VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

February 25, 2021

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VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNITS 1 AND 2
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 Virginia Electric and Power Company (Dominion Energy Virginia) final supplemental response for North Anna Power Station Units 1 and 2 (NAPS 1 and 2) 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.

On May 15, 2013, Dominion Energy Virginia 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" (ADAMS Accession No. ML13141A278), indicating NAPS 1 and 2 would pursue Closure Option 2 – Deterministic of the SECY recommendations (refinements to evaluation methods and acceptance criteria). Two remaining actions to be completed for NAPS 1 and 2 were also identified in that letter with respect to GL 2004-02: 1) evaluation of in-vessel downstream effects to demonstrate long-term core cooling (LTCC) can be adequately maintained for postulated accident scenarios requiring sump recirculation, and 2) remediation of TempMat insulation that was subsequently identified in piping penetrations in the reactor vessel primary shield wall of the Units 1 and 2 containments. Both of these actions have been completed. Specifically, the in-vessel downstream effects evaluation has been completed for NAPS 1 and 2 with satisfactory results as documented in the enclosure to this letter. Also, the TempMat insulation was remediated through the removal of fibrous insulation from the steam generators in both containments and replacement with reflective metal insulation.

The completion of these two activities satisfies the final GSI-191 commitments identified in the NAPS 1 and 2 May 15, 2013 Closure Option letter.

If you should 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. Dominion Energy Virginia will update the current licensing basis (Updated Final Safety Analysis Report in accordance with 10 CFR 50.71(e)) following NRC acceptance of the final supplemental response for NAPS 1 and 2.

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 Virginia Electric and Power Company. 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 25th day of February, 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

Virginia Electric and Power Company
(Dominion Energy Virginia)
North Anna Power Station Units 1 and 2

Table of Contents

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.*

Dominion Energy Virginia Response:

In accordance with SECY-12-0093, and as identified in the May 15, 2013 Dominion Energy Virginia letter to the NRC (ADAMS Accession No. ML13141A278), North Anna Power Station Units 1 and 2 (NAPS 1 and 2) elected to pursue Generic Safety Issue (GSI)-191 Closure Option 2 – Deterministic. The May 15, 2013 letter also identified two remaining actions to be completed to permit closure of GSI-191 for NAPS 1 and 2: 1) evaluation of in-vessel downstream effects to demonstrate long-term core cooling (LTCC) can be adequately maintained for postulated accident scenarios requiring sump recirculation, and 2) remediation of TempMat insulation identified in piping penetrations in the reactor vessel primary shield wall of both containments.

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 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 NAPS 1 and 2. By letter dated August 13, 2015 (ADAMS Accession No. ML15232A026), NAPS revised its commitment for resolving in-vessel downstream effects to specifically state it would demonstrate compliance with WCAP-17788 in-vessel debris acceptance criteria.

In addition, during the 2016 NAPS 1 and 2 refueling outages, Dominion Energy Virginia replaced steam generator (SG) Thermal Wrap insulation with reflective metal insulation (RMI) to remediate the TempMat insulation concern noted above. Replacement of SG insulation with RMI ensures this requirement of GL 2004-02 and NEI 04-07 (Reference 4.1) is met to maintain the in-containment fibrous insulation inventory within the design basis limits assumed in the plant strainer testing.

1.1 Overview of North Anna Power Station Resolution to GL 2004-02

On February 29, 2008 (ADAMS Accession No. ML080650563), Dominion Energy Virginia submitted a Supplemental Response to GL 2004-02 for NAPS 1 and 2 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 letter dated February 27, 2009 (ADAMS Accession No. ML090641038), Dominion Energy Virginia submitted an Updated Supplemental Response to GL 2004-02 for NAPS 1 and 2 with information regarding 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 February 27, 2009 letter, Dominion Energy Virginia committed to address the resolution of downstream in-vessel effects for NAPS 1 and 2 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). An additional update was submitted by letter dated April 27, 2011 (ADAMS Accession No. ML111180686) to address discrepancies subsequently identified in the earlier responses regarding insulation types and quantities in containment and the sump strainers' surface areas.

By letter dated May 15, 2013 (ADAMS Accession No. ML13141A278), Dominion Energy Virginia provided its plan for resolving downstream in-vessel effects pursuant to the PWROG comprehensive program underway to develop new acceptance criteria for in-vessel debris (i.e., WCAP-17788), as well as the plan for TempMat remediation for NAPS 1 and 2. That letter also included a summary of the corrective actions and analyses that had been implemented for NAPS 1 and 2 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 NAPS May 15, 2013 correspondence remain valid.

By letter dated August 13, 2015 (ADAMS Accession No. ML15232A026), Dominion Energy Virginia committed to develop plans for demonstrating compliance with WCAP-17788 in-vessel debris acceptance criteria and to communicate that plan to the NRC in a final updated supplemental response to support closure of GL 2004-02 for NAPS 1 and 2. This commitment has been completed. The resolution of in-vessel downstream effects is provided in Section 3.n below. This analysis does not credit alternate flow paths

(AFPs) and conservatively assumes all fibrous debris that enters the reactor vessel will accumulate at the core inlet, even though, in reality, some fraction of fibrous debris will penetrate the core inlet or bypass the core inlet via AFPs.

1.2 Correspondence Background

Table 1 provides a list of GL 2004-02 correspondence issued by the NRC or submitted by Dominion Energy Virginia applicable to NAPS 1 and 2.

TABLE 1 – GENERIC LETTER 2004-02 CORRESPONDENCE		
Document Date	**ADAMS Accession Number**	**Document**
September 13, 2004	ML042360586	NRC GL 2004-02
March 4, 2005	ML050630559	First response to GL 2004-02
September 1, 2005	ML052500378	Follow-up response to GL 2004-02
March 28, 2006	ML060870274	NRC Alternate Approach for GL 2004-02 Response
October 3, 2006	ML062850195	License Amendment Request (LAR) to revise the method for starting the Inside and Outside Recirculation Spray (IRS and ORS, respectively) pumps
January 24, 2007	ML070250058	Supplemental letter to provide clarifying information for the proposed LAR
March 13, 2007	ML070720043	NRC issuance of License Amendments (LAs) 250/230 to revise the method for starting the IRS and ORS pumps
November 15, 2007	ML073100167 ML072740400	NRC Memorandum - North Anna Power Station: Report on Results of Staff Audit of Corrective Actions to Address Generic Letter 2004-02
November 21, 2007	ML073110389	NRC Revised Content Guide
December 19, 2007	ML090860438	Draft Benchtop Test Plan for determining chemical effects
February 29, 2008	ML080650563	Supplemental Response to GL 2004-02
August 4, 2008	ML082130180	NRC audit report letter
February 10, 2009	ML090410602 ML090410618	NRC Audit Report on Chemical Effects-Related Actions to address GL 2004-02

February 27, 2009	ML090641038	Updated Supplemental Response to GL 2004-02
May 28, 2009	ML091350073	NRC RAI regarding in-vessel downstream effects
December 10, 2010	ML103440476	NRC Special Inspection Report regarding Microtherm insulation in containment
April 27, 2011	ML111180686	Second Updated Supplemental Response
May 15, 2013	ML13141A278	GSI-191 Closure Option and TempMat Insulation Remediation
August 13, 2015	ML15232A026	Regulatory Commitment Change Letter

1.3 General Plant System Description

NAPS 1 and 2 are Westinghouse three-loop pressurized water reactors (PWRs). 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. The NAPS 1 and 2 NSSS are enclosed in subatmospheric containments that are highly compartmentalized, i.e., there are distinct robust structures surrounding the major components (steam generators, RCPs, etc.) of the RCS. Except for the pressurizer, RCS components are located within the S/G cavities. The S/G cavities are open to the annulus below EL. 241'-0" and are open to the dome above EL. 291'-10". The pressurizer is located in a separate room with an opening in the room floor that connects to the containment annulus. The highly compartmentalized containment design slows transport of debris to the sump.

The NAPS Emergency Core Cooling System (ECCS) and containment heat removal systems (i.e., the Quench Spray (QS) and the Recirculation Spray (RS) Systems) include several pumps that reduce containment temperature and pressure and remove core heat following an accident. Following a design basis loss of coolant accident (LOCA), RCS pressure will drop, resulting in a Safety Injection (SI) signal, and containment pressure will rise, resulting in a containment depressurization actuation (CDA) signal. The SI and RS systems use the containment sump water following a LOCA to facilitate LTCC and to maintain subatmospheric conditions and decay heat removal in the containment, respectively.

The SI signal starts the High Head Safety Injection (HHSI) and Low Head Safety Injection (LHSI) pumps, which inject water from the Refueling Water Storage Tank (RWST) into the RCS cold legs. Each NAPS unit has three HHSI pumps, two of which start on an SI signal, and two LHSI pumps. When the RWST water level reaches the Low-Low setpoint, the SI system swaps automatically from the injection to the recirculation mode. The HHSI pumps swap suction from the RWST to the LHSI pump discharge. The LHSI pumps swap suction from the RWST to the containment sump and deliver flow to both the RCS cold legs and the suction of the HHSI pumps. Later in recirculation mode operation, SI flow is directed to the hot legs to preclude exceeding boron solubility limits. The SI system does not have heat exchangers between the containment sump and the RCS. The SI system depends on the RS system to cool the containment sump water sufficiently to provide adequate net positive suction head (NPSH) margin for the LHSI pumps operating in the recirculation mode.

The RS system is the long-term containment heat removal system. The RS system assists in depressurizing the containment to subatmospheric conditions consistent with the containment leakage assumptions in the dose consequences analyses. The RS system consists of four pumps (two inside containment and two outside containment) that start on a CDA signal coincident with an RWST Level-Low signal, take suction directly from the containment sump, discharge to a dedicated heat exchanger that is cooled by the Service Water (SW) System, and spray the sump water into the containment via dedicated spray headers. The two ORS pumps (located outside containment) start immediately once the coincidence logic is satisfied, while the IRS pumps start following a time delay of 120 seconds once the coincidence logic is satisfied. Two casing cooling pumps and the common casing cooling tank are designed to increase NPSH available to the ORS pumps by injecting cold water into the suction of the pumps. Each casing cooling pump supplies one ORS pump with cold borated water from the casing cooling tank. The casing cooling pumps are considered part of the ORS subsystems.

The NAPS 1 and 2 design also includes two QS pumps that are started by the CDA signal. The QS pumps draw water from the RWST and deliver flow to the spray headers to lower the containment pressure and temperature before the RS pumps start. The QS pumps are operated until the RWST is empty.

1.4 General Description of Containment Sump Strainers

As stated in the NAPS 1 and 2 Supplemental Response dated February 29, 2008, two new separate strainer assemblies have been designed and installed to address RS and LHSI system requirements. The strainers were provided by Atomic Energy Canada, Ltd. (AECL). The design has independent strainers for the RS and LHSI systems with the LHSI strainer mounted on top of the RS strainer. The strainer assemblies are located in an area outside the crane wall. There are no high-energy pipelines overhead, so jet impingement or pipe whip from a high-energy line break (HELB) is not a concern. In addition, missiles resulting from a HELB accident, for which sump recirculation is required, would not occur close enough to the strainer to cause damage. The entire containment sump strainer assembly is raised off of the floor. The bottom of the RS strainer is six inches off the floor. The LHSI strainer is located on the top of the RS strainer and sits approximately 19 inches off the floor. Since the strainer is raised off the floor, heavy pieces of debris are prevented from reaching the fins and blocking them.

The strainer assemblies consist of a number of modules which channel water to the respective pumps' suctions. Each module contains a number of fins which filter the water flowing into the modules. Each fin contains a number of holes 0.0625-inch (nominal) in diameter that prevents particles larger than 0.06875-inch (0.0625-inch plus 10 percent) from entering the system. Modules are connected to each other by flexible metal seals. Seal closure frames with Metex seals are installed over the existing flexible metal seals. The seal closure frame assemblies form the seal between adjacent strainer modules.

Since the installation of the strainers, inspections have identified gaps in the strainers larger than the allowable 0.0625-inch gap size. Consequently, particles larger than 0.06875 inches were evaluated in response to the identified gaps in the strainer assembly. As part of the evaluation, it was assumed that 1% of the total generated particles between 0.06875 inches (0.0625 inches plus 10 percent) and 0.1375 inches (0.125 inches plus 10 percent) would pass through the strainer. It was determined that these particles would not impact the performance of downstream components.

- <u>RS Strainer</u> - One strainer assembly is provided for both the IRS and ORS pumps. The RS strainer assembly consists of two trains which traverse along the containment wall on both sides of the sump. Each suction opening is connected to the modules via the strainer header. For the ORS pumps, the strainer header is connected to each suction opening by a flanged transition adapter. The outer diameter (OD) of the strainer header is machine cut and slip-fitted into the pump suction inlet ensuring that the gaps between the strainer header and the pump suction inlet do not exceed 0.0625 inches. For the IRS pumps, the strainer header is connected to the pump well via a well housing extension. Water from the containment floor is filtered as it passes through perforated fins and into the modules. The filtered water flows through the modules to the pump suction inlets.

  Perforations on the strainer fins prevent particles larger than 0.06875 inches (0.0625 inches plus 10 percent) from entering the RS System. The strainer fins provide filtered water to the strainer header. The total perforation area is large enough to allow sufficient flow to the suctions of the RS pumps to meet NPSH requirements. Each ORS pump suction is fed directly from the strainer headers. The IRS pumps take suction from the bottom of a well located within the containment sump. This well is also provided with water directly from the strainer headers. The IRS pumps, piping, and strainer modules are configured such that only water coming directly from the strainer modules reaches the pump suction.

- <u>LHSI Strainer</u> - The design of the LHSI strainer assembly is similar to the design of the RS strainer assembly. The LHSI strainer assembly provides filtered borated water to both LHSI pumps during recirculation mode. The strainer assembly consists of a number of modules which channel water to the pump suction. Each module contains a number of fins which filter the water flowing into the modules. Each fin contains a number of holes 0.0625-inch (nominal) in diameter. Perforations on the strainer fins prevent particles larger than 0.06875-inch (0.0625-inch plus 10 percent) from entering the LHSI System. The total perforation area is large enough to allow sufficient flow to the suctions of the LHSI pumps to meet NPSH requirements.

The LHSI strainer assembly consists of two trains which traverse along the containment wall on both sides of the sump, on top of the RS strainer assembly. Each suction opening is connected to the modules via the strainer header. The strainer header is connected to each suction opening by a flanged transition adapter. The outer diameter of the strainer header is machine cut and slip-fit into the pump suction inlet ensuring the gaps between the header and the pump suction inlet do not exceed 0.0625 inches.

The RS and LHSI strainers are designed and fabricated to the requirements of ASME Section III, Subsection NF, Class 3. The material used in the construction of the strainer assemblies is austenitic stainless steel. The strainer assemblies are capable of withstanding the full debris loading in conjunction with design basis conditions without collapse or structural damage.

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

TABLE 2 – CONTAINMENT SUMP STRAINER SURFACE AREA

Strainer	Surface Area (ft^2)
Unit 1 RS Strainer	~4000
Unit 2 RS Strainer	~4000
Unit 1 LHSI Strainer	~2000
Unit 2 LHSI Strainer	~1860

* The difference in surface area between the Unit 1 and Unit 2 LHSI strainers is due to the fin configurations needed to clear interferences.

2 General Description and Schedule for Corrective Actions

<u>NRC Issue:</u>

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.

Dominion Energy Virginia Response:

Dominion Energy Virginia performed analyses to determine the susceptibility of the ECCS (LHSI) and RS functions for NAPS 1 and 2 to the adverse effects of post-accident debris blockage and operation with debris-laden fluids. The analyses considered postulated design basis accidents for which the containment 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 4.1), as modified by the NRC Safety Evaluation (SE) dated December 6, 2004 (Reference 4.2):

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

Detailed analyses of debris generation and transport were performed to ensure that a bounding quantity and a limiting mix of debris are assumed at the containment sump strainer following a design basis accident (DBA). Using the results of the analyses, conservative evaluations and strainer testing were performed 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 using two separate test rigs, and multi-loop testing 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 containment sump after a LOCA.

Numerous plant modifications were completed at NAPS 1 and 2 in support of GSI-191 resolution including the following:

- Two new containment sump strainers (with corrugated, perforated stainless steel fins) were installed with a total surface area of approximately 4000 ft^2 for the RS pumps in each unit, approximately 2000 ft^2 for the Unit 1 LHSI pumps and approximately 1860 ft^2 for the Unit 2 LHSI pumps. These strainers replaced the previous containment sump screens, which had a surface area of approximately 168 ft^2.

- Calcium-Silicate (Cal-Sil) insulation within the SG cubicles and pressurizer room was removed and replaced with Paroc and TempMat insulation in both Units 1 and 2.
- Microtherm insulation within the break zone of influence (ZOI) was removed from the NAPS 1 and 2 containments.
- A drain was installed in the Primary Shield Wall to the Incore Sump Room (ISR) in NAPS 1 and 2 to reduce the water holdup volume and to increase the total volume of water available for strainer submergence and recirculation.
- Engineered Safety Features (ESF) circuitry was modified to start the RS pumps on a CDA signal coincident with an RWST Level-Low signal. The ORS pumps now start immediately once the coincidence logic is satisfied, and the IRS pumps start following a time delay of 120-seconds once the coincidence logic is satisfied. These changes ensure sufficient water is available to meet the RS strainer submergence and RS pump NPSH requirements.
- The RWST level instrumentation was modified to change the safety injection Recirculation Mode Transfer (RMT) setpoint from 19.4% to 16.0% RWST wide range level. This allows more energy to be removed from the containment and lowers the sump temperature prior to the LHSI pump suction switching from the RWST to the containment sump. This change also provides a higher water level in the containment sump prior to the LHSI pump suction switching to the containment sump. The combination of lower sump temperature and higher water level provides increased NPSH to the LHSI pumps and ensures the required volume of water is available to maintain strainer submergence.
- The containment sump level transmitters were modified to protect them from clogging due to debris.
- Level transmitters located within the containment sump were modified by drilling holes through stilling wells at various places to prevent the element from clogging.
- Level transmitters located above the containment floor were provided with debris shields to protect them from containment spray generated debris.
- TempMat insulation identified in piping penetrations in the reactor vessel primary shield wall of both containments was remediated by removal of fibrous insulation from the steam generators in both containments and replacement with RMI.

In addition to the modifications listed above, the following actions have been completed in support of GSI-191 resolution for NAPS 1 and 2:

- Debris generation and debris transport analyses were completed. These analyses contain:
  - Break selection criteria
  - Calculation of amount and type of debris generated for limiting breaks
  - Breakdown of debris sizes

- Physical debris characteristics (i.e. density, fiber size, particulate size)
- Calculation of amounts of each debris postulated to reach the strainers.

- A downstream effects analysis for clogging/wear of components in ECCS and RS flow streams downstream of LHSI and RS strainers was performed.

- An analysis of water hold-up in containment to identify locations where water will be blocked from reaching the ECCS strainer was completed.

- The NAPS 1 and 2 TS were revised to increase the containment air partial pressure limits to provide analytical margin, including NPSH margin, for the RS and LHSI pumps. The TS were also revised to provide new containment sump inspection requirements associated with the new strainers.

- The LOCTIC containment analysis methodology for analyzing the response to postulated pipe ruptures inside containment, including a loss of coolant accident (LOCA) and a main steam line break (MSLB), was replaced with the NRC-approved GOTHIC evaluation methodology discussed in Dominion Topical Report DOM-NAF-3-0.0-P-A. The change to the GOTHIC code provided margin in LOCA peak containment pressure and other accident analysis results.

- The LOCA Alternate Source Term (AST) analysis was revised to include the effects from changing the RS pump start methodology and other changes.

- Procedures and programs were revised and developed to ensure future changes to the plant do not adversely affect the ability of the new containment strainers to perform their design function.

- Operators were trained on the operation of the RS and LHSI Systems with respect to the new containment sump strainers.

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

- Test evaluations demonstrate that a fully formed thin-bed of debris takes significant time (hours) to form and that formation of a thin-bed is dependent upon disturbing settled debris throughout the test tank. Consequently, a worst-case thin-bed of debris would be difficult to form and would not be expected to form until several hours after sump recirculation is initiated. Significant debris settling and sump water subcooling occurs during the formation of a debris-bed so additional NPSH margin is present for chemical effects head loss. However, as a conservative measure, chemical effects testing began with an established debris thin-bed on the strainer fin and was conducted for the 30-day mission time.

- The debris load in head loss testing was taken from the debris transport calculation, which conservatively credits no particulate settling.
- Debris introduction procedures in chemical effects testing ensured minimum near-field settling and resulted in conservatively high debris bed head losses.
- Debris introduction was accomplished in a carefully controlled manner to result in the highest possible head loss. Particulate was introduced initially, which was followed by discrete fiber additions after the particulate debris had fully circulated.
- Only fines of fibrous debris were used in head loss testing as if all the fibrous debris erosion, which is expected to take a considerable amount of time, occurred at recirculation start.
- Debris bed formation during testing included agitating (or "stirring") the settled debris to ensure maximum debris on the strainer. However, any turbulence in post-LOCA containment sump water is expected to be localized to limited areas of the strainers. Consequently, much of the sump water will be quiescent, which would promote debris settling.
- Particulate settling in head loss testing was conservatively minimized through use of a lower density walnut shell particulate as a surrogate for the higher density epoxy coating particulate that may be present in post-LOCA sump water.
- Downstream effects analyses (components) were completed consistent with WCAP-16406-P, Rev. 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI [Generic Safety Issue]-191," to identify any wear, blockage or vibration concerns with components and systems due to debris-laden fluids. Significant conservatisms are inherent in these analyses, which provide reasonable assurance that downstream component clogging will not occur, and downstream component wear will not significantly affect component or system performance. The downstream wear analyses used the Large Break LOCA particulate load to determine abrasive and erosive wear. This is a conservative particulate loading, in view of the following:
    - Much of the particulate included in the analyses is unqualified coating that is outside the break ZOI. This unqualified coating is assumed to dislodge due to exposure to the containment environment. However, such dislodgement is likely only after many hours, if at all.
    - The low velocity of the sump water column and the significant number of surfaces throughout containment promote significant settling of particulate in containment. Settled coating will not be drawn through the sump strainer since the RS strainer

is located approximately six inches above the containment floor and the LHSI strainer is approximately nineteen inches above the containment floor.

- The analyses assume 100% strainer bypass of particulate conservatively maximizing the effects of downstream wear.

- Chemical effects testing results were conservative based upon several conditions:

  - Aluminum corrosion amounts were calculated at high pH (pH 9 at 77 °F), where aluminum corrosion and release rates are high. Testing was performed at neutral pH (pH 7 at 77 °F), where aluminum solubility is low to encourage aluminum compound precipitation. Sump water pH is expected to be approximately pH 8 at 77 °F in the long-term.

  - The minimum sump water volume at specified times post-LOCA were used to maximize the calculated sump aluminum concentrations.

  - The analysis of aluminum load conservatively does not account for the possible inhibitory effect of silicate or other species on aluminum corrosion.

  - The rate of corrosion is maximized by not assuming development of passive films, i.e., no aluminum oxides remain adhered to aluminum surfaces. The formation of passive films could be credited to decrease the corrosion and release rates at long exposure times. Consequently, it is conservative to assume that all aluminum released by corrosion enters the solution.

  - All aluminum released into the solution is conservatively assumed to transport to the debris-bed instead of plating out on the multiple surfaces throughout containment. During bench-top testing, aluminum plated out on glass beakers and, during reduced-scale testing, aluminum plated out on fiber. It is reasonable to expect that a portion of the aluminum ions released into solution will plate out on some of the multiple surfaces in containment prior to arriving at the debris-bed on the strainer.

  - Chemical effects test evaluations conservatively neglect the effect of the presence of oxygen in the sump water. The corrosion rate of aluminum in aerated pH 10 alkaline water can be a factor of two lower than that measured in nitrogen-deaerated water. This data is in NUREG/CR-6873, "Corrosion Rate Measurements and Chemical Speciation of Corrosion Products Using Thermodynamic Modeling of Debris Components to Support GSI-191."

- NPSH margins were determined with the following conservatisms:

  - No credit was taken for additional NPSH margin in the short-term due to subcooling of the sump water combined with the several hours required to form the limiting thin-bed of debris. Analyses conservatively assume transport of debris to the strainer occurs much sooner following the break.

- There is conservatism in scaling from test temperatures to higher specified sump temperatures. The debris bed will expand slightly when head loss is lower, i.e., at the higher sump temperature, the bed would be expected to be slightly more porous than at the lower test temperature. The assumption of a purely linear relationship between head loss and viscosity when scaling to higher temperatures is, therefore, conservative.

- The NPSH calculations were guided by the observation that the minimum margin would likely occur for the combination of parameters that would minimize the containment pressure and maximize the sump water temperature (and, hence the vapor pressure of this fluid), thereby conservatively minimizing the contribution of containment accident pressure to the calculated NPSH margin.

• Chemical effects testing and analyses were completed for the LHSI and RS strainers. AECL performed various hydraulic tests that simulated the actual debris loading and chemical conditions specific to NAPS 1 and 2 based on debris generation, debris transport, and chemical effects evaluations. Fibrous and particulate debris and chemicals were added to a test rig to simulate the plant-specific chemical environment present in the water of the containment sump following a DBA. Each test was operated for more than 30 days after the formation of the debris bed and initial chemical addition at specified temperatures and flow rates to assess chemical precipitate formation and head loss change. These tests verified that adequate NPSH is available to support the operation of the LHSI and RS pumps during the post-LOCA recirculation mode.

• Aluminum release analysis was conducted using the release rate equation developed by AECL, which can be more conservative under certain conditions than the release rate equation specified by Equation 6-2 of WCAP-16530-NP. The results of the application of the AECL release rate model were compared to the WCAP-16530-NP model results using North Anna aluminum inventories and were found to predict a greater 30-day release of aluminum.

<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 and the remediation of the TempMat in containment, Dominion Energy Virginia has effectively resolved for NAPS 1 and 2 the issues identified in GL 2004-02 and is in compliance with the applicable regulations.

3 Specific Information for Review Areas

As stated in the NAPS 1 and 2 GL 2004-02 Supplemental Response dated February 29, 2008 (ADAMS Accession No. ML080650563), as amended on February 27, 2009 (ML090641038), April 27, 2011 (ADAMS Accession No. ML111180686), May 15, 2013 (ADAMS Accession No. ML13141A278), and August 13, 2015 (ADAMS Accession No. ML15232A026), review areas 3.a through 3.m have been addressed for NAPS 1 and 2; 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.*

Dominion Energy Virginia Response:

Topical Report (TR) WCAP-17788-P, Rev. 1, 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), the staff expects that many of the methods developed in the TR may be used by PWR licensees to demonstrate adequate LTCC. Dominion Energy Virginia used methods and analytical results developed in WCAP-17788-P, Rev. 1, to address in-vessel downstream debris effects for NAPS 1 and 2 and has evaluated the applicability of the methods and analytical results from WCAP-17788-P, Rev. 1, for NAPS 1 and 2.

3.n.1 Sump strainer fiber penetration

An engineering evaluation was performed to determine a conservative estimated cumulative fiber bypass fraction for the NAPS 1 and 2 containment sump strainers to facilitate the evaluation of the in-vessel debris effects for NRC GL 2004-02.

From the debris generation and transport analyses performed for NAPS 1 and 2, Dominion Energy Virginia conservatively determined the types and quantities of fibrous debris that could be transported to the strainers, as discussed in letters dated February 29, 2008 and April 27, 2011 and NRC letter dated August 4, 2008 (ADAMS Accession No. ML082130180). The fibrous debris sources considered in these analyses include Thermal Wrap, TempMat, Paroc/mineral wool, fiberglass and latent fiber. The total fibrous debris quantity from these sources that could potentially reach the sump strainer was conservatively calculated to be 2289 pounds-mass (lbm). However, once the TempMat fiber was remediated by removing Thermal Wrap on the SGs and replacing it with RMI, the maximum amount of fiber that could potentially reach the strainers is bounded by the AECL tested limit of 1818.7 lbm.

The strainer fiber bypass testing performed by AECL for the strainer design installed at NAPS 1 and 2 did not measure the cumulative quantities of fiber bypassed after each fiber addition to the test tank. Instead, the testing used a "grab sample" method that looked at fiber mass in a water sample taken downstream of the strainer fins at discrete points in time. This testing provided insights that long-term strainer bypass was low but did not provide insights into bypass occurring early in ECCS operation. Consequently, data was not available for the quantity of bypassed fiber as the debris bed is forming, and cumulative fiber bypass fractions could not be determined. Lastly, the mix of fibrous insulation types has significantly changed, which impacts the theoretical debris bed thickness for determination of fiber bypass fraction.

However, other plants in the industry have performed strainer bypass testing with downstream continuous on-line filters that were able to determine cumulative fiber bypass fractions for various debris bed thicknesses. Consequently, Dominion Energy Virginia performed an evaluation to develop an engineering basis for the use of cumulative fiber bypass data from other plants to apply to the AECL strainers installed at NAPS 1 and 2. As noted above, NAPS has two hydraulically independent strainers that serve the LHSI system and the RS system pumps. Since only the LHSI strainer delivers sump water to the reactor vessel, the bypass fraction was only determined for the LHSI strainer.

General Strainer Bypass Characteristics

Based on review of strainer bypass testing data for the Point Beach and South Texas Project (STP) plants (References 4.6 and 4.13, respectively), it was observed that, as a debris bed forms and continues to build on a strainer, the filtration efficiency will plateau at nearly 100%. Testing was performed with continuous on-line filters downstream of the strainer assemblies to ensure a cumulative fiber bypass fraction could be determined. The filtration efficiency behavior is also consistent with the results of the bypass testing that was performed for NAPS by AECL. However, since the AECL tests were based only on grab samples taken at specific turnover intervals for the fiber additions, it was necessary to utilize other industry testing that used continuous on-line fiber bypass capture to determine cumulative bypass fractions for the NAPS LHSI strainers. It is noted AECL test reports determined that "Fiber bypass concentrations show a near exponential decreasing trend with time." The quantity of fiber that bypassed the strainer was so low that a scanning electron microscope evaluation was required for accurate determination of fiber concentration and size. Considering these results, there is reasonable engineering justification for applying corrected industry strainer bypass test results, including appropriate conservatism, to the NAPS 1 and 2 LHSI strainers.

Review of Industry Test Data and NRC Staff Guidance for Strainer Fiber Bypass

Using NRC staff guidance (Reference 4.3) for strainer fiber bypass, industry strainer bypass test results and approach velocity from Point Beach and Vogtle, respectively (References 4.4 through 4.10), a cumulative strainer bypass fraction was developed for NAPS. Consistent with NRC staff guidance, the largest fibrous debris amount for each plant that could transport to the sump strainers was assumed and included fiber transport and erosion based on the bounding fiber break. Application of Point Beach strainer bypass data to the NAPS LHSI strainers was based on fiber bypass at various tested and extrapolated theoretical debris bed thicknesses (derived from fiber mass per strainer area).

NAPS has a higher approach velocity than Point Beach, so it was necessary to apply a correction factor to scale the Point Beach data to the higher velocity. Derivation of the correction factor was from the Vogtle plant tests that recorded bypass fractions at various velocities (Reference 4.10). Bypass mass, normalized by flow rate, was determined in the Vogtle test report to be linearly related to approach velocity. This supported the calculation of cumulative bypass fractions for the Vogtle strainer at flow rates comparable to NAPS and Point Beach. A cumulative bypass correction factor could then be determined at a given debris bed thickness by scaling the Vogtle data at the NAPS velocity to the Point Beach test velocity. This methodology is based on the premise that the impact of approach velocity on the filtering efficiency of a debris bed is not strongly dependent on the specific strainer design.

The geometry for the Performance Contracting Incorporated (PCI) furnished Point Beach disk strainer was compared with the AECL furnished NAPS fin strainers and was assessed to be conceptually equivalent in their hydraulic performance characteristics. Both strainers have a central collection duct that receives filtered water from perforated sheets that is delivered to ECCS pump suctions. Debris-laden water flowing to the strainers in both designs will generally be in a perpendicular direction to the perforations.

Debris bed formation on the strainers at Point Beach and NAPS is expected to be relatively uniform due to the use of internal flow restrictions to ensure even distribution of flow through entire strainer surfaces. The AECL strainer hydraulic reports (Reference 4.11) discuss the use of internal flow restrictions in the NAPS strainers.

With regard to the sacrificial area of the NAPS strainer, it was assumed the area would be available for formation of the fibrous debris beds as this would minimize the thickness of the calculated theoretical debris bed, which would result in a larger cumulative bypass fraction for the maximum debris load at NAPS.

The case that resulted in the maximum design flow rate for the NAPS strainer was selected to provide the highest approach velocity. For NAPS, which uses separate strainers for the RS system and the LHSI system, the maximum flow rate is assumed for LHSI and only one of the two RS system trains is assumed to be in service. This maximizes the fibrous debris available for transport to the LHSI Strainer.

The strainer perforation size for Point Beach (0.066") is slightly larger than for the NAPS strainer (0.0625"), which has a conservative influence on cumulative bypass fraction when applying the Point Beach test results to NAPS.

<u>Conservatisms Applied</u>

Conservatisms applied when determining the cumulative bypass fraction for NAPS include the following:

- Maximum strainer design flow rates were used that result in highest calculated approach velocities and cumulative bypass fractions.
- The NAPS AECL strainer has a slightly smaller perforation size (0.0625") compared to the Point Beach strainer (0.066") that was used for bypass test data applied to NAPS.
- Point Beach test results were used for Nukon only insulation since it provided slightly higher bypass than for other limited insulation mixes that were tested.
- When theoretical debris bed thicknesses were calculated, designated sacrificial areas were included in order to minimize the thicknesses, which result in higher cumulative bypass. Also, the fiber quantities identified in the strainer head loss testing were used, which exceeds the current fibrous insulation inventories of record for NAPS.
- A percentage of the total fiber load on the NAPS strainer includes intact pieces that do not erode and, as such, do not contribute to strainer fiber bypass. This contrasts with the Point Beach and Vogtle bypass tests that used shredded fiber, all of which may contribute to strainer bypass.

A comparison of the Point Beach and NAPS critical parameters for sump strainer bypass testing is provided in Table 3. A summary of fiber load, debris bed thickness, and velocity adjusted bypass fraction is provided in Table 4.

TABLE 3 – CRITICAL PARAMETER COMPARISON FOR SUMP STRAINER BYPASS TESTING

Parameter	Point Beach Value			North Anna Power Station Value
Strainer Manufacturer	PCI			AECL
Strainer Perforation Size	0.066"			0.0625"
Strainer Area[1]	1904.6 ft^2			2008/1855 ft^2
Flow Rate through Single Strainer Train	2300 gpm (test scaled)			5609 gpm
Approach Velocity[2]	0.0027 ft/sec			0.00674 ft/s
Nominal Theoretical Debris Bed Thickness	1.5"		0.60"	1.066"
Debris Type and Quantity (% Fiber Mass Type[3])	<u>Test 1</u>	<u>Test 2</u>	<u>Test 3</u>	
Fiberglass[4]	40.7%	28.8%	100%	33.31%
Mineral Wool	59.3%	67.7%	0%	0%
Mineral Fiber	0%	0%	0%	0%
Temp-Mat	0%	3.5%	0%	60.87%
Paroc	0%	0%	0%	5.82%
Asbestos	0%	0%	0%	0%
Cumulative Tested Bypass	2.01%	2.42%	5.61%	N/A

Notes:

1. The sacrificial area is not deducted since it is more conservative to use the maximum area available when calculating the theoretical fiber bed thickness. A thinner bed thickness results in a higher cumulative fiber bypass fraction. Also, there is no need for comparison of surface areas since the terminal Point Beach cumulative bypass fractions are not being applied to the AECL strainers. Determination of cumulative bypass fractions is only being based on a theoretical debris bed thickness comparison with Point Beach and each plant.
2. For NAPS, the approach velocity is based on the unit with the smaller strainer area to provide the bounding largest velocity for both units.
3. Actual fiber quantities are not provided as there is no intent to apply the terminal Point Beach cumulative bypass fractions to the AECL strainers. The bypass fraction for NAPS is derived by comparison of theoretical bed thicknesses.
4. For NAPS, all low density (2.4 lbm/ft3) fiber types were listed together as "Fiberglass."

NAPS has a theoretical debris bed thickness of 1.066" that exceeds the theoretical bed thicknesses for Point Beach Test 3. However, use of the fitted power curve equation with extrapolation is judged to provide acceptable results due to the demonstrated exponential decay behavior of fiber bypass with increasing debris bed thickness. Then the cumulative bypass fraction at 1.066" is calculated using the Point Beach Test 3 curve fitted equation:

Cumulative Fiber Bypass = 0.040303*(Bed Thickness)$^{-0.758434}$ = 0.040303*(1.066)$^{-0.758434}$ = 3.8%.

Since the approach velocity for the NAPS strainers (0.00674 ft/s) is significantly greater than for the Point Beach data (0.0027 ft/s), a correction factor was applied to the cumulative bypass fraction. The Dominion Energy engineering evaluation includes a spreadsheet that developed cumulative bypass fraction correction factors from the Alden Test Report for Vogtle (Reference 4.10) that may be applied to the Point Beach derived cumulative bypass fraction for NAPS. The spreadsheet determined that a correction factor of 1.948 is applicable for a debris bed thickness of 1.066" in order to scale to a velocity of 0.00674 ft/s. Applying this information to NAPS results in a cumulative fiber bypass of 3.8% x 1.948 = **7.4%.**

TABLE 4 - SUMMARY OF FIBER LOAD, DEBRIS BED THICKNESS, & VELOCITY ADJUSTED BYPASS FRACTIONS	
Strainer Characteristic	**NAPS 1 & 2**
Fiber Load	909.35 lbm
Theoretical Debris Bed Thickness	1.066 inches
Cumulative Bypass Fraction	7.4%

The data in Table 4 was used to perform the evaluation of downstream in-vessel effects discussed below.

3.n.2 <u>Applicability to WCAP-17788 methods and analysis results</u>

NAPS is a Westinghouse 3-loop design. Per Section 3.0 of the NRC Staff Review Guidance, Reference 4.3, it is necessary to confirm that NAPS 1 and 2 are 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

NAPS uses Westinghouse 17x17 Robust Fuel Assembly 2 (RFA-2) fuel.

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 NAPS.

3.n.5 Methodology used to calculate the fibrous debris amounts

The amount of fibrous debris calculated to arrive at the reactor vessel was determined for NAPS following the method described in WCAP-17788-P, Volume 1, Rev. 1, Section 6.5. Specifically, an engineering calculation was performed to determine the core inlet fibrous debris load for the Hot Leg Break (HLB) for NAPS Units 1 and 2. The calculation included the following design inputs and assumptions:

Design Inputs

1. Plant Type - The NAPS 1 and 2 reactor internals have been modified to change the flow path of the reactor coolant from downflow between the core barrel and baffle plates to an upflow direction.

2. Number of Assemblies - Each NAPS core contains 157 Westinghouse RFA-2 fuel assemblies.

3. Core Thermal Power - The core thermal power is 2951 MWt (100.37% of 2940 MWt, the rated thermal power).

4. Initial Sump Fiber Load - The total fine mass at the LHSI and RS strainers including fines generated due to erosion is 219.08 lbm. Only the debris loading at the LHSI strainer is of concern, as the debris at this strainer may bypass the strainer and enter the reactor vessel. Debris loading at the RS strainer is neglected, as debris that bypasses the RS strainer does not reach the reactor vessel internals. The assumed debris loading of the LHSI strainers is 50% of the full debris loading at the LHSI/RS strainers. Therefore, the total debris loading used in the calculation is 109.54 lbm (= 219.08 lbm * 0.5). On a per fuel assembly basis, the initial sump fiber load is 316.47 g/FA (= [109.54 lbm * 453.592 g/lbm] / 157 assemblies).

5. Active Sump Volume - The active sump volume, also referred to as the active recirculation volume, is the volume of liquid in the containment sump which actively participates in the recirculation process. This volume acts as the system inventory when calculating the concentration of debris to be injected into the RCS. A conservatively low sump volume was used that accounts for potential holdup areas within containment.

6. Time of Sump Switch Over (SSO) - The time of SSO, also known as sump recirculation activation or recirculation mode transfer (RMT), is the time at which fiber is injected into the reactor vessel/sump screen. The minimum time of sump switchover is 33.3 minutes based on the RMT setpoint of 16% RWST level and accounting for instrument uncertainty.

7. ECCS Flow Rates Following SSO - The ECCS flow rate after the time of SSO (i.e., during recirculation mode) is used to calculate the rate of fiber injection into the reactor vessel. Both minimum and maximum ECCS flow rates were analyzed. The minimum LHSI recirculation mode flow rate is 3,542 gpm with one operable LHSI train. The maximum cold leg recirculation flow rate is 5,609 gpm assuming two operable trains.

8. RS System (RSS) Flow Rates Following SSO - For conservatism, RSS flow rates are set to zero gpm. This ensures all fiber not caught on the sump screen is injected into the reactor vessel.

9. Time of Hot Leg Switch Over (HLSO) – NAPS station procedures direct operators to switch over to hot leg recirculation within 5 hours after event initiation (post-LOCA).

10. Time Step - A time step of 100 seconds was used for the iterative solution.

11. Time to Chemical Effects, t_{chem} - The time to chemical effects, t_{chem}, is the time at which chemical precipitates affect the formed debris bed. Per Table 4.4-1 of Reference 4.12, the time at which chemical effects affect the debris bed is 24 hours for NAPS 1 and 2. Therefore, a maximum value of 24 hours was used in the calculation.

12. Maximum Core Inlet Resistance (K_{max}), Time for Core Inlet Blockage (t_{block}), and Inlet Debris Limit - K_{max} is the maximum core inlet resistance prior to complete core inlet blockage. t_{block} is the minimum acceptable time of complete core inlet blockage. NAPS is a Westinghouse Upflow plant with Westinghouse Fuel; therefore,

    - t_{block} is 143 min
    - The core inlet debris limit is the value listed in WCAP-17788, Table 6-3, and
    - K_{max} is $5x10^5$

13. Sump Strainer Bypass Fraction - The bypass fraction is the portion of debris transported to the sump strainer that is not collected on the sump strainer, and instead penetrates through the sump strainer and into the reactor vessel through the ECCS. As noted in Section 3.n.1 above, the NAPS cumulative bypass percentage was determined to be 7.4% for the LHSI strainer.

14. RFA-2 Assembly Pitch - The RFA-2 assembly pitch was used in the calculation.

Assumptions

1. The fiber and particulate are well mixed in the sump fluid such that a homogeneous mixture is present at the time of sump recirculation. Therefore, the debris transport is proportional to ECCS flow rate.

2. No debris is held up in any location other than the sump strainer(s), core inlet, or within the core. Further, no settling of debris is credited in any location of the RCS. Therefore, the maximum amount of debris reaches the core.

3. Chemical precipitates are assumed to form at 24 hours.

4. The fiber is in its constituent form, i.e., individual fibers. This is consistent with maximum transport assumptions.

5. Alternate Flow Paths (AFP) were not credited. Per PWROG-16073-P, Rev. 0, the NRC staff expects the debris bed at the core inlet will not be uniform due to the variations in flow velocities at the core inlet. Therefore, it will take more debris than determined by WCAP-17788 to result in activation of the AFPs and redirection of some flow and debris to the heated core. Because of the non-physical nature of the assumption of a uniform debris bed (which remains conservative in other aspects), credit for debris bypassing the core inlet and entering the heated core should not be used. As such, the values for "M_{-split}" in the engineering calculation were set to zero.

6. It was assumed no debris exits the break (i.e., once it is in the RCS, it stays in the RCS). Therefore, the maximum amount of debris reaches the core.

7. It was assumed sump debris will build-up across the core inlet in a uniform manner, and blockage is only considered at the core inlet. This is a simplifying, conservative assumption.

Analysis

The HLB debris is the sum of the fiber that is captured at the core inlet and the in-core fiber:

$$M_{f,\ HLB} = M_{f,\ CI} + M_{f,\ in\text{-}core}$$

Where:

- $M_{f,\ HLB}$ is the total fiber mass for the hot leg break
- $M_{f,\ CI}$ is the mass of fiber at the core inlet
- $M_{f,\ in\text{-}core}$ is the mass of fiber in the heated core

The mass of fiber that reaches the heated core can travel through two paths, either the AFP or from the hot leg post-HLSO:

$$M_{f,\ in\text{-}core} = M_{f,\ AFP} + M_{f,\ CE}$$

Where:

- $M_{f,\ AFP}$ is the mass of fiber that reaches the core through the AFP, and

- $M_{f,\ CE}$ is the mass of fiber that reaches the core via the core exit (i.e., fiber injection post-HLSO)

The above quantities were determined iteratively at each time step. The calculation was terminated at the time at which the sump fiber load was less than or equal to 1% of the initial sump fiber load.

As previously noted, AFPs were not credited in the analysis. Therefore, $M_{f,\ AFP}$ will always equal zero. If the termination criteria is reached before the time of HLSO, then $M_{f,\ CE}$ will also equal zero. If that is the case, then the $M_{f,\ in\text{-}core}$ term is zero, and the total mass of fiber for the HLB is simply the fiber at the core inlet.

Acceptance Criteria

The total core inlet fiber must be less than or equal to the core inlet fiber load limit included in WCAP-17788-P prior to the time of HLSO. The total injected fiber must be less than or equal to the in-core fiber limit included in WCAP-17788-P after the time of HLSO.

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

Using the design inputs and assumptions noted above, the maximum amount of fiber for NAPS 1 and 2 calculated to potentially reach the reactor vessel is 23.19 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

NAPS 1 and 2 are Westinghouse 3-loop designs with Westinghouse 17x17 RFA-2 fuel. The core inlet fiber threshold for Westinghouse fuel is provided in Table 6-3 of WCAP-17788-P, Rev. 1. The core inlet fiber amount for NAPS is calculated to be 23.19 g/FA, which is less than the applicable WCAP-17788-P, Rev. 1, core inlet fiber threshold for Westinghouse fuel designs.

3.n.8 Confirmation that the earliest sump switchover (SSO) time is 20 minutes or greater

As previously stated, the earliest possible SSO time for NAPS 1 and 2 was determined to be 33.3 minutes based on the RMT setpoint of 16% RWST level and accounting for instrument uncertainty.

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 4.12) identifies Test Groups 5 and 15 as representative of NAPS 1 and 2, respectively, and 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

Station Emergency Operating Procedures instruct operators to switch to hot leg recirculation no later than 5 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

NAPS 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 NAPS is 143 minutes.

3.n.12 Confirmation that chemical effects do not occur prior to t_{block}

The earliest time of chemical precipitation for NAPS 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

NAPS has a rated thermal power of 2940 MWt. NAPS is a Westinghouse 3-loop design, and the applicable analyzed thermal power is 3658 MWt as provided in WCAP-17788-P, Rev. 1, Volume 4, Table 6-1. The NAPS 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

NAPS is a Westinghouse upflow barrel/baffle plant. The Proprietary analyzed AFP resistance is provided in Table 6-1 of WCAP-17788-P, Volume 4, Rev. 1. The Proprietary NAPS specific AFP resistance is provided in Table RAI-4.2-24. The NAPS specific AFP resistance is less than the analyzed value; therefore, the NAPS 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

NAPS is a Westinghouse upflow barrel/baffle plant. 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 NAPS ECCS recirculation flow rate analyzed is 22.56 gpm/FA. The NAPS ECCS recirculation flow rate corresponding to the most limiting fiber injection hot leg break scenario is 35.73 gpm/FA. 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 NAPS specific values is summarized in Table 5. Based on these comparisons NAPS is bounded by the key parameters; therefore, the WCAP-17788 methods and results are applicable.

TABLE 5 – KEY PARAMETER VALUES FOR IN-VESSEL DEBRIS EFFECTS

Parameter	WCAP-17788 Value	North Anna Power Station Value	Evaluation
Maximum Total In-Vessel Fiber Load (g/FA)	Volume 1 Section 6.5	< the 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	23.19	Maximum core inlet fiber load is less than WCAP-17788 threshold.
Minimum Sump Switchover Time (min)	20	33.3	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})	5	Latest hot leg switchover occurs well before the earliest potential chemical product generation.
Rated Thermal Power (MW_t)	3658	2940	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.

TABLE 5 – KEY PARAMETER VALUES FOR IN-VESSEL DEBRIS EFFECTS			
Parameter	**WCAP-17788 Value**	**North Anna Power Station Value**	**Evaluation**
ECCS Recirculation Flow (gpm/FA)	Volume 4 Table 6-1	35.73	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.

Dominion Energy Virginia Response:

The NAPS chemical effects analysis of the sump strainers was submitted in Supplemental Response dated February 29, 2008 and further supplemented by letter dated February 27, 2009. The NAPS 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.

Dominion Energy Virginia Response:

Dominion Energy Virginia's February 29, 2008 Supplemental Response discussed the licensing bases changes that had been implemented for NAPS 1 and 2 associated with the resolution of the sump issues considered in GSI-191 and GL 2004-02 in the form of Updated Final Safety Analysis Report (UFSAR) revisions, analysis methodology changes, and license amendment requests. These changes are summarized below:

UFSAR

The NAPS UFSAR has been revised to reflect the installation of the new containment strainers for the RS and LHSI pumps, as well as the adoption and application of the GOTHIC code for containment analysis. Dominion Energy Virginia will update the current licensing basis (Updated Final Safety Analysis Report in accordance with 10 CFR 50.71(e), etc.) following NRC acceptance of the final supplemental response for NAPS 1 and 2.

Containment Analysis Methodology

The method for performing NAPS containment analyses for analyzing the response to postulated pipe ruptures inside containment was changed by converting from the Stone and Webster LOCTIC computer code to the Generation of Thermal-Hydraulic Information for Containments (GOTHIC) code. In a letter dated November 1, 2005, (ADAMS Accession No. ML053060266), Dominion Energy Virginia submitted Topical Report DOM-NAF-3, "GOTHIC Methodology for Analyzing the Response to Postulated Pipe Ruptures Inside Containment," which documents the Dominion Energy methodology for analyzing the containment response to postulated pipe ruptures using the GOTHIC code. The NRC approved Topical Report DOM-NAF-3 in a letter dated August 30, 2006 (ADAMS Accession No. ML062420511). NAPS plant-specific applications of the DOM-NAF-3 methodology to effect GSI-191 changes associated with the RS pump start method and the containment air partial pressure operating limits, as noted below, were then implemented through the license amendment process.

License Amendment Requests

A license amendment request (LAR) was submitted by letter dated October 3, 2006 (ADAMS Accession No. ML062850195) for NRC review and approval in support of the installation of the new strainers and resolution of GSI-191 and NRC GL 2004-02. As detailed further below, the NRC approved the LAR, and Dominion Energy Virginia implemented the approved license amendment for NAPS 1 and 2. Specifically, the LAR included the following changes:

- Revised the method for starting the IRS and ORS pumps in response to a DBA. Previously, the NAPS RS pumps were started by delay timers that were initiated when the containment pressure reached the Containment Depressurization Actuation (CDA) High-High containment pressure setpoint. The license amendment request changed the start of the RS pumps to receipt of a CDA High-High pressure signal coincident with a refueling water storage tank (RWST) Level-Low signal. The two ORS pumps (located outside containment) start immediately once the coincidence logic is satisfied, while the IRS pumps start following a time delay of 120 seconds once the coincidence logic is satisfied. This change ensures that adequate water volume is available to submerge the new containment sump strainer prior to the pumps taking suction from the strainer and meets the safety analysis acceptance criteria. The revised TS surveillance requirements verify that each RS pump automatically starts on a CDA High-High test signal coincident with the receipt of an RWST Level-Low test signal. A plant modification associated with the license amendment request was required to install the new RS pump start circuitry.

- Replaced the current LOCTIC containment analysis methodology for analyzing the response to postulated pipe ruptures inside containment, including loss of coolant accident (LOCA) and main steam line break (MSLB) events, with the NRC-approved GOTHIC evaluation methodology discussed in Dominion Topical Report DOM-NAF-3-0.0-P-A. The change to the GOTHIC code from the LOCTIC code provides margin in LOCA peak containment pressure and other accident analysis results for both the existing and the revised GSI-191 licensing bases.

- Lowered the maximum containment operating temperature limit, modified the containment air partial pressure operating limit, and lowered the plant setpoint and TS allowable values for the RWST Level Low-Low function that initiates safety injection recirculation mode transfer.

- Revised the TS surveillance requirements for containment sump inspection to be consistent with the separate strainers installed for the LHSI and RS systems.

- Revised the TS value for Pa, the peak calculated containment pressure from a LOCA, based on the GOTHIC containment analyses.

- Revised the LOCA Alternate Source Term (AST) analysis to include the effects from changing the RS pump start methodology and from the other modifications associated with the GSI-191 project.

The NRC approved the license amendment request for North Anna Units 1 and 2 in Amendments 250/230, respectively, in a letter dated March 13, 2007 (ADAMS Accession No. ML070720043). Implementation of these changes was completed during the spring 2007 refueling outage for NAPS Unit 2 and during the fall 2007 refueling outage for NAPS Unit 1.

4 References

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

4.2 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 16, 2004.

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

4.4 AREVA Calculation 32-9201054-000, "PWR Strainer Fiber Bypass Length Distribution" (Framatome Proprietary).

4.5 AREVA Summary Test Report 66-9199574-000, "Fiber Bypass Size Characterization Test Report."

4.6 Alden Test Report 1142PBNBYP-R2-01, "Point Beach Large Scale Fibrous Debris Penetration Test Report."

4.7 Alden Calculation 1142PBNBYP-600-00, "Fibrous Debris Penetration Model for Point Beach Calculation."

4.8 NextEra Energy Point Beach Letter No. NRC 2017-0045; "Updated Final Response to NRC GL 2004-02," December 29, 2017.

4.9 NRC Document ML15320A087 – "Vogtle GSI-191 Resolution Plan and Current Status NRC Public Meeting," November 5, 2015.

4.10 Alden Test Report 1130VNPBYP-R2-00-NONQA, "Vogtle Nuclear Plant Fiber Penetration Testing."

4.11 NA-CALC-MEC-NAN1-34325-AR-001, Rev. 6 and NA-CALC-MEC-NAN2-34325-AR-001, Rev. 6.

4.12 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.

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