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

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License Nos.: DPR-65/NPF-49

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNITS 2 AND 3
NRC GENERIC LETTER 2004-02, POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS
GENERIC SAFETY ISSUE (GSI)-191 CLOSURE OPTION

By letters dated November 15, 2007 (ML073190553), February 29, 2007 (ML080650561), December 18, 2008 (ML083650005), March 13, 2009 (ML090750436), July 8, 2010 (ML102010413), September 16, 2010 (ML102640210), and December 20, 2010 (ML103620562), Dominion Nuclear Connecticut, Inc. (DNC) submitted information in response to GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for Millstone Power Station Units 2 (MPS2) and/or 3 (MPS3) to resolve the containment sump issues identified in GSI-191. The remaining open item for resolution concerns downstream in-vessel effects.

By letter dated May 4, 2012 (ML12142A316), the Nuclear Energy Institute (NEI) submitted a letter to the NRC recommending actions for resolving GSI-191 containment sump issues that a licensee could select based on the amount of fiber in containment. The letter stated that licensees would submit a plant specific path and schedule for resolution of GSI-191. In SECY-12-0093, *Closure Options for Generic Safety Issue - 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance*, dated July 9, 2012 (ML121310648), the NRC staff presented three options to the Commission as viable paths for licensees to resolve GSI-191 and recommended that the Commission allow licensees the flexibility of choosing any of the options presented subject to the conditions and schedules discussed therein. The Commission approved the staff's recommendation in the Staff Requirements Memorandum dated December 14, 2012 (ML12349A378).

Attachment 1 provides information regarding the current status of DNC's efforts to address GL 2004-02 and also describes the GSI-191 closure option, resolution plan and implementation schedule for MPS2 and MPS3. Attachment 2 provides a summary of the corrective actions and analyses that have been implemented at MPS, including inherent margins and conservatisms, to address GSI-191 containment sump performance issues and to also provide reasonable assurance that the health and safety of the public will be maintained until the identified actions discussed herein have

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been completed. Attachment 3 provides the regulatory commitment included in this submittal.

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

Sincerely,

Eugene S. Grecheck
Vice President – Nuclear Engineering and Development

Commitments contained in this letter: See Attachment 3.

Attachments:
1. Generic Safety Issue-191 (GSI-191) In-vessel Effects Resolution Plan
2. Implemented Corrective Actions to Address GL 2004-02
3. Regulatory Commitment

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Mr. Eugene S. Grecheck, who is Vice President – Nuclear Engineering and Development, of Dominion 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 MAY, 2013.

My Commission Expires: MAY 31, 2014

VICKI L. HULL
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My Commission Expires May 31, 2014

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Attachment 1

Generic Safety Issue-191 (GSI-191) In-vessel Effects Resolution Plan

Dominion Nuclear Connecticut, Inc. (DNC)
Millstone Power Station Units 2 and 3

Generic Safety Issue-191 (GSI-191) In-vessel Effects Resolution Plan Millstone Power Station Units 2 and 3 (MPS2 and MPS3)

Introduction

SECY-12-0093, *Closure Options for Generic Safety Issue -191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance*, dated July 9, 2012, presented three options for the resolution of GSI-191.

The three options are as follows:

- Option 1 Compliance with 10 CFR 50.46 based on approved models,
- Option 2 Mitigative measures and alternate methods approach (which includes deterministic and risk-informed alternatives), and
- Option 3 Different regulatory treatment for suction strainer and in-vessel effects.

DNC has selected Option 2 (deterministic) for final resolution of GSI-191 for MPS2 and MPS3 and intends to pursue refinements to evaluation methods and acceptance criteria associated with downstream in-vessel effects. To support the use of this path and continued operation for the period required to complete the necessary analysis and testing, DNC has evaluated the existing design and procedural capabilities that provide defense-in-depth for identifying and mitigating potential in-vessel blockage. A description of these measures is provided later in this document. A summary of the corrective actions, and associated margins and conservatisms, previously implemented to resolve GSI-191 containment sump issues for MPS2 and MPS3 is provided in Attachment 2.

Current Containment Fiber Status

From the debris generation and transport analyses performed for MPS2 and MPS3, DNC 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 (ML080650562). The fibrous debris sources considered in the MPS analyses include fiberglass, mineral fiber, mineral wool and latent fiber for MPS2 and fiberglass and latent fiber for MPS3. The total fibrous debris quantity from these sources that could potentially reach the sump strainer was conservatively calculated to be approximately 5363 lbm for MPS2 and 2053 lbm for MPS3.

Reduced scale testing for MPS2 was previously performed and included fiber bypass testing that determined the amount of fiber bypass that would occur for the replacement strainers. Bypass testing was conducted with the full fibrous debris load with no added particulate or reflective metal insulation (RMI). The test debris was not thermally aged prior to the test, and tap water was used during the test. Three fiber bypass tests were performed: two at the two-train flow rate, and one at the one-train flow rate. The total test duration of each test was at least ten (10) tank turnovers. Multiple grab samples were collected from the pump return line downstream of the strainer for each test. Each sample was filtered using a membrane filter with 0.1-micrometer (μm) pore size, and the dried filter paper was weighed to determine the quantity of bypass fiber. The amount of fiber that passed through the strainer was extremely low; consequently, Scanning Electron Microscopy (SEM) and/or Energy Dispersive X-ray analysis were performed on one sample from each of the first five turnovers (at one half turnover) to determine the quantity and characteristics of the fibrous debris that passed through the MPS strainer.

Analysis of the fiber bypass test results showed that:

- Fiber bypass concentrations exhibited a near exponential decreasing trend with time.
- The vast majority (~90%) of the fibers that bypassed the strainer were less than 1 millimeter (mm) in length. (The strainer hole size is 1/16 inch or 1.6 mm.)
- Fiber bypass concentrations were similar at both two- and one-train flow rates.

From the fiber bypass testing, it was determined that 99.7% of the fiber concentration would be filtered out by the MPS2 strainer on the first pass through the strainer. Therefore, based on the strainer bypass testing performed and assuming 99.7% filtration, approximately 16.09 pounds-mass (lbm) of fibrous debris will bypass the sump strainer, and the total quantity of fiber calculated to bypass the strainer and reach the reactor fuel is 33.7 grams/fuel assembly (g/FA) for MPS2. The fiber bypass testing performed for the MPS2, North Anna Power Station Units 1 and 2, and Surry Power Station Units 1 and 2 strainers demonstrated strainer capture fractions for fiber greater than 99.7%. In addition, these strainer designs are virtually identical (i.e., all Atomic Energy of Canada Limited (AECL) strainers with the same hole size, corrugated fin design and fin materials). Since the MPS3 strainer is also an AECL strainer of the same design, the MPS3 fiber capture fraction would reasonably be expected to be in the same range. Therefore, using a conservative value of 99% capture fraction and the total fibrous debris load stated above of 2053 lbm, the total fiber bypass for MPS3 is 20.5 lbm or 48.3 g/FA.

Consequently, the calculated values for MPS2 and MPS3 would not meet the limits specified in WCAP-16793, Revision 2. In addition, the fiber bypass test procedure that was used for MPS2 was not consistent with the current Nuclear Energy Institute (NEI) test protocol. As a result, Dominion is participating in the Pressurized Water Reactor Owners Group (PWROG) comprehensive program to develop new acceptance criteria for in-vessel debris. At the time the PWROG establishes new in-vessel acceptance criteria, Dominion will develop an action plan for demonstrating compliance with the PWROG program limits and communicate the plan to the NRC within 60 days of the PWROG establishing new in-vessel acceptance criteria. The defense-in-depth measures discussed below and the completed corrective actions and conservatisms discussed in Attachment 2 provide support for the extension of time required to completely address GL 2004-02 for MPS2 and MPS3.

Characterization of Strainer Head Loss Status

DNC previously provided the results of strainer head loss testing, including the impact of chemical effects, in letters dated February 29 and December 18, 2008, and July 8, September 16, and December 20, 2010. The results of this testing demonstrate acceptable results with regard to allowable strainer head loss.

Characterization of In-vessel Effects

As noted above, DNC intends to follow the resolution strategy proposed by the PWROG for establishing in-vessel acceptance criteria for the type of plant design that exists at MPS2 and MPS3. The PWROG Comprehensive GSI-191 Program is designed to develop acceptance criteria to support resolution under Option 2 (deterministic) as described in SECY-12-0093. The PWROG program includes Loss of Coolant Accident (LOCA) analyses and corroborative testing that will develop acceptance criteria that may provide less restrictive in-vessel debris limits than WCAP-16793, Revision 2, or preclude the need for specific in-vessel debris limits altogether.

Licensing Basis Commitments

DNC does not currently have any open NRC commitments associated with the resolution of GSI-191 and closure of GL 2004-02. However, in a letter dated March 13, 2009 (Serial No. 09-175), DNC stated that an evaluation of in-vessel downstream effects would be performed within 90 days of the issuance of the final NRC Safety Evaluation Report (SER) for WCAP-16793-NP, Rev. 2, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid." The NRC SER for WCAP-16793, Rev. 2, is dated April 8, 2013. However, based on the information contained within this document regarding the intended direction to be taken to resolve GSI-191 in-vessel downstream effects, this statement is no longer applicable. A new commitment as a result of this closure effort is listed in Attachment 3.

Resolution Schedule

DNC currently anticipates that it will achieve closure of GSI-191 and GL 2004-02 for MPS2 and 3 per the following schedule:

- In-vessel Testing/Analysis – DNC is participating in the PWROG Program for establishing revised and bounding in-vessel debris limits. As noted above, DNC will develop a plan for demonstrating compliance with the PWROG program limits and communicate that plan to the NRC within 60 days of the PWROG establishing new in-vessel acceptance criteria.

- Plant Modifications - The need for additional plant modifications or strainer bypass testing has not been determined at this time, since the PWROG effort to determine revised in-vessel fiber limit acceptance criteria is ongoing. However, laser measurements (scans) of insulation installed in the MPS2 containment were performed during the fall 2012 refueling outage (RFO), and laser measurement scans were begun for MPS3 during the ongoing 2013 RFO. Consequently, if the revised in-vessel fiber limit acceptance criteria being developed by the PWROG indicate insulation removal/replacement is required at MPS, the effort to obtain the necessary measurements for insulation removal/replacement will already be well underway to facilitate and expedite the removal/replacement effort. DNC will notify the NRC if insulation modifications are required as part of its plan for demonstrating compliance with the PWROG program limits as noted above.

Summary of Actions Completed to Address GL 2004-02

A summary of the corrective actions that DNC has completed for MPS2 and MPS3 to resolve GSI-191 and address GL 2004-02 is provided in Attachment 2.

Summary of Margins and Conservatisms for Completed Actions for GL 2004-02

A summary of the margins and conservatisms associated with the resolution actions taken to date to resolve GSI-191 is provided in Attachment 2. These margins and conservatisms provide support for the extension of time required to address GL 2004-02 for MPS2 and MPS3.

Summary of Defense-in-Depth Measures

The following describes the plant specific design features and procedural capabilities that provide defense-in-depth for detecting and mitigating a fuel blockage condition for MPS2 and MPS3:

- MPS2

  Description of Post-LOCA ECCS Operation and Effect on In-Vessel Debris

  The MPS2 Emergency Operating Procedures (EOPs) provide direction for the transfer of the Emergency Core Cooling System (ECCS) operating mode from Cold Leg Injection to Cold Leg Recirculation (EOP 2532) and subsequently from Cold Leg Recirculation to Simultaneous Hot and Cold Leg Injection (EOP 2541, Appendix 18). By design these modes of ECCS operation ensure sufficient core cooling for the duration of the design basis LOCA. The transfer to Cold Leg Recirculation involves the automatic re-alignment of the suction of the high pressure safety injection pumps to the Containment Sump following sufficient depletion of the Refueling Water Storage Tank (RWST). The low pressure safety injection pumps are automatically stopped at the end of Cold Leg Injection.

The EOPs direct the initiation of Simultaneous Hot and Cold Leg Injection be completed between eight and ten hours from the onset of the LOCA. MPS2 has options to align the ECCS for Simultaneous Hot and Cold Leg Injection, depending on availability of equipment and power supplies. Although the primary purpose of Simultaneous Hot and Cold Leg Injection is to flush the reactor vessel and prevent boron precipitation on the surfaces of the fuel rod cladding and reactor vessel internals, the flow re-alignment can maintain adequate core heat removal and/or serve to disrupt a debris bed that may have formed in the lower core region during Cold Leg Recirculation.

Per WCAP-16793, Revision 2, fuel assembly tests have shown that the limiting conditions for fuel blockage require the combination of fibrous debris, particulates, and chemical precipitates. Significantly higher fiber debris loads can be accommodated without flow reductions with the absence of chemical precipitates. Before the initiation of Simultaneous Hot and Cold Leg Injection in eight to ten hours, MPS2 does not expect chemical precipitates to form and affect core cooling, based on the following evaluation.

As part of the design evaluation for containment sump strainer performance, MPS2 performed calculations and bench-top testing for post-LOCA containment sump chemical effects that focused on calcium (from bare concrete) and aluminum corrosion. The MPS2 chemical effects analysis and testing program demonstrated that chemical effects would not begin to influence the strainer debris head loss for several hours or days. The MPS2 chemical effects program was summarized in Attachment 1 of DNC letter dated December 18, 2008 (ML083650005).

Because chemical precipitates form over the long-term and would not be considered to be of sufficient concentration within the strainer bypass content to result in significant in-vessel deposition within 10 hours of the onset of the LOCA, the current initiation of Simultaneous Hot and Cold Leg Injection directed by the MPS2 EOPs is considered to be a mitigating measure for debris bed formation and a means of preventing potential flow degradation below decay heat removal levels. Once the reactor vessel is flushed with ECCS from the hot and cold sides simultaneously, in-vessel fiber and particulates could be returned to the containment pool for subsequent filtration by the sump strainer. MPS2 plant-specific strainer bypass testing has shown very high fiber filtration once a very thin debris bed forms on the sump strainer.

MPS2 is a Combustion Engineering Nuclear Steam Supply System design with a designed upflow barrel-baffle core bypass flow configuration. This design feature includes pressure relief holes in the baffle wall that provide additional core cooling flow area that are not subject to the same blockage limitations as the bottom of the fuel assemblies. MPS2 calculations for complete blockage of the fuel assembly inlets during a hot leg break scenario demonstrated that the ECCS would be directed to the baffle bypass area with a flow rate 1.75 times the core boil-off requirement at the time of sump recirculation. Thus, the upflow baffle bypass configuration provides additional defense-in-depth to ensure ECCS can reach the fuel region and maintain long-term core cooling in the event of lower core blockage.

The fuel fiber limit of 15 g/FA that was proposed in WCAP-16793, Revision 2, was generated from testing that simulated hot leg break conditions with cold leg ECCS injection of 44.7 gallons per minute (gpm) per fuel assembly. For MPS2, the maximum ECCS flow rate during recirculation mode is 17.1 gpm per fuel assembly. Thus, MPS2 has significant ECCS flow margin, and thus fuel assembly differential pressure margin, compared to the PWROG test program. This translates to a much higher fibrous debris allowance. The ECCS maximum flow capability at MPS2 compared to the generic, bounding test flow rate is considered another defense-in-depth element for MPS2.

Review of EOPs for Lower Core Blockage

As described above, the MPS2 EOPs direct the ECCS modes of operation in the designed sequence to ensure core cooling. This sequence includes the establishment of Simultaneous Hot and Cold Leg Injection to flush the reactor vessel and prevent boron precipitation. It is expected that the simultaneous injection alignment, in the current sequence, can also act to mitigate the potential for In-Vessel lower core region flow blockage in some cases. In addition, the EOPs also direct routine monitoring of the Safety Functions during accident conditions. This is facilitated by performing the Safety Function Status Checks. For LOCAs, two of these checks are related to Core Cooling: RCS Inventory Control and Core Heat Removal. Following transfer to Sump Recirculation, the RCS Inventory Control Safety Function status is checked by monitoring Safety Injection (SI) Flow and Reactor Vessel Level, and the Core Heat Removal Safety Function is checked by monitoring Core Exit Temperature. Should lower core debris blockage occur in a manner that significantly degrades flow to the Reactor Core, it is expected that Core Exit Temperature will exhibit an increasing trend. If this occurs, it is anticipated that the Technical Support Center (TSC) personnel would assist in the evaluation of the situation and recommend alignment of Simultaneous Hot and Cold Leg Injection, regardless of the elapsed time, in an attempt to disrupt the blocking debris bed and restore core cooling.

As an enhancement, MPS2 intends to improve the defense-in-depth measures for early diagnosis and response to potential lower core region flow blockage. This enhancement will involve a modification to Technical Support Center Procedure MP-26-EPI-FAP12 "Thermal Hydraulic Evaluations" that will initiate early actions to monitor and evaluate the trends of parameters indicative of lower core region blockage following the completion of the sump recirculation alignment. This monitoring and longer-term trending and evaluation support will be provided by the TSC. Should parameter trends support a diagnosis of significant flow blockage in the lower core region prior to the normal designated time for establishing Simultaneous Hot and Cold Leg Injection, guidance will be provided to evaluate performing the re-alignment earlier as a mitigating measure to disturb the blocking debris bed and maintain adequate core cooling. In this manner, a more timely diagnosis and proactive response would be possible.

MPS2 plans to implement the described change to Technical Support Center Procedure MP-26-EPI-FAP12 "Thermal Hydraulic Evaluations" and complete required training before September 30, 2013.

Although these defense-in-depth measures are not expected to be required based on the very low probability of an event that would result in significant quantities of debris being transported to the reactor vessel that would inhibit the necessary cooling of the fuel, they do provide additional assurance that the health and safety of the public would be maintained. These measures provide reasonable assurance of safety for the necessary time required to completely address GL 2004-02 for MPS2.

- <u>MPS3</u>

<u>Description of Post-LOCA ECCS Operation and Effect on In-Vessel Debris</u>

The MPS3 EOPs provide direction for the transfer of the ECCS operating mode from Cold Leg Injection to Cold Leg Recirculation (ES-1.3) and subsequently from Cold Leg Recirculation to Hot Leg Recirculation (ES-1.4). By design, these modes of ECCS operation ensure sufficient core cooling for the duration of the design basis LOCA. The transfer to Cold Leg Recirculation involves starting the recirculation spray system (RSS) pumps with suction from the Containment Sump following sufficient depletion of the RWST. The discharge flow of the RSS pumps feeds the suction of the SI pumps and the centrifugal charging (CHS) pumps, which in turn inject to the Reactor Coolant System (RCS) cold legs.

At four hours from the onset of the LOCA, the EOP E-1, "Loss of Reactor or Secondary Coolant" directs the transfer of ECCS from Cold Leg Recirculation to Hot Leg Recirculation. During Hot Leg Recirculation, the discharge of the SI pumps is aligned to the Hot Leg injection points. The CHS pumps continue to inject to the cold legs. The alignment is completed within five hours of the LOCA onset.

Although the primary purpose of this Simultaneous Hot and Cold Leg Injection is to flush the reactor vessel and prevent boron precipitation on the surfaces of the fuel rod cladding and reactor vessel internals, the flow reversal can also serve to disrupt a debris bed that may have formed in the lower core region during Cold Leg Recirculation.

Per WCAP-16793, Revision 2, fuel assembly tests have shown that the limiting conditions for fuel blockage require the combination of fibrous debris, particulates, and chemical precipitates. Significantly higher fiber debris loads can be accommodated without flow reductions with the absence of chemical precipitates. Before the transfer to hot leg recirculation, MPS3 does not expect chemical precipitates to form and affect core cooling, based on the following evaluation.

As part of the design evaluation for containment sump strainer performance, MPS3 performed calculations and bench-top testing for post-LOCA containment sump chemical effects that focused on calcium (from bare concrete) and aluminum corrosion. The MPS3 chemical effects analysis and testing program demonstrated that chemical effects would not begin to influence the strainer debris head loss for several hours or days. The MPS3 chemical effects program was summarized in Attachment 2 of DNC letter dated December 18, 2008 (ML083650005).

Because chemical precipitates form over the long-term and would not be considered to be of sufficient concentration within the strainer bypass content to result in significant in-vessel deposition within five hours of the onset of the LOCA, the current transfer to Hot Leg Recirculation directed by the MPS3 EOPs is considered to be a major mitigating measure for debris bed formation and a means of preventing potential flow degradation below decay heat removal levels. Once the reactor vessel is flushed with ECCS simultaneously from the hot and cold sides, a significant amount of in-vessel fiber and particulates should be disrupted and potentially returned to the containment pool for subsequent filtration by the sump strainer. AECL strainer bypass testing has shown very high fiber filtration once a very thin debris bed forms on the sump strainer.

MPS3 is a Westinghouse Nuclear Steam Supply System design with a designed upflow barrel-baffle core bypass flow configuration. This design feature includes pressure relief holes in the baffle wall that provide additional core cooling flow areas that are not subject to the same blockage limitations as the bottom of the fuel assemblies. The upflow barrel-baffle bypass configuration provides additional defense-in-depth to ensure ECCS flow can reach the fuel region and maintain long-term core cooling in the event of lower core blockage.

Review of EOPs for Lower Core Blockage

As described above, the MPS3 EOPs direct the ECCS modes of operation in the designed sequence to mitigate the potential for in-vessel lower core region flow blockage. In addition, the EOPs also direct routine monitoring of the Critical Safety Functions during accident conditions. This is facilitated by monitoring the Critical Safety Function Status Trees. One of these trees is related to the Core Cooling safety function (F-0.2). The status of the Core Cooling safety function is assessed using the tree logic, based on the monitoring of RCS Subcooling, Core Exit Temperature, and Reactor Vessel Level. Should lower core debris blockage occur in a manner that significantly degrades flow to the Reactor Core, it is expected that Core Exit Temperature will exhibit an increasing trend. Uncorrected, this temperature trend would lead to a diagnosis of an Inadequate Core Cooling condition by the tree logic. In accordance with the Critical Safety Function Status Tree rules of usage, diagnosis of such a condition would require immediate entry into the Functional Restoration procedure FR-C.1 for Response to Inadequate Core Cooling. Based on expected indications of associated Core Cooling parameters and ECCS flow, FR-C.1 would direct interim cooling strategies that involve depressurization of intact Steam Generators and starting of Reactor Coolant Pumps (RCPs), one at a time, regardless of the status of RCP support conditions. It is anticipated that in the course of these conditions and interim cooling strategies, TSC personnel would assist in the evaluation of the situation and recommend realignment of the ECCS to Hot Leg Recirculation.

Using recent generic guidance from the PWROG, MPS3 intends to improve the EOP defense-in-depth measures for early diagnosis and response to potential lower core region flow blockage. This enhancement will involve a modification to EOP ES-1.3, "Transfer to Cold Leg Recirculation", that will initiate early actions to monitor and evaluate the trends of parameters indicative of lower core region blockage following the completion of the sump recirculation alignment. It is expected that monitoring would be initially performed by Control Room Operators, with longer-term trending and evaluation support provided by the TSC. Should parameter trends support a diagnosis of significant flow blockage in the lower core region prior to the normal designated time for Transfer to Hot Leg Recirculation, guidance will be provided to evaluate performing the transfer earlier as a mitigating measure to disturb the blocking debris bed and maintain adequate core cooling. In this manner, a more timely diagnosis and proactive response would be possible without over-reliance on the Core Cooling Critical Safety Function Tree assessment.

MPS3 plans to implement the described change to EOP ES-1.3, "Transfer to Cold Leg Recirculation" and complete required training before September 30, 2013.

Although these defense-in-depth measures are not expected to be required based on the very low probability of an event that would result in significant quantities of debris being transported to the reactor vessel that would inhibit the necessary cooling of the fuel, they do provide additional assurance that the health and safety of the public would be maintained. These measures provide reasonable assurance of safety for the necessary time required to completely address GL 2004-02 for MPS3.

Conclusion

DNC expects the GSI-191 resolution path for MPS2 and MPS3 to be acceptable based on the information provided herein. The execution of the actions identified in this document will result in successful resolution of GSI-191 and closure of GL 2004-02. Given the significantly increased size and advanced design of the installed strainers, the extensive corrective actions already taken, the design margins and conservatisms inherent in the analyses performed, the defense-in-depth measures in place and planned enhancements, and the low probability of challenging pipe breaks, there is reasonable assurance that the health and safety of the public will be maintained until the identified actions have been completed.

Attachment 2

Implemented Corrective Actions to Address GL 2004-02

Dominion Nuclear Connecticut, Inc. (DNC)
Millstone Power Station Units 2 and 3

Implemented Corrective Actions to Address GL 2004-02 Millstone Power Station Units 2 and 3 (MPS2 and MPS3)

Corrective Actions

A summary of the corrective actions that Dominion has completed to resolve NRC Generic Safety Issue (GSI)-191, *"Assessment of Debris Accumulation on PWR Sump Performance,"* for MPS2 and MPS3 is provided below.

Modifications to Improve Plant Performance

Numerous plant modifications have been completed for MPS2 and MPS3 in support of GSI-191 resolution including the following:

1. A new MPS2 Emergency Core Cooling System (ECCS) strainer (with corrugated, perforated stainless steel fins) was installed with a total surface area of approximately 6120 square feet (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 has been 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. A new MPS3 ECCS strainer (with corrugated, perforated stainless steel fins) was installed with a total surface area of approximately 5000 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 has been designed to withstand up to approximately 10 pounds per square inch (psi) of differential pressure and has a strainer hole size of 1/16 inch, which is smaller than the previous screen size of 3/32 inch.

3. The start signal for the MPS3 Recirculation Spray System (RSS) pumps (which are the only ones that take their suction from the containment sump) was changed during the spring 2007 refueling outage, as permitted by Amendment No. 233 (ML062220160). The modification changed the automatic start signal at approximately 660 seconds following the postulated accident to an automatic start when the Refueling Water Storage Tank (RWST) level reaches the low-low level setpoint. This ensures that the replacement strainer is fully submerged prior to drawing water through the strainer for coolant recirculation.

4. Calcium silicate insulation, which could become dislodged by any break that could require recirculation, was removed from the piping and equipment in the MPS2 containment such that no calcium silicate insulation could 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 any break that would require ECCS recirculation.

5. Safety related cover plates were installed over the MPS2 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:

1. Detailed analyses of debris generation and transport ensure that 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 analysis.

2. Chemical effects bench-top tests conservatively demonstrate 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 Atomic Energy of Canada, Limited (AECL) and Dominion 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 Loss-of-Coolant-Accident (LOCA).

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

5. Containment cleanliness standards have been defined and detailed in a station housekeeping procedure.

6. Design controls have been put in place to require evaluation of potential debris sources in containment created by or adversely affected by design changes.

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

Margins and Conservatisms

MPS2 and MPS3 Margins and Conservatisms

1. 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, entering the containment pool.

3. Although credit is 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 MPS2 and MPS3 licensing bases which reduces the size of the break which could occur prior to its detection. The reactor coolant pipes for the debris generation analysis are assumed to break instantaneously for the debris generation and transport analysis.

4. All 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 large LOCA 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 LOCA 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 net positive suction head (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 in the computational fluid dynamics (CFD) analysis.

9. The replacement strainers have very large surface areas and strainer footprints 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 footprints 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 that 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 when significant subcooling of the sump water has occurred.

13. Test evaluations demonstrate 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.

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. Only fines of fibrous debris were used in head loss testing, 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 Large Break LOCA particulate load to determine abrasive and erosive wear. This is a conservative particulate loading, in view of the following.

    - Much of the particulate included in 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," (Jain et al. April 2005).

23. No near-field settlement is credited in the MPS2 and MPS3 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 is 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 which 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 quite conservative. Additionally, all of the unqualified coating is postulated to fail as small, transportable particulate when in reality, much of the failure is far more likely to occur as large pieces which 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.

Additional MPS3 Margins and Conservatisms

1. 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, currently the calculation of wear of component surfaces due to debris conservatively neglects this particle debris settling and capture.

2. 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 now conservatively uses the water level from a small break LOCA that exists at the start of the RSS pumps.

3. 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 (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 for qualified coating.

4. 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.

5. 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.

6. All unqualified coating was deemed to fail immediately as transportable particulate. This is particularly conservative since unqualified coating makes up 45% of the total tested coating load and 34% 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 design basis accident (DBA) testing.

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

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

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

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

11. A sacrificial strainer area of 655 ft^2 was installed.

12. The effective installed strainer area (4544 ft^2) exceeds the tested strainer area (4290 ft^2). The effective installed strainer area does not include the 655 ft^2 of sacrificial area which is also installed in containment. The total strainer area installed is approximately 5200 ft^2.

13. Debris load refinements after the Rig 33 testing was completed (and before the Rig 89 test) led to a reduction of about 10% in total particulate which would lead to a reduction of thin-bed head loss.

Attachment 3

Regulatory Commitment

Dominion Nuclear Connecticut, Inc. (DNC)
Millstone Power Station Units 2 and 3

Regulatory Commitment

The following table identifies the action in this document to which Dominion Nuclear Connecticut, Inc. (DNC) has committed. Statements in this submittal with the exception of the table below are provided for informational purposes and are not considered commitments. Please direct any questions regarding this commitment to Gary D. Miller at (804) 273-2771.

No.	Commitment	Expected Completion Date
1	At the time the Pressurized Water Reactor Owner's Group (PWROG) establishes new in-vessel acceptance criteria, DNC will develop an action plan for demonstrating compliance with the PWROG program limits and communicate that plan to the NRC.	Within 60 days of the PWROG establishing new in-vessel acceptance criteria