Dominion Energy Nuclear Connecticut, Inc.
5000 Dominion Boulevard, Glen Allen, VA 23060
DominionEnergy.com

Dominion Energy®

April 15, 2021

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

Serial No.:	21-016
NRA/GDM:	R2
Docket No.:	50-423
License No.:	NPF-49

DOMINION ENERGY NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3
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 Nuclear Connecticut, Inc., (DENC) final supplemental response for Millstone Power Station (MPS) Unit 3 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 (ADAMS Accession No. ML13141A277), DENC submitted a letter of intent per SECY-12-0093, "Closure Options for Generic Safety Issue – 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance," indicating MPS Unit 3 would pursue Closure Option 2 – Deterministic of the SECY recommendations (refinements to evaluation methods and acceptance criteria). The final outstanding issue for MPS Unit 3 with respect to GL 2004-02 is the in-vessel downstream effects evaluation to demonstrate long-term core cooling can be adequately maintained for postulated accident scenarios requiring sump recirculation.

The in-vessel downstream effects evaluation has been completed for MPS Unit 3 and is documented in the enclosure to this letter. This satisfies the final GSI-191 commitment identified in the May 15, 2013 Closure Option letter.

This response constitutes DENC's final supplemental response to GL 2004-02 for MPS Unit 3.

Should you have any questions or require additional information, please contact Mr. Gary D. Miller at (804) 273-2771.

Respectfully,

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

Commitment contained in this letter:

1. DENC 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 MPS Unit 3.

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 Nuclear Connecticut, 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 15th day of April, 2021.

My Commission Expires: August 31, 2023.

GARY DON MILLER
Notary Public
Commonwealth of Virginia
Reg. # 7629412
My Commission Expires August 31, 2023

Notary Public

cc: U.S. Nuclear Regulatory Commission - Region I
2100 Renaissance Blvd, Suite 100
King of Prussia, Pennsylvania 19406 - 2713

NRC Senior Resident Inspector
Millstone Power Station

Mr. R. Guzman
NRC Senior Project Manager - Millstone
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop 08 C2
11555 Rockville Pike
Rockville, Maryland 20852-2738

Enclosure

FINAL SUPPLEMENTAL RESPONSE TO GL 2004-02

Dominion Energy Nuclear Connecticut, Inc.
(DENC)
Millstone Power Station Unit 3

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)] *ECCS and* [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.*

DENC Response:

In accordance with SECY-12-0093 and as identified in DENC letter to the NRC dated May 15, 2013 (ADAMS Accession No. ML13141A277), Millstone Power Station (MPS) Unit 3 elected to pursue GSI-191 Closure Option 2 – Deterministic and identified in-vessel downstream effects as the last outstanding issue to be resolved. 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-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 MPS Unit 3.

1.1 Overview of MPS Unit 3 Resolution to GL 2004-02

By letter dated February 29, 2008 (ADAMS Accession No. ML080650561), DENC submitted a supplemental response to GL 2004-02 for MPS Unit 3 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 December 18, 2008 (ADAMS Accession No. ML083650005), DENC updated its supplemental response for MPS Unit 3 to provide additional information regarding the analyses performed and the corrective actions taken that had not been completed at the time of the February 29, 2008 response. The content and level of detail provided were consistent with the NRC guidance provided in NRC letter dated November 21, 2007 (ADAMS Accession No. ML073110389).

Additional information was provided in DENC letters dated March 13, 2009 (ADAMS Accession No. ML090750436), September 16, 2010 (ADAMS Accession No. ML102640210), December 20, 2010 (ADAMS Accession No. ML103620562), and June 13, 2017 (ADAMS Accession No. ML17171A229). DENC committed to address the resolution of downstream in-vessel effects for MPS Unit 3 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).

By letter dated May 15, 2013 (ADAMS Accession No. ML13141A277), MPS Unit 3 provided its resolution plan for resolving downstream in-vessel effects pursuant to the Pressurized-Water Reactor Owner's Group (PWROG) comprehensive program underway to develop new acceptance criteria for in-vessel debris (i.e., WCAP-17788-P). That letter also included a summary of the corrective actions and analyses that had been implemented for MPS Unit 3 to address GSI-191, as well as inherent margins and conservatisms included in the analyses.

The plant analyses, changes, margins, and conservatisms summarized and updated in the May 15, 2013 MPS Unit 3 correspondence remain valid.

By letter dated August 13, 2015 (ADAMS Accession No. ML15232A026), DENC committed to developing plans for demonstrating compliance with PWROG WCAP-17788-P in-vessel debris acceptance criteria for MPS Unit 3 and to communicate that plan to the NRC in a final updated supplemental response to support GL 2004-02 closure. This effort has been completed, and 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

A listing of the salient correspondence issued by the NRC or submitted by DENC for MPS Unit 3 regarding the resolution of the containment sump issues identified in GL 2004-02 is provided in Table 1.

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

TABLE 1 – GENERIC LETTER 2004-02 CORRESPONDENCE		
Document Date	**ADAMS Accession Number**	**Document**
September 1, 2005	ML052500378	Follow-up Response to GL 2004-02
September 15, 2005	ML052580387	License Amendment Request (LAR) to modify Technical Specifications (TS) regarding initiation of the MPS Unit 3 Recirculation Spray (RS) system
September 20, 2006	ML062220160	NRC issuance of License Amendment (LA) 233 to modify MPS Unit 3 TS regarding initiation of the RS system
September 1, 2006	ML062480263	LAR to revise MPS Unit 3 TS to use generic terminology for ECCS containment sump strainers
September 18, 2007	ML072290132	NRC issuance of LA 240 to revise MPS Unit 3 TS to use generic terminology for ECCS containment sump strainers
November 21, 2007	ML073110389	NRC Revised Content Guide
December 19, 2007	ML090860438	Draft Benchtop Test Plan for determining chemical effects
February 29, 2008	ML080650561	Supplemental Response to GL 2004-02
December 17, 2008	ML083230469	First NRC Request for Additional Information (RAI)
December 18, 2008	ML083650005	Notice of Completion of Activities to address GL 2004-02
March 13, 2009	ML090750436	Response to first NRC RAI
February 4, 2010	ML100070068	Second NRC RAI
September 16, 2010	ML102640210	MPS Unit 3 response to second RAI
December 20, 2010	ML103620562	Final response for MPS Unit 3 second RAI
May 15, 2013	ML13141A277	GSI-191 Closure Option Letter
August 13, 2015	ML15232A026	Regulatory Commitment Change Letter
June 13, 2017	ML17171A229	Third NRC RAI response

1.3 General Plant System Description

MPS Unit 3 is a Westinghouse four-loop PWR design. The Nuclear Steam Supply System (NSSS) consists of one reactor pressure vessel (RPV), four steam generators (SGs), four reactor coolant pumps (RCPs), one pressurizer and the Reactor Coolant System (RCS) piping. Each of the four reactor coolant loops (RCLs) consists of a SG, an RCP, and associated RCS piping and is contained in a concrete enclosure referred to as a cubicle. These four cubicles are essentially equivalent with respect to piping and equipment insulation. The reactor is operated inside a reinforced concrete containment structure maintained at a subatmospheric pressure between 10.6 and 14.0 psia. The containment structure is equipped with a containment sump located at the outer wall of the containment. Extensive use is made of gratings and openings in the upper floors and structures of the containment to allow water entering the containment to drain down to the containment sump. Also, the compartmentalized containment design slows transport of debris to the sump.

The emergency core cooling system (ECCS) provides borated water to cool the reactor core following a major loss of coolant accident (LOCA). This is accomplished by the automatic injection of water from the Safety Injection (SI) accumulators into the RCLs and by the automatic pumping of a portion of the Refueling Water Storage Tank (RWST) contents into the loops via the charging pumps, SI pumps, and Residual Heat Removal (RHR) pumps (low head SI). After the injection mode of emergency core cooling, long term core cooling (LTCC) is maintained by recirculating water from the containment sump by the Containment Recirculation Spray System (RSS) pumps, through the RSS coolers, and into the RCLs directly and via the charging and SI pumps.

The containment heat removal system consists of the Quench Spray (QS) system and the containment RSS. Following the postulated design basis accident (DBA), containment pressure is reduced by employing both systems. Heat is transferred from the containment atmosphere to the QS system and the RSS spray water. Heat is transferred from the containment to the Service Water (SW) system via the RSS heat exchangers. The QS system sprays borated water from the RWST. The RSS draws suction from the containment sump, the content of which consists of the primary or secondary system effluent and the quench spray. The start signal for the RSS pumps (which are the only pumps that take suction from the containment sump prior to sump switchover) was changed to automatically start when RWST level reaches the Low-Low Level setpoint coincident with a containment depressurization actuation (CDA) signal. This ensures the strainer is fully submerged prior to drawing water through the strainer for coolant recirculation.

1.4 General Description of Containment Sump Strainers

As stated in the MPS Supplemental Response dated February 29, 2008 and the MPS Unit 3 FSAR, a new, replacement ECCS strainer manufactured by Atomic Energy

Canada, Ltd. (AECL) was installed to replace the previous trash rack, coarse mesh, and fine mesh screen that had a surface area of approximately 240 ft^2. The four RSS pumps take suction from a common containment sump that is enclosed by the strainer assembly. The strainer consists of multiple fins constructed from corrugated perforated plate with 0.0625-inch holes. The fins are erected vertically over the sump and extend beyond the sump to achieve the required surface area. Post-accident water covers the strainer and is filtered by the strainer prior to entering the containment recirculation pumps' suctions. Design of the strainer is based on a thorough mechanistic analysis and debris-bed head loss testing to demonstrate that adequate net positive suction head (NPSH) and pump suction line flashing margin exists under worst-case debris clogging scenarios. Vortex suppression is provided by the design of the strainer as confirmed by analysis and head loss testing. Strainer design also included structural analysis to demonstrate structural adequacy under all possible conditions of debris blockage. Thus, water will be available to the suctions of the RSS pumps under DBA conditions.

The strainer has a solid cover plate installed approximately eight inches above the fins that protects the fins from inadvertently dropped debris during outages and also provides a work platform. The fins on the strainer are nominally seven inches off the containment floor, and the support structure for the strainer comprises a nominal seven-inch curb. The strainer is designed to withstand design basis earthquake loading and hydraulic loading prior to and during operation. The sump strainer structure's seventeen interconnected modules are anchored to a support frame, which is internally anchored to the containment structure basement slab. The strainer is located outside of the containment structure crane wall in the annulus between the crane wall and the containment exterior wall.

TABLE 2 – CONTAINMENT SUMP STRAINER SURFACE AREA	
Strainer	**Surface Area (ft^2)**
MPS Unit 3 Strainer	~5041

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.

DENC Response:

DENC performed analyses to determine the potential for adverse effects of post-accident debris blockage and debris-laden fluids to prevent the recirculation functions of the ECCS and RSS for MPS Unit 3. The analyses considered postulated DBAs for which the recirculation of these systems is required. Mechanistic analysis 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 Report (SER), 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 ECCS containment sump strainer following a DBA. Using the results of the analyses, conservative head loss testing was 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 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.

In addition, plant modifications were completed for MPS Unit 3 in support of GSI-191 resolution including the following:

1. A new MPS Unit 3 ECCS strainer (with corrugated, perforated stainless steel fins) was installed with a total surface area of approximately 5041 ft^2 to replace the previous trash rack, coarse mesh, and fine mesh screen that had a surface area of approximately 240 ft^2. The replacement strainer was designed to withstand up to

approximately 10 pounds per square inch (psi) of differential pressure and has a strainer hole size of 0.0625 inches, which is smaller than the previous screen size of 0.09375 inches.

2. The start signal for the MPS Unit 3 RSS pumps (which are the only pumps that take suction from the containment sump prior to sump switchover) was changed during the spring 2007 refueling outage, as permitted by Amendment No. 233 (ADAMS Accession No. ML062220160). The modification changed the automatic start signal at approximately 660 seconds following the postulated accident to an automatic start when the RWST level reaches the Low-Low Level setpoint coincident with a CDA signal. This ensures the strainer is fully submerged prior to drawing water through the strainer for coolant recirculation.

In addition to the modifications listed above, the following actions have been completed in support of GSI-191 resolution for MPS Unit 3:

1. Detailed analyses of debris generation and transport were performed to ensure a bounding quantity and a limiting mix of debris are assumed at the ECCS containment sump strainer. Using the results of the analyses, conservative head loss testing was performed to determine worst-case strainer head loss and downstream effects.

2. Chemical effects bench-top tests conservatively demonstrated the solubility and behaviors of precipitates, and applicability of industry data on the dissolution and precipitation tests of station-specific conditions and materials.

3. Reduced-scale testing was performed by AECL and Dominion Energy personnel. The reduced-scale 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.

4. Downstream effects analyses were performed for clogging/wear of components in flow streams downstream of the strainers.

5. Design controls were put in place to require evaluation of potential debris sources in containment created by, or adversely affected by, design changes.

6. Insulation specification changes were made to ensure that changes to insulation in containment can be performed only after the impact on containment strainer debris loading is considered.

To ensure the modifications implemented and the analyses performed effectively addressed uncertainties with sufficient margin, the following margins and conservatisms were incorporated:

1. Debris generation analysis used very conservative zones of influence (ZOIs) that resulted in the removal of virtually all insulation within the affected cubicle. Conservative ZOIs from NEI 04-07 were applied for fibrous insulation, which did not credit the metal encapsulation for much of the fibrous insulation in the steam generator cubicles. No credit was taken in the debris generation calculation for any reduction of insulation destruction due to location of the insulation with respect to the break.

2. There are numerous surfaces throughout containment where insulation and other debris are likely to settle following break blowdown and not be dislodged by washdown or containment spray. Consequently, this material debris would not be available for transport to the strainer. However, all insulation generated was assumed in the debris generation analysis to be immediately transported to the containment floor, entering the containment pool.

3. Although credit is taken in the design of the strainer for leak-before-break in consideration of pipe whip, jet impingement and missiles, no credit was taken for leak-before-break to determine the amount of debris generated or transported. Analysis of leak-before-break effects that reduce the size of the break that could occur prior to its detection has been approved by the NRC for use as part of the MPS Unit 3 licensing basis. The reactor coolant pipes are assumed to break instantaneously for the debris generation and transport analysis.

4. The debris transport analysis conservatively assumes all fibrous fines are transported to the strainer surface, 90% of large and small fibrous debris pieces are eroded into fines and transported to the strainer surface, and all particulate debris is transported to the strainer surface.

5. Conservative assumptions from the debris transport analysis were added to the conservative basis for the debris head loss determination from testing. The debris head loss testing was done with a particulate surrogate that has a lower density than the epoxy coating that is expected to make up much of the particulate debris. Stirrers were used in the test tank to minimize settling of debris to the greatest extent possible. The testing evaluated both extremes of debris loading (thin-bed debris load and the full debris load) and determined the worst-case head loss. Both thin-bed and full debris load testing used the particulate loading generated by the large break LOCA (LBLOCA). The worst-case head loss (thin-bed) is unlikely to occur for a LBLOCA because the quantity of fiber transported to the strainer is likely to be too high to allow for creation of a thin-bed. The thin-bed head loss is also unlikely to occur for a small break LOCA (SBLOCA) since the quantity of particulate necessary for formation of the worst-case thin-bed would not be generated.

6. No credit was taken for accident-induced overpressure in calculation of NPSH margin for the ECCS pumps.

7. No credit was taken for settling of particulate debris on surfaces throughout containment that would occur prior to and during coolant recirculation, including in the areas of the containment pool that have extremely low velocities during recirculation as shown by computational fluid dynamics (CFD) analysis.

8. The replacement strainer has a very large surface area and the strainer footprint is spread over a very large region of containment. For any one break in containment, the break-induced turbulence in the post-LOCA sump pool would be localized. The large strainer footprint combined with the localized turbulence results in large areas of the containment sump pool having very low velocities, which would enable extensive debris settling on the containment floor and may result in a nearly clean strainer area over some portion of the strainer surface. However, clean strainer area was not credited in chemical effects or head loss evaluations, and no significant settling of debris was credited in the downstream effects evaluation.

9. No credit was taken for additional NPSH margin due to subcooling of the sump water. The containment sump water was conservatively assumed to be saturated for calculation of NPSH for the ECCS pumps. No credit was taken for the several hours required to form the worst-case debris bed (thin-bed), during which time subcooling of the sump water would add significant NPSH margin for the ECCS pumps. The analysis conservatively assumes there is no time delay in transport to the strainer following the break. Formation of chemical precipitates and their subsequent transport to the strainer debris bed would occur many hours after the accident when containment heat removal requirements are significantly reduced and when significant subcooling of the sump water has occurred. Test evaluations demonstrated that a fully formed thin-bed of debris takes significant time (hours) to form and is dependent on unsettling debris throughout the test tank. Consequently, a worst-case thin-bed of debris will be difficult to form and will not form until several hours after sump recirculation can be initiated. Significant debris settling and significant sump water subcooling occurs during the formation of a debris-bed so additional NPSH margin is present for chemical effects head loss.

10. The debris load in head loss testing was taken from the debris transport calculation, which credits no particulate settling.

11. Debris introduction procedures in chemical effects testing resulted in minimum near-field settling and conservatively high head losses.

12. 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 was fully circulated.

13. The test tanks were stirred during testing. However, local areas of turbulence that may exist in any post-LOCA containment sump water are expected to be limited to

certain portions of sump water volume. Consequently, much of the sump water will be still and have near zero velocity.

14. 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.

15. Downstream wear analysis used the LBLOCA 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 analysis is unqualified coating that is outside the break ZOI. This unqualified coating is assumed to potentially dislodge due to exposure to the containment environment. However, an exposure-based mechanism to dislodgement, if it occurs at all, is likely only after many hours and days.

    - 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 ECCS strainer since the strainer sits approximately seven inches above the containment floor. Additionally, qualified coating postulated to fail in the presence of the ZOI is not buoyant in the sump water column.

    - The capture of particulate in the debris-bed on the strainer does not occur in this analysis, maximizing effects of downstream wear.

16. The base concrete dissolution is conservatively assumed to be uninhibited by the presence of tri-sodium phosphate (TSP), even though bench scale test solutions demonstrate inhibition of concrete degradation at containment sump water pH levels. Consequently, calculations of the amount of calcium to be added to the test tank for head loss tests were conservative.

17. The amount of aluminum and associated test results concerning its release into the simulated post-LOCA sump water through corrosion of aluminum surfaces was conservative based upon several conditions:

    - Aluminum corrosion amounts were calculated at high pH to favor corrosion, and aluminum precipitation was evaluated at low pH to favor precipitation.

    - Testing with a lower pH favors precipitation. Rig 89 testing was performed with a pH 7 at 77 °F to encourage aluminum compound precipitation, even though the actual pH in the sump water is approximated as pH 8 at 77 °F. Also, TS requirements for the RWST and TSP baskets ensure sump water pH is $\geq$ 7 at 77 °F.

- Rig 89 testing was evaluated conservatively with low short-term acceptance criteria, along with the maximum aluminum concentration of the sump water that exists only after 30 days.

- Analysis conservatively did not account for the possible inhibitory effect of silicate, phosphate, or other species on aluminum corrosion.

- The rate of corrosion was maximized by analysis that does not assume development of passive films, e.g., no aluminum oxides remain on aluminum surfaces. Passive films can otherwise be used to decrease the corrosion rate by a factor of the exposure time. Consequently, having no aluminum oxides remain on aluminum surfaces so all aluminum released by corrosion enters the solution is conservative.

- Aluminum not submerged in containment was considered by analysis to be exposed to containment sprays and therefore available for corrosion. However, some of the aluminum sources in containment, such as the out-of-core detector holders, may not be subject to a continuous containment spray and would not contribute to the total aluminum concentration in the containment pool.

- Aluminum released into the solution was 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 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 neglected the effect of the presence of oxygen in the sump water. Corrosion rate of aluminum in aerated pH 10 alkaline water can be a factor of two lower than when the rate is 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," (Jain et al. April 2005).

18. No near-field settlement was credited in the MPS Unit 3 testing.

19. The conservatism of the Rig 89 test results relative to the containment was demonstrated by the following factors:

    - The test tank size for Rig 89 was a 16-in x 16-in x 36-in stainless box. No significant debris transport was needed for debris to reach the strainer surface. Debris transport distance in the test tank was essentially zero whereas in

containment, due to the large footprint of the strainer, debris transport distances to at least one leg of the strainer are expected to be substantially greater than this test tank size.

- Walnut shell particulate (used as the surrogate for epoxy) has a density of approximately 80 pounds per cubic foot (lb/ft^3) as compared to the higher density of epoxy (94 lb/ft^3). Thus, epoxy is more likely to settle than the particulate surrogate used in testing.

- A significant portion of the particulate expected to be generated is from unqualified coatings that are postulated to be dislodged from components throughout containment by temperature and humidity in containment post-LOCA. Degradation of these unqualified coatings will take significant time (hours, and probably days), and thus the amount of particulate in the debris-bed (and in the test tank) is conservative. Additionally, all of the unqualified coating is postulated to fail as small, transportable particulate when in reality, much of the unqualified coating is more likely to fail as large pieces that will not transport.

- The strainer in containment sits approximately seven inches above the containment floor. Thus, any particulate which slides along the floor with the sump water motion is unlikely to reach the strainer surface.

20. Particulate debris settling and capture could be credited to occur prior to and during recirculation, minimizing the amount of debris downstream in the recirculating fluid. However, the calculation of wear of component surfaces due to debris conservatively neglects this particle debris settling and capture.

21. RSS pump start occurs when the RWST is approximately half full. The water level continues to rise until it is several feet above the top of the strainer for the first few hours after the accident while the RWST continues to be pumped into containment, adding NPSH margin for the RSS pumps. However, analysis conservatively used the water level from a SBLOCA that exists at the start of the RSS pumps.

22. A 5D (5 times pipe diameter) ZOI was used for qualified epoxy coating particulate resulting in a total generation and transport of 10.4 ft^3 of qualified coating particulate to the strainer. Based on the April 6, 2010 NRC to NEI Letter (ADAMS Accession No. ML100960495), a 4D ZOI is acceptable for qualified epoxy coatings. Use of a 4D ZOI would result in only 8.0 ft^3 of qualified coating particulate. Thus, the strainer testing used 23% more (2.4 ft^3) qualified coating particulate than what is expected to occur in containment due to use of the more conservative 5D ZOI.

23. A 10% margin was added to the coatings particulate debris quantities generated from the ZOI and from unqualified coatings (a total of 2.1 ft^3 of coatings margin). Reduction

of coating debris, which is all modeled as particulate, would result in a reduction in thin-bed head loss.

24. The above two conservatisms result in a total excess of 4.5 ft^3 of coating over what is expected to occur on the strainer in containment. The total particulate coating load on the strainer was calculated to be 23 ft^3. A reduction of 4.5 ft^3 is equivalent to a 20% reduction in coating particulate, which would result in a reduction in strainer head loss for a thin-bed from the tested values.

25. Unqualified coating was deemed to fail immediately as transportable particulate. This is particularly conservative since unqualified coating makes up 46% of the total tested coating load and 39% of the total particulate load on the strainer. Electric Power Research Institute (EPRI) testing (Reference EPRI Technical Report 1011753 dated September 2005) has shown that less than one-third of unqualified coatings actually failed when subjected to DBA testing.

26. Five percent margin was added to the fibrous debris quantities generated from the ZOI (a total of over 60 ft^3 of fiber margin).

27. Five percent margin was added to the microtherm debris quantity generated from the ZOI (a total of 0.1 ft^3 of microtherm margin).

28. In both Rig 33 and Rig 89 testing, fibrous debris was conservatively prepared as "single fine."

29. One hundred percent debris transport was assumed for coatings, microtherm, and latent debris.

30. A sacrificial strainer area is installed in containment to accommodate transport of foreign material to the strainer. The installed strainer area (5041 ft^2) exceeds the tested strainer area (4290 ft^2) by at least the amount of the sacrificial area.

<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, DENC has effectively resolved for MPS Unit 3 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 MPS Unit 3 Supplemental Response dated February 29, 2008 (ADAMS Accession No. ML080650561) and amended on December 18, 2008 (ADAMS Accession No. ML083650005), as well as subsequent RAI responses submitted on March 13, 2009 (ADAMS Accession No. ML090750436), September 16, 2010 (ADAMS Accession No. ML102640210), December 20, 2010 (ADAMS Accession No. ML103620562), and June 13, 2017 (ADAMS Accession No. ML17171A229), MPS Unit 3 has addressed review areas 3.a through 3.m. Therefore, only the outstanding review areas of 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.*

DENC Response:

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-P. Although the NRC staff did not issue a Safety Evaluation for WCAP-17788-P, 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. DENC used methods and analytical results developed in WCAP-17788-P, Rev. 1, to address in-vessel downstream debris effects for MPS Unit 3 and has evaluated the applicability of the methods and analytical results from WCAP-17788-P, Rev. 1, for MPS Unit 3.

3.n.1 Sump Strainer Fiber Penetration

An engineering evaluation was performed to determine a conservative estimated cumulative fiber bypass fraction for the MPS Unit 3 containment sump strainer to facilitate the evaluation of the in-vessel debris effects for NRC GL 2004-02.

From the debris generation and transport analyses performed for MPS Unit 3, DENC has conservatively determined the types and quantities of fibrous debris that could be transported to the strainers, as documented by letter dated February 29, 2008 (ADAMS Accession No. ML080650562). The fibrous debris sources considered in the MPS Unit 3 analyses included fiberglass and latent fiber. The total fibrous debris quantity from these sources that could potentially reach the MPS Unit 3 sump strainer was conservatively calculated to be approximately 2053 lbm.

The strainer fiber bypass testing performed by AECL that was applied to the MPS Unit 3 strainer did not measure the cumulative quantities of fiber bypassed after each fiber addition to the test tank. 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 certain insights, such as long-term strainer bypass was low, but did not provide insight into the extent of fiber bypass occurring early in ECCS operation. Consequently, there is no data for the quantity of bypassed fiber as the debris bed is forming; therefore, cumulative fiber bypass fractions cannot be determined.

However, other plants in the industry have performed strainer bypass testing with downstream continuous in-line filters that were able to determine cumulative fiber bypass fractions for various debris bed thicknesses. Consequently, Dominion Energy performed an evaluation to develop an engineering basis for the use of cumulative fiber bypass data from other plants to apply to the AECL strainer installed at MPS Unit 3.

General Strainer Bypass Characteristic

Based on review of strainer bypass testing data for the Point Beach and South Texas Project (STP) plants (References 4.6 and 4.14, 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%. Each of these tests was performed with continuous in-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 that indicated in the bypass testing results for the Dominion Energy fleet that was performed by AECL. But 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 in-line fiber bypass capture to determine cumulative bypass fractions for the MPS Unit 3 strainer. It is noted AECL test reports determined, "Fiber bypass concentrations show a near exponential decreasing trend with time." The quantity of fiber that bypassed the strainer was so low a scanning electron microscope evaluation was

required for accurate determination of concentration and size. Considering these results, there is reasonable engineering justification to apply Point Beach test results, after correcting for differences in approach velocity, to the MPS Unit 3 strainer.

Review of NRC Staff Guidance for Strainer Fiber Bypass

Using NRC staff guidance (Reference 4.3) for strainer fiber bypass and 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 MPS Unit 3. 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 MPS Unit 3 was based on fiber bypass at various tested and extrapolated theoretical debris bed thicknesses (derived from fiber mass per strainer area).

The MPS Unit 3 strainer approach velocity is higher than the Point Beach test results; consequently, it was necessary to apply a correction factor to scale the Point Beach data to the higher velocity. Derivation of the correction factor was based on the Vogtle plant tests that recorded bypass fractions at various velocities. 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 Vogtle strainers at flow rates comparable to MPS Unit 3 and Point Beach. Then a cumulative bypass correction factor could be determined at a given debris bed thickness by scaling the Vogtle data at the MPS Unit 3 plant 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 MPS Unit 3 strainer and assessed to be conceptually equivalent in its 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. MPS Unit 3 does not utilize any specific design features for promoting even flow distribution; however, the AECL strainer hydraulic report discusses that uniform flow is expected as soon as a small fiber layer starts to form. (Reference 4.12).

With regard to sacrificial areas for the MPS Unit 3 strainer, it was assumed all of the areas 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 larger cumulative bypass fractions for the maximum debris loads at each plant.

Cases that result in the maximum design flow rates for the MPS Unit 3 strainer were selected to provide the highest approach velocity. The strainer perforation size for Point Beach (0.066") is slightly larger than for the MPS Unit 3 strainer perforation size (0.0625"). Upon consideration of this design attribute, it has a conservative influence on cumulative bypass fractions when applying Point Beach test results to MPS Unit 3.

Conservatisms Applied

Conservatisms applied when determining cumulative bypass fractions for the MPS Unit 3 include:

- Maximum strainer design flow rates were used that result in the highest calculated approach velocities and cumulative bypass fractions.
- The MPS Unit 3 strainer has a slightly smaller perforation size (0.0625") as compared to the Point Beach strainer (0.066") that was used for bypass test data applied to the MPS Unit 3.
- Point Beach test results for Nukon only insulation were used since they 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 to minimize the thicknesses, which result in higher cumulative bypass.
- A percentage of the total fiber load on the MPS Unit 3 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.

TABLE 3 – CRITICAL PARAMETER COMPARISON FOR SUMP STRAINER BYPASS TESTING

Parameter	Point Beach Value			Millstone Unit 3 Value
Strainer Manufacturer	PCI			AECL
Strainer Perforation Size	0.066"			0.0625"
Strainer Area[1]	1904.6 ft^2			5041 ft^2
Flow Rate through Single Strainer Train	2300 gpm (test scaled)			8220 gpm
Approach Velocity	0.0027 ft/sec			0.00363 ft/s
Nominal Theoretical Debris Bed Thickness	1.5"		0.60"	2.037"
Debris Type and Quantity (% Fiber Mass Type)[2]	Test 1	Test 2	Test 3	
Fiberglass	40.7%	28.8%	100%	100%
Mineral Wool	59.3%	67.7%	0%	0%
Mineral Fiber	0%	0%	0%	0%
Temp-Mat	0%	3.5%	0%	0%
Paroc	0%	0%	0%	0%
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 strainer. Determination of cumulative bypass fractions is only being based on a theoretical debris bed thickness comparison with Point Beach and each plant.
2. Actual fiber quantities are not provided as there is no intent to apply the terminal Point Beach cumulative bypass fractions to the AECL strainer. The bypass fraction for MPS Unit 3 is derived by comparison of theoretical bed thicknesses.

MPS Unit 3 has a theoretical debris bed thickness of 2.037" that exceeds the final nominal theoretical bed thicknesses for the Point Beach tests. 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. The cumulative bypass fraction at a 2.037" thickness is then calculated using

the Point Beach Test 3 curve fitted equation developed in the calculation: Cumulative Fiber Bypass = 0.040303*(Bed Thickness)$^{-0.758434}$ = 0.040303*(2.037)$^{-0.758434}$ = 2.3%.

Since the approach velocity for the MPS Unit 3 strainer (0.00363 ft/s) is 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 MPS Unit 3. The spreadsheet determined that a correction factor of 1.514 is applicable for a debris bed thickness of 2.037" to scale to a velocity of 0.0043 ft/s, which conservatively bounds 0.00363 ft/s. Applying this information to MPS Unit 3, the cumulative fiber bypass is 2.3% x 1.514 = **3.5%.**

TABLE 4 - SUMMARY OF FIBER LOAD, DEBRIS BED THICKNESS, & VELOCITY ADJUSTED BYPASS FRACTIONS

Strainer Characteristic	MPS Unit 3
Fiber Load	2053.24 lbm
Theoretical Debris Bed Thickness	2.037 inches
Cumulative Bypass Fraction	3.5%

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

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

MPS Unit 3 is a Westinghouse 4-loop PWR with an upflow barrel/baffle configuration. Per Section 3.0 of the NRC Staff Review Guidance (Reference 4.3), it is necessary to confirm MPS Unit 3 is within the key parameters of the WCAP-17788-P, Rev. 1, methods and analysis. Therefore, each of the key parameters is discussed below.

3.n.3 Fuel Design

MPS Unit 3 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 limits contained in WCAP-17788-P, Volume 1, Rev. 1, apply to MPS Unit 3.

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

The amount of fibrous debris calculated to arrive at the reactor vessel is determined for MPS Unit 3 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 MPS Unit 3. The calculation included the following design inputs and assumptions:

Design Inputs

1. Plant Type - MPS Unit 3 is a four-loop Westinghouse upflow configuration plant.

2. Number of Assemblies – The MPS Unit 3 core contains 193 Westinghouse RFA-2 fuel assemblies (FAs).

3. Core Thermal Power - The current rated core thermal power is 3650 MWt. The analyzed core thermal power of 3723 MWt, which includes instrument uncertainty, was used for this evaluation.

4. Initial Sump Fiber Load - The total fibrous debris fines mass at the ECCS sump strainer, including fines generated due to erosion, is 380.32 lbm. The fiber "fines" are the fibers that are small enough to bypass the sump strainers and collect at the core inlet (i.e., Fuel Assembly Lower End Fittings). On a per fuel assembly basis, the initial sump fiber load is 893.83 g/FA (= [380.32 lbm * 453.592 g/lbm] / 193 FAs).

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 minutes.

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 ECCS flow rate during recirculation is 965.25 gpm with one operable train, and the maximum recirculation flow rate is 1753 gpm with both trains operating.

8. RSS Flow Rates Following SSO - The containment RSS helps reduce the total mass of debris delivered to the reactor vessel by diverting a fraction of debris that bypasses the sump strainer back into the sump. Per guidance provided in WCAP-17788-P, Rev. 1, Volume 1, Section 6.5.2.10, a minimum RSS flow rate should be analyzed. The minimum RSS flow rate during ECCS recirculation alignment is 4071 gpm. The maximum RSS flow rate during ECCS recirculation alignment is 7202 gpm.

9. Time of Hot Leg Switch Over (HLSO) – The MPS Unit 3 HLSO time must occur between 3 and 5 hours. Since a maximum HLSO value is limiting, a value of 5 hours was used in the calculation.

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 are assumed to greatly increase the resistance across the formed debris bed. Per Table 4.4-1 of Reference 4.13, the earliest time at which chemical effects form is 24 hours for MPS Unit 3. Therefore, a value of 24 hours was used in the calculation.

12. Maximum Core Inlet Resistance (K_{max}), Time for Core Inlet Blockage (t_{block}), and Core Inlet Debris Limit - K_{max} is the maximum core inlet resistance that can be tolerated prior to complete core inlet blockage. t_{block} is the minimum acceptable time of complete core inlet blockage. MPS Unit 3 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 MPS Unit 3 strainer cumulative bypass percentage was determined to be 3.5%.

14. RFA-2 Assembly Pitch - The RFA-2 FA 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, which is consistent with maximum transport assumptions.

5. AFPs were not credited. Per PWROG-16073-P, Rev. 0, (Reference 4.13), 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-P, Rev. 1, 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.

8. At the time of HLSO, the charging pumps (high head) continue to deliver cooling flow to the cold legs, and the (low head) SI pumps are realigned to deliver cooling flow to the hot legs. A maximum flow rate will deliver the most fiber into the reactor pressure vessel (RPV), which is conservative, so with two pumps operating for both the charging and SI pumps, the maximum flow rates are 876.1 and 830.7 gpm, respectively. Therefore, 51.3% of the flow is delivered to the cold legs and 48.7% is delivered to the hot legs. The sum of these two flow rates is 45.2 gpm less than the total ECCS flow rate prior to recirculation, but because a higher flow rate is conservative and results in more fiber being delivered into the core, the flow split was applied to the total ECCS flow rate before HLSO.

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 injected fiber must be less than or equal to the core inlet fiber load limit included in WCAP-17788-P, Vol. 1, Ref. 1, Table 6-3, for Westinghouse fuel.

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 MPS Unit 3 calculated to potentially reach the reactor vessel is 9.6 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

MPS Unit 3 is a Westinghouse 4-loop design with Westinghouse 17x17 RFA-2 FAs. The applicable core inlet fiber threshold for Westinghouse fuel is provided in Table 6-3 of WCAP-17788-P, Rev. 1. The calculated core inlet fiber amount for MPS Unit 3 is 9.6 g/FA, which is less than the applicable WCAP-17788-P, Rev. 1, core inlet fiber threshold limit for Westinghouse fuel.

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 MPS Unit 3 was determined to be 33 minutes.

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 4.13) identifies Test Group 35 as representative of MPS Unit 3, 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

MPS Unit 3 performs injection realignment to mitigate the potential for boric acid precipitation (BAP) no later than 5 hours, which is less than 24 hours.

3.n.11 WCAP-17788 t_{block} value for the RCS design category

MPS Unit 3 is a Westinghouse 4-loop upflow configuration design. Based on WCAP-17788-P, Rev. 1, Volume 1, Table 6-1, t_{block} for MPS Unit 3 is 143 minutes.

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

The earliest time of chemical precipitation for MPS Unit 3 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

The MPS Unit 3 rated core thermal power (RTP) is 3650 MWt. The analyzed core thermal power is 3723 MWt, which includes instrument uncertainty. MPS Unit 3 is a Westinghouse 4-loop design, and the applicable analyzed thermal power is 3658 MWt as provided in WCAP-17788-P, Rev. 1, Volume 4, Table 6-1. Therefore, the MPS Unit 3 analyzed thermal power is greater than the WCAP-17788-P analyzed value.

The WCAP-17788-P, Vol. 1, Rev. 1, thermohydraulic analysis assumes an SSO time of 20 minutes together with an RTP of 3658 MWt. To justify the use of the analysis and fuel limit described in WCAP-17788-P, it is necessary to demonstrate the decay heat for MPS Unit 3 at the time of SSO (i.e., when fibrous debris begins to arrive at the core inlet) is less than the decay heat in the WCAP-17788-P thermohydraulic analysis at the time of SSO as discussed in PWROG-16073 (Reference 4.13).

Table 4.5-2 of PWROG-16073 provides a decay heat at 20 minutes of 87.4 MWt, which is the decay heat available at the time of SSO in the WCAP-17788-P thermohydraulic analysis. The decay heat model is based on the 1971 ANS Infinite Standard plus 20% uncertainty [PWROG-16073, Section 4.5.1.2]. As noted above, the earliest time of SSO for MPS Unit 3 is 33 minutes, which will result in additional time for the core to decay and thus a lower normalized core power than that resulting at 20 minutes. The MPS Unit 3 plant-specific post-LOCA decay heat fraction is 0.0216 at 30 minutes. This decay heat fraction includes a 20% uncertainty and is conservative for an SSO time of 33 minutes. The decay heat at the time of SSO is then calculated to be 80.5 MWt (0.0216 * 3723 MWt), which is less than the decay heat from the WCAP-17788-P thermohydraulic analysis at the time of SSO (87.4 MWt). Therefore, the WCAP-17788-P thermohydraulic analysis and fuel limits are still bounding for MPS Unit 3. In addition, there is significant margin to the maximum core inlet fiber load to help offset this power level difference.

3.n.14 Plant alternate flow path (AFP) resistance compared to the analyzed AFP resistance for the plant RCS design category

MPS Unit 3 is a Westinghouse upflow barrel/baffle configuration plant. The proprietary analyzed AFP resistance is provided in Table 6-1 of WCAP-17788-P, Volume 4, Rev. 1. The proprietary MPS Unit 3 specific AFP resistance is provided in Table RAI-4.2-24 of WCAP-17788-P, Volume 4, Rev. 1. The MPS Unit 3 specific AFP resistance is less than the analyzed value; therefore, the MPS Unit 3 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

MPS Unit 3 is a Westinghouse upflow barrel/baffle configuration plant. The AFP analysis for Westinghouse upflow plants analyzed a range of ECCS recirculation flow rates from 8 – 40 gpm/FA, as shown in Table 6-1 of WCAP-17788-P, Volume 4, Rev. 1. The MPS Unit 3 ECCS recirculation flow rate corresponding to the worst-case GSI-191 hot leg break scenario is 9 gpm/FA, which is within the range of ECCS recirculation flow rates considered in the AFP analysis.

While the MPS Unit 3 ECCS recirculation flow rate corresponding to the worst-case GSI-191 hot leg break scenario is within the range of ECCS recirculation flow rates considered in the AFP analysis, the minimum plant-specific ECCS flow rate, 5 gpm/FA, is less than the minimum analyzed ECCS flow rate used to develop K_{max} in Reference 4.14. Debris bed resistance increases as ECCS flow rate decreases, so an unbounded low flow has the potential to cause the K_{max} used in the calculation to be non-conservative. However, the maximum ECCS flow rate at MPS Unit 3 creates the most limiting case, which has significant margin to the WCAP-17788 core inlet fiber limit. As such, the

unbounded minimum ECCS flow rate is acceptable because it does not create the limiting fiber load at the core inlet; therefore, K_{max} is valid for the limiting fiber load case.

3.n.16 Summary

The comparison of key parameters used in the WCAP-17788 AFP analysis to the MPS Unit 3 specific values is summarized in Table 5. Based on these comparisons, MPS Unit 3 is bounded by the key parameters, and the WCAP-17788 methods and results are applicable.

TABLE 5 – KEY PARAMETER VALUES FOR IN-VESSEL DEBRIS EFFECTS			
Parameter	**WCAP-17788 Value**	**MPS Unit 3 Value**	**Evaluation**
Maximum Total In-Vessel Fiber Load (g/FA)	Volume 1, Section 6.5	< than 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	9.6	Maximum core inlet fiber load is less than WCAP-17788 threshold.
Minimum Sump Switchover Time (min)	20	33	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	3723	This value is not bounded by the WCAP-17788-P value and is dispositioned in Section 3.n.13 above.

TABLE 5 – KEY PARAMETER VALUES FOR IN-VESSEL DEBRIS EFFECTS			
Parameter	**WCAP-17788 Value**	**MPS Unit 3 Value**	**Evaluation**
Maximum AFP Resistance	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	9	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.

DENC Response:

The MPS Unit 3 chemical effects analysis of the sump strainers was submitted in the MPS Unit 3 Supplemental Response dated February 29, 2008 (ADAMS Accession No. ML080650561) and amended on December 18, 2008 (ADAMS Accession No. ML083650005), as well as subsequent RAI responses submitted on March 13, 2009 (ADAMS Accession No. ML090750436), September 16, 2010 (ADAMS Accession No. ML102640210), and December 20, 2010 (ADAMS Accession No. ML103620562). The MPS Unit 3 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.

DENC Response:

DENC's February 29, 2008 Supplemental Response discussed the licensing bases changes that had been implemented for MPS Unit 3 associated with the resolution of the sump issues considered in GSI-191 and GL 2004-02. These changes are restated below:

MPS Unit 3 FSAR

The MPS Unit 3 FSAR was revised to reflect the installation of the new containment sump strainer. DENC 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 MPS Unit 3.

MPS Unit 3 License Amendments

Two license amendments related to GL 2004-02 corrective actions were approved and implemented.

- A change to the start signal for the RSS pumps was submitted and approved to ensure the strainer was fully submerged and adequate NPSH existed for the RSS pumps prior to their start considering a mechanistic debris blockage analysis. Amendment No. 233 was approved for MPS Unit 3 by NRC letter dated September 20, 2006 (ADAMS Accession No. ML062220160). Implementation of this change was completed during the MPS Unit 3 spring 2007 refueling outage.

- An amendment was approved and implemented for an administrative change to replace obsolete text in the TS Section 4.5.2.d sump surveillance requirement with generic terminology for ECCS containment sump strainers. MPS Unit 3 Amendment No. 240 was approved by NRC letter dated September 18, 2007 (ADAMS Accession No. ML072290132).

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 MIL3-34325-TR-001, Rev. 0; "Reduced-Scale Testing for Millstone 3 Replacement Containment Sump Strainers", AECL Test Report.

4.12 MIL3-34325-AR-001, Rev. 2 w/Addendum 00A; "Hydraulic Performance of Replacement Containment Sump Strainers Millstone 3 Power Station

4.13 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.

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