1.47.1). These procedures are performed approximately every three years or every other refueling outage. Coating discrepancies discovered during these inspections are entered into the corrective action program and identified as requiring resolution prior to plant heatup.

A new, containment coatings inspection and assessment program is to be implemented starting with the BVPS-2 Spring 2008 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 L-07-519; Reference 10).

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 removed at the conclusion of work in containment.

In addition, by procedure a visual inspection of the BVPS-1 containment sump (accessible areas) and the BVPS-2 containment sump are performed to verify that they are not restricted by debris and that 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 and a limited latent debris sampling program in accordance with the guidance of NEI 04-07 is currently planned. To further reduce the latent debris burden on the sump, BVPS will enhance containment cleanliness by implementing a periodic containment cleaning program. This enhancement will be implemented during the next refueling outage for each unit (Spring 2008 for BVPS-2 and Spring 2009 for BVPS-1) and performed each refueling outage thereafter. The need to clean inaccessible areas such as cable trays and large pipes such as the main steam/feedwater piping systems will be reviewed during the development of this enhancement program.

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 MSR-32, Feedwater piping between the RSG Feedwater nozzle and on the first rupture restraint FWR-38 and the existing Blowdown and Shell Drain piping between the RSG nozzles to 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 equipment up-grades noted above.

At BVPS-2, to reduce the debris head loss across the containment sump strainer, two different insulation replacement activities will be undertaken during the scheduled Spring 2008 refueling outage (2R13), as described in FENOC letter L-08-054 (Reference 20).

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

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

In summary – as discussed in this response area and as noted in FENOC letter L-07-519 (Reference 10), FENOC has implemented, or plans to implement, the necessary programmatic and process controls to ensure the recirculation function will be maintained into the future.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAI 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 up by the specific response.

RAI #34 (from Reference 14)

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 14)

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.

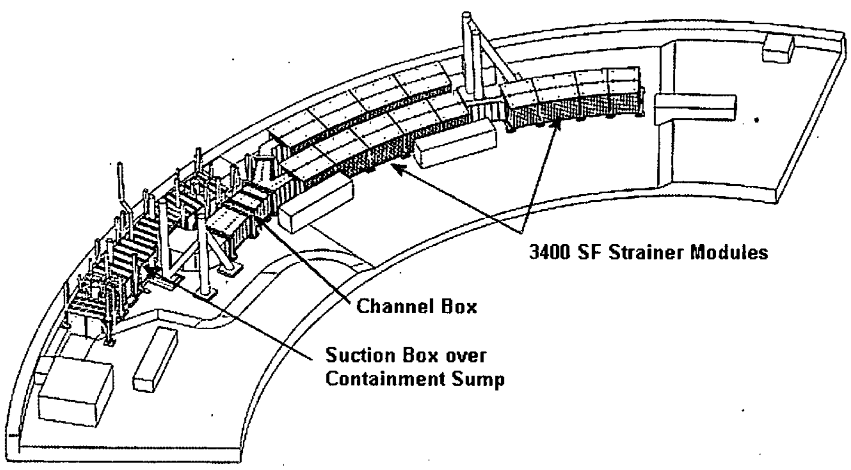
The original containment sump screen assembly was composed of a structural steel frame that supported trash racks, two layers of screening that comprised approximately 130 ft^2 of strainer surface area and cylindrical cruciform screens around six pump inlets. The top of the frame is covered with steel deck plate and supports pumps, piping and other equipment. Additionally, existing anti vortex grids were located inside the sump screens adjacent to the pump inlets.

The trash racks were made of vertical, sloped 1" x 1/8" galvanized carbon steel grating that were supported at the top at the existing frame and at the bottom by short support posts anchored to the concrete floor. Inside the trash racks were two layers of vertical screens composed of rough mesh screens with 3/4" openings, 6 gage, 304 stainless steel and fine mesh screens with 4 x 4 openings, 16 gage, 304 stainless steel. Inside these screens were cylindrical cruciform screens made from 1/8" thick perforated plate with 1/4" holes. The cruciform screens were at the inlets for the two inside Recirculation Spray Pumps, the two outside Recirculation Spray pumps and the two outside Low Head Safety Injection pumps. Around these cruciform screens were two horizontal layers of anti vortex grids comprised of 3" deep, galvanized carbon steel bars. The trash racks adjacent to the screens, the vertical screens, the cylindrical cruciforms and anti vortexing grids were all removed and discarded.

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 ft^2 of strainer area. The flow velocity through the screens is 0.01 fps based on 14,500 gpm maximum flow and 3,086 ft^2 effective flow area. The strainer configuration is designed to a differential pressure of 5.78 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.

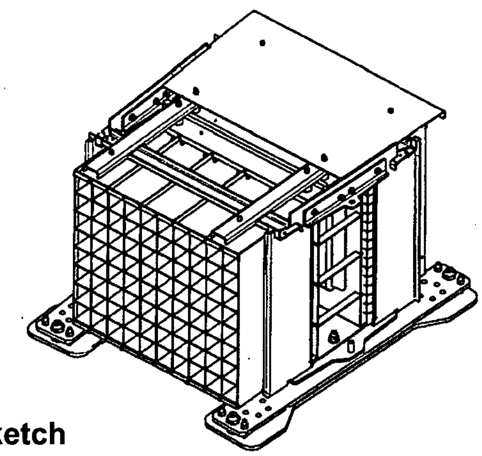
The sketch below shows the primary components for the new containment sump assembly.



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" x 3" x 16" deep. The perforations are 1/16" 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. Access to the internals of the stilling wells is provided by removable covers on the duct boxes around the stilling well bases, or the boxes themselves may be disassembled, because they are of bolted construction.

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 insures 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 ft^2 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 ft^2 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.

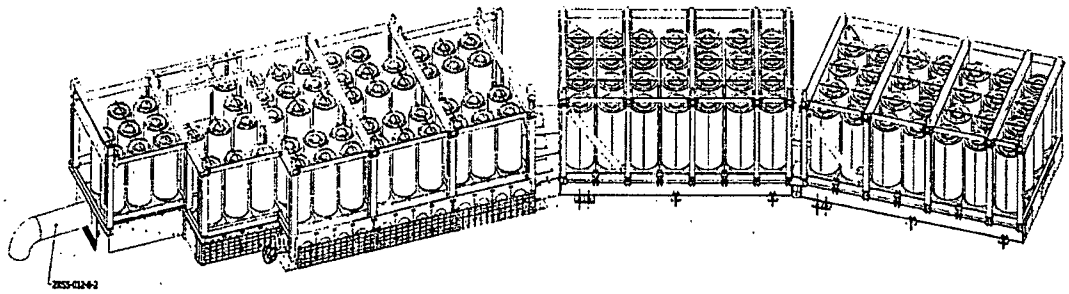
The frame's vertical columns were welded to embedded plates in the floor. The trash racks were made of vertical 1" x 1/8" galvanized carbon steel grating. Inside the trash racks were vertical screens composed of outer screens with 3/4" square openings of 0.192" diameter wire, 304 stainless steel, and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

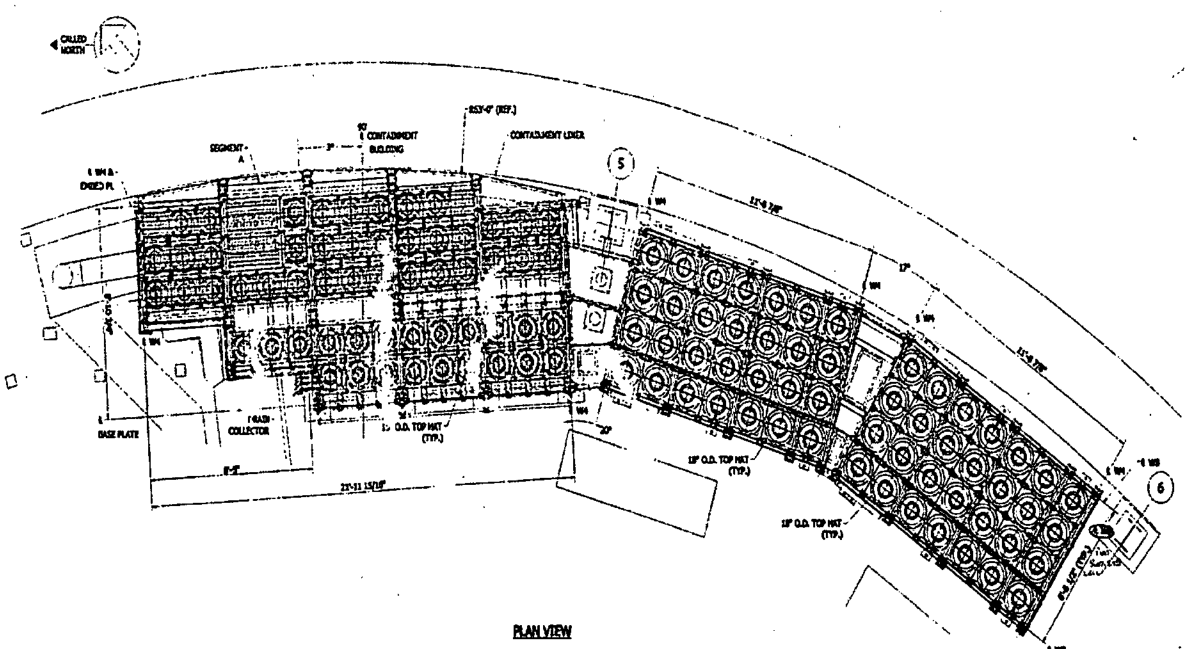
The modification installed a passive, safety-related strainer assembly engineered by Enercon and fabricated by Transco. The design does not include an active approach for the strainer. Reverse flow back flushing strategy was not used. The new containment sump strainer provides approximately 3300 ft^2 of strainer area. The flow velocity through the screens is 0.009 fps based on upon 12,600 gpm maximum flow and 3,396 ft^2 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 ft 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" 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 twenty-eight (28), fifty-six (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.





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" x 1/8" 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 are 16 temporary horizontal, tubular screens installed in the water box area of the strainer segment A. These screens represent approximately 170 ft^2 area vs. the original 150 ft^2 area of the original screens. These horizontal screens are made of stainless steel plate perforated with 3/32" diameter holes. These temporary screens will be removed during 2R13 in the spring of 2008 after the recirculating pump start on low RWST level logic change is 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 will also be removed in 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).

The relocation of temperature sensors TRB-1RS-150A and TRB-1RS-150B, which are used to provide containment water temperature post LOCA.

Removal of the reactor cavity drain barrier.

Pipe Supports RS-A-24, 1RH-A-1 and 110-SI-R19 were locally modified.

Pipe Supports SI-R-19, SI-R-309, CH-R-6A and CH-R10 were locally modified.

Transmitters for FT-1RC-435 and FT-1SI-929 were relocated locally.

Support columns for the existing sump screens' frame were deleted or relocated.

RWST Level Interlock modified to change RS Pump start.

Replace High Head Safety Injection throttle valves.

Modify Quench Spray loop seals.

Modify RS test return pipe and support.

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 instruments 2DAS-LE200 and 2DAS-LE222 were modified.

Instruments 2DAS-LE200 and 2DAS-LE222 (Containment Sump Level transmitters) and 2DAS-LS200 and 2DAS-LS210 (Containment Sump Level Switches) were relocated locally within the sump.

Conduits to instruments 2DAS-LS200 and 2DAS-LS210 were modified.

During BVPS-2 refueling outage in the Spring of 2008 horizontal screens in strainer segment A will be removed and water box closure plates and train separation plates will be installed.

Remove reactor cavity drain barrier during 2R13.

RWST Level Interlock modified to change RS Pump start.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAI 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 up by the specific response.

RAI #40 (from Reference 14)

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).

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

Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under flow conditions.

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 PC-PREPS 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.

Loads:
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. I 0080-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 + Sesimic OBE is qualified by comparison to the Faulted load case = DL + Seismic SSE + LL

The live load is considered to by 75 lb / ft^2 or 734 lb / ft^2 on the overhead grating.

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 *	Allowable Value *	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	**
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%

* 1 MPa = 145 psi 1kN = 224.809 lb

** 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	*
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%

* 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 El. 692'-11" 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 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 El. 692'-11" 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 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAI 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 up by the specific response.

RAI #38 (from Reference 14)

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 3k "Sump Structural Analysis" no active approach such as backflushing is used for either BVPS-1 or BVPS-2 strainer design.

3.I. Upstream Effects

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

Provide a summary of the upstream effects evaluation including the information requested in GL 2004-02 Requested Information Item 2(d)(iv).

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

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

The response previously provided to NRC under FENOC Letter L-05-146, dated September 6, 2005 (Reference 6), for BVPS-1 and BVPS-2 continues to apply as it relates to upstream effects. Activities subsequent to this response identified additional potential holdup points. A discussion on these locations is provided within this section and serves to addend the previous response to GL 2004-02.

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" 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 has been removed from BVPS-1 and will be removed from BVPS-2 during the upcoming Spring 2008 refueling outage (2R13).

The integrated containment response analysis also established the post-LOCA minimum containment water level during the recirculation phase. In order to support the installation of replacement sump strainers, the BVPS-1 and BVPS-2 Recirculation Spray System actuation scheme was modified to establish adequate water level to ensure the strainers would be submerged prior to RSS pump start. The BVPS-1 and BVPS-2 ESF recirculation sump strainers were then designed in consideration of this water level to ensure sufficient water level was available to prevent vortexing or excessive air entrainment, as well as ensuring adequate NPSH available for the ECCS and RSS pumps. An extension for completion of GL 2004-02 response was granted for BVPS-2 to allow for modifications to the RSS pump start circuitry to be completed. This modification was installed in BVPS-1 during the fall, 2007 refueling outage (1R18); and it will be installed at BVPS-2 during the Spring 2008 refueling outage (2R13), as noted in FENOC letter L-05-146 (Reference 6).

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.

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

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

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

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

FENOC Response

The ex-vessel downstream analysis is still under development; however, preliminary results are available. FENOC Letter L-08-054 has requested an extension to August 30, 2008, to complete all documentation related to downstream effects. The following provides a response to this issue based on preliminary information.

The downstream impact of containment sump debris on the performance of the BVPS-1 and BVPS-2 Emergency Core Cooling System (ECCS) and the Recirculation Spray

System (RSS) flow path components is being 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 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. Separate unit specific bounding debris concentrations were established at BVPS-1 and BVPS-2, and were then used in the assessment of component blockage and wear.

The sump strainer screens at both BVPS-1 and BVPS-2 have a series of circular openings. The screens are constructed of perforated plate that on BVPS-1 have 1/16" (0.0625") diameter holes and on BVPS-2 have 3/32" (0.09375") diameter holes. The downstream effects calculations conservatively assumed that the openings in the screens were 1/8" (0.125") in diameter. Using guidance in Westinghouse WCAP-16406-P, the calculations very conservatively assume that 1) all fibrous and particulate debris with a diameter up to 0.14" (0.125" plus 10% then rounded upward) and 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 or 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 has been assessed for blockage and wear using the guidance of WCAP-16406-P.

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 were completed in using 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 was credited in these evaluations.

The blockage evaluations revealed that the high pressure safety injection throttle valves on both BVPS-1 and BVPS-2 have gaps that are smaller than the size of the opening in the new strainer. High pressure safety injection throttle valves have been replaced at BVPS-1 during 1R18 and are scheduled to be modified at BVPS-2 during 2R13. Debris passing through the strainers at BVPS-1 and BVPS-2 would not block other components.

The high head safety injection pumps used at BVPS-1 and BVPS-2 do not pass the WCAP acceptance criteria for wear. However these pumps are determined not to be prototypical of the pumps evaluated in the WCAP. These pumps are therefore presently undergoing a detailed analysis.

Preliminary information on the high head safety injection pumps has been made available to FENOC. A stability assessment has been completed through the use of a dynamic model for different impeller running clearances. This assessment indicates that the lateral natural frequencies are not significantly affected by the specified worn clearances and that the wear rings, balance drum, and journal bearings provide sufficient damping to avoid vibration issues. A preliminary assessment on hydraulic performance as well as the effects on the mechanical seals was also developed. These assessments conclude that the HHSI pumps at BVPS will meet the pump hydraulic requirements. The mechanical seal evaluation concluded that there is little potential for significant debris-induced wear of the seal faces due to the tight running gap. There are no seal injection flow lines for the BVPS HHSI pumps and therefore there are no cyclone separators installed.

The evaluations discussed above are presently ongoing with the final documentation to be completed as identified in the extension request in FENOC letter L-08-054 (Reference 20). Exceptions to the approved methodology will be addressed at that time.

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

FENOC Response

As noted above the ex-vessel downstream effects evaluations are ongoing. However FENOC anticipates that the evaluations will result in acceptable results for all components evaluated with the exception of the High Pressure Safety Injection Throttle Valves which have been replaced on BVPS-1 and are scheduled to be modified at BVPS-2 during 2R13.

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

FENOC Response

Activities Already Completed

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

Activities to be Completed During the BVPS-2 Spring 2008 Refueling Outage (2R13)

- 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.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAI pertaining to downstream effects at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed up by the specific response.

RAI #37 (from Reference 14)

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

The ex-vessel and in-vessel downstream analyses are still under development. An extension request for the completion of these evaluations has been submitted in FENOC letter L-08-054 (Reference 20). This letter provides the schedule for submitting a supplemental response for downstream effects. The responses included in 3.m above and 3.n below provides information on the present status of ex-vessel and in-vessel downstream effects.

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

FENOC is in the process of evaluating the in-vessel effects with consideration to the industry guidance (WCAP-16793), as modified by NRC staff comments, for BVPS-1 and BVPS-2. A request for an extension on the completion of this activity has been submitted to the NRC via FENOC Letter L-08-054 (Reference 20). The following is preliminary information received from Westinghouse who is developing the analysis.

The preliminary conclusion of the WCAP-16406-P, Revision 1 evaluation for BVPS-1 indicates that the amount of fibrous debris generated by a large break LOCA at BVPS-1 will not produce a fibrous debris build-up on the underside of the fuel bottom nozzle that exceeds the acceptance criterion of less than 0.125 inches. This preliminary conclusion is based on fibrous debris bypass test data specific to BVPS-1 conditions.

The preliminary conclusion of the WCAP-16406-P, Revision 1 evaluation for BVPS-2 indicates that the amount of fibrous debris generated by a large break LOCA at BVPS-2 will not produce a fibrous debris build-up on the underside of the fuel bottom nozzle that exceeds the acceptance criterion of less than 0.125 inches. This preliminary conclusion is based on fibrous debris bypass test data from the screen vendor that is not specific to BVPS-2 conditions. Taking into consideration the fraction of fibers shorter than 500 microns (approximately 90%), the fiber bed thickness is determined to be 0.072 inches, which meets the acceptance criteria of WCAP-16406-P, Revision 1.

3.o. Chemical Effects

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

1. *Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.*
2. *Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425).*

   2.1 Sufficient 'Clean' Strainer Area

   i. Those licensees performing a simplified chemical effects analysis should justify the use of this simplified approach by providing the amount of debris determined to reach the strainer, the amount of bare strainer area and how it was determined, and any additional information that is needed to show why a more detailed chemical effects analysis is not needed.

   2.2 Debris Bed Formation

   i. Licensees should discuss why the debris from the break location selected for plant-specific head loss testing with chemical precipitate yields the maximum head loss. For example, plant X has break location 1 that would produce maximum head loss without consideration of chemical effects. However, break location 2, with chemical effects considered, produces greater head loss than break location 1. Therefore, the debris for head loss testing with chemical effects was based on break location 2.

   2.3 Plant Specific Materials and Buffers

   i. Licensees should provide their assumptions (and basis for the assumptions) used to determine chemical effects loading: pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects.

   2.4 Approach to Determine Chemical Source Term (Decision Point)

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

   2.5 Separate Effects Decision (Decision Point)

   i. State which method of addressing plant-specific chemical effects is used.

   2.6 AECL Model

   i. Since the NRC USNRC is not currently aware of the testing approach, the NRC USNRC expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results.

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

2.7 WCAP Base Model

i. For licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart [in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425)], justify any deviations from the WCAP base model spreadsheet (i.e., any plant specific refinements) and describe how any exceptions to the base model spreadsheet affected the amount of chemical precipitate predicted.

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

2.8 WCAP Refinements: State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

2.9 Solubility of Phosphates, Silicates and Al Alloys

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

ii. For crediting inhibition of aluminum that is not submerged, licensees should provide the substantiation for the following: (1) the threshold concentration of silica or phosphate needed to passivate aluminum, (2) the time needed to reach a phosphate or silicate level in the pool that would result in aluminum passivation, and (3) the amount of containment spray time (following the achieved threshold of chemicals) before aluminum that is sprayed is assumed to be passivated.

iii. For any attempts to credit solubility (including performing integrated testing), licensees should provide the technical basis that supports extrapolating solubility test data to plant-specific conditions. In addition, licensees should indicate why the overall chemical effects evaluation remains conservative when crediting solubility given that small amount of chemical precipitate can produce significant increases in head loss.

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

2.10 Precipitate Generation (Decision Point)

i. State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.

2.11 Chemical Injection into the Loop

i. Licensees should provide the one-hour settled volume (e.g., 80 ml of 100 ml solution remained cloudy) for precipitate prepared with the same sequence as with the plant-specific, in-situ chemical injection.

ii. For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminum), the percentage that precipitates, and the percentage that remains dissolved during testing.

iii. Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100 percent 140 percent).

2.12 Pre-Mix in Tank

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

2.13 Technical Approach to Debris Transport (Decision Point)

i. State whether near-field settlement is credited or not.

2.14 Integrated Head Loss Test with Near-Field Settlement Credit

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

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

2.15 Head Loss Testing Without Near Field Settlement Credit

i. Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable.

ii. Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).

2.16 Test Termination Criteria

i. Provide the test termination criteria.

2.17 Data Analysis:

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

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

2.18 Integral Generation (Alion)

i. A sufficient technical basis is developed to support selecting plant-specific test parameters that produce a conservative chemical effects test

ii. Inability to reach peak sump temperatures is offset by extended testing at highest loop temperatures.

2.19 Tank Scaling / Bed Formation

i. Explain how scaling factors for the test facilities are representative or conservative relative to plant-specific values.

ii. Explain how bed formation is representative of that expected for the size of materials and debris that is formed in the plant specific evaluation.

2.20 Tank Transport

i. Explain how the transport of chemicals and debris in the testing facility is representative or conservative with regard to the expected flow and transport in the plant-specific conditions.

2.21 30-Day Integrated Head Loss Test

i. Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.

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

2.22 Data Analysis Bump Up Factor

i. Licensees should provide the details and the technical basis that show why the bump-up factor from the particular debris bed in the test is appropriate for application to other debris beds.

FENOC Response

3.o.1. Beaver Valley Integrated Chemical Effects testing was recently completed by Alion Science and Technology at the VUEZ facility in Slovakia. Test results show the following:

1) Chemical effects testing results using Sodium Hydroxide for a buffer for BVPS-1 are inconclusive. Although testing with Sodium Tetraborate buffer yielded acceptable head loss, during the test with Sodium Hydroxide buffer (presently in use at BVPS-1), the debris bed failed to completely cover the test screen; attempts made to re-distribute the debris on the screen failed. As a result, the measured head loss across the screen was not representative.

2) Chemical effects testing results for BVPS-2 showed that although the results of testing with the sodium hydroxide buffer challenged the NPSH requirements, testing with the sodium tetraborate buffer yielded favorable NPSH results.

FENOC has developed an action plan to address the potential uncertainties related to head loss from chemical effects and identified corrective actions necessary to come into full compliance with GL 2004-02. Corrective actions will be required in the form of additional testing for BVPS-1 and licensing changes and modifications for BVPS-2. The details and schedule for implementation of corrective actions are included in FENOC letter L-08-054 (Reference 20).

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

i. As was discussed in FENOC letter L-08-054 (Reference 20), the BVPS-1 chemical effects tests yielded inconclusive results. Additional testing will be conducted using the specific debris mix for BVPS-1 based on precipitates calculated and using the existing sodium hydroxide buffer. A follow-up supplemental response detailing the results of the testing for BVPS-1 will be provided to the NRC by August 30, 2008.

At BVPS-2, chemical effects testing was done with the highest debris head loss case; the cross-over leg line break scenario.

The WCAP-16530-NP chemical testing methodology was not used for the chemical testing at BVPS. However, to gain insight into the chemical effects head loss, the amount of debris developed by applying the WCAP methodology was used as an indicator of the severity of the chemical effects from each accident.

When the amount of chemical precipitates for each line break was calculated using WCAP-16530-NP and WCAP-16785-NP, the cross-over leg line break also had the largest generation of chemical precipitates by almost 20%:

LOCA	$NaAlSi_3O_8$	AlOOH	$Ca_3(PO_4)_2$	Total (kg)
Cross-over Leg Line Break	348.19	329.60	0	677.79
Reactor Vessel Nozzle Break	86.12	388.42	0	474.54
Main Steam Line Break	189.7	364.76	0	554.46

Since the cross-over leg line break generated the largest debris head loss and also generated the largest amount of chemical effects precipitates of the LOCA scenarios studied, the cross-over leg line break was appropriately selected as the limiting line break for BVPS-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.

FENOC Response

pH Range:

Since testing was performed for each of the Beaver Valley units and for two different pH buffers (Sodium hydroxide (NaOH) and Sodium Tetraborate (NaTB)), different pH profiles were necessary during the chemical effects testing. The pH profiles of record for BVPS-1 and BVPS-2 apply to the tests being performed with the NaOH buffer. Note that these profiles list pH values of sump water cooled to 77^0 F (25 ^{0}C). These profiles were adjusted for testing to use the minimum sump pH value (4.84) immediately after the LOCA and were then gradually increased to the sump PH value at the start of spray recirculation. The pH of the test water was increased by incrementally adding portions of the NaOH buffer solution.

The pH profile for the tests using the NaTB buffer was developed using the minimum sump pH value (4.84) immediately after the LOCA and was then gradually increased to the sump PH value of 8.0 at the start of spray recirculation. This method was chosen to simulate the gradual submersion of the NaTB baskets by gradually increasing the pH to 8.0 as the pool level increases. The pH of the test water was increased by incrementally adding portions of the NaTB buffer.

Figure 3.o.2.3-1: BVPS-1 Test pH Profiles

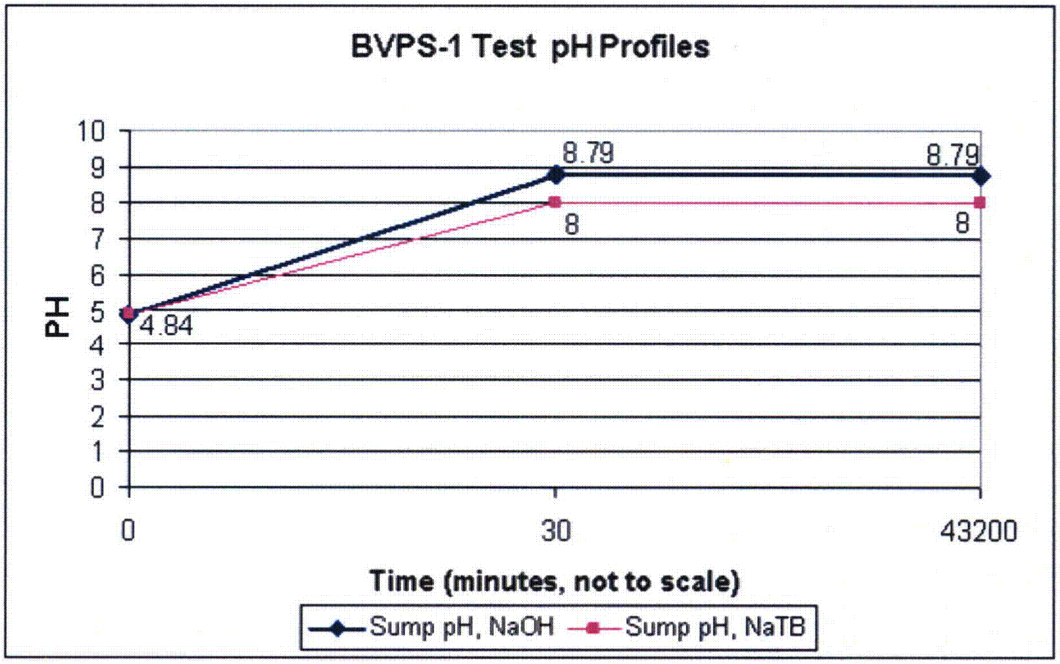
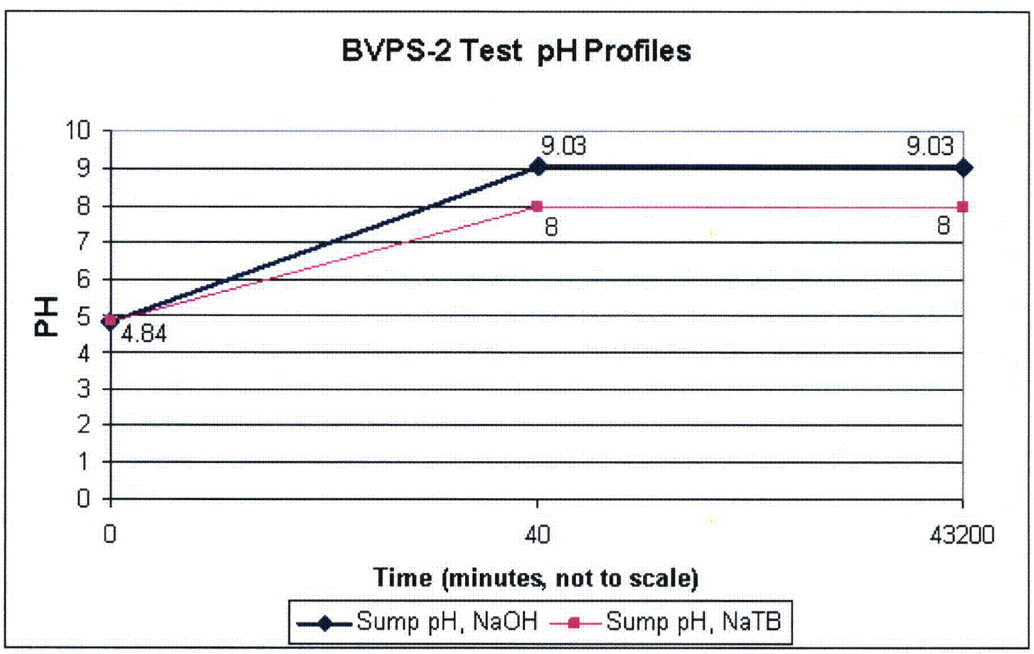


Figure 3.o.2.3-2: BVPS-2 Test pH Profiles



Temperature Profile:

The temperature time history of the chemical effects testing represented that of the containment pool during Emergency Core Cooling System (ECCS) recirculation as closely as possible. For this purpose, the design basis maximum temperature profile for each Beaver Valley containment pool following a Loss of Coolant Accident (LOCA) was used. For both plants, the maximum sump temperature occurs immediately after the break event and this temperature gradually decreases over the remainder of the ECCS mission time. Sump Temperature profiles for the BVPS-1 and BVPS-2 post-LOCA events can be found in Figure 3.o.2.3-3 and Figure 3.o.2.3-4.

Figure 3.o.2.3-3: Sump Temperature Profile for BVPS-1 Post-LOCA Scenario

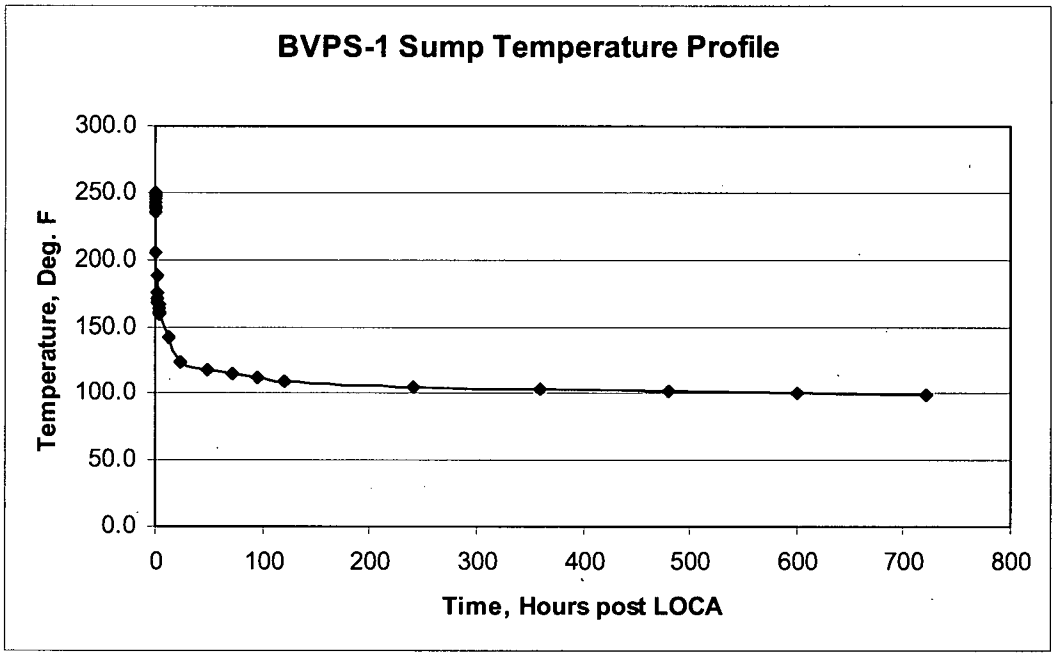
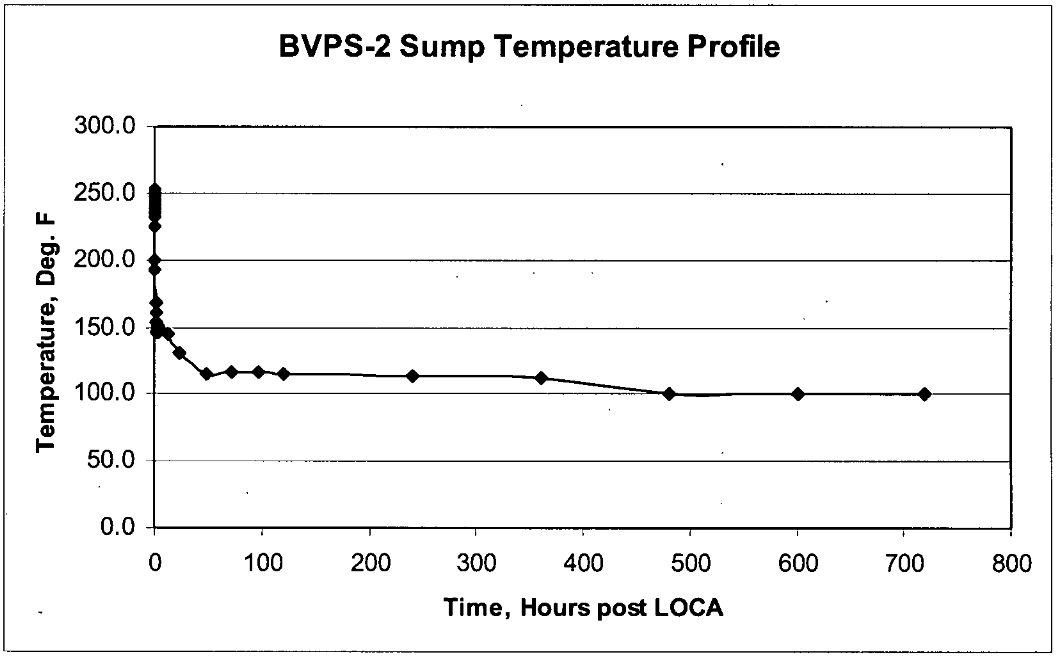


Figure 3.o.2.3-4: Sump Temperature Profile for BVPS-2 post-LOCA Scenario



The maximum temperature profiles are the basis from which the test temperature profiles were developed because they are the most conducive to any leaching processes that may contribute to chemical effects-related head loss at the early point of the tests. The temperature profile for BVPS-1 presented in Figure 3.o.2.3-3 is the maximum sump temperature profile which provides the highest temperatures at the beginning of the accident scenario and decreases towards the end of the scenario.

The temperature profile for BVPS-2 presented in Figure 3.o.2.3-4 is the maximum sump temperature profile which provides the highest temperatures at the beginning of the accident scenario and decreases towards the end of the scenario.

The resulting test temperature profile is appropriate and conservative for the following reasons:

1) It is based upon containment analysis.
2) It incorporates the highest and longest peak temperature, which permits the maximum extent of chemical activity (e.g., leaching) that could be expected during an accident scenario of this type.
3) It incorporates ten days of temperatures below 108°F, well below the temperature (118°F) where aluminum and silica compounds were found to precipitate during benchtop testing.

The use of a variable temperature profile for the test was assumed to provide a more representative scenario for chemical attack and subsequent precipitation than a single temperature held for the full length of the experiment.

To simplify the design of the test, the temperature profile during the testing did not exceed the VUEZ test apparatus temperature limit of 190 °F. As can be seen from Figures 3.o.2.3-3 and 3.o.2.3-4, the sump temperatures for the actual containments are higher than this maximum operating temperature for the test unit for approximately the first 77 minutes for BVPS-1, and approximately the first 41 minutes for BVPS-2 of the post-LOCA event.

The graphs in Figure 3.o.2.3-5 and Figure 3.o.2.3-6 give more detail on the BVPS-1 and BVPS-2 design temperature profiles over the first 100 minutes of the postulated post-LOCA event.

Figure 3.o.2.3-5: BVPS-1 Temperature Profiles over the first 100 minutes of post-LOCA Event

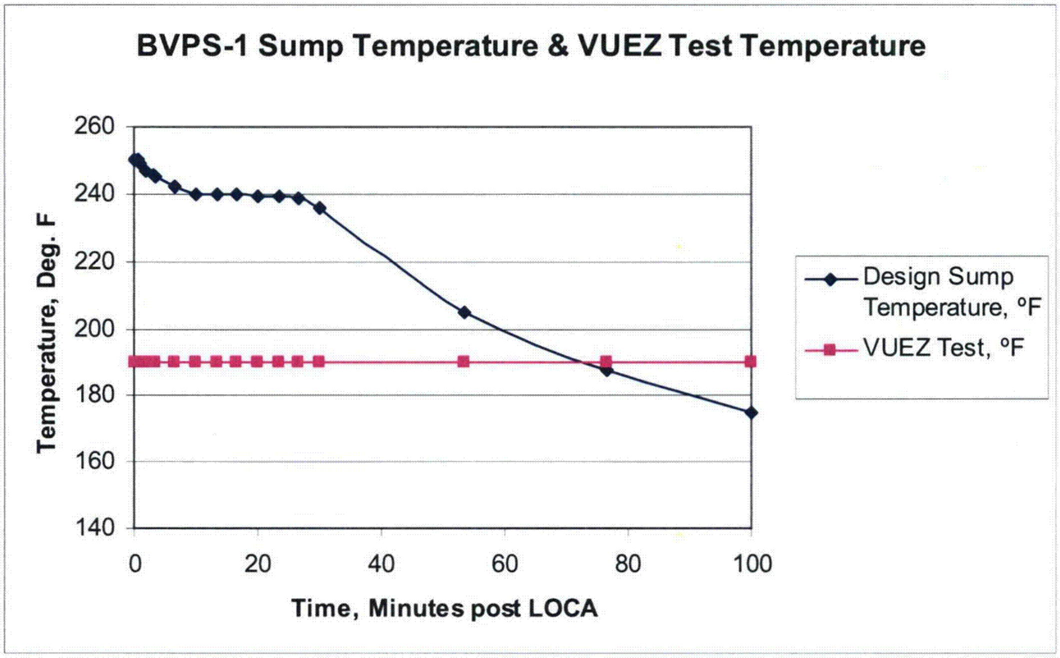
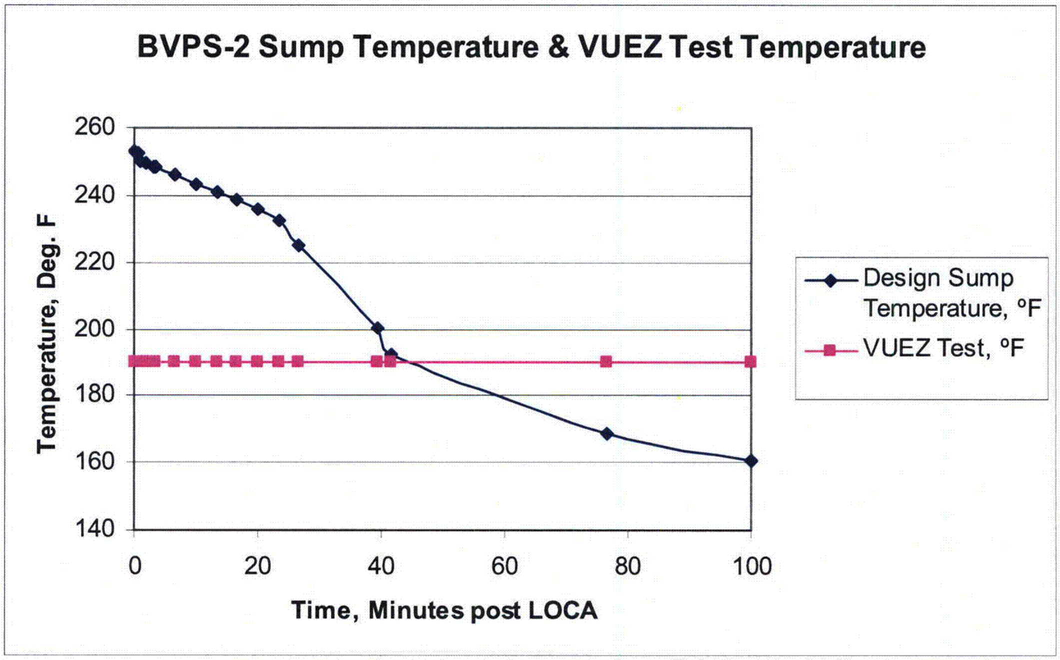


Figure 3.o.2.3-6: BVPS-2 Temperature profiles over the first 100 minutes of post-LOCA event



To account for the elevated corrosion, dissolution, or reaction rates that could occur at the higher temperatures expected from the design temperature data during this period of time, rate expressions were developed as a function of temperature.

In very general terms, the rate of most chemical reactions increases in rate with increases in system temperature. This is due to a minor extent by the increase in collision frequency of molecules in a specific system and to a much greater extent by an increase in the percentage of molecules in a system that have sufficient energy to exceed the activation energy of a particular reaction. This doesn't necessarily apply to reactions which occur essentially instantaneously, such as a precipitation reaction due to ionic reactions in solution; however, it can apply to reactions such as corrosion. Physical chemistry provides a rough approximation of the effect temperature has on general reaction rates. This approximation is that the rate of reaction doubles for every 10 °C (18 °F) increase in temperature.

The rate of corrosion of metal from a solid surface is dependent upon not only the electrochemical reaction which occurs at the metal surface but also the transport of metal ions away from anodic sites and the transport of cathodic reagents to the surface. These transport processes are strongly influenced by the thickness of the diffusion boundary layer, which exists at the metal/liquid interface. The thicker this diffusion layer, the more resistance to transport of the various cathodic and anodic agents from/to the metal surface and subsequently less corrosion would occur. Because the bulk liquid is being slightly agitated and this liquid motion will be present at the surface of the various test materials, the thickness of the boundary layer will be reduced and the effect these processes will have on corrosion rates will be enhanced, such that its influence will approach an asymptotic value under these conditions. Because of this, the electrochemical reaction rates drive the variability of the release rate of material from the metal surfaces. These fundamental electrochemical mechanisms are not expected to change significantly over the temperature range of interest; however, the rates at which they do occur are directly proportional to temperature. It is convenient, then, to normalize these rates of reaction to those expected to occur at 190 °F. This general grouping of reactions would then be assigned a normalized value of 1 at 190 °F. Then, using the aforementioned approximation, the reaction rate would then double or equal 2, at a temperature of 208 °F. Conversely, these normalized general reaction rates would then be 0.5 at a temperature of 172 °F. The resulting relationship is captured graphically in Figure 3.o.2.3-7. An equation representing the resulting relationship is also shown on this graph. Applying this relationship to the design sump temperature profiles and the maximum temperature assumed in the test equipment to characterize the normalized reaction rates, the results can be found in Figure 3.o.2.3-8 and Figure 3.o.2.3-9.

Figure 3.o.2.3-7: Normalized Reaction Rates as a Function of Temperature

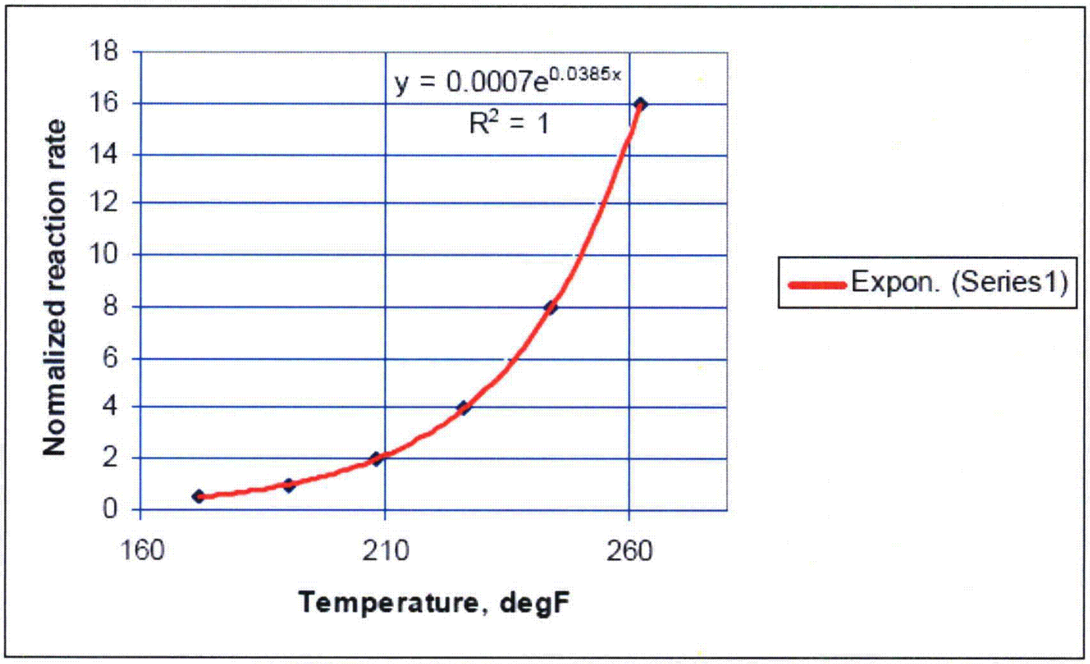


Figure 3.o.2.3-8: BVPS-1 Normalized Reaction Profiles for the Design and Testing

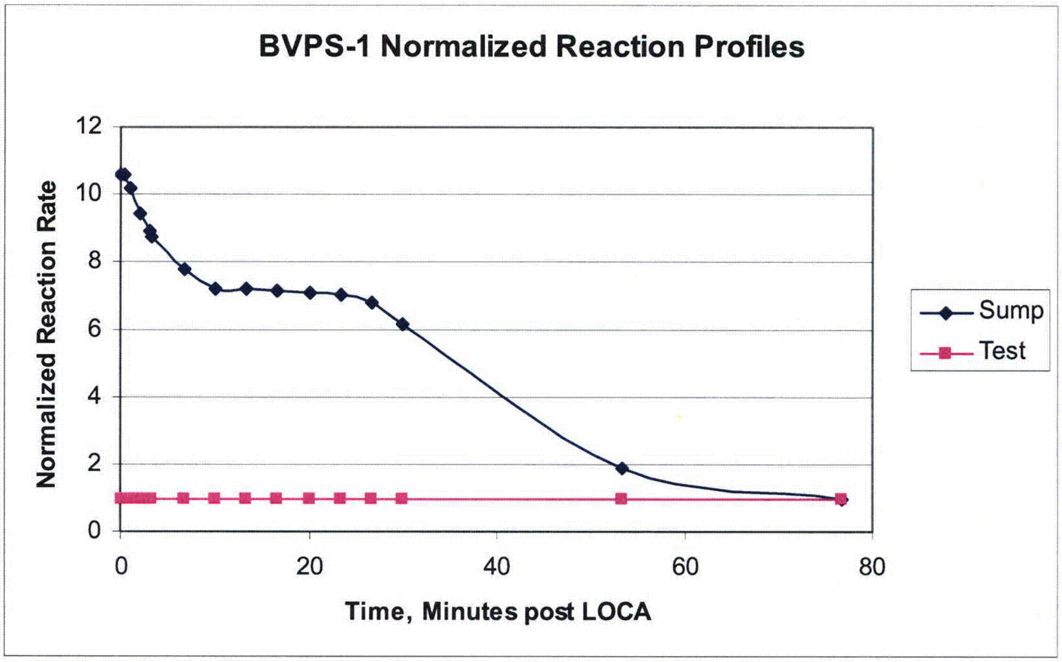
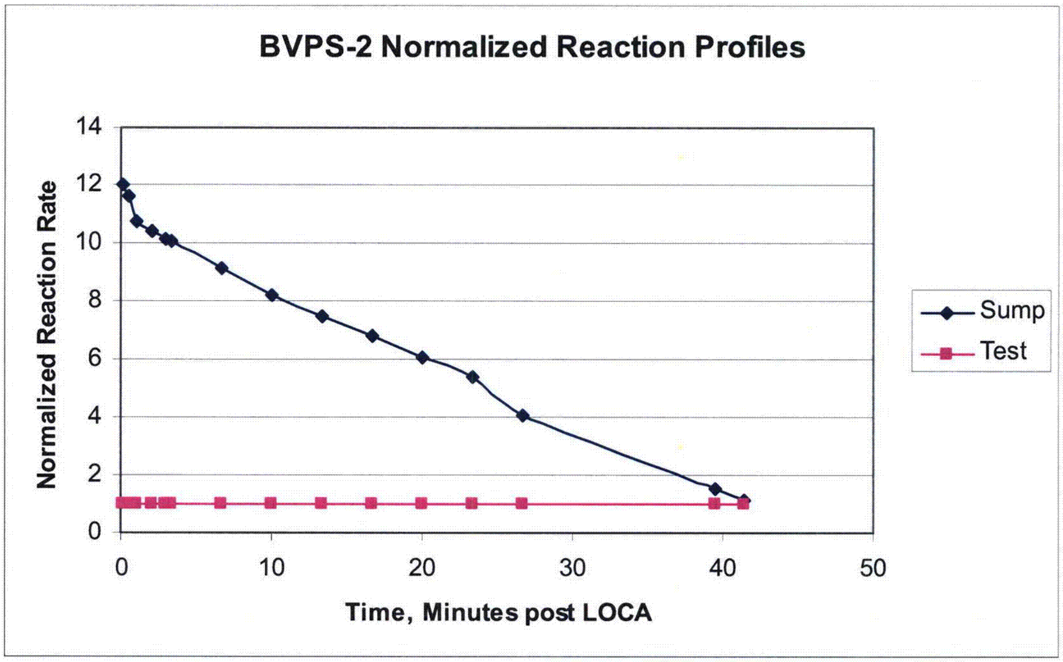


Figure 3.o.2.3-9: BVPS-2 Normalized Reaction Profiles for the Design and Testing

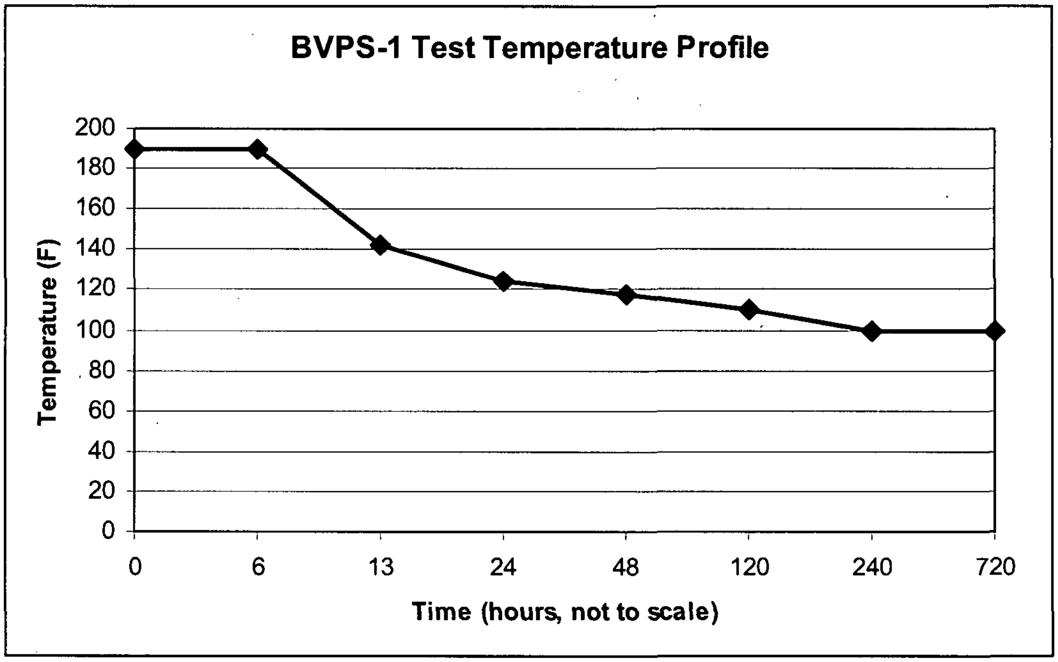


This discussion and the result it had on the test procedure can be summarized as follows:

1) To avoid having to use a pressure vessel to conduct any tests, the temperature limit for any testing was 190° F;
2) By agitating the liquid at a constant velocity, any variability from process conditions on corrosion rates was due to changes in temperature;
3) The electrochemical reaction mechanisms did not differ over the temperature range of interest;
4) The test compensated for using a lower temperature than that specified from design data by extending the amount of time that the system is held at the maximum test temperature (i.e., 190° F).

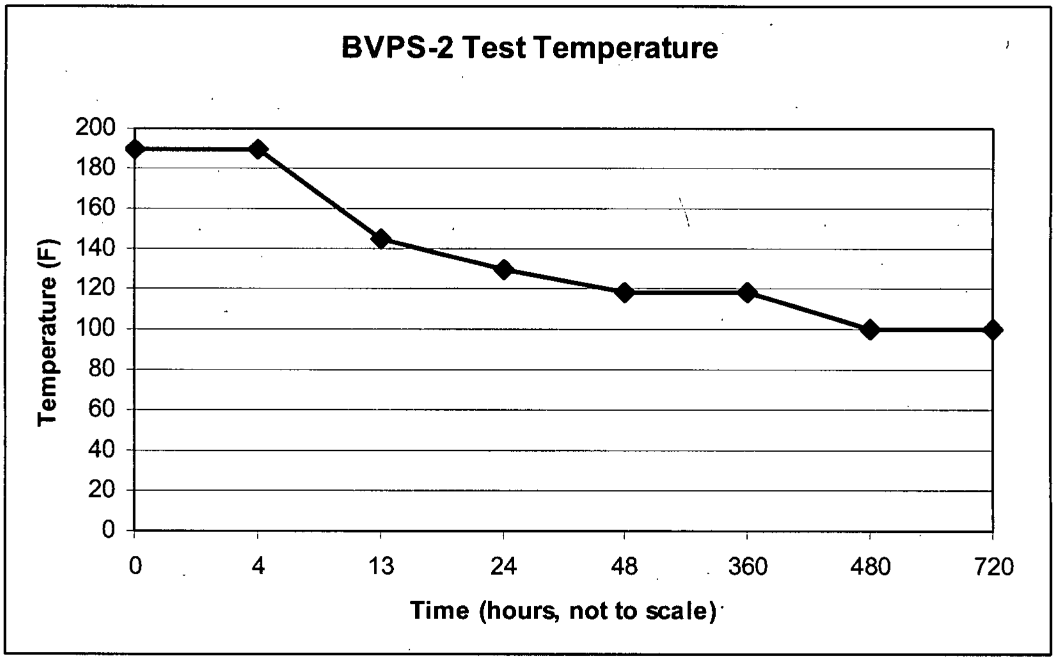
Therefore, the integral of the area for each of these curves is representative of the amount of reaction progress that occurs for each scenario. For BVPS-1, the area under the curve for the design temperature profile is ~351 (minutes), and the area under the curve for the test temperature profile is 77 (minutes). Considering the previous approximations regarding this evaluation, the areas under these two curves would need to be equivalent in order to maintain the same level of reaction progress. This criterion can only be met if the amount of time applied to the lower temperature condition (i.e. the test condition) were extended out another ~274 minutes. Because of this, the overall time for the test was extended out 274 minutes to account for this assumed higher reaction rate at the higher temperatures suggested by the design profile. In addition, for ease of testing, the temperature profile was simplified by reducing the number of data points in order to smooth out some of the minor temperature fluctuations. The temperature profile for the test is shown on Figure 3.o.2.3-10.

Figure 3.o.2.3-10: BVPS-1 Test Temperature Profile



For BVPS-2, the area under the curve for the design temperature profile is ~240 (minutes), and the area under the curve for the test temperature profile is 41 (minutes). Considering the previous approximations regarding this evaluation, the areas under these two curves would need to be equivalent in order to maintain the same level of reaction progress. This criterion can only be met if the amount of time applied to the lower temperature condition (i.e. the test condition) were extended out another ~199 minutes. Because of this, the overall time for the test was extended out 199 minutes to account for this assumed higher reaction rate at the higher temperatures suggested by the design profile. In addition, for ease of testing, the temperature profile was simplified by reducing the number of data points in order to smooth out some of the minor temperature fluctuations. The temperature profile for the test is shown on Figure 3.o.2.3-11.

Figure 3.o.2.3-11: BVPS-2 Test Temperature Profile



Duration of Containment Sprays:

It was assumed that containment recirculation sprays will operate for the full 30 day mission time.

Materials Expected to Contribute to Chemical Effects:

To simulate the various containment materials in BVPS-1 and BVPS-2 and how they influence chemical effects after a Loss of Coolant Accident (LOCA), the materials were divided into the three categories that correspond to exactly where the materials will lie within the test tank: submerged, unsubmerged, and on the sump screen. Submerged materials are insulation and debris that is created by the line break but not transported to the sump. This material does not contribute to sump screen head loss but can affect pool pH and chemical properties. Unsubmerged materials are materials within containment that undergo coolant spray but are above the pool volume. These materials do not contribute to head loss or pool chemistry directly but can affect the pool pH and chemistry due to coolant spray corrosion and run off that enters the containment pool. Materials that reach the sump screen are insulation and debris that are created by the line break and transport to the sump screen via the containment pool recirculation. These materials contribute to the sump screen head loss via bed thickness and porosity.

Different types and amounts of materials are generated by the worst case break in each unit, and are further broken down by the buffer used to raise the Containment sump pool pH, either NaOH or NaTB. The breakdown is detailed on the following four tables:

Table 3.o.2.3-1: BV1 - Full Debris Load w/ NaOH

Exposed Metallics in Pool - Submerged	
Metallic Aluminum	36 ft2
Zinc In Galv. Stl	150000 ft2
Exposed Concrete	7533 ft2
Temp-Mat	32.5 ft3
Exposed Metallics in Spray - Unsubmerged	
Metallic Aluminum	1764 ft2
Unqualified Zinc Coatings	6314.2 ft2
Unqualified Al Coatings	2009.4 ft2
Carbon Steel	7651.7 ft2
Debris Quantities on Sump Screen	
Temp-Mat ft3	21.76 ft3
Latent Fiber ft3	9.8 ft3
Cal-Sil lbs	222.0 ft3
Latent Particulate lbs	134.7 lbs
Qualified IOZ Coatings	147.0 lbs
Qualified 823 Epoxy	798.3 lbs
Qualified High Temp Al	66.0 lbs
Qualified Vi-Cryl CP-10	3.0 lbs
Unqualified IOZ Coatings	8.6 lbs
Unqualified 823 Epoxy	149.4 lbs
Unqualified Alkyd Enamel	50.3 lbs
Unqualified Cold Galv.	11.1 lbs
Chemical Addition	
Boron	2564.5w ppm-B
HCl – hydrochloric acid	133.7 w ppm-HCl
HNO3 – nitric acid	21.5 w ppm-HNO3 - NO3
NaOH	3.0 g/L

Table 3.o.2.3-2: BV1 - Full Debris Load w/ NaTB

Exposed Metallics in Pool - Submerged	
Metallic Aluminum	36 ft2
Zinc In Galv. Stl	150000 ft2
Exposed Concrete	7533 ft2
Temp-Mat	32.5 ft3
Exposed Metallics in Spray - Unsubmerged	
Metallic Aluminum	1764 ft2
Unqualified Zinc Coatings	6314.2 ft2
Unqualified Al Coatings	2009.4 ft2
Carbon Steel	7651.7 ft2
Debris Quantities on Sump Screen	
Temp-Mat ft3	21.76 ft3
Latent Fiber ft3	9.8 ft3
Cal-Sil lbs	222.0 ft3
Latent Particulate lbs	134.7 lbs
Qualified IOZ Coatings	147.0 lbs
Qualified 823 Epoxy	798.3 lbs
Qualified High Temp Al	66.0 lbs
Qualified Vi-Cryl CP-10	3.0 lbs
Unqualified IOZ Coatings	8.6 lbs
Unqualified 823 Epoxy	149.4 lbs
Unqualified Alkyd Enamel	50.3 lbs
Unqualified Cold Galv.	11.1 lbs
Chemical Addition	
Boron	2564.5w ppm-B
HCl – hydrochloric acid	133.7 w ppm-HCl
HNO3 – nitric acid	21.5 w ppm-HNO3 - NO3
Na2B4O7 10H2O	10.9 g/L

Table 3.o.2.3-3: BV2 - Full Debris Load w/ NaOH

Exposed Metallics in Pool - Submerged		
Metallic Aluminum	64.7	ft2
Zinc In Galv. Stl	177166	ft2
Exposed Concrete	7533	ft2
TIW	319.3	ft3
Temp-Mat	9.5	ft3
Exposed Metallics in Spray - Unsubmerged		
Metallic Aluminum	3170.3	ft2
Unqualified Zinc Coatings	36319.9	ft2
Unqualified Al Coatings	8164.8	ft2
Carbon Steel	3125.7	ft2
Debris Quantities on Sump Screen		
TIW	198.0	ft3
Temp-Mat	56.8	ft3
Thermal Wrap	2.0	ft3
Damming Material	0.5	ft3
Latent Fiber	11.3	ft3
Cal-Sil	517.5	ft3
Latent Particulate	156.4	lbs
Qualified IOZ Coatings	166.9	lbs
Qualified Carboline 191 HB	78.7	lbs
Qualified Nutec 11S Epoxy	0.7	lbs
Qualified Nutec 1201 Epoxy	0.6	lbs
Qualified High Temp Si Al	20.4	lbs
Unqualified IOZ Coatings	59.7	lbs
Unqualified Carboline 191 HB	15.7	lbs
Unqualified Alkyd	102.0	lbs
Unqualified Cold Galvanizing	19.5	lbs
Chemical Addition		
Boron	2252.4 w ppm-B	
HCl – hydrochloric acid	30.5 w ppm-HCl	
HNO3 – nitric acid	13.5 w ppm -HNO3	
NaOH	3.3 g/L	

Table 3.o.2.3-4: BV2 - Full Debris Load w/ NaTB

Exposed Metallics in Pool - Submerged	
Metallic Aluminum	64.7 ft2
Zinc In Galv. Stl	177166 ft2
Exposed Concrete	7533 ft2
TIW	319.3 ft3
Temp-Mat	9.5 ft3
Exposed Metallics in Spray - Unsubmerged	
Metallic Aluminum	3170.3 ft2
Unqualified Zinc Coatings	36319.9 ft2
Unqualified Al Coatings	8164.8 ft2
Carbon Steel	3125.7 ft2
Debris Quantities on Sump Screen	
TIW	198.0 ft3
Temp-Mat	56.8 ft3
Thermal Wrap	2.0 ft3
Damming Material	0.5 ft3
Latent Fiber	11.3 ft3
Cal-Sil	517.5 ft3
Latent Particulate	156.4 lbs
Qualified IOZ Coatings	166.9 lbs
Qualified Carboline 191 HB	78.7 lbs
Qualified Nutec 11S Epoxy	0.7 lbs
Qualified Nutec 1201 Epoxy	0.6 lbs
Qualified High Temp Si Al	20.4 lbs
Unqualified IOZ Coatings	59.7 lbs
Unqualified Carboline 191 HB	15.7 lbs
Unqualified Alkyd	102.0 lbs
Unqualified Cold Galvanizing	19.5 lbs
Chemical Addition	
Boron	2252.4 w ppm-B
HCl – hydrochloric acid	30.5 w ppm-
HNO3 – nitric acid	13.5 w ppm -HNO3
Na2B4O7 10H2O	10.9 g/L

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

Beaver Valley chemical effects testing was performed by Alion at the VUEZ facility ELISHA test loops in Slovakia.

2.5 Separate Effects Decision (Decision Point)
i. State which method of addressing plant-specific chemical effects is used.

FENOC Response

Requested Response is not applicable to BVPS (Alion Testing)

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 BVPS (Alion Testing)

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

Requested Response is not applicable to BVPS (Alion Testing)

2.8 WCAP Refinements: State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

FENOC Response

Requested Response is not applicable to BVPS (Alion Testing)

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

Requested Response is not applicable to BVPS (Alion Testing)

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

Requested Response is not applicable to BVPS (Alion Testing)

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

Requested Response is not applicable to BVPS (Alion Testing)

2.12 Pre-Mix in Tank
i. Licensees should discuss any exceptions taken to the procedure recommended for surrogate precipitate formation in WCAP-16530.

FENOC Response

Requested Response is not applicable to BVPS (Alion Testing)

2.13 Technical Approach to Debris Transport (Decision Point)
i. State whether near-field settlement is credited or not.

FENOC Response

Requested Response is not applicable to BVPS (Alion Testing)

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

Requested Response is not applicable to BVPS (Alion Testing)

2.15 Head Loss Testing Without Near Field Settlement Credit
i. Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable.
ii. Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).

FENOC Response

Requested Response is not applicable to BVPS (Alion Testing)

2.16 Test Termination Criteria
i. Provide the test termination criteria.

FENOC Response

Requested Response is not applicable to BVPS (Alion Testing)

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

Requested Response is not applicable to BVPS (Alion Testing)

2.18 Integral Generation (Alion)
i. A sufficient technical basis is developed to support selecting plant-specific test parameters that produce a conservative chemical effects test

ii. Inability to reach peak sump temperatures is offset by extended testing at highest loop temperatures.

FENOC Response

i. The technical basis for the selection of plant specific parameters for Beaver Valley chemical effects testing has been given as a response to question 2.3, which details the selection of the pH profile, temperature profile, spray duration, and materials expected to contribute to chemical effects.

ii. The Beaver Valley chemical effects testing sump temperature profile, which offsets the inability to reach peak sump temperatures by extended testing at elevated temperatures, is detailed in the response to question 2.3, part b).

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. For chemical effects testing, two scaling factors were utilized based on screen area and sump pool volume. The area scaling factor was used to scale debris quantities at the sump screen, and the volume scaling factor was used to scale debris submerged in the sump pool (but not on the screen) and debris in the spray (un-submerged).

The screen area scaling factor was determined based on the ratio of the test screen area to the plant replacement strainer screen area (minus latent blockage due to tags and labels) in order to produce a debris bed on the test screen with a bed thickness representative of the debris bed on the actual plant strainer. The area scaling factor was also used to scale the test flow rate in order to produce an approach velocity through the test screen representative of the actual approach velocity through the plant strainer. For BVPS-2, the area scaling ratio was equal to: 0.0897 ft^2 / 2833 ft^2 = 3.17E-05.

The volume scaling factor was determined based on the ratio of the volume of the test loop (59 L) to the minimum plant sump pool volume. The minimum pool volume is used to conservatively maximize the materials that could interact within the containment solution. For BVPS-2, the volume scaling ratio was equal to: 2.0836 ft^3 / 101069 ft^3 = 2.06E-05.

The test screen area was selected to achieve close correlation between the area scaling ratio and the pool volume scaling ratio; however the test screen area was limited, and the area and volume scaling ratios could not be matched exactly. For BVPS-2 the difference between the scaling ratios yielded an overly conservative value of fiber in the test. To compensate for this, an amount of fiber was subtracted from the submerged portion, based on the difference in the two scaling ratios and the amount of screen fiber for each BVPS-2 case. The fiber that was subtracted was calculated as follows:

2.06E-05 – 3.17E-05 = -1.10E-05
-1.10E-05* (BVPS-2 volume of fiber on screen) * (fiber density)

This term yielded the amount of fiber that was subtracted from the submerged portion of fiber to account for the larger screen scaling ratio and allow the proper amount of fiber in the pool for chemical effects.

ii. For BVPS-1, prototype testing with WCAP-16530 precipitant loads is planned. The test plan and test report for this testing will address tank scaling/bed formation.

For BVPS-2, comparing the array non-chemical prototype debris head losses with the flat plate debris head losses without chemical effects illustrates the impact of strainer geometry and non-uniform flow fields on debris accumulation and resulting head loss. The impact of chemical effects alone is seen through a comparison of flat plate debris head losses with and without chemical effects. The debris preparation protocol and debris bed formation protocol ensured to the extent possible that the debris size distribution is representative and the bed is formed homogenous and representative of that on the prototype array.

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. Prior to addition of materials, debris and chemicals, the required quantity of boric acid was introduced to the test loop water and the loop was operated for a period of time equivalent to 1 pool turnover. This ensured thorough mixing of the boric acid which is representative of the condition of the coolant in the plant.

The submerged materials in the sump water (not on the screen) were added to test loop either as metal coupons or as insulation contained in stainless steel (SS) wire mesh that allowed water to flow through the various samples while confining the material. The metal coupons and material in baskets were added in such a manner that no stagnant pockets were formed. The arrangement of the submerged materials was representative of plant conditions because it allowed the test loop water to freely circulate around and interact with the submerged materials without allowing any submerged material to transport to the screen.

For the test cases where the passive buffer (Sodium Tetraborate (NaTB)) was used, the unsubmerged materials (in the sprays) were added to the test loop in the same manor as the submerged materials described above. This is representative of plant conditions because in the plant the buffer would be located in baskets in the sump and would be dissolved in the containment pool, and after the start of recirculation the spray pH would be equal to the sump pH.

For test cases where the active buffer (Sodium Hydroxide (NaOH)) was used, a portion of the test loop fluid was removed after the boron addition and prior to material addition, and placed in separate containers. To the fluid of these containers NaOH was added to raise the pH to the level of the spray pH. The materials exposed to the spray were submerged into the fluid for the time interval from the start of the event until the start of recirulation. At the start time of recirculation the unsubmerged materials were placed in the test loop in the same manor as submerged materials for the remainder of the test. This is representative of plant conditions because the active buffer is added to the spray at the beginning of the event and therefore materials in the spray are exposed to the high pH value until recirculation starts at which point the spray pH is equal to the sump pH.

The quantities of debris materials on the screen were scaled based on quantities that reach the sump screen as indicated in the debris transport calculation. For debris addition, a portion of the hot fluid from the tank being loaded was removed and placed into a container. Then the scaled quantity of debris reaching the strainer was introduced into the container with the hot fluid. The debris in the container was thoroughly mixed for at least 5 minutes. The debris slurry was then introduced to the test apparatus screen such that all the debris could distribute across the screen while avoiding bypass from the screen area. This was representative of plant conditions because it ensured that all of the debris reached the test screen and formed an even homogenous debris bed.

The buffer and remaining acids (Hydrochloric (HCl) and Nitric (HNO3)) were added to the test loop in a manner and location within the test apparatus such that localized elevated pH levels did not temporarily occur near the debris samples. Buffer addition and dissolution were carefully performed and monitored to ensure the target pH was attained. This was representative on plant conditions because the size of the sump pool and nature of buffer addition (either by sprays for active system, or by dissolution of passive buffer in baskets in the sump) and acid generation are such that large localized chemical concentrations are not likely to occur near debris in the pool.

2.21 30-Day Integrated Head Loss Test

i. Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.

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

FENOC Response

i. The BVPS chemical assessment considered the same basic environmental conditions as that of the previous USNRC/EPRI sponsored ICET project and the PWROG WCAP-16530 program. The sump chemistry considered ~2600 mg/L of boron, hydrochloric acid (HCl), nitric acid (HNO_3) along with the appropriate amount of buffer (added at the appropriate time). Lithium Hydroxide was not added due to the extremely low concentrations seen at BVPS-1 and BVPS-2. By performing tests using both BVPS-1 and BVPS-2 conditions, a broad range of chemical and material conditions were investigated. It should be noted that additional BVPS-1 testing will be conducted using a prototype strainer with WCAP-16530 precipitant loads. Chemical concentrations are shown in Tables 3.o.2.21-1 and 3.o.2.21-2 for BVPS-1 and BVPS-2, respectively.

Table 3.o.2.21-1: Chemical Compound Concentrations of the BVPS-1 Containment Pool

Chemical	Atomic Weight (AU)	Concentration (M/L)	(ppm)
HCl	36.46	0.003666	133.7
HNO_3	63	0.000342	21.5
Boron	10.81	N/A	2564.5

Table 3.o.2.21-2: Chemical Compound Concentrations of the BVPS-2 Containment Pool

Chemical	Atomic Weight (AU)	Concentration (M/L)	(ppm)
HCl	36.46	0.001097	30.5
HNO_3	63	0.000282	13.5
Boron	10.81	N/A	2252.4

Separate tests were conducted using both NaOH and NaTB as pH buffers. The pH profile was based on the maximum calculated long term sump pH values for BVPS-1 and BVPS-2. After 30 minutes it was not feasible to adjust the pH profile over the length of the test, due to the numerous variables that could affect precipitate formation and actual sump pH over time. Therefore, a fixed pH was used. Maximum pH values were used for testing because higher pH results in a higher reaction rate with the main source of problematic precipitates (aluminates), especially at elevated temperatures. Although a lower pH could reduce the solubility of these precipitates slightly, this effect was more than offset by the higher quantities of precipitate forming materials using the higher pH. The BVPS-1 pool pH was established at 8.79 and the BVPS-2 pool pH was established at 9.03.

The effects of spray water pH were considered as well. For the tests involving NaOH, the initial spray water pH would be greater than that of the recirculation pool until recirculation started. To ensure that this effect was captured, a scaled quantity of containment materials exposed to spray was initially placed in a separate bath of water with a pH of 10.1 to simulate the injection phase. The baths were maintained at the high pH for the calculated time to recirculation; 30 minutes for BVPS-1 and 40 minutes for BVPS-2. When the unsubmerged materials had reached the specified time, the materials and the water from the high pH bath were introduced to the tank to simulate the onset of recirculation and the equalization of sump and spray pH. Adding the materials and water from the high pH bath ensured that any precipitate components dissolved in the high pH bath water or deposited on the sample coupons was introduced to the recirculation pool for accumulation on the test debris bed.

For the NaTB test, unbuffered borated water was introduced to the material coupons and debris bed at the start of the test and the low pH condition was maintained until the recirculation time was reached. This ensured that any corrosion products generated by a low pH environment would be captured in a manner similar to the actual BVPS environment. The buffer was then added at the end of the injection period to simulate the effects of dissolving and mixing the pH buffer with the sump water.

The temperature profile was developed to represent the worst case condition, of high temperature over the 30-day test period. Because the test rig could not produce temperatures greater than 190°F, the recirculation pool was maintained at approximately 190°F for a period of time that would produce a similar quantity of dissolved reactants to that which would be generated by the higher initial temperature conditions. Temperature was then allowed to fall using a profile that assured conservatively high pool temperatures for the early phase of the test. Using longer periods at high temperatures maximizes the reaction rates to release the largest amount of reactants to the pool water. Later in the experiment, the pool temperature was lowered to 100°F to ensure that the lower solubility of some reactants at low temperature was accounted for.

The materials within the chemical environment considered were aluminum, zinc, carbon steel, and concrete as well as all post-LOCA debris materials (settled and transported to the sump). The containment materials at BVPS-1 and BVPS-2 were divided into the three locations relative to the sump pool: submerged, unsubmerged (above flood plane), and on the sump screen. Submerged materials are insulation and debris that are created by the line break but not transported to the sump as well as structural materials within containment below the flood plane. Unsubmerged materials are materials within containment that undergo containment spray but are above the pool flood plane. Tables 3.o.2.3-1 and 3.o.2.3-2 provide the submerged and unsubmerged materials for BVPS-1 and Tables 3.o.2.3-3 and 3.o.2.3-4 provide the submerged and unsubmerged materials for BVPS-2.

Materials that reach the sump screen are insulation and debris that are created by the line break and transport to the sump screen via the containment pool recirculation. These materials contribute to the sump screen head loss and are the non-chemical debris load. Because the BVPS-1 maximum debris load result in a high particulate to fiber ratio, while the BVPS-2 debris load results in the largest fiber load, along with a significantly higher quantity of particulate, the maximum debris loads for each unit were chosen to represent a range of debris bed conditions that would bound most debris conditions at either unit.

The two controlling loads were defined as follows:
Cases 1 & 2: BVPS-1 Full Debris Load (High Particulate to Fiber ratio)
Cases 3 & 4: BVPS-2 Full Debris Load (Maximum Fiber and Particulate load)

Cases 1 & 3 used NaOH for a buffer and Cases 2 & 4 used NaTB as a buffer.

Tables 3.o.2.3-1, -2, -3 & -4 show the debris loads used for the various cases. These debris loads were then scaled to the test facility strainer area.

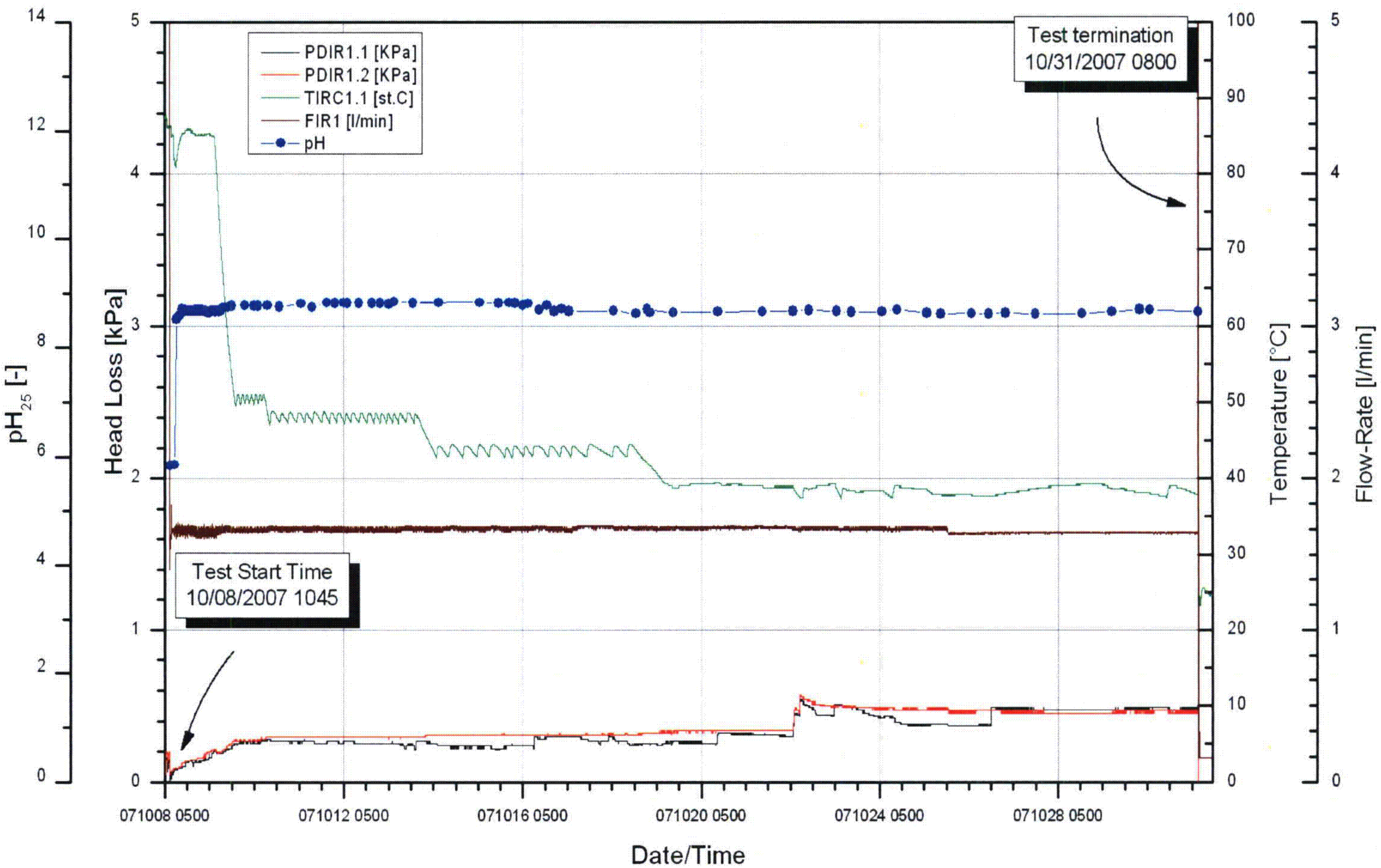
In summary, the 30-day chemical effects test conditions were designed to maximize the potential for head loss by conservatively assuming worst case pH and temperature profiles, maximum debris and chemical constituents, and both thin bed and maximum load debris bed thicknesses. The tests were conducted to evaluate the effects of both NaOH and NaTB on precipitate formation.

ii. Testing was performed using four separate cases.
Cases 1 & 2: BVPS-1 Full Debris Load (High Particulate to Fiber ratio)
Cases 3 & 4: BVPS-2 Full Debris Load (Maximum Fiber and Particulate load)

Cases 1 & 3 used NaOH for a buffer and Cases 2 & 4 used NaTB as a buffer.

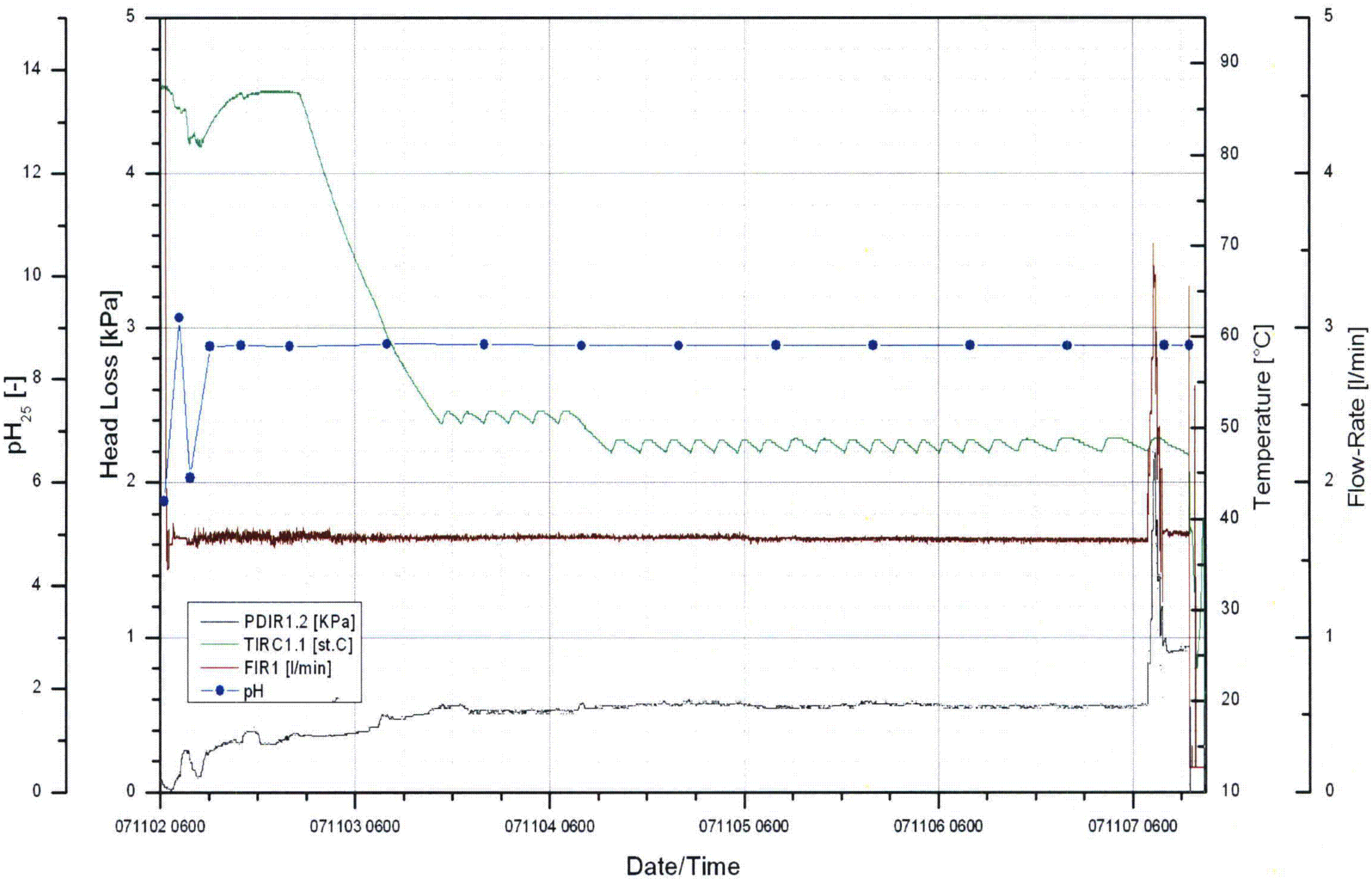
Each case produced a separate pressure drop curve as shown in Figures 3.o.2.21a-1 through 3.o.2.21a-5. It should be noted that for Case 1, two figures are presented. The initial test (Case 1R), illustrated by figure 3.o.2.21a-1 was terminated after approximately 20 days, due to an anomaly observed in the debris bed. The anomaly was corrected; however, a follow-up test for Case 1 (Case 1R2) was then performed to verify that the results from the initial test could be used. This follow-up test illustrated by figure 3.o.2.21a-2 lasted approximately 10 days. A brief summary of each case is provided following the illustration.

Figure 3.o.2.21a-1: Case 1R Head Loss Evolution



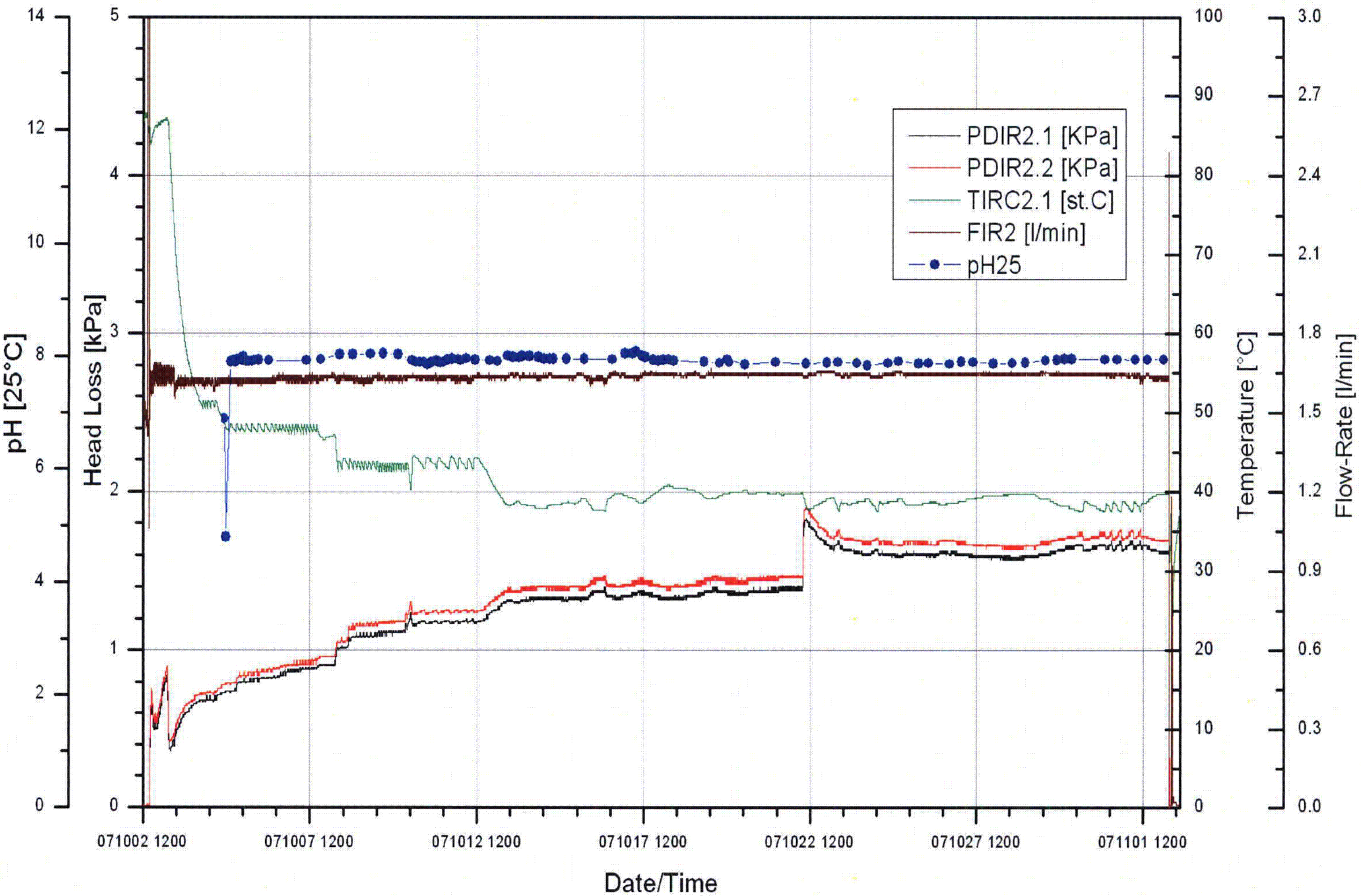
Case 1R demonstrated the conditions associated with BVPS-1 thin bed and NaOH buffer. No chemical precipitation effects were noted in the test. On 10/22/07, it was observed that a small gap was developing in the debris bed. Some fiber was re-positioned to ensure that the gap was closed. This resulted in the step change in pressure drop seen at that time.

Figure 3.o.2.21a-2: Case 1R2 Head Loss Evolution



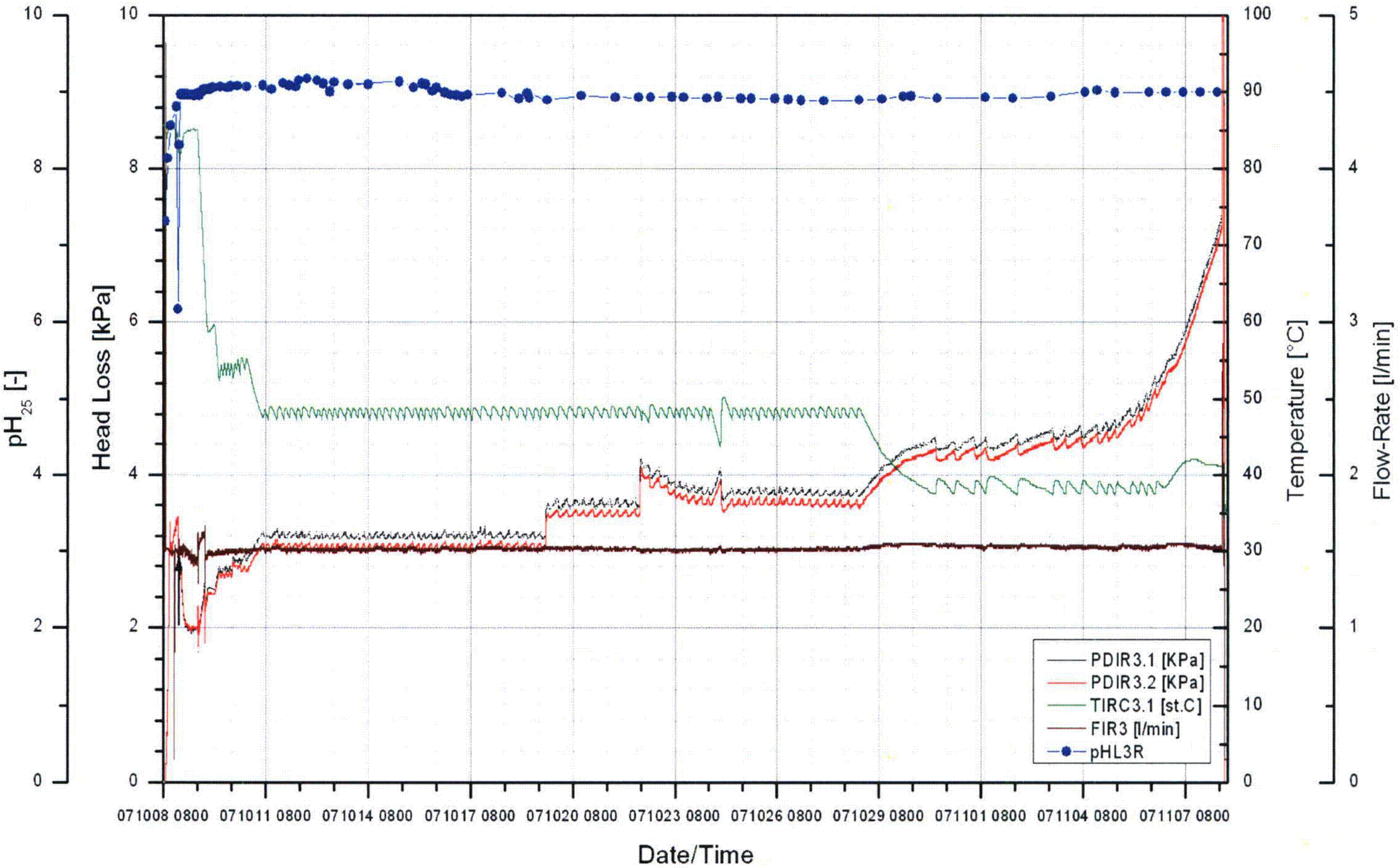
Case 1R2 was performed to demonstrate that the head loss associated with test 1R was consistent with the "repaired" debris bed's head loss. No chemical precipitation effects were noted in the test. Test results for Case 1 were inconclusive and will be used for comparison purposes only. BVPS-1 testing will be performed using a prototype strainer and WCAP-16530 generated precipitates.

Figure 3.o.2.21a-3: Case 2 Head Loss Evolution



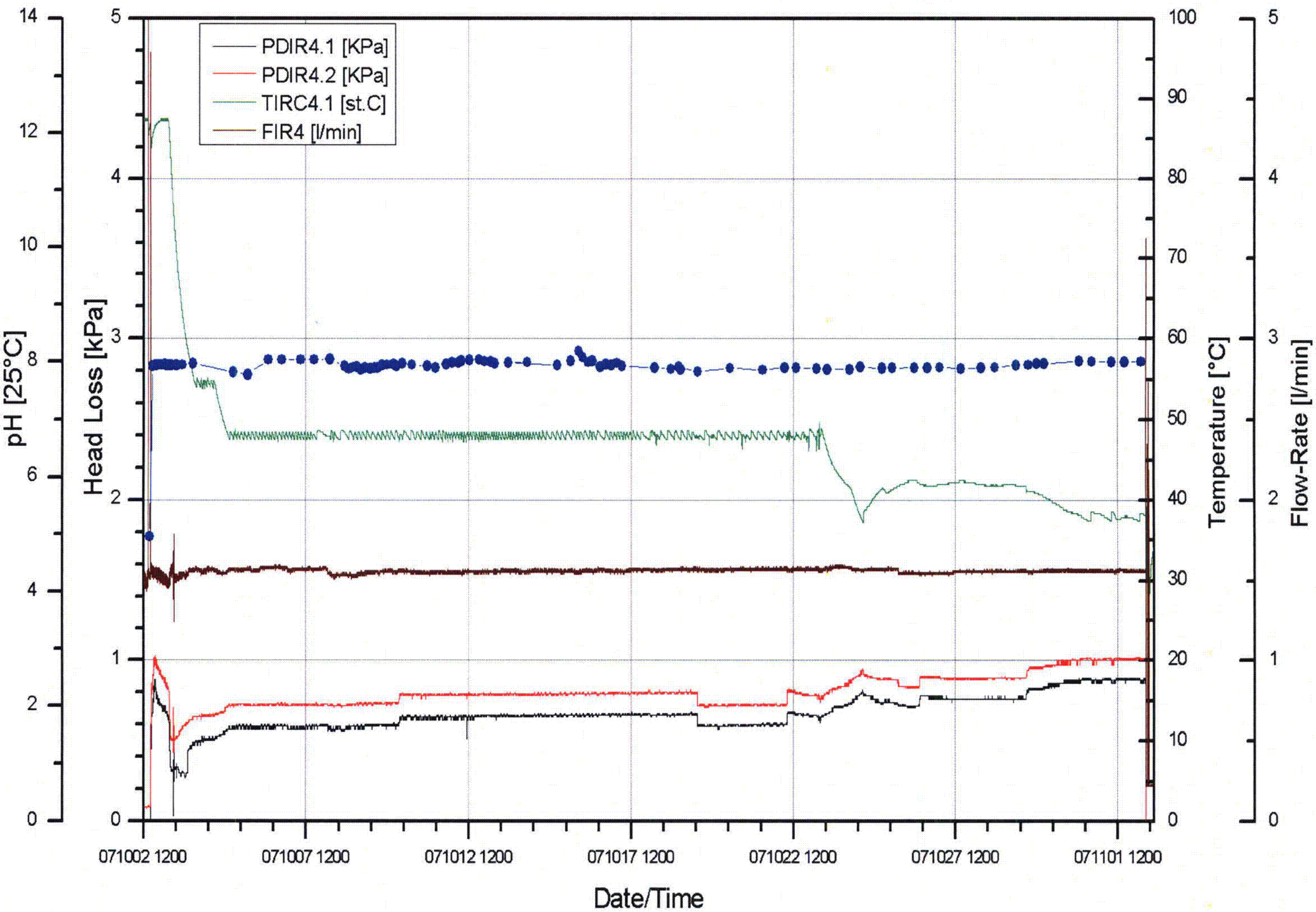
Case 2 demonstrated the conditions associated with BV-1 thin bed and NaTB buffer. No chemical precipitation effects were noted in the test. On 10/22/07, a sudden increase in pressure drop was observed. This increase is consistent with a debris bed shift, possibly caused by fibrous debris bed settling as the bed aged. Head loss then stabilized for the remainder of the test. The results of this test are used in the evaluation of NaTB as a replacement buffer for BVPS-2. They will not be applied to BVPS-1.

Figure 3.o.2.21a-4: Case 3 Head Loss Evolution



Case 3 demonstrated the conditions associated with BVPS-2 full load debris bed and NaOH buffer. On two occasions, sudden increases in pressure drop were observed. These increases are consistent with a debris bed shift, possibly caused by fibrous debris bed settling as the bed aged. Head loss then stabilized until temperature was reduced below 48°C (approx. 118°F). At that point, pressure drop began to increase independent of temperature and with a slope indicative of chemical precipitate formation. Based on wet chemistry results, it was concluded that precipitation began to occur at a temperature of 125 - 130°F. However, the amount of precipitate collected on the debris bed did not begin to affect pressure drop until temperature was reduced below 118°F.

Figure 3.o.2.21a-5: Case 4 Head Loss Evolution



Case 4 demonstrated the conditions associated with BVPS-2 full load debris bed and the NaTB buffer. No evidence of chemical precipitate formation was noted in the test. The increase in pressure drop seen over the duration of the test appears consistent with a viscosity increase due to lowering temperatures. In combination with the results from Case 2, the results of this test are used in the evaluation of NaTB as a replacement buffer for BVPS-2.

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. FENOC has determined that precipitate formation at BVPS-2, using sodium hydroxide as a buffer, may occur when the temperature falls below 130°F. Once precipitate formation begins to occur, head loss continues to increase and does not stabilize.

The results of the 30-day chemical effects testing using NaTB as a buffer indicate that there is no evidence that chemical precipitate formation occurred. FENOC is in the process of developing a LAR to change the buffer at BVPS-2 to NaTB, as noted in FENOC letter L-08-054 (Reference 20).

In order to account for testing uncertainties, additional conservatism may be applied. This will be addressed in the revised supplemental response.

However, the testing with BVPS-1 specific debris loads was inconclusive as to the potential for precipitate formation. FENOC has decided to perform further chemical effects testing using a prototype strainer with WCAP-16530 chemical precipitate loads to verify that head loss remains within acceptable range.

The NRC, in its letter to FENOC dated February 9, 2006 (Reference 14), requested BVPS to provide additional information relative to Generic Letter 2004-02. Additional information is presented for the following RAIs pertaining to chemical effects at BVPS-1 and BVPS-2. The format for the response first includes the request itself and is then followed up by the specific response.

RAI #5 (from Reference 14)
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, Accumulators, and Boron Injection Tank (BIT) (BVPS-1 only) are all assumed to be at their maximum boron concentration and maximum delivered volume; the RWST 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, Accumulators, and Boron Injection Tank (BIT) (BVPS-1 only) are all assumed to be at their minimum boron concentration and minimum delivered volume; the RWST is assumed to be at its maximum NaOH concentration and maximum delivered volume.

BVPS-1

Minimum Sump pH	7.80
Maximum Sump pH	8.79

BVPS-2

Minimum Sump pH	8.14
Maximum Sump pH	9.03

With the corrective actions planned for changing the BVPS-2 buffer from injected sodium hydroxide to sodium tetraborate stored in baskets in containment, the values for BVPS-2 are subject to change after implementation of the buffer modification. As noted in FENOC letter L-08-054 dated February 14, 2008 (Reference 20), a LAR will be submitted for the buffer change by August 30, 2008.

RAI # 6 (from Reference 14)

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	MIN	MAX	MIDPOINT	MIN	MAX	MIDPOINT
pH	9.80	7.80	8.79	8.30	8.14	9.03	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% Calcium Silicate (Cal-Sil) and 20% fiberglass. BVPS-1 ranges from 100% fiberglass, 0% Cal-Sil to 79% fiberglass, 21% Cal-Sil, depending on the break location. BVPS-2 ranges from 100% fiberglass, 0% Cal-Sil to 94% fiberglass, 6% Cal- Sil, depending on 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.

RAI # 8 (from Reference 14)
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 and BVPS-2 overall strategies to evaluate chemical effects. Chemical effects testing has resulted in corrective actions required. Schedules for these corrective actions are provided in FENOC letter L-08-054 dated February 14, 2008.

RAI #9 (from Reference 14)
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

The following materials are planned to be removed from the BVPS-2 Containment Building during the scheduled Spring 2008 outage (2R13):

1) The existing "Borated Temp Mat" encapsulated Reflective Metal Insulation (RMI) on the Reactor Vessel Closure head (RVCH) flange will be replaced with RMI insulation.

2) The existing "Min-K™" encapsulated in RMI in portions of the Reactor Coolant System (RCS) piping and Safety Injection System (SIS) piping will be replaced with "Thermal Wrap" insulation encapsulated in RMI.

The buffer for BVPS-2 will be changed from sodium hydroxide to sodium tetraborate. The details and schedule for implementation of corrective actions are included in FENOC letter L-08-054 (Reference 20).

RAI #*10* (from Reference 14)

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 VUEZ test loops in Slovakia where the Beaver Valley Integrated Chemical Effects Testing was carried out. The design of the loop, with a horizontal strainer, allows all of the debris mix and chemical precipitates to be placed directly on the strainer suction. This orientation is highly conservative with respect to the actual in-plant strainers, which are vertically oriented, and are much less likely to have large quantities of debris adhere to their suctions at the low flowrates involved. The VUEZ test loops are also temperature controlled; with temperature playing a key role in the formation of precipitates, the VUEZ test loops can be made to follow a temperature profile that more closely resembles the prototypical post-LOCA cooldown of the containment sump pool than test facilities that are always at constant temperature, such as the ICET facilities. Finally, the Beaver Valley Integrated Chemical Effects testing was carried out for the full 30 day duration (strainer operation mission time), so that no extrapolation errors are present in developing the expected strainer head loss over the total expected mission time. These conservatisms, coupled with plant improvements such as the installation of large surface area containment sump strainers should offset any uncertainties in the Chemical Effects testing results.

RAI # 11 (from Reference 14)

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

Beaver Valley Integrated Chemical Effects testing was conducted during the fall of 2007 by Alion Science and Technology at the VUEZ facility in Slovakia. BVPS-1 test results were inconclusive, and as such, Alion will be conducting follow-up testing for BVPS-1 using WCAP-16530-NP methodology in the spring of 2008.

BVPS-2 Integrated Chemical Effects Testing was conducted in a vessel (with an integral test loop) with representative structural materials, insulation and debris samples included in the simulated containment environment, their quantities scaled to preserve (to the extent possible) the BVPS-2 specific conditions. Representative debris samples were placed in the vessel in a chemically non-reactive container that allows water to flow in the region of the samples while confining the material. Test conditions, i.e., material quantities and containment environment were BVPS-2 specific and chosen to be conservative from a chemical effects perspective. Two separate tests were carried out in different vessels: one with Sodium Hydroxide buffer, and one with Sodium Tetraborate buffer.

The test tank has appropriate temperature control such that temperatures of the simulated sump fluid follow the time-temperature profile that match the plant estimated temperature profile to within ±5 °F. The maximum temperature of the test tank is 190°F. The experiment temperature profile was modified to account for the release of materials associated with the early portion of the accident where the plant sump temperature is in excess of 190°F. The test temperature profile ranged from 190°F at the beginning of the test to 100°F at the conclusion of the 30 day test.

The initial make-up of the solution within the tank replicates that which is assumed to occur at the start of a post-LOCA event. The water in the tank was borated to 2250 ppm Boron, for a resultant pH of 4.84. Buffer was added to the test tank at an appropriate conservative rate as it is expected to be introduced into the containment environment, over a 30-minute period. For testing with NaOH buffer, the resultant pH was 9.03; for testing with NaTB buffer, the resultant pH was 8.00. Once the scaled amount of buffer was added, no further pH adjustment was made, i.e., system pH was not artificially maintained at a certain level, but instead allowed to seek its own equilibrium level due to corrosion, etc., to be as representative as possible of actual events during post-LOCA; pH is monitored. Based on bench-top experiments and ICET results, pH does not change appreciably throughout the 30 day experiment.

Within the test tank is a screen that was loaded with appropriately scaled quantities of the plant specific debris mixture. The fluid was circulated through the debris bed at the same approach velocity as the new strainer approach velocity. Head loss measurements across the debris bed were recorded continuously for the duration of the experiment.

The test tank chemistry, temperature, and flow rate were calculated to approximate post-LOCA containment sump conditions as closely as possible. Test tank pH was biased to the high end of the band to conservatively facilitate Aluminum dissolution; test tank temperature was held above the expected temperature profile for an extended period to compensate for the inability to duplicate the high sump temperatures (~250°F) that occur early in the accident sequence, and the temperature was lowered toward the end of the thirty day test period to conservatively enhance Aluminum precipitation.

The differences between the post-LOCA containment sump conditions and the test tank conditions are so small as to make any differences in their effects on surrogate materials inconsequential. Surrogates were used in the BVPS-2 Integrated Chemical Effects Testing in lieu of the following debris sources:

- Dirt/Dust
- Qualified and Unqualified Coatings
- Latent Fiber
- Containment Concrete

Dirt/Dust - The containment dirt/dust is represented by a debris mixture of 70% dirt and 30% iron oxide. This surrogate material has a lower density (133 lb/ft3) than the prescribed dirt mix (169 lb/ft3) used in head loss testing. In order to ensure that full representation of chemical activity occurs in the test loop, the scaled quantity of containment dirt/dust is represented by the same mass of dirt/dust surrogate. This would yield a slightly conservative mass of dirt/dust surrogate based on the difference in densities of dirt/dust in containment and dirt/dust surrogate. This mix meets the particle size distribution and chemical element composition as defined in NUREG/CR-6877, "Characterization and Head Loss Testing of Latent Debris from Pressurized Water Reactor Containment buildings", July 2005.

Qualified and Unqualified Coatings - Unqualified alkyd, epoxy, and aluminum coatings and qualified epoxy coatings are represented by chemically inert silicon carbide surrogate with a density of 199 lbs/ft3 and a particle size of 10 microns. The unqualified and qualified coatings are scaled by the appropriate scaling factor, and then adjusted by the density of the material and the density of the surrogate. This calculates the proper weight of the surrogate that must be used in order to represent each coating.

Metallic Materials - Metallic materials that are exposed to spray, aluminum, zinc, and carbon steel, are represented in the test with those metals in the form of thin plates. The plates were submerged in the test water for the duration of the testing.

Latent Fiber - The thermal wrap, damming material, and latent fiber were represented using NUKON, as was recommended in NUREG/CR-6877, "Characterization and Head Loss Testing of Latent Debris from Pressurized Water Reactor Containment Buildings," July 2005, based on density comparisons. NUKON has a density of 2.4 lb/ft3 and a fiber diameter of 7 microns.

Containment Concrete – Per Pressurized Water Reactor Owner's Group (PWROG) Letter OG-07-129, Response to the NRC Second set of Requests for Additional Information (RAIs) on WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191", Revision 0, February 2006, dated 4/3/07. RAI #5, comparisons of detailed concrete specifications are deemed unnecessary with respect to dissolution in sump fluid. Concrete dissolution is determined by surface area. Therefore, commercial grade concrete was employed in the BVPS-2 Integrated Chemical Effects Tests. The concrete supplied is a cure spare (compression test) specimen consisting of a mixture of aggregate and Portland cement manufactured in accordance to ASTM C494 specifications. The properties of commercial-grade cement (such as density, incorporation of small slag and iron, chemical mixtures in aggregates, etc.) is assumed to be more susceptible to sump containment chemistries and temperature and hence is considered to likely generate more conservative results in head loss testing.

RAI # 12 (from Reference 14)

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

Beaver Valley Integrated Chemical Effects testing was conducted during the fall of 2007 by Alion Science and Technology at the VUEZ facility in Slovakia. BVPS-1 test results were inconclusive, and as such, Alion will be conducting follow-up testing for VPS-1 using WCAP-16530-NP methodology. FENOC has committed to providing the NRC the results of this follow-up testing no later than August 30, 2008, as noted in FENOC letter L-08-054 (Reference 20).

BVPS-2 testing at the VUEZ facility demonstrated favorable results during the entire thirty days, provided BVPS-2 changes from Sodium Hydroxide (NaOH) buffer to Sodium Tetraborate (NaTB) buffer. BVPS-2 has committed to submit a License Amendment Request (LAR) to replace the current NaOH buffer with NaTB by August 30, 2008; contingent on NRC approval of the LAR, BVPS-2 has committed to complete the buffer change to NaTB within 60 days of approval of the LAR or March 31, 2009, whichever is sooner. The maximum projected head loss will be addressed with the revised supplemental response (August 30, 2008).

RAI #17 (from Reference 14)

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

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% Calcium Silicate (Cal-Sil) and 20% fiberglass. BVPS-1 insulation content ranges from 100% fiberglass, 0% Cal-Sil to 79% fiberglass, 21% Cal-Sil, depending on the break location. BVPS-2 insulation content ranges from 100% fiberglass, 0% Cal-Sil to 94% fiberglass, 6% 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

The new containment sump strainer design changes were implemented under the provisions of 10 CFR 50.59 for BVPS-1 and BVPS-2. The associated Updated Final Safety Analysis Report (UFSAR) changes were identified as part of the design change process.

Additionally, to achieve sufficient water level to cover the containment sump strainers following a containment pressurization event, the start signal for the RSS pumps was changed. A license amendment request (LAR No. 334) to change RSS pump start signal was approved for BVPS-1 by the NRC (Amendment 280, dated October 5, 2007), and is pending approval for BVPS-2 (LAR No. 205). In addition, a LAR will be submitted for the buffer change and crediting containment overpressure at BVPS-2 by August 30, 2008. The proposed licensing changes and modifications for BVPS-2 were documented in FENOC's extension request letter L-08-054 dated February 14, 2008 (Reference 20).

At this time, FENOC does not anticipate any additional licensing changes for BVPS-1 and BVPS-2 to achieve compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of GL 2004-02.

Changes to the licensing basis will be implemented in accordance with the requirements of 10 CFR 50.59. The BVPS-1 and BVPS-2 UFSARs will be updated to reflect the results of the analyses and plant modifications performed for demonstrating compliance with GL 2004-02 in accordance with the requirements of 10 CFR 50.71.

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-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.

3. FENOC Letter L-06-171 "Revised Commitment Date Relevant to FirstEnergy Nuclear Operating Company Correspondence to the NRC, Dated September 29, 2006," dated December 21, 2006.

4. 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.

5. 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.

6. 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.

7. NRC letter dated May 18, 2006 Beaver Valley Power Station, Unit No. 2 (BVPS-2) - Request for Schedular Extension from Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors."

8. Summary of July 26-27, 2001, Meeting with Nuclear Energy Institute and Industry on ECCS Strainer Blockage in PWRs, dated August 14, 2001.

9. SECY-06-0078, from L. A. Reyes, NRC Executive Director for Operations, to NRC Commissioners, "Status of Resolution of GSI -191, 'Assessment of [Effect of] Debris Accumulation on PWR [Pressurized Water Reactor] Sump Performance,'" dated March 31, 2006.

10. 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.

11. NRC Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors," dated June 9, 2003.

12. FENOC Letter L-03-117, "60-Day Response to NRC Bulletin 2003-01," dated August 8, 2003.

13. NRC letter dated September 6, 2005 "Beaver Valley Power station, Unit Nos. 1 and 2 Response to NRC Bulletin 2003-01, Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized Water Reactors (TAC NOS. MB9554 and MB9555).

14. 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).

15. NRC letter to NEI dated November 30, 2007 "Supplemental Responses to Generic Letter 2004-02 Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors."

16. NRC letter to NEI dated November 8, 2007 "Plant-Specific Requests for Extension of Time to Complete One or More Corrective Actions for Generic Letter 2004-02 Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors."

17. NRC letter dated December 27, 2007 Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors" Extension Request Approval for Beaver Valley Power Station, Unit Nos. 1 and 2 (TAC Nos. MC4665 and MC4666).

18. NEI 04-07 Pressurized Water Reactor Sump Performance Evaluation Methodology; Volume 1– Pressurized Water Reactor Sump Performance Evaluation Methodology & Volume 2 – Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Revision 0, December 6, 2004.

19. NRC 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.

20. 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.

21. 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.