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A SCANA COMPANY

February 29, 2008

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
SUPPLEMENTAL RESPONSE TO NRC GENERIC LETTER 2004-02: POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

Reference:
1. J. B. Archie to Document Control Desk, 90 Day Response to NRC Generic Letter 2004-02, dated March 7, 2005, RC-05-0037
2. J. B. Archie to Document Control Desk, Response to NRC Generic Letter 2004-02, dated September 1, 2005, RC-05-0138
3. W. H. Ruland (NRC) to A. Pietrangelo (NEI), Revised Content Guide for Generic Letter 2004-02 Supplemental Responses, November 21, 2007

This letter and the associated attachment provide South Carolina Electric & Gas Company's (SCE&G's) supplemental response to Generic Letter 2004-02 for Virgil C. Summer Nuclear Station (VCSNS). Reference 1 above provided SCE&G's initial response for the request for information in part 1 of the generic letter. Reference 2 provided the additional details requested in part 2 of the generic letter. Reference 3 provides NRC guidance for industry response to NRC issues of concern regarding Generic Letter 2004-02. SCE&G is submitting supplemental information based on these guidelines.

There are no regulatory commitments provided in this submittal.

Should you have questions, please call Mr. Bruce Thompson at (803) 931-5042.

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

2/29/08
Executed on

Jeffrey B. Archie
Vice President, Nuclear Operations

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Attachment

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File (815.14)
PRSF (RC-08-0031)

A116

NRR

NRC Generic Letter 2004-02
Supplemental Information

1. Overall Compliance:

South Carolina Electric and Gas Company (SCE&G) installed modifications during the Fall 2006 Refueling Outage (RF16) and completed supporting analysis to address the concerns for V. C. Summer Nuclear Station (VCSNS) under Generic Service Issue, GSI-191, "Assessment of Debris Accumulation on Pressurized-Water Reactor (PWR) Sump Performance." The new recirculation sump strainers meet the minimum Net Positive Suction Head for the Residual Heat Removal (RHR) pumps and Reactor Building (RB) Spray pumps which take suction on the recirculation sumps. The system design will meet Long Term Cooling requirements under 10CFR50.46.

2. General Description of and Schedule for Corrective actions:

SCE&G completed several modifications during the RF16 to address the concerns under GSI-191.

2.1 Recirculation Sump Strainer Replacement

The two RB Engineered Safety Features (ESF) recirculation sumps (one per train) are located approximately 45 degrees apart in the annular region between the secondary shield (bio-shield) wall and the RB wall. These are shown on Figure 1. SCE&G installed two Atomic Energy of Canada, Ltd (AECL) fin strainers. A description of the Sump Strainers is provided under the response to items 3j and 3k.

2.2 Vertical Trash Rack Gates

Two Vertical Trash Rack Gates are provided in the RB annulus on the 412 ft elevation. The gates are located on either side of the recirculation sumps to stop large debris from entering the sump area. The gates have 8 inch openings to allow smaller material to pass through. The gates are a non-deterministic design feature added to enhance the sump design based on the guidance provided in Section 1.1.1.3 of Regulatory Guide 1.82, Revision 3. No credit is taken for these gates in the GSI-191 analysis.

The gates are stainless steel, seismic category 1. Since they are outside the bio-shield wall they will not be subject to LOCA jet forces. The large openings provide little hydraulic resistance, so these are not a design consideration.

2.3 Stairwell Gate

A stairwell is located adjacent to the A train sump. Regulatory Guide 1.82, Revision 3, Section 1.1.1.5 provides the following guidance:

> "All drains from the upper regions of containment should terminate in such a manner that directs streams of water, which may contain entrained debris, will not directly impinge on the debris interceptors or discharge in close proximity to the sump."

The Pressurizer cubicle floor is located on the 436 ft elevation (one floor above the 412 ft elevation with the sumps). If a break were to occur within the Pressurizer cubicle, the break flow would come down the stairwell directly adjacent to the A sump. For this reason, a gate is located across the stairwell entrance on the 436 ft elevation. The bottom 6 inches of the gate is solid to direct flow away from the stairwell. Two lengths of toe-kick plate (8 ft each) are removed at a location away from the sump strainers to allow for flow down from the 436 ft elevation.

The stairwell gate is a non-deterministic design feature added to enhance the sump design based on Regulatory Guide 1.82, Revision 3. The Pressurizer cubicle break is a non-limiting break location. The stairwell gate is not modeled in the GSI-191 analysis.

The gate is stainless steel, seismic category 1. Since it is outside the bio-shield wall it will not be subject to LOCA jet forces.

2.4 High Head Safety Injection Throttle Valve Replacement

Analysis of high Head Safety Injection (HHSI) flow balancing data concluded that the HHSI throttle valve position (i.e., opening clearance) was not acceptable for downstream effects. The 12 HHSI throttle valves were replaced during the Fall 2006 Refueling Outage with FloServe Pressure-Combo valves. These valves feature an outlet flow nozzle which takes up most of the required pressure drop for the flow balance, permitting the valve to have adequate clearance for the downstream effects.

The downstream effects analysis for the valves is complete. Erosion is less than the 3% allowable. The minimum valve opening based on the ECCS flow balancing criteria is approximately 3/32" compared to the 1/16" screen openings. The evaluation is covered in further detail in response to Item 3m.

2.5 Debris Interceptor Deletion

The SCE&G response to GL 2004-02 in letter RC-05-0138 [Reference 5] indicated the likely installation of Reflective Metal Insulation (RMI) debris interceptors. The concern was the high volume of RMI debris transporting to the sump location. Since the sump strainers are located below grade there was a concern that filling the sump pit around the new strainer may result in unacceptable head loss.

SCE&G funded RMI debris transport testing to augment available data. The transport metrics from the test along with a robust barrier analysis to decrease debris generation were applied to significantly reduce the RMI material transport to the sump strainers. The analysis demonstrates RMI debris will not fill the outboard space of the strainer. The need for debris interceptors was eliminated.

In parallel with the RMI debris reduction, SCE&G also had a large scale test performed with the outboard space of the sump pit completely filled with RMI debris. This was followed by the addition of fiber and particulate debris from the limiting fiber case. The head loss results were acceptable and did not result in a design limiting head loss.

2.6 Pressurizer Cubicle Door Replacement Deletion

The SCE&G response to GL 2004-02 in letter RC-05-0138 [Reference 5] indicated the likely replacement of the Pressurizer Cubicle Door. The concern was that the solid architectural door could potentially hold water up inside the pressurizer cubicle if other drainage paths are blocked by the LOCA generated debris.

Upon further investigation and plant walk downs, the Pressurizer Cubicle Door is not equipped with a latching mechanism. The door has a simple spring closure. It will not hold up water in the pressurizer cubicle. The Pressurizer Cubicle Door will not be replaced.

2.7 Cumulative Effects Program on Insulation

As discussed in the SCE&G response to GL 2004-02 in letter RC-05-0138, a cumulative effects program has been established for tabulating, controlling and evaluating changes to quantities of insulation inside the RB. This included the development of a calculation listing the type, location and quantities of insulation inside the RB. The cumulative effects program was implemented by revision of existing procedures which cover other design control data such as containment heat sinks, fire loading, and electrical loading.

2.8 Cumulative Effects Program on Unqualified Coatings

As discussed in the SCE&G response to GL 2004-02 in letter RC-05-0138, a cumulative effects program has been established for tabulating, controlling and evaluating changes to quantities of unqualified coatings inside the RB. This included the development of a calculation listing the type, location and quantities of unqualified coatings inside the RB. The cumulative effects program was implemented by revision of existing procedures which cover other design control data such as containment heat sinks, fire loading, and electrical loading.

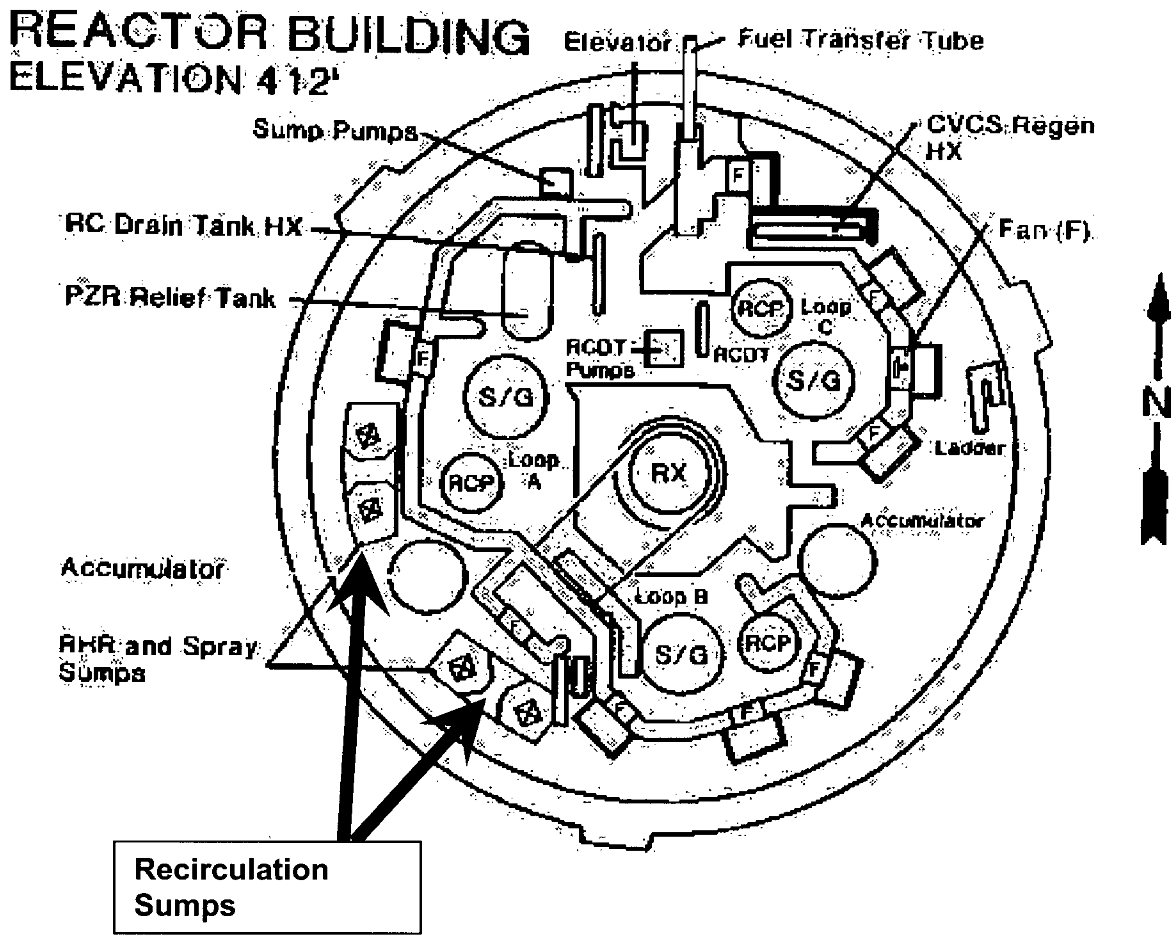
2.9 Cumulative Effects Program on Qualified Coatings

VCSNS has an established Level 1 coatings program for the RB. The qualified coatings within a 4D Zone of Influence (ZOI) will also be tracked. The quantity of qualified coatings may increase with the installation of platforms, supports, ladder cages or electric boxes. The cumulative effects program was implemented by revision of existing procedures which cover other design control data such as containment heat sinks, fire loading, and electrical loading.

2.10 Alternate Source Term LOCA Dose Analysis

The current licensing basis LOCA Dose Analyses requires the assumption of a pump seal (RHR pump is assumed but also applies to charging pump and RB Spray pump) failure at 24 hours after the event and assumes the leak rate is limited to 50 gpm. The Down Stream Effects analysis identified a concern with pump seal backup bushings (also called disaster seals) made of graphite. These seals may leak greater than 50 gpm if the primary seal fails. SCE&G contacted the pump vendor and Westinghouse for replacement seals which do not use graphite. No replacement seals packages were identified. To address this concern, SCE&G is proceeding with Alternate Source Term analysis. The Alternate Source Term does not require the assumption of a pump seal failure, thus eliminating the concern related to the graphite backup bushing. All LOCA Dose Analyses are complete and demonstrate acceptable dose results. Formal submittal of a license amendment request is projected for the Fall of 2008.

Figure 1
V.C. Summer Nuclear Station Reactor Building
412 Ft Elevation



3. Specific Information Regarding Methodology for Demonstrating Compliance:

3a. Break Selection

Break selection consisted of determining the size and location of the High Energy Line Breaks 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 Safety Evaluation Report (SER) [Reference 2], piping under 2 inch diameter can be excluded when determining the limiting break conditions.

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.

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

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 the 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 VCSNS, there are four possible break locations that have the potential to generate the largest concentration of debris. The first is the 31 inch RCS Cross-over line (LBLOCA) which is located inside the Steam Generator (S/G) compartments inside the bio-shield. The second is the 6 inch Pressurizer Safety Relief to Safety Valve Line (SBLOCA) in the Pressurizer cubicle. The third is the 14 inch Pressurizer Surge Line (LBLOCA) in the Pressurizer cubicle. The fourth is a break at a Reactor Vessel Nozzle (LBLOCA). According to data collected from the insulation drawings, the following specific break locations were assessed:

- RCS Cross-over Line break (31") at the S/G outlet
- Pressurizer Safety Relief Line break (6")
- Pressurizer Surge Line break (14") below the Pressurizer
- Reactor Vessel Nozzle break (hot leg or cold leg break)

The break selection at VCSNS was simplified in some aspects based upon the discreet location of non-RMI used inside the RB. No single break location impacts more than one type of non-RMI. Placing the break in large diameter pipes, close to the non-RMI maximizes the Debris Generation. For RMI, the large ZOI for the Diamond Power Mirror insulation essentially results in all the insulation within a loop compartment being dislodged. Analyzing Debris Generation at 5-foot intervals for break locations was not necessary.

Secondary side breaks are not considered in the analysis for the sump strainer. Consistent with the VCSNS licensing basis analysis provided in Chapter 15 of the VCSNS Final Safety Analysis Report (FSAR), secondary side breaks are mitigated and do not proceed to recirculation alignment of the Safety Injection System (SI) or Reactor Building Spray System (SP).

3b. Debris Generation/Zone of Influence (ZOI) (excluding coatings)

3b.1 Debris Sources and Identification

3b.1.1 Diamond Mirror Reflective Metallic Insulation (RMI)

SCE&G primarily uses RMI for insulation of piping and equipment inside the VCSNS RB. The Diamond Power Specialty Company (DPSC) Mirror insulation has been maintained through the life of the plant and used during the replacement S/G 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. 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 SER [Reference 2].

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 [Reference 3]. 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 [Reference 3], 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. The NRC samples were provided by DPSC, the manufacturer of Mirror® RMI cassettes. This is the manufacturer and design used at VCSNS. The 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 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 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%

3b.1.2 Temp-Mat

Temp-Mat is used for two applications. The first is on the HVAC ducts in the pressurizer cubicle. This is in the upper levels, above the pressurizer. The second is on the S/G level instrument tubing. The tubing is run inside the secondary shield wall, primarily in the upper region the S/G 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, NEI Guideline 04-07 [Reference 31] recommends a size distribution with two categories - 60% small fines, and 40% large pieces. The SER (Appendix VI, Section 3.2) [Reference 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 SER a debris size distribution for Temp-Mat was developed by Alion . The basic methodology for this approach is as follows:

1) Destruction fractions at various distances from the jet nozzle were determined using AJIT data.
2) The distances were correlated to calculated pressures, and a plot was created showing the destruction fraction of small debris versus pressure.
3) A curve was fit through the data ranging from 0% small debris at low pressures to 100% small debris at high pressures. The data for Temp-Mat was specifically taken from Appendix II, Figure II-4 of the SER [Reference 2]
4) The small debris fraction curve was split into two ranges of pressures (sub-zones) and an equivalent sphere size was determined for each sub-zone (based on the debris damage curves).
5) The area under the curve for each sub-zone was calculated using a series of trapezoids.
6) Since limited testing indicates that a two phase jet could generate a larger fraction of small pieces and fines than an air jet, a 10% penalty was added to the small debris fraction determined by the area under the AJIT data curve (e.g., 5% small debris was increased to 15%). This is the same approach taken in Appendix VI of the SER.
7) Based on applicable data, the small debris category was subdivided into fines (individual fibers) and small pieces. Also, the large debris category was further subdivided into intact blankets, and large exposed pieces. Since Temp-Mat has a higher destruction pressure than Low Density Fiber Glass (LDFG), it was assumed that the breakdown of the fines/small pieces and large pieces/intact blankets can be conservatively estimated based on the LDFG data.

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 2. This distribution will be used in this calculation for Temp-Mat insulation.

From Table 2 in the NEI Guideline 04-07, the as-fabricated density of Temp-Mat is 11.8 lb/ft^3 and the density of individual fibers is 162 lb/ft^3. The fiber size is 9 μm (2.95E-5 ft).

Table 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%

3b.1.3 Marinite XL

Marinite XL insulation is used around the Reactor Vessel nozzles and on the RCS piping inside the primary shield wall penetration.

The Marinite XL on the RCS piping is 1 inch thick, encased in stainless steel with standard banding. For the RCS hot leg or cold leg pipe in which the rupture is assumed to occur, the RCS pipe will move within the penetration gap provided by the steel shim restraining points, crushing the Marinite XL insulation in the process. It is conservative to assume the Marinite XL is completely destroyed to particulate and is carried out of the penetration by the break flow. Marinite insulation in chunks or pieces is not highly transportable [Reference 3]. The SER does not recommend a destruction pressure or ZOI for this material and insufficient data exists on its material properties, destruction pressure or size distribution. The conservative assumptions are made that the Marinite XL on the RCS pipe where the break occurs is in particulate form and is 100% transportable to the sump. Marinite XL is 5% Mineral Wool fiber by weight. Marinite I particulate is 5 μm based on material testing funded by SCE&G. This is assumed for the Marinite XL material which is no longer available for testing.

The Marinite XL insulation cassettes around the Reactor Vessel nozzle serve two functions. The first is thermal insulation for the reactor vessel nozzles to limit heat loss. The second is to act as a flow restrictor in conjunction with the nozzle baffle jet assemblies. The Marinite XL is rigid and non-crushable under the LOCA jet forces. It is fully encapsulated in 1/4" stainless steel plate specifically designed and detailed so that the annular ring remains in place and not destroyed by pipe jet forces. The insulation is designed to have a clearance of approximately 1/2" to the nozzle baffle assembly. The tight fit limits LOCA break flows into the reactor vessel cavity. The design is credited in the Primary Shield Wall compartment pressurization and pipe reactions and jet forces. The LOCA break flow is directed out into the secondary S/G compartment and up in to the RB above the reactor vessel.

The design and analysis of the Primary Shield Wall are covered in VCSNS FSAR Section 3.8.3.1.5. The baffle assemblies are specifically covered and shown in Figures 3.8-47 and 3.8-48. The design and analysis was approved by the NRC in the SER (NUREG-0717, Reference 18). The design was completed prior to Leak-Before-Break licensing considerations were available. Section 6.2.1.3.9.3 of the FSAR covers the Reactor Cavity Analysis licensing position taken for the S/G replacement with Leak-Before-Break. The FSAR states

> "*Continued use of these original bases results in a conservative design for the steam generator compartments and the reactor cavity which bounds any potential effects of the replacement steam generators and changes in the plant operating conditions.*"

The original design basis, including the Marinite XL insulation cassettes and baffle assembly, has been maintained to encompass any impact from the S/G replacement. The Marinite XL insulation cassettes around the nozzle are designed to stay intact for a LOCA at the reactor vessel safe ends. This basis has been retained and the insulation remains in place and intact.

3b.1.4 Kaowool and Kaowool M-Board

The Kaowool and Kaowool M-Board are fire barriers. The fire barrier is 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 SER 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 SER.

Kaowool M-board exists in several locations within the RB. 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 will be assumed that Kaowool M-board has the same fiber diameter as Temp-Mat, or 9.0 μm. The lowest destruction pressure listed in the SER 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.

3b.2 Miscellaneous Debris

SCE&G completed a study of the VCSNS RB in which the quantity of latent unqualified material in containment was conservatively estimated based on plant walk downs and records searches. The plant walk downs were based on the guidance provided in NEI 02-01. The unqualified materials included such items as placards, paper, tape and tags. This debris is assumed 100% transportable to the sump. The total unqualified material in containment is conservatively estimated to be 189.8 ft^2. The large scale test used a value of 200 ft^2. Based on the NRC Safety Evaluation (SE), 75% of this total or 150 ft^2, is set aside as a "sacrificial" area assumed to be completely blocked by the unqualified material.

3b.3 Debris Generation

3b.3.1 Cross-Over Line Break

For RCS cross-over line break, Loop "A" was selected because it generated the most fibrous insulation debris (Temp-Mat). No robust barriers are considered in the Temp-Mat generation term. The RMI generation term does credit robust barriers. The VCSNS RB is compartmentalized. The spherical ZOI is truncated and only the RMI within the loop compartment with the break becomes debris. The Pressurizer is also within its own cubicle and the Reactor Vessel is within the primary shield wall. The debris generation for the S/G Loop "A" 31 inch cross-over outlet is presented in Table 3.

3b.3.2 Pressurizer Relief Line Break

A break postulated in the 6 inch 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 degree bend. 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 presented in Table 4.

3b.3.3 RCS Cavity Break

A break in any one RCS pipe will only affect that pipe. The baffle assembly (shown in FSAR Figures 3.8-47 and 3.8-48) completely encloses each nozzle and prevents LOCA jet expansion to the other pipes. Section 3.4.2.3 of the NRC Safety Evaluation [Reference 2] covers ZOI and Robust Barriers. The baffle assembly and primary shield wall function as robust barriers protecting adjacent loops and redirecting the LOCA jet.

The SER states

> *"Where the sphere extends beyond robust barriers, such as walls, or encompasses large components, such as tanks and steam generators, the extended volume can be truncated."*

For the Reactor Vessel nozzle safe end break, the ZOI is truncated such that only the Marinite XL on the broken loop is affected. As discussed in Section 3b.1.3, pipe whip within the primary shield wall penetration is conservatively assumed to destroy the insulation, regardless of the actual ZOI. The Marinite XL is 1 inch thick on the piping. The OD of the insulation is 36 inches on the cold legs and 37.75 inches on the hot legs. The volume of Marinite XL is calculated as the length of piping insulation times the cross sectional area of the insulation. The debris generation and size distribution are presented in Table 5.

3b.3.4 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 (PRT) 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 PRT at approximately elevation 431'-3" and the surge line is completely contained within the bio-shield. The stuck open Safety Valve with release through the PRT rupture disk will be bounded by the 14 inch Pressurizer Surge line directly above the PRT. The materials exposed to a break in the 14 inch Pressurizer Surge Line are RMI and Kaowool M-board. The debris generation and size distribution are presented in Table 6.

3b.4 Debris Source Term Evaluation

It is apparent by examining the results listed in Tables 3, 4 and 6 that the break in the 14 inch Pressurizer Surge Line or the 6 inch Pressurizer Safety Relief line is bounded by the break in the 31 inch RCS Cross-over Line. The 31 inch RCS Cross-over line break generates the same materials as the 6 inch Safety Relief line break but in larger quantities. Also, the 6 inch 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 Reactor Vessel 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 inch RCS Cross-over Line break at the S/G
- Reactor Vessel Cold Leg Nozzle "C"

Table 3 **31" RCS Cross-over Line DEGB Debris Generation (LBLOCA)**	
Insulation Type	Insulation Type Loop "A" Crossover Break
RMI	47,577 ft^2
Temp-Mat: 11.7D ZOI Temp-Mat: 3.7D ZOI	7.2 ft^3 1.0 ft^3

Table 4 **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 Temp-Mat: 3.7D ZOI	7.1 ft^3 0.0 ft^3

Table 5 **Reactor Vessel Cavity Break at a Nozzle Debris Generation (LBLOCA)**	
Insulation Type	Loop "C" Cold Leg to RV Nozzle Break
RMI	12,581 ft^2
Marinite	8.58 ft^3

Table 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

3c. Debris Characteristics

The Debris Characteristics are provided on Table 7. As recommended by the SER, the latent fibers were assumed to have the same material properties as NUKON. The properties of NUKON are reported in NUREG/CR-6224. The properties are taken from the SER unless otherwise noted. The coating debris sizes are covered in response Section 3h.2.

Table 7
Debris Characteristics

Debris Material	Macroscopic Density (lbs/ft^3)	Microscopic Density (lbs/ft^3)	Characteristic Size (μm)
Insulation			
Temp-Mat	11.8	162.0	9[b]
Marinite XL Particulate Portion [a]	46	144.0	5
Marinite XL Mineral Wool Portion	8	180	5[b]
Latent Debris			
Latent Fiber	N/A	175.0	7[b]
Dirt/Dust	N/A	169.0	17.3
Coatings			
Alkyds (unqualified)	N/A	98	83
Epoxy (unqualified)	N/A	94	32.00% (1"–2")[d] 9.04% (½"–1")[d] 4.41% (¼"–½") 5.02% (⅛"–¼") 49.50% (<⅛")[e]
Inorganic Zinc (unqualified)	N/A	457	40 [Ref. 18 and 35]
Amercoat 66	N/A	125[c]	10
Amercon 89	N/A	94	10
NU-KLAD 110A	N/A	132[c]	10
MobilZinc 7	N/A	457	10
Degraded Qualified Epoxy Coating (Amercoat 66)	N/A	125[c]	32.00% (1"–2")[d] 9.04% (½"–1")[d] 4.41% (¼"–½") 5.02% (⅛"–¼") 49.50% (<⅛")[e]

a - The properties of Marinite XL particulate are obtained from vendor data sheets and material testing of Marinite I
b - This is the fiber diameter
c - Based on vendor data sheets
d - 50% of these chips are curled and 50% flat
e - 75% of the < 1/8" are 1/64" (15.6 mils) and 25% are 6 mils

3d. Latent Debris

SCE&G completed sampling of the RB latent debris during the Spring 2005 refueling outage (RF15). The sampling was completed just prior to containment closeout, but before the final containment cleaning was complete. No special or new cleaning efforts were made prior to the sampling.

A total of 20 samples were used on the latent debris calculation as follows.

Floor Samples	# of Samples	Average Load
Inside the Bio-shield	3	2.3 lb/10000 ft^2
Outside the Bio-shield	4	0.52 lb/10000 ft^2
Vertical Surfaces		
Inside the Bio-Shield	2	0.31 lb/10000 ft^2
Outside the Bio-Shield	3	0.02 lb/10000 ft^2
Containment Wall	1	0.31 lb/10000 ft^2
Structural/Support Steel	4	3.1 lb/10000 ft^2
Heavy Debris Load Areas	3	12.6 lb/10000 ft^2

The Heavy Debris Load Areas are locations that are not easily accessible and not normally cleaned during refueling outages. The Heavy Debris Load Area samples were from cable trays and structural steel. Contributions from inaccessible areas have been taken into account in the debris loading calculations. The total sample surface area was approximately 500 square feet. The latent debris calculation followed the guidance provided in NEI 04-07. The total latent debris load based on the samples and the surface area was calculated to be 55.5 pounds. A cleaning efficiency for the sampling was assumed to be 80% to yield a total latent debris load of 69.3 pounds.

A 50% margin was added to yield a total latent debris load of 105 pounds. This was used on the analysis and testing of the VCSNS sump strainer. This conservative value is used to bound future operation.

The latent debris properties are as recommended by the SER: 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 SER. The sacrificial surface area for miscellaneous latent debris is covered in Section 3b.2.

3e. Debris Transport

3e.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 high energy blowdown following a double-ended guillotine pipe rupture would destroy only the insulation and paint coatings in the vicinity of the break location. Blowdown is considered to be omni-directional within lower containment. After pressuring up the compartment inside the bioshield wall, the blowdown would primarily relieve upward past the S/G and pumps to upper containment. Some of the pressure would also be relieved through the openings in the bioshield wall. During blowdown, it is likely that some small debris would adhere to the walls and equipment around the break. However, due to a lack of quantifiable data on this phenomenon, all debris not ejected upward was conservatively assumed to fall to the floor. The steam from the break would continue to expand outside the S/G compartment, transporting entrained fibers and particulate to virtually every area of containment. Fine debris would be easily suspended and carried by the blowdown flow. Small and large piece debris would 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 be likely to fall to the floor. Since the openings to upper containment are directly above the postulated break locations, some small piece debris would be blown into upper containment. Large piece debris would be blown upward as well. However, since there is grating between the break locations and upper containment, the large piece debris would be blown against the grating and fall or be washed back to the floor after blowdown has ended.

Washdown Spray transport – During the washdown phase, debris in upper containment could be washed down by containment sprays. Since all of the fibrous and particulate debris blown to upper containment was determined to be fines and small pieces, it is conservatively assumed that all of it would be washed back to lower containment. The washdown flow paths are the two stair wells and the equipment hatch. The split between these locations is based on perimeter of the opening.

Pool fill-up transport – During pool fill-up, the flow of water would transport insulation debris from the break location to all areas of the recirculation pool. Some of the debris could be transported to inactive areas of the pool. Some of the debris could also be transported directly to the sump screens as the recirculation sump cavity is filled. As water pours onto the containment floor, it would initially flow in shallow, high velocity sheets. This sheeting action may cause both small and large pieces of insulation debris (that may not transport easily during recirculation flow) to be scattered around the containment floor. As the water level rises, debris would preferentially be swept to cavities below the containment floor elevation. Since VCSNS has a 6-inch curb around the emergency sumps, the water level would have to rise high enough to flow over this curb before filling these cavities.

Recirculation transport – NEI Guideline 04-07 [Reference 31] recommends 100% transport of small debris during recirculation through the RB Recirculation sumps. However, the methodology provides for two refinement techniques to reduce this transport fraction: (1) nodal network approach, and (2) 3D computational fluid dynamics (CFD) modeling of the containment recirculation pool. The 3D CFD modeling is used at

VCSNS. CFD is used to determine transport fractions of debris during recirculation. The analysis was performed for all three cross-over legs in order to determine the most limiting break location for recirculation transport. Response Sections 3e.3 and 3e.4 have more details on the CFD modeling and results.

Section 3.6.2 of NEI Guideline 04-07 [Reference 31] 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 1 provides a view of the VCSNS containment to demonstrate the compartments and equipment layout.

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, size and type of debris, and for the type of containment. A computational fluid dynamics (CFD) analysis provides the worst case transport fractions for large pieces.

3e.2 Assumptions and Analysis Clarifications

(a) Material transport properties used in the analysis are provided in Table 8.

(b) Latent debris and failed coating particulate (fine debris) are conservatively assumed to be in the active pool at start of recirculation and 100% fraction available for transport to the sumps.

(c) 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.

(d) 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.

(e) Temp-Mat terminal velocity is based on NUKON.

(f) A series of tests were run at Alion Science Inc. Flume Test Facility for RMI transport. Using a representative size distribution (see response Section 3b.1.1), the RMI bulk tumbling velocity was measured. Use of the bulk tumbling velocity more accurately predicts transport of RMI debris. The large quantity of RMI debris generated (see response Table 3) forms a 1 inch thick layer of debris over the containment floor area assumed for the transport analysis. This combined with the fact that RMI is not "stirred up" anywhere in the distribution area other than directly in the vicinity of the break, it is reasonable to use the bulk tumbling velocity (0.65 ft/sec) as the metric for RMI transport. Also, as RMI debris is washed toward the sump, the tendency for agglomeration to occur will increase. Therefore, even if less RMI is generated and/or the RMI is more distributed at the beginning of recirculation, this analysis will still apply.

(g) Paint chip transport was modeled for epoxy coatings outside of the Zone of Influence. Five coating locations, which reflect different transport paths, were specifically modeled.

- Upper Containment - These chips will wash down the stair wells and equipment hatch
- Refueling Cavity - This covers the refueling equipment (reactor vessel internals racks) located in the refueling cavity. These transport through the 8 inch cavity drain
- Inside the Shield Wall - These are located inside the shield wall and may only transport out via one of three openings
- Annulus - These are located outside the shield wall on the 412 ft elevation
- A Sump - This is a special designation for unqualified coatings on two ventilation fans located partially over the "A" train sump.

The transport during recirculation is based on the metrics provided on Table 8. The metrics for 1.5" curled chips cover the ½" to 1" and 1" to 2" inch curled chips. The metrics for the ⅛" flat chips covers all flat chips ⅛" to 1".

Table 8
Material Properties for Transport

Debris Type	Size	Terminal Settling Velocity (ft/sec)	Reference	Calculated Minimum Turbulent Kinetic Energy Required to Suspend (ft^2/sec^2)	Flow Velocity Associated with Incipient Tumbling (ft/sec)	Reference
Temp-Mat	Individual Fibers	0.0074 (a)	NUREG/CR-6808 Fig. 5-2	8.2E-05	---	---
Temp-Mat	Small Pieces (< 6 inches)	0.15 (a)	NUREG/ CR-6772	0.034	0.50	NUREG/ CR-2982
Temp-Mat	Large Pieces (> 6 inches)	0.41 (a)	NUREG/ CR-6772	0.25	0.90	NUREG/ CR-2982
Stainless Steel RMI	Distribution	0.37	NUREG/ CR-6772 Table 3.5	0.21	0.65	Test Data (b)
Unqualified Epoxy Paint Chip	⅛"	0.15	Correlated to NUREG/ CR-6916	3.5E-02	1.08	Correlated to NUREG/ CR-6916(c)
Unqualified Epoxy Paint Chip	2" Flat	0.23	Correlated to NUREG/ CR-6916	7.8E-02	1.76	Correlated to NUREG/ CR-6916(c)
Unqualified Epoxy Paint Chip	1.5" Curled	0.22	Correlated to NUREG/ CR-6916	7.2E-02	0.12	Correlated to NUREG/ CR-6916(c)
Unqualified Epoxy Paint Chip	1/64"	0.09	Correlated to NUREG/CR-6916	1.3E-02	0.75	Correlated to NUREG/ CR-6916(c)

(a) Based on NUKON fibers
(b) Based on test data for bulk transport as discussed in response Section 3e.2
(c) Transport metrics for epoxy paint chips were correlated to the data in NUREG/CR-6916 based on the Dried Film Thickness and density

3e.3 CFD Model Recirculation Transport

VCSNS applied the debris transport refinement discussed in Section 4.2.4.2 of NEI 04-07, as modified in Section 4.2.4 of the NRC SE on NEI 04-07, which allows the use of Computational Fluid Dynamics (CFD) software. Using this approach, the transport of debris to the RB sump associated for each postulated high energy pipe break and for each type of debris generated was evaluated.

The Flow-3D Version 9.0 was used by Alion Science to perform the flow field calculations for VCSNS.

The basic steps taken to accomplish the CFD analysis are

1. A three dimensional model of the VCSNS floor was built using computer aided draft (CAD) software based on RB drawings. This is shown in Figure 2. The CAD model was then incorporated into the CFD model.
2. The mesh in the CFD model was nodalized to sufficiently resolve the features of the CAD model, but at the same time keep the cell count low enough for simulation to run in a reasonable amount of time.
3. The dimensions of the solid objects from the CFD model output were checked with the appropriate drawings to verify accuracy of the model.
4. Boundary and initial conditions in the CFD model were defined consistent with the particular configuration of break location, pool depth, pool temperature and recirculation flow rate being addressed.
5. RB spray drainage was included in the CFD calculation with the appropriate velocity and flow rates. Drain flow from the operating decks is through the equipment hatch and stairwells as shown on Figure 2.
6. At the postulated LOCA break location, a mass source was added to the model to introduce the appropriate velocities and kinetic energies associated with the break flow.
7. Negative mass sources were added at the two sump locations with the total flow rates equal to the sum of the spray flow and break flow. The new strainers are installed in the same foot print as the original strainers, so the CFD modeling is applicable to both the original and current designs.
8. The appropriate turbulence modeling equations were selected for the CFD model. The Renormalized Group Theory (RNG) turbulence model was applied to the CFD analysis. 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).
9. Three calculations were carried out to achieve steady state conditions. The break locations are shown on Figure 2. After running the CFD calculations, the mean kinetic energy was checked to verify that the model had been run long enough to reach steady state conditions.

10. Transport metrics were determined based on relevant tests and calculations for each significant debris type present in the RB.
11. The distribution of debris at the beginning of recirculation was conservatively assumed to be between the break locations.
12. A graphical determination of the fraction of each type of debris that would transport through the containment pool to the emergency sump was made from the velocity and turbulence fields predicted in the CFD calculations along with the determined initial distribution of debris.

Figure 2 shows the CAD model with spray drain paths, break locations and recirculation sump locations highlighted. As an example, Figure 3 shows the CFD results with velocity vectors for a break at the S/G A outlet nozzle.

Transport velocities and terminal velocities used in the CFD modeling are provided in Table 8. Debris Transport fraction for the recirculation phase based on the CFD analysis are summarized in response Section 3e.4.

Figure 2
CAD Model with Spray Drainage, Break Locations and Sump Locations

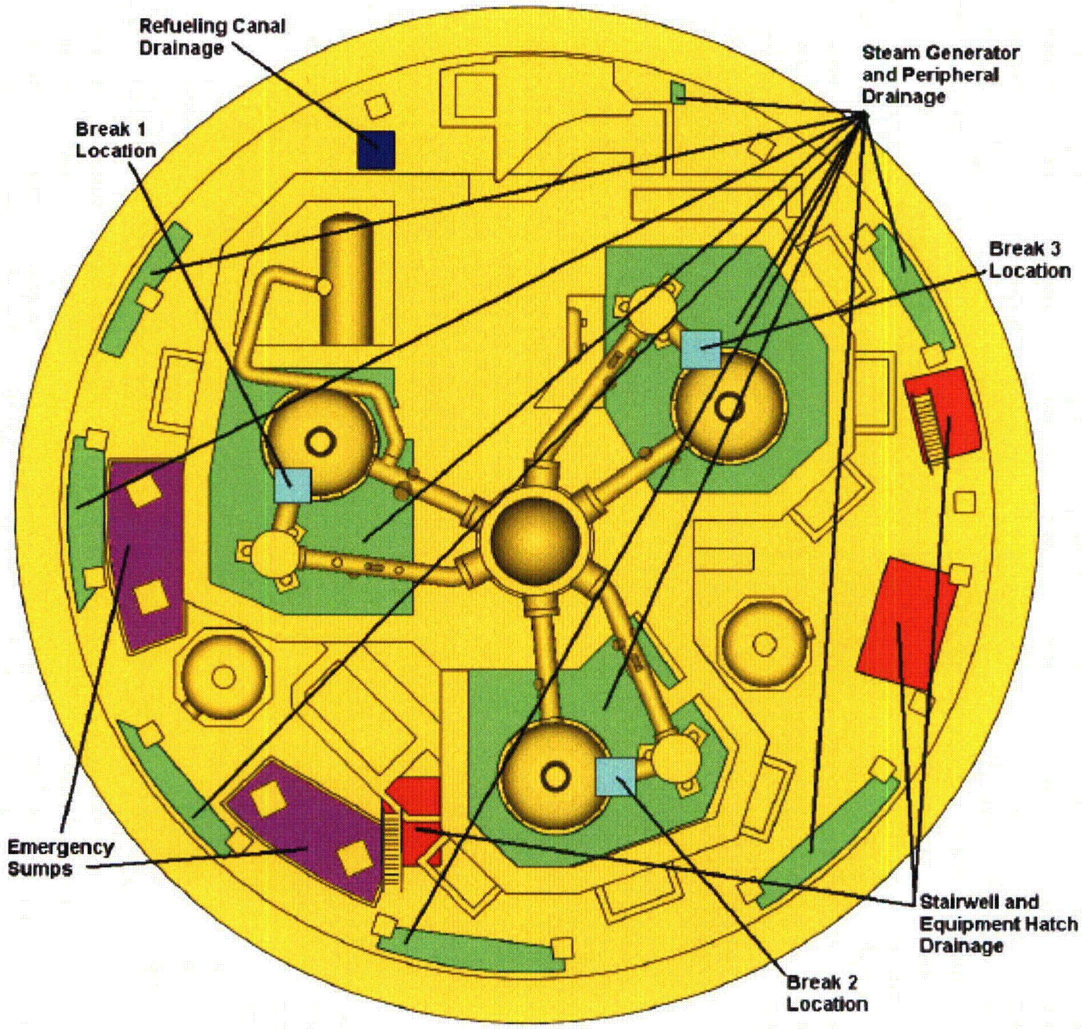
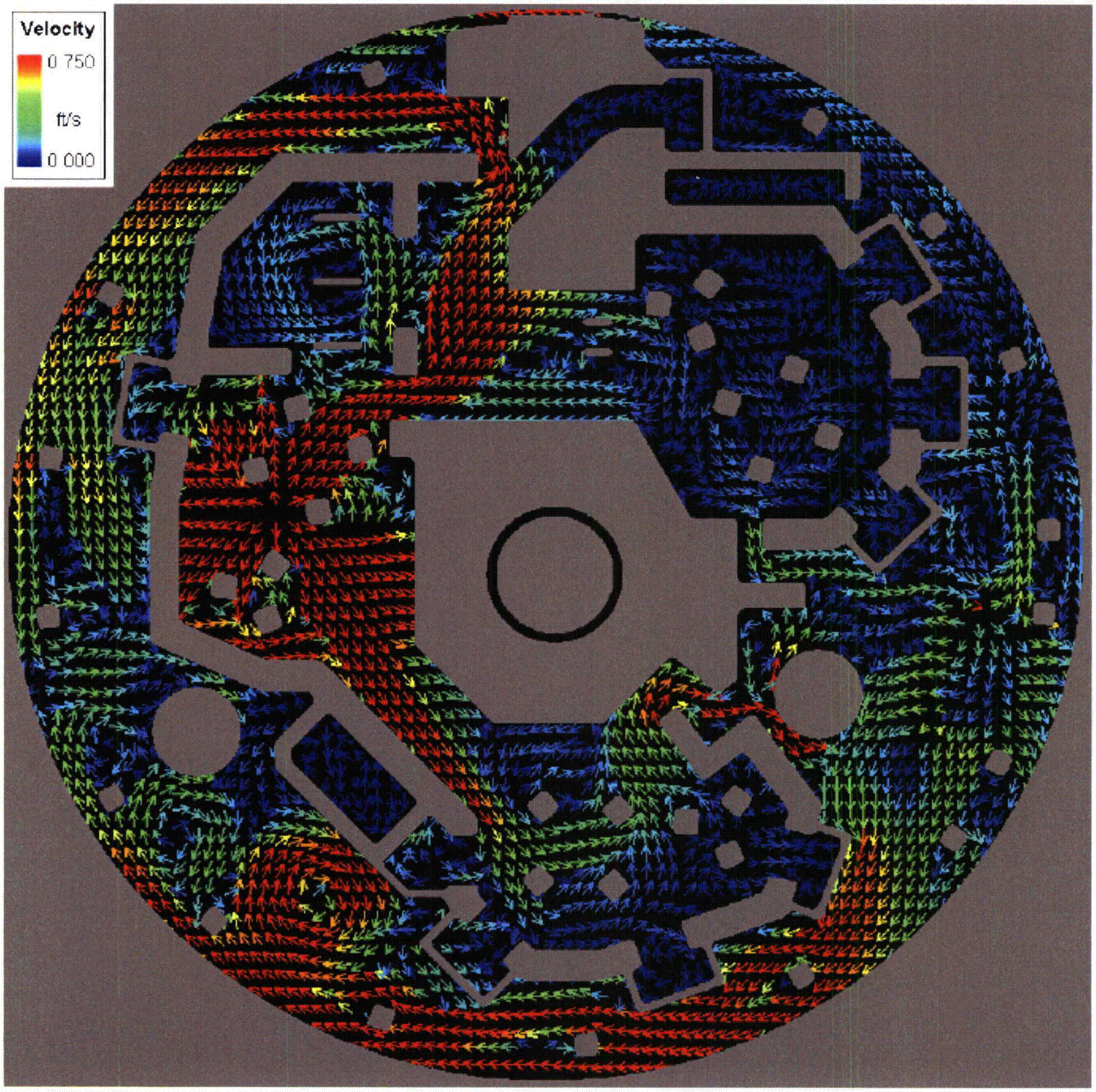


Figure 3
CFD Results with Velocity Vectors – S/G A Outlet Break



3e.4 Debris Transport Results

The transport of debris to each sump (A and B) was calculated for each of the break locations identified on Figure 2. The maximum transport fraction is used with the debris generation to determine the debris arriving at the sump strainers.

Debris transport logic tree examples for Temp-Mat, RMI and 1.5" curled paint chips are presented in Figures 4, 5 and 6.

The transport of the various Temp-Mat size fibers to the individual sumps are provide below:

A Sump Size	Transport Fraction		Weight Fraction	Total Fraction to the Sump
Individual Fibers	50%		9%	4.5%
< 6" Pieces	19.4%	(Fig.4)	33%	6.4%
> 6" Pieces	10.6%		28%	2.97%
Intact Blankets	0%		30%	0%
Total			100%	13.87%

B Sump Size	Transport Fraction	Weight Fraction	Total Fraction to the Sump
Individual Fibers	50%	9%	4.5%
< 6" Pieces	0%	33%	0%
> 6" Pieces	0%	28%	0%
Intact Blankets	0%	30%	0%
Total		100%	4.5%

The transport of the RMI debris to the individual sumps is provided below:

A Sump Size	Transport Fraction		Weight Fraction	Total Fraction to the Sump
Small Pieces	4.4%	(Fig.5)	49.1%	2.16%
< 6" Pieces	5.0%		50.9%	2.55%
Total			100%	4.7%

B Sump Size	Transport Fraction	Weight Fraction	Total Fraction to the Sump
Small Pieces	0%	49.1%	0%
< 6" Pieces	0%	50.9%	0%
Total		100%	0%

The transport of the various size epoxy chips to the individual sumps are provide below:

A Sump Size	Transport Fraction	Weight Fraction	Total Fraction to the Sump
2", flat	5.5%	16.0%	0.88%
1.5", curled	40.3%	20.5%	8.3%
1/8"	5.5%	14.0%	0.77%
1/64" (15.6 mil)	30.7%	37.1%	11.4%
Particulate (6 mil)	50%	12.4%	6.2%

B Sump Size	Transport Fraction	Weight Fraction	Total Fraction to the Sump
2", flat	0%	16.0%	0%
1.5", curled	46.3% (Fig.6)	20.5%	9.5%
1/8"	0%	14%	0%
1/64" (15.6 mil)	0%	37.1%	0%
Particulate (6 mil)	50%	12.4%	6.2%

The transport fractions for coating chips are based on representative sizes for the chip distribution presented in Table 19. The sizes in the transport analysis were selected based on bounding transport metrics. The correlation is:

Size Distribution	Transport Calc
1" to 2" flat	2", flat
1" to 2" curled	1.5", curled
½" to 1" curled	1.5", curled
½" to 1" flat	⅛"
¼" to ½"	⅛"
⅛" to ¼"	⅛"

Tables 9 through 12 combine the transport metrics with debris generation to show the debris loading at each strainer. The tables reflect 50% of fine particulate and fine fiber transporting to each strainer. During two train operation, this would be approximately representative. If one train failed to align for post-LOCA recirculation, all of the fine material would transport to one strainer under the conservative 100% transport assumption. The loading of 100% of the fine material was used in the large scale testing program. The large scale testing program establishes the design basis head loss for the strainers.

A review of Tables 9 through 12 demonstrates that the Marinite XL case for the B train is limiting in terms of fiber and particulate loading. The Mineral Wool content on the Marinite XL (assumed to be 100% transportable) is greater than the Temp-Mat transport to the strainer. The B strainer is limiting since it has less total surface area. The coating chips total for the A strainer is slightly higher than the B strainer loading. However, with the lower surface area for the B strainer, it is again limiting. The large scale test program is based on the Marinite XL case with the B strainer surface area.

Figure 4
Transport Logic Tree for S/G C Loop Break for <6" Temp-Mat

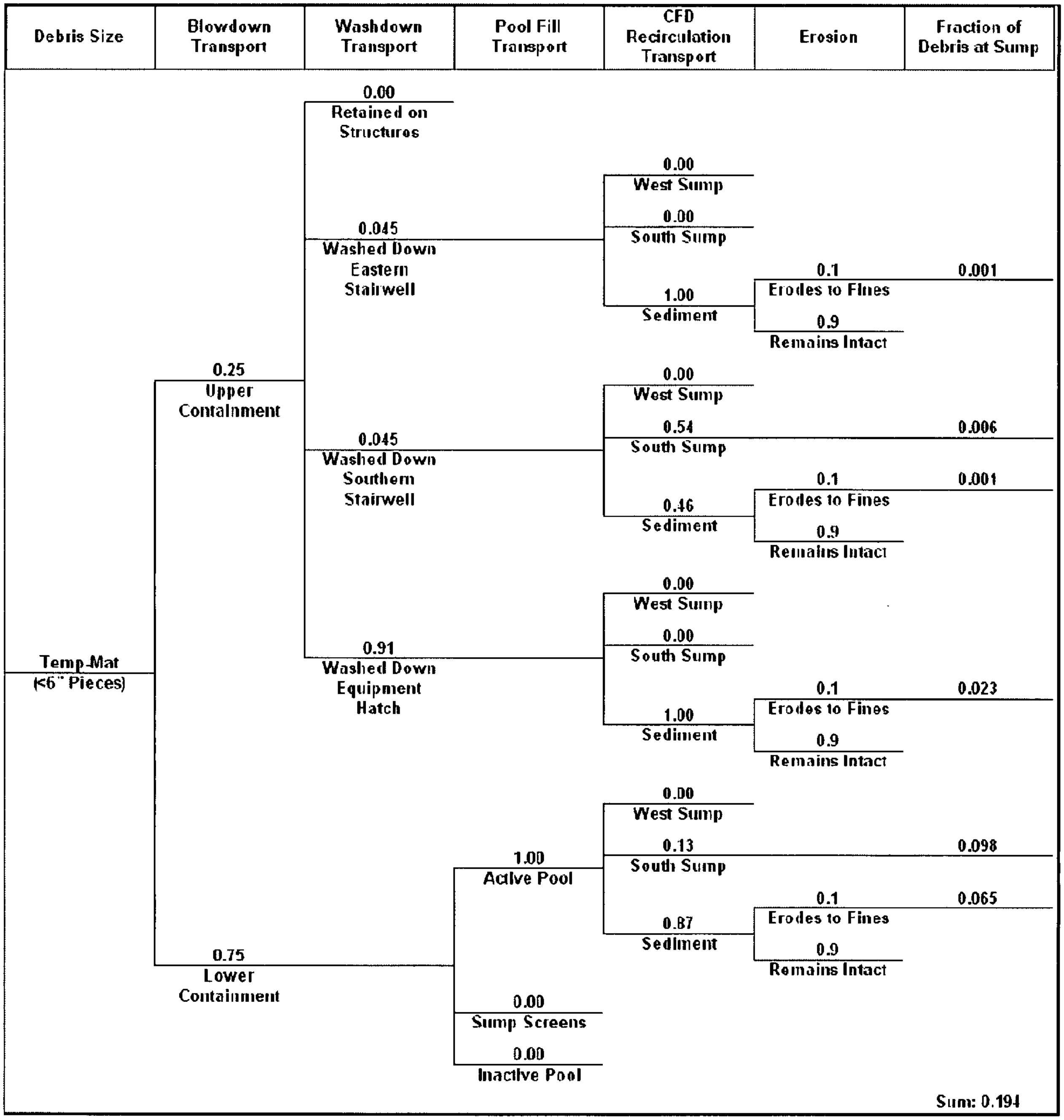


Figure 5
Transport Logic Tree for S/G C Loop Break for Small RMI

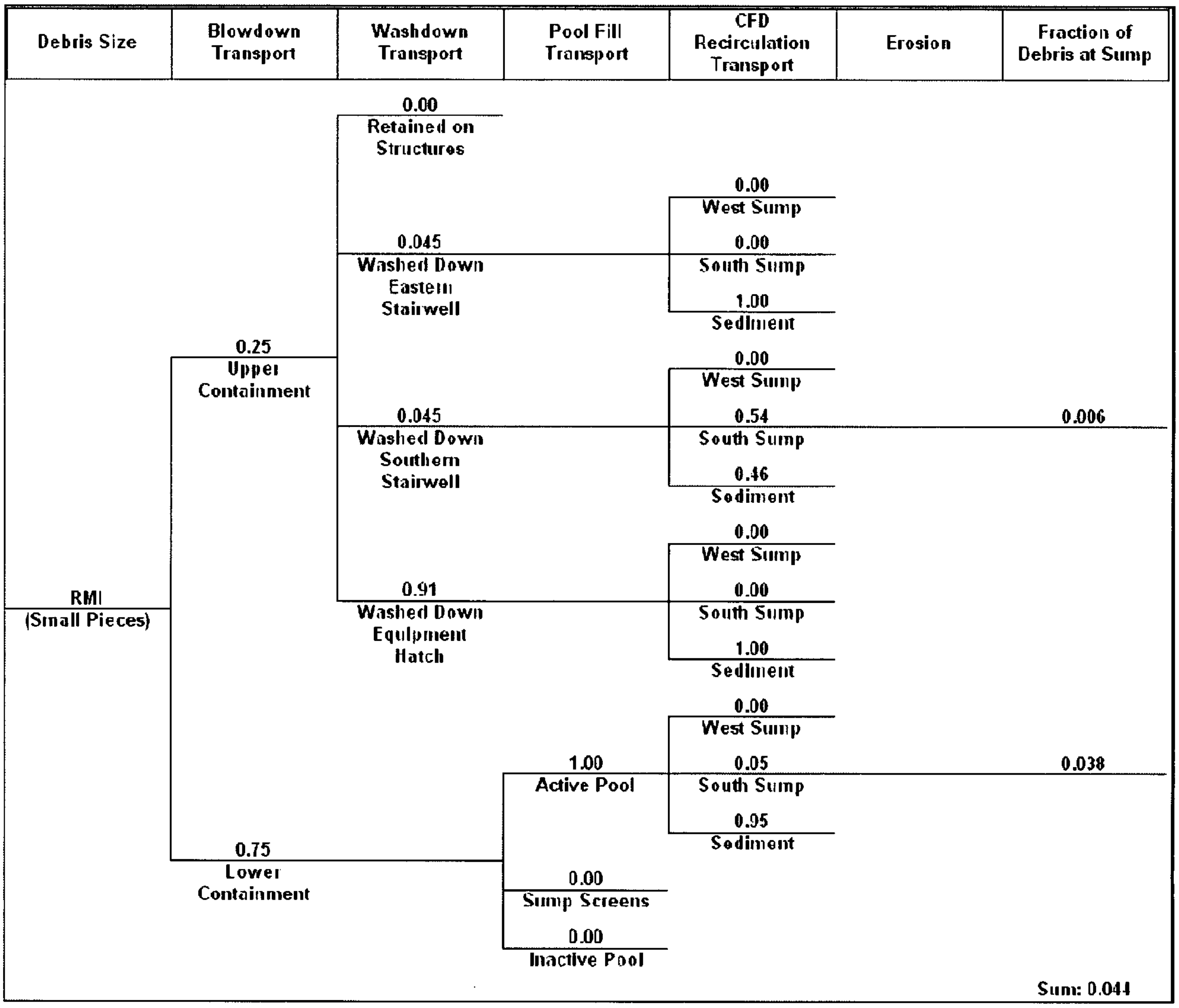


Figure 6
Transport Logic Tree for S/G B Loop Break for 1.5" Curled Paint Chips

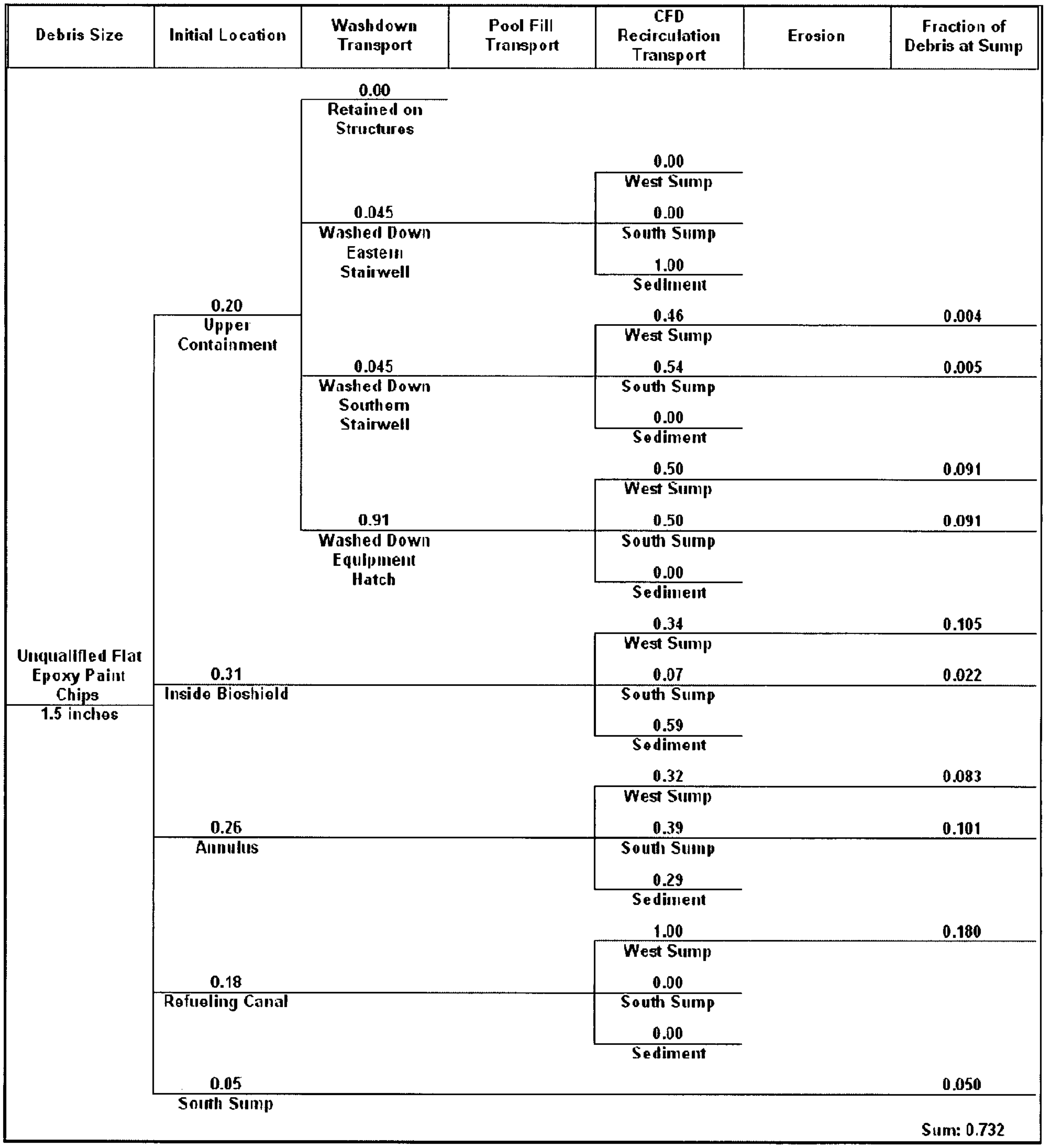


Table 9
Debris Loading on A Sump for Temp-Mat Case

Debris Type	Debris Generation	Weight Fraction / Transport Fraction	Quantity at the Sump
Insulation			
Reflective Metal	47,577 ft^2	4.7%	2231 ft^2
Temp-Mat	8.2 ft^3	13.87%	1.1 ft^3
Qualified Coating within the Zone of Influence			
Epoxy (Ameron 89)	126 lb	50%	63 lb
Epoxy (Nu-Klad)	54 lb	50%	27 lb
Epoxy (Amercoat 66)	6 lb	50%	3 lb
Zinc (MobilZinc 7)	352 lb	50%	176 lb
Unqualified Coatings and Operating Margin Coatings			
Alkyd	410 lb	50%	205 lb
Inorganic Zinc	233 lb	50%	117 lb
Cold-galvanizing	17.4 lb	50%	9 lb
Epoxy - 1" to 2" flat	7863 ft^2 (a)	16.0% / 5.5%	69 ft^2
Epoxy - 1" to 2" curled	7863 ft^2 (a)	16.0 % / 40.3%	507 ft^2
Epoxy - ½" to 1" flat	7863 ft^2 (a)	4.52% / 5.5%	20 ft^2
Epoxy - ½" to 1" curled	7863 ft^2 (a)	4.52% / 40.3%	143 ft^2
Epoxy - ¼" to ½"	7863 ft^2 (a)	4.41% / 5.5%	19 ft^2
Epoxy - ⅛" to ¼"	7863 ft^2 (a)	5.02% / 5.5%	22 ft^2
Epoxy - 15.6 mil	382 lbs (a)	37.1% / 30.7%	44 lb
Epoxy - 6 mil	382 lbs (a)	12.4% / 50%	24 lb
Epoxy (Nu-Klad Operating Margin)	343 lb	50%	172 lb
Latent Debris			
Fiber	16 lbs / 6.7 ft^3	50%	3.4 ft^3
Particulate	89 lbs	50%	45 lbs

Note (a): The epoxy debris includes 7363 ft^2 (346 lbs) of unqualified epoxy coatings and 500 ft^2 (36 lbs) of operating margin for degraded qualified epoxy coatings outside the Zone of Influence.

Table 10 Debris Loading on B Sump for Temp-Mat Case			
Debris Type	Debris Generation	Weight Fraction / Transport Fraction	Quantity at the Sump
Insulation			
Reflective Metal	47,577 ft^2	0%	0 ft^2
Temp-Mat	8.2 ft^3	4.5%	0.4 ft^3
Qualified Coating within the Zone of Influence			
Epoxy (Ameron 89)	126 lb	50%	63 lb
Epoxy (Nu-Klad)	54 lb	50%	27 lb
Epoxy (Amercoat 66)	6 lb	50%	3 lb
Zinc (MobilZinc 7)	352 lb	50%	176 lb
Unqualified Coating and Operating Margin Coatings			
Alkyd	410 lb	50%	205 lb
Inorganic Zinc	233 lb	50%	117 lb
Cold-galvanizing	17.4 lb	50%	9 lb
Epoxy - 1" to 2" flat	7863 ft^2 (a)	16.0% / 0%	0 ft^2
Epoxy - 1" to 2" curled	7863 ft^2 (a)	16.0 % / 46.3%	582 ft^2
Epoxy - ½" to 1" flat	7863 ft^2 (a)	4.52% / 0%	0 ft^2
Epoxy - ½" to 1" curled	7863 ft^2 (a)	4.52% / 46.3%	165 ft^2
Epoxy - ¼" to ½"	7863 ft^2 (a)	4.41% / 0%	0 ft^2
Epoxy - ⅛" to ¼"	7863 ft^2 (a)	5.02% / 0%	0 ft^2
Epoxy - 15.6 mil	382 lbs (a)	37.1% / 0%	0 lb
Epoxy - 6 mil	382 lbs (a)	12.4% / 50%	24 lb
Epoxy (Nu-Klad Operating Margin)	343 lb	50%	172 lb
Latent Debris			
Fiber	16 lbs / 6.7 ft^3	50%	3.4 ft^3
Particulate	89 lbs	50%	45 lbs
Note (a): The epoxy debris includes 7363 ft^2 (346 lbs) of unqualified epoxy coatings and 500 ft^2 (36 lbs) of operating margin for degraded qualified epoxy coatings outside the Zone of Influence.			

Table 11
Debris Loading on A Sump for Marinite XL Case

Debris Type	Debris Generation	Weight Fraction / Transport Fraction	Quantity at the Sump
Insulation			
Reflective Metal	12, 581 ft^2	4.7%	591 ft^2
Marinite XL Particulate (b)	8.58 ft^3 / 395 lb	95% / 50%	188 lb
Marinite XL Mineral Wool (b)	8.58 ft^3 / 395 lb	5% / 50%	9.9 lb / 1.2 ft^3
Qualified Coating within the Zone of Influence			
Epoxy (Ameron 89)	126 lb	50%	63 lb
Epoxy (Nu-Klad)	54 lb	50%	27 lb
Epoxy (Amercoat 66)	6 lb	50%	3 lb
Zinc (MobilZinc 7)	352 lb	50%	176 lb
Unqualified Coatings and Operating Margin Coatings			
Alkyd	410 lb	50%	205 lb
Inorganic Zinc	233 lb	50%	117 lb
Cold-galvanizing	17.4 lb	50%	9 lb
Epoxy - 1" to 2" flat	7863 ft^2 (a)	16.0% / 5.5%	69 ft^2
Epoxy - 1" to 2" curled	7863 ft^2 (a)	16.0 % / 40.3%	507 ft^2
Epoxy - ½" to 1" flat	7863 ft^2 (a)	4.52% / 5.5%	20 ft^2
Epoxy - ½" to 1" curled	7863 ft^2 (a)	4.52% / 40.3%	143 ft^2
Epoxy - ¼" to ½"	7863 ft^2 (a)	4.41% / 5.5%	19 ft^2
Epoxy - ⅛" to ¼"	7863 ft^2 (a)	5.02% / 5.5%	22 ft^2
Epoxy - 15.6 mil	382 lbs (a)	37.1% / 30.7%	44 lb
Epoxy - 6 mil	382 lbs (a)	12.4% / 50%	24 lb
Epoxy (Nu-Klad Operating Margin)	343 lb	50%	172 lb
Latent Debris			
Fiber	16 lbs / 6.7 ft^3	50%	3.4 ft^3
Particulate	89 lbs	50%	45 lbs

Note (a): The epoxy debris includes 7363 ft^2 (346 lbs) of unqualified epoxy coatings and 500 ft^2 (36 lbs) of operating margin for degraded qualified epoxy coatings outside the Zone of Influence.

Note (b): The weight of Marinite XL Debris Generation is based on the bulk density of Marinite I (assumed to apply to Marinite XL). The volume of Mineral Wool from the Marinite XL is based on the bulk density of Mineral Wool.

Table 12
Debris Loading on B Sump for Marinite XL Case

Debris Type	Debris Generation	Weight Fraction / Transport Fraction	Quantity at the Sump
Insulation			
Reflective Metal	12,581 ft^2	0%	0 ft^2
Marinite XL Particulate (b)	8.58 ft^3 / 395 lb	95% / 50%	188 lb
Marinite XL Mineral Wool (b)	8.58 ft^3 / 395 lb	5% / 50%	9.9 lb / 1.2 ft^3
Qualified Coating within the Zone of Influence			
Epoxy (Ameron 89)	126 lb	50%	63 lb
Epoxy (Nu-Klad)	54 lb	50%	27 lb
Epoxy (Amercoat 66)	6 lb	50%	3 lb
Zinc (MobilZinc 7)	352 lb	50%	176 lb
Unqualified Coating and Operating Margin Coatings			
Alkyd	410 lb	50%	205 lb
Inorganic Zinc	233 lb	50%	117 lb
Cold-galvanizing	17.4 lb	50%	9 lb
Epoxy - 1" to 2" flat	7863 ft^2 (a)	16.0% / 0%	0 ft^2
Epoxy - 1" to 2" curled	7863 ft^2 (a)	16.0 % / 46.3%	582 ft^2
Epoxy - ½" to 1" flat	7863 ft^2 (a)	4.52% / 0%	0 ft^2
Epoxy - ½" to 1" curled	7863 ft^2 (a)	4.52% / 46.3%	165 ft^2
Epoxy - ¼" to ½"	7863 ft^2 (a)	4.41% / 0%	0 ft^2
Epoxy - ⅛" to ¼"	7863 ft^2 (a)	5.02% / 0%	0 ft^2
Epoxy - 15.6 mil	382 lbs (a)	37.1% / 0%	0 lb
Epoxy - 6 mil	382 lbs (a)	12.4% / 50%	24 lb
Epoxy (Nu-Klad Operating Margin)	343 lb	50%	172 lb
Latent Debris			
Fiber	16 lbs / 6.7 ft^3	50%	3.4 ft^3
Particulate	89 lbs	50%	45 lbs

Note (a): The epoxy debris includes 7363 ft^2 (346 lbs) of unqualified epoxy coatings and 500 ft^2 (36 lbs) of operating margin for degraded qualified epoxy coatings outside the Zone of Influence.

Note (b): The weight of Marinite XL Debris Generation is based on the bulk density of Marinite I (assumed to apply to Marinite XL). The volume of Mineral Wool from the Marinite XL is based on the bulk density of Mineral Wool.

3f. Head Loss and Vortexing

A schematic diagram of the Safety Injection (SI) System and RB Spray (SP) System is provided in Figure 7.

3f.1 Minimum Submergence

As detailed in response Section 3g.2.3, the minimum water level in the RB sump is

Large Break LOCA	3.42 ft
Small Break LOCA	2.60 ft

These levels are in terms of feet above the RB floor elevation of 412 ft. The recirculation sump strainers are installed in a pit at the 408 ft elevation. The top of the access hatch and grating is located at the 412 ft, 9 inch elevation. The minimum submergence of the access hatch and grating is

Large Break LOCA	2.67 ft
Small Break LOCA	1.85 ft

The strainer uses different height fins to fit under various interfaces. The largest fins (with no interferences) are 45 ¾" tall. The minimum submergence of the largest strainer fin is

Large Break LOCA	3.23 ft

The strainer is fully submerged. Venting is accomplished through the strainer fins and through vent holes provided on the access hatch riser. The vent holes are covered with the same 1/16" punched plate used for the strainer surface. The vent location is below the water level. The strainer will vent well before the start of recirculation.

3f.2 Vortex Evaluation

Vortex evaluations were completed for two limiting design considerations.

- Air ingestion to the strainer through an air vent hole
- Vortex formation at the grating engineered opening

There are 24 air vent holes located just below the top deck of the strainer. These are located on the vertical riser and are located closest to the surface of the water. Each hole is 3/8" in diameter and is covered by the same punched plate used for the strainer fins. To investigate the potential for vortex ingestion, the vent holes were analyzed assuming they were not covered by the perforated plates.

The critical submergence equations proposed by Harleman et al [Reference 8] and by McDuffie [Reference 9] are used to predict critical submergence below which vortex formation through the vent holes is possible. Critical submergence is a function of the vent hole diameter and the Froude number. Assuming the vent holes are completely unblocked by debris and a 6 ft head loss across the strainer (to calculated velocity), the critical submergence is less than one inch. For a small break LOCA, the submergence is 1.85 ft and air ingestion through the vent holes is not considered a credible scenario.

Additionally, during the clean strainer pressure drop testing flow rates up to approximately 170% of design flow were tested. No vortex formation was observed in the test module.

Engineered openings are provided in the horizontal grating surface over each sump. The openings are non-deterministic design features to address concerns related to bridging or blocking of the grating horizontal surface. The design case for vortex formation assumes that the entire horizontal grating surface is blocked to flow. All flow for the strainer, 7500 gpm, enters the sump pit through the engineered opening. Limiting the flow to the engineered opening is more limiting for the vortex evaluation since the flow is restricted to a smaller area which increases the potential for vortex formation.

The critical submergence equations proposed by Harleman et al [Reference 8] and by McDuffie [Reference 9] are again used to predict critical submergence below which vortex formation through the engineered opening is possible. The A train opening of 9 ft^2 is the smaller of the two sumps and is used for the evaluation. With a flow of 7500 gpm and a submergence of 1.85 ft, the Froude Number is calculated to be 0.241. The limiting critical submergence was calculated to be 15.3 inches. For a small break LOCA, the submergence is 1.85 ft and air ingestion through the engineered opening is not considered a credible scenario.

Regulatory Guide 1.82, Revision 3 was also considered in the vortex evaluation. Table A-1 of the guide provides PWR Hydraulic Design Guidelines for Zero Air Ingestion. The maximum allowable Froude Number is 0.25. As listed above, the Froude Number for the engineered opening is 0.241. So, based on Regulatory Guide 1.82, Revision 3, no air ingestion is predicted.

ECCS COMPOSITE

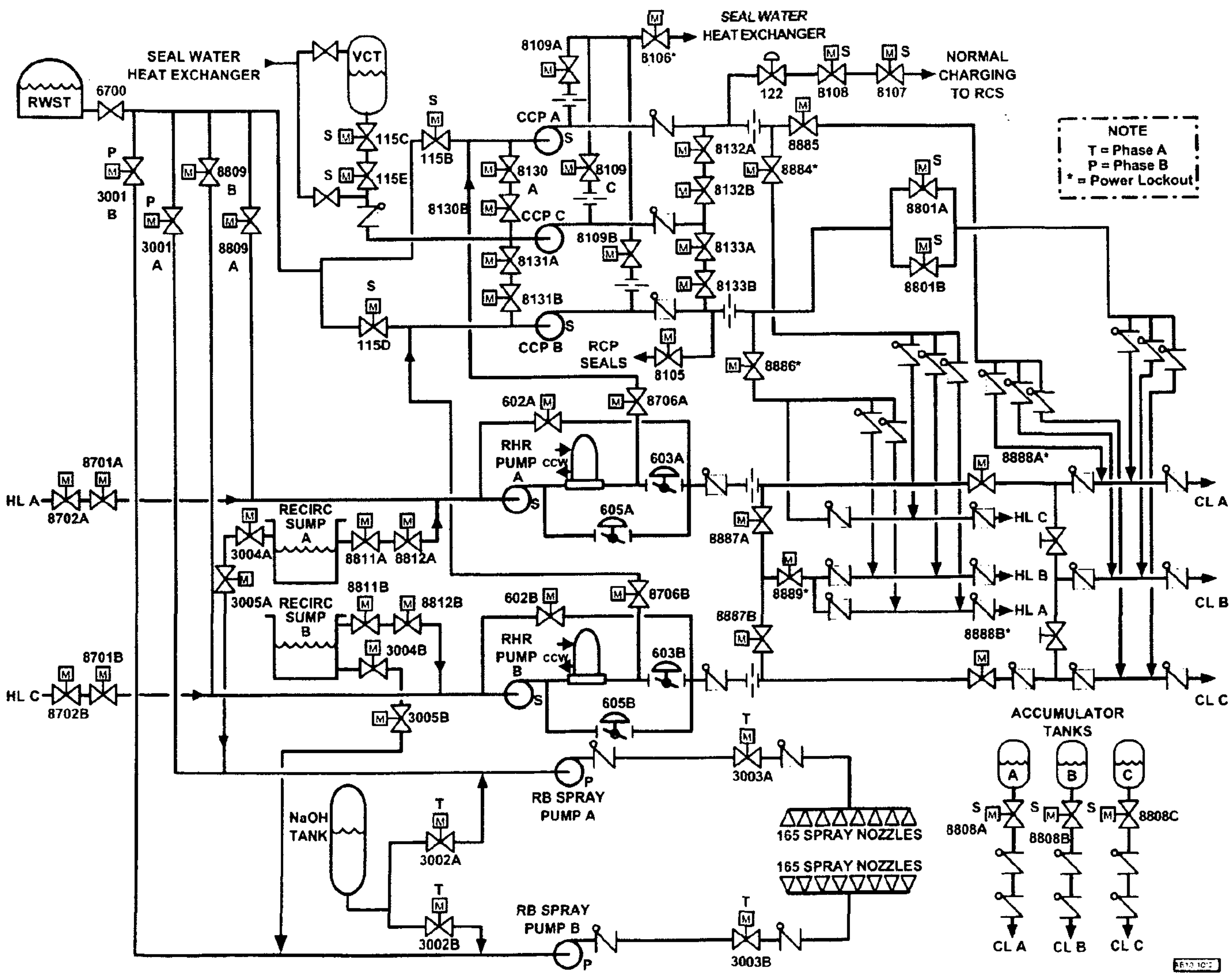


Figure 7

3f.3 Prototypical Head Loss Testing

Head loss testing was completed at the AECL facilities using debris loading specified by SCE&G based on the Debris Generation and Debris Transport calculations. The test temperature was 104°F. The testing is covered in the following sections.

3f.3.1 Test Module

The test program used full scale strainer fins, representative of one bank of fins on the B sump on the RHR side of the strainer as shown in Figure 8. The layout of the test module in the tank is shown in Figure 9. A photo of the test module installed in the tank is provided in Figure 10.

The test module was mounted on supports on the tank bottom that positioned the module at the same distance above the tank bottom (floor) as for the installed configuration and occupied the same volume beneath the fins. The tank water level was set to match the submerged water depth of the installed strainer when the containment water level is 2.9 feet above the floor elevation. The 2.9 foot level was based on draft level calculations and is conservative for the large break LOCA level.

Solid baffles were positioned around the test module to simulate the side of the sump pit, the concrete divider in the sump pit and the approximate diagonal midpoints between the modeled side of the RHR strainer (left-hand side) and the adjacent sides (lower side and upper side).

The grating design for the replacement strainer includes an edge support bar that is attached to the top of the curb around most of the sump periphery. The effective height of the curb for the test is set equal to the curb plus support bar height. Thus, the heights of the baffles representing the side of the sump pit and the concrete divider correspond to the height of the top of the edge support bar for the floor grating, 3 inches above the top of the curb (i.e., 9 inches) above the floor elevation. Note that the height of the concrete divider is actually 18 inches below the top of the curb. The height of the simulating baffle was set equal to the height of the edge support bar in the test tank so that the flow of water over both front baffles was approximately equal.

The heights of the baffles representing the midpoints between the modeled portion of the strainer and the adjacent sides extended above the water level to prevent debris from settling into the area of the tank behind the test module. Baffles were positioned on top of the header portion of the test module for the same purpose.

The total surface area of the test model was 357 ft^2. The strainer in Sump B was selected because it is the smaller of the two strainers (2379 ft^2 versus 2939 ft^2) and, thus, would have a higher head loss than the strainer in Sump A for the same quantity of debris. Allowing for 200 ft^2 of latent debris, a sacrificial area of 150 ft^2 (75%) is applied per the NRC SE [Reference 2]. The debris loading and flow was scaled to a strainer surface area of 2229 ft^2. The design flow rate of 7500 gpm is scaled as 1201 gpm in the test.

Figure 8
V.C. Summer B Recirculation Strainer – Test Module Identification

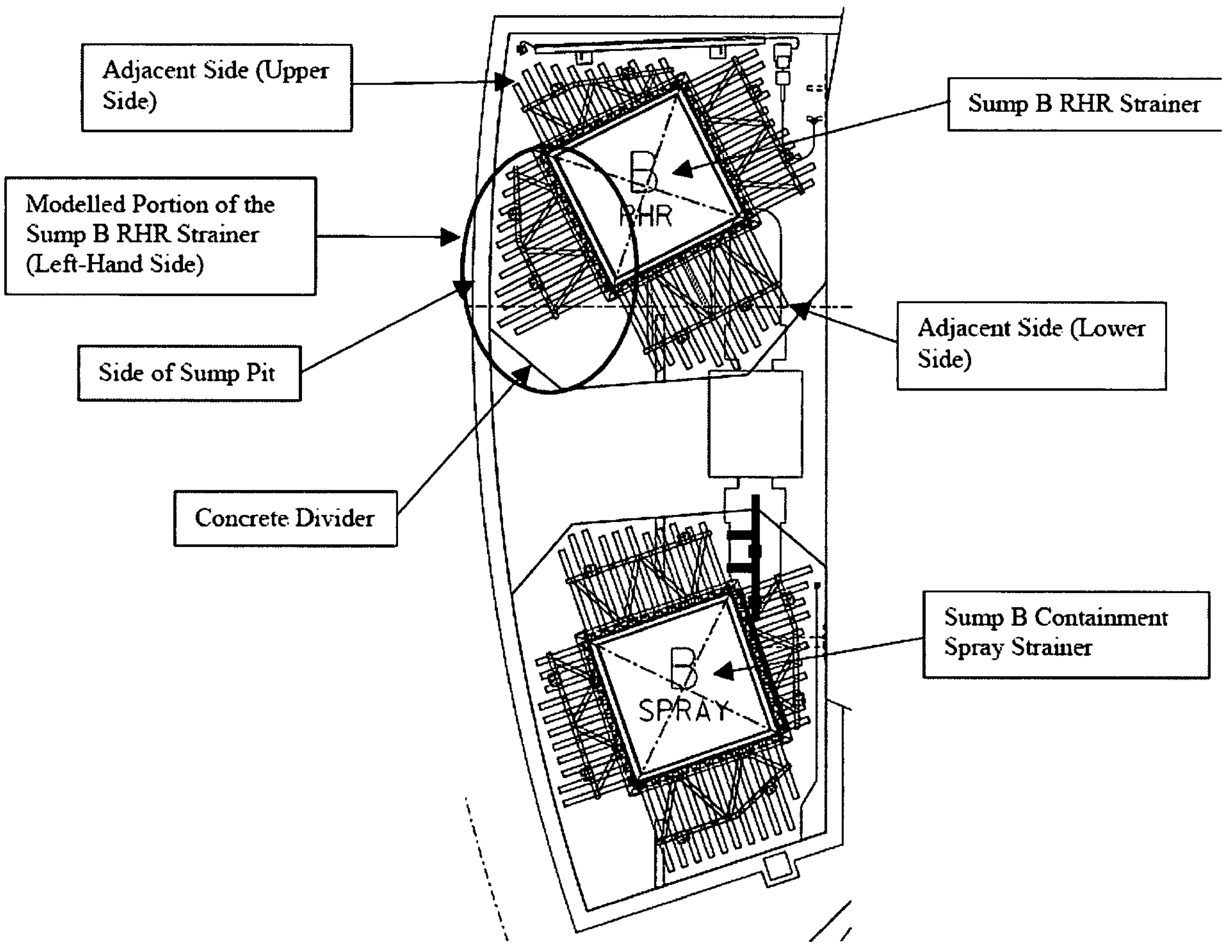
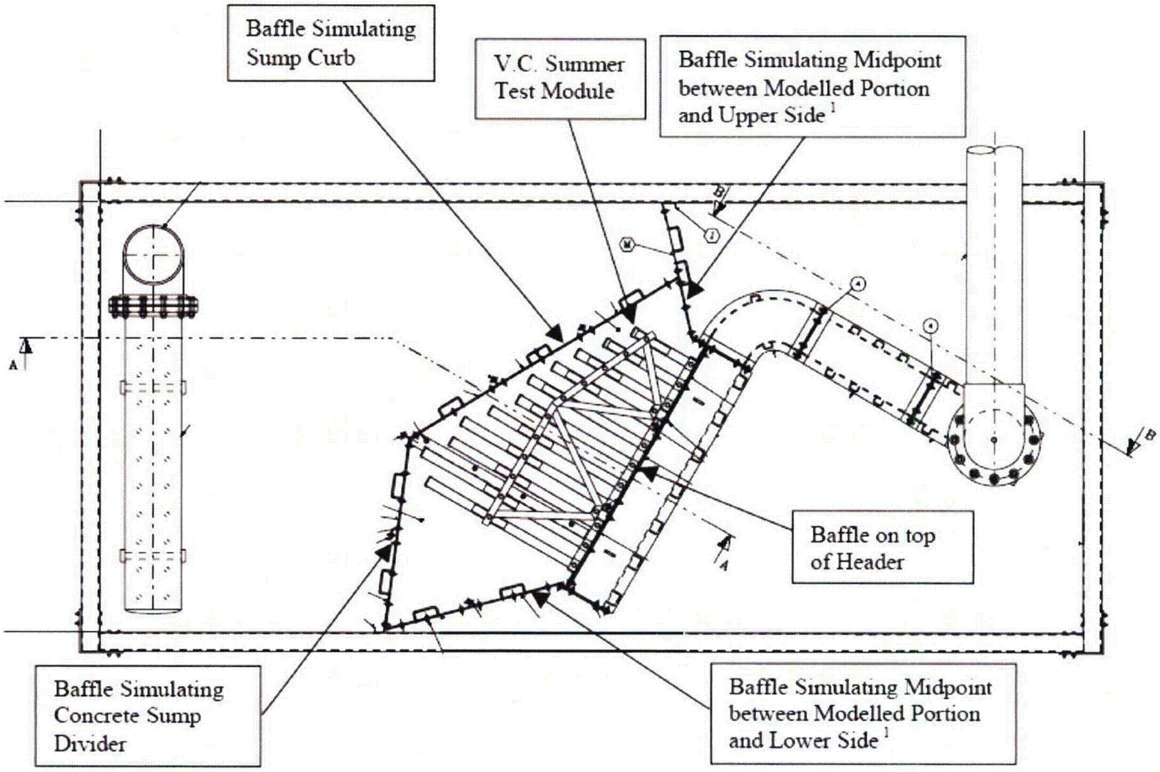
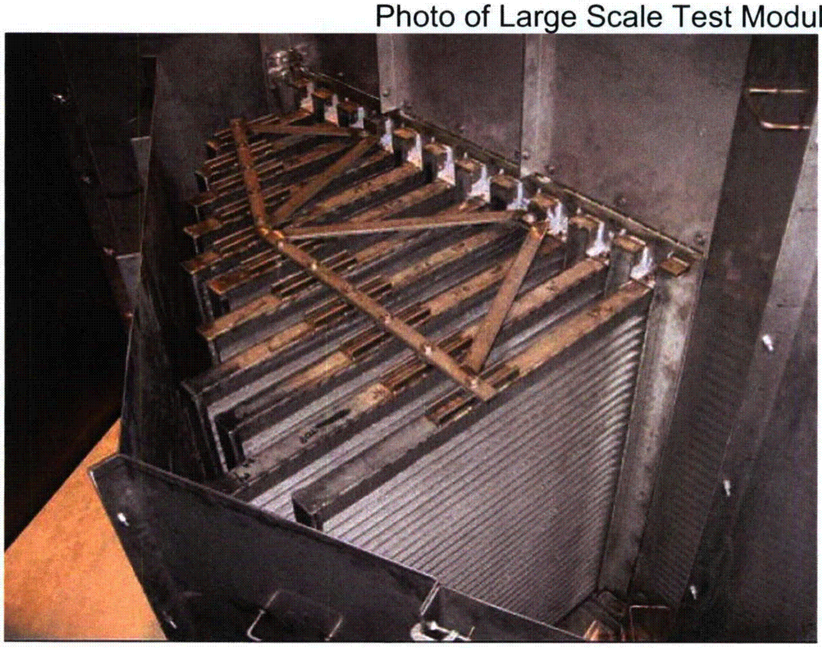


Figure 9
Large Scale Test Module Layout in the Tank



[1] "Upper Side" and "Lower Side" refer to adjacent quadrants of the strainer. See Figure 2 for more detail.

Figure 10
Photo of Large Scale Test Module



3f.3.2 Debris Preparation

The fibrous debris was PCI NUKON (for latent fiber) and Temp-Mat fiberglass. The debris was prepared as follows:

- Cut the fiber batts into pieces of approximately 6 inches (0.15 m) by 6 in. (0.15 m),
- Broke the pieces into smaller pieces using a leaf shredder,
- Measured the mass of fiber for each specific addition,
- Photographed the first fiber addition,
- Combined the fiber additions with water,
- Mixed the fiber and water to wet the fiber,
- Agitated the mixture with a water jet from a pressure washer to separate the fibers,
- Confirmed that the degree of fiber separation met expectations and was consistent with other batches used.

The particulate debris was walnut shell flour and/or Inorganic Zinc filler. The debris was prepared as follows:

- Measured the mass of particulate for each specific addition,
- Photographed the first particulate addition of each type,
- Combined the particulate addition with water, and
- Mixed the particulate and water to wet the particulate.

The Marinite XL debris contains both particulate (95%) and fiber (5%) based on the MSDS. Marinite XL is no longer available, so the test used Marinite I as a substitute. The Marinite I was procured as saw dust and has the following fiber content based on the MSDS (Reference 16).

Organic Fiber	4% to 8%
Fiberglass	0% to 8%

The Marinite I sawdust was mixed with the fiber and particulate debris.

Keeler and Long 4500 was used to produce paint chips to model the unqualified epoxy coating in the third large scale test. The coating Died Film Thickness (DFT) was maintained with the range found at VCSNS with an average DFT of 4.5 mils. This is less than the average found at VCSNS and is conservative. Some of the chips were curled prior to the test to more closely replicate the chips transported to the VCSNS sump strainer, however, the chips tended to flatten after being introduced to the test tank.

RMI debris used precut RMI foil. The size distribution is presented in Table 1. The foils were mechanically crumpled using a leaf shredder and/or chipper. This material was only used in Test 1 (discussed below) which covered the entire strainer with RMI foils.

3f.3.3 Debris Quantities

Three large scale tests were run for the VCSNS design.

1. Test 1 covered the case with a high RMI debris load such that the outboard space of the strainer was completely filled with RMI debris. This is not an actual design case for the VCSNS sump strainer. The final debris transport analysis demonstrated much lower RMI debris loading at the strainer. The test was designed to evaluate the potential for fiber buildup on the RMI debris bed surface, above the actual strainer, forming a circumscribed fiber bed substantially smaller than the actual strainer surface area. The test was specified to use Temp-Mat debris loading of 5 ft^3 and latent fiber loading of 16 lbs to bounding expected fiber debris loads. The complete debris loading is listed in Table 13. Note that the coating debris loads were also higher than the final analysis has demonstrated as shown on Tables 9 through 12.

2. Test 2 covered the Marinite XL case with all coatings failing as particulate. The test was scaled to a Marinite XL loading of 30.2 ft^3 compared with a final analysis debris loading of 8.58 ft^3. The test used Marinite I which has a different fiber content range than the Marinite XL as discussed in Section 3f.3.2. Applying the minimum fiber content for Marinite I, Test 2 was scaled to a Marinite fiber load of at least 55.5 lbs (4% x 30.2 ft^3 x 46 lb/ft^3). The fiber load based on the final debris generation and transport of Marinite XL is 19.7 lbs (5% x 8.58 ft^3 x 46 lb/ft^3). Test 2 with Marinite I bounds the final debris load for the Marinite XL case assuming all coatings fail as particulate. After the specified debris load was added and the test met the termination criteria, additional Temp-Mat fiber was added to characterize head loss with high levels of fiber loading and to evaluate the onset of thin bed formation. The Temp-Mat was added in equivalent 1/16" fiber bed batches. When the strainer pressure drop spiked after the second addition the test was terminated.

3. Test 3 covered the Marinite XL case with epoxy outside the Zone of Influence failing as shown on Table 7. Approximately 50% of the epoxy fails as chips larger than the opening of the strainer. All other coatings fail as particulate as discussed in Section 3h.2. The test used a high epoxy chip loading 3436 ft^2 based on preliminary chip transport estimates. The epoxy chips were added in three alternating batches with the fiber and particulate load. Each of the three epoxy chip additions were approximately 1145 ft^2 compared to the final analysis total load of 747 ft^2 as listed on Table 12. The coating particulate load in this test was based on the loading listed in Table 12, but did not include the 6 mil epoxy loading of 48 lbs. The 48 lbs is a small fraction of the total particulate load of over 2000 lbs in a test with fiber quantities too low to form a thin bed.

Table 13
Debris Loading for Large Scale Test 1 - RMI Test

Debris Type	Test Debris	Case 1	Test 1
RMI			
Transco RMI Foil (fines) (ft^2)	Transco Stainless Steel RMI Foil	29974 (~450 ft^3)[a]	~6700 (~100 ft^3)[a]
Fiber			
Temp-Mat (ft^3)	Temp-Mat	5.0	0.8
Latent Fiber (lb_m)	PCI NUKON	16	2.6
Particulate			
Latent Particulate (lb_m)	Walnut Shell	89	6.8
Coatings			
Epoxy (6548/7107) (lb_m)	Walnut Shell	272.6	32.1[b]
Epoxy (6129) (lb_m)	Walnut Shell	48.2	8.8[b]
Epoxy (5000) (lb_m)	Walnut Shell	175.2	24.8[b]
Epoxy (4500) (lb_m)	Walnut Shell	445.6	51.6[b]
Epoxy (lb_m)	Walnut Shell	452	62.4[b]
Alkyds (lb_m)	Walnut Shell	136	18[b]
Inorganic Zinc (lb_m)	Inorganic Zinc Filler	1642	263
Cold Galvanized (Zinc) (lb_m)	Inorganic Zinc Filler	17.4	2.8

Note: a) Equivalent volume of crumpled RMI.
b) Mass corrected for density difference.

Table 14
Debris Loading for Large Scale Test 2 – Particulate Test

Debris Type	Test Debris	Case 2	Test 2
Fiber			
Temp-Mat (ft^3)	Temp-Mat	0	3.7 [a]
Latent Fiber (lb_m)	PCI NUKON	16	2.6 [a]
Particulate			
Marinite (ft^3)	Marinite I Powder	30.2	4.8
Latent Particulate (lb_m)	Walnut Shell	89	6.8 [b]
Coatings			
Epoxy (6548/7107) (lb_m)	Walnut Shell	272.6	32.1 [b]
Epoxy (6129) (lb_m)	Walnut Shell	48.2	8.8 [b]
Epoxy (5000) (lb_m)	Walnut Shell	175.2	24.8 [b]
Epoxy (4500) (lb_m)	Walnut Shell	445.6	51.6 [b]
Epoxy (lb_m)	Walnut Shell	452	62.4 [b]
Alkyds (lb_m)	Walnut Shell	136	18 [b]
Inorganic Zinc (lb_m)	Inorganic Zinc Filler	1642	263
Cold Galvanized (Zinc) (lb_m)	Inorganic Zinc Filler	17.4	2.8

Note: a) Equivalent volume of crumpled RMI.
b) Mass corrected for density difference.

Table 15 Debris Loading for Large Scale Test 3 – Chip Test			
Debris Type	**Test Debris**	**Case 2**	**Test 3**
Fiber			
Latent Fiber (lb_m)	PCI NUKON	16	2.6
Particulate			
Marinite (ft^3)	Marinite I Powder	8.58	1.3
Latent Particulate (lb_m)	Walnut Shell	89	6.8 [a]
Coatings			
Ameron 89 (lb_m)	Walnut Shell	126	17.39 [a]
Nu-Klad (lb_m)	Walnut Shell	397	39.02 [a]
Amercoat 66 (lb_m)	Walnut Shell	6	0.62 [a]
Unqualified Alkyds (lb_m)	Walnut Shell	410	54.28 [a]
Inorganic Zinc (lb_m)	Inorganic Zinc Filler	233	37.32
Cold Galvanized (Zinc) (lb_m)	Inorganic Zinc Filler	17.4	2.79
Mobilzinc 7	Inorganic Zinc Filler	352	56.38
Coatings as Chips			
Epoxy Chips	Epoxy 4500 Chips	3436 ft^2	28.28 lbs
Note: a) Mass corrected for density difference.			

3f.3.4 Debris Additions

RMI debris was used in Test 1 only. This test modeled the sump strainer completely covered by RMI debris. Debris transport testing and analysis have shown that this quantity of RMI debris will not transport to the sump pit. While the test demonstrated successful results (no circumscribed surface was created for fiber build up), it is not considered a design case for VCSNS. The RMI debris addition was made before water was added to the test tank. Debris was added between the fins up to the top of the simulated curb, completely covering the fins.

The particulate and fiber debris were mixed together in a separate water tank. The combined mixture was pumped into the test tank directly on top of the strainer test module. For Test 2 only, once the design basis loading was added and the termination criteria were met, additional Temp-Mat fiber debris was added. The purpose of the test was to determine head loss at elevated fiber loadings and to characterize the onset of thin bed formation. The Temp-Mat fiber was added directly on top of the strainer after being mixed in a separate water tank. Fiber was added in two 1/16" equivalent fiber volumes. After the second fiber addition, pressure drop spiked above the allowable test module limit and the test was terminated.

Test 3 used coating chips for the unqualified epoxy coatings and degraded qualified epoxy. The chip preparation and sizing is covered in response Section 3h. The chips were mixed together and then divided into three separate batches. The fiber/particle debris and chips were added in three alternating batches. The chips were added using a trough with a water spray to rinse the chips into the test tank directly above the strainer test module. This simulates coating chips entering the sump pit over the surrounding curb. A photo of the chip addition is shown in Figure 11.

Figure 11
Photo of Coating Chip Addition During Test 3

3f.3.5 Termination Criteria

The stability criterion for head loss was a change of less than 5% or 0.01 psi (0.07 kPa), whichever is greater, and exhibiting no general steadily increasing trend in pressure within 12 tank turnovers. A tank turnover was defined as the time equal to the circulating portion of the test tank water volume divided by the flow rate. For these tests, the tank turnover time was approximately 3.0 min.

3f.3.6 Test Results

Clean Strainer - The clean strainer portion of the testing indicated no localized vortex formation at flow up to 175% of design flow rate. The measured clean strainer pressure drop was 0.02 psi at the design flow rate.

Test 1 – Test 1 covered the RMI debris test with the strainer test module completely covered by RMI debris. The measured pressure drop with just RMI debris was 0.08 psid. Subtracting the clean strainer pressure drop gives an RMI pressure drop of 0.06 psid. The test was continued and the fiber/particulate load (listed in Table 13) was added over a 3 hour period. The head loss stabilized and met the Termination Criteria approximately 21 hours after the last debris addition. The pressure drop across the strainer for Case 1 full debris load is 1.3 psid at 104°F.

Fiber and particulate were captured throughout the RMI debris bed. Some fiber was deposited on the outside surface of the RMI, but a fiber debris bed did not form on the outside surface of the RMI. Some fiber and particulate penetrated the RMI debris bed and collected on the strainer surface. A continuous fiber debris bed did not develop on any surface.

Based on the Debris Transport analysis and testing of RMI debris, the sump pit will not fill with RMI debris as was modeled in Test 1.

Test 2 – Test 2 covered the thin bed test with all coatings failing as particulate. The particulate load was maximized by use the break location that included Marinite. The mixed fiber and particulate debris (listed in Table 14) was prepared in a separate tank and added to the top of the test tank directly over the strainer in seven batches over a two hour period. Over this time, pressure drop increased linearly, stopping when the last addition was made. The pressure drop remained stable at 1.9 psid at a temperature of 104°F, meeting the Termination Criteria just 42 minutes after the last addition.

After the design debris load, additional Temp-Mat fiber was added to measure head loss at increased fiber load and to characterize the onset of thin bed head losses. Temp-Mat was added to an equivalent of 1/16" (0.0625") bed thickness. After the first addition, pressure drop increased rapidly to 7.1 psid. After several hours, the pressure drop stabilized at 5.8 psid. After the second addition of Temp-Mat, pressure drop spiked above the 10 psid operating limit of the test module and the test was terminated.

Test 3 – Test 3 covers unqualified epoxy coatings failed as paint chips instead of particulate. The fiber/particulate debris and coatings were added in three alternating batches over a 30 minute period. Pressure drop was monitored between each addition, but no attempt was made to satisfy the Termination Criteria until after the final batch of paint chips was added. The coating chip additions during the test were approximately 4.5 times greater than the actual debris loading. The pressure drop at 104°F across the strainer after each addition is provided below.

Debris Addition	Pressure Drop (psid)	Increase in Pressure Drop (psid)
Clean	0.02	
1/3 Fiber/Particulate	0.05	0.03
1/3 Chips	0.10	0.05
1/3 Fiber/Particulate	0.92	0.82
1/3 Chips	1.45	0.53
1/3 Fiber/Particulate	3.15	1.70
1/3 Chips (peak)	3.97	0.82
Final stable	3.47	

Additional observations are outlined in response Section 3h.5.

3f.4 Debris Volume at the Strainer

The debris volume arriving at the strainer is not sufficient to fill the area and develop a circumscribed area. The VCSNS strainer is designed as a "no thin bed" strainer. The full debris load, scaled to the test module surface area, was used in the large scale test program. The strainer remained a functional fin design. No circumscribed surface area was formed.

3f.5 Thin Bed

The VCSNS strainer design is for "no thin bed". This was demonstrated in the test program. The full load of fiber was added to the large scale test. While head loss did increase above the clean strainer head loss, a thin bed did not form and the head loss was within the allowable NPSH margin.

3f.6 Clean Strainer Head Loss

The clean strainer head loss is comprised of three parts for the AECL fin strainer design at VCSNS:

- head loss across the strainer holes
- head loss for flow through the corrugated duct to the header box
- head loss as the flow enters the header box.

The head loss through the strainer holes is based on the sudden contraction and then expansion through the strainer holes. Standard methodology from Idelchek [Reference 10] was applied to determine a pressure drop of 0.108 Pa.

The head loss for flow through the corrugated duct to the header box is a simple flow problem in a diamond shaped duct. The longest duct (41") is assumed for conservatism. The pressure drop was determined to be 36.1 Pa.

The head loss as the flow exits the corrugated duct and enters the header box is a simple expansion flow with a pressure drop of 25.3 Pa.

The clean strainer pressure drop was calculated to be 61.6 Pa or 0.009 psi. Clean strainer pressure drop was measured during large scale testing. At the design flow of 7500 gpm, the measured pressure drop was 0.007 psi. The clean strainer head loss is very small compared to the debris load head loss.

3f.7 Debris Head Loss

The VCSNS debris loading may be characterized as a high particulate to fiber ratio. The head loss correlation from NUREG-6224 as presented in NEI 04-07, Equation 3.7.2-1 is not appropriate for the application. Additionally, the test indicated the coating chips case is limiting, further restricting use of the correlation. For these reasons, the VCSNS strainer head loss is based on test data.

The coating chips test added substantially more chips than the analysis predicts. Each paint chip addition was approximately 1145 ft^2 compared to an analysis value of 747 ft^2. As presented in Section 3f.3.6, the maximum increase in pressure drop for one 1145 ft^2 paint chip addition is 0.82 psid. This is the bounding pressure drop increase when the paint chip load is applied. The second component of the total sump strainer pressure drop is the fiber and particulate loading. This pressure drop is taken directly from the all particulate load with Marinite XL covered by Test 2. Test 2 used an excess of Marinite I (a substitute for Marinite XL) which is conservative for both fiber loading and particulate loading. The pressure drop for Test 2 was 1.9 psid. Combining the two tests gives a bounding sump strainer pressure drop of 2.72 psid at 104°F. This pressure drop is used for the NPSH and other evaluations applying the appropriate viscosity correction based on temperature.

3f.8 Mechanical Design Allowable Head Loss

The maximum allowable pressure drop across the strainers to meet the mechanical design is 6.5 psid . This value is used in analysis and various load combinations in the stress report for the strainer. The temperature corrected pressure drop across the strainer is 4.08 psid at a conservatively low 70°F. Further details of the stress analysis are presented in response Section 3k.

3f.9 Near Field Effects

No credit is taken for Near Field Effects. As discussed in response section 3f.3, the strainer test simulated the sump pit using baffle plates around the test assembly. All debris was added directly on top of the strainer test module. The particulate debris and fiber was noted as not settling below the strainer fins. The particulate debris circulated through the system. The paint chips that did not adhere to the screen, settled to the area below the fins as would be expected in the actual sump pit. The area outside of the baffles was swept to keep material in suspension and flowing through the strainer.

3f.10 Bypass Fraction

Samples for Bypass Fractions were collected for all three tests. Grab samples of the bypass flow were taken from the pump discharge piping downstream of the test module at 2 hour intervals after the fiber/particulate addition. Each sample was filtered through filter paper with 0.1-μm openings, and the dried filter papers were weighed to determine the total quantity of bypass debris (particulate plus fiber). SEM/EDX analysis was performed on selected samples to determine debris characteristics, such as the approximate fraction of fiber bypass versus particulate bypass.

The particulate bypass fraction is not used in subsequent analyses. A 100% bypass is conservatively assumed for the particulate bypass fraction for the downstream effects.

Fiber bypass was measured via SEM analysis. Individual fiber lengths were measured from SEM micrographs of filtered portions of the samples. Most of the fibers (90%) were less than 0.039 inches in length. The volumes and masses of fiber bypass were calculated from the measured fiber lengths. The quantity of fiber bypass decreased exponentially over time.

The maximum fiber bypass fraction from each test was

Test #1	0.096%
Test #2	1.4%
Test #3	0.42%

These values demonstrate the 5% bypass assumed in the downstream effects analysis is conservative.

3f.11 Flashing Across the Strainer Surface

An evaluation of flashing across the strainer surface under full debris load conditions was completed and did take credit for containment over pressure at low sump temperatures . The VCSNS containment is designed for a maximum external pressure of 3.5 psi (containment pressure less than outside pressure) as described in FSAR Sections 6.2.1.2.2 and 6.2.1.3.6. The design limiting case is inadvertent actuation of both Containment Spray pumps with an RWST temperature of 40°F. This case is more limiting than the LOCA event for the sump strainer since there are no energy releases (LOCA blow down) into the containment. Applying the maximum external pressure and assuming a bounding atmospheric pressure of 14.0 psia based on meteorological data, the minimum containment pressure is 10.5 psia. This corresponds to a saturated temperature of 195.5°F.

At temperatures of 195.5°F and above, the sump fluid is assumed to be saturated. At temperatures below 195.5°F the containment pressure is assumed to be 10.5 psia and the fluid is sub-cooled. This assessment is a conservative approach to sub-cooling based on the existing design and licensing basis for VCSNS.

Several sump temperatures were evaluated to confirm the limiting temperature was selected. The strainer pressure drop was adjusted to the appropriate temperature based on water viscosity. Temperatures above 195.5°F were not evaluated since the strainer pressure drop would continue to decrease and level margin increase.

Temperature	Strainer Pressure Drop	Level Margin
70°F	4.08 psi	17.2 ft
104°F	2.72 psi	18.8 ft
130°F	2.13 psi	17.2 ft
190°F	1.35 psi	2.8 ft
195.5°F	1.30 psi	0.12 ft

Based on this assessment and use on containment over pressure consistent with the existing VCSNS design and licensing basis, flashing fill not occur across the sump strainer.

3g. Net Positive Suction Head (NPSH)

3g.1 System Response and Single Failure Assumptions

A composite diagram of the VCSNS Safety Injection (SI) System and RB Spray System (SP) is provided in Figure 7. When the SI System is actuated in response to a LOCA, two (2) Charging pumps and two (2) RHR pumps are started and aligned to inject to the Reactor Coolant System (RCS) cold legs. The charging pumps provide high head, low flow and the RHR pumps provide high flow, low head injection. The pump suction is aligned to the Refueling Water Storage Tank (RWST) for this injection phase. As the RCS pressure decreases, three accumulators will also discharge to the RCS cold legs.

The RB Spray pumps are actuated by a High-3 Containment Pressure. The pump suction is aligned to the RWST. The Spray Additive Tank (SAT) also provided flow to the pump suction for Sodium Hydroxide (NaOH) addition. The RB Spray pumps discharge to spray ring headers located in the RB dome. For the purposes of the sump strainer design, the RB Spray pumps are assumed to start to provide wash down of the upper containment and operating decks.

As the SI System and SP System operate, the RWST volume is depleted. At the RWST Lo-Lo level, the RHR pump and RB Spray pump suction is automatically realigned from the RWST to the Containment Recirculation Sump. Each pump has a separate suction line and suction bell inside containment. There are two Containment Recirculation Sumps. One sump is for RHR Pump A suction and RB Spray pump A suction. The second sump is for RHR Pump B and RB Spray pump B.

After the RHR pump suction is aligned to the Containment Recirculation Sump, the charging pump suction is manually aligned to the RHR pump discharge just downstream of the RHR heat exchanger. Again, the alignment is train specific with one Charging Pump taking suction from one RHR pump.

The only single failure considered with regard to the Containment Sump Strainers is the loss of one train of equipment at some point during recirculation. The loss of one train will increase RHR pump flow in the operating train. This maximizes the Containment Sump Strainer head loss and increases the NPSH required for the RHR pump.

3g.2 Pump Flow Rates

The RHR pumps inject to the RCS through the same cold leg injection lines. So, individual pump flow rates are different for one pump and two pump operation. The Debris Transport calculations assume two pumps operating to maximize flow through the RB which in turn maximizes Debris Transport. The NPSH calculation assumes one pump operating to maximize head loss through the train specific strainer and to 0increase the required NPSH (since pump flow is higher for one pump operation). Additionally, the Debris Transport and NPSH calculation use flow rates higher than the calculated maximum pump flow rates. This provides a quantified flow margin. The RHR flow rates are in Table 16.

Table 16
RHR Pump Flow Rates

Single Train Operation	Analytical Maximum	NPSH Flow Assumption
RHR Pump A	4290 gpm	4500 gpm
RHR Pump B	4196 gpm	4500 gpm
Two Train Operation	Analytical Maximum	Debris Transport Flow Assumption
RHR Pump A	3669 gpm	4288 gpm
RHR Pump B	3590 gpm	4288 gpm

The RB Spray pumps have separate spray headers. The pumps do not interact when both trains are operating. The individual pump flow rate is the same for one pump and two pump operation. The maximum RB Spray pump flow is 3000 gpm per operating pump. This is used in both the Debris Transport and NPSH calculations.

The total recirculation flow rate used in the Debris Transport for two trains operating is 14576 gpm (4288 + 4288 + 3000 + 3000). The total recirculation flow rate used in the NSPH calculation for a single sump strainer is 7500 gpm (4500 + 3000).

3g.3 Containment Sump Level

The minimum containment sump level was calculated using conservative assumptions.

3g.3.1 Water Sources

Water sources for the sump level depend on the break size and location. Large Break LOCA and Small Break LOCA were considered separately.

Large Break LOCA Water Sources

- Initial RCS Water Mass 414728.6 lb
- Minimum RWST injection 2763276 lb
  - Instrument uncertainty applied
  - Instantaneous switchover from injection to recirculation
- Three SI Accumulators 190882 lb
- Spray Additive Tank 25306 lb

Small Break Water Sources

- Initial RCS Water Mass: 414728.6 lb
- Minimum RWST injection 2763276 lb
  - Instrument uncertainty applied
  - Instantaneous switchover from Injection to recirculation
- Spray Additive Tank 25306 lb

3g.3.2 Water Holdup

Water holdup is defined to mean any place water can be other than the RB floor at the sump elevation providing elevation head to the pumps.

- RCS - For Large Break, assume the RCS is filled to the top of the Cold Leg at 70°F and 0 psig. For Small Break, assume no change in RCS level, but pressure and temperature decrease.

- Two inch water level on 463 ft elevation operating deck floor (direct spray). Weir flow calculation model estimates actual level less than one inch.
- One inch water level on 436 ft elevation mezzanine level floor (no direct spray)
- Spray ring header (initially empty) is filled with water.
- Transient time for spray flow to impact operating deck is considered.
- The containment atmosphere is assumed saturated steam with a T_{sat} of 240°F. This is the maximum containment temperature during recirculation.
- Transient time for Safety Injection spill flow from the break to the sump water level.
- Water droplets adhering to vertical surfaces.
- Water holdup in the 8" Refueling cavity drain line.
- Water holdup in the Reactor Vessel Cavity as detailed below.

As the RB fills, water can drain into the Reactor Vessel cavity through a ventilation fan located slightly above the floor level. This will occur for any break location. If the break is located within the primary shield, the cavity can fill directly. The ventilation fan is provided with two stainless steel dampers designed to limit air flow out of the cavity if the fan is off. Under post-LOCA conditions, the fan is off and these dampers may restrict water flow out of the cavity. As a conservative assumption, the Reactor Cavity is assumed to fill up to the primary shield wall penetrations for the RCS primary loop piping. This is applied to all break locations.

3g.2.3 Sump Water Level

The sump water level was calculated by determining the mass of water on the floor of the RB providing elevation head to the RHR and RB Spray pumps during recirculation. The water density is based on 70°F and 1 atmosphere (14.7 psia). Significant structures and components are assumed to displace water. These include the Secondary Shield Wall, Primary Shield Wall, Accumulator, and Pressurizer Relief Tank.

The minimum water level in the RB sump is

Large Break LOCA	3.42 ft
Small Break LOCA	2.60 ft

The Debris Transport calculation uses a water level of 2.9 ft based on initial water level calculations. This is conservative for the limiting Large Break LOCA Debris Generation cases. The vortex formation uses a water depth of 2.60 ft since this is a concern for both Small and Large Break LOCA. The NPSH calculation also uses the 2.6 ft level to bound the water level.

3g.4 Net Positive Suction Pressure Calculation

The NPSH calculation does not credit containment overpressure (assume $T_{sat} = T_{vap}$). Under this assumption, the available NPSH is simply calculated as

$$NPSH_A = Z_{sump} - Z_{pump} - h_{piping} - h_{strainer}$$

Where:

$NPSH_A$ is the available NPSH
Z_{sump} is the water level elevation of the sump
Z_{pump} is the suction inlet for the pump
h_{piping} is the head loss due to the piping from the sump to the pump
$h_{strainer}$ is the head loss across the strainer under debris loading

The piping head loss follows conservative piping pressure drop calculation methodologies consistent with Crane Technical Paper No. 410. The sump temperature is assumed to be 70°F since this has little effect on the piping pressure drop.

The sump strainer head loss is discussed in response to item 3f.

The required NPSH is based on vendor supplied pump performance curves. The RHR pumps are Ingersoll Rand model 8x20WDF vertical centrifugal pumps. The RB Spray pumps are Gould Pump, Inc. Model 3415 centrifugal 8x22-10 pumps.

NPSH Margin is provided in Table 17. Two temperatures are evaluated for NPSH to demonstrate the margin in the conservative assumption of no containment over pressure at low sump temperatures. The higher temperature is the conservative minimum saturation temperature detailed in Section 3f.11.

Table 17
NPSH Margin

Pump	Flow rate	NPSH Required	NPSH Available	NPSH Margin	Temperature
RHR Pump A	4500 gpm	18 ft	19.5 ft	1.5 ft	70°F
RHR Pump A	4500 gpm	18 ft	25.8 ft	7.8 ft	195.5°F
RHR Pump B	4500 gpm	18 ft	19.8 ft	1.8 ft	70°F
RHR Pump B	4500 gpm	18 ft	26.1 ft	8.1 ft	195.5°F
Spray Pump A	3000 gpm	20 ft	23.9 ft	3.9 ft	70°F
Spray Pump A	3000 gpm	20 ft	30.2 ft	10.2 ft	195.5°F
Spray Pump B	3000 gpm	20 ft	24.1 ft	4.1 ft	70°F
Spray Pump B	3000 gpm	20 ft	30.4 ft	10.4 ft	195.5°F

3h. Coatings Evaluation

3h.1 Level 1 Coating Systems

The following Level 1 (Qualified) coating systems are present in the VCSNS RB. The Dried Film Thickness (DFT) is based on Quality Control (QC) records documenting the as applied DFT.

<u>Original Coating Systems</u>

			DFT
Steel	Mobilzinc 7	Primer	4 mils
	Amercoat 66	Top Coat	7 mils
Concrete	Nuclad 110A/114	Surfacer	Walls: 1/16" Floors: 1/8"
	Ameron 89	Top Coat	7 mils

<u>Current Coating System</u>

Steel	Keeler and Long 6548/7107	
Concrete	Keeler and Long 6149	Sealer
	Keeler and Long 5000	Top Coat - Floors
	Keeler and Long 4500	Top Coat - Walls

The Reactor Coolant Pump (RCP) motors were supplied by Westinghouse. Based on Westinghouse supplied data (TB-06-15, Revision 1), the motors are provided with qualified coatings. The coating system is either Dimetcote No. 2 primer with Amercoat 66 top coat or Dimetcote EZ-II primer with Amercoat 66 top coat. [Reference 1]. The pump motors fall outside the ZOI for the limiting break locations analyzed, so the specific DFT of the coating was not further researched.

3h.2 Coating Debris Generation

The Coating Loads are summarized on Tables 9 through 12 for the limiting breaks considered in the analysis. The basis of the coating loads is covered in this section.

The Unqualified Coatings were assumed to fail 100%. The total Unqualified Coatings generation by coatings type is presented in Table 18. These values include a Cumulative Effects margin for future operating margin. For the strainer thin bed test and downstream effects analysis, all Unqualified Coatings were assumed to fail as particulate. For the strainer paint chip test, the unqualified epoxy coatings were assumed to fail as chips.

The alkyd coatings outside the coatings ZOI fail as particles with a thickness equivalent to the original coating thickness. EPRI Report 1011753 [Reference 17] concluded from the autoclave tests that failed coatings average particle size was 83 μm for samples 1-19 and 301 μm for samples 20-42. The analysis assumes a particle size of 83 μm.

Luminant with Keeler and Long performed a test which studied Design Basis Accident testing of epoxy and zinc coatings samples. ALION-REP-TXU-4464-02, "TXU Paint Chip Characterization" characterizes the samples from the TXU DBA testing. The report documents a size distribution of epoxy chips and the particle size of zinc particulate from the coating debris. It is indicated that zinc fails as particulate with an average particle size of 1.7 mils (40 microns). The epoxy size distribution presented in the report is shown in Table 19. The range of average thickness reported for the failed epoxy coatings is 2.8 mil to 7.5 mil. The thickness of the unqualified epoxy coatings at VCSNS fails within this range. For the size categories of ½"-1" and 1"-2", 50% of these epoxy chips are curled. The report was supplied "For Information Only" to the NRC by Luminant Power in Letter CP-200700051 [Reference 22]. The Luminant letter also included an assessment by Corrosion Control Consultants [Reference 23] comparing the test epoxy (Carboline Phenoline 305) with various other qualified epoxy coatings. Both the Amercoat 66 and Ameron 89 (aka Valpsar 89 series) used at VCSNS are similar to the test epoxy and are expected to yield similar results.

Table 18
Unqualified Coating Debris Generation

Coating Type	Area (ft^2)	Volume (ft^3)	Weight (lbs)
Alkyd	12302	4.188	410
Epoxy	7363	3.683	346
Inorganic Zinc	2038	0.510	233
Cold Galvanizing (Zinc)	300	0.038	17.4

Table 19
Epoxy Paint Chip Size Distribution

Size Range of Coating	Mass Percent
1" to 2" (a)	32.0%
½" to 1" (a)	9.04%
¼" to ½"	4.41%
⅛" to ¼"	5.02%
< ⅛" (b)	49.5%
Total	100%

(a) 50% of chips greater than ½" and larger are curled
(b) 75% are 1/64" (15.6 mil) and 25% are 6 mil

The Level 1 Coatings (Qualified Coating) ZOI was modeled as 4 Diameters based on Westinghouse WCAP-16568-P [Reference 4]. Testing was completed on both epoxy-epoxy coating systems and zinc-epoxy coating systems. This covers both coating Level 1 system types used at VCSNS.

Break locations considered were on the 31 inch cross-over pipe between the S/G and RCP. Breaks in the 27 inch Cold Leg Piping and 29 inch Hot Leg piping were not specifically analyzed. These breaks create a smaller spherical ZOI and move the break location away from floor grating and supports which are the most significant contributor to the coating load. The following specific break locations were considered.

- A break at the S/G A outlet nozzle was selected as the limiting S/G outlet break for a detailed tabulation of surface area within the ZOI. The S/G A location is limiting since the grating area is higher, the Pressurizer Surge line and its supports are located within the S/G A cubicle and a RHR Hot Leg Suction line and its supports are located within the S/G A cubicle.
- A break at the bottom of the cross-over loop in the S/G A cubicle was selected as representative of each cubicle. This break was tabulated since this low elevation is the only one to include the RB floor which has the thickest coating.
- A break at each of the three RCP inlets was tabulated. The RCP locations are closer to the bio-shield walls and fall within the ZOI.

The break at S/G A inlet nozzle was determined to be limiting. The debris load for qualified coatings is present in Table 20. All steel coatings were assumed to be Mobilzinc 7 with an Ameron 66 topcoat to maximize the latent debris mass. All qualified coating debris within the ZOI fail as particulate due to erosion.

An assumption of 500 ft^2 of degraded qualified coating was added for operating margin. For high particulate load head loss and downstream effects, the degraded qualified coating was assumed to fail as particulate. For the paint chip head loss test, the top coat of epoxy is assumed to fail as chip. The surfacer (Nu-Klad) is assumed to fail as particulate.

Table 20
Qualified Coating Debris Load

Coatings		Area (ft^2)	DFT (in)	Weight (lbs)
Steel				
	Mobilzinc 7	2297	0.004	352
	Ameron 89	2297	0.007	126
Floors				
	Nu-Klad	0	0.125	0
	Amercoat 66	0	0.007	0
Walls				
	Nu-Klad	79	.0625	54
	Amercoat 66	79	.007	6
Failed Qualified Coating Operating Margin				
	Nu-Klad	500	0.0625	343
	Amercoat 66	500	0.007	36

3h.3 Coating Debris Transport

All fine particulate coating debris is assumed to be 100% transportable to the sump strainer. This includes qualified coating within the ZOI, alkyd coatings and zinc primer for all cases. The unqualified epoxy and epoxy from the qualified coating debris margin fail with the size distribution shown in Table 19. Transport calculations were completed for the epoxy debris as discussed in response Section 3e.4. A sample Transport Logic Tree is shown in Figure 6. The 6 mil epoxy particulate is assumed to be 100% transportable.

For the large scale Test 2 (particulate loading test), all unqualified coatings, coating within the ZOI and qualified coating debris operating margin were assumed to fail as particulate and be 100% transportable to the sump screen.

3h.4 Coating Debris Surrogates for Testing

Large scale strainer testing was completed at Atomic Energy of Canada, Limited (AECL). The NRC trip report to the AECL facility is provided through ADAMS in ML062020596. [Reference 6] The surrogate for coating particulate was walnut shell flour (~325 Mesh). As started in the NRC trip report

> "Based on density, the staff would expect walnut shell flour to transport to the strainer surface more readily than actual debris of an equivalent size and would therefore be a conservative surrogate from the debris transport perspective."

The outstanding item listed for the use of walnut shell flour is

> "Providing evidence that walnut shell flour is not affected by the test tank environment in a manner that would change its particle size or otherwise impact its head loss or transport properties."

As noted in the NRC trip report, AECL has performed bench top testing to evaluate walnut shell flour water absorption. [Reference 7] The test was monitored for walnut shell flour expansion in water using column height in a test tube as the measurement. The test ran for 71 hours and included 5 hours in a 40°C (104°F) water bath. The average expansion over this time was 2.3%. This is within an acceptable range for the head loss testing.

The surrogate material for zinc coatings was Inorganic Zinc Filler from Carbonline/Plastic Division of StonCor Group. This was approved in the NRC trip report.

Coating chips were made using Keeler and Long No. 4500 based on the current VCSNS qualified coating for steel. The coating was applied to plastic sheets and then peeled off following curing. The chips were loaded into a cement mixer with dry ice. All chips were broken into sizes smaller than 2 inches. A hand sieve was used to determine the size distribution of the chips which is presented on Table 21. The paint chip test preceded completion of the chip size distribution and chip transport analysis in order to meet the December 31, 2007 deadline for resolution of GSI-191. Therefore, the size distribution and quantities do not match the analysis values.

As shown in Table 21, the quantity of chips added during the test bound the chip loading as determined by the transport analysis. The epoxy chips used in the test had a slightly smaller size distribution. Smaller chips have a lower settling velocity which would provide a greater opportunity for the chip to adhere to the strainer surface. A qualitative observation during the test was that chip size did not appear to be an important factor for chips to adhere to the surface. The analytical chip loading is bounded by a single chip addition during the test.

Table 21
Epoxy Paint Chip Size Distribution Test Comparison

Chip Size	Weight Percent	Total Chip Surface Area for Test 3	Surface Area per Addition (1/3 of total)	Debris Loading Calculation (Table 12)
< ¼"	2%	7 ft^2	2.3 ft^2	0
¼" to ½"	13%	447 ft^2	149 ft^2	0
½" to 1"	59%	2027 ft^2	675.7 ft^2	165 ft^2
1" to 2"	26%	893ft^2	297.7 ft^2	582 ft^2
Total	100%	3436 ft^2	1145.3 ft^2	747 ft^2

3h.5 Head Loss Testing

Three large scale tests were run to measure head loss across the sump strainers under design basis debris loading and flow rates. Testing details including debris loads, scaling, debris preparation and debris additions are provided in response to Item 3f.3. Two tests relate to coatings.

The high particulate load Test 2 was based on reactor vessel nozzle safe end break which generated Marinite XL debris. The fiber loading was based on the latent debris term and the fiber content of the Marinite XL. All coatings were assumed to fail as particulate and be 100% transportable to maximize the particulate loading.

The paint chip load Test 3 was also based on the reactor vessel nozzle safe end break with Marinite XL, but used chips for unqualified epoxy and qualified epoxy coating operating margin. A comparison of the calculated chip loading and that used in Test 3 is provided on Table 21.

The following qualitative observations were made on the paint chip test.

- Most of the paint chips that adhered to the strainer tended to be along the upward facing part of the corrugated fin. Some small chips did adhere to the bottom of the corrugation.
- Most of the paint chips deposited on the floor under the strainer fins.
- The paint chips that were initially curled flattened out.
- Both large and small paint chips adhered to the strainer. The size of the paint chip does not appear to be a determining factor for strainer blockage.
- Some paint chips were at a 90° angle from the strainer surface indicating the chips were caught on the fiber rather than pulled to the strainer surface by the flow.

3h.6 Coating Condition Assessment

The acceptability of visual inspection as the first step in monitoring of Containment Building coatings is validated by EPRI Report No. 1014883, "Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level 1 Coatings," August 2007 [Reference 21]. The Containment Coating Monitoring and Maintenance Program provides for maintenance of protective coatings inside the RB. Visual inspections and condition assessments of certain coatings inside containment are periodically conducted as part of the containment structural integrity verification, Maintenance Rule monitoring, general maintenance planning, and during recovery from refueling outages. Containment coatings are visually inspected via walk downs from accessible floors, platforms or other permanent vantage points. The degree of examination depends on many factors such as accessibility, environmental and radiological conditions, and safety. In cases of inaccessibility, sampling approaches based on plant specific characteristics, industry wide experience and testing history are evaluated in lieu of actual visual inspections. This is discussed in FSAR Section 18.2.11.

3i. Debris Source Term Refinements

To maintain the required configuration of the containment recirculation function that supports the inputs and assumptions utilized to perform the mechanistic evaluation of this function, VCSNS has programmatic and process controls as described below.

The VCSNS Foreign Material and Debris Control program (FME) is covered in Station Administrative Procedure SAP-363 [Reference 26]. Personnel are provided FME awareness training as a part of Site Orientation Training (SOT). FME training covers responsibilities, types of foreign materials and operating experience.

Following an outage, once plant maintenance and modification activities are complete, the QC organization is notified by outage management to perform a two part (preliminary and final) containment closeout inspection. This inspection is performed in accordance with Quality Services Procedure QSP-522 [Reference 28]. After the final

QC inspection, the entire RB is declared and maintained as a foreign materials exclusion (FME) area.

The operations closeout inspection, performed in accordance with Surveillance Test Procedure STP-109.001 [Reference 27] is performed after completion, or in conjunction with the final QC walk down inspection, and is the final inspection performed before the lights are turned off in the RB. The procedure directs the operator to confirm the RB is free of loose debris (rags, trash, clothing, etc.), which could be transported to the RB recirculation sumps, causing restriction of the pump suctions during LOCA conditions. The Shift Supervisor will initiate necessary corrective action and will direct additional inspections until the cleanliness conditions of the RB meet the acceptance criteria.

At power RB entries are controlled under procedure OAP-108.1 [Reference 29]. At power entries treat the RB as an FME area. Following planned activities, a walk down is completed by Operations per STP-109.001. Due to ALARA considerations and the use of an FME area, QC does not perform an independent walk down for the at power RB entries.

Containment coating condition assessment is addressed in Section 3h.6 of the response. Latent debris and fiber is covered in Section 3d of the response.

The Cumulative Effects Program [Reference 25] of the Engineering Change Process was updated to track important design inputs that support the GSI-191 issue resolution. The program provides for the tracking of margins for important design parameters by the designated principle design engineer. The procedure points to the referenced document which calculates the design input and to the referenced document which uses the design inputs. The specific design inputs added are:

- The existing program that tracks aluminum inside the RB for hydrogen control was revised to include the Chemical Effects aspects of GSI-191. The same design margin used for hydrogen control was used for Chemical Effects.
- A new program was added to track Unqualified Coatings inside the RB. The program is referenced to the Unqualified Coatings calculation which lists the Unqualified Coatings and design margins.
- A new program was added to track insulation inside the RB. This program is referenced to the Debris Generation calculation which lists the insulation and reference drawings.
- A new program was added to track the addition of structures or components inside the loop compartments that may fall within the qualified coating ZOI. The program is referenced to the 4D ZOI calculation for Qualified (Level 1) Coatings inside the RB.

Insulation drawings have been maintained at VCSNS and are a part of the Design Control System (DCS) database. Maintenance procedures provide caution that non-metallic insulation may not be installed inside the RB except under an Engineering Change Request (ECR) or Equal To or Better Than (ETBT) modification package. [Reference 24]

The inputs and assumptions for debris generation, debris transport, head loss determination (including chemical effects considerations), containment sump level, and downstream effects analyses and associated testing have been documented in an approved engineering document (subject to the requirements of 10CFR50 Appendix B) to facilitate evaluation of conditions that may be contrary to analysis and modification input assumptions, and to ensure that future changes to the plant can be readily evaluated against these design and licensing basis criteria.

In summary, SCE&G has implemented the necessary programmatic and process controls to ensure the recirculation function will be maintained into the future.

The design and operational refinements listed in Section 5.1 of the SE have not been utilized in the VCSNS analysis for GSI-191.

3j. Screen Modification Package

In the event of a LOCA, water from the spray nozzles and water spilled through the break in the RCS is collected in either the A or the B RB recirculation sumps. Each of these two sumps has a suction line to 1 RHR pump and a suction line to 1 RB Spray pump. Each recirculation sump is irregular in shape as shown in Figure 1. The overall plan dimensions of each sump are approximately 17 feet by 28 feet. Each of the recirculation sumps is surrounded by a 6 inch high curb. One side of Sump B abuts directly against the adjacent secondary compartment wall and does not have the 6 inch curb. The basement floor of the RB is at elevation 412 ft. The floor level of the recirculation sump area is at elevation 408 ft. There are 4 individual deep sump pits for the RHR and RB Spray pump suctions - 1 RHR and 1 RB Spray deep pit located in each of Sump A and Sump B. The deep pits are 4 foot by 4 foot in plan extending down to elevation 400 ft. The centerline of the suction pipe within each deep pit is at elevation 402 ft.

A schematic vertical section through a typical deep sump pit is shown in Figure 13. A removable welded stainless steel bar grating walkway is provided over the sump for a personnel access walkway and to support maintenance in the area. The grating is designed to remain in place during plant operation. The top of the grating walkway cover over the sumps is at elevation 412'-9". A large opening is provided through the grating to ensure adequate flow to the pumps through the opening for the postulated worst case assuming full blockage of the grating by debris transported to the sump following the postulated pipe break.

Each of the four deep sump pits is protected against the entry of unacceptable types and quantities of debris generated as the result of hypothetical, postulated LOCA pipe break events by a strainer assembly. The RHR and SP strainer modules are interconnected by a cross-duct to allow water to flow from one module to the other conservatively assuming one of the strainer modules becomes heavily blocked by postulated debris.

Each strainer assembly is composed of a single square module, the header box, equipped with 44 hollow fins, 11 on each of the 4 sides of the strainer header box. The fins are connected laterally to the approximately 4.75 foot high sides of the header box located directly over each sump pit. The fins are of varied length designed to fit within the available space in the sump. Each vertically oriented strainer fin consists of 18 gauge stainless steel sheet, perforated with 1/16" diameter holes. The performance of the strainer is enhanced by the extremely low approach velocity to the perforated fins of less than 0.1 in/second. The area ratio of holes is approximately 41% and the surfaces of the fins are corrugated to increase their surface area. As the water level rises in the strainer during filling, air can escape through the fins and through the vent holes provided at the top of the strainer header box. This design ensures that there is no risk of air ingestion due to trapped air pockets during filling.

The total strainer surface areas provided are:

Sump A:	A RHR	-	1405 ft^2	Total Sump A:	2939 sq ft
	A SP	-	1534 ft^2		
Sump B:	B RHR	-	1251 ft^2	Total Sump B:	2380 sq ft
	B SP	-	1129 ft^2		

The design of both the Sump A and Sump B strainers includes a closed cross duct connecting the RHR and SP header boxes within the sump as shown on Figure 12. The cross duct design consists of 1/4" thick stiffened stainless steel plates. The cross duct provides a flow area approximately 5 inches high by 30 inches wide for flow between the interior of the two header boxes. The cross duct connection to the header boxes is located on the side and near the top of the header boxes. The cross duct is designed and fabricated to the same criteria as the strainers. The cross duct serves to provide additional redundancy to the strainer design for both the Sump A and Sump B. For a postulated event where the fin strainers on either the RHR or SP sides of the sump are assumed to be blocked by debris generated by the postulated LOCA pipe break event, the flow into the unblocked strainer header box provides sufficient recirculation flow through the cross duct to satisfy the NPSH requirements for the pumps on both the RHR and SP sides of that sump. A photo of the RHR Pump B sump strainer is shown in Figure 14.

The header boxes, strainer fins, and cross ducts are designed, fabricated, and installed in accordance with ASME Code and Seismic Category 1 requirements. Each strainer fin bank consisting of 11 fins is supported as an integral unit by bolting each fin to a horizontal truss located along the top and also along the bottom of each fin bank. The trusses are bolted to the header box assemblies. Each fin is also securely pinned at the bottom and bolted at the top to the header box assembly. Adjustable vertical supports for each fin bank are provided beneath the horizontal truss at the bottom of the fin bank to the sump floor at elevation 408'. The top of each header box consists of 3/8" stainless steel plate with stiffeners. A solid 3/8" thick plate for personnel access down into the deep pit is secured to the top of each header box by bolting all 4 sides of the personnel access hatch plate to the welded flange assembly on the header box top plate.

Figure 12
B Sump Strainer With Cross Duct

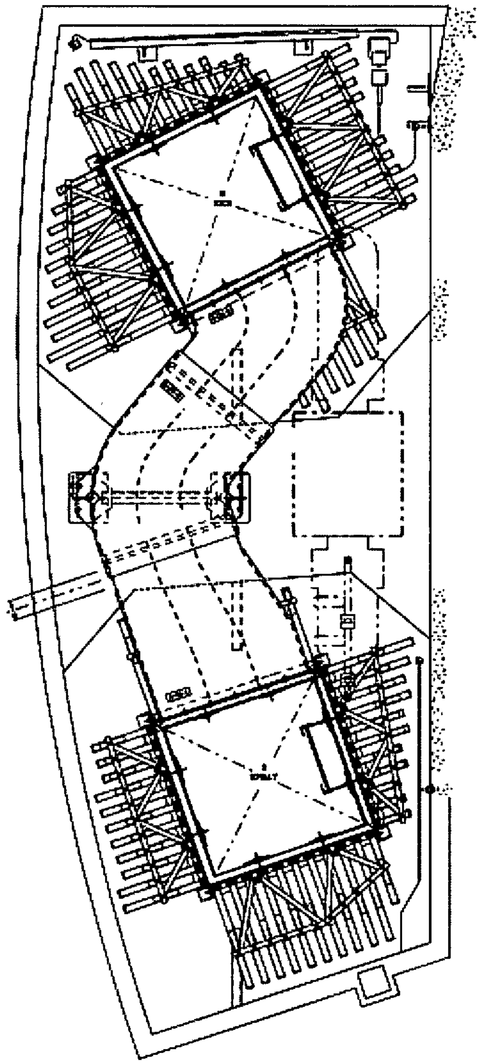


Figure 13

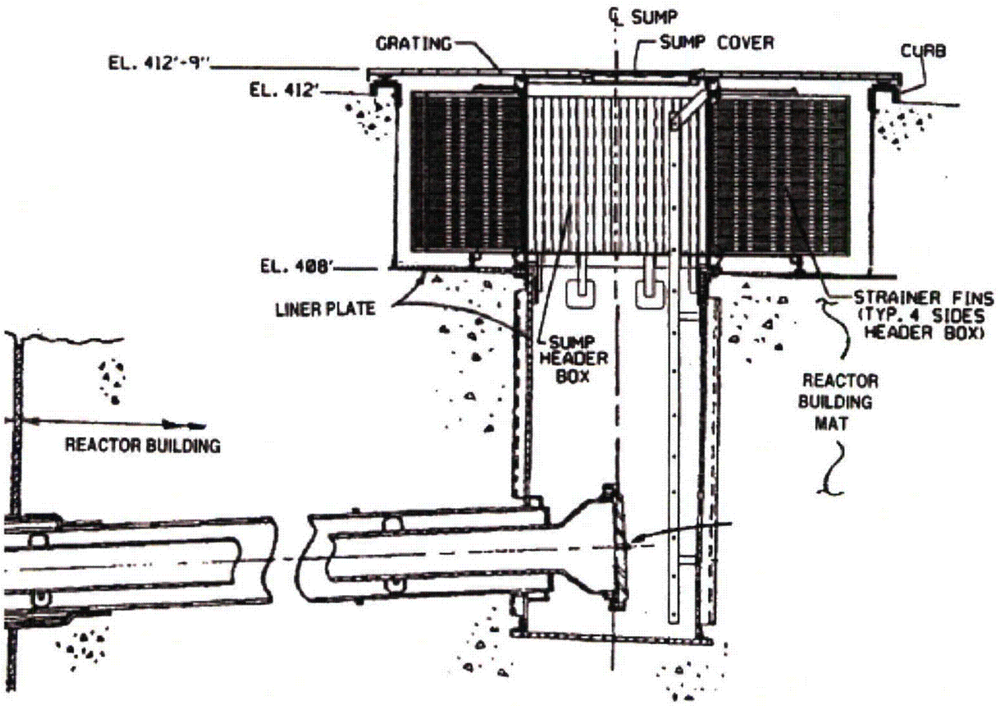


Figure 14
Photo of Assembled Strainer in the Fabrication Shop (w/o top cover)

3k. Sump Structural Analysis

The modified recirculation sump strainer assembly for VCSNS is located in the same foot print as the previous strainer screens. Sketches showing the location of the modified strainer assembly are attached to this report (Figures 1 and 2). The modified recirculation sump strainer assembly was structurally analyzed and found to meet all design requirements given in the VCSNS FSAR.

The load combinations used in this analysis are the same as already defined for structures in safety related applications at VCSNS. A structural evaluation was performed to qualify the new strainers installed in the containment recirculation sumps. This evaluation was by analysis, and included the strainer modules as well as the supporting structures associated with the strainers. The evaluation was performed using a combination of manual calculations and finite element analysis using commercially available computer codes. The evaluations followed the requirements of the plant specific design specifications. The strainers are designed for the following loads:

- Seismic loads - Both the Operating Basis Earthquake (OBE) and the Safe Shutdown Earthquake (SSE) loads are developed from response spectra curves that envelope the response spectra curves for VCSNS.
- Live Loads - Live loads include the differential pressure across the strainer perforated plates in the operating condition.
- Thermal Loads - Thermal expansion is considered in the design and layout of the structures. The design temperature of 270°F is slightly above the maximum expected sump water temperature. The maximum atmosphere temperature inside containment can reach higher temperatures, however this is a short term spike and the structure (which is below grade) is submerged early in the event. Therefore, the use of the maximum water temperature for material properties and thermal expansion is appropriate.

The references used in the analysis, the design inputs used, and the loadings used in the analysis are defined in the structural analysis separately provided to the NRC for their information.

Pipe whip and jet impingement were reviewed for their impact on the modified strainers, and were found not to be a concern. The strainers are located outside the bio-shield wall in areas where there are no pipe whip loads or missile loads on the strainers.

The strainer location is located such that there are no LOCA jet impingement loads that could strike the strainers or their related equipment.

Existing plant procedures require that the modified recirculation sump strainer assembly be inspected during each refueling outage [Reference 19]. This inspection is required by VCSNS Technical Specifications. If any damage or degradation is found, the responsible supervisor follows test deficiency resolution procedures [Reference 20] which include entering the deficiency in the correction action program.

In summary, SCE&G has evaluated the modified VCSNS sump strainers and has determined that all design requirements are met.

3l. Upstream Effects

3l.1 Spray Wash Down

The spray flow will return to the RB sump pool by one of four paths. These return paths are all modeled in the Computational Fluid Dynamics calculation.

1. Spray flow landing on the concrete operating deck at the 463 ft elevation will return via the equipment hatch or one of the two stair wells. There are no curbs at these locations. There are curbs or toe-kick plates at all other locations to direct the spray flow. As covered in response to item 3g, a 2 inch water level is used for the operating deck.
2. Spray flow may enter the S/G cubicles directly. There are no solid floors within the cubicles (grating only), so the flow returns directly to the sump pool.
3. Spray flow may drop between the operating deck and the RB wall. The operating deck is not cylindrical and openings are provided between the floor and the RB wall. This spray flow returns directly to the sump pool.
4. Spray flow directly entering the Refueling Cavity returns to the sump pool via an 8" line into the normal RB sump. The normal RB sump is located on the same elevation as the sump pool. A 2 inch continuous curb around the Refueling Cavity prevents water from the 463 ft operating deck from entering the Refueling Cavity.

Two other small wash down paths are also available, but not specifically modeled. The pressurizer cubicle has three small openings. Some small amount of spray flow will enter the cubicle and empties on to the mezzanine level at the 436 ft elevation. This is covered by the 1 inch water level assumption for the 436 ft elevation as covered in response to item 3g. The spray flow may also enter the reactor vessel cavity around the vessel head seal. This seal is used during refueling operation. During power operation, a small gap is available for spray flow to enter the reactor vessel cavity. This is covered by the assumption that the cavity fills to the RCS cold leg primary shield wall penetrations as covered in response to item 3g.

3l.2 Break Locations and Choke Points

There are no curbs or debris interceptors in the VCSNS design which will hold up or choke water flow return to the sump pool. Three possible break areas were identified which have different characteristic break flow return paths.

1. A break in any one of the S/G cubicles will spill directly into the sump pool. The same holds for the Pressurizer Surge line. These break locations are all within the bio-shield wall. There are three openings in the bio-shield wall which allow flow out to the sump strainers. Flow is not choked at the bio-shield exits.
2. A break at the Reactor Vessel safe end is inside the primary shield wall. A baffle assembly directs the initial LOCA jet out the primary shield wall penetration and up into the RB above the Reactor Vessel. Spill flow during recirculation is directed out on the primary shield wall penetration, directly into the sump pool. Some flow may drain between the baffle assembly and reactor vessel into the vessel cavity. This is covered by the assumption that the cavity fills to the RCS cold leg primary shield wall penetrations as covered in response to item 3g.
3. A break in one of the Pressurizer Safety Valve or Power Operated Relief Valve lines would result in spill flow inside the pressurize cubicle. As covered in response to item #2, the Pressurizer cubicle door does not present a hold up concern. Flow would exit the Pressurizer door on to the mezzanine level at the 436 ft elevation. Two 8 foot lengths of toe kick plate have been removed from the mezzanine level (in the vicinity of the equipment hatch) to provide a larger flow path to the sump pool. Prior to the modification, the flow return to the sump pool via one of two stairwells. The stairwell adjacent to the A train sump was provided with a gate to direct flow away from the sump.

3l.3 Reactor Vessel Cavity

Hold up in the Reactor Vessel cavity has been taken into consideration. Two stainless steel dampers isolate air flow out of the cavity at the sump pool elevation. It is assumed these dampers adequately restrict flow out of the cavity resulting in cavity fill to the primary shield penetrations for the main reactor coolant loop piping. This slightly reduces the sump pool level.

3l.4 Refueling Cavity

The Refueling Cavity is drained by an 8 inch diameter pipe. The drain opening into the pipe is located on the floor level in the cavity at an elevation of 423 feet, 5.25 inches. The centerline of the pipe outlet into the normal RB sump (at a location away from the recirculation sump strainers) is at 409 feet, 2 inches. There are no valves in the line. During refueling operation, a blind flange is installed to block the drain flow path. Based on the assessment summarized below, a debris interceptor for the Refueling Cavity drain is not required.

A continuous two inch curb is provided around the Refueling Cavity at the 463 ft operating deck elevation. During post-LOCA conditions, this curb prevents water collected on the operating deck (from the spray flow) from entering the refueling cavity. This limits the amount of water that must drain from the refueling cavity through the

8 inch pipe. The curb also prevents wash down of any debris from the operating deck into the Refueling Cavity.

VCSNS containment is highly compartmentalized. The shield wall around the S/Gs extends up to an elevation of 475 feet, 5 inches on the side facing the Refueling Cavity. The limiting design break at the S/G outlet is at an elevation of 431 feet. Debris large enough to block the 8 inch diameter drain is not expected to be carried up and over this elevation difference.

If it were postulated that large debris were to dislodge from the top of the S/G and fall laterally into the Refueling Cavity, it would then have to transport to the 8 inch drain line. The insulation on the S/Gs is reflective metal cassettes. The failure mechanism for a cassette located near the top of the S/G is for the cassette buckle to fail and the cassette to break open as it impacts the floor. The Refueling Cavity drain line is located near the containment wall in the fuel transfer cannel. This is well away from the S/Gs. Testing has shown that water readily flows through a pile of crumpled reflective metal insulation debris.

3m. Downstream effects - Components and Systems

SCE&G contracted Westinghouse to develop the five calculations listed below to address downstream effects. These calculations were developed in accordance with PWROG WCAP-16406-P, Revision 1 [Reference 11] and NRC Safety Evaluation [Reference 2].

- Calculation DC04410-016, [Reference 12]
- Calculation DC04410-015, [Reference 13]
- Calculation DC04410-021, [Reference 14]
- Calculation DC04410-022, [Reference 15]
- Calculation DC04410-023, [Reference 16]

VCSNS system line-ups, mission times, flows and pressures used to bound downstream evaluations are described in the applicable downstream effects calculations listed above. The calculations confirm that SI and RB Spray operation during small-break, medium-break, and large break LOCAs is adequate to meet the requirements of the VCSNS accident analyses.

The calculations evaluate the downstream effects of debris ingestion of the auxiliary equipment in VCSNS including the valves, pumps, heat exchangers, orifices, spray nozzles, and instrumentation tubing, following the methodology in WCAP-16406-P, Revision 1 [Reference 11]. The WCAP was supplemented with erosion data from WCAP-16571, Revision 0 [Reference 32]. The effects of debris ingested through the containment sump strainers during the recirculation mode of the SI and RB Spray include erosive wear, abrasion and potential blockage of equipment and flow paths. The calculations also document an assessment of changes in system or equipment operation caused by wear, including an evaluation of pump hydraulic performance due to internal wear.

The Downstream Effects evaluation prompted the replacement of the High Head Safety Injection Throttle Valves. The new valves are Y-pattern Edward PressurCombo Globe Valves which feature a flow nozzle at the valve outlet. The flow nozzle provides a large pressure drop allowing the valve to be opened further. The minimum valve opening is now approximately 3/32" compared to a sump strainer opening of 1/16". No other physical or operational plant changes were made to address Downstream Effects.

WCAP-16406-P [Reference 11] identified a concern for the carbon/graphite disaster bushings in the pump seals. These bushings limit pump seal leakage to 50 gpm if the primary seal fails. With the debris loading expected during post-LOCA conditions, the seals may not be limited to a 50 gpm leak rate. The current LOCA dose calculations are required to assume the passive failure of a pump seal at 24 hours after the event with isolation in 30 minutes. After consulting with the pump vendor and NSSS vendor, no replacement seal packages without the carbon/graphite bushing were available. To eliminate the need for replacement, an Alternate Source Term dose analysis and licensing submittal is being prepared. The LOCA dose calculation has been completed, demonstrating reduced doses. Without the assumption of a pump seal failure, there is no need to replace the carbon/graphite disaster bushing.

3n. Downstream Effects - Fuel and Vessel

VCSNS contracted Westinghouse to apply the methodology of WCAP-16406-P, Revision 1 [Reference 11] for the evaluation of potential core blockage following a hot leg or a cold leg break. With the low flow velocity calculated in the reactor vessel lower plenum, particulate debris with a density that is heavier than water will settle in the lower plenum and not be passed into the core. Fibrous debris with a density approximately the same as water would be carried along with the circulated sump water but would be filtered by the sump strainers and by screens located at the inlet to the fuel bundles.

Reference 15 models 3.46 cubic feet of Temp-Mat and 6.7 cubic feet of latent fiber arrive at the sump strainer. Even though some or most of the fibrous debris is expected to be retained on the sump screens, the Reference 15 calculation assumes that all such debris passing through the strainer reaches the core. A sump screen efficiency of 95% for filtration of fibrous debris and 95% capture of debris by fuel assembly nozzles.

For the Temp-Mat limiting case, Tables 9 and 10 show the total Temp-Mat arriving at both of the sump strainers is 1.5 ft^3 (i.e., 1.1 ft^3 + 0.4ft^3) with 6.7 ft^3 of latent fiber. For the Marinite XL limiting case, Tables 11 and 12 show 2.4 ft^3 of mineral wool with 6.7 ft^3 of latent fiber. These are both bounded by the fiber assumed in Reference 15. The sump screen efficiency (bypass) testing indicated a sump screen efficiency of greater than 95% as described in response Section 3f.9. The Reference 15 calculation is bounding in both assumed fiber at the sump strainer and bypass fraction.

The VCSNS sump screen testing program was based on the screen velocity which would occur for a flow rate of 7500 gpm . This flow rate would be appropriate for operation of one RHR pump, one Charging pump and one RB Spray pump operating in one engineered safety features train. This maximizes the flow velocity and, therefore, the bypass fraction for the sump strainer.

The acceptance criterion of a fibrous debris bed thickness is no more than 0.125 inches across the core inlet. This acceptance criterion is based on pressure drop studies for BWR strainer blockage concerns in NUREG/CR-6224 [Reference 33]. This acceptance criterion is conservative because it is expected that low, non-uniform flow rates would likely exist at the core inlet during the post-LOCA long-term cooling period, making the formation of a uniform compact fiber bed at the core inlet unlikely.

Using the methodology of WCAP-16406-P, Reference 15 calculates a fiber bed thickness at the core inlet of 0.002 inches following a postulated cold leg break and 0.075 inches following a hot leg break [Reference 15]. These thicknesses are for the latest time of switchover from cold leg recirculation to simultaneous cold/hot leg recirculation, which is 8 hours at VCSNS.

To prevent excessive concentration of boric acid within the core following a large cold leg break, the existing emergency procedures at VCSNS instruct operators to align for simultaneous hot and cold leg recirculation. The Charging pump discharge is aligned to the hot leg injection lines and the RHR pumps remain aligned to the cold legs. Since the location of the break will not be known to the plant operators, simultaneous hot leg/cold leg recirculation would begin approximately 8 hours after the accident at VCSNS regardless of break location.

In addition to locations at the core inlet and exit, other possible locations for blockage within the Reactor Vessel internals which might affect core cooling were assessed [Reference 14]. The smallest clearance was found to be 1.04 inches. This dimension is approximately a factor of 16 greater (1.04 inches / 0.0625 inches) than the dimension of the strainer holes in the containment sump screen.

3o. Chemical Effects

A chemical effects assessment for the VCSNS replacement strainer has been conducted by AECL. VCSNS uses sodium hydroxide (NaOH) for pH control. The primary concern is the corrosion of aluminum and the formation of aluminum hydroxide or aluminum oxy-hydroxide precipitant adding to the debris loading on the strainer. The amount of aluminum inside the RB has been tracked under cumulative effects procedures to support hydrogen generation calculations as follows.

Not Submerged	863.5 ft^2
Submerged	6.3 ft^2
Unknown	219.5 ft^2
Operating Margin	191.8 ft^2

Calculations were carried out for two cases:

1) Case 1: A conservative limiting design case with all unknown locations and all operating margin of aluminum assumed to be submerged. The total submerged surface area was 417.6 ft^2.
2) Case 2: A realistic design case with 50% of unknown locations and 50% of operating margin of aluminum are assumed to be submerged. The total submerged surface area was 212 ft^2.

The fluid pH is based on the current analysis as follows;

Sump pH	Maximum	Minimum
End of Injection	8.5	7.5
Equilibrium	8.5	7.5
Spray pH		
Injection Phase	10.5	8.8
Recirculation Phase (0 to 2 hours)	10.5	7.5
Recirculation Phase (2 hours to 40 days)	8.5	7.5

The level of pH affects the calculation in two competing ways. First, the corrosion rate of aluminum increases exponentially with increasing pH. A high pH causes the greatest aluminum release. Second, the solubilities of aluminum hydroxides and oxy-hydroxides decrease with decreasing pH, such that a low pH increases the likelihood of precipitation. To assess the impact of a lower pH, Case 1 was re-evaluated (Case 3) using an initial pH of 10.5 (to give the highest corrosion at high temperatures) and a lower pH of 7.5 (to give the highest precipitation at the lowest temperatures).

The sump temperature profile was based on the existing Environmental Qualification maximum sump temperature profile. The calculation was carried out for 42 days which is representative of the mission time for VCSNS. The RB Spray pumps may operated for up to 40 days (based on current analysis) until boil off is stopped. At that time, the spray pumps would be stopped, significantly reducing the flow through the strainer. Additionally, corrosion at the low sump temperatures is very limited.

The corrosion rate based on pH was fitted with an exponential fit from data including that presented in WCAP-16530 [Reference 30]. The temperature dependence was fitted with an Arrhenius equation.

The conclusions of the assessment are:

1) The maximum aluminum release, 24.0 lbm (10.9 kg), is expected for Case 1. The maximum concentration of aluminum reached in this solution after 42 days will be 10 mg/L (10 ppm).

2) For all three cases, the aluminum concentration in the solution never exceeds the solubility of amorphous aluminum hydroxide, which was the aluminum hydroxide phase tested in the NRC-sponsored head loss tests, and the phase most likely to form a gelatinous precipitate. In Case 3, using pH values chosen to promote high corrosion initially and to increase the likelihood of precipitation at later times, and making reasonable assumptions about the dependence of aluminum hydroxide solubility on pH, the predicted aluminum concentration after 42 days (8.3 mg/L) is lower than the extrapolated solubility of aluminum hydroxide at pH = 7.5 (>10 mg/L).
3) Aluminum hydroxide is not expected to precipitate in the VCSNS sump water for any of the three cases examined. The aluminum release calculations are believed to be conservative by one to three orders of magnitude. As a result, chemical effects testing is not required for VCSNS.

3p. Licensing Basis

A licensing submittal will be made for the application of Alternate Source Term to dose analysis. The intent of the Alternate Source Term is to eliminate the assumption of a passive failure of a pump seal at 24 hours after the accident as required by the current licensing basis dose analysis. This eliminates the concern over the carbon/graphite disaster bushing in the pump seals. With no primary seal failure assumption in the licensing basis dose analysis, there is no design requirement to limit the pump seal leakage to 50 gpm.

Replacement of the carbon/graphite disaster bushing with an acceptable alternative was investigated. The pump vendor did not have an acceptable alternative and had no active program to develop an acceptable alternative.

Given the time constraints to close out the effort for GSI-191 the licensing submittal could not be completed. The Alternate Source Term analysis for LOCA dose, which covers the pump seal leakage, is completed. The offsite and control dose have decreased compared to the current licensing basis dose analysis. The Alternate Source Term licensing submittal is projected to be made in the Fall of 2008.

No other licensing changes will be necessary for the resolution of GSI-191 in response to Generic Letter 2004-02.

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19. Procedure STP-406-002, Reactor Building Recirculation Sump Inspection, Revision 7A
20. Procedure SAP-134, Control of Station Surveillance Activities, Revision 11
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25. ES-425, Cumulative Effects Program, Revision 3
26. SAP-363, Foreign Material and Debris Control, Revision 6
27. STP-109.001. Reactor Building Closeout Inspection, Revision 9
28. QSP-522, Reactor Building Inspection, Revision 0
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