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May 27, 2021

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

Serial No.: 21-040
NRA/GDM: R1
Docket No.: 50-336
License No.: DPR-65

DOMINION ENERGY NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 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 Dominion Energy Nuclear Connecticut, Inc., (DENC) final supplemental response for Millstone Power Station (MPS) Unit 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 (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 2 would pursue Closure Option 2 – Deterministic of the SECY recommendations (refinements to evaluation methods and acceptance criteria). The final outstanding issue for MPS Unit 2 with respect to GL 2004-02 is the in-vessel downstream effects evaluation to demonstrate long-term core cooling (LTCC) can be adequately maintained for postulated accident scenarios requiring sump recirculation.

The in-vessel downstream effects evaluation has been completed for MPS Unit 2 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 2.

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 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 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 27th day of May, 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 GL 2004-02

Dominion Energy Nuclear Connecticut, Inc.
(DENC)
Millstone Power Station Unit 2

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1 Overall Compliance

NRC Issue:

Provide information requested in GL 2004-02, "Requested Information," Item 2(a) regarding compliance with regulations. That is, provide confirmation that the [Emergency Core Cooling System (ECCS)] *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 Unit 2 (MPS Unit 2) 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 2.

1.1 Overview of MPS Unit 2 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 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 December 18, 2008 (ADAMS Accession No. ML083650005), DENC updated its supplemental response for MPS Unit 2 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) and July 8, 2010 (ADAMS Accession No. ML102010413). In the March 13, 2009 letter, DENC committed to address the resolution of downstream in-vessel effects for MPS Unit 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).

By letter dated May 15, 2013 (ADAMS Accession No. ML13141A277), MPS Unit 2 provided its resolution plan for resolving downstream in-vessel effects pursuant to the Pressurized Water Reactor Owners 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 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 May 15, 2013 MPS Unit 2 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 2 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 2 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
September 1, 2005	ML052500378	Follow-up Response to GL 2004-02
February 9, 2006	ML060380188	NRC RAI Request

TABLE 1 – GENERIC LETTER 2004-02 CORRESPONDENCE		
Document Date	**ADAMS Accession Number**	**Document**
September 1, 2006	ML062480263	License Amendment Request (LAR) to revise MPS Unit 2 Technical Specifications (TS) to use generic terminology for the description of the ECCS containment sump strainer
August 30, 2007	ML072290531/530	NRC MPS Unit 2 Corrective Actions Audit Report
September 18, 2007	ML072290132	NRC issued License Amendment 300 to update the TS text with more generic terminology for the containment sump strainer
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
July 8, 2010	ML102010413	Response to second NRC RAI
August 10, 2010	ML102140437	NRC closeout letter for MPS Unit 2 with the exception of in-vessel downstream effects
May 15, 2013	ML13141A277	GSI-191 Closure Option Letter
August 13, 2015	ML15232A026	Regulatory Commitment Change Letter

1.3 General Plant System Description

MPS Unit 2 is a Combustion Engineering (CE) PWR design. The containment completely encloses the reactor, Reactor Coolant System (RCS), and portions of the auxiliary and

Engineered Safety Features (ESF) systems. It ensures an acceptable upper limit for leakage of radioactive materials to the environment will not be exceeded even if gross failure of the RCS occurs. The RCS consists of two heat transfer loops connected in parallel across the reactor pressure vessel. Each loop contains one steam generator, two reactor coolant pumps, connecting piping, and flow and temperature instrumentation. Coolant system pressure is maintained by a pressurizer connected to one of the loop hot legs.

The MPS Unit 2 ECCS design includes Low Pressure Safety Injection (LPSI) pumps, High Pressure Safety Injection (HPSI) pumps, and Containment Spray (CS) pumps that work together to reduce containment temperature and pressure and remove core decay heat following an accident. Additionally, MPS Unit 2 has four safety related Containment Air Recirculation Coolers that provide containment atmosphere cooling using a closed cooling water system following a loss of coolant accident (LOCA).

The ECCS function is performed by the Safety Injection (SI) system, which includes the safety injection tanks (SITs), HPSI, and LPSI subsystems. The SI system injects borated water into the RCS in the event of loss of coolant accident (LOCA). This provides cooling to limit core damage and fission product release and assures adequate shutdown margin. The SI system also provides continuous long-term post-accident cooling of the core by recirculation of borated water from the containment sump. The SI pumps initially take suction from the Refueling Water Storage Tank (RWST). After the tank level has decreased to a low-level setpoint, a sump recirculation actuation signal (SRAS) transfers the SI pump suction to the containment sump for long-term recirculation.

The CS system removes heat by spraying cool borated water through the containment atmosphere. The sprayed heated water is then collected in the containment sump and cooled by the Reactor Building Closed Cooling Water system through the shutdown heat exchangers and recirculated into the containment atmosphere. The RWST also provides the initial source of borated water for the CS pumps.

Following a design basis LOCA, RCS pressure will drop resulting in an SI actuation signal (SIAS), and containment pressure will rise resulting in a CS actuation signal (CSAS). Upon receipt of the SIAS, the LPSI pumps and the HPSI pumps start to inject water into the RCS from the RWST. Upon receipt of the CSAS, the CS pumps start drawing water from the RWST and spraying that water into containment via spray headers to lower containment temperature and pressure. When the RWST reaches its low level setpoint, transfer to the recirculation mode is automatically initiated by the SRAS. The LPSI pumps automatically stop on the SRAS, and the sump suction valves open so the HPSI and CS pumps can take suction from the containment sump. In the long term, if the RCS is not refilled, simultaneous hot and cold leg injection is initiated for boron precipitation control. Lineups for this include restarting one LPSI pump to provide either hot leg or cold leg injection.

The containment sump collects the water from the SI, CS, and reactor coolant blowdown for recirculation after the water has been nearly exhausted from the RWST. The RWST capacity is adequate to provide a minimum water level in the containment sump for operation of the SI and CS pumps during post-accident operation for both Large Break (LB) and Small Break (SB) LOCAs. The containment sump is located at the bottom of the containment building and is formed by the floor and the lowest elevation of containment. The borated water from the SI, CS, and RC systems is collected and subsequently recirculated to the SI and CS pumps' suctions. Two 24-inch containment sump recirculation pipes are provided from the sump to the suction of the SI and CS pumps. The CS water is cooled by one heat exchanger on each train to remove heat from containment during recirculation.

1.4 General Description of Containment Sump Strainers

As stated in the MPS Supplemental Response dated February 29, 2008 and the MPS Unit 2 FSAR, a new ECCS strainer (with corrugated, perforated stainless steel fins) manufactured by Atomic Energy Canada, Ltd. (AECL) was installed with a total surface area of approximately 6120 ft^2 to replace the previous trash rack and fine mesh screen that had a surface area of approximately 110 ft^2. The strainer is a single unit and is designed to support the full flow rate from both trains of ECCS simultaneously. The strainer is fully submerged on the start of recirculation and is designed to withstand up to approximately 1 atmosphere (atm) of differential pressure.

The strainer is constructed of 304/304L stainless steel (SS) or equivalent materials and consists of a pump inlet closure surrounding the ECCS inlet lines, which are located near the containment exterior wall. From the pump enclosure, two collection headers extend approximately 40 feet in toward the center of containment. Each collection header contains six individual modules. On each side of these headers are fins made of thin corrugated stainless steel perforated with 0.0625-inch holes. This perforation size prevents larger particles from passing and thus avoids clogging of downstream equipment, including pump flow clearances, CS nozzles or HPSI throttle valves. Each of the fins is nominally 10 inches apart (center to center distance). There are no vents or other penetrations through the strainer control surfaces that connect the volume internal to the strainer to the containment atmosphere above the containment minimum water level. The head loss across the strainer is limited to a value that will not adversely affect the available net positive suction head (NPSHa) for the SI and CS pumps.

TABLE 2 – CONTAINMENT SUMP STRAINER SURFACE AREA

Strainer	Surface Area (ft^2)
MPS Unit 2 Strainer	~6120

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 SI and CS systems for MPS Unit 2. The analyses considered postulated design basis accidents (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 May 28, 2004 (Reference 4.1), as modified by the NRC Safety Evaluation (NRC SE), dated December 6, 2004 (Reference 4.2):

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

Detailed analyses of debris generation and transport were performed to ensure 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.

Modifications to Improve Plant Performance

In addition, plant modifications were completed for MPS Unit 2 in support of GSI-191 resolution including the following:

1. A replacement MPS Unit 2 ECCS strainer (with corrugated, perforated stainless steel fins) was installed with a total surface area of approximately 6120 ft^2 to replace the previous trash rack and fine mesh screen that had a surface area of approximately 110 ft^2. The replacement strainer was designed to withstand up to approximately 1 atmosphere (atm) of differential pressure and has a strainer hole size of 1/16 inch, which is smaller than the previous screen hole size of 3/32 inch.

2. Calcium silicate insulation that could become dislodged by any break that could require recirculation was removed from the piping and equipment in the MPS Unit 2 containment so the insulation could not become part of the ECCS strainer debris bed. The remaining calcium silicate insulation in containment is jacketed with stainless steel and is not susceptible to being dislodged by a break that would require ECCS recirculation.

3. Safety related cover plates were installed over the MPS Unit 2 strainer to minimize the potential of air ingestion from water splashdown onto, and entraining air into, the strainer.

Additional Actions Taken to Address GSI-191

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

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 changes to insulation in containment can be performed only after the impact on containment strainer debris loading is considered.

Margins and Conservatisms

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

1. The debris generation analysis uses very conservative zones of influence (ZOIs) that result 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 which encases 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 and to enter the containment pool.

3. Although credit was taken in the design of the strainers 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. Leak-before-break is an NRC-approved part of the MPS Unit 2 licensing bases that reduces the size of the break that could occur prior to its detection. However, the reactor coolant pipes are assumed to break instantaneously for the debris generation and transport analyses.

4. Unqualified coatings in containment are assumed to fail as transportable particulate.

5. 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.

6. Conservative assumptions from the debris transport analysis were added to the conservative basis for the debris head loss determination from testing. This 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). This 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.

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

8. No credit was taken for settling of particulate debris that would occur on surfaces throughout containment 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.

9. The replacement strainer has a very large surface area, and the strainer footprint is spread over a 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 only very low velocities, which will 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, no clean strainer area has been credited in chemical effects or head loss evaluations, and no significant settling of debris has been credited in the downstream effects evaluation.

10. No credit was taken for additional NPSH margin due to subcooling of the sump water. Currently, the containment sump water was conservatively assumed to be saturated for calculation of NPSH for the ECCS pumps.

11. 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. Currently, the analysis conservatively assumes there is no time delay in transport to the strainer following the break.

12. 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 significant subcooling of the sump water has occurred.

13. Test evaluations demonstrated 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.

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

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

16. 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.

17. Fibrous debris was prepared to simulate fines to the extent possible, as if all the fibrous debris erosion occurred at recirculation start.

18. The test tank was periodically stirred in the Rig 89 testing and continuously stirred in the Rig 33 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.

19. 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.

20. 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 the 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.

21. Conservatively, the base concrete dissolution is assumed 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.

22. 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 to encourage aluminum compound precipitation, even though the actual pH in the sump water is approximated as pH 8. Also, Technical Specifications requirements for the RWST and TSP baskets ensure sump water pH is $\geq$ 7.

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

- The rate of corrosion is 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 is 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 is 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. 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."

23. No near-field settlement is credited in the MPS Unit 2 testing.

24. 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.

- Turbulence created by the break will serve to maintain heavier debris in solution only in a small region local to the break waterfall. This turbulence will not significantly impact approach velocity, or the amount of debris entrained in the water column, near much of the strainer surface area due to the large strainer footprint.

- Much of the small particulate debris created by the break blowdown will be directed upwards in containment and will settle on myriad surfaces throughout containment and only slowly, if at all, be washed to the containment floor by containment sprays.

- 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); thus, the amount of particulate in the debris-bed (and in the test tank) is conservative. Additionally, the unqualified coating is postulated to fail as small, transportable particulate when much of the failure is far more likely to occur as large pieces that would 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.

Resolution of Downstream Effects – Fuel and Vessel: 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 the issues identified in GL 2004-02 for MPS Unit 2 and is in compliance with the applicable regulations.

3 Specific Information for Review Areas

As stated in the MPS Unit 2 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) and July 8, 2010 (ADAMS Accession No. ML102010413), MPS Unit 2 has addressed review areas 3.a through 3.m. By letter dated August 10, 2010 (ADAMS Accession No. ML102140437), the NRC acknowledged that MPS Unit 2 had completed the necessary actions to resolve GL 2004-02 with the exception of in-vessel downstream effects. Therefore, only the outstanding review areas of 3.n, Downstream Effects – Fuel and Vessel, 3.o, Chemical Effects, and 3.p, Licensing Basis, 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:

By letter dated August 13, 2015, (ADAMS Accession No. ML15232A026), DENC informed the NRC that MPS Unit 2 would demonstrate compliance with the in-vessel debris acceptance criteria included in Topical Report (TR) WCAP-17788, as opposed to WCAP-16793. 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 2 and has evaluated the applicability of the methods and analytical results from WCAP-17788-P, Rev. 1, for MPS Unit 2.

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 2 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 2, 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 analyses for MPS Unit 2 included fiberglass and latent fiber. The total fibrous debris quantity from these sources that could potentially reach the sump strainer was conservatively calculated to be approximately 5429 lbm.

The strainer fiber bypass testing performed by AECL for the strainer design installed at MPS Unit 2 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 insights such as long-term strainer bypass was low but did not provide insights into bypass 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 on-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 2.

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 4.12, 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 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 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 on-line fiber bypass capture to determine cumulative bypass fractions for the MPS Unit 2 strainer. It is noted AECL test reports determined that "Fiber bypass concentrations show a near exponential decreasing trend with time." The quantity of fiber that came through was so low that 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 to the MPS Unit 2 strainer as detailed below.

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 from Point Beach (References 4.4 through 4.8), a cumulative strainer bypass fraction was developed for MPS Unit 2. Consistent with the 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 2 was based on fiber bypass at various tested and extrapolated theoretical debris bed thicknesses (derived from fiber mass per strainer area).

The MPS Unit 2 strainer approach velocity is bounded by the Point Beach test results; consequently, no correction factor to scale the Point Beach data to a higher velocity was necessary.

The geometry for the Performance Contracting Incorporated (PCI) furnished Point Beach disk strainer was compared with the AECL furnished MPS Unit 2 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. The MPS Unit 2 strainer includes the use of flow control orifices that ensure flow entering the strainer is proportionally distributed among the modules based on the fin area. This design feature ensures uniform debris deposition.

With regard to sacrificial area for the MPS Unit 2 strainer, it was assumed that all of the sacrificial area would be available for formation of the fibrous debris bed 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.

The strainer perforation size for Point Beach (0.066") is slightly larger than for the MPS Unit 2 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 2.

Conservatisms Applied

Conservatisms applied when determining the cumulative bypass fraction for the MPS Unit 2 strainer include:

- Maximum strainer design flow rate was used that results in the highest calculated approach velocity and cumulative bypass fraction.

- The MPS Unit 2 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 MPS Unit 2.

- 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 the theoretical debris bed thickness was calculated, the designated sacrificial area was included to minimize the thickness, which results in higher cumulative bypass.

- A percentage of the total fiber load on the MPS Unit 2 strainer includes intact pieces that do not erode and, as such, do not contribute to strainer fiber bypass. This contrasts with the Point Beach 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 2 Value
Strainer Manufacturer	PCI			AECL
Strainer Perforation Size	0.066"			0.0625"
Strainer Area[1]	1904.6 ft^2			6118 ft^2
Flow Rate through Single Strainer Train	2300 gpm (test scaled)			6800 gpm
Approach Velocity	0.0027 ft/sec			0.00248 ft/s
Nominal Theoretical Debris Bed Thickness	1.5"		0.60"	2.665"
Debris Type and Quantity (% Fiber Mass Type)[2]	Test 1	Test 2	Test 3	
Fiberglass	40.7%	28.8%	100%	40.6%
Mineral Wool	59.3%	67.7%	0%	29.4%
Mineral Fiber	0%	0%	0%	30.1%
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 fraction is only being based on a theoretical debris bed thickness comparison with Point Beach and MPS Unit 2.

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 2 is derived by comparison of theoretical bed thicknesses.

3. All low density (2.4 lbm/ft^3) fiber types were listed together as "Fiberglass."

As noted in Table 3, MPS Unit 2 has a theoretical debris bed thickness of 2.665", which exceeds the 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 2.665" thickness is then calculated using the Point Beach test 3 curve fitted equation developed in the calculation: Cumulative Fiber Bypass = $0.040303 * (\text{Bed Thickness})^{-0.758434}$ = $0.040303 * (2.665)^{-0.758434}$ = **1.9%**.

With MPS Unit 2 having an approach velocity of 0.00248 ft/s that is bounded by the 0.0027 ft/s approach velocity for the Point Beach tests, no additional correction factors are required to be applied to the calculated 1.9% cumulative fiber bypass.

TABLE 4 - SUMMARY OF FIBER LOAD, DEBRIS BED THICKNESS, & VELOCITY ADJUSTED BYPASS FRACTIONS	
Strainer Characteristic	**MPS Unit 2**
Fiber Load	5428.68 lbm
Theoretical Debris Bed Thickness	2.665 inches
Cumulative Bypass Fraction	1.9%

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 2 is a Combustion Engineering (CE) PWR design. Per Section 3.0 of the NRC Staff Review Guidance, Reference 4.3, it is necessary to confirm MPS Unit 2 is within the key parameters of the WCAP-17788-P, Rev. 1, methods and analyses. Therefore, each of the key parameters is discussed below.

3.n.3 Fuel Design

MPS Unit 2 uses Framatome's (AREVA) CE14 HTP fuel assemblies.

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 MPS Unit 2.

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 2 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 2. The calculation included the following design inputs and assumptions:

Design Inputs

1. Plant Type - MPS Unit 2 is a Combustion Engineering (CE) plant.

2. Fuel Type, Vendor, and Number of Assemblies - MPS Unit 2's core consists of 217 fuel assemblies comprised of Framatome's (AREVA) CE14 HTP fuel type.

3. Core Thermal Power - The core thermal power assumed for a LBLOCA is 2754 MWt including instrument uncertainty.

4. Initial Sump Fiber Load - The mass of fiber transported to the sump is 660.15 lbm, which includes the fiber generated due to ten hours of erosion. Ten hours is the time of hot leg switchover (HLSO). The fiber mass is divided by the Nukon density of 2.4 lbm/ft^3 to get a volume of 275.1 ft^3. Therefore, the total fibrous debris volume transported to the sump strainers is 275.1 ft^3. On a per fuel assembly (FA) basis, the initial sump fiber load is 1379.90 g/FA (= [660.15 lbm * 453.592 g/lbm] / 217 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 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 575 gpm with one operable train, and the maximum recirculation flow is 4100 gpm, which can occur during hot leg injection (boron precipitation control) with one CS pump operating.

8. Containment Recirculation Spray System (RSS) Flow Rates Following SSO - The CS system 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, Section 6.5.2.10, a minimum CS system flow rate should be analyzed. The minimum CS system flow rate during ECCS recirculation alignment is 1450 gpm.

9. Time of Hot Leg Switch Over (HLSO) – The MPS Unit 2 HLSO time is between 8 and 10 hours. A maximum value is limiting so a value of 10 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 affect the formed debris bed. Per Table 4.4-1 of Reference 4.11, the time at which chemical effects affect the debris bed is 24 hours for MPS Unit 2. Therefore, a maximum value of 24 hours was used in the calculation (Test Group 38).

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 prior to complete core inlet blockage. t_{block} is the minimum acceptance time of complete core inlet blockage. The core inlet debris limit is the maximum amount of debris that can be tolerated at the core inlet prior to t_{block}. MPS Unit 2 is a CE plant with Framatome fuel. Therefore, from WCAP-17788-A, Rev. 1 (Reference 4.12):

   - t_{block} is 333 mins
   - The core inlet debris limit allowed is the value listed in WCAP-17788-A, Rev. 1, Table 6-5, and
   - K_{max} is 6.5 x 10^6.

13. Fuel Assembly Pitch - The Framatome fuel 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, which is consistent with maximum transport assumptions.

5. AFPs were not credited. Per PWROG-16073-P, Rev. 0, (Reference 4.11), 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.

8. It is assumed that no flow is diverted to the hot leg after the initiation of boron precipitation control (i.e., hot leg switchover). The entirety of the ECCS recirculation flow including its associated fibrous debris continues to be injected into the cold leg resulting in a higher core inlet debris load, which is conservative.

9. As noted in Section 3.n.1, the MPS Unit 2 sump strainer bypass fraction is 1.9%.

Analysis

WCAP-17788-P, Volume 1, Rev. 1, Section 6.5.1, defines the HLB debris as 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 <u>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</u>

Using the design inputs and assumptions noted above, the maximum amount of fiber for MPS Unit 2 calculated to potentially reach the reactor vessel is 20.67 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 <u>Confirmation that the core inlet fiber amount is less than the WCAP-17788-P, Rev. 1 threshold</u>

MPS Unit 2 is a Combustion Engineering plant with AREVA CE14 HTP fuel. The applicable WCAP-17788-P, Rev. 1 core inlet fiber threshold for AREVA fuel is provided in Table 6-5 of WCAP-17788-P, Rev. 1, Volume 1. The core inlet fiber amount for MPS Unit 2 is calculated to be 20.67 g/FA, which is less than the applicable WCAP-17788-P, Rev. 1, core inlet fiber threshold.

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

As previously stated, the earliest possible SSO time for MPS Unit 2 was determined to be 33 minutes.

3.n.9 <u>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</u>

Chemical precipitation timing is dependent on the plant buffer, sump pool pH, volume and temperature, and debris types and quantities. Table 4.4-1 of PWROG-16073 (Reference 4.11) identifies Test Group 38 as representative of MPS Unit 2 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 2 performs injection realignment to mitigate the potential for boric acid precipitation no later than 10 hours, which is less than 24 hours.

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

MPS Unit 2 is a Combustion Engineering design. Based on WCAP-17788-P, Rev. 1, Volume 1, Table 6-1, t_{block} for MPS Unit 2 is 333 minutes.

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

The earliest time of chemical precipitation for MPS Unit 2 was determined to be 24 hours, which is greater than the applicable t_{block} value of 333 minutes.

3.n.13 Plant rated thermal power compared to the analyzed power level for the RCS design category

MPS Unit 2 has a rated thermal power (RTP) of 2754 MWt, which includes instrument uncertainty. MPS Unit 2 is a Combustion Engineering plant design, and the applicable analyzed thermal power is 3458 MWt as provided in WCAP-17788-P, Rev. 1, Volume 4, Table 6-3. The MPS Unit 2 rated thermal power is less than the analyzed power; therefore, this parameter is bounded by the WCAP-17788-P, Rev. 1, analysis.

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

MPS Unit 2 is a Combustion Engineering plant design. The Proprietary analyzed AFP resistance is provided in Table 6-3 of WCAP-17788-P, Rev. 1, Volume 4. The Proprietary MPS Unit 2 specific AFP resistance is provided in Volume 4, RAI Table 4.3-7. The MPS Unit 2 specific AFP resistance is less than the analyzed value; therefore, the MPS Unit 2 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

The range of ECCS recirculation flow rates at MPS Unit 2 is not bounded by the range analyzed as part of the WCAP-17788-P, Rev. 1 thermohydraulic (T/H) analysis. The unbounded flow rates are dispositioned pursuant to guidance provided in PWROG-16703-P (Reference 4.11).

The minimum plant-specific ECCS recirculation flow rate is less than the minimum analyzed ECCS flow rate used to develop K_{max} in WCAP-17788-P, Rev. 1. As noted in the Technical Evaluation Report (TER) included in WCAP-17788-P, Rev. 1, debris bed resistance increases as ECCS flow rate decreases, so an unbounded low flow will cause the K_{max} used in the calculation to be non-conservative. However, the maximum ECCS flow rate at MPS Unit 2 creates the most limiting case, which has 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, and K_{max} is valid for the limiting fiber load case

The maximum plant-specific ECCS recirculation flow rate is higher than the analyzed ECCS flow rate in WCAP-17788-P, Rev. 1. Based on discussion in RAI 4.26 of WCAP-17788-P, Rev. 1, a higher than analyzed flow rate will be conservative with respect to K_{max} (i.e., more water being delivered to the core thereby increasing the tolerance for debris accumulation and K_{max}/fiber limit) but non-conservative with respect to debris arrival timing. The maximum ECCS flow rate has been evaluated as acceptable because the limiting calculated cumulative fiber load remains below the fiber limit. In addition, margin is available in multiple parameters as shown in Table 5 that ensure the calculated fiber load is conservative, including thermal power, SSO time, and AFP resistance. Finally, AFPs, while they are not credited in the MPS Unit 2 T/H analysis, would exist and provide core cooling.

3.n.16 Summary

The comparison of key parameters used in the WCAP-17788 AFP analysis to the MPS Unit 2 specific values is summarized in Table 5. Based on these comparisons, MPS Unit 2 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 2 Value	Evaluation
Maximum Total In-Vessel Fiber Load (g/FA)	Volume 1 Section 6.5	< WCAP-17788 Value	Maximum in-vessel fiber load is less than WCAP-17788 limit.
Maximum Core Inlet Fiber Load (g/FA)	Volume 1 Table 6-5	20.67	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.

TABLE 5 – KEY PARAMETER VALUES FOR IN-VESSEL DEBRIS EFFECTS			
Parameter	**WCAP-17788 Value**	**MPS Unit 2 Value**	**Evaluation**
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})	10	Latest hot leg switchover occurs well before the earliest potential chemical product generation.
Rated Thermal Power (MW_t)	3458	2754	Lower rated thermal power results in lower decay heat.
Maximum AFP Resistance	Volume 4 Table 6-3	Volume 4 RAI Table 4.3-7	The AFP resistance is less than the analyzed value, which increases the effectiveness of the AFP.
Minimum ECCS Recirculation Flow (gpm/FA)	Volume 4 Table 6-3	2.6	Maximum debris bed resistance at the core inlet occurs at lower flow rates. The minimum ECCS flow rate of 575 gpm is not bounded by the WCAP-17788 analyzed minimum value and is dispositioned in Section 3.n.15 above.
Limiting ECCS Recirculation Flow Rate Resulting in Maximum Core Inlet Fiber Load (gpm/FA)	Volume 4 Table 6-3	18.9	Limiting fiber loads at the core inlet occur at high flow rates using WCAP-17788 methods. The maximum ECCS flow rate of 4100 gpm is not bounded by the WCAP-17788 analyzed range of flow rates value and is dispositioned in Section 3.n.15 above.

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 2 chemical effects analysis of the sump strainers was submitted in the MPS Unit 2 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 dated March 13, 2009 (ADAMS Accession No. ML090750436) and July 8, 2010 (ADAMS Accession No. ML102010413). The MPS Unit 2 sump strainer chemical effects analysis is unchanged. The MPS Unit 2 in-vessel chemical effects analysis is described in Sections 3.n.9 through 3.n.12.

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 2 associated with the resolution of the sump issues considered in GSI-191 and GL 2004-02. These changes are restated below:

MPS Unit 2 FSAR

The MPS Unit 2 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 2.

MPS Unit 2 License Amendment

One license amendment related to GL 2004-02 corrective actions has been approved and implemented.

- A license amendment was approved and implemented for an administrative change in Technical Specifications Section 4.5.2.j to replace the text “screen and trash rack” in a surveillance requirement with the word “strainer”. Amendment No. 300 was approved by NRC letter dated September 18, 2007 (ADAMS Accession No. ML072290132). This change was implemented within 30 days of receipt of the amendment.

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 MIL2-34325-TR-001, Rev 0, "Reduced-Scale Testing for Millstone 2 Replacement Containment Sump Strainers," AECL Test Report.

4.10 MP-CALC-ENG-MIL2-34325-AR-001, Rev. 1 w/Addenda 00A & 00B; "Hydraulic Performance of Replacement Containment Sump Strainers Millstone 2 Power Station."

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

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