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U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

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DOMINION ENERGY SOUTH CAROLINA, INC.
VIRGIL C. SUMMER NUCLEAR STATION (VCSNS) UNIT 1
NRC GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS"
FINAL SUPPLEMENTAL RESPONSE

The purpose of this submittal is to provide the Dominion Energy South Carolina, Inc. (DESC) final supplemental response for VCSNS Unit 1 to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004.

By letter dated May 16, 2013 (ADAMS Accession No. ML13140A007), DESC submitted a letter of intent per SECY-12-0093, "Closure Options for Generic Safety Issue (GSI) – 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance," indicating VCSNS Unit 1 would pursue Closure Option 2 – Deterministic of the SECY recommendations (refinements to evaluation methods and acceptance criteria). The final outstanding issue identified in that letter for VCSNS Unit 1 with respect to GL 2004-02 closure is the in-vessel downstream effects evaluation to demonstrate long-term core cooling (LTCC) can be adequately maintained for postulated accident scenarios requiring sump recirculation.

The in-vessel downstream effects evaluation has been completed for VCSNS Unit 1 with satisfactory results as documented in the enclosure to this letter. The completion of this activity and the update of the Final Safety Analysis Report following NRC acceptance of the final supplemental response satisfy the final GSI-191 commitments identified in the VCSNS Unit 1 May 16, 2013 Closure Option letter.

If you have any questions regarding this submittal, please contact Mr. Gary D. Miller at (804) 273-2771.

Sincerely,

Mark D. Sartain
Vice President – Nuclear Engineering and Fleet Support

Commitment contained in this letter:

1. DESC will update the current licensing basis (Final Safety Analysis Report in accordance with 10 CFR 50.71(e)) following NRC acceptance of the final supplemental response for VCSNS Unit 1.

Enclosure: Final Supplemental Response to GL 2004-02

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Mark D. Sartain, who is Vice President – Nuclear Engineering and Fleet Support of Dominion Energy South Carolina, Inc. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 17th day of June, 2021.

My Commission Expires: 12/31/24.

CRAIG D SLY
Notary Public
Commonwealth of Virginia
Reg. # 7518653
My Commission Expires December 31, 2024

Notary Public

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Enclosure

FINAL SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02

Dominion Energy South Carolina, Inc.
(DESC)
V. C. Summer Nuclear Station (VCSNS) Unit 1

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1 Overall Compliance

NRC Issue:

Provide information requested in GL 2004-02, "Requested Information," Item 2(a) regarding compliance with regulations. That is, provide confirmation that the Emergency Core Cooling System (ECCS) and the [Containment Spray System (CSS)] *CSS recirculation functions under debris loading conditions are or will be in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter. This submittal should address the configuration of the plant that will exist once all modifications required for regulatory compliance have been made and this licensing basis has been updated to reflect the results of the analysis described above.*

DESC Response:

In accordance with SECY-12-0093, and as identified in the May 16, 2013 DESC letter to the NRC (ADAMS Accession No. ML13140A007), V. C. Summer Nuclear Station (VCSNS) Unit 1 elected to pursue Generic Safety Issue (GSI)-191 Closure Option 2 – Deterministic. Topical Report (TR) WCAP-17788-P, Rev. 1, "Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090)," provides evaluation methods and results to address in-vessel downstream effects. As discussed in NRC "Technical Evaluation Report of In-Vessel Debris Effects" (ADAMS Accession No. ML19178A252), the NRC staff has performed a detailed review of WCAP-17788-P. Although the NRC staff did not issue a Safety Evaluation for WCAP-17788, as discussed further in "U.S. Nuclear Regulatory Commission Staff Review Guidance for In-Vessel Downstream Effects Supporting Review of Generic Letter 2004-02 Responses" (ADAMS Accession No. ML19228A011), the staff expects many of the methods developed in the TR can be used by pressurized water reactor (PWR) licensees to demonstrate adequate long term core cooling (LTCC). Completion of the analyses demonstrates compliance with 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power plants," (b)(5), "Long-term cooling," as it relates to in-vessel downstream debris effects for VCSNS Unit 1.

1.1 Overview of VCSNS Unit 1 Resolution to GL 2004-02

On February 29, 2008 (ADAMS Accession No. ML080640545), DESC submitted a Supplemental Response to GL 2004-02 for VCSNS Unit 1 that provided specific information regarding the methodology used for demonstrating compliance with the applicable regulations, as well as the corrective actions that had either been implemented or planned to support the resolution of GSI-191. By letters dated November 29, 2009 (ADAMS Accession No. ML093360336) and December 17, 2010 (ADAMS Accession No. ML103610171), DESC submitted additional information for VCSNS Unit 1 regarding the analyses and corrective actions that had not been completed at the time of the 2008 response. The content and level of detail provided were consistent with the NRC guidance dated November 21, 2007, "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," (ADAMS Accession No. ML073110389). In the November 29, 2009 and the December 17, 2010 letters, DESC committed to address the resolution of downstream in-vessel effects for VCSNS Unit 1 following the issuance of revised WCAP-16793, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," and the associated NRC Safety Evaluation Report (SER).

However, by letter dated May 16, 2013 (ADAMS Accession No. ML13140A007), DESC provided its plan for resolving in-vessel downstream effects pursuant to the PWROG comprehensive program underway to develop new acceptance criteria for in-vessel debris (i.e., WCAP-17788) for VCSNS Unit 1. That letter also included a summary of the corrective actions and analyses that had been implemented for VCSNS Unit 1 to address GSI-191, as well as inherent margins and conservatisms included in the analyses. The plant analyses, modifications, margins, and conservatisms summarized and updated in the May 16, 2013 correspondence remain valid.

The resolution of in-vessel downstream effects for VCSNS Unit 1 is provided in Section 3.n below. DESC opted to apply the NEI clean plant methodology, as described in Reference 4.1 and as approved by the NRC in Reference 4.2, to conservatively determine the amount of fiber that can bypass the Reactor Building (RB) recirculation sump strainers.

1.2 Correspondence Background

Table 1 provides a list of the pertinent GL 2004-02 correspondence issued by the NRC or submitted by DESC applicable to VCSNS Unit 1.

TABLE 1 – GENERIC LETTER 2004-02 CORRESPONDENCE		
Document Date	**ADAMS Accession Number**	**Document**
September 13, 2004	ML042360586	NRC GL 2004-02
March 7, 2005	ML050690207	90-day Response to GL 2004-02
September 1, 2005	ML052520333	Follow-up response to GL 2004-02
February 8, 2006	ML060410214	Supplemental Response to NRC GL 2004-02
February 21, 2006	ML060380003	NRC Request for Additional Information
March 28, 2006	ML060870274	NRC Alternative Approach for GL 2004-02 Response

TABLE 1 – GENERIC LETTER 2004-02 CORRESPONDENCE		
Document Date	**ADAMS Accession Number**	**Document**
November 21, 2007	ML073110389	NRC Revised Content Guide
December 21, 2007	ML073601006	Preliminary Supplemental Response to NRC GL 2004-02 and Extension Request
December 28, 2007	ML073620338	NRC Approval of Extension Request
February 29, 2008	ML080640545	Supplemental Response to GL 2004-02
March 18, 2008	ML080810190	Identification of commitment to submit Alternate Source Term (AST) licensing submittal to facilitate resolution of GL 2004-02
December 10, 2008	ML083510086	New projected date for AST licensing submittal
February 3, 2009	ML090270927	NRC Request for Additional Information
February 17, 2009	ML090720887	License Amendment Request (LAR) to implement full scope Alternative Source Term (AST) in accordance with 10 CFR 50.67
May 1, 2009	ML091270196	Request for Extension to respond to RAI
November 29, 2009	ML093360336	Response to NRC GL 2004-02 RAI
January 14, 2010	ML100210969	Supplemental Response to AST LAR RAI
October 4, 2010	ML102160020	AST License Amendment (LA) No. 183
December 17, 2010	ML103610171	Follow-up response to RAI
May 16, 2013	ML13140A007	GSI-191 Closure Option

1.3 General Plant System Description

VCSNS Unit 1 is a Westinghouse three-loop pressurized water reactor (PWR). The Nuclear Steam Supply System (NSSS) consists of one reactor pressure vessel (RPV), three steam generators (SGs), three reactor coolant pumps (RCPs), one pressurizer, and the Reactor Coolant System (RCS) piping and instrumentation. The VCSNS Unit 1 containment is compartmentalized, i.e., there are distinct robust structures surrounding the major components (steam generators, pressurizer, RCPs, etc.) of the RCS. The containment compartmentalization slows the transport of debris to the sump.

The Emergency Core Cooling System (ECCS) components are designed such that a minimum of two accumulators, one Charging pump and one Residual Heat Removal (RHR) pump, together with their associated valves and piping, will assure adequate core cooling in the event of a Design Basis Accident (DBA). The Charging and RHR pumps serve as the Safety Injection (SI) pumps. The emergency core cooling injection mode is initiated by an SI signal.

When the SI system is actuated in response to a LOCA, two Charging pumps and two RHR pumps are started and aligned to inject into the RCS cold legs. The Charging pumps provide high head, low flow, and the RHR pumps provide high flow, low head injection. The pumps' suction is aligned to the Refueling Water Storage Tank (RWST) for the injection phase. As the RCS pressure decreases, three accumulators will also discharge into the RCS cold legs.

The two RB Spray pumps are actuated by a High Containment Pressure signal. The pumps' suction is also aligned to the RWST. The Spray Additive Tank (SAT) also provides flow to the pump suction for sodium hydroxide (NaOH) addition. The RB Spray pumps discharge to spray ring headers located in the RB dome. As the SI and RB Spray systems operate, the RWST volume is depleted. At the RWST Lo-Lo Level, the RHR pump and RB Spray pump suctions are automatically realigned from the RWST to the RB recirculation sumps. Each pump has a separate suction line and suction bell inside the RB recirculation sumps.

There are two RB recirculation sumps. One sump supplies Train A of the RHR and RB Spray pumps, and the second sump supplies Train B. After the RHR pumps' suction is aligned to the RB recirculation sumps, the Charging pump suction is manually aligned to the RHR pump discharge downstream of the RHR heat exchanger. The alignment is train specific with one Charging pump taking suction from one RHR pump.

Within 8 hours following a LOCA, simultaneous hot leg and cold leg recirculation will be initiated to avoid boron precipitation in the core and to terminate boiling.

1.4 General Description of Containment Sump Strainers

As stated in the VCSNS Unit 1 Supplemental Response dated February 29, 2008, two separate strainer assemblies have been designed and installed to address RB Spray and RHR system requirements. The strainers were provided by Atomic Energy Canada, Ltd. (AECL). The RB has two recirculation sumps, Sump A and Sump B, that are internally separated into two sump pits, one for RHR and one for RB Spray, each of which is protected by a common strainer assembly against the entry of potential types and quantities of debris generated as the result of hypothetical, postulated LOCA pipe break events. Each sump supports one redundant train of RHR and RB Spray equipment.

The RHR and RB Spray strainer modules in each sump 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 blocked by postulated debris. Each strainer assembly is composed of a single square module, the header box, equipped with forty-four hollow fins, eleven on each of the four 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 and are designed to fit within the available space in the sump. Each vertically oriented strainer fin consists of 18 gauge stainless steel sheet, perforated with nominal 0.0625-inch diameter holes. The performance of the strainer is enhanced by the extremely low approach velocity to the perforated fins of less than 0.1 inch/second. The area ratio of holes is about 41 percent, 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 precludes air ingestion due to trapped air pockets during filling.

As noted above, the design of both the Sump A and Sump B strainers includes a closed cross duct connecting the RHR and RB Spray header boxes within the sump. 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 and is connected 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 and serves to provide additional redundancy to the strainer design for both Sump A and Sump B. For a postulated event where the fin strainers on either the RHR or the RB Spray 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 net positive suction head (NPSH) requirements for the pumps on both the RHR and RB Spray sides of that sump. The header boxes, strainer fins, and cross ducts are designed, fabricated, and installed in accordance with ASME Code and Seismic Category 1 requirements.

The surface areas for the containment sump strainers are summarized in Table 2 below.

TABLE 2 – CONTAINMENT SUMP STRAINERS SURFACE AREAS		
Sump A Strainer	**Surface Area (ft^2)**	**Total (ft^2)**
RHR Strainer	~1404	~2939
RB Spray Strainer	~1534	
Sump B Strainer	**Surface Area (ft^2)**	**Total (ft^2)**
RHR Strainer	~1251	~2380
RB Spray Strainer	~1129	

2 General Description and Schedule for Corrective Actions

NRC Issue:

Provide a general description of actions taken or planned, and dates for each. For actions planned beyond December 31, 2007, reference approved extension requests or explain how regulatory requirements will be met as per "Requested Information" Item 2(b). That is, provide a general description of and implementation schedule for all corrective actions, including any plant modifications, that you identified while responding to this generic letter. Efforts to implement the identified actions should be initiated no later than the first refueling outage starting after April 1, 2006. All actions should be completed by December 31, 2007. Provide justification for not implementing the identified actions during the first refueling outage starting after April 1, 2006. If all corrective actions will not be completed by December 31, 2007, describe how the regulatory requirements discussed in the Applicable Regulatory Requirements section will be met until the corrective actions are completed.

DESC Response:

DESC performed analyses to determine the susceptibility of the ECCS and RB Spray system functions for VCSNS Unit 1 to the adverse effects of post-accident debris blockage and operation with debris-laden fluids. The analyses considered postulated DBAs for which the RB sump recirculation mode of these systems is required. Mechanistic analyses supporting the evaluation satisfied the following areas of the NRC approved methodology in the Nuclear Energy Institute (NEI) 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology" Guidance Report (GR), as submitted by NEI on May 28, 2004 (Reference 4.3), and as modified by the NRC Safety Evaluation (SE) dated December 6, 2004 (Reference 4.4):

- Break Selection
- Debris Characteristics
- Debris Transport
- Vortexing
- Debris Source Term
- Upstream Effects
- Debris Generation and Zone of Influence
- Latent Debris
- Head Loss
- Net Positive Suction Head Available
- Structural Analysis

Detailed analyses of debris generation and transport were performed to ensure a bounding quantity and a limiting mix of debris are assumed at the RB recirculation sumps' strainers following a DBA. The results of the analyses, conservative evaluations, and strainer testing were used to determine worst-case strainer head loss and downstream effects. Chemical effects bench-top tests conservatively assessed the solubilities and behaviors of precipitates and the applicability of industry data on the dissolution and precipitation tests of station-specific conditions and materials. Reduced-scale testing was performed by AECL and established the influence of chemical products on head loss across the strainer surfaces by simulating the plant-specific chemical environment present in the water of the RB recirculation sumps after a LOCA.

In addition, several plant modifications were completed for VCSNS Unit 1 in support of GSI-191 resolution including the following:

- The two RB recirculation sumps' original strainers had a surface area of 23 ft^2 for each of the Train A and B RHR and RB Spray pumps, with nominal 1/4-inch square openings. The strainers were replaced with AECL fin-type strainers having surface areas of approximately 2939 ft^2 and 2380 ft^2, with nominal 0.0625-inch circular openings.

- Twelve High Head Safety Injection (HHSI) throttle valves were replaced with Flowserve Pressure-Combo valves. These valves feature an outlet flow nozzle that takes up most of the required pressure drop for the flow balance, permitting the valve to have adequate clearance for the downstream effects of debris. The minimum valve opening based on the ECCS flow balancing criteria is approximately 0.0938 inches compared to the 0.0625-inch screen openings.

- Two vertical trash rack gates were installed in the RB annulus on the 412-foot 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 (Reference 4.5). No credit is taken for these gates in the GSI-191 analysis.

In addition to the modifications listed above, the following actions were completed in support of GSI-191 resolution:

- An AST LOCA Dose Analysis LAR was submitted and approved for VCSNS Unit 1 to address a downstream effects analysis concern regarding pump seal backup bushing failures. Incorporating the AST analysis into the licensing basis eliminated the pump seal backup bushing failure from the dose analysis basis, thereby addressing the concern.

- Latent debris sampling was completed and established a 105-pound load that includes a 50 percent margin. Walkdowns for unqualified material were also completed consistent with NEI 02-01 (Reference 4.6). A design input of 200 ft^2 sacrificial area was set based on the walk downs.

- Debris generation and debris transport analyses were completed and included the use of computer-aided design (CAD) modeling of the RB and target insulation. The debris transport analyses used computational fluid dynamic (CFD) modeling and debris transport trees to establish debris loading at the strainers.

- Ex-vessel downstream effects analysis was completed per PWROG WCAP-16406-P, Revision 1 (Reference 4.7), with augmented data from WCAP-16571-P (Reference 4.8). Application of WCAP-16571-P was reviewed and approved by the NRC.

- Chemical effects testing was performed and data was collected at various temperatures and flow rates. The strainer head loss supported NPSH calculations.

- The RHR pump and RB Spray pump NPSH values were calculated at 70 °F consistent with the original design basis. No credit was taken for subcooling. The updated RHR and RB Spray Pump NPSH margins are as follows:

TABLE 3 - UPDATED RHR AND RB SPRAY PUMPS NPSH MARGINS

	Pump Flow Rate [gpm]	NPSH Required [ft]	NPSH Available [ft]	NPSH Margin [ft]
RHR Pump A	4300	17	20.2	3.2
RHR Pump B	4200	16	20.8	4.8
RB Spray Pump A	3300	17	22.1	5.1
RB Spray Pump B	3300	17	21.9	4.9

- A cumulative effects program was 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.

- A cumulative effects program was 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.

- A Level 1 coatings program was established for the RB that includes the tracking of qualified coatings within a 4D Zone of Influence (ZOI).

To ensure the modifications implemented and the analyses performed effectively addressed uncertainties with sufficient margin, the following margins and conservatisms were incorporated into the GSI-191 corrective actions as detailed below:

- The Temp-Mat debris loading case has the greatest fiber load at the strainers. The transport calculations conservatively assume 10 percent erosion. However, the tested erosion rates were in the 1 percent range.

- Marinite XL insulation is installed around the RCS loop piping inside the primary shield wall. With the pipe whip within the shield wall, the Marinite XL is assumed to be 100 percent particulate with all fiber released, and all the Marinite XL is assumed to transport to the sump strainer.

- The chemical debris load includes a 100 ft^2 operating margin out of a total of 320 ft^2 of aluminum inside the RB.

- Each strainer in each RB recirculation sump provides a suction source for an RHR pump and an RB Spray pump. The flow and associated fiber to the RB Spray nozzles will not enter the reactor vessel on the first pass through the strainer. The flow rates with two trains operating are as follows:

TABLE 4 – FLOW SPLIT WITH TWO OPERATING TRAINS		
	RHR Flow [gpm]	**Spray Flow [gpm]**
Train A	3669	3300
Train B	3590	3300

- Flow in the bottom of the reactor vessel is directed up through the core and through holes in the baffle former plates. Each former plate is provided with holes so that flow travels up through the former plates. If flow through the core becomes restricted, flow will continue through the former plate holes thereby providing flow to the top of the core plate. This core bypass flow will provide some level of core cooling.

<u>Resolution of Downstream Effects – Fuel and Vessel</u>: This item is dispositioned in Section 3.n below.

With the completion of the downstream effects analysis for the fuel and vessel detailed below, DESC has resolved the issues identified in GL 2004-02 for VCSNS Unit 1 and is in compliance with the applicable regulations.

3 Specific Information for Review Areas

As stated in the VCSNS Unit 1 GL 2004-02 Supplemental Response dated February 29, 2008 (ADAMS Accession No. ML080640545), as amended on November 29, 2009 (ADAMS Accession No. ML093360336), December 17, 2010 (ADAMS Accession No.

ML103610171), and May 16, 2013 (ADAMS Accession No. ML13140A007), review areas 3.a through 3.m have been addressed for VCSNS Unit 1; therefore, only the outstanding review areas 3.n through 3.p are addressed in this submittal.

3.n Downstream Effects – Fuel and Vessel

NRC Issue:

The objective of the downstream effects, fuel and vessel section is to evaluate the effects that debris carried downstream of the containment sump screen and into the reactor vessel has on core cooling.

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

DESC Response:

TR WCAP-17788-P, Rev. 1, (Reference 4.9) provides evaluation methods and results to address in-vessel downstream effects. As discussed in NRC "Technical Evaluation Report of In-Vessel Debris Effects," (ADAMS Accession No. ML19178A252), the NRC staff has performed a detailed review of WCAP-17788. Although the NRC staff did not issue a Safety Evaluation for WCAP-17788, as discussed further in "U.S. Nuclear Regulatory Commission Staff Review Guidance for In-Vessel Downstream Effects Supporting Review of Generic Letter 2004-02 Responses" (ADAMS Accession No. ML19228A011) (Reference 4.10), the staff expects many of the methods developed in the TR may be used by PWR licensees to demonstrate adequate LTCC. DESC used methods and analytical results developed in WCAP-17788-P, Rev. 1, to address in-vessel downstream debris effects for VCSNS Unit 1 and has evaluated the applicability of the methods and analytical results from WCAP-17788-P, Rev. 1, for VCSNS Unit 1.

3.n.1 Sump Strainer Fiber Penetration

DESC has applied the NEI clean plant criteria to determine the amount of fibrous debris penetrating the sump strainers for use in the downstream in-vessel debris effects analysis for VCSNS Unit 1. The clean plant criteria, as applied to in-vessel effects, utilize a fiber penetration (bypass) fraction of 45% and a debris transport fraction of 75%.

To determine the appropriate debris loading to use for the in-vessel debris effects analysis, the mass of fiber that penetrates the strainer and is free to travel into the SI and RB Spray systems was determined.

Sources of fiber in the VCSNS Unit 1 RB are Temp-Mat exposed blankets, large pieces, fines, and latent fiber. Considering the quantities of these fiber sources, the fiber load that could bypass the strainers and transport to the core inlet was determined by evaluating the latent debris sources and the large pieces and fines originating from Temp-Mat blankets (including erosion). The following steps were performed to determine the total fiber load for use in the strainer bypass calculation:

- Determine the total quantity of fibrous insulation debris generated in the bounding break, fiber fines and latent fiber.
- Determine the quantity of erosion products created during a LOCA at 8 hours into the event from exposed insulation blankets and small pieces of Temp-Mat.
- Add the break-generated fiber to the amount of fiber created by erosion to determine the total fiber load.

Analysis

<u>Determine the total quantity of fibrous insulation debris generated in the bounding break, fiber fines and latent fiber</u>

The RCS A Loop 31" crossover line double-ended guillotine break creates the largest amount of fibrous debris, 15.49 ft^3. Table 5 breaks down the amount of Temp-Mat destroyed as either large pieces or fines:

TABLE 5 – TEMP-MAT FIBROUS INSULATION DEBRIS SOURCE TERM – CASE 1 LBLOCA					
Amount Destroyed	Large Pieces			Fines	
	Intact Blankets	Exposed Blankets	Small Pieces	Amount	Size
15.49 ft^3	5.27 ft^3 (34%)	4.96 ft^3 (32%)	4.18 ft^3 (27%)	1.08 ft^3	2.95 E-05 ft

NEI 04-07 (Reference 4.3) classifies the destroyed insulation debris created into two categories: fines and large pieces. Fines include individual fibers and small pieces less than 4 inches x 4 inches, and large pieces include material 4 inches and larger. This size distribution is used for materials for which debris generation data is provided in NEI 04-07, with the exception of high-density fiberglass and reflective metal insulation materials. The total fiber load for evaluation of in-vessel effects consists of eroded large Temp-Mat pieces (4.96 ft^3 from exposed blankets and 4.18 ft^3 from small pieces) and fines (1.08 ft^3). Fines are conservatively considered to completely pass through the sump strainers, so the fiber load of 1.08 ft^3 is added to the fiber created through erosion of large pieces of

Temp-Mat to establish the total fiber load to be used for in-vessel debris effects. NEI 04-07, Table VI-1, notes that intact blankets are not subject to erosion and can be excluded from the fiber strainer bypass calculation. This calculation of VCSNS Unit 1 downstream in-vessel effects used the WCAP-17788-P methodology which only requires consideration of fibrous and chemical product debris. This method bounds all particulate loads, so it was not necessary to consider particulate debris in the evaluation.

Converting the volume of Temp-Mat fines fiber to lbm: 1.08 ft^3 * 11.8 lbm/ft^3 = 12.74 lbm.

The RB latent debris loading used in the GSI-191 sump evaluation was conservatively determined to be 105 lbm (which includes significant margin). Per the NRC SER for NEI 04-07 (Reference 4.4), the size distribution of latent debris is considered to be 15% fibrous and 85% particulate. Consequently, the latent fiber load considered in this calculation is 105 lbm x 0.15 = 16 lbm.

Therefore, the total fiber transported to the strainers is 12.74 lbm + 16 lbm = 28.74 lbm.

<u>Determine the quantity of erosion products created during a LOCA at 8 hours into the event from exposed insulation blankets and small pieces of Temp-Mat</u>

From Table 5 above, the amount of fiber available for erosion from exposed blankets and small pieces of Temp-Mat is equal to:

Temp-Mat (exposed blankets) + Temp-Mat (small pieces) = 4.96 ft^3 + 4.18 ft^3 = 9.14 ft^3.

The NRC SER for NEI 04-07 (Reference 4.4) includes the following equation for the calculation of the percentage of eroded fiber (f_{eroded}) generated from the small pieces and exposed Temp-Mat blankets:

$$f_{eroded} = 1 - (1 - rate)^{number\ of\ hours}$$

Using an erosion rate of 0.3 % from NEI 04-07 and the VCSNS Unit 1 Hot Leg Switchover (HLSO) time of 8 hours in the above equation, the percentage of eroded fines generated at HLSO would be:

$$f_{eroded} = 1 - (1 - 0.003)^8 = 0.02375 = 2.375\%$$

Applying the erosion percentage to the amount of exposed blankets and small pieces of Temp-Mat insulation:

Erosion fines from Temp-Mat exposed blankets = 4.96 ft^3 * 2.375% = 0.118 ft^3

Erosion fines from Temp-Mat small pieces = 4.18 ft^3 * 2.375% = 0.0993 ft^3

Therefore, a total of 0.218 ft^3 (= 0.118 ft^3 + 0.0993 ft^3) of eroded fines was added to the total fiber load that reaches the sump strainers. Converting 0.218 ft^3 to lbm:

$$0.218 \text{ ft}^3 * 11.8 \text{ lbm/ft}^3 = 2.57 \text{ lbm}$$

Add the break generated fiber to the amount of fiber created by erosion to determine the total fiber load to use for the strainer bypass calculation

Total fiber transported to the strainers = Eroded Fines + Temp-Mat Fines + Latent Debris (fiber)

Total fiber transported to strainers = 2.57 lbm + 12.74 lbm + 16 lbm = 31.31 lbm

The amount of fibrous debris calculated to arrive at the reactor vessel was determined for VCSNS Unit 1 by calculating the strainer bypass using the NEI clean plant 45% bypass factor.

$$g/FA = (M * T * CF * P)/N$$

where: g/FA = grams of fiber per fuel assembly

M = mass of transported and latent fiber, including erosion products

T = transport fraction to strainer

CF = conversion from lbm to grams

P = strainer fiber bypass fraction, and

N = number of fuel assemblies

The grams of fiber per fuel assembly (g/FA) for VCSNS Unit 1 was calculated using the equation above. This equation accounts for the fiber debris source terms at the strainer being fiber from insulation, erosion fines, and latent debris (Reference 4.1).

The g/FA for VCSNS Unit 1 was determined using the following values:

M = mass of transported and latent fiber, including erosion products = 31.31 lbm

T = transport fraction to strainer = 0.75 (DESC did not apply the transport factor of 0.75 for added conservatism.)

CF = conversion from lbm to grams = 453.6 grams/lbm

P = strainer fiber bypass fraction = 0.45 (Reference 4.2)

N = number of fuel assemblies = 157 assemblies

Using the clean plant 45% strainer bypass fraction, the calculated grams per fuel assembly is:

$$g/FA = (31.31 * 453.6 * 0.45) /157 = 40.71 \text{ or } \mathbf{40.7\ g/FA}$$

This is the VCSNS Unit 1 specific in-vessel fiber load that will be compared to the applicable WCAP-17788-P, Rev. 1, in-vessel debris acceptance criterion, which assumes all fibrous debris calculated to penetrate the strainer will reach the reactor core.

Conservatisms in the above calculation include the following:

- The entire 16 lbm of latent fiber load was assumed to reach the strainer.
- The 75% transport factor was not applied when calculating the fiber load for in-vessel debris effects, i.e., 100% of the fiber load was assumed to transport to the strainer.
- All fines, particulate, transportable miscellaneous debris (tags, labels, etc.), eroded fines, and latent debris were assumed to transport in unity (100%) to the recirculation sumps with an equal fraction to each respective sump.

3.n.2 Applicability to WCAP-17788 Methods and Analysis Results

VCSNS Unit 1 is a Westinghouse 3-loop upflow barrel/baffle configuration plant design. Per Section 3.0 of the NRC Staff Review Guidance (Reference 4.10), it is necessary to confirm VCSNS Unit 1 is within the key parameters of the WCAP-17788-P, Rev. 1, methods and analysis. Each of the key parameters is discussed below.

3.n.3 Fuel Design

The VCSNS Unit 1 core consists of 157 VANTAGE+ 17 x 17 optimized fuel assemblies (OFAs). As documented in WCAP-17788-P, Volume 1, Table RAI-1.1-1, this fuel design was included in the WCAP testing program. Since the VCS fuel assembly type was tested, the core inlet debris load does not require adjustment or scaling to account for differences between the as tested and VCSNS Unit 1 OFAs.

3.n.4 WCAP-17788 Debris Limit

The Proprietary total in-vessel (core inlet and heated core) fibrous debris limit contained in Section 6.5 of WCAP-17788-P, Volume 1, Rev. 1, applies to VCSNS Unit 1.

3.n.5 Methodology Used to Calculate the Fibrous Debris Amounts

As described in Section 3.n.1 of this submittal, VCSNS Unit 1 assumes that all fibrous debris calculated to penetrate the strainer reaches the reactor vessel.

3.n.6 Confirm Maximum Combined Amount of Fiber that may Arrive at the Core Inlet and Heated Core for Hot Leg Break is below the WCAP-17788 Fiber Limit

As shown in the sump strainer fiber penetration section (3.n.1), the maximum amount of fiber for VCSNS Unit 1 calculated to potentially reach the reactor vessel is 40.7 g/FA, which is less than the proprietary in-vessel fibrous debris limit provided in Section 6.5 of WCAP-17788-P, Volume 1, Rev. 1.

3.n.7 Confirmation that the Core Inlet Fiber Amount is Less than the WCAP-17788-P, Rev. 1, Threshold

VCSNS Unit 1 is a Westinghouse 3-loop upflow barrel/baffle configuration design with Westinghouse VANTAGE + 17 x 17 OFAs. The applicable WCAP-17788-P, Rev. 1, core inlet fiber threshold is provided in Table 6-3 for Westinghouse fuel. The core inlet fiber amount for VCSNS Unit 1 is calculated to be 40.7 g/FA, which is less than the applicable WCAP-17788-P, Rev. 1, core inlet fiber threshold.

3.n.8 Confirmation that the Earliest Sump Switchover (SSO) Time is 20 Minutes or Greater

The SSO time for maximum ECCS flow (using the design basis RB Spray pump flow rate of 3,000 gpm/pump for LOCA pressure and temperature) is 1460 sec, or 24.4 minutes. The SSO time with a maximum RB Spray pump flow of 3381 gpm resulting from an overfill of the RWST when the containment backpressure is 0 psig, is 1382 sec, or 23.0 minutes. Both SSO times are greater than the 20 minutes assumed in Table 6-1 of WCAP-17788-P, Rev. 1, Volume 4.

3.n.9 Predicted Chemical Precipitation Timing from WCAP-17788-P, Rev. 1, Volume 5 Testing and the Specific Test Group Considered to be Representative of the Plant

Chemical precipitation timing is dependent on the plant buffer, sump pool pH, volume and temperature, and debris types and quantities. Table 4.4-1 of PWROG-16073 (Reference 4.11) identifies Test Group 11 as representative of VCSNS Unit 1; therefore, the predicted chemical precipitation timing (t_{chem}) is 24 hours.

3.n.10 Confirmation that Chemical Effects will not Occur Earlier than Latest Time to Implement BAP Mitigation Measures

Per Section 6.2.1.3 of the VCSNS Unit 1 Final Safety Analysis Report (FSAR), switchover to hot leg recirculation occurs no later than 8 hours after event initiation (post-LOCA) to mitigate the potential for boric acid precipitation, which is less than 24 hours.

3.n.11 WCAP-17788-P, Rev. 1, t_{block} Value for the RCS Design Category

VCSNS Unit 1 is a Westinghouse 3-loop baffle/barrel upflow configuration design. Based on WCAP-17788-P, Rev. 1, Volume 1, Table 6-1, t_{block} for VCSNS Unit 1 is 143 minutes.

3.n.12 Confirmation that Chemical Effects do not Occur Prior to t_{block}

Per Table 4.4-1 of PWROG-16073 (Reference 4.11), the earliest time of chemical precipitation for VCSNS Unit 1 was determined to be 24 hours, which is greater than the applicable t_{block} value of 143 minutes.

3.n.13 Plant Rated Thermal Power Compared to the Analyzed Power Level for the RCS Design Category

VCSNS Unit 1 has a rated thermal power of 2900 MWt. VCSNS Unit 1 is a Westinghouse 3-loop design; therefore, the applicable analyzed thermal power is 3658 MWt as provided in WCAP-17788-P, Rev. 1, Volume 4, Table 6-1. The VCSNS Unit 1 rated thermal power is less than the analyzed power; therefore, this parameter is bounded by the WCAP-17788-P, Rev. 1, alternate flow path analysis.

3.n.14 Plant Alternate Flow Path (AFP) Resistance Compared to the Analyzed AFP Resistance for the Plant RCS Design Category

VCSNS Unit 1 is a 3-loop Westinghouse upflow barrel/baffle configuration design. The Proprietary analyzed AFP resistance is provided in Table 6-1 of WCAP-17788-P, Volume 4, Rev. 1. The Proprietary VCSNS Unit 1 specific AFP resistance is provided in Table RAI-4.2-24. The VCSNS Unit 1 specific AFP resistance is less than the analyzed value; therefore, the VCSNS Unit 1 AFP resistance is bounded by the resistance applied to the AFP analysis.

3.n.15 Consistency Between the Minimum ECCS Flow per FA Assumed in the AFP Analyses and that at the Plant

VCSNS Unit 1 is a Westinghouse upflow barrel/baffle configuration design. The AFP analysis for Westinghouse upflow plants analyzed a range of ECCS recirculation flow rates as shown in Table 6-1 of WCAP-17788-P, Volume 4, Rev. 1. The minimum VCSNS Unit 1 ECCS recirculation flow rate analyzed is 21.9 gpm/FA, and the maximum ECCS recirculation flow rate is 37.7 gpm/FA. The VCSNS Unit 1 ECCS recirculation flow rate corresponding to the most limiting fiber injection hot leg break scenario is 22.7 gpm/FA. Therefore, all of these flow rates are within the range of ECCS recirculation flow rates considered in the AFP analysis.

3.n.16 Summary

The comparison of key parameters used in the WCAP-17788 AFP analysis to the VCSNS Unit 1 specific values is summarized in Table 6. Based on these comparisons, VCSNS Unit 1 is bounded by the key parameters; therefore, the WCAP-17788 methods and results are applicable.

TABLE 6 – KEY PARAMETER VALUES FOR IN-VESSEL DEBRIS EFFECTS

Parameter	WCAP-17788 Value	V. C. Summer Nuclear Station Unit 1 Value	Evaluation
Maximum Total In-Vessel Fiber Load (g/FA)	Volume 1 Section 6.5	< WCAP-17788 Value	Maximum in-vessel fiber load is less than WCAP-17788 limit.
Maximum Core Inlet Fiber Load (g/FA)	Volume 1 Table 6-3	40.7	Maximum core inlet fiber load is less than WCAP-17788 threshold.
Minimum Sump Switchover Time (min)	20	23	Later switchover time results in a lower decay heat at the time of debris arrival, reducing the potential for debris induced core uncovery and heatup.
Minimum Chemical Precipitate Time (hr)	2.4 (t_{block})	24 (t_{chem})	Potential for complete core inlet blockage due to chemical product generation would occur much later than assumed.
Maximum Hot Leg Switchover Time (hr)	24 (t_{chem})	8	Latest hot leg switchover occurs well before the earliest potential chemical product generation.
Rated Thermal Power (MW_t)	3658	2900	Lower rated thermal power results in lower decay heat.
Maximum AFP Resistance, ft^{-4}	Volume 4 Table 6-1	Volume 4 Table RAI-4.2-24	AFP resistance is less than the analyzed value, which increases the effectiveness of the AFP.
ECCS Recirculation Flow (gpm/FA)	Volume 4 Table 6-1	22.7	ECCS recirculation flow rate corresponding to the most limiting fiber injection hot leg break scenario is within the analyzed flow range.

3.o Chemical Effects

NRC Issue:

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

1) Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.

DESC Response:

The VCSNS Unit 1 chemical effects analysis of the sump strainers was submitted in its Supplemental Response dated February 29, 2008 and further supplemented by letters dated November 29, 2009 and December 17, 2010. The VCSNS Unit 1 sump strainer chemical effects analysis is unchanged.

3.p Licensing Basis

NRC Issue:

The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the sump evaluation or plant modifications.

1) Provide the information requested in GL 04-02 Requested Information Item 2(e) regarding changes to the plant licensing basis. The effective date for changes to the licensing basis should be specified. This date should correspond to that specified in the 10 CFR 50.59 evaluation for the change to the licensing basis.

DESC Response:

License Amendment

DESC's February 29, 2008 Supplemental Response discussed the licensing basis change for VCSNS Unit 1 associated with the resolution of the sump issues considered in GSI-191 and GL 2004-02. Specifically, a LAR was submitted by letter dated February 17, 2009 (ADAMS Accession No. ML090720887) for NRC review and approval in support of the resolution of GSI-191 and NRC GL 2004-02. As detailed further below, the NRC approved the LAR, and DESC implemented the approved license amendment for VCSNS

Unit 1. Specifically, the LAR implemented an alternative source term application methodology for analyzing the radiological consequences for six design-basis accidents. The AST amendment eliminated the need to assume a passive failure of a pump seal at 24 hours after an accident as required by the previous licensing basis dose analysis. This eliminated a concern regarding the use of carbon/graphite disaster bushings in pump seals. With no primary seal failure assumption in the AST licensing basis dose analysis, there was no design requirement to limit the pump seal leakage to 50 gpm, and the carbon/graphite disaster bushings were no longer required to be replaced.

The NRC approved the LAR for VCSNS Unit 1 in Amendment No. 183 dated October 4, 2010 (ADAMS Accession No. ML102160020).

Final Safety Analysis Report

The VCSNS Unit 1 FSAR was previously updated to describe the installation of the new strainers. DESC will update the current licensing basis (Final Safety Analysis Report in accordance with 10 CFR 50.71(e)) following NRC acceptance of the final supplemental response for VCSNS Unit 1.

4 References

4.1 Letter from J. Butler (NEI) to S. Bailey (NRC) dated December 22, 2011, Transmittal of GSI-191 Resolution Criteria for "Low Fiber" Plants (with enclosure) (ADAMS Accession Numbers ML113570219 and ML113570226).

4.2 Letter from W. Ruland (NRC) to J. Butler (NEI) dated May 2, 2012, NRC Review of Nuclear Energy Institute Clean Plant Acceptance Criteria for Emergency Core Cooling Systems (ADAMS Accession Number ML120730181).

4.3 NEI 04-07, Revision 0, "Pressurizer Water Reactor Sump Performance Evaluation Methodology," May 28, 2004.

4.4 NRC SER for NEI 04-07, "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), 'Pressurized Water Reactor Sump Performance Evaluation Methodology'," dated December 6, 2004.

4.5 NRC Regulatory Guide 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," November 2003.

4.6 NEI 02-01, Revision 1, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments."

4.7 PWROG WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191."

4.8 WCAP-16571-P, "Test of Pump and Valve Surfaces to Assess the Wear from Paint Chip Debris Laden Water."

4.9 WCAP-17788-P, Rev. 1, "Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090)," December 2019.

4.10 NRC Staff Review Guidance for In-Vessel Downstream Effects Supporting Review of Generic Letter 2004-02 Responses, ADAMS Accessions No. ML19228A011, September 2019.

4.11 PWROG-16073-P, Rev. 0, "TSTF-567 Implementation Guidance, Evaluation of In-Vessel Debris Effects, Submittal Template for Final Response to Generic Letter 2004-02 and FSAR Changes," February 2020.