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SCE&G®
A SCANA COMPANY

September 1, 2005
RC-05-0138

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

Dear Sir/Madam:

Subject: VIRGIL C. SUMMER NUCLEAR STATION (VCSNS)
DOCKET NO. 50/395
OPERATING LICENSE NO. NPF-12
RESPONSE TO NRC GENERIC LETTER 2004-02:
POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

Reference: J. B. Archie to Document Control Desk, 90 Day Response to NRC Generic Letter 2004-02, dated March 7, 2005, RC-05-0037

This letter and the enclosed attachments provide South Carolina Electric & Gas Company's (SCE&G's) supplemental response to Generic Letter 2004-02 for Virgil C. Summer Nuclear Station (VCSNS). The referenced letter above provided SCE&G's initial response for the request for information in part 1 of the generic letter. This letter provides the additional details requested in part 2 of the generic letter.

Should you have questions, please call Mr. Ron Clary at (803) 345-4757.

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

9-1-05
Executed on

Jeffrey B. Archie
Vice President, Nuclear Operations

AMM/JBA/mb
Attachments

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R. J. White
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NRC Resident Inspector
NSRC
CER (0-C-04-2911)
File (815.14)
DMS (RC-05-0138)

A114

Attachment I
NRC Generic Letter 2004-02
Requested Information

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.

Response:

South Carolina Electric and Gas (SCE&G) has completed the baseline analysis, as defined in NEI Guideline 04-07, and several enhanced analyses, to evaluate the existing VCSNS Reactor Building (RB) recirculation sump and strainer design. The analysis has indicated that design modifications will be necessary to meet the applicable regulatory requirements for the Emergency Core Cooling System (ECCS) and Containment Spray System (CSS) under postulated debris loading conditions. The modifications will be installed and the supporting analysis and programmatic controls will be in place on or before December 31, 2007. At this time SCE&G does not anticipate making licensing amendment request submittals in support of these efforts.

The analysis (described in response to Item 2c) has indicated two primary design concerns for the sump strainers.

- The current strainers have limited surface area (approximately 23 ft^2 per pump). Even with the low fiber loading at VCSNS, this area must be increased. The design modification for VCSNS will size the new passive strainers with sufficient surface area to preclude thin bed formation.
- VCSNS primarily uses Diamond Power Mirror Insulation (RMI). The destruction pressure for this insulation is low, resulting in a large Zone of Influence (ZOI). The design modification for VCSNS will place RMI debris interceptors at strategic locations as necessary to reduce the RMI loading at the strainer to acceptable levels.

The design modification process is underway at SCE&G. The general description of these anticipated modifications and a few supporting design changes are as follows.

Sump Strainer Design

The design modification for VCSNS will size the passive strainers with sufficient surface area to preclude thin bed formation. The two RB Engineered Safety Features (ESF) recirculation sumps (one per train) are located approximately 45° apart in the annular region between the secondary shield (bio-shield) wall and the RB wall. These are shown on Figure 1. Each sump is an irregularly shaped pit with plan dimensions of approximately 10' x 22' and a depth of 4 feet. A 6" curb surrounds each sump. The current strainer will be removed and replaced with a complex geometry strainer designed to substantially increase the surface area. The new strainer will be installed within the existing sump pit. The new strainer will be shared by the Residual Heat Removal (RHR) and Spray pumps. This change is necessary to ensure sufficient flow to both pumps under the assumption of uneven debris accumulation if the strainers remained separated. The strainers will be constructed of stainless steel using perforated plate with round holes. The maximum diameter will be 1/8", however, a smaller size may be used if deemed appropriate. The minimum strainer surface area has been established by analysis to preclude thin bed formation. As covered in the response to Item 2c (Analysis Description), a minimum sump screen surface area to prevent a uniform debris bed for the calculated design basis fiber load is 912 ft^2. Latent debris blockage accounts for an additional 71.6 ft^2 for a total minimum screen surface area of approximately 985 ft^2.

SCE&G provided a request for proposal to selected, qualified vendors with proven experience in recirculation strainer design, fabrication and installation within the nuclear industry. Contract award is anticipated in October 2005. Installation for the new strainers and related modification will occur during the Refueling Outage scheduled for the Fall 2006. SCE&G will provide a supplement to this response after contract award to inform the NRC of vendor selection and to provide additional conceptual design information.

Debris Interceptor Design

VCSNS primarily uses Diamond Power Mirror Insulation (RMI) within the RB. The destruction pressure for this insulation is low, resulting in a large ZOI. A large volume of RMI debris may be generated as discussed under the response to Item 2c. The VCSNS sumps are located outside the secondary shield wall (See Figure 1). The calculated flow pattern between the secondary shield wall and the containment wall indicates flow velocities capable of tumbling RMI debris along the floor. The VCSNS sump strainers are within a pit, below the floor grade. Due to the large volume of RMI debris generated, the potential exists for the entire sump area filling with RMI debris, out board of the strainer. This condition may result in an unacceptable flow configuration regardless of sump strainer surface area. The design modification for VCSNS includes RMI debris interceptors at strategic locations to reduce the potential RMI loading at the sump strainers to acceptable levels.

As covered in the response to Item 2c (Analysis Description), up to 67,691 ft^2 of RMI foils are transportable to the sump locations under worst case conditions. This volume of RMI may completely fill the sump recess external to the strainer, potentially reducing the effectiveness of the strainers to permit the necessary flow of water across the strainer to the pumps. Of the total postulated transportable RMI, 80% to 90% will be stopped by debris interceptors. The debris interceptors will consist of stainless steel and be classified as Seismic Category 1 structures. The conceptual design interceptor locations are;

- One interceptor at each of the three entrances through the secondary shield wall. These interceptors will span the openings (3 ft to 4 ft) and will be approximately 2 ft high. They will have a horizontal screen reaching from 2 ft to 3 ft to maximize the debris capture. The screens will be removable to allow for outage work.
- A large interceptor spanning the outlet from Steam Generator B and Steam Generator C, along a line of columns in the southeast portion of the RB annulus. This interceptor will also be 2 ft tall with a 2 ft horizontal screen to maximize debris capture.
- Three interceptor locations will be place in the northwest annulus to catch debris coming from the secondary shield opening near the pressurizer. The height will again be approximately 2 ft with a horizontal screen.

The final design and effectiveness of these debris interceptors will be confirmed using the Computational Fluid Dynamics (CFD) model of the VCSNS 412 ft elevation.

Additional Design Modifications

Three additional, minor modifications are also being planned. These modifications are associated with the flow of water around the containment and to the sump.

Block Flow down Southern Stairwell

The pressurizer cubicle floor is on the 436 ft elevation. If a break were to occur within the cubicle, fluid and debris would flow around the RB annulus on the 436 ft elevation above the sump elevation. The flow would go down the south stairwell, directly adjacent to a sump location. A small barrier with a solid bottom toe kick plate at the bottom will be placed at the top of the stairwell to channel flow away from the stairwell. The stairwell is not used during power operation, so this will not be an operational concern. Design of the removable toe kick plate will meet Seismic Category 1 requirements.

Removal of Toe Kick Plates on the 436 ft Elevation

By blocking the flow down the stairwell, the potential exists for a holdup volume of water and spillage over the toe kick plate from the 436 ft elevation down to the sump location on the 412 ft elevation. To control the flow location, the toe kick plate will be removed at two locations away from the sump. The plate may be reinstalled during outage operations.

Replacement of Pressurizer Cubicle Door

The pressurizer cubicle door is a standard, steel architectural door used to restrict access to a high radiation area. If a break in the spray line or safety relief line were to occur in the pressurizer cubicle, the door latching mechanism would fail and the door would be thrust open allowing flow out of the cubicle. There is also a piping penetration in the cubicle floor which would allow flow out of the cubicle. However, to ensure an open flow path out of the cubicle, the pressurizer door will be replaced by a gated door. The openings will be adequate to prevent flow blockage at the door.

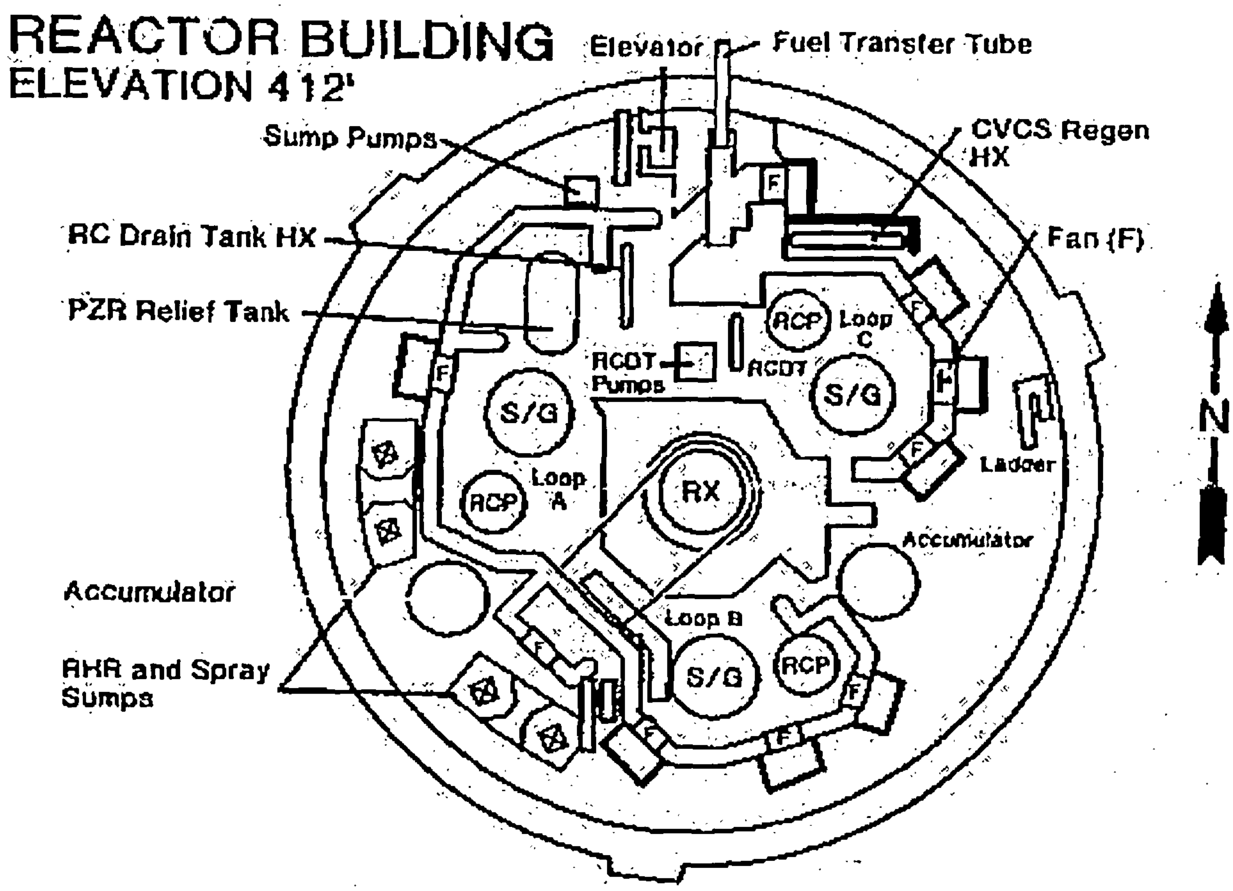


Figure 1
V.C. Summer 412 ft RB Elevation with Recirculation Sumps

Attachment II
NRC Generic Letter 2004-02
Requested Information

2(b) A general description of and implementation schedule for all corrective actions, including any planned modification, that you identified while responding to the generic letter. Efforts to implement the identified action should be initiated no later than the first refueling outage 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.

Response:

In addition to the plant modifications addressed in response to Item 2a and the NEI 04-07 analysis addressed in response to Item 2c, a number of supporting activities have been completed or are planned to support the resolution of GSI-191. The following provide a brief description of these efforts.

Activities Completed

Sump Pool Minimum Level Calculation
A detailed calculation was completed to document a minimum sump pool depth to support the NEI 04-07 evaluations. The calculation specifically evaluated holdup volumes at several locations. The details of this calculation are provided in response to Item 2d (iv) for holdup water volumes

Laser Scanning
During the Spring 2005 refueling outage, 3-Dimensional laser scans of the recirculation sumps and 412 ft elevation annulus were completed. The scans will support the detailed designs for the sump strainers and the debris interceptors. The scans permit three dimensional measurements of the as-built plant to approximately +/- 3 mm.

Coatings Walk Down
During the Spring 2005 refueling outage, SCE&G contracted Mr. Jon Cavallo of Corrosion Control Consultants and Labs, Inc. to complete a GSI-191 coatings walk down of the RB. The walk down included identification of unqualified coatings, visual condition inspection of qualified coatings and a review of our Level 1 coatings program.

Upstream Effects (Holdup Volume) RB Walk Down

During the Spring 2005 refueling outage, SCE&G completed RB walk downs to identify potential upstream effects that may hold up water, reducing the water level in the recirculation pool. The walk down confirmed the as-built plant reflected the design input used in the sump pool minimum level calculation. The walk downs are discussed in detail in response to Item 2d (iv).

Unqualified Materials RB Walk Down
During the Spring 2005 refueling outage, SCE&G completed RB walk downs to identify material inside the RB that was not qualified for post-LOCA conditions. These walk downs focused on stickers, placards and labels that remain in the RB during power operation. The two largest contributors were floor labeling for fire protection zones and paper warning labels on cable trays from original procurement. The total unqualified material is discussed in response to Item 2c.

Latent Debris Sampling
During the Spring 2005 refueling outage, SCE&G completed sampling of the RB to establish a latent debris source (dirt and dust) for use in the NEI 04-07 analysis. A total of 22 samples were collected. Horizontal and vertical surfaces were included in the sampling. These data were conservatively applied to establish a debris loading calculation for input to the NEI 04-07 analysis. The total debris loading was established at 105 lbs. This includes a 50% margin over the calculated value.

Downstream Effects
A downstream effect evaluation per WCAP-16406 was completed by Westinghouse for VCSNS. The evaluation used design input provided by SCE&G and debris loading from the NEI 04-07 analysis described in response to Item 2c. The evaluation is covered in further detail in response to Item 2d(v).

Planned Activities

Cumulative Effects Program on Unqualified Paint
A cumulative effects program will be established for unqualified paint inside the RB. This includes the development of a calculation listing equipment and/or locations with unqualified coatings and the surface area/quantities of the unqualified coatings. The calculation will be based on the coatings walk down completed during the Spring 2005 refueling outage. The calculation will also review equipment lists to ensure all components with unqualified paint were captured during the walk down. The cumulative effects program will be implemented by revision of existing procedures which cover other design control data for containment heat sinks, fire loading and electrical loading.

Cumulative Effects Program on Insulation
A cumulative effects program will be established for tabulating, controlling and evaluating changes to quantities of insulation inside the RB. This includes the development of a calculation listing the type, location and quantities of insulation inside the RB. The calculation will be based on the Debris Generation calculation completed

for the NEI 04-07 analysis which tabulates the insulation. The cumulative effects program will be by revision to existing procedures which cover other design control data for containment heat sinks, fire loading and electrical loading.

Schedule

<u>Sump Strainer Replacement</u>	
Award Contract	October 2005
Installation	Fall 2006 RF Outage
<u>Debris Interceptor Design and Installation</u>	
CFD Analysis to Validate Design	October 2005
Installation	Fall 2006 RF Outage
<u>Cumulative Effects Programs</u>	
Implementation of Cumulative Effects	Fall 2006 RF Outage

Attachment III
NRC Generic Letter 2004-02
Requested Information

2c A description of methodology that was used to perform the analysis of the *susceptibility of the ECCS and CSS recirculation functions* to adverse effects of post-accident debris blockage and operation with debris laden fluids. The submittal may reference a guidance document (e.g. Regulatory Guide 1.92, Rev. 3, industry guidance) or other methodology previously submitted to the NRC. (The submittal may also reference the response to Item 1 of the Requested Information described above. The documents to be submitted or referenced should include the results of any supporting containment walkdown surveillance performed to identify potential debris sources and other pertinent containment characteristics.)

<u>Response:</u>

1.0 OVERVIEW

SCE&G has performed analyses to determine the susceptibility of the Safety Injection System (SIS) and Containment Spray System (CSS) recirculation functions for VCSNS to the adverse effects of post-accident debris blockage and operation with debris-laden fluids. These analyses were contracted to Enercon Services Inc. working with Alion Science and Technology, and Westinghouse Electric Company, LLC.

The analysis was completed in two phases. The first phase was a baseline analysis as defined by NEI Guidance Report 04-07 enhanced with the use of material specific ZOI and CFD. The second phase incorporated walk down information collected during the Spring 2005 refueling outage, applied a refined size distribution model, preformed material testing and completed additional CFD analysis to confirm transport fractions. The final reports are documented in a series of calculations [Refs. 6.6, 6.7, 6.8, 6.9, and 6.10]. A summary of the methodology and results are provided in the following sections. Further refinements and final design considerations may change the stated results. A supplemental letter will be provided if substantial impacts on margin or significant design changes of the sump strainer are identified.

2.0 ACCIDENT SCENARIOS CONSIDERED

The Guidance Report and Safety Evaluation (GR & SE) (Ref. 6.1) recommends that a sufficient number of breaks in each high-pressure system that relies on ECCS recirculation be considered in addition to ensuring they bound variations in debris generation by the size, quantity, and type of debris identified. The following general break locations were considered:

Break Type No. 1:	Breaks in the RCS with the largest potential for debris
Break Type No. 2:	Large breaks with two or more different types of debris

Break Type No. 3:	Breaks in the most direct path to the sump
Break Type No. 4:	Large breaks with the largest potential particulate debris to insulation ratio by weight
Break Type No. 5:	Breaks that generate a "thin bed" – high particulate with low fiber

A review of the accident analysis and operational procedures has been performed to determine the scenarios that require the recirculation safety injection and/or recirculation spray. This review has identified the high energy piping systems that are evaluated for a postulated High Energy Line Break (HELB) and associated debris generation.

2.1 Large Break LOCAs

The VCSNS FSAR, Chapter 15 classifies LBLOCAs as >1.0ft^2 cross sectional break area (13.5" ID pipe). These events will result in full Engineered Safety Features initiation, which initiates 2 Centrifugal Charging Pumps (CCPs), 2 RHR pumps, and 2 Containment Spray pumps.

A review of the flow diagrams associated with the RCS identified those large bore lines directly attached to the RCS. The LBLOCA lines are:

31" RCS Cross-over Line
29" RCS Hot Leg
27.5" RCS Cold Leg
14" Pressurizer Surge Line

Locations of these lines are:

RCS Legs: Steam Generator A, B, and C Compartments
14" Pressurizer Surge Line: Pressurizer cubicle and SGA Compartment

A review of piping arrangement, plan and physical arrangement drawings for the above lines indicates that all RCS-communicating, high energy piping is located entirely within the secondary shield wall.

2.2 Small Break LOCAs

The VCSNS FSAR, Chapter 15 classifies SBLOCAs as the break of any RCS piping in excess of one CCP capacity (approximately 0.375" hole) but less than 1.0 ft^2 total cross sectional area. Since SBLOCAs may not be able to be isolated, they must also be considered for debris generation, as they may eventually lead to recirculation. Based on criteria established by the GR, only SBLOCA lines 2" and larger (up to 13.5") were included in this evaluation. A review of piping arrangement, plan and physical arrangement drawings indicated that all RCS-communicating, high energy piping is located entirely within the secondary shield wall.

2.3 Other HELB Scenarios

While LOCAs are considered the most likely type of debris generating HELBs that could lead to RB sump recirculation, other scenarios are evaluated to ensure that they could not result in debris generation followed by the need for ECCS recirculation as a means of long term core cooling. As long as the RCS remains intact, the intent in Pressurized Water Reactor design is to provide decay heat removal via the steam generators (SG) until the plant can be cooled down, depressurized and placed on the RHR system. Based on the establishment of decay heat removal via the steam generators, it can be stated that the ECCS system flow through the core is not necessary for long term decay heat removal. Therefore, the analysis of the effects of debris generation from these scenarios on ECCS recirculation performance is not necessary.

3.0 Debris Generation

3.1 Methodology

The following sections provide an overview of the methodology used in the debris generation analysis.

3.1.1 Identification of Debris Sources

The process begins with the identification of potential debris sources that could, in the event of a high-energy line break, challenge the performance of the RB Recirculation sump screens and ultimately the RHR and SP systems. The types and locations of these potential debris sources (insulation, coatings, dirt/dust, etc.) were identified on insulation drawings, fire barrier drawings, specifications and walk downs of the RB. The debris sources necessary for this analysis are:

- Insulation within the potential ZOI
- Qualified coatings within the ZOI and unqualified coatings within all of containment.
- Estimates on labels, tags, etc. and dirt/dust are also necessary within all of containment as these debris sources occur from the post accident environment.

3.1.2 Accident Characterization

The Recirculation Sumps are only vulnerable to debris blockage when the pool is in recirculation and the sump is active. The analysis therefore requires an understanding of the accident progression to identify the extent of high-energy line breaks to be evaluated for the potential to generate debris. These are covered in Section 2.0.

3.1.3 CAD Model

A CAD model was developed for the CFD recirculation pool debris transport analysis. This model includes the lower and upper levels of containment and major equipment. Structural drawings were used to create the model and verification of the model was completed in the CFD analysis to check the accuracy and validity of the model. This model was used to assist in the identification of debris sources and robust barriers within a given ZOI. The CAD Model is shown in Figure 3-1.

For the postulated break, a ZOI sphere was placed in the model centered at the break location. The painted surface area within the sphere was then determined using various features of AutoCAD™. Credit was taken in a conservative manner for some areas shielded by robust barriers. The CAD model includes walls, floors, major equipment, and structural supports. Coated items not included in the CAD model (e.g. grating, minor equipment, valves, etc.) were accounted for by incorporating a safety factor in the overall coated steel surface area.

3.1.4 Computational Fluid Dynamics

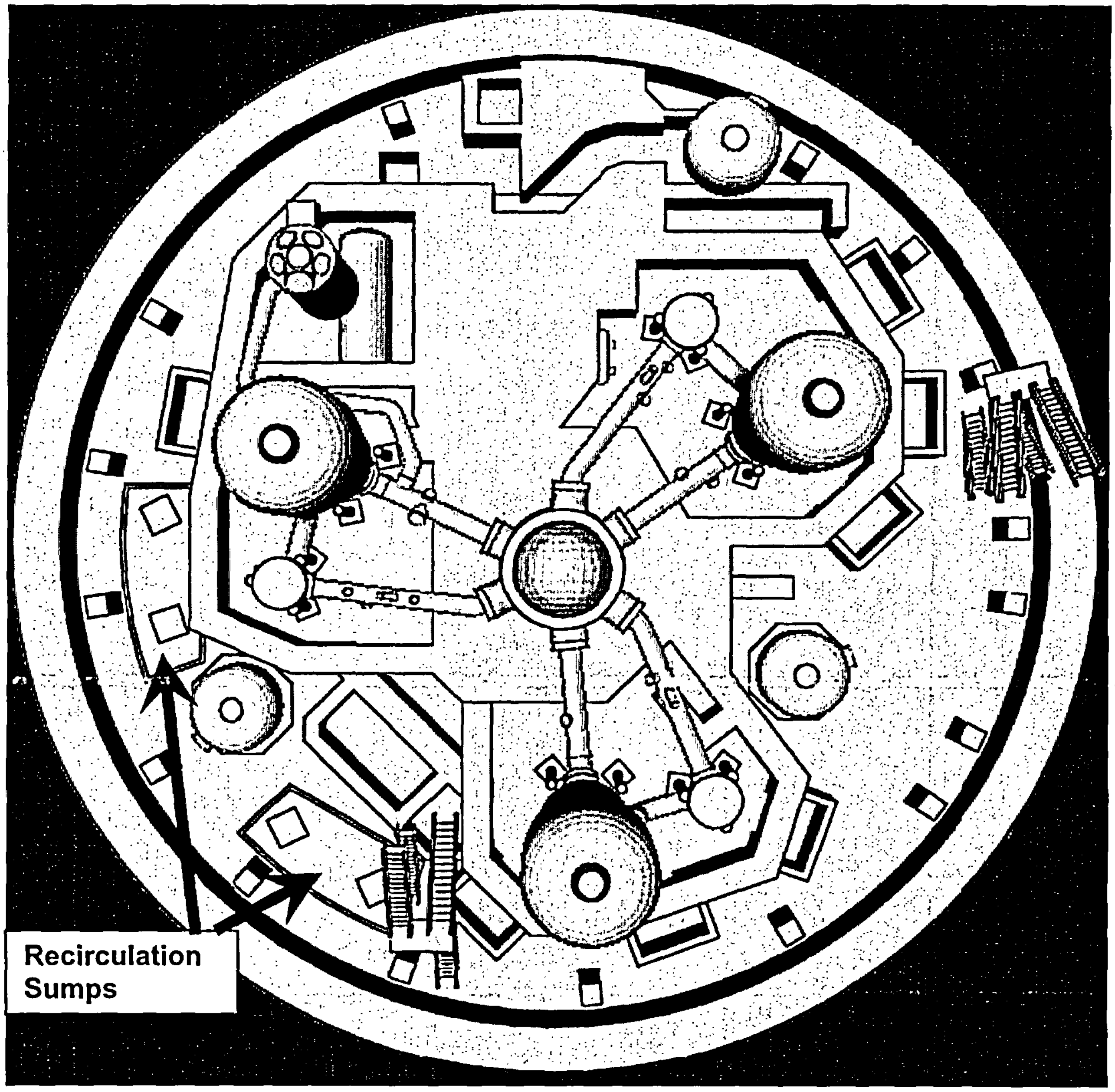
The CFD code used is Flow-3D® Version 8.2. Flow-3D® is a commercially available general-purpose computer code for modeling the dynamic behavior of liquids and gasses influenced by a wide variety of physical processes. The program is based on the fundamental laws of mass, momentum, and energy conservation. It has been constructed for the treatment of time-dependent multi-dimensional problems, and is applicable to most flow processes.

3.1.5 Break Selection

Break selection consisted of determining the size and location of the HELBs that will produce debris and potentially challenge the performance of the RB Recirculation sump screens. Since this break location was not known prior to the evaluation, the break selection process required evaluating a number of break locations in order 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 both considered when making this determination.

Break selection identified the breaks that produce the maximum amount of debris and also the worst combination of debris with the possibility of being transported to the RB Recirculation Sump screens. From Section 3.3.4.1, Item 7 of the SE, piping under 2" diameter can be excluded when determining the limiting break conditions.

Figure 3-1
CAD Model of V.C. Summer Nuclear Plant



3.2 Debris Sources and Identification

3.2.1 Insulation and Fire Barrier

The types, locations, and quantities of insulation inside containment were obtained from VCSNS insulation and fire barrier drawings. The following types of insulation exist within the RB:

- Diamond Mirror Reflective Metallic Insulation (RMI)
- Temp-Mat
- Marinite
- Kaowool
- Kaowool M-board

3.2.1.1 Diamond Mirror Reflective Metallic Insulation (RMI)

VCSNS uses primarily RMI for insulation of piping and equipment inside the RB. The Diamond Mirror insulation has been maintained through the life of the plant and used during the replacement steam generator project. The RMI drawings are up to date and document the installation. The RMI installed in VCSNS is Diamond Power Mirror RMI with Standard Bands [Ref. 3.12]. The destruction pressure for Mirror RMI is 2.4 psig which corresponds to a ZOI radius of 28.6D in Table 3-2 of the NRC SE.

A specific RMI debris size classification was not developed in the NRC study of BWR strainer performance. However, four (4) broad classes are suggested based on observations of Mirror RMI debris generation tests described in NUREG/CR-6808 [Ref. 6.5]. These 4 classes include:

- Small crumpled pieces of RMI foil (0.5 to 1.0 inches across)
- Small flat pieces typically 2 inches across
- Large crumpled pieces of outer casing
- Large flat sheets of RMI foil

As described in NUREG/CR-6808 [Ref. 6.5], in 1995 the NRC conducted a single debris generation test to generate representative RMI debris to obtain insights and data on the effect of RMI relative to US plants. This test was conducted at the Siemens AG Power Generation Group test facility in Karlestein, Germany. Most of the RMI debris was recovered and categorized by the location where it was found. Approximately 91% of the debris was recovered as loose foil pieces; the remainder was found wedged in place among the structures. The debris was analyzed with respect to size distribution. Table 3-1 provides a summary of the size distribution of the RMI debris generated by the steam jet. This distribution was used for Diamond Mirror® Reflective Metal Insulation.

Table 3-1
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%

3.2.1.2 Temp-Mat

Temp-Mat is used for two applications. The first is on the HVAC ducts in the pressurizer cubicle. This location is in the upper levels, above the pressurizer. The second is on the SG level instrument tubing. The tubing is run inside the secondary shield wall, primarily in the upper region the SG cubicles. Both applications are encased in stainless steel and will only become debris if subject to a LOCA jet.

For a baseline analysis of Temp-Mat, the GR recommends a size distribution with two categories—60% small fines, and 40% large pieces. The SE (Appendix VI, Section 3.2) suggests a more refined approach for determining the debris size distribution based on applicable air jet impact tests (AJIT). Using Appendices II and VI from the SE a debris size distribution for Temp-Mat was developed by Alion [Ref. 6.11]. It was determined that within the overall ZOI, the size distribution would vary based on the distance of the insulation from the break (i.e. insulation debris generated near the break location would consist of more small pieces than insulation debris generated near the edge of the ZOI). Therefore, based on the data, two separate sub-zones were defined for Temp-Mat and the corresponding size distribution within each sub-zone was determined. These size distributions and sub-zone ZOIs are shown in Table 3-2. This distribution will be used in this calculation for Temp-Mat insulation. From Table 3-2 in the GR, the as-fabricated density of Temp-Mat is 11.8 lb/ft3 and the density of individual fibers is 162 lb/ft3. The fiber size is 9 µm (2.95E-5 ft).

Table 3-2
Temp-Mat Debris Size Distribution Within Each Zone

Size	45.0 psi ZOI (3.7 L/D)	10.2 – 45.0 psi ZOI (11.7 – 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%

3.2.1.3 Marinite

Marinite insulation is used around the Reactor Vessel (RV) nozzles. This insulation was specified by the NSSS vendor as a "non-crushable" insulation. The location is inside the primary shield wall. The Marinite is encased in stainless steel and will only become debris if subject to a LOCA jet. The SE does not recommend a destruction pressure or ZOI for this material and insufficient data exists on its material properties, destruction pressure or size distribution. Until further applicable experimental data is gathered, the lowest destruction pressure listed in the SE and maximum destruction are assumed. The lowest destruction pressure listed is 2.4 psig which corresponds to a 28.6D ZOI. The Marinite is assumed to fail as particulate and transport to the sump screens. The material properties of the Marinite were tested. The Marinite particulate is 5 um based on material testing (Ref. 6.13).

3.2.1.4 Kaowool and Kaowool M-Board

The Kaowool and Kaowool M-Board are fire barriers. The fire barriers are used primarily outside the secondary shield wall except for one location. Kaowool M-Board is used under the pressurizer, in close proximity to the pressurizer surge line. The Kaowool and Kaowool M-Board are encased in stainless steel and will only become debris if subject to a LOCA jet. The SE recommends a destruction pressure of 24 psig and a ZOI of 5.4D for Kaowool. The debris size distribution for Kaowool is 60% fines and 40% large pieces as shown in Table 3-3 of the SE.

Kaowool M-board exists in several locations within the RB [Ref. 3.6]. There is currently insufficient data on its material properties, destruction pressure or size distribution. The lowest destruction pressure and the maximum destruction are assumed. Kaowool M-board is assumed to be a fibrous material where the properties (fiber diameter and microscopic density) of Temp-Mat fiberglass will be adopted absent specific information on the fiber characteristics. This is appropriate because the microscopic density is 160 lb/ft^3 for Kaowool M-board as obtained from vendor data compared to 162 lb/ft^3 density for Temp-Mat. The fiber diameter of Kaowool M-Board is unknown but it will be assumed that Kaowool M-board has the same fiber diameter as Temp-Mat, or 9.0 µm. Until further applicable experimental data is gathered, the lowest destruction pressure listed in the SE and maximum destruction are assumed. The lowest destruction pressure listed is 2.4 psig which corresponds to a 28.6D ZOI. This material will conservatively fail as 100% fines.

3.2.2 Coatings

3.2.2.1 Qualified Coatings

Qualified coatings used in the RB are listed in Specification SP-218, Field Application of Coatings for Concrete Inside Reactor Building [Ref. 6.14] and Specification SP-713, Painting Steel – Inside Reactor Building [Ref. 6.15]. These documents cover the types (epoxy) and application of coatings (DFT), but do not provide quantities or exact locations of painted components. All Qualified Coatings are assumed to have a ZOI of 10D. The quantity of qualified coating debris is based on the break location and size.

3.2.2.2 Unqualified Coatings

All unqualified coatings are assumed to fail. The primary source is Original Equipment Manufacturer (OEM) coatings on Reactor Coolant Pump (RCP) motors, air-operated valves and motor operated valves. The analysis assumed 10,000 ft^2 of unqualified coatings as provided in Table 3-15. As discussed in response to Item 2b, a GSI-191 coatings RB walk down was completed in the Spring 2005 refueling outage and a Cumulative Effects program will be established to track unqualified paint use inside the RB. The limits established in the Cumulative Effects program will be used in the final detailed design for the sump strainer.

3.2.3 Latent and Miscellaneous Debris

SCE&G completed sampling of the RB latent debris in the Spring 2005 refueling outage. A calculation was completed to determine a conservative latent debris loading for use in the GSI-191 sump evaluation [Ref. 6.2]. The conservative value of 105 lbs of latent debris specified in the calculation provides approximately 50% margin over the calculated value.

The latent debris properties are as recommended by the SE: 15% fiber and 85% particulate. The general latent debris term will be comprised of dirt/dust term and latent fiber term with properties defined in the Section 3.5.2.3 of the SE. The dirt/dust term will have a characteristic size of 5.68E-05 ft (17.3 μm) as specified in the SE. The latent fiber term will have a density of 175 lbm/ft^3 (as reported in NUREG/CR-6224) [Ref. 6.12] and the dirt/dust will have a density of 169 lbm/ft^3 per the SE. Fiber characteristic size is unspecified, and therefore the size of the NUKON individual fibers, 2.30E-05 ft from the GR will be assumed.

SCE&G also performed a study of the VCSNS RB in which the quantity of latent unqualified material and material left in containment was estimated [Ref. 6.3 and 6.4]. These materials include such items as placards, paper, tape, tags, and miscellaneous non-recoverable debris. This debris is available for transport to the sump where it may block the sump screens. The preliminary calculation of unqualified materials developed a conservative value of 80.4 ft^2 of material which includes a margin greater than 20%. The calculation of material left in containment developed a conservative value of 15 ft^2 of material which includes a margin of approximately 100% including an allowance for danger tags.

3.3 Break Selection

Civil and mechanical layout drawings were used to divide the RB into zones that were defined by physical barriers. In addition, some RB zones were created using predetermined locations to limit the zone size. An insulation inventory spreadsheet quantified the volume of insulation within each of the zones. Results were summarized in pivot tables. These pivot tables take break location specific results and summarize the amount and type of insulation for each affected zone.

As discussed in Section 2.0, the following break locations are considered:

- Break No. 1: Breaks in the RCS with the largest potential for debris
- Break No. 2: Large breaks with two or more different types of debris
- Break No. 3: Breaks in the most direct path to the sump
- Break No. 4: Large breaks with the largest potential particulate debris to insulation ratio by weight
- Break No. 5: Breaks that generate a "thin bed" – high particulate with 1/8" fiber bed

There are several breaks within the RCS that have the potential to generate the largest quantity of debris. The following breaks will be evaluated under Break No. 1:

- 31" ID Cross-over Line at the steam generator (LBLOCA)
- 6" Pressurizer Safety Relief to Safety Valve Lines (SBLOCA)
- 14" Pressurizer Surge Line (LBLOCA)
- RV Cavity Break in Nozzle (LBLOCA)

The debris generated by the most limiting cases in Break No. 1 will bound Break No. 2 because each of the breaks for Break No. 1 create at least two different types of debris. There are no breaks that are within the proximity of the sump therefore Break No. 3 will not be evaluated. Break No. 4 is designed to primarily capture particulate type insulation. Since Marinite is expected to be a particulate product, Break No. 4 will apply to VCSNS. Therefore, Break types 1, 4, and 5 are applicable and included in this analysis.

The break with the largest potential for debris generation is the largest break in an area with the largest concentration of debris source material. For this analysis, there are four possible break locations that have the potential to generate the largest concentration of debris. The first is the 31" RCS Cross-over line (LBLOCA) which is located inside the SG compartments inside the bio-shield. The second is the 6" Pressurizer Safety Relief to Safety Valve Line (SBLOCA) in the Pressurizer cubicle. The third is the 14" Pressurizer Surge Line (LBLOCA) in the Pressurizer cubicle. Finally, the fourth is a break at the RCS Hot Leg in the RV Cavity at a Nozzle (LBLOCA). According to data collected from the insulation drawings, the following specific break locations will be assessed:

- Loop "A" 31" RCS Cross-over Line break at the steam generator
- Loop "A" Pressurizer Safety Relief Line break from Nozzle 4A.
- 14" Pressurizer Surge Line break below the Pressurizer
- RCS Hot Leg Break at a Nozzle in Reactor Cavity

3.4 Debris Generation

3.4.1 Cross-Over Line Break

For RCS cross-over line break, Loop "A" was selected instead of Loop "B" and "C" because it was the worst in terms of the amount insulation involved (Temp-Mat). The debris generation and size distribution are present in Table 3-3.

3.4.2 Pressurizer Relief Line Break

A break postulated in the 6" Pressurizer Safety Relief line must be evaluated because a significant amount of Temp-Mat is installed on the HVAC ductwork above the pressurizer. The break is postulated at the first 90° bend in Loop "A" (Nozzle 4A loop). This particular line was selected because out of the four total relief lines from the pressurizer, the Loop "A" line produced the largest quantity of Temp-Mat. The debris generation and size distribution are present in Table 3-4.

3.4.3 RCS Cavity Break

The RB subcompartments have been analyzed for the largest breaks possible in each compartment. The Marinite is located on all six (6) of the RV nozzles. Since the RCS piping is restrained from movement in the case of a pipe break by the primary shield wall, a completely offset pipe break is not expected. A break in this location will not cause direct impingement on the insulation on the opposite side of the RV. Due to the fact that a break in the hot leg piping within the Reactor Cavity would not be fully offset and would not allow direct impingement of the break flow on the insulation on the opposite side of the RV, shadowing of the RV will be credited. Therefore only half of the Marinite installed on the RV nozzles will be destroyed. There is no destruction of insulation in the adjacent SG compartments as a result of this break. The debris generation and size distribution are present in Table 3-5.

As discussed above, the RCS piping is restrained from movement and a break in this location will not cause direct impingement on the insulation on the opposite side of the RV. Therefore only half of the RMI installed on the RV will be destroyed. The debris generation and size distribution are present in Table 3-5.

3.4.4 Pressurizer Surge Line Break

Stuck open Safety Valves and breaks in the Power Operated Relief Valve (PORV) and Safety Valve lines must be considered in this debris generation calculation. The stuck open Safety Valve will release through the Pressurizer Relief Tank which is located directly below the Pressurizer near elevation 425'-0". The Pressurizer Surge Line from the bottom of the Pressurizer is located directly above the Relief Tank approximately at elevation 431'-3" and the surge line is completely contained within the bio-shield. The stuck open Safety Valve with release through the Pressurizer Relief Tank rupture disk will be bound by a 14" Pressurizer Surge line directly above the Relief Tank. The materials exposed to a break in the 14" Pressurizer Surge line are RMI and Kaowool M-board. The debris generation and size distribution are presented in Table 3-6.

Table 3-3
Break No. 1 – 31" RCS Cross-over Line DEGB Debris Generation (LBLOCA)

Insulation Type	Insulation Type Loop "A" Crossover
RMI	95,340 ft^2
Temp-Mat: 11.7D ZOI	7.2 ft^3
Temp-Mat: 3.7D ZOI	1.0 ft^3

Table 3-4
Break No. 1 – 6" Pressurizer Safety Relief Line DEGB Debris Generation (SBLOCA)

Insulation Type	6" Pressurizer Safety Line Break
RMI	15,618 ft^2
Temp-Mat: 11.7D ZOI	7.1 ft^3
Temp-Mat: 3.7D ZOI	0.0 ft^3

Table 3-5
Break No. 1 – Reactor Vessel Cavity Break at a Nozzle Debris Generation (LBLOCA)

Insulation Type	Loop "A" Hot Leg to RV Nozzle Break
RMI	12,374 ft^2
Marinite	30.2 ft^3

Table 3-6
Break No. 1 – Pressurizer Surge Line

Insulation Type	14" Pressurizer Surge Line Break
RMI	2,025 ft^2
Kaowool M-Board	4.4 ft^3

3.4.5 Qualified Coatings

As stated earlier, VCSNS Specification for Field Application of Coatings for Concrete Inside Reactor Building and Engineering Services Specification SP-713 Painting Steel – Inside Reactor Building lists types of qualified coatings for the concrete and steel structures inside containment. The qualified coatings in the RB are epoxy coatings. Qualified coatings have a spherical ZOI with a radius of 10D (or a ZOI determined by material specific destruction data) as listed in Section 8.0 of the SE.

The most accurate way to quantify the coating debris source term for the ZOI would be to base that calculation on the surface area within the 10D coating ZOI. This method was accomplished by utilizing the CAD model developed as a part of the RB Recirculation Sump analysis and estimating the total concrete and steel surface area within the ZOI. The CAD model was manipulated such that the surface areas of concrete and structural steel, within the 10D ZOI can be calculated. For the postulated break, a ZOI sphere was placed in the model centered at the break location. The painted surface area within the sphere was then determined using various features of AutoCAD™. Credit was taken in a conservative manner for some areas shielded by robust barriers. The CAD model includes walls, floors, major equipment, and structural supports. Coated items not included in the CAD model (e.g. grating, minor equipment, valves, etc.) were accounted for by incorporating a safety factor in the overall coated steel surface area.

The total concrete surface area of the compartment walls within the ZOI was estimated (crediting only a small area shielded from the break by other walls or equipment) to be 4,270 ft^2. An additional 500 ft^2 of degraded/failed Design Basis Accident (DBA) qualified paint on the interior bio-shield concrete walls is assumed to be destroyed giving a total wall surface area of 4,770 ft^2. The total concrete surface area of the compartment floor was conservatively estimated to be 655 ft^2. The total concrete surface area (walls and floors combined) is 5,425 ft^2. The total steel surface area including the supports, beams, and the pressurizer relief tank was conservatively estimated to be 1,499 ft^2. In order to account for other steel surfaces like the stairs, handrails, and miscellaneous items not included in the CAD model, the steel surface area was increased by 10% to 1,648 ft^2. This gives a total qualified paint total surface area of 12,498 ft^2. Table 3-7 provides a tabulation of qualified coatings source term.

Table 3-7 Qualified Coatings Source Term						
Coating Type	Type	Area (ft^2)	Thickness (mils)	Analysis Size (μm)	Density (lbs/ft^3)	Weight (lbs)
Epoxy Qualified Coatings (ZOI – 10D)	K&L No. 6548/7107 (Steel)	1,648	18	10	110.28	272.6
	K&L No. 6149 (Concrete Primer)	5,425	1.5	10	71.02	48.2
	K&L No. 5000 (Concrete Floor)	655	35	10	91.73	175.2
	K&L No. 4500 (Concrete Walls)	4,770	10	10	112.10	445.6
Total Qualified Coatings	-	12,498	-	10	-	941.6

3.5 Debris Source Term Evaluation

It is apparent by examining the results listed in Tables 3-3, 3-4 and 3-6 that the break in the 14" pressurizer surge line or the 6" Pressurizer Safety Relief line is bounded by the break in the 31" RCS Cross-over Line. The 31" RCS Cross-over line break generates the same materials as the 6" Safety Relief line break but in larger quantities. Also, the 6" Pressurizer Safety Relief line is located within an enclosed compartment which will minimize debris transport to the sumps.

The break that produces Marinite (break at the RV nozzle) is potentially limiting from a head loss perspective and will be considered in the transport and head loss calculations. The results establish two limiting breaks for Break No. 1, the largest potential for debris. They are:

- Loop "A" 31" RCS Cross-over Line break at the steam generator
- RV Cavity Break at a Nozzle

3.6 Debris Generation Results

Results of the debris generation analysis are summarized below. The insulation debris source term is presented for the maximum loading condition. This consists of the RCS Cross-over line double-ended guillotine break (DEGB) in the SG Loop "A" compartment (LBLOCA) and the RCS Hot Leg break at the RV nozzle (LBLOCA). Failed coatings and latent debris source terms are provided for the LBLOCA of the RCS Loop "A" Cross-over line.

The insulation debris source terms for the LBLOCAs are summarized in Tables 3-8 through 3-15:

Table 3-8
Loop "A" 31" RCS Cross-over Line Break (LBLOCA)
Debris Size Distribution for Temp-Mat

Total Amount Destroyed		Amount Destroyed by Size Distribution: Intact (Covered) Blankets	Intact (Uncovered) Blankets	Small Pieces (<6" on a Side)	Fines (Individual Fibers)
11.7D ZOI	7.2 ft^3	2.45 ft^3	2.30 ft^3	1.95 ft^3	0.50 ft^3
3.7D ZOI	1.0 ft^3	0.00 ft^3	0.00 ft^3	0.80 ft^3	0.20 ft^3
Total	8.2 ft^3	2.45 ft^3	2.30 ft^3	2.75 ft^3	0.70 ft^3

Table 3-9
Loop "A" 31" RCS Cross-over Line Break (LBLOCA)
Debris Size Distribution for RMI

Total Amount Destroyed	Amount Destroyed by Size Distribution: 6"	4"	2"	1"	½"	¼"
95,430 ft^2	11,631.5 ft^2	16,017.1 ft^2	24,407.0 ft^2	19,926.1 ft^2	19,258.7 ft^2	4099.6 ft^2

Table 3-10
Reactor Vessel Cavity Break at Nozzle (LBLOCA)
Particulate Insulation Debris Size Source Term for Marinite

Total Amount Destroyed	Particle Size	Macroscopic Density	Microscopic Density
30.2 ft^3	5 um	46 lb/ft^3	114.0 lb/ft^3

Table 3-11
Reactor Vessel Cavity Break at Nozzle (LBLOCA)
Debris Size Distribution for RMI

Total Amount Destroyed	Amount Destroyed by Size Distribution: 6"	4"	2"	1"	½"	¼"
12,374 ft^3	1,509 ft^3	2079 ft^3	3168 ft^3	2586 ft^3	2500 ft^3	532 ft^3

Table 3-12
Latent Debris Source Term

Latent Debris Type	Mass (lb_m)	Density (lb_m/ft^3)	Characteristic Size (ft)
Dirt and Dust	82	169	5.68E-05
Latent Fiber	16	175	2.30E-05

Table 3-13
Placards, Tape and Danger Tag Source Term

Latent Debris Type	Area (ft^2)
Unqualified Material	80.4
Materials Left	14.5
Danger Tags	0.5

Table 3-14
Qualified Coatings Source Term

Coating Type	Type	Area (ft^2)	Thickness (mils)	Analysis Size (μm)	Density (lbs/ft^3)	Weight (lbs)
Epoxy Qualified Coatings (ZOI – 10D)	K&L No. 6548/7107 (Steel)	1,648	18	10	110.28	272.6
	K&L No. 6149 (Concrete Primer)	5,425	1.5	10	71.02	48.2
	K&L No. 5000 (Concrete Floor)	655	35	10	91.73	175.2
	K&L No. 4500 (Concrete Walls)	4,770	10	10	112.10	445.6
Total Qualified Coatings	-	7,073	-	10	-	941.6

Table 3-15
Unqualified Coatings Source Term

Location	Surface Area (ft^2)	Average DFT (mils)	Density (lbm/ft^3)	Weight (lb)
Miscellaneous Locations	4977.5	8	94	311.9
OEM Paint (alkyds)	5000	5	98	204.2
Air Regulators (alkyds)	22.5	5	98	0.9
Total Unqualified Paint	10,000	--	--	517.0

4.0 Debris Transport

4.1 Methodology

Debris transport is the estimation of the fraction of debris that is transported from the debris source (break location) to the RB Recirculation Sump screens. The four major debris transport modes considered are:

- Blowdown transport – the transport of debris by the break jet to active and inactive areas of containment
- Washdown Spray transport – the vertical (downward) transport of debris by the containment spray/break flow
- Pool fill-up transport – the horizontal transport of the debris by the break and containment spray flows to active and inactive areas of recirculation pool during fill-up
- Recirculation transport – the horizontal transport of the debris in the active portions of the recirculation pool to the sump screens by the recirculation flow through the ECCS

Section 3.6.2 of the GR states that Westinghouse 3-Loop plants are typical examples of a highly compartmentalized containments. VCSNS is a three-loop Westinghouse design plant and therefore was modeled as a highly compartmentalized containment. Figure 3-1 provides a view of the VCSNS containment to demonstrate the compartments.

The debris transport analysis considers each type and size of debris. The transport fractions are dependent on the path the debris is expected to travel from the ZOI to the RB Recirculation Sump screens. Therefore, not only does the transport fraction consider the type and size of debris, but it considers the break location as well.

Debris transport fraction is assigned for each phase of the transport and size and type of debris and for the type of containment. A CFD analysis provides the worst case transport fractions for large pieces.

4.2 Assumptions and Analysis Clarifications

4.2.1 Material transport properties used in the analysis are provided in Table 4-1.

Table 4-1
Material Properties for Transport

Debris Type	Size	Terminal Settling Velocity (ft/s)	Reference	Calculated Minimum TKE Required to Suspend (ft^2/sec^2)	Flow Velocity Associated with Incipient Tumbling (ft/s)	Reference
Temp-Mat	Individual fibers	0.0074 (2)	NUREG/CR-6808 Fig. 5-2 [3]	8.2E-05	-	-
Temp-Mat	Small pieces (< 6")	0.15 (3)	NUREG/CR 6772 [4]	0.034	0.50	NUREG/CR-2982 [13]
Temp-Mat	Large pieces (> 6")	0.41 (3)	NUREG/CR 6772 [4]	0.25	0.90	NUREG/CR-2982 [13]
Stainless Steel RMI	½" square crumpled foils small pieces	0.37	NUREG/CR-6772 Table 3.5 [4]	0.21	0.28	NUREG/CR-6772 Table 3.5 [4]
Stainless Steel RMI	2" square crumpled foils large pieces	0.48	NUREG/CR-6772 Table 3.5 [4]	0.35	0.28	NUREG/CR-6772 Table 3.5 [4]
Qualified Epoxy Paint	10-micron particulate (110 lbm/ft^3)	2.5E-04	Calculated per Stokes' law (1)	9.4E-08	NA	-
	10-micron particulate (71 lbm/ft^3)	4.8E-05	Calculated per Stokes' law (1)	3.5E-09	NA	-
	10-micron particulate (92 lbm/ft^3)	1.6E-04	Calculated per Stokes' law (1)	3.8E-08	NA	-
	10-micron particulate (112 lbm/ft^3)	2.6E-04	Calculated per Stokes' law (1)	1.0E-07	NA	-
Unqualified Epoxy Paint (4)	10-micron particulate (94 lb/ft^3)	1.7E-04	Calculated per Stokes' law (1)	4.3E-8	NA	-
	8-mil thick chips	0.08	ARL (for 95 lbm/ft^3 density [8]	0.0096	0.4 (5)	NUREG/CR-6772 Section 3.3.2 [4]
Unqualified Alkyds	10-micron particulate (98 lbm/ft^3)	1.9E-04	Calculated per Stokes' law (1)	5.4E-08	NA	-
Dirt/Dust	17.3-micron particulate (169 lbm/ft^3)	1.6E-03	Calculated per Stokes' law (1)	4.0E-06	NA	-

(1) Calculated using water properties at 120° F
(2) Settling velocity for individual Nukon fibers
(3) Settling velocity for pieces of Nukon fiberglass
(4) In the Debris Generation Calculation, all epoxy coatings are assumed to fail as particulate. However, unqualified epoxy paint chips will be analyzed as well to provide additional information/benefit for VCS in the event this failure mechanism is acceptable from a regulatory stand point in the submittal of future analyses.
(5) Tumbling velocity for 15-mil thick chips

4.2.2 There are only three openings to which debris laden water can exit through the secondary shield wall (bio-shield). A break in the Loop "A" compartment would require debris laden water to make three 90° turns to get from the Loop "A" compartment through the pressurizer cubicle and the small connected compartment in the annulus area and through the doorway on the north side of the bio-shield. Also, instead of debris exiting through the doorway at the north end, the debris can continue to the Loop "C" compartment and travel to the compartment doorway on the east side of the bio-shield. Another tortuous pathway could be through the walkway from Loop "A" compartment to the Loop "B" compartment and exit at a doorway along the far east side of the cubicle. In general, the pathways that the debris laden water must follow do require navigation through a tortuous path where large debris can be caught up.

4.2.3 Latent debris and failed coatings are conservatively assumed to be in the active pool at start of recirculation and 100% fraction available for transport to the sumps.

4.2.4 For the break inside the reactor cavity it is assumed that there is no transport of large pieces of RMI. For a break within the Reactor Cavity, large debris would have to be lifted up through the incore instrument pit and then spill out through the screened ventilation outlet in order to reach the RB Recirculation Sumps.

4.2.5 It is assumed that ¼"-4" pieces of RMI debris can be conservatively treated as ½" pieces and 4"- 6" pieces can be conservatively treated as 2" pieces for transport purposes. This is a conservative assumption since smaller pieces of RMI transport more readily than larger pieces.

4.2.6 It is assumed that the RMI would not break down into smaller pieces following the initial generation. This is a reasonable assumption since RMI is a metallic insulation that would not be subject to erosion by the flow of water. It was also assumed that any erosion that may occur for fibrous debris would taper off over time and that no further erosion would occur after 24 hours. This assumption is addressed in more detail in Section 7.3.

4.2.7 It is conservatively assumed that the transportable miscellaneous debris addressed in the debris generation calculation including tags, labels, etc. would be transported to the emergency sump during recirculation.

4.2.9 For Temp-Mat debris not blown into upper containment, it is assumed that the recirculation transport fractions are equal for both jacketed and unjacketed large pieces.

4.3 CAD Model

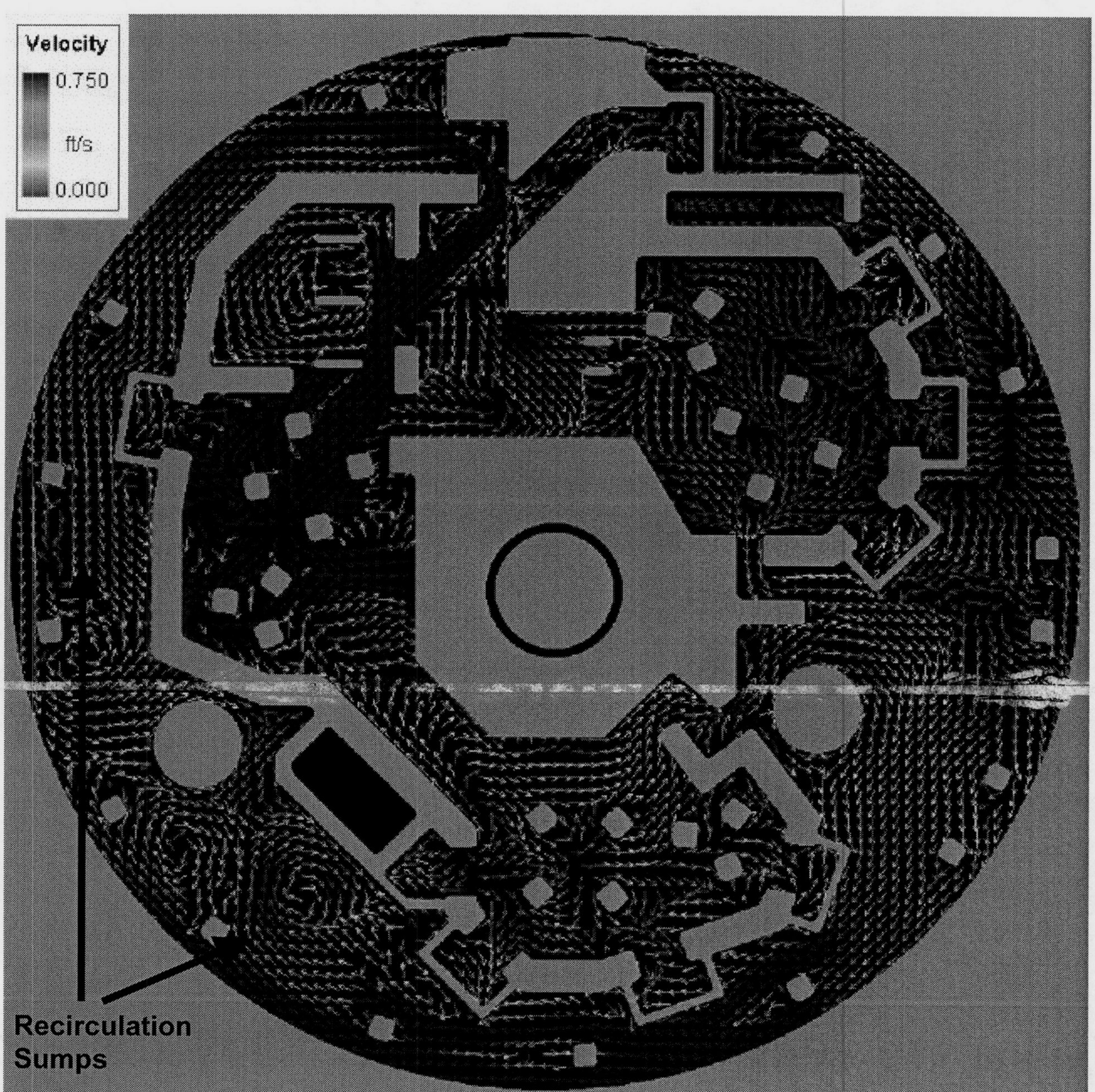
A picture of the CAD model is provided in Figure 3-1. Figure 3-1 specifically shows the sump level elevation (412 ft elevation) and the major components. The model actually includes each operating deck. However, only the sump level is used in the CFD analysis.

4.4 CFD Model

A picture of the CFD Model for a break in SG Loop A is shown in Figure 4-1. The break flow travels out through the three openings in the secondary shield wall to the recirculation sump. Spray flow is introduced in each of the three S/G loops and at appropriate locations around the containment annulus. Flow draining from higher operating decks is modeled through the stairwell and equipment hatch. Refueling cavity flow is modeled through the 8" drain line in the normal RB Sump.

Breaks in each of the three SG loops were modeled. The CFD results are used to determine the maximum debris transport fraction for large pieces. This information is then used in the debris transport trees. The CFD model is used for Temp-Mat, RMI and paint chips.

Figure 4-1
CFD Model for Break in SG A Loop



4.5 Debris Transport Logic Trees

Two break locations were identified in the Debris Generation for further analysis in the Debris Transport step. These are the 31" cross-over line at the SG A outlet that maximizes the amount of Temp-Mat generated and break in the RCS loop piping inside the RV Cavity that will generate Marinite debris. Each case was evaluated using Debris Transport logic trees for the specific debris type (Temp-Mat, RMI and Marinite). The logic trees are presented in Figures 4-2 through 4-5.

Figure 4-2
Cross-Over Line Break At SG A Outlet
Temp-Mat Transport Logic Tree

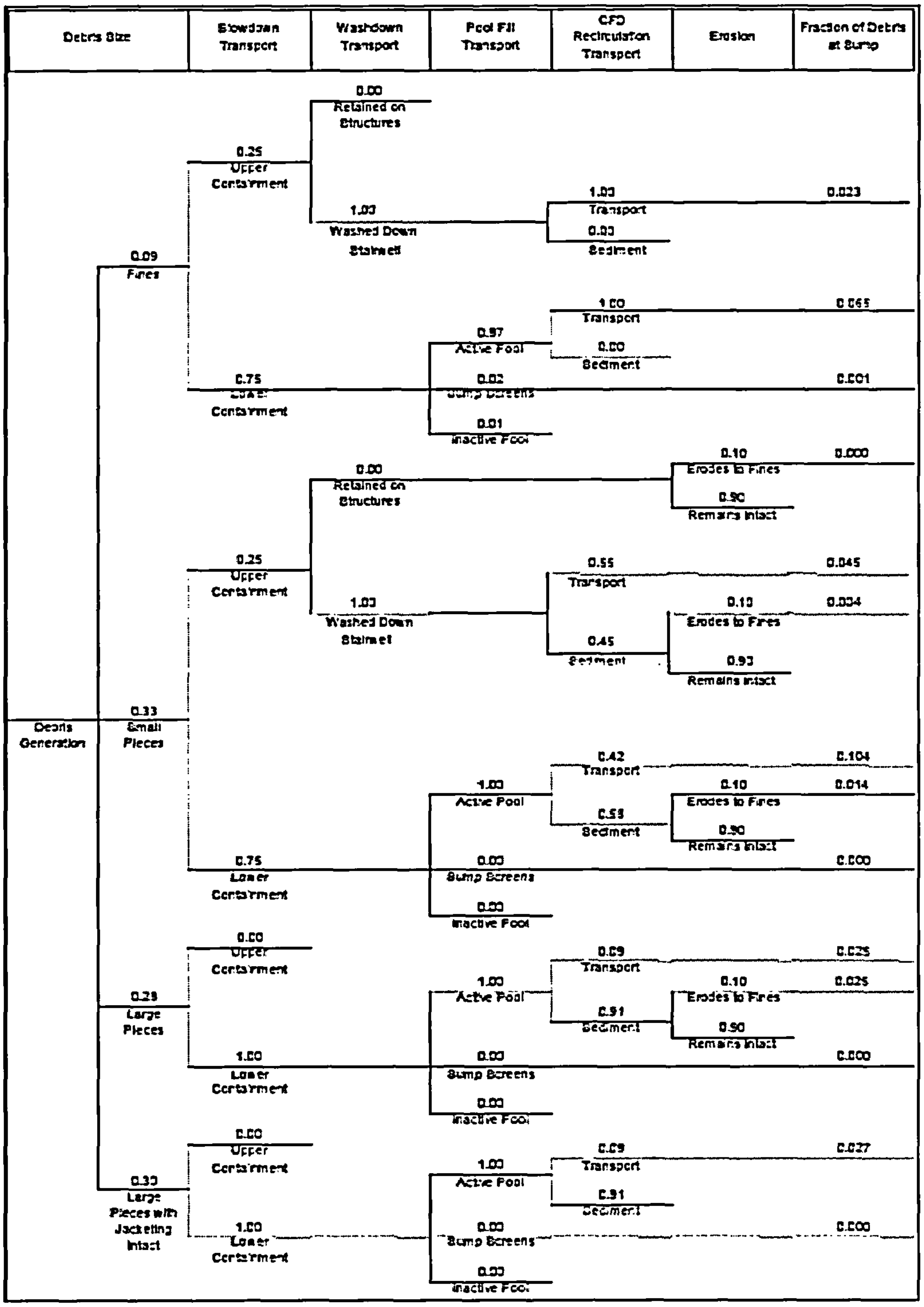


Figure 4-3
Cross-Over Line Break At SG A Outlet
RMI Transport Logic Tree

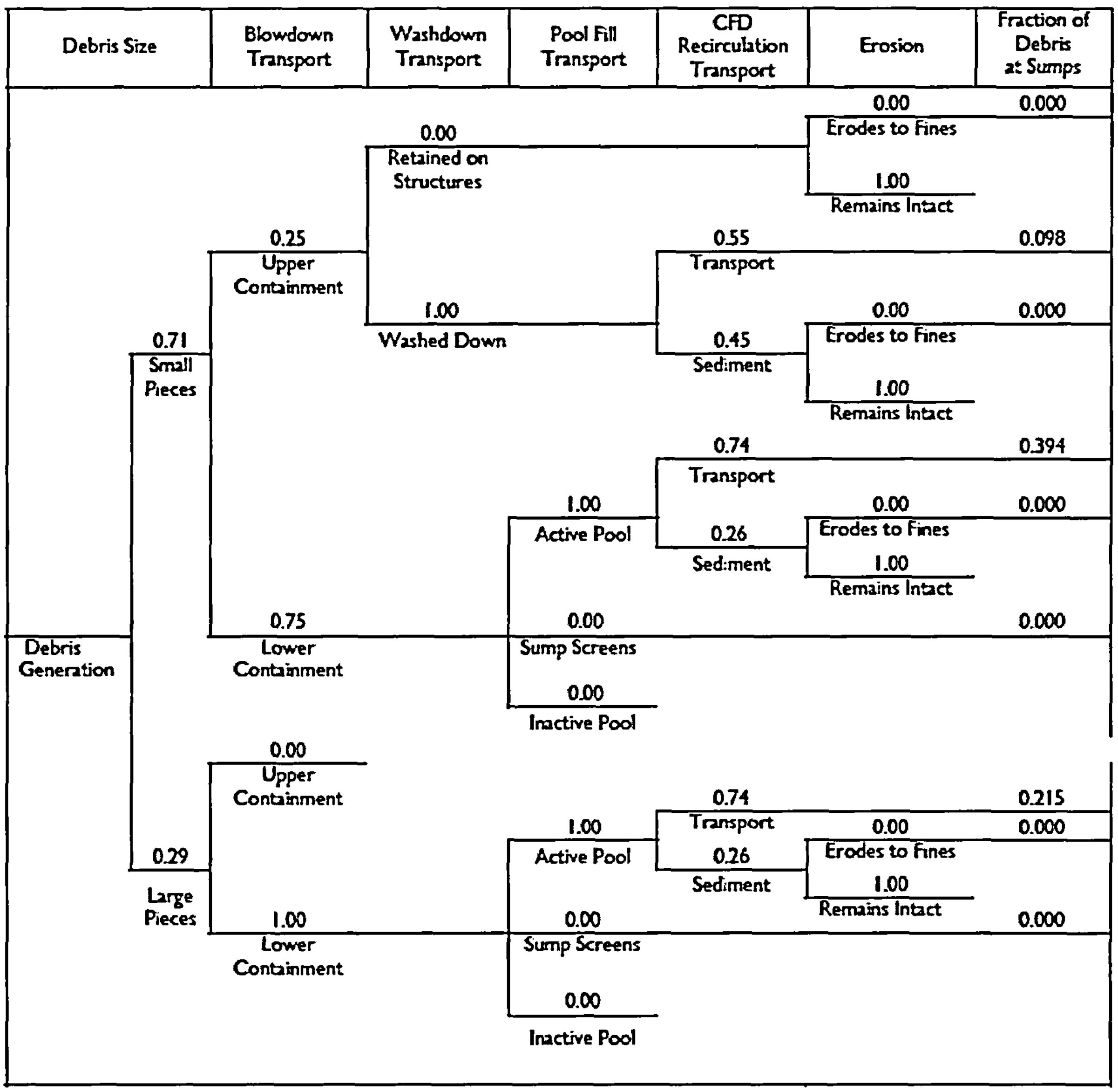


Figure 4-4
RCS Loop Pipe Break Inside the RV Cavity
Marinite Transport Logic Tree

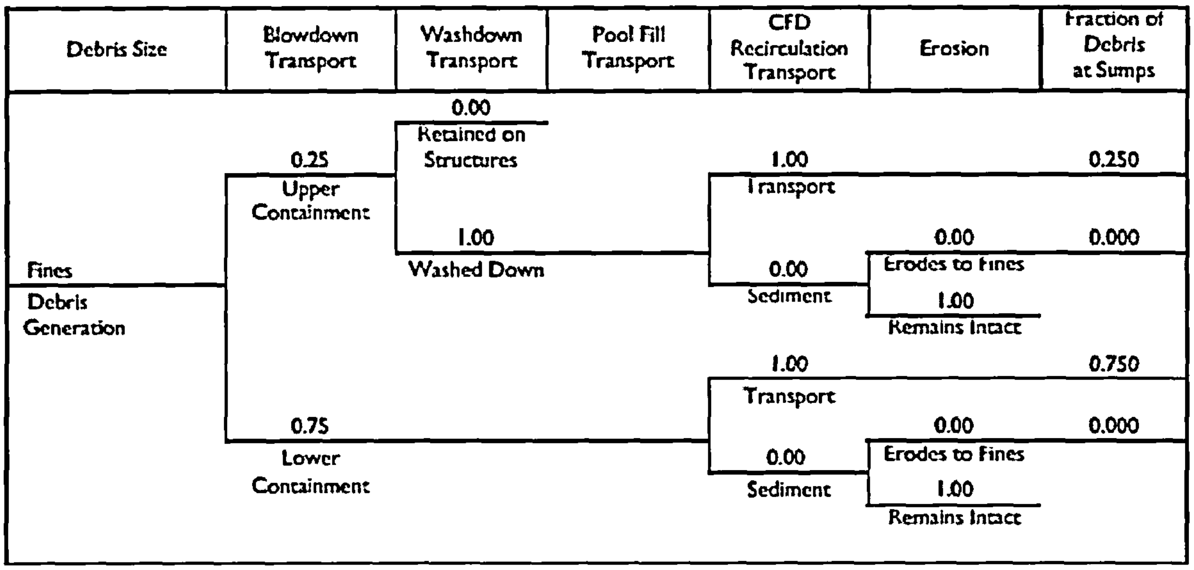
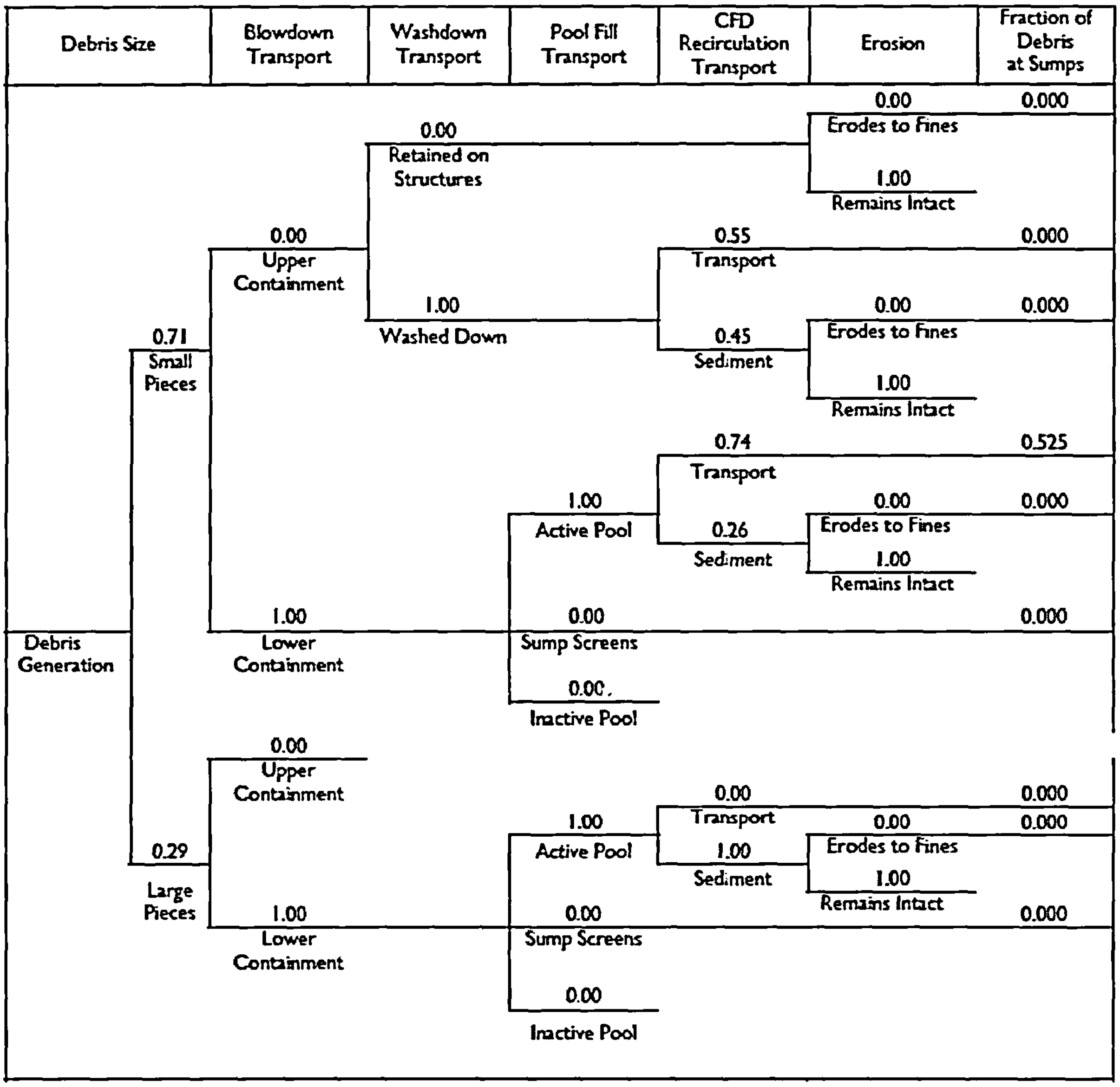


Figure 4-5
RCS Loop Pipe Break Inside the RV Cavity
RMI Transport Logic Tree



4.6 Debris Transport Results

The debris transport fractions for the two cases are provided on Tables 4-2 and 4-3.

Table 4-2
Debris Transport Fractions for SG A Cross-Over Line Loop "A"

Load Case	Debris Transport Fraction (DTF)
Temp-Mat	34%
Marinite	N/A
RMI Debris	71%
Paint Inside ZOI	100%
Paint Outside ZOI	100%
Dirt/Dust	100%
Latent Fiber	100%

Table 4-3
Debris Transport Fractions for RCS Loop Inside RV Cavity Break

Load Case	Debris Transport Fraction (DTF)
Temp-Mat	N/A
Marinite	100%
RMI Debris	53%
Paint Inside ZOI	100%
Paint Outside ZOI	100%
Dirt/Dust	100%
Latent Fiber	100%

5.0 Head Loss

Applying the Debris Transport Fractions to the Debris Generation data provides the debris accumulation at the sump strainers. The results for the two cases evaluated are provided in Tables 5-1 and 5-2.

For the cross-over line break, the large amount of particulates results in a high particulate loading, exceeding the level for available head loss correlations. It will therefore be necessary to size the sump strainer surface area such that thin bed formation is precluded. In order to form a debris bed, there needs to be sufficient fibrous material to accumulate a minimum of 1/8" thick uniform bed such that it will efficiently filter the particulate. The total fiber loading is 2.8 ft^3 from Temp-Mat and 6.7 ft^3 from latent fiber for a total of 9.5 ft^3. A minimum sump screen surface area to prevent a uniform debris bed is for this fiber load is 912 ft^2. There is also the latent debris blockage of 71.6 ft^2 for a total of approximately 985 ft^2. The head loss from RMI for this large surface area is minimal. However, the volume of RMI generated and transported to the sump strainer may be adequate to fill the entire sump pit. This may change the geometry of the strainer, reducing the effective surface area. For this reason, debris interceptors will be strategically placed in multiple locations to reduce the RMI debris to an acceptable loading. Additional detail on the debris interceptors is provided in response Item 2(a).

For the RCS loop break inside the RV cavity, the fiber loading is based solely on the latent fiber. So, for thin bed formation the cross-over line break is limiting. The RV cavity break also includes a large amount of Marinite board. Head loss data for Marinite is not available in public literature. SCE&G contracted Alion Science and Technology to complete flow loop testing for particulate Marinite. The tests results (Ref. 6.13) demonstrate that Marinite will not form a debris bed. The RMI loading is bounded by the cross-over line break.

Therefore, the minimum surface area for the VCSNS sump strainers will be based on precluding a uniform debris bed following a double end guillotine break of the 31" cross-over loop at the SG A outlet. An additional consideration for surface area is chemical effects. Margin over the minimum sump strainer area for potential chemical effects is discussed in response to Item 2d (iii).

Table 5-1
Debris Accumulation for Cross-Over Loop At SG A Outlet

Debris Type	Debris Quantity	Debris Transport Fraction (DTF)	Quantity At Sump
Insulation			
RMI	95,340 ft^2	71%	67,691 ft^2
Temp-Mat	8.2 ft^3	34%	2.8 ft^3/33.0 lbm
Qualified Coatings in ZOI			
Epoxy (6548/7107)	272.6 lbm	100%	272.6 lbm (2.47 ft^3)
Epoxy (6149)	48.2 lbm	100%	48.2 lbm (0.68 ft^3)
Epoxy (5000)	175.2 lbm	100%	175.2 lbm (1.91 ft^3)
Epoxy (4500)	445.6 lbm	100%	445.6 lbm (3.98 ft^3)
Unqualified Coatings			
Alkyds	205.1 lbm	100%	205.1 lbm (2.09 ft^3)
Unknown	311.9 lbm	100%	311.9 lbm (3.31 ft^3)
Latent Debris			
Latent Fiber	16 lbm	100%	16 lbm/6.7[2] ft^3
Dust & Dirt	89 lbm	100%	89 lbm
Tags and Tape[1]	95.4ft^2	75%[1]	71.6 ft^2

(1) Section 3.5.2.2.2 of the SER allows for the wetted sump-screen flow area to be reduced by an area equivalent to 75% of the total of the single sided surface area of the tags.

(2) The volume of latent fiber was calculated by dividing the mass of latent fiber by the bulk density of NUKON® as shown in the GR is 2.4 lb/ft^3. This gives a latent fiber volume of 6.7 ft^3 (16 lb/2.4 lb/ft^3).

Table 5-2
Debris Accumulation for RCS Pipe Break Inside the RV Cavity

Debris Type	Debris Quantity	Debris Transport Fraction (DTF)	Quantity At Sump
Insulation			
RMI	12,374 ft^2	53%	6,558 ft^2
Marinite	30.2 ft^3	100%	30.2 ft^3
Qualified Coatings in ZOI			
Epoxy (6548/7107)	272.6 lbm	100%	272.6 lbm (2.47 ft^3)
Epoxy (6149)	48.2 lbm	100%	48.2 lbm (0.68 ft^3)
Epoxy (5000)	175.2 lbm	100%	175.2 lbm (1.91 ft^3)
Epoxy (4500)	445.6 lbm	100%	445.6 lbm (3.98 ft^3)
Unqualified Coatings			
Alkyds	205.1 lbm	100%	205.1 lbm
Unknown	311.9 lbm	100%	311.9 lbm
Latent Debris			
Latent Fiber	16 lbm	100%	16 lbm (6.7(2) ft^3)
Dust & Dirt	89 lbm	100%	89 lbm
Tags and Tape(1)	95.4 ft^2	75%(1)	71.6 ft^2

(1) Section 3.5.2.2.2 of the SER allows for the wetted sump-screen flow area to be reduced by an area equivalent to 75% of the total of the single sided surface area of the tags.

(2) The volume of latent fiber was calculated by dividing the mass of latent fiber by the bulk density of NUKON® as shown in the GR is 2.4 lb/ft^3. This gives a latent fiber volume of 6.7 ft^3 (16 lb/2.4 lb/ft^3).

6.0 REFERENCES

6.1 NEI Guidance Report 04-07, Pressurized Water Reactor Sump Performance Evaluation Methodology, Revision 1
6.2 Calculation DC03190-020, Latent Debris Loading in the Reactor Building for the Recirculation Sump Blockage Analysis
6.3 Calculation DC03190-021, Unqualified Material Loading in the Reactor Building for the Recirculation Sump Blockage Analysis
6.4 Calculation DC03190-022, Material Left Inside the Reactor Building after Closeout for the Recirculation Sump Blockage Analysis
6.5 NUREG/CR-6808
6.6 Alion Calculation ALION-CAL-SCEG2810-003, Revision 1, GSI-191 Reactor Building Recirculation Sump Evaluation: Debris Generation
6.7 Alion Calculation ALION-CAL-SCEG2810-002, Revision 0, Virgil C. Summer Nuclear Station: Characterization of Events That May Lead to ECCS Sump Recirculation
6.8 Alion Calculation ALION-CAL-SCEG2810-005, Revision 1, GSI-191 Reactor Building Recirculation Sump Evaluation: Debris Transport
6.9 Alion Calculation ALION-CAL-SCEG2810-004, Revision 1, V.C. Summer Reactor Building GSI-191 CFD Analysis Calculation
6.10 Alion Calculation ALION-CAL-SCEG2810-006, Revision 1, GSI-191 Containment Sump Evaluation : Debris Accumulation and Head Loss
6.11 Alion Report No. ALION-REP-ALION-2806-01, Insulation Debris Size Distribution for use in GSI-191 Resolution
6.12 NUREG/CR-6224
6.13 Alion Test Report No. ALION-REP-LAB-2352-60, Rev. 0 – Hydraulic Properties of Marinite Insulation Test Report: Vertical Loop
6.14 Specification SP-218, Field Application of Coatings for Concrete Inside Reactor Building
6.15 Specification SP-713, Painting Steel – Inside Reactor Building

Attachment IV
NRC Generic Letter 2004-02
Requested Information

2(d) The submittal should include, at a minimum, the following information:

- **(i) The minimum available NPSH margin for the ECCS and CSS pumps with an unblocked sump screen.**
- **(ii) The submerged area of the sump screen at this time and the percent of submergence of the sump screen (i.e. partial or full) at the time of the switchover to sump recirculation.**
- **(iii) The maximum head loss postulated from debris accumulation on the submerged sump screen, and a description of the primary constituents of the debris bed that result in this head loss. In addition to debris generated by jet forces from the pipe rupture, debris created by the resulting containment environment (thermal and chemical) and CSS washdown should be considered in the analyses. Examples of this type of debris are disbonded coatings in the form of chips and particulates and chemical precipitants by chemical reactions in the pool.**
- **(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.**
- **(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.**
- **(vi) Verification that 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.**
- **(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 predicted flow conditions.**
- **(viii) If an active approach (e.g., backflushing, powered screens) is selected in lieu of or in addition to a passive approach to mitigate the effects of the debris blockage, describe the approach and associated analyses.**

Response:

Item 2d (i) – NPSH

SCE&G calculation DC04410-007, Revision 2 documents the current RHR pump NPSH calculation. The following results are provided.

	Flow	NPSH Required	NPSH Available	NPSH Margin
RHR Pump A	4500 gpm	18 ft	27.2 ft	9.2 ft
RHR Pump B	4500 gpm	18 ft	27.4 ft	9.4 ft

The calculation does not credit containment over pressure (i.e. no sub-cooling the fluid). It also assumes a flood level of 412 ft, even with the containment floor. The minimum flood level is now documented at 2.9 ft (calculation DC03190-019) above the floor. So, the NPSH margin for the RHR pump is 9.2 ft + 2.9 ft = 12.1 ft. When the final strainer design is established, RHR pump NPSH calculation will be revised. Given the significant margin, NPSH shortfall will not be a concern for a clean strainer.

SCE&G calculation DC03190-013, Revision 3 documents the current Containment Spray pump NPSH calculation. The following results are provided.

	Flow	NPSH Required	NPSH Available	NPSH Margin
Spray Pump A	3000 gpm	20 ft	28.1 ft	8.1 ft
Spray Pump B	3000 gpm	20 ft	28.0 ft	8.0 ft

The calculation does not credit containment over pressure (i.e. sub-cooling the fluid). It also assumes a flood level of 412 ft, even with the containment floor. The minimum flood level is now documented at 2.9 ft (calculation DC03190-019) above the floor. So, the NPSH margin for the spray pump is 8.0 ft + 2.9 ft = 10.9 ft. When the final strainer design is established, Spray pump NPSH calculation will be revised. Given the significant margin, NPSH shortfall will not be a concern for a clean strainer.

Item 2d (ii) – Submerged Screen

As covered under Item 2a, the final screen surface area to be installed during the Fall 2006 refueling outage has not been established. A minimum sump screen surface area to prevent a uniform debris bed for the fiber load is 912 ft^2. There is also the latent debris blockage of 71.6 ft^2 for a total minimum screen surface area of approximately 985 ft^2. SCE&G anticipates the entire surface area (100%) will be submerged at recirculation switchover. The new strainers are planned to be physically located below the top of the existing 6 inch curb around the perimeter of the sumps. The top of the curb is at elevation 412.5 ft. When the contract is awarded, SCE&G will provide a supplemental response covering the vendor selection and surface area of the conceptual design.

Item 2d (iii) – Debris Head Loss

The maximum calculated head loss across the replacement sump screen is dependent upon the replacement sump screen design. The sump strainer will be sized to prevent the formation of a thin bed. A minimum sump screen surface area to prevent a uniform debris bed for the fiber load is 912 ft^2. There is also the latent debris blockage of 71.6 ft^2 for a total minimum screen surface area of approximately 985 ft^2.

Another consideration for sump strainer surface area is the potential for chemical effects head loss. VCSNS has a Spray Additive Tank (SAT) and uses NaOH as the buffering agent. VCSNS is most similar to Test 1 from the Chemical Effects Test Program. Four specific chemical effects were noted in the test.

- Sediment Particulate
- Precipitate Particulate
- Kinematic Viscosity Increase
- Sump Solution/Reaction with Fiberglass

Sizing the sump strainer to preclude a uniform debris bed should reduce the concerns related to sediment and precipitate particulate. Also, the limited amount of fiberglass will reduce the potential reaction with fiberglass. Any increase in kinematic viscosity would likely have an impact on strainer head loss. To account for the potential chemical effects, design margin will specifically be added to the sump strainer surface area. A design margin of 30% of the surface area will be added to the analytical minimum and dedicated for chemical effects. The need for this margin will be evaluated when suitable chemical effect guidance is available.

By adding a 30% margin for chemical effects, the minimum surface area for the replacement sump strainers will be 1300 ft^2 per train. When the contract has been awarded, a supplemental letter will be provided to identify the vendor and minimum surface area for installation in the Fall 2006 refueling outage.

Item 2d (iv) – Holdup Volumes

SCE&G calculation DC03190-019, Revision 0, was developed to document the minimum water level in the recirculation sump pool. The calculation specifically accounted for holdup volumes at several locations including spray flow accumulation on operating decks and the refueling cavity drain through an 8" pipe. The results of the this evaluation were used to establish a minimum water level used in debris transport and head loss calculations, as well as the conceptual design effort discussed elsewhere in this submittal. With a set of conservative assumptions, the minimum water depth was determined to be 2.9 ft or an elevation of 414.9 ft.

During the Spring 2005 outage, RB walk downs were completed to visually confirm the design inputs of the calculation. The walk downs specifically included;

- Each level of the RB to look for areas of curbing where water may be holdup. The path for spray flow down to the recirculation pool elevation was also confirmed.
- Each entrance into the secondary shield wall on the 412 ft elevation (recirculation pool level) to confirm water will flow out to the sump location.
- Each door in the RB was photographed to confirm design drawings. No discrepancies were found.
- The 8" refueling cavity drain pipe outlet into the normal RB sump was photographed. There are no interferences at the outlet pipe.

Two concerns were identified during the walk downs.

- The pressurizer cubicle door is a solid, architectural door. While the door latching mechanism would fail open under postulated breaks, the door will be replaced with a large opening gated door during the Fall 2006 Refueling outage.
- The walk down identified a dual set of dampers on the RV cavity fans. If the break location were within the primary shield wall, these dampers could restrict flow out of the RV cavity. This is not a limiting break location or representative of the break locations covered by the Debris Transport analysis. A separate sump level will be developed for breaks inside the primary shield wall to confirm NPSH requirements are met.

Item 2d (v) – Downstream Debris Blockage

An evaluation of the potential for blockage due to ingestion of debris beyond the sump screen and into the ECCS and CSS flow paths has been performed using the methods described in WCAP-16406-P. This effort was completed by Westinghouse Electric Company, LLC. A sump screen hole size of 1/8-inch (round) was used as a basis to evaluate debris size that might be ingested into the ECCS and CSS flow paths. The replacement sump screen hole size for VCSNS is expected to be 1/8-inch or smaller. Both particulate and fibrous debris were considered in this evaluation. The components evaluated for potential blockage included pumps, pump bearings, pump seals, valves containment spray nozzles, and fuel. Results of the evaluation have shown that there are no flow restrictions in the ECCS and CSS flow paths that would result in blockage due to the ingestion of debris through a sump screen having a 1/8-inch flow path. The HHSI throttle valves were not included in this evaluation. The opening clearance of the valve has not yet been determined. Resolution of the downstream effects is an on going effort at SCE&G.

Item 2d (vi) – Downstream Wear

An evaluation of the potential for excessive wear of close-tolerance subcomponents in pumps and valves due to ingestion of debris beyond the sump screen and into the ECCS and CSS flow paths has been performed using the methods described in WCAP-

16406-P. This effort was completed by Westinghouse Electric Company, LLC. A sump screen hole size of 1/8-inch (round) was used as a basis to evaluate debris size that might be ingested into the ECCS and CSS flow paths. The replacement sump screen hole size for VCSNS is expected to be 1/8-inch or smaller. Both particulate and fibrous debris were considered in this evaluation. The components evaluated for potential wear included pumps, valves and spray nozzles. The mechanical shaft seal assembly performance evaluation resulted in one recommendation with regard to the replacement of the RHR, charging and RB spray pumps' carbon/graphite backup seal bushings with a more wear resistant material.

Item 2d (vii) – Mechanical Design on Sump Strainers and Trash Racks

Detailed structural design calculations will be provided by the sump strainer vendor for the specific sump strainer design and configuration that is selected for installation at VCSNS. The three strainer designs being considered are inherently rugged steel design that have been either installed at nuclear plants or have undergone full structural design qualification for nuclear plants. The vendor structural calculations provided for VCSNS will address the generic design of the strainers as well as the unique configuration of the strainers designed to fit the VCSNS sumps. The structural design will be performed following vendor selection and contract award. The trash racks, sump strainers, and interceptors are located so that loads from postulated high energy pipe ruptures including expanding jets and missiles are not applicable. Trash racks, sump strainers, and interceptors are all designed for the applicable loads defined in the FSAR for Seismic Category I steel structures. These include loads imposed by the accumulation of debris, and pressure differentials caused by post-LOCA blockage under predicted flow conditions, as well as dead, OBE, and SSE loads.

Item 2d (viii) – Active Strainers

Currently, SCE&G is not considering implementing active replacement sump screens at VCSNS. In the event that consideration is given to active replacement sump screens, this submittal will be amended to include the information requested under this item.

Attachment V
NRC Generic Letter 2004-02
Requested Information

2(e) A general description of and planned schedule for any changes to the plant licensing bases resulting from any analyses 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 exception requests needed to support changes to the plant licensing basis should be included.

Response:

With due consideration of the proposed modifications and the current plant licensing basis, SCE&G does not foresee the need to submit License Amendment Requests (LARs) in conjunction with the resolution of GSI-191 for VCSNS. Should circumstances warrant a change to this plan, this submittal will be amended in a timely manner to identify the anticipated LARs and the expected schedule for their submittal.

Attachment VI
NRC Generic Letter 2004-02
Requested Information

2(f) A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduction into containment (e.g. insulation, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions. Addresses may reference their response 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 response address these specific foreign material control issues.

Response:

Existing Programmatic Controls

SCE&G has listed and described existing Programmatic Controls for containment cleanliness, Foreign Material in Containment and Service Level 1 coatings in response to Generic Letter 98-04 and Bulletin 03-01. These are contained in the following SCE&G letters

- RC-98-0207, "Response to Generic Letter 98-04", November 11, 1998
- RC-03-0164, "Response to NRC Bulletin 2003-01", August 6, 2003
- RC-03-0236, "Response to NRC Bulletin 2003-01", November 18, 2003

Planned Programmatic Controls

SCE&G will incorporate Unqualified Paint and Insulation into the existing Cumulative Effects Program. The program is used to track modification impacts on items like heat sinks for the containment analysis and material additions for maximum flood level in the RB.

To establish the Cumulative Effects Program on Unqualified Paint, a calculation will be developed documenting all unqualified paint inside the RB. The calculation will be based on the coatings walkdown completed during the Spring 2005 refueling outage. The calculation will also review equipment lists to ensure all components with unqualified paint were captured during the walk down. The coatings procedure controls application of the proper coatings inside the RB which may fall outside of the change control process.

To establish the Cumulative Effects Program on Insulation, a calculation will be developed listing the type, location and quantities of insulation inside the RB. The calculation will be based on the Debris Generation calculation completed for the NEI 04-07 analysis which tabulates the insulation. The current insulation procedures do not permit a change in insulation type without an Engineering Change Request (ECR). The ECR procedures direct the engineers to the Cumulative Effects Programs.